Excel & Succeed

Senior Secondary Biology

MG 2/02

Form 4

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Unit 1

Problem solving

Specific objectives

By the end of this unit, you should be able to:

(a) Identify and define problems to be solved.

(b) Gather information on the problem and suggest possible solutions.

(c) Draw conclusions, evaluate evidence and make decisions.

(d) Write reports.

Introduction

In Form One, we learnt about problem solving. We learnt that problem solving involves the use of scientific findings to come up with solutions to problems in our day-to-day lives.

In Form Four, we will apply problem solving skills to solve various problems in our surroundings.

Problem solving process involves:

(a) Identification of problem

In Form One we learnt that problems are identified by observing situations in our day-to-day lives.

(b) Definition of the problem to be solved

After a problem is identified, it must be put in form of a statement.

For example the problems identified in Hema village can be stated as follows:

(i) Poor health in children in Hema village.

(ii) Deteriorating health of children in Hema village.

Definition of the problems gives reasons why a given investigation should be carried out.

(c) Gathering information

This involves reading about the problem from books, magazines, and journals.

It also involves talking to experts to gather information about the problem.

In this case, one can read on disease symptoms from books. One can also visit the local health centre to ask the health officers to explain the problem in health terms.

In gathering information about the problem, one asks the following questions:

- Where else does the above problem occur or in which other place was such a problem observed?
- What other observation are made when such a problem occurs?
- What are the probable causes of the problem?
- What are the probable solutions to the above problem?

(d) Suggesting possible solutions

After the information is gathered, it is then analysed. In the analysis, information similar to the situation observed is identified. For instance, in which other area was such a problem observed? Possible solutions to the problem are then listed down. From the possible solutions, the ones more applicable to the situations observed are identified.

(e) Testing the possible solutions

Testing involves experimenting whether the solution suggested can really work to solve the problem. This is first done in a small group called a sample. If it works in a sample, then the solution can be implemented in the whole population. In the test, the following are done:

- Choose a sample population where the test will be carried out. Identify resources to be used in the test. For instance educational materials, resource persons such as nurses, food items such as meat, milk, fish among others.
- Identifying the variables to be used and what variable will be changed, what variable will be kept constant and what variable will be observed.
- Method to be used in the test. This is the systematic way of carrying out the test.

(f) Conclusions

From the data collected, a conclusion is made as to whether the suggested solution can really work. In the conclusion, the following are considered:

(i) Some factors that were not considered.
(ii) Weaknesses of the method.
(iii) Obstacles observed.

(g) Evaluation of the evidence

This involves evaluating the evidence in the conclusion to make decisions. The evaluation involves comparing the advantages and disadvantages of the solution. This is in terms of:

(i) How effective it can solve the problem.
(ii) How expensive the method is. In this case, you consider whether funds can be available to solve the problem and if it can be implemented.
(iii) The benefits of the solution. How was it received by the beneficiaries?

(h) Making decisions

This involves making a choice on whether to:

- Accept the solution and implement it as it is.
- Choose the solution but make some changes on the method before implementation.
- Reject the suggested solution and propose an alternative one. After the decision is made, reasons as to why it is the best decision are given.

Consequences of the solution are also stated. These include possible reactions after the solution is implemented.

Report writing

After a decision has been made, a report is written. The report gives a guideline on how the problem was identified and tested. The report shows that the suggested solution can really work to solve the problem in the village.

A report should have the following parts:

(a) The aim of the investigation.
(b) Description of the method used.
(c) Presentation of results.
(d) Drawing of conclusions.

Activity 1.1

You are provided with the following situations observed in certain areas of Malawi. Read them carefully and design possible solutions that can be used to address the above problems.

Case study 1

Problem of increased use of Cannabis in some villages in Malawi.

It has been observed that some Malawi young men do not complete their secondary school education due to the *Cannabis* use.

- Design a suitable way that can be used to address the above problem.
- Write a report on your recommendations.

Case study 2

HIV and AIDS infection among the youth in Africa has been rising of late. The problem is similar to what we are having in Malawi today.

- Design a suitable way of addressing this problem amongst students in your school and in your locality.
- Write a report to present your findings.

Case study 3

In a given village, it has been found out that the problem of ringworm becomes prevalent when schools are opened. It is possible that the spread of ringworms takes place amongst school going children.

- Design a suitable solution to address this problem in the schools around your locality.

Revision Exercise 1

1. What is the meaning of problem solving?
2. What is a sample?
3. How is sampling done?
4. Why is it important to first test a given suggested solution by issuing a sample population?
5. Write an essay on the steps that one need to follow in problem solving.
6. Discuss the benefits of using investigations to come up with solutions to problems that face us in our day-to-day activities.

Unit 2 Investigative techniques and skills

Specific objectives

By the end of this unit, you should be able to:

(a) Observe safety measures when doing investigations.

(b) Use science equipment and materials safely and take measurements.

(c) Design and carry out investigations.

(d) Make observations, record and analyse data.

Introduction

In Form One and Form Two, we learnt about investigative skills and techniques. We learnt about the safety measures we need to consider when carrying out activities in the laboratory. We also learnt about making detailed drawings and making accurate measurement. After learning about the techniques, we used the skills learned to carry out various investigations.

In this unit, we will review what we learned and then set up various experiments.

Activity 2.1: Safety measures in a Biology laboratory

Discuss the following questions and write a report.

1. What safety measures should one take into account when carrying out food tests in the laboratory?
2. Explain accidents that take place in a laboratory when safety measures are not considered.

Activity 2.2: Field study

Requirements/materials

- Pooters
- Sweep net
- Specimen jar
- Rulers
- Polythene bag
- Pegs
- Strings

Procedure

1. Go to the school farm or field and identify an area with vegetation.
2. Measure an area of 10m by 10m and mark it using pegs.
3. Design a method to sample plants and animals in the area.
4. Record the sampled organisms and their distribution.
5. Make a plan diagram of the area

of study showing how various plants were distributed.

6. Make a possible food chain for the area you have studied.
7. Present your findings in a report.

Activity 2.3: How aphids affect you

Some insects such as aphids are serious pests in agriculture. They have mouthparts that pierce and penetrate the sieve tubes of the phloem and feed on plant sap. They are found in crops such as cabbage.

Carry out the following investigation to find out more on aphids and write a report.

1. Go out into the field and identify aphids. Collect some and place them in a jar. Take them to laboratory, examine them using a hand lens and draw and label large diagrams of the aphids.
2. Find out the plants that aphids commonly affect and the parts affected.
3. Identify reasons why aphids affect plants only.
4. Estimate the number of aphids that affect a single stem in the field.
5. Describe effects of aphids on growth and development of the plant.
6. Explain the economic impact of aphids on agriculture.
7. Suggest possible biological methods that can be used to control aphids.

Activity 2.4: Dissection of a mammal

Dissection of a rabbit to observe blood circulatory system

Requirements/materials

- A freshly killed mammal such as a small rabbit or a rat.
- Dissecting kits.
- Dissecting boards.
- Charts on circulatory system of a mammal.
- Guide to dissection.

Procedure

1. Dissect a small mammal following guidelines given to you by your teacher.
2. From the dissection, display the heart, the liver, the spleen, the kidneys, the intestines and the limbs.
3. Identify blood vessels that are connected to each body part.
4. Compare the arteries and the veins.
5. Draw a well-labelled diagram of the various parts you have observed.
6. Write a report of your findings.

Activity 2.5: Comparing rise of water in different soils

Requirements/materials:

- Long capillary tubes.
- Cotton wool.
- Dry sand, clay and loam.
- Water trough.

- Clock.
- Ruler.
- Clamp.

Procedure

1. Close the lower end of each tube with cotton wool.
2. Dry the soils and crush them except sand (sand is a structureless soil). The particles of sand soil are not sticking together and therefore it does not require crushing.
3. Fill each soil into its own tube, ensuring that soils are well packed.
4. Support the tubes by use of clamps with the lower ends closed with cotton resting inside an empty trough as shown in fig. 2.1.
5. Put water into the trough up to a depth of five centimetres.

   Measure the height of water that has risen in each tube after 10 minutes, then after two hours.

   Allow the tubes to rest overnight. Measure the height of water that has risen in the tubes after 24 hours.
6. Record your readings in a table like the one shown below.

Soil	Height of water after		
	10 mins	2 hrs	24 hrs
Sand			
Loam			
Clay			

Observations

- From the activity, you may have noted that in loam and sandy soils, water rises very fast within the first 10 minutes, but it rises

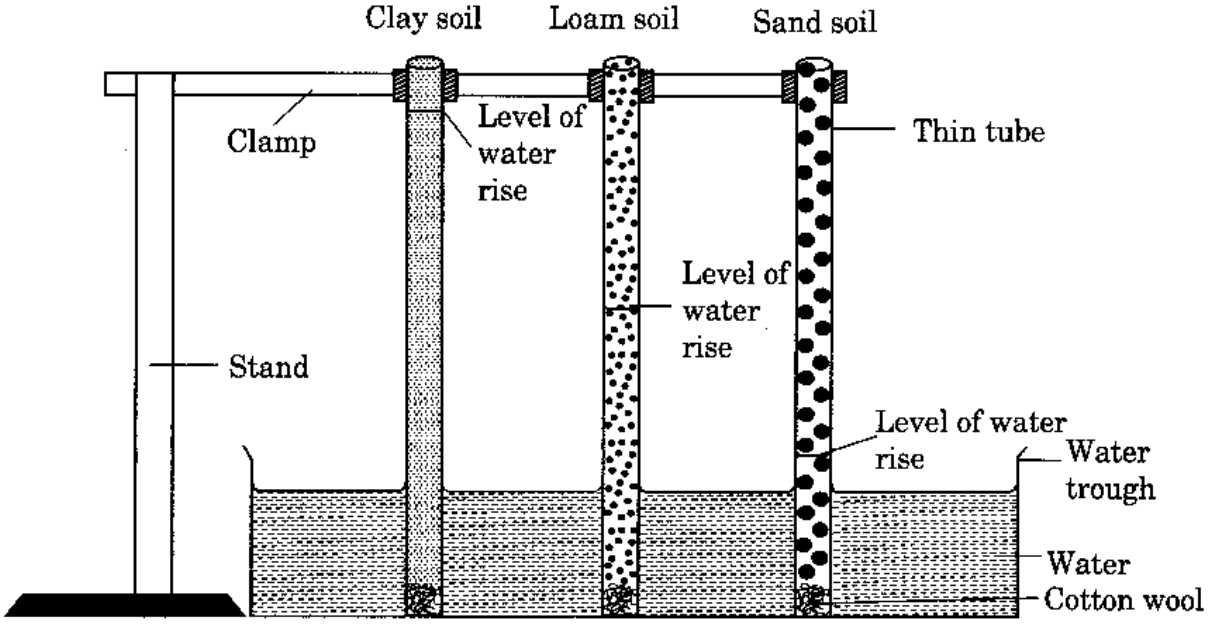


Fig. 2.1: Capillarity in different types of soils.

very slowly in clay. After 2 hours, the rise of water in sand stops but rises higher in loam than in clay.

- After about 8 hours, the rise of water in loam stops, but in clay it continues. After 24 hours, the rise of water in clay will have reached the top.

Conclusion

Rise of water in soils is called **capillarity.** However, clay soil has the highest capillarity while sand has the least capillarity.

Activity 2.6: To investigate porosity of clay, sand and loam

Requirements/materials

- Measuring cylinders
- Cotton wool
- Water
- Dry sand, clay and loam soil
- Clock
- Funnel

Procedure

1. Crush the clay and loam soil into small particles to break up the aggregate.
2. Measure equal volumes of each soil about 50g and put them in funnels clogged with cotton wool.
3. Place each funnel onto a measuring cylinder.
4. Pour 50 cm^3 of water into each funnel at the same time. Note the time taken for the first drop of water to drip through into the measuring cylinder.
5. Allow the setup to stand overnight. Measure the amount of water collected in each measuring cylinder.

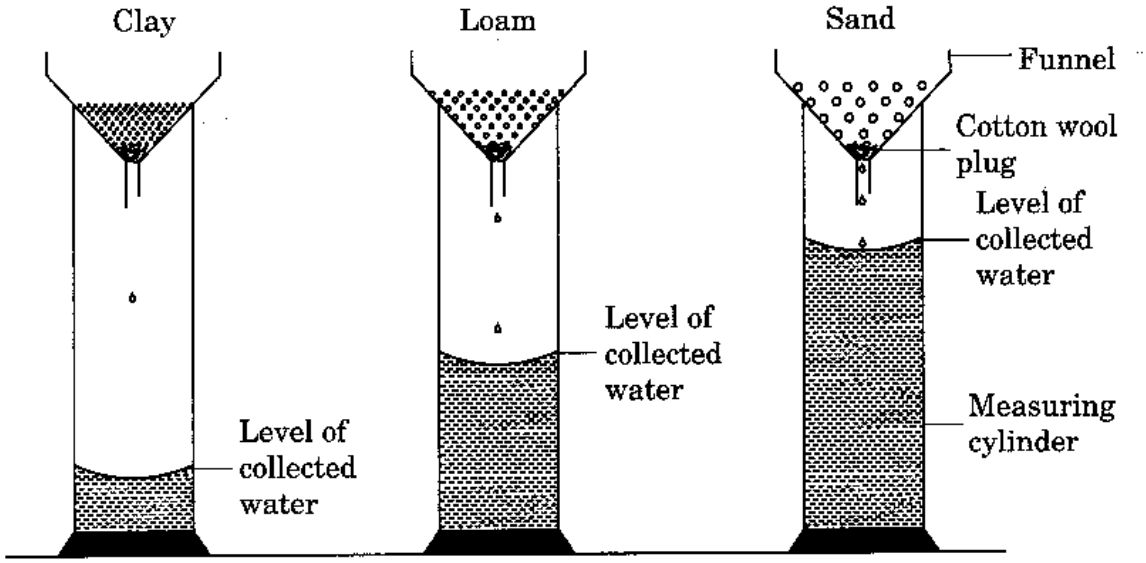


Fig. 2.2: Comparing porosity and water retention of different soils.

6. The amount of water drained is the amount collected in the measuring cylinder. The amount of water retained is calculated from the difference between the water drained and the water that was poured into the soil. That is,

$$\text{Volume of water retained} = \text{Volume of water poured into funnel (50 cm}^3\text{)} - \text{Volume of water collected}$$

Observations

- From the experiment, you may have noted that the time taken for one drop of water to drip through the soil and out into the measuring cylinder vary from one soil to another.
- Fig. 2.2 shows more water was collected from the sand soil than other soils.
- In the sand soil, water dripped very fast because the soil has large air spaces that allow water to pass through easily.
- It took longer time for water to drip in clay soil. Clay soil has lower porosity.
- In the same way, clay soil retained more water than loam and sand soil. Sand soil retained the least amount of water.
- This means that where porosity is high, a soil will have more spaces. It will allow faster drainage of water, but retains less water.
- When the porosity is low, a soil will have less space. It will allow water to drip slowly but it will retain a lot of water.

Activity 2.7: Comparing limbs of vertebrates

Requirements/materials

Specimens

- Wings with feathers of a chicken or suitable bird.
- Leg of a goat, cow or sheep.
- Pictures of arm of a human.
- Foot of a cat or dog.
- Leg of a frog.
- Leg of a rabbit.
- Scalpel.
- Mounting needles.

Procedure

1. Study the external appearance of each vertebrate limb. Draw the external appearance of each limb.
2. Compare the limbs and note any external similarities or differences.
3. Cut open each limb and expose the arrangement of the bones.
4. Draw the limbs and show how the bones are arranged.
5. Compare the arrangement of bones in different limbs and note any differences and similarities.

Questions

1. Are the external appearances of the limbs different or similar?
2. From the external appearance of the limbs, suggest what use it is

put to. Suggest how each limb is suited to this use.

3. What are the similarities and differences in the arrangement of bones in these limbs?
4. Do you think the animals from which these limbs were obtained could be related in any way? Explain your answer.

Discussion

The external appearance of the limbs in vertebrates is quite different. Some vertebrates like the birds have forelimbs that have feathers and have a flat shape. The goats, sheep or cows have hooves. The cat has paws with claws while human beings have fingers. The birds use the wings to fly while humans use fingers to grip. Goats, sheep and cows have limbs which are good for walking due to the strong hoofs on them.

The bones in these limbs have the same pattern of arrangement, one long bone is next to the end of two long bones and several small bones arranged close to each other, at the end of the two long bones. The organisms could be related because they have similarities. This indicate a common group of organisms from which they could have evolved from.

Let us now study the following illustration that shows the arrangement of bones in forelimbs of selected vertebrates.

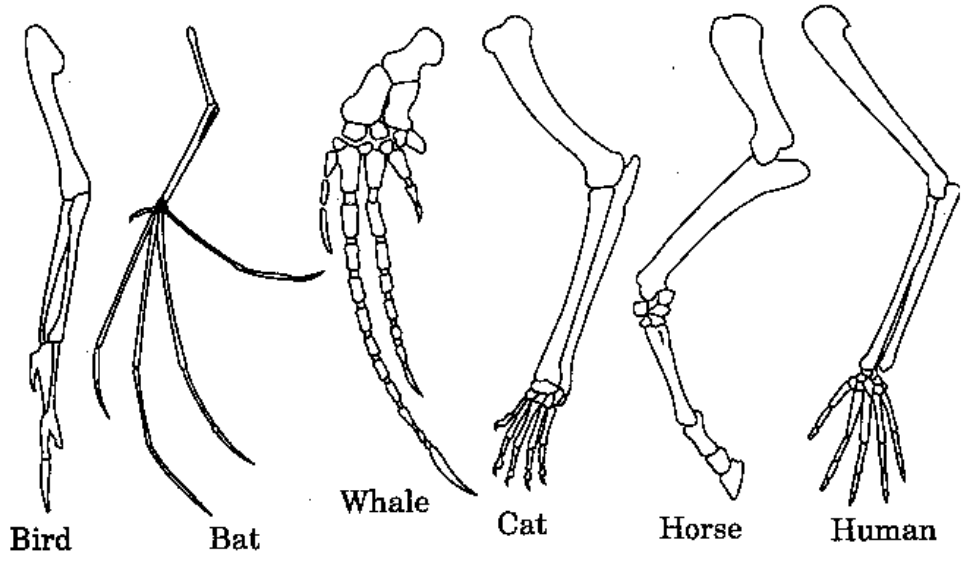


Fig. 2.3: Forelimbs of different vertebrates adapted to different functions.

Activity 2.8: Comparing wings of birds and those of insects

Requirements/materials

- Winged insects for example, butterflies, moths and houseflies.
- Wings of birds for example, chicken (wings must have feathers on them).
- Hand lens.

Procedure

1. Examine the wings of the insects using a hand lens and write down observable features.
2. Draw and label a single wing from an insect.
3. Examine the external features of the wing of the chicken. Write down all the observable features noted.
4. Draw and label a single wing from a bird.
5. Cut up and expose the internal structure of the wing of the bird. Note how exceptionally different the structure is from that of an insect.
6. Describe what you see. Draw and label the internal structures of the wing from the bird.

Questions

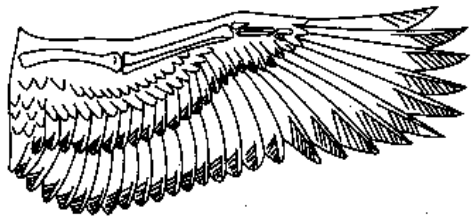
1. What are the observable features of insect wings?
2. What are the external and internal features of the bird wings?
3. What do the wings of insects and birds;
   (a) have in common?
   (b) do not have in common?
4. Do you think that the animals from which these specimens were obtained could be related? Explain your answer.

Discussion

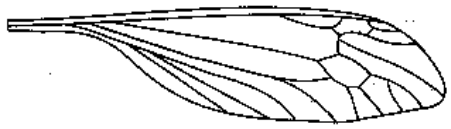
Wings of insects are made up of stiff membranes, with veins running through them. The veins are hard and made of materials called **chitin.** The wings of the bird have an internal arrangement of bones and muscles. It is covered by skin and feathers. They both have a wide surface which is flat. The species from which these specimens were collected are probably unrelated because their wing structure is different.

When you examine the internal structures of the birds and insect wings, you note very few similarities. For example, both wings are broad and flattened because they are both adapted to fly. However, their internal structures are completely different.

Study the illustrations below and note the similarities and differences between the two wings.



(a) Bird wing



(b) Insect wing

Fig 2.4: Wings of a bird and an insect.

Revision Exercise 2

1. An investigation was carried out between 1994 and 2003 to study changes in population of some fish in a given lake.

   During the investigations, it was found out that some time in 1995 some wastes were being discharged into the lake. It was also discovered that during the same time some factories started to release hot water into the lake.

   This made the temperature of the water to rise from 20°C to 25°C. The fish population of four fish species were sampled in those years and the data below obtained.

Fish species	1994	1996	1998	2000	2002
A	6000	5000	4000	6000	7000
B	200	30	11	22	65
C	30	0	0	0	0
D	4500	270	23	20	45

(a) Identify the problems that resulted to the investigation to be carried out.

(b) Describe how the above population was obtained.

(c) Suggest other variables that were also considered and measured in the water.

(d) List down all tools that may have been used to carry out the above study.

(e) Select suitable solution and explain how they can be tested.

(f) Write a report on what possible findings and solutions can be made from the above investigation.

Unit 3

Tropisms

Specific objectives

By the end of this unit, you should be able to:

(a) Explain the meaning of tropisms.

(b) Describe the types of tropisms.

(c) Carry out investigations on tropisms.

(d) Explain how tropisms occur.

Introduction

In this unit, you will learn about how plants respond to changes in their environment.

A change in the environment that results to changes in activity in an organism's body is called a **stimulus** (singular – stimuli).

A response is the change in activity.

Plants are capable of responding to changes in light, water, temperature, contact and gravity.

In this section, we will learn about a type of response called **tropism.**

Tropisms

Have you ever placed a potted plant to grow in a dark room with a small window? What did you notice? Irrespective of where the plant is placed in the room, the plant will grow towards the window.

The light coming from the direction of the window is the stimulus to which the plant responds by growing towards it. This type of a response is an example of **tropism.** Tropism can be defined as a growth response towards or away from a stimulus coming from one direction. In this case, the response is towards light coming from the window.

We will now look at the various types of tropisms.

Types of tropisms

(i) Phototropism

The growth response involving light is known as **phototropism.** The response involving growth towards the direction of light is called **positive phototropism** whereas growth away from light is called **negative phototropism.** Shoots are positively phototropic. They grow towards light to manufacture food by photosynthesis. Roots are negatively phototropic.

(ii) Geotropism

The response of plants to gravitational pull is referred to as geotropism. The radicle grows towards the force of gravity. It shows **positive geotropism**

whereas the plumule grows away from the force of gravity. The plumule shows **negative geotropism**.

(iii) Hydrotropism

Growth response by roots towards water in the soil is called hydrotropism.

Investigating tropisms

(i) Phototropism

Phototropism is a growth response to light. It is mainly found in green plants.

Activity 3.1: Investigating phototropism in plants

Materials

Each group of students should have:

- Pre-soaked bean seeds/maize seeds.
- 2 pots containing moist soil.
- 1 carton box.

Procedure

1. Plant three pre-soaked bean seeds in each of the pots containing moist soil. Label the pots A and B.
2. Place pots A and B under normal light conditions. Allow the seeds to germinate until they form the first foliage leaves.
3. Place pot B in a box with a small hole 0.5 cm x 1.5 cm on one side at the level of the tip of the seedlings.
4. Allow the seedlings in pot A to continue growing under normal light conditions.
5. Allow all seedlings to continue growing for one more week.
6. Compare the seedlings in all the pots after one week.
7. Record your observations.

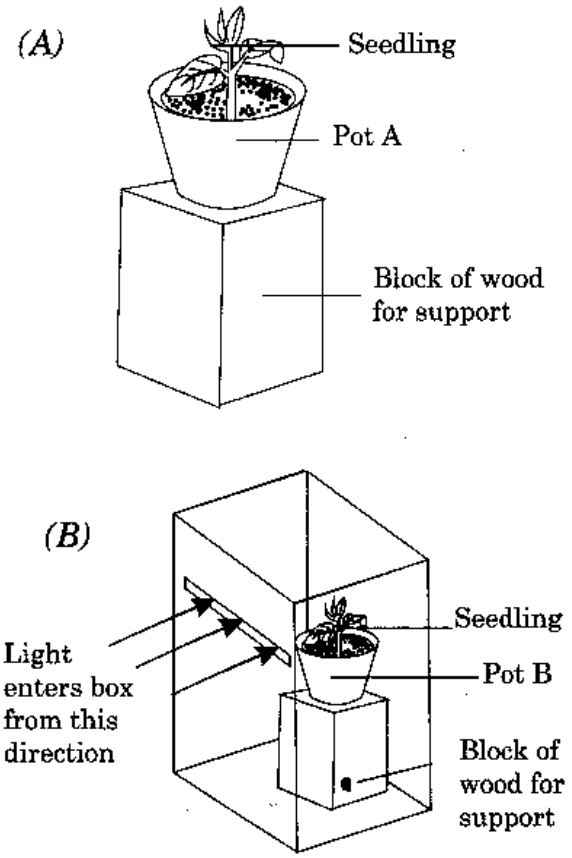


Fig. 3.1: Experiment demonstrating phototropism.

Questions

1. What differences did you notice in the growth of the stems of the seedlings?
2. Does light affect the differences observed above? Describe.
3. What is the relevance of these results in the survival of a plant, with respect to light?

Observation

You probably noticed that the seedlings grown in the presence of light (Pot A)

grew normally in an upright manner and the ones growing in the light coming from one direction, grew towards the light source.

Discussion

The seedlings that grew in the pot placed in normal light coming from all directions (Pot A) had stems that were upright.

The seedlings that grew in the pot placed in a box with a hole where light was coming from one direction (Pot B) had stems that grew bending towards the direction of light. This growth response towards or away from a unilateral stimuli is known as **tropism**.

(ii) Geotropism

From your experience about germination, you may have observed that the plumule of a germinating seed always grows upwards while the radicle always grows downwards. Suppose you took the germinating seedlings and positioned them in such a way that the plumules and the radicles were growing horizontally in the soil. What do you think will happen?

Let us carry out the following activity to find out what would happen.

Activity 3.2: Investigating geotropism in seedlings

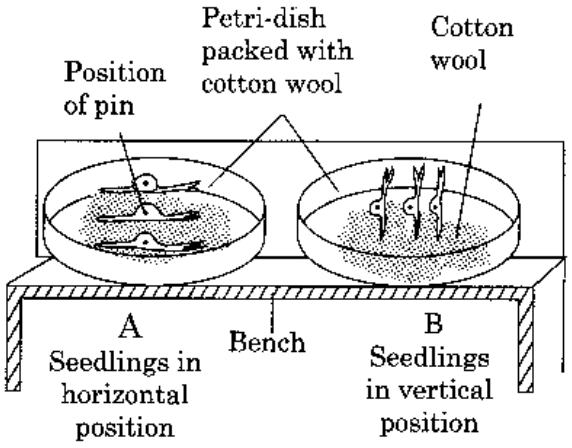
Requirements/materials

- Pre-germinated bean or maize seedlings with straight plumule and radicle.
- Moist cotton wool.
- Pins.
- Petri-dishes or bottles.
- Clamps.

Procedure

1. Take two Petri-dishes and tightly pack them with moist cotton wool. Label them A and B.
2. Pin 2 – 3 pre-germinated maize/ bean seedlings on the cotton wool parallel to each other, making sure there is space between them.
3. Make the petri-dishes stand on a bench and lean them against a wall such that in petri-dish A, the seedlings are in horizontal position.

   In petri-dish B, the seedlings are in vertical position in a way that plumule points upwards and radicle points downwards as shown in the following figure.



(a) Start of experiment

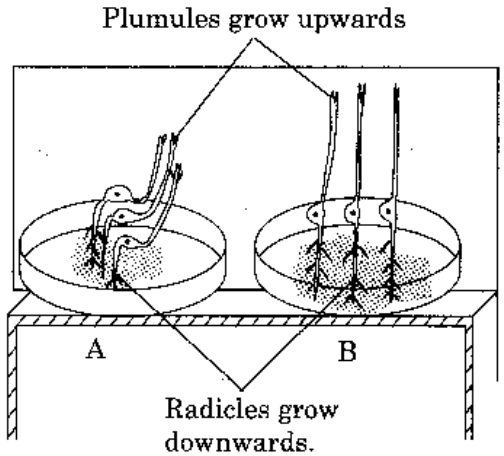
4. Leave the sets undisturbed and observe what happens after 2 days (48 hours).
5. Draw diagrams to show the appearance of the seedlings after 48 hours.

Questions

1. Describe the direction of growth of radicle and the plumule in:
   (a) Seedlings that were positioned horizontally (petri-dish A).
   (b) Seedlings that were positioned vertically (petri-dish B).

Observation

In the experiment, you probably observed that the plumule of seedlings in petri-dish A, grew with the plumule bending upwards while the radicle grew bending downwards. The plumule therefore grew away from the pull of gravity while the radicle grew towards the pull of gravity.
In petri-dish B, the seedlings continued to grow straight, the plumule upwards, and the radicle downwards.
The growth of the seedlings before and after 48 hours were as illustrated in the figure below.



(b) End of experiment

Fig. 3.2: Experiment to investigate geotropism.

Discussion

The growth response of the radicle and plumule of the seedlings in response to the downward pull of gravity is referred to as **geotropism** or **gravitropism**. The response of the radicle to gravity is therefore said to be **positive geotropism** and that of the plumule, to be **negative geotropism.**

Importance of geotropism in plants

(i) Geotropism enables roots to grow downwards into the soil. In this way, roots are able to absorb water and mineral salts for the synthesis of their food.
(ii) Geotropism enables plants to anchor well into the soil hence ensuring that the plant remains firm against possible physical destruction such as wind and run-off water.
(iii) Geotropism also enables the shoot to grow upwards and as such, leaves are in a position to get light which plants require to carry out the process of photosynthesis.

(iii) Hydrotropism

Plant roots respond to moisture as a stimulus. In this way, they grow in the soil towards regions with high moisture content. A growth response towards moisture is referred to as **hydrotropism**. Roots grow towards moisture. This is called **positive hydrotrophism**.
The survival value of this response is that roots are able to obtain moisture necessary for plant growth.

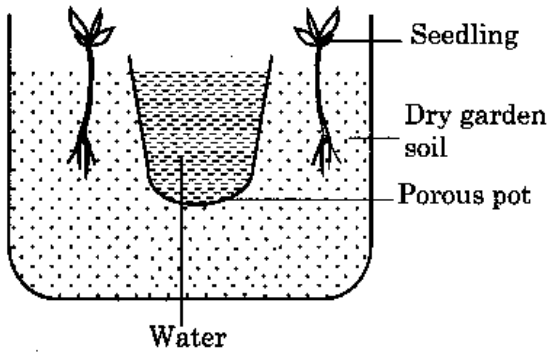
Activity 3.3: To demonstrate positive hydrotropism in plant roots

Requirements/materials

- A glass trough.
- Seedlings.
- A porous pot.
- Dry garden soil.

Procedure

1. Place a porous pot at the centre of a glass trough. Fill the pot with water.
2. Place dry garden soil all around the pot in the trough.
3. Place the seedlings 3 – 5 cm from the porous pot as shown in the figure below.

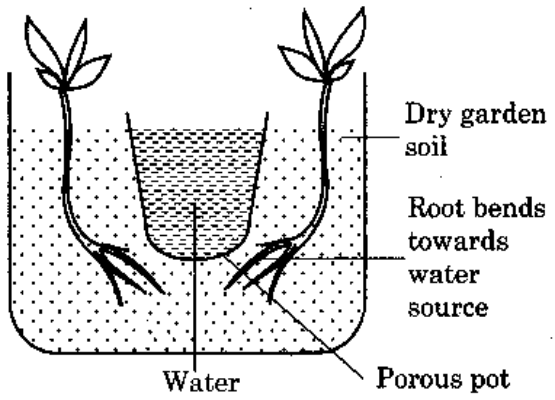


4. Allow the setup to stand for 3 days. Observe the growth of the roots.

Discussion

The radicles of the seedlings grow downwards and bend towards the water source as the shoot continues to grow upwards.

The results of the setup after three days are illustrated as follows.



Roots grow towards a water source. They are therefore **positively hydrotropic**.

Plant hormones and tropisms

We found out that growth in plants starts with roots growing downwards and the shoot emerging upwards above the ground. Growth in plants is controlled by **hormones.** Hormones are chemical substances that influence the way the plant grow, the direction of growth and also the rate of growth. Hormones influence growth aspects in plants such as:

- Lengthening of the shoots.
- Expansion of the stems.
- Growth of the lateral branches .
- Flowering.
- Fruit formation and ripening.
- Leaf fall.
- Senescence or death of the plant.

Plant growth hormones are made in one part of a plant and transported to another part where they cause an effect on growth.

Let us now discuss each of the hormones and how it regulates growth.

1. Auxins

Auxins are produced at the shoot tips. They are the most common and naturally occurring groups of growth

hormones that affect the growth of plant tissues.
The most common example of auxins is Indole-acetic Acid (IAA). Auxins are concentrated on shoot tips of plants.

Effects of auxins on plant growth

- Auxins influence cell elongation. They do this by facilitating stretching of the cell walls as the cells gain water and by stimulating formation of sap vacuoles.
- Auxins stimulate the development of adventitious roots.
- Auxins suppress the growth of lateral buds.
- Auxins induce pathenocarpy. This is a process whereby fruits are formed without fertilisation.
- Auxins prevent abscission or falling of fruits before reaching maturity.
- Auxins initiate secondary growth by stimulating cell division in the cambium.
- Synthetic auxins are used as herbicides and as stimulants in rooting of cuttings.

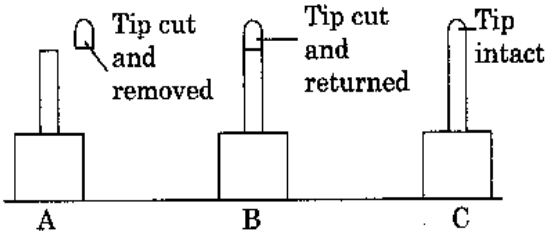
Activity 3.4: To investigate the involvement of auxins produced at shoot tip on plant growth

Requirements/materials

- Three maize seedlings just after germination.
- Scalpel.

Procedure

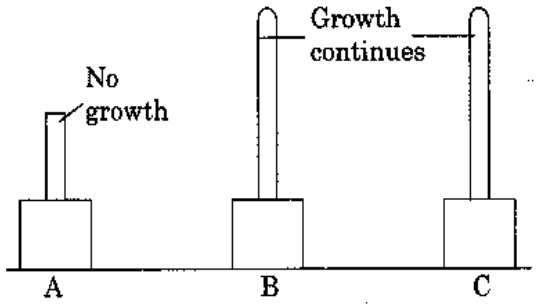
1. Water the seedlings.
2. Cut the tip (decapitate) of the seedling as shown in the figure below. The tip should be cut at least 1 – 2 cm from the tip.



3. To the second seedling, cut the tip and then replace it immediately.
4. Leave the third seedling intact.
5. Allow the seedlings to grow for 2 days.

Observations

- In shoot A, it was observed that growth stopped.
- In the second shoot, the growth of the shoot continued normally.
- In the third shoot, growth was observed to continue normally.
- The shoots were as shown in the following figure after 2 days.



Discussion

Shoot tips always produce a substance that influences the elongation of the shoot. When the tips are cut off, the substance is eliminated hence no further elongation.
The tip that was cut and returned demonstrates that the substance diffused

down the shoot to cause elongation. When it was replaced, the auxins still diffused down to cause elongation.

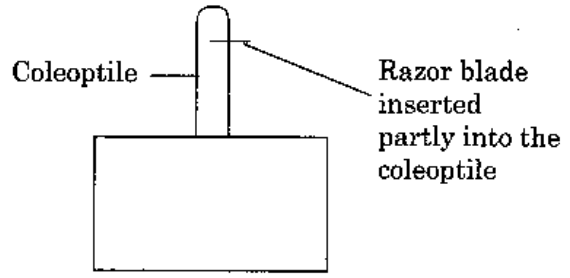
Activity 3.5: To investigate effects of auxin distribution on the shoot growth

Requirements/materials

- A potted germinating seedling (maize).
- A razor blade.

Procedure

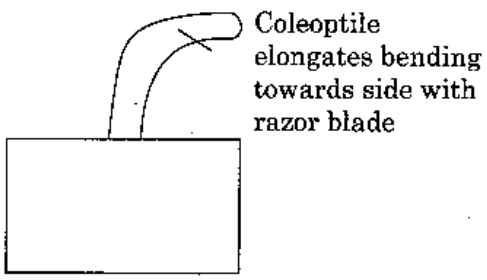
1. Allow a maize seed to germinate and have a straight coleoptile.
2. Insert a razor on one side of the coleoptile as shown in the figure below.



3. Leave the seedling to grow in the dark for two days.

Observations

After two days, the coleoptile is found to continue with an upward growth but it grows bending towards the side with the razor blade. The coleoptile is as illustrated in the figure below.



Conclusion

- The side where the razor blade was not inserted continued with normal growth. It elongated more than the side with the razor blade. This was because the razor blade prevents diffusion of auxins down the stem thus less elongation.
- The experiment shows that growth substances are produced at shoot tip and growth depends on their distribution.

Auxins and phototropism

A plant shoot always grows in an upright manner because auxins produced at the tip migrate uniformly down the shoot. As a result, they cause all the cells at the zone of cell elongation to elongate uniformly. This leads to uniform growth of the shoot.

The shoot will only grow this way under light coming from all directions or under total darkness. This growth occurs as shown in Fig. 3.3 below.

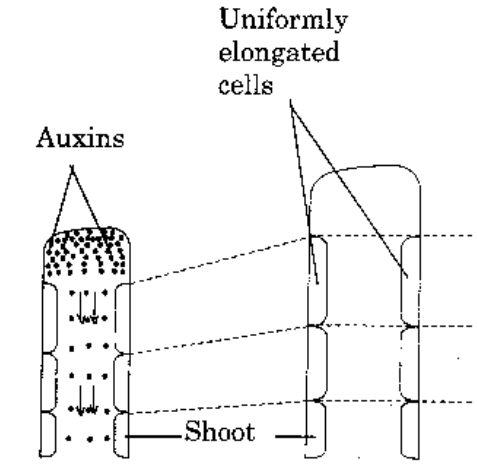


Fig. 3.3: Growth of shoot under light coming from all directions or total darkness.

Auxins are sensitive to light. They usually move away from light. If a plant shoot is exposed to light coming from one direction or unidirectional light, auxins on that side of the shoot of the plant move to the side not exposed to light. The unidirectional light becomes the stimulus. Therefore, the side of the shoot exposed to the unidirectional light has lower concentration of auxins than the side not exposed to the unidirectional light. This is as shown in the figure below.

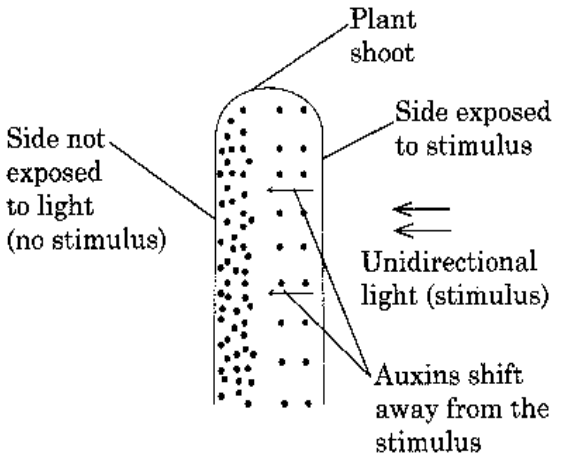


Fig. 3.4: Auxins shift to the darker side of shoot away from side exposed to unidirectional light.

The higher concentration of auxins on the side not exposed to the unidirectional light causes cells on that side to elongate more than the cells on the side exposed to the unidirectional light.

The side exposed to the light therefore grows less, whereas the side not exposed to the light grows more.

This results in growth curvature of the shoot towards the light as shown in Fig 3.5. This growth response is referred to as **phototropism.**

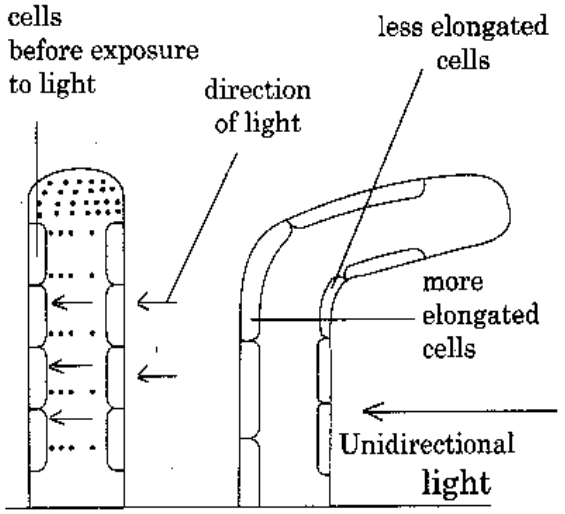


Fig. 3.5: More growth of cells on darker side leads to bending of shoot towards the direction of light.

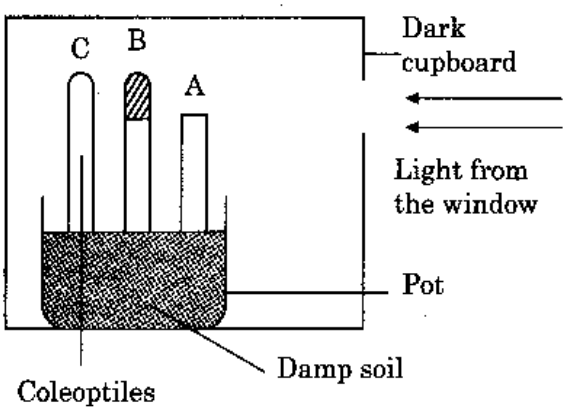
Activity 3.6: To investigate how auxins influence phototropism

Requirements/materials

- Germinating maize seedlings
- A pot with damp soil.
- Aluminium foil.
- A light cupboard or box with a small hole on one side.

Procedure

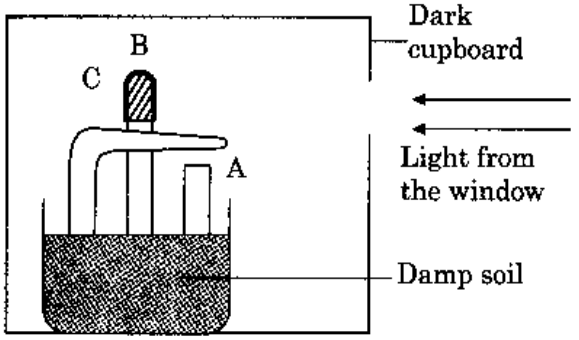
1. Select three upright coleoptiles.
2. Label them A, B and C.
3. Decapitate seedling A.
4. Cover the tip of seedling B with an aluminium foil.
5. Leave seedling C intact.
6. Place the seedlings in the box with one small hole on one side as shown in the following figure.



7. Keep the box near a window where it can get light.
8. Observe the setup after two days.

Results

The figure below illustrates the expected results after two days.



- Coleoptile A with cut off tip remained unchanged.
- Coleoptile B which was covered with aluminium foil elongated straight upwards.
- Coleoptile C, that was not treated, elongated and bent towards the direction of light.

Discussion

- Shoots are positively phototrophic. This is because in presence of light coming from all directions, auxins migrate uniformly down the shoot causing uniform elongation of the cells. This results in upward growth of the shoot.
- If the tip is cut as in A, the auxin producing cells are eliminated. The absence of auxins inhibits any cell elongation and therefore no growth of the shoot.
- If the shoot is exposed to light coming from one direction as in set up C, light causes lateral migration of auxins to the dark side. This causes unequal distribution of auxins.
- The side far from light receives more auxins and causes faster rate of cell elongation more than the side with light. The shoot therefore will bend towards the direction of light.
- The shoot whose tip was covered using aluminium foil did not respond to unidirectional light. It continued to grow upwards.

Auxins and geotropism

We learnt earlier that geotropism is a response of plants to the stimulus of the pull of gravity. We also learnt that the roots show positive geotropism while the shoot show negative geotropism.

Under normal circumstances, the shoot (plumule) grows upwards and the root grow downwards.

If a seedling was growing horizontally, the radicle grow bending downwards while the plumule grow bending upwards.

This is because as auxins are produced, they diffuse away from the tip. The force of gravity pulls the auxins downwards. This cause auxins to concentrate along the lower part of the radicle and plumule as shown in Fig. 3.6.

The upper side of the radicle and plumule end up with a lower concentration of auxins.

In the plumule (young shoot), the lower part has a higher concentration of

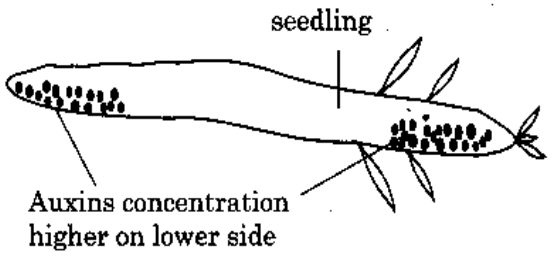


Fig. 3.6: Seedling with auxin concentrated more on the lower side.

auxins. The cells here elongate more. This results in more growth.

The upper part has lower auxin concentration. The cells here undergo less elongation. This results to less growth. As a result, the plumule grows curving upwards. This is **negative geotropism.**

In the radicle (young root), the lower part has a higher auxin concentration. The cells here undergo less elongation. This causes less growth. The upper part has a lower auxin concentration. The cells here elongate more. This causes more growth. As a result, the radicle grows curving downwards. This is **positive geotropism**.

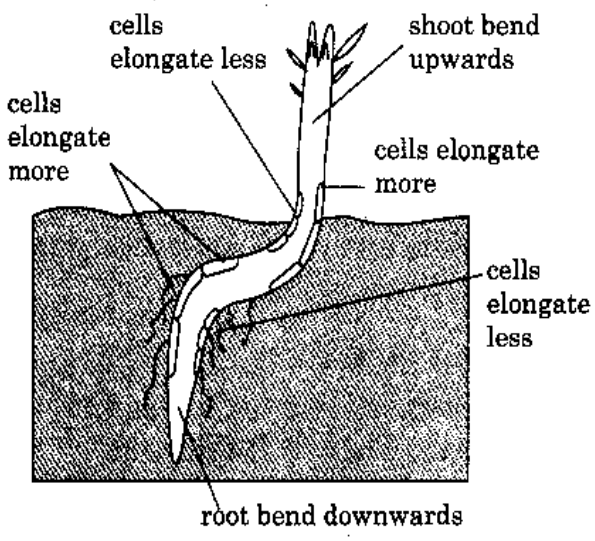


Fig. 3.7: Geotropism as explained by distribution of auxins due to gravity.

Auxins and thigmotropism

The growth response of plants towards the stimulus of contact coming from one direction is referred to as **thigmotropism.**

This response is also controlled by auxins. The contact influences the migration of auxins away from it. As a result, the side of the seedling in contact has less auxins. Cells on this side undergo less elongation. This causes less growth. The side further away from the point of contact has a higher concentration of auxins. As a result, the parts in contact with the supporting structure grows curving towards the point of contact. This way, the plant grows twinning along the supporting structure as shown in Fig. 3.8.

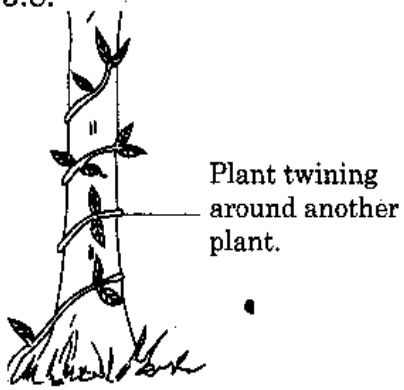


Fig. 3.8: Thigmotropism.

Revision Exercise 3

1. (a) What do you understand by the word tropism?
   (b) Name two types of tropism.
2. What are the effects of auxins on growth of plants.
3. Give the name of the following responses.
   (a) A plant shoot growing upright.
   (b) Plant roots growing down into the soil.
   (c) A plant in a dark room grows bending towards a source of light.

Unit 4

Excretion

Specific objectives

By the end of this unit, you should be able to:

(a) Explain the meaning of excretion.
(b) Label the parts of a kidney.
(c) Explain how a kidney works.
(d) State the substances that are excreted by the kidney.
(e) Explain the role of ADH in osmoregulation.
(f) Explain how a dialysis machine works.

Meaning of excretion

Excretion is the removal of metabolic waste products from the body.

During metabolism (that is, reactions in the tissues), waste substances are produced. If these waste substances accumulate in the cells or even in its surroundings, they affect normal functioning of the cells. The wastes become toxic and can even kill the cells.

Examples of metabolic wastes produced by cells include:

(i) Carbon dioxide – from the process of respiration.
(ii) Nitrogenous wastes – these are produced by protein metabolism. They include urea, uric acid, ammonia, cretinine among others.
(iii) Excess water – absorbed in the body after taking in excess fluids and drinks.
(iv) Waste of chemical substances such as hormones and drugs after their functions.
(v) Bile pigment produced after breakdown of red blood cells.

During excretion, these substances are selected and removed from the blood and then eliminated.

Excretory organs in the body

Organs in a human body involved in excretion include:

(i) The kidney.
(ii) The liver.
(iii) The skin.
(iv) The lungs.

Let us now learn about the structure and functions of the kidney.

Parts of a kidney

The kidney is an organ found in vertebrates. Each vertebrate has two kidneys. Kidneys are bean-shaped and are red-brown in colour. They lie near the back of the abdominal cavity about the level of the waistline. Each kidney weighs approximately 142.5 g. It is about the size of a clenched fist. The right kidney is slightly lower than the

left. The kidney is surrounded by a layer of fat which helps to cushion it from mechanical or physical injury.

The kidney is supplied with blood from the general circulatory system via the **renal artery** which branches off from the aorta. Blood from the kidney goes back to the general circulation through the **renal vein** which joins the vena cava. A tube called the ureter connects each kidney to the **bladder** located in the lower abdomen. From the bladder, another tube called the **urethra** opens to the exterior of the organism. Two rings of **sphincter muscles** encircle the urethra. They control the emptying of the bladder. The two kidneys, two ureters, the bladder and the urethra make up the **urinary system.** The diagram below shows parts of the human urinary system.

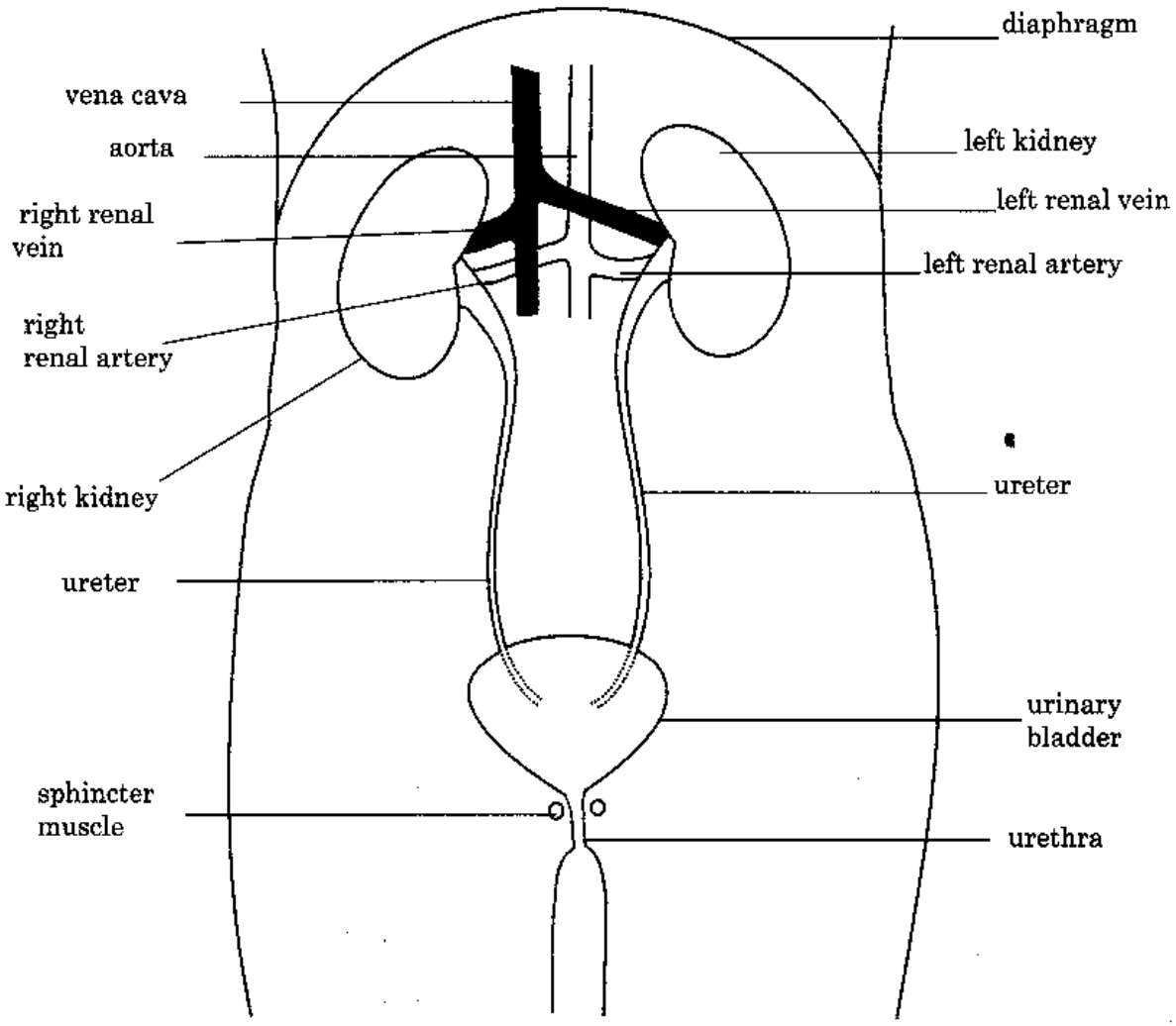


Fig. 4.1: The human urinary system.

Activity 4.1: To examine and draw the mammalian kidney

Requirements/materials

- Sheep kidney.

Procedure

1. Examine the whole kidney.
2. Note the various tubes attached to it.
3. What is the external colour of the kidney?
4. Draw and label the external structure of the kidney.

Activity 4.2: To make a vertical section of the kidney

Requirements/materials

- Fresh kidney of sheep/goat/cow, sharp razor, knife or scalpel, small dissecting board, hand lens or dissecting microscope.

Procedure

1. Place the kidney on the dissecting board.
2. Use the scalpel to cut the kidney along its length at the middle.
3. Identify the following parts: Cortex, medulla, pelvis, renal artery, renal vein and urethra. Refer to Fig. 4.2 during this exercise.

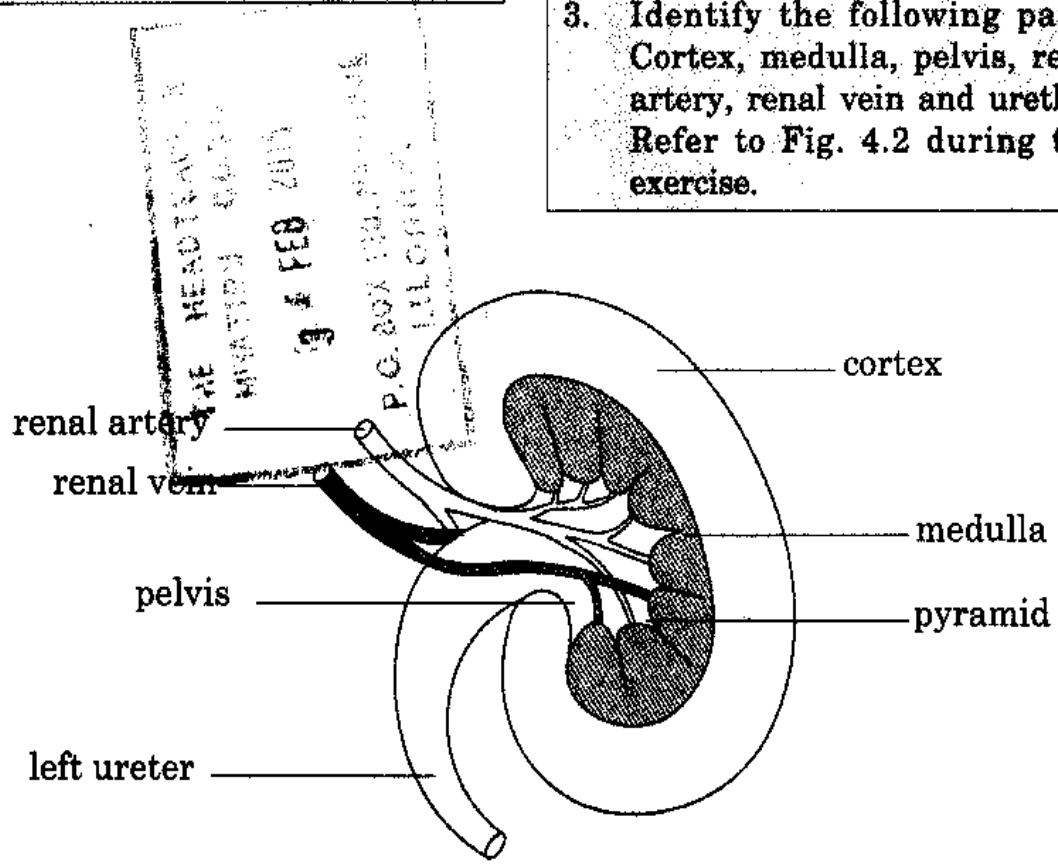


Fig. 4.2: Longitudinal section through the kidney.

4. Draw and label the structures you have identified.

A longitudinal section through the kidney (Fig. 4.2) reveals two main regions; the outer part which is darker in colour called the **cortex** and the inner light coloured region called the **medulla**. The **pelvis** is the widened end of the urethra which enters the kidney. The medulla extends into the pelvis in triangular projections called **pyramids.**

The kidneys have two main functions. First, they remove excess **salts, water** and **nitrogenous wastes** from the blood. This is referred to as **excretion**. Secondly, they regulate the concentration of water and salts found in the body fluids. This is referred to as **osmoregulation.** What would happen to a person if the kidneys fail to perform these functions?

As an excretory organ, the most important work of the kidneys is to filter wastes from the blood. This takes place in tiny units called **nephrons** or renal tubules. A nephron is therefore referred to as the functional unit of the kidney.

Each kidney has about 1.25 million nephrons. One part of the nephron is in the cortex and the other part in the medulla, Fig. 4.3 shows the detailed structure of the nephron.

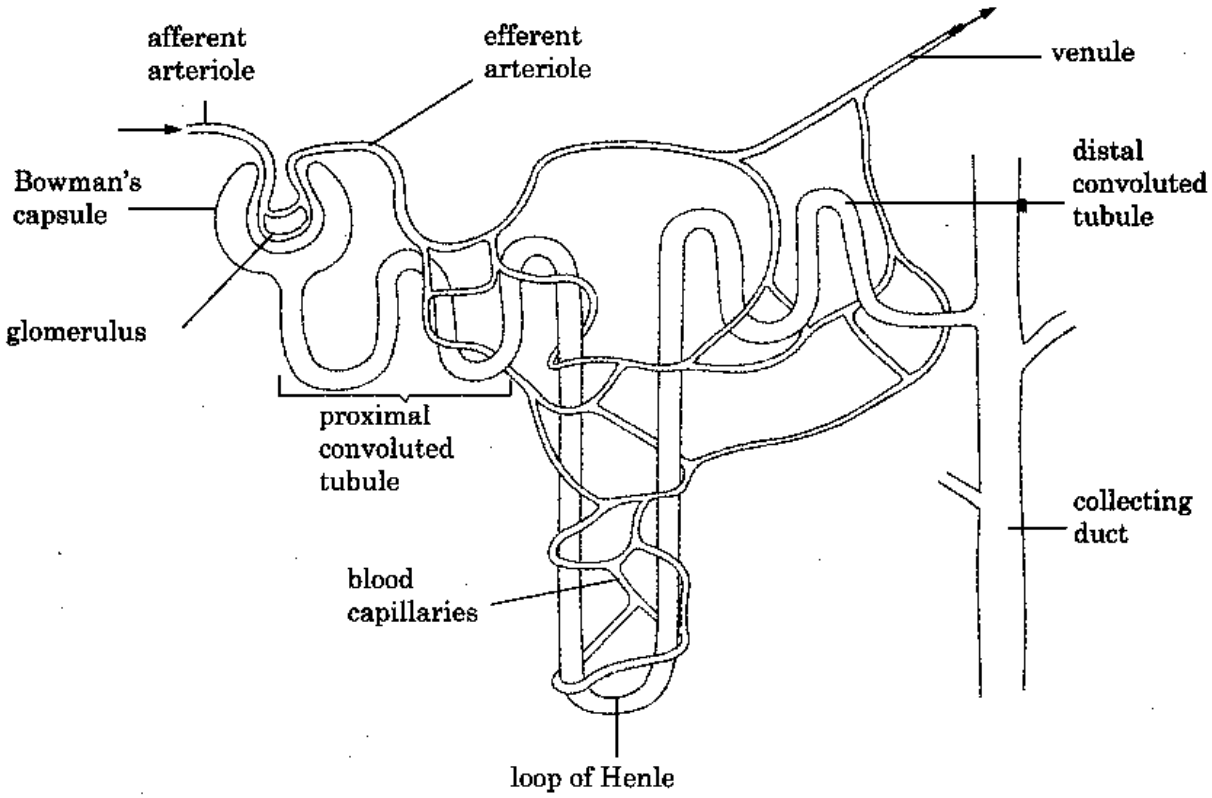


Fig. 4.3: Structure of the nephron.

The nephron has three distinct coiled parts; **the proximal convoluted tubule**, a **U-shaped loop of Henle** and a **distal convoluted tubule.** One end of the nephron is modified to form a cup shaped structure called the **Bowman's capsule.**

The nephron is supplied with an extensive network of blood capillaries. In the Bowman's capsule, the capillaries form a knot called the **glomerulus** (plural glomeruli) which branches from an **afferent arteriole** that originates from the **renal artery.** The glomeruli capillaries reunite to form an efferent arteriole which channels blood away from the glomerulus. The efferent arteriole branches out into a second network of capillaries that surround the convoluted tubules and the loop of Henle. These capillaries eventually reunite to form **venules** which link up with other venules to form the renal vein that takes blood out of the kidney to the vena cava.

Thus, on one end of the nephron is blood supply from the artery, and on the other end is blood supply to the vena cava. Explain this arrangement on the basis of what has been mentioned as the function of the nephron.

Fig. 4.4 below shows the location of the nephron in the kidney.

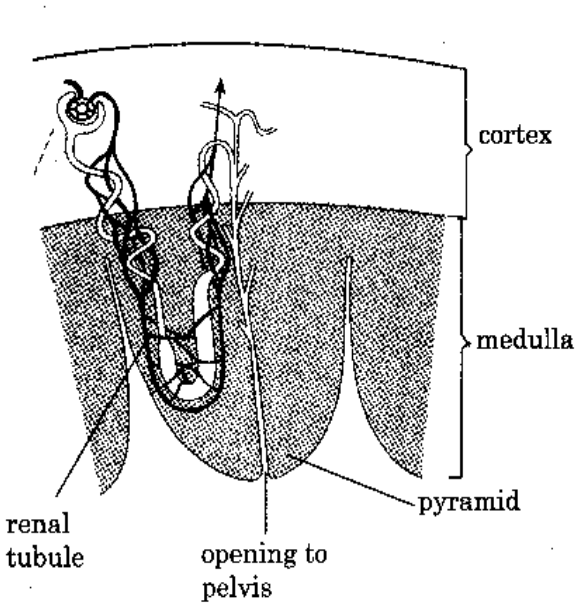


Fig. 4.4: Location of the nephron in the kidney.

How the kidney functions

Excretion in the nephron is carried out in two stages: **Ultrafiltration** and **selective reabsorption.** Blood coming into the kidney from the artery contains both waste substances and useful substances.

These wastes must enter the nephron, where separation takes place. The body must not lose the useful substances. Substances enter the nephron by **ultrafiltration.**

The useful substances must be taken back into the blood so that they are not lost. This process is known as **selective reabsorption.**

Note: This is referred to as selective reabsorption because only useful substances are reabsorbed.

Name the substances carried by the blood. Try to categorise these into useful ones that the body should retain, and wastes that should be excreted.

Ultrafiltration

Ultrafiltration takes place in the glomerulus. Note that the afferent arteriole that takes blood to the glomerular capillaries has a wider lumen than the efferent arteriole that takes blood away from it. Due to this difference, a high pressure of blood is created in the glomerulus.

This pressure forces water, mineral ions and small molecules like glucose, amino acids and urea out of the glomerulus. These pass through the tiny pores in the walls of the glomerular capillaries into the Bowman's capsule. The liquid collected in the Bowman's capsule is called **glomerular filtrate**.

The larger molecules in the blood, like blood proteins, white blood cells, red blood cells and platelets have large molecules and cannot pass through the capillary walls of the glomerulus. These remain in the blood and continue to flow to the efferent arteriole.

The glomerular filtrate flows down the nephron where re-absorption will take place as it flows along.

Selective reabsorption

As the glomerular filtrate passes along the nephron, some substances that are useful to the body are selectively taken back or reabsorbed into the blood capillary network surrounding the nephron.

All amino acids and glucose are reabsorbed by active transport in the proximal convoluted tubule.

Some salts and water are reabsorbed depending on how much of them the body still needs. Water is reabsorbed by osmosis and salts by active transport.

Salts are reabsorbed in the loop of Henle and mainly in the distal convoluted tubule.

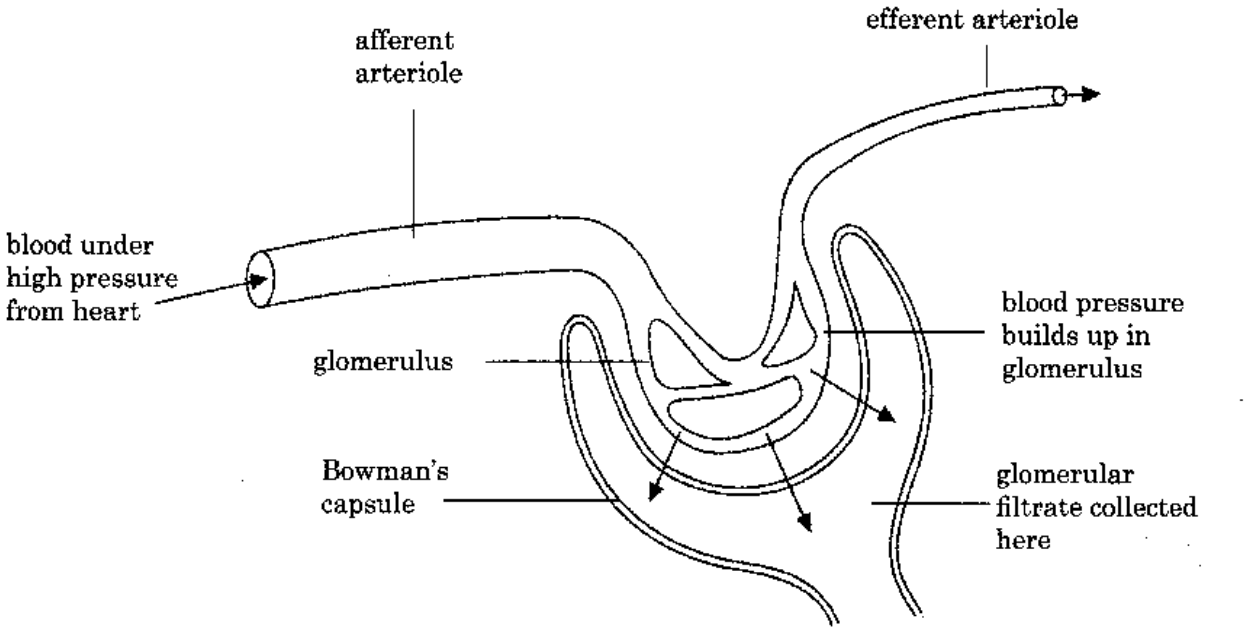


Fig. 4.5: Ultrafiltration at the glomerulus.

Water is reabsorbed in both the proximal and distal convoluted tubules. However, most of the water is reabsorbed in the collecting duct.

No urea is reabsorbed into the blood.

By the time the filtrate from the glomerulus completes its movement down the nephron, it has a high concentration of **urea, some salts** and **water.** The liquid is now called **urine.**

Several nephrons empty into one collecting duct, and all the collecting ducts of a kidney empty into the ureter. The process of urine formation is a continuous one and the ureter continuously receives small amounts of urine. The bladder stores the urine until it is full, then one begins to experience an uncomfortable feeling. The sphincter muscles must then be relaxed in order to empty the bladder.

Note

The loop of Henle is found only in mammals and birds. It enables them to reabsorb very large quantities of water from the glomerular filtrate. This makes the urine concentrated and enables the animals to conserve and retain water in the body. Animals that live in dry habitats like deserts tend to produce little but very concentrated urine because they have long loops of Henle.

Note that it is good practice to empty the bladder in the right places like toilets, latrines or urinals. Emptying the bladder in places like bus stops, near the road, in water bodies on walls is extremely unhygienic. In addition to destroying the environment, the urine may also contain disease-causing micro-organisms that can contaminate drinking water and vegetables.

The following table gives a comparison of the composition of the urine with that of both the glomerular filtrate and plasma.

Main substances	Grams of substance per 100 ml of fluid		
	Plasma	*Glomerular filtrate*	*Urine*
Urea	0.03	0.03	2.0
Uric acid	0.005	0.005	0.05
Ammonia	0.001	0.001	0.04
Glucose	0.10	0.10	0
Amino acids	0.05	0.05	0
Mineral salts	0.70	0.70	1.50
Blood proteins	8.00	0	0

Table 4.1: Comparison of composition of urine with that of glomerular filtrate and plasma.

Substances excreted by the kidney

Study Table 4.1 that compares substances formed in the blood in the glomerular filtrate and in the urine.

From the table identify substances that:

(i) Are excreted by the kidney.

(ii) Are not excreted by the kidney.

From your discussion you may have realised that the kidney does not excrete glucose, amino acids and proteins. This is because amino acids and glucose are reabsorbed back into the blood in the proximal convoluted tubule. Proteins on the other hand are large molecules and thus they are not ultra-filtered.

You may also have realised that the kidney excretes the following substances:

(i) Urea.

(ii) Uric acid.

(iii) Water.

(iv) Ammonia.

(v) Excess mineral salts – This is because some mineral salts cannot be stored in the cells. They can cause changes in osmotic pressure making the cells to absorb excess water hence swell and then burst.

Kidneys also excrete toxic substances from the body. These are substances that are mainly taken into the body with drugs or with food substances. Such substances include:

(i) Remains of drugs or medicine.

(ii) Chemical additives used in food preservation.

(iii) Chemicals not useful to the body contained in some soft drinks.

Presence of glucose and proteins in urine

In some patients, glucose and proteins can be passed out through urine.

The presence of glucose and proteins in urine indicates a disease or disorder. Examples of such diseases or disorders include:

(a) Proteinuria

This is a condition whereby capillaries in the glomerulus lose their ability to be selective. This makes them allow large protein molecules to pass through and enter the kidney tubules. These molecules cannot be reabsorbed. They are thus passed out through urine.

(a) Diabetes mellitus

Presence of glucose in urine is common in people suffering from diabetes mellitus. The blood in such patients contain excess glucose.

In the glomerulus, the glucose is ultra-filtered into the kidney tubule. The proximal convoluted tubule cannot reabsorb all the glucose back to the blood. This allows some glucose to be passed out through urine, explaining why one of the test for diabetes involves testing for the presence of glucose in the urine of a patient.

The role of ADH in osmoregulation

Water balance (control of blood osmotic pressure)

We have seen that the kidney is an excretory organ. The other function of the kidney is to keep the concentration of some substances in the body constant. These substances include water and

mineral salts. When the concentration of these substances is controlled, the osmotic pressure of blood and tissue fluid is also regulated. This is known as **osmoregulation**.

Blood and tissue fluid must be kept at a constant osmotic pressure to avoid unnecessary movement of water into and out of cells by osmosis. If for example, the osmotic pressure of these liquids is higher than that of the cell contents, the hypotonic cells will lose water by osmosis to the body fluids. If this continues for long, normal cell function is affected because the cells become crenated and the body can become dehydrated. This can cause death.

On the other hand, if the blood and body fluids contain too much water, the osmotic pressure of these fluids becomes lower than that of cells. The cell contents become hypertonic to the fluids and gain water by osmosis. If this continues for long, normal cell function is affected because the cells enlarge. If this situation is not corrected, they burst.

Therefore, it is important that the amount of water and hence the osmotic pressure between the cell and body fluids are balanced at levels which are optimum (normal) for normal cell activity.

Special sensory cells in the brain called **osmoreceptor cells** detect changes in water balance or the osmotic pressure of the body fluids. These cells send out signals which initiate the appropriate corrective mechanisms in the kidney.The regulation of water in the body is under the control of the **antidiuretic hormone** (ADH). This hormone is produced by the pituitary gland located at the base of the brain. ADH regulates the amount of water absorbed in the kidney. The regulation process is summarised in Fig. 4.6.

Questions

(a) What is happening to osmotic pressure of body fluids at A? What circumstances lead to too little water in the body?

(b) What is happening to the osmotic pressure of body fluids at B? Under what circumstances is there excess water in the body?

When the concentration of water in the blood and tissue fluid drops below normal (too little water in the body), the osmoreceptor cells in the brain detect this change and send a signal to the pituitary gland. The pituitary gland increases the secretion of anti-diuretic hormone (ADH) into the blood.
When ADH reaches the nephron in the kidney, it causes increased permeability of the walls of collecting ducts and distal convoluted tubule to water. Nephrons increase reabsorption of water from the glomerular filtrate into the blood. Little water is lost through urine and one produces small quantities of concentrated urine. Therefore the body conserves water.

When the concentration of water in the blood rises above normal (too much water in the body), the osmoreceptors in the brain detect the change and send a signal to the pituitary gland to secrete less anti-diuretic hormone (ADH) into the blood. This causes the nephron to become less permeable to water. Reabsorption of water into the blood reduces from the glomerular filtrate. This causes the elimination of the excess water via urine. One produces large quantities of dilute urine.

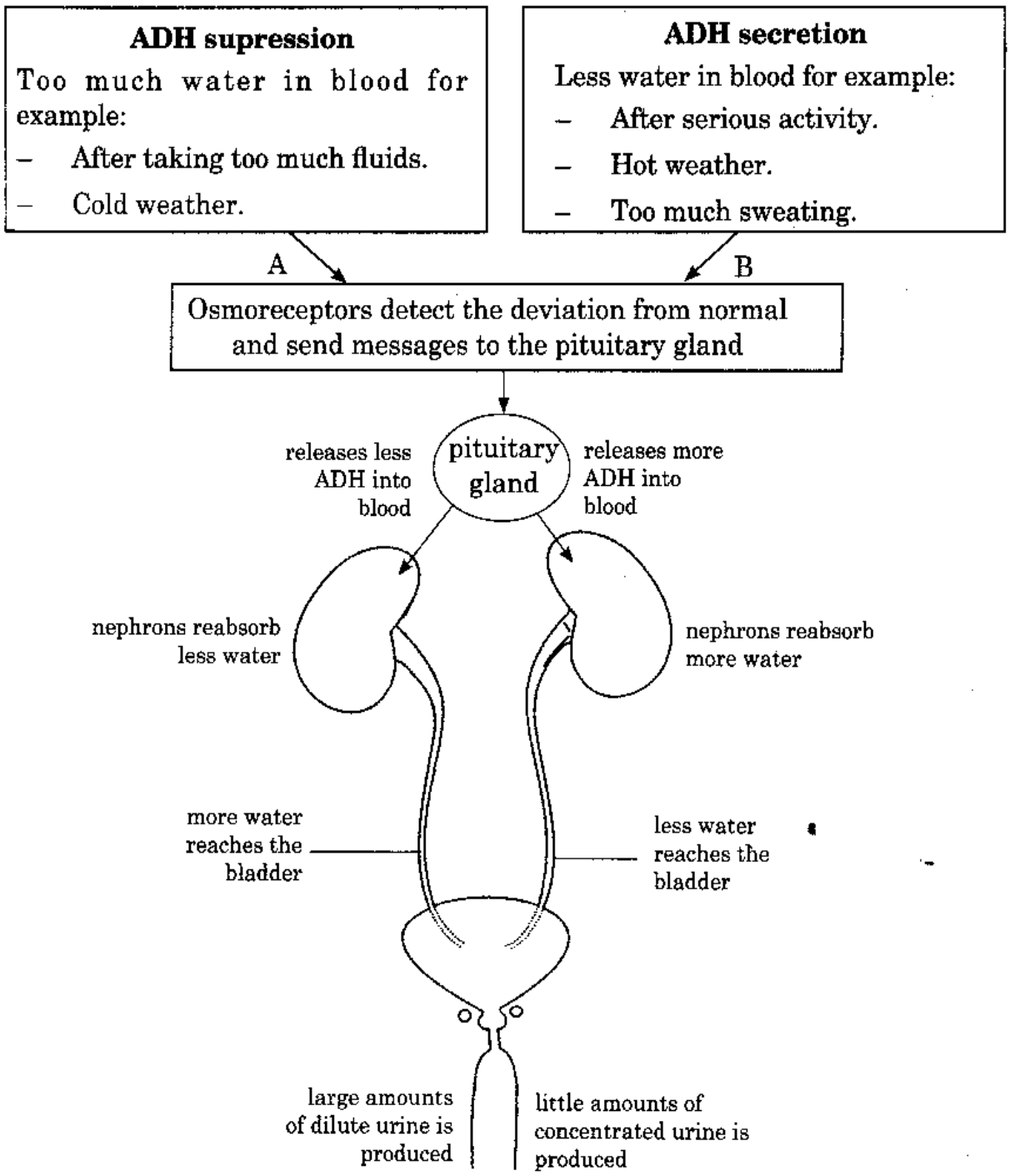


Fig. 4.6: Homeostatic control of amount of water in the body.

Dialysis machine

Sometimes, a kidney or kidneys in a person can fail to work due to acute kidney injury or disease. In such a situation, the normal kidney function does not occur and wastes like urea and excess salts or water start to accumulate in the body.

Dialysis is a process by which waste and excess water can be removed from the blood in an artificial way. Dialysis treatment involves the use of a dialysis machine. The machine works on the principle of diffusion of solutes and ultrafiltration of fluid across a semi permeable membrane. The patient is

connected to the machine by allowing blood from the patient to flow into the machine and back to the patient. In the machine, wastes and excess water are removed. The blood flows through a tube made of semi-permeable membrane which is surrounded by a special dialysis fluid. Dialysis works on the principal of ultra-filtration and diffusion as studied in the functions of the kidney. Excess water and salts leave the blood into the dialysis fluid and so does the urea. The blood is then returned into the body of the patient. See figure 4.7.

A dialysis machine cannot replace the kidney because it does not respond to hormones like ADH.

The dialysis tubing inside the dialysis machine is a narrow, long tubing. This increases the surface area to volume ratio hence increases the rate of diffusion.

The temperature of the dialysis fluid is almost the temperature of the patients blood. Therefore, the patient's blood returns to the vein in the arm at almost the temperature of the body.

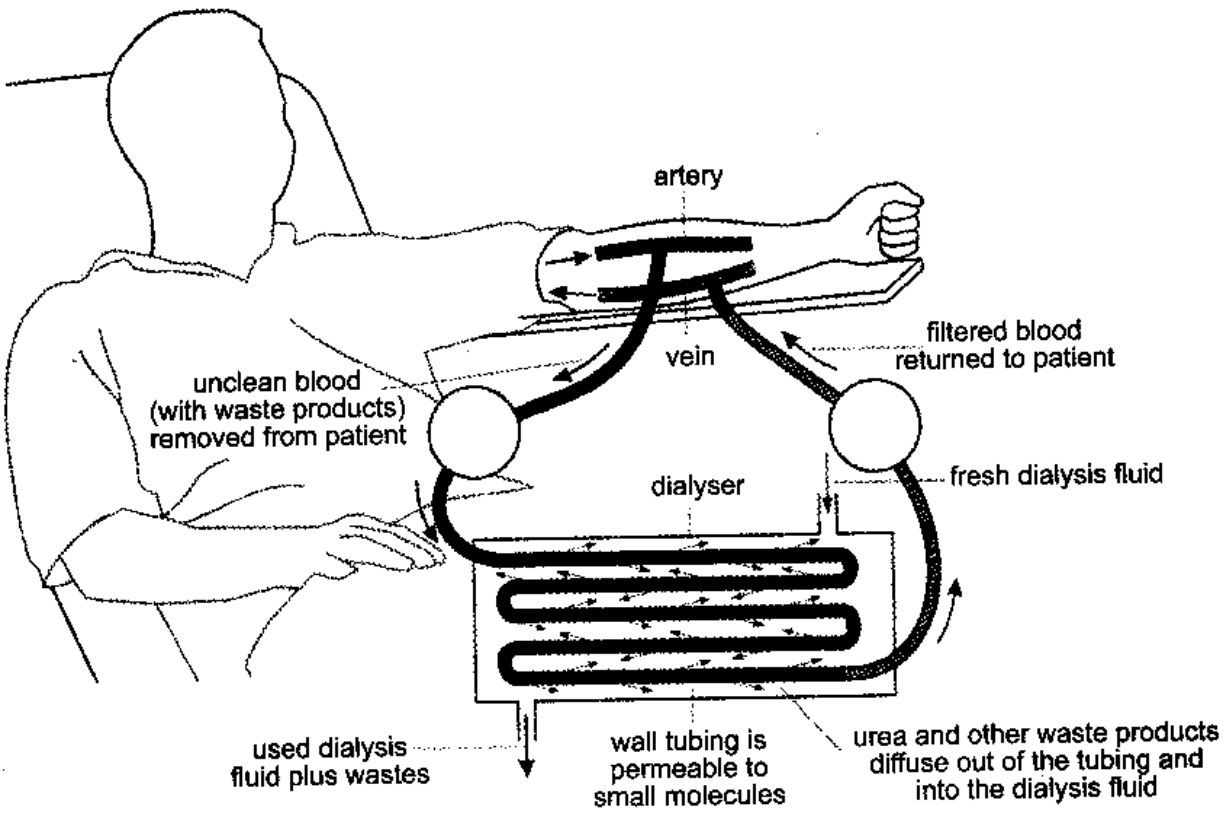


Fig. 4.7: Dialysis machine in use.

To clean the blood off all waste materials, the blood must pass through the dialysis machine many times. This process takes up to ten hours and must be repeated often.

Revision Exercise 4

1. What is excretion?
2. What is the difference between egestion and excretion?
3. Name the cup-shaped structure that surrounds the glomerulus of the nephron.
4. Name the organs of excretion in humans.
5. Describe the two stages involved in the formation of urine by the nephron.
6. Discuss the role of ADH in the control of water balance in the body.
7. Explain why excretion is important to living organisms.
8. Explain the working of a dialysis machine.

Unit 5

Genetics

Specific objectives

By the end of this unit, you should be able to:

(a) Explain the causes of variation among organisms of the same species.

(b) Distinguish between continuous and discontinuous variations.

(c) Use mathematical skill to describe variations.

(d) Investigate variations amongst varieties of a chosen plant.

(e) Describe the principles underlying Mendelian genetics.

(f) Work out the ratio of genotype of offsprings in monohybrid crosses.

(g) Use genetic terms to describe crosses.

(h) Explain how sex is determined in human beings.

(i) Explain how sex-linked characteristics are inherited.

(j) Explain the relationship between chromosomes, DNA and genes.

(k) Describe how mutation works.

(l) State examples of plant and animal breeding in Malawi.

Concepts of genetics

The passing of characteristics from parents to offspring is referred to as **heredity**. **Genetics** is the scientific study of heredity. To understand genetics, we need to know how variation occurs in plant and animal species.

Causes of variations in populations

Variation refers to the differences within the observable and non-observable characteristics in a given species of organisms. The word variation comes from the word 'vary' which means 'to differ'.

Variation is used to place each organism in its own taxonomic group. For instance, given a dog and a domestic fowl, we use differences such as presence of mammary glands, skin covered with fur or skin covered with feathers to place the dog in **class Mammalia** and the domestic fowl in **class Aves.**

In genetics, we will look at the differences within a particular characteristic in a given species. For instance, in dog species, all have skin covered with fur. But the fur coat has

different colours. The colours may be black, white or grey. These differences in the colour of the fur constitute **variation** within that characteristic.

In animals, variation is observed in their skin colour, height, colour of eyes, blood group, sex, shape of nose, colour of hair and finger print patterns.

In plants, for instance in pea plants, variation is observed in the length of the stems, colour of flowers, shape of pods, colour of pods and colour of seeds.

Variations can be caused by:

- Segregation of chromosomes during gamete formation and crossing over during meiosis.
- Mutations.
- Sexual reproduction where a zygote is formed by gametes of two parents with varied features.
- Environment.
- Age.
- Heredity.

(i) Segregation of chromosomes during gamete formation

As gametes are formed, chromosomes number in a cell is halved. At this time, chromosomes in a pair are separated and move to different gametes. The gametes formed therefore are not similar in their genetic composition.

(ii) Mutations

These are sudden changes in the structure and amount of genetic material in the cells of an organism. Mutations cause changes in characteristics of an offspring.

(iii) Sexual reproduction

During sexual reproduction, a zygote is formed by fusion of two cells from separate parents. This results to differences in characteristics.

(iv) Environment

The environment in which an organisms lives determines how it will grow and how characteristics in it will be developed.

For example, a certain plant that is tall in nature will only grow to its fullest height if all factors necessary for growth are available.

Absence or reduced quantities of some factors may end up making the plant to be a dwarf. The environment therefore brings about variation in characteristics.

(v) Age

Characteristics are known to develop with age.

Differences in age results to differences in the development of characteristics such as weight and height in offspring produced from the same parent. This brings about variations.

For instance, two individuals born by same parents will vary in weight of their bodies although they are brought up in the same environment.

Types of variations

There are two types of variations:

(a) Continuous variation
(b) Discontinuous variation

Discontinuous variation

This is a variation whereby individuals in a given species show definite or distinct differences in a given characteristic.

Let us carry out the following activity to demonstrate discontinuous variation within members of your class.

Activity 5.1: To investigate variation in tongue rolling ability among members in Form Four class

Procedure

1. Let the members of your class try and roll their tongue to form a U-shape.
2. Count the number of students in the class who;
   (i) are able to roll their tongues.
   (ii) are incapable of rolling their tongues.
3. Fill your results in a table like the one shown below.

Rollers	
Non-rollers	
Total	

4. Plot a **histogram** showing those who are able to roll their tongues and those who are not able.

Questions

(i) How many students had the ability to roll their tongues?

(ii) How many students were unable to roll their tongues?

(iii) Were there students who could not fall in either of the groups?

(iv) Suggest another characteristic in your class members that can put them into distinct groups.

Discussion

From the activity, you may have found out that the students in the class can be put into two groups according to the ability and inability to roll their tongues. One group was able to roll the tongue while the other group was not able.

Also, you may have found out that there were no students in between the two groups that is, students who could roll the tongue half way. In this case, each student was either a roller or a non-roller.

The characteristic for tongue rolling therefore has two variations that are distinct from each other. This is referred to as **discontinuous variation.**

Another characteristic that has two distinct variations is **gender.** If the class is mixed, an individual is either male or female, or if it is a single gender school, the members of the entire student community are either males or females. There is a clear cut difference between the two variations.

Discontinuous variations show clear cut differences in individuals of the same species with regard to a given characteristic.

Discontinuous variations is caused by genetic factors called **genes** found in the nucleus of the cell. The genetic factors are inherited by the offspring from the parents.

Tables 5.1 and 5.2 gives a summary of discontinuous variation in selected plants and animals.

Characteristic traits	Variation
1. Leaf venation	Parallel or network
2. Flower colour in garden peas	Red or pink
3. Pod shape in peas	Inflated or constricted

Table 5.1: Examples of discontinuous variations in plants

Characteristic traits	Variation
1. Sex	Male or female
2. Blood groups	A, B, AB, or O
3. Skin coat in dogs	Rough or smooth
4. Finger print patterns	Tentarch, loop or double looped

Table 5.2: Examples of discontinuous variations in animals.

Some characteristics like blood groups and finger print patterns have more than two variations.

double loop

loop

mixed

pocked loop

tentarch

Fig. 5.1: Finger print patterns – they show discontinuous variation.

Continuous variation

Some variations in individuals in a given species show many slight differences in a given characteristic. The differences range from one extreme end to another with *many intermediate forms* in between.

Let us carry out the following activities to demonstrate continuous variation.

Activity 5.2: To measure and record height of class members

Requirements/materials

- Metre rule.
- Notebook.

Procedure

1. Work in groups of five.
2. Ask each member of your group to stand straight against a vertical wall.
3. Measure the height of each member from the heel to the top of the head using the meter rule.
4. Record the height of each member in your notebook.
5. Get the heights recorded by other students in other groups and record in your notebook.

Questions

1. From the data in your notebook, identify;
   (a) the shortest height.
   (b) the tallest height.
2. Can you group the students into two groups (tall or short) as you did with tongue rolling?
3. If your answer in (2) is no, try to put the heights obtained into various groups or classes according to their range; for instance, the number of students with a height of between 100 cm – 109 cm. Count the number of students in each range. This number is known as the **frequency** (number of students who are found in a given range of height).
4. Determine the mean, median and mode.
5. Identify the range with the least number of students.
7. Identify the range with the largest number of students.

Activity 5.3: To investigate variations amongst varieties of a chosen plant

You will carry out a long term project that will take the whole term. In this project, you will investigate the outcome of planting pea seeds.

Requirements/materials

- Your teacher will provide you with several dried pea seeds. (work in groups of five).

  Note the colour of the pea seeds, their shape and size.

Procedure

1. Plant the seeds and allow them to grow (keep watering them frequently).
2. When the plants start flowering, note the colour of the flowers. How many varieties of colour do you notice? What about the position of the flowers on the stems. Is it the same?
3. (a) Note the colours and count the plants with each colour.
   (b) Plot a histogram of the plants with each respective colour.
   (c) Find the ratios of the number of plants of each type of colour to each other.
4. What other features do you notice in the maturing plants? Measure the lengths of stem. Are all the plants tall? Are some short? Record the number of tall and short plants (if any). Record their ratios to each other.
5. Repeat this procedure for other traits you observe for example,
   (a) Type of pod (inflated or constructed).
   (b) Position of the flowers (terminal or axial).
   (c) Shape of seed (round or wrinkled.
   (d) Colour of seed coat (yellow or green).
6. Visit the plots/tins/boxes of other groups apart from yours and repeat your observations.
7. Draw conclusions from your findings.
8. Write a report.

Principles of Mendelian genetics

Gregory Mendel was an Austrian monk who carried out investigations in the inheritance of characteristics. In his experiments, he grew garden peas. He chose the pea plant because it had many varieties. When he self-pollinated these varieties, the offspring were like the parent plant and also like each other. He called these parents **true breeding**.

The characteristics he studied in the plants were for example, the inheritance of seed shape, seed colour, flower colour or stem length among others.

After many experiments, he arrived at his first law, **the law of segregation** which is key in understanding the inheritance of characteristics.

The first law of heredity

We have learnt that, a given characteristic is determined by a pair of alleles found in the nucleus of a cell.

During meiosis, the alleles separate into different gametes. The alleles are eventually inherited separately by offspring as a result of fertilisation. The zygote formed receives one allele from each parent to form a pair of alleles which will determine the way a particular characteristic develops in it. This is how characteristics are inherited by offspring from parents.

The idea of heredity was first established by a scientist called **Gregory Mendel.** He carried out experiments from which he formulated the first law of heredity which states that *"An organism's characteristics are determined by internal factors that occur in pairs. Only one of a pair of such factors can be represented in a single gamete.* In modern terms, this means the characteristics of a diploid organism are controlled by alleles occurring in pairs.

Of a pair of such alleles, only one can be carried in a single gamete. He called this law, **the law of segregation.** We can now study some of the experiments that Mendel carried out that led to the formulation of this law.

Mendel's experiments: Monohybrid inheritance (3:1 ratio)

Mendel carried out his experiments in a small garden in his monastery. He used garden peas of the species *Pisum sativum.* He preferred to use the peas because:

- Peas grow very fast and are able to produce seeds within a very short period of time (about three months).
- Peas are usually self pollinating but could easily be manipulated to allow cross pollination.
- It was possible to produce many seeds from pea plants grown in a small area.
- The peas showed several characteristics with variations that were easily distinguishable from each other. For instance, some pea plants had long stems (tall plants) while others had short stems (dwarf plants). Some had purple flowers while others had white flowers. Table 5.3 shows the characteristics that Mendel investigated.

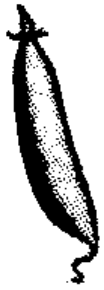
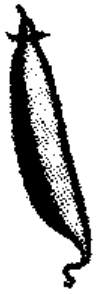
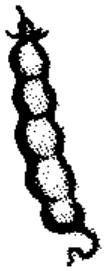
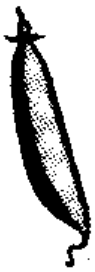
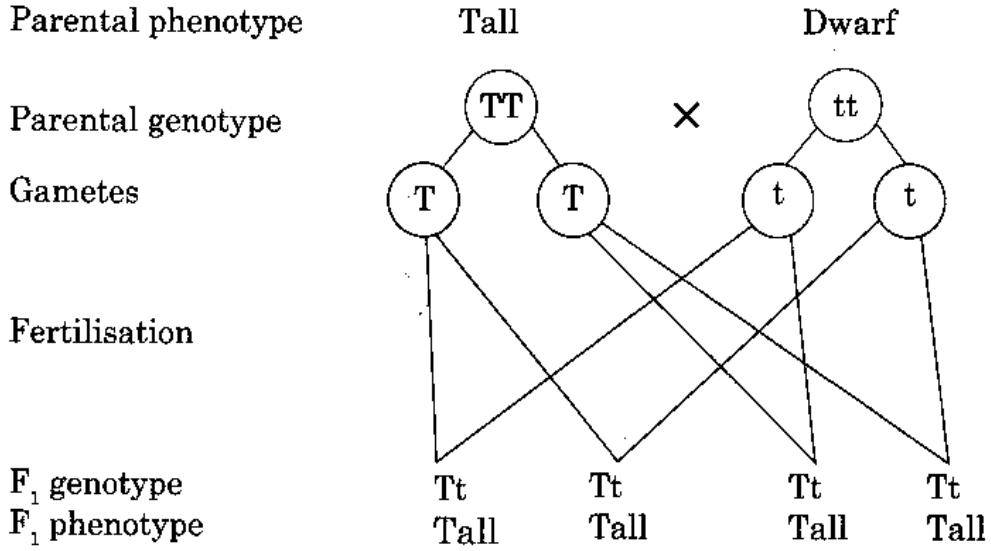
Trait studied	Stem length	Flower position	Seed shape	Seed colour	Flower colour	Pod shape	Pod colour
Dominant	 Tall	 Axial	 Round	 Yellow	 Red	 Inflated	 Green
Recessive	 Short	 Terminal	 Wrinkled	 Green	 White	 Constricted	 Yellow

Table 5.3: Traits in garden pea plant investigated by Mendel

Mendel chose to study each of these characteristics. He selected one characteristic of the plant at a time. He started by identifying groups of plants that were pure lines or true breeding homozygous plants. These were plants which when allowed to self-pollinate, could only produce an offspring identical to themselves. For instance, if the parent plant was tall and was allowed to self-pollinate, all the offsprings produced were tall. All pure lines are homozygous to a given characteristic. For example, pure tall plant have genotype TT meaning it is homozygous dominant. Pure line dwarf plant has a genotype tt meaning it is homozygous recessive.

Mendel identified two true breeding plants, one homozygogous dominant and another homozygous recessive which he cross pollinated by carefully first removing the stamens from the flowers of the dwarf plants. The removal of the stamens ensured that self pollination did not take place in that flower. He then transferred pollen from the anthers of the flowers of the tall plants and dusted them over the stigma of the flowers of the dwarf plant. This resulted in **fertilisation.** The process of fertilisation is also referred to as **crossing.** The fertilisation process that was involved is as shown in the following cross diagram.



Note: All gametes must be circled.

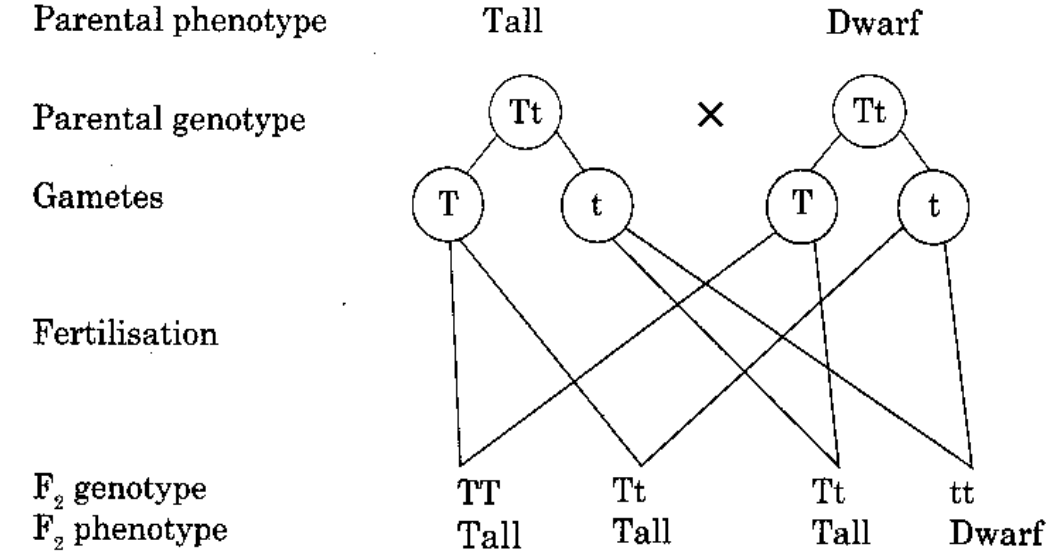
He allowed the fertilised flowers of the dwarf plant to produce seeds. He then planted these seeds, allowed them to grow and develop into new plants. These plants are referred to as the **F_1 generation plants.** F_1 stands for the first filial generation.

The word "Filial" means offspring and so F_1 means the first offspring.

He noted that all the plants in the F_1 generation were tall. He concluded that on crossing a pure tall plant with a pure dwarf pea plant, an F_1 generation that was composed of only tall pea plants were produced.

The reason for this was that the offspring had obtained a dominant allele for tallness and a recessive allele for dwarfness giving a heterozygous genotype Tt. This resulted in plants which were phenotypically tall.

Mendel then allowed the flowers of F_1 generation plants to undergo self pollination and fertilisation. He took the seeds produced and planted them to get the second Filial (F_2) generation. The fertilisation that resulted in the F_2 generation is illustrated in the cross diagram below.



He noted that the F_2 generation pea plants were composed of tall pea plants and dwarf plants.

On counting, he noted that the number of tall plants were approximately 3 times the number of dwarf plants. For example, in one field the tall plants were 787 while the dwarf plants were 277. This gives a ratio of approximately 3:1 of the tall to dwarf plants.

Female gamete / **Male gamete**	Genes/ Alleles	Genes/ Alleles
Genes/Alleles		
Genes/Alleles		

Table 5.3: Punnet square.

The example given above is typical of all Mendel's experiments involving the inheritance of a single characteristic. This inheritance is referred to as

	Female	Male
Parental phenotype	Tall	Dwarf
Parental genotype	TT	tt

Female gamete / **Male gamete**	T	T
t	Tt	Tt
t	Tt	Tt

F_1 generation genotype – Tt for All
F_1 generation phenotype – All Tall

monohybrid inheritance.

The crosses can also be illustrated by use of a table known as a **Punnet square** to predict possible genotypes and phenotypes of offsprings. It involves use of a table with rows and columns.

The first row and first column of the table are used to give information on the distribution of genes in the gametes of the parents as shown in the table below.

For example, if we consider the cross between the tall and dwarf plant discussed earlier, the Punnet square would look like the one shown below.

Note that the genotype and phenotype of the parents are indicated above the punnet square and those of the offspring below the punnet square.

Revision Exercise 5A

1. Give two reasons why Mendel used garden peas for his experiments.
2. Explain how Mendel determined whether a given individual plant was a pure line.
3. State Mendel's first law of heredity.
4. Mendel crossed a pure purple-flowered plant to a pure white-flowered plant. All the offsprings that were produced had purple flowers.
   (a) What name is given to the generation of offspring produced by the two pure lines?
   (b) Between the pure purple-flowered and the pure white-flowered plants, which one carries dominant alleles? Give reasons for your answer.
   (c) What type of inheritance is represented by the above cross?

(d) Assuming that the purple-flowered offspring was self-pollinated, give the name of the generation it would produce.

(e) State the phenotypic ratio expected in the generation mentioned in (d) above?

5. Mendel made a cross between pea plants with inflated pods and constricted pods. The allele for inflated pods is dominant over the allele for constricted pods. Carry out the following crosses.

(a) A cross between homozygous dominant and homozygous recessive to get F_1 generation.

(b) Self the F_1 generation to get the F_2 generation. Show the phenotypic ratios.

We have learnt that some characteristics show variation in species. For example, in dogs, the skin fur could be white, black or brown. Each colour is determined by a different gene. These genes determine variation in the same characteristic and are therefore found on the same loci or position on the homologous chromosomes.

Such genes are referred to as **alleles.** An allele is a short form of allelomorph which comes from two Greek words "allelo and morphe" meaning "each other" and "form" respectively. Therefore, the word allele means **different forms of the same gene.**

It is important to note that each characteristic is represented in the cell by alleles which always occur in pairs.

These pairs of alleles in the homologous chromosomes can be the same or different alleles. For example, the dog can have two alleles for white fur. The dog ends up having white fur. The dog may have two alleles for black fur and it ends up having black fur.

However, the dog may also have a pair of different alleles that is, one for white fur and the other for black fur. What colour do you think the fur will be? The fur colour which the dog will have will depend on the relationship between the alleles. If the fur in the dog is black then the allele for black fur is said to be **dominant.** A dominant allele is the allele that influences a characteristic to develop in an individual over another allele.

The allele for white fur is said to be recessive. **A recessive allele** is the one that cannot influence a characteristic to develop in an individual in the presence of the dominant allele. The dominant allele is usually represented by a **capital letter** while the recessive allele is represented by a **small letter.** For instance, we can represent the allele for **black fur colour** with a capital letter **B** while the allele for **white fur** with a small letter **b**.

The particular set of alleles in each cell determining a given characteristic is referred to as the **genotype**. This is also referred to as the **genetic composition** of an organism for that specific characteristic.

The genotype is always denoted by use of letters. The letters used are in 'twos' or in 'pairs'. In the example above, the alleles were denoted by B and b.

As such, from the example above, the possible genotypes are **BB, bb** and **Bb.**

When two alleles in a genotype are similar, the individual is said to be **homozygous** or **true breeding** to that particular characteristic. For instance,

if the genotype is BB, the individual is **homozygous dominant,** if the genotype is bb, the individual is said to be **homozygous recessive. "Homo"** means **"same".**

If the two alleles are different, the individual is said to be **heterozygous** for that particular characteristic. **"Hetero"** means **different.** If the individual has genotype Bb,the individual is said to be heterozygous for that particular characteristic.

The genotype influences the development of physical characteristics in an individual. The physical characteristics of an organism resulting from the influence of the genotype and the environment is referred to as the **phenotype.**

The phenotype of an individual is expressed in words. Black fur and white fur are examples of phenotypes.

In the example of the dog above, the phenotypes for the possible genotypes are as shown in the table below.

Genotype	Phenotype
BB	Black
Bb	Black
bb	White

Table 5.4: Genotypes and possible phenotypes.

Examples of characteristics inherited by incomplete dominance

- Coat colour in shorthorn cattle.
- Blood group inheritance in humans (AB blood group).
- Flower colour in 4 – O'clock plant *(Mirabilis jalapa).*
- Speckled colour in *Andalusi fowl.*

Test cross

A farmer wanted to breed white rabbits only for sale. He selected two white rabbits as parents for breeding. He then crossed the parents. To his dismay, some of the rabbits in the litter produced were black and he could not sell them. If the allele for white fur is dominant over the allele for black fur, how would the farmer ensure that only parents that produce white rabbits, all the time were used?

Note that the genotype for the white rabbits could either be homozygous dominant (BB) or heterozygous (Bb). By merely looking at the rabbits, the farmer will not know their genotypes. To breed white rabbits only all the time, the genotype of the parents need to be known. In this case, the farmer would need to know that in order to produce all white offsprings, two homozygous parents would be required. In selecting these parents, he would first need to determine their genotypes before crossing them. This method of determining the unknown genotype is known as a **test-cross** or **back cross.** It is carried out by crossing the organism whose genotype is unknown with a **homozygous recessive** organism for that particular genotype. Back cross means a test cross whereby one parent is crossed with an offspring.

If no offspring with homozygous recessive genotype is produced, then it is concluded that the parent whose genotype is unknown does not have a recessive allele. Therefore, the parent is homozygous dominant.

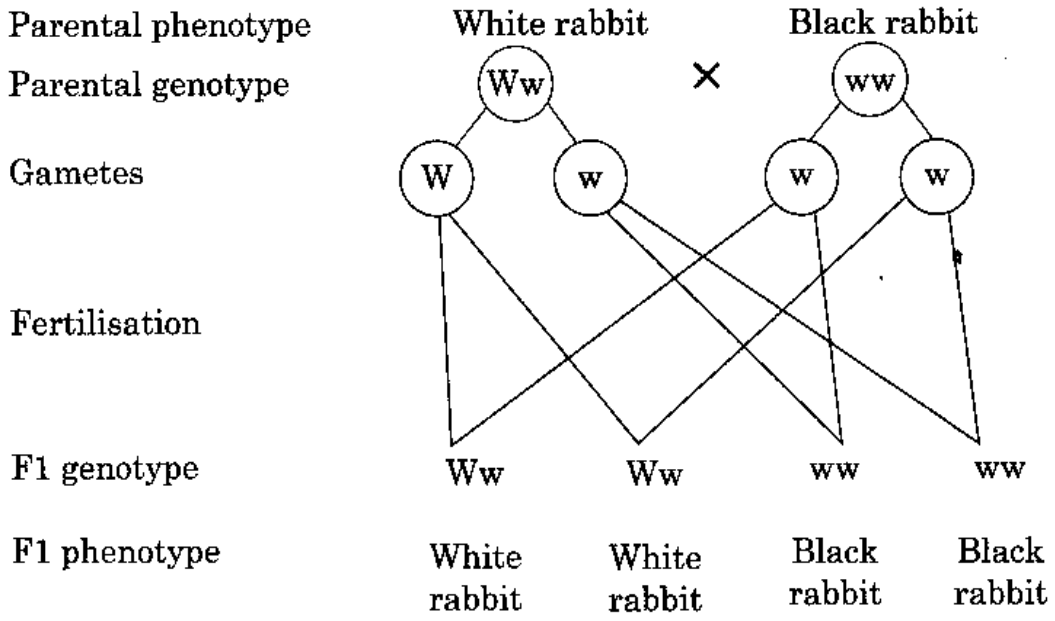
If some offspring have the recessive trait, this means that the parent whose genotype is unknown has a recessive allele. Therefore, the parents' genotype is heterozygous.

Consider the example above. The farmer would carry out the test cross to determine the unknown genotype of the white rabbit by crossing the white rabbit with a black rabbit which has a homozygous recessive genotype.

The white rabbit with the unknown genotype can be genotypically homozygous dominant (WW) or heterozygous (Ww). The possible outcomes of the crosses are as shown in diagram below.

ABO blood groups

Blood groups in humans are determined by antigens found on the surface of red blood cells. These antigens are antigen A and antigen B. They determine whether a given blood belongs to blood group A, B, AB or O. Blood plasma contains other proteins known as antibodies. Human blood may also contain another antigen known as the **Rhesus antigen (factor).** This antigen determines whether these blood groups will be rhesus positive or rhesus negative. We will discuss in this section how ABO blood groups are inherited.



Phenotypic ratio 1:1

The presence of black rabbits amongst the offsprings indicates the presence of a recessive allele in both parents. This shows that the genotype of the white rabbit is heterozygous (Ww).

Inheritance of ABO blood groups

The inheritance of the ABO blood group is determined by three alleles (multiple alleles) that influence formation of antigens on the red blood cells. These alleles are Allele A, Allele B and Allele O. Allele A determines the formation of Antigen A on the red blood cells. Allele B determines the formation of antigen B on the red blood cells and allele O prevents the formation of antigen A and antigen B on the red blood cells in their homozygous forms.

Alleles A and B show incomplete dominance to each other yet both are dominant to allele O. In other words allele O is recessive to alleles A and B.

The alleles as we learnt earlier are always found in pairs in the homologous chromosomes. These alleles can occur in the following combinations which represent the possible genotypes of the individuals. These are AA, AB, AO, BB, BO, and OO.

If the genotypes are AA or AO only, antigen A is formed. The individual has blood group A.

If the genotypes are BB or BO only antigen B is formed. The individual has blood group B.

If the genotype is AB, both antigen A and B are formed, the blood group is AB and allele A is co-dominant with allele B.

If the genotype is OO, neither antigen A nor antigen B are formed. The blood group is O. Allele O is recessive to allele A and B.

The relationships between these genotypes are given in the table below.

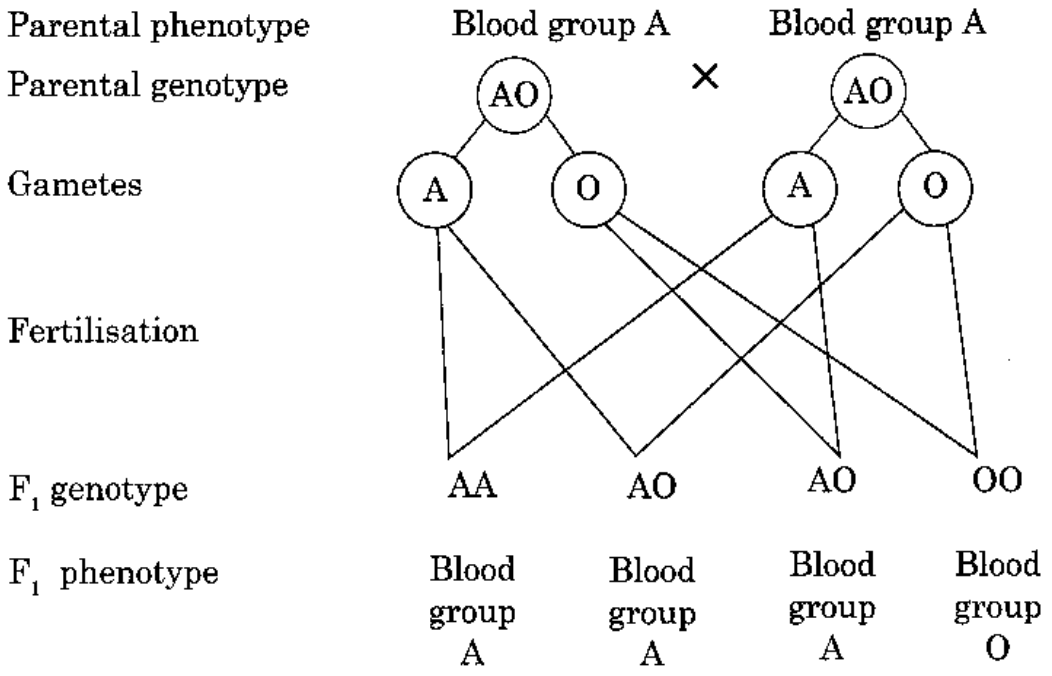
Possible genotype	**Antigen formed on red blood cell**	**Blood group**
AA	Antigen A	A
AO	Antigen A	A
BB	Antigen B	B
BO	Antigen B	B
AB	Antigen A and B	AB
OO	No antigen	O

Table 5.5: Genotypes and their respective blood groups (Phenotypes).

Note

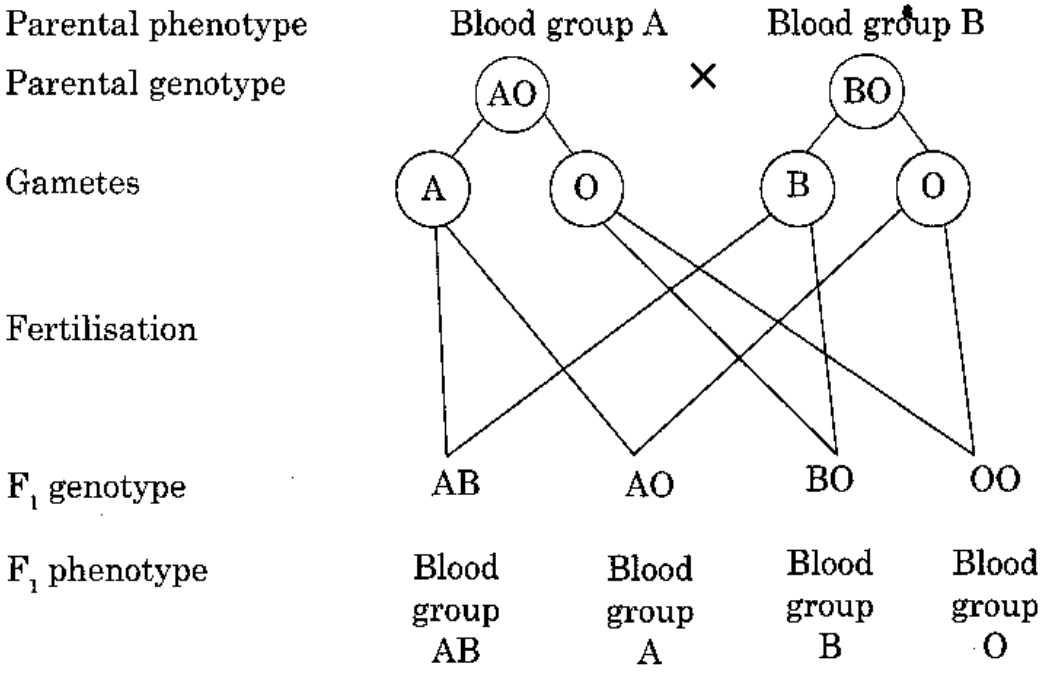
The blood groups are considered to be the phenotypes of the genotypes involved.

Below is an example showing a cross between individuals whose genotypes are heterozygous for blood group A.



From the crossing, we can see that it is possible for parents who are heterozygous (AO) with blood group A to produce an offspring with blood group O. The probability of such an occurrence is $\frac{1}{4}$.

Let us now study the cross between individuals with blood groups A and B (both heterozygous).



From the cross, we find that the parents can have children of any of the four blood groups.

Sex determination in humans

We learnt earlier that every organism has a constant number of chromosomes in its nucleus. In humans for instance, there are 23 pairs of homologous chromosomes. Out of the 23 pairs, 22 pairs determine body characteristics other than those associated with sexual characteristics.

The 22 pairs of chromosomes that determine body characteristics are called **autosomes.** The two chromosomes that form the 23rd pair are called **sex chromosomes.**

They are referred to as sex-chromosomes because they carry genes that determine the sex of an individual.

There are two types of sex chromosomes in humans. One is referred to as the X-chromosome while the other is referred as the Y-chromosome. The X-chromosome is longer than the Y-chromosome.

Genes on the sex chromosomes are described as **sex-linked genes.**

The sex chromosomes may also carry genes whose characteristics are not related to the sex of the individual.

The figure below shows a display (Karyotype) of a human male's chromosomes. The sex chromosomes are shown separately as 'X' and 'Y' while the rest are autosomes.

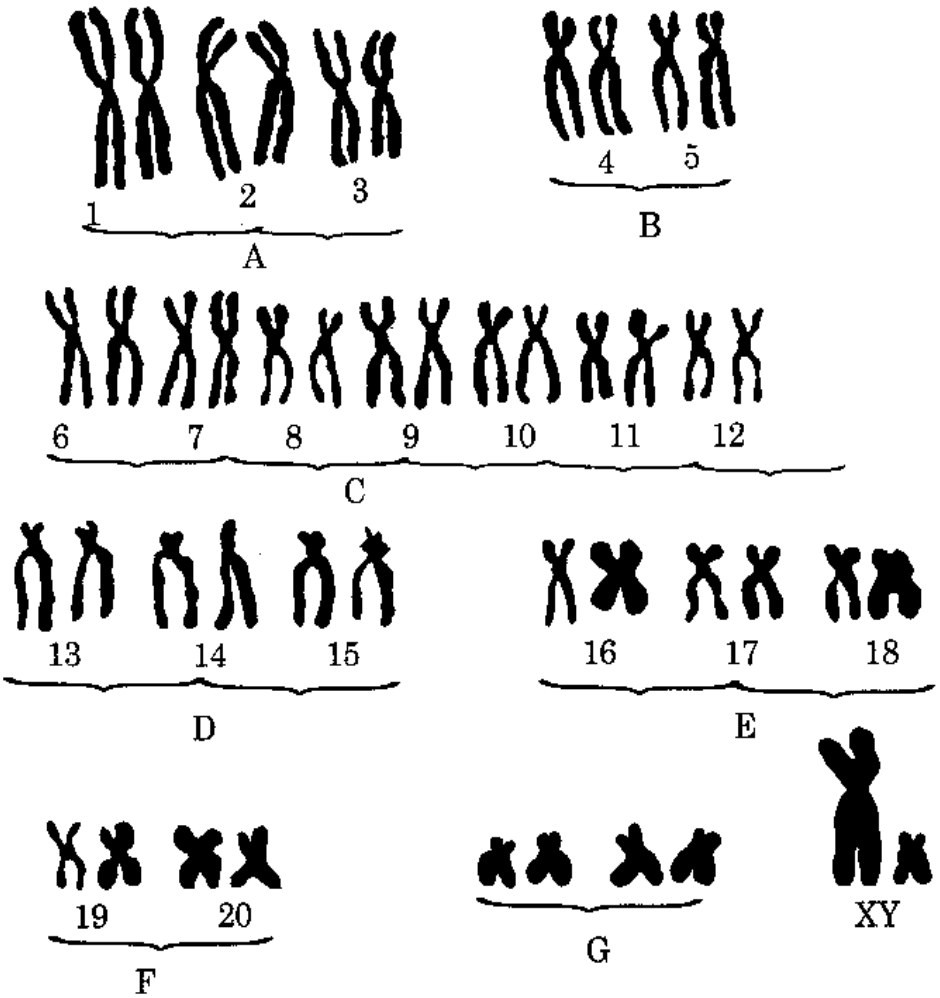


Fig. 5.2: Karyotype of a human male.

In humans, these chromosomes can occur in only two combinations.

> Note that these combinations involve homologous chromosomes, not alleles.

These combinations represent the genotypes of the individual.

If the genotype is **XX,** the individual develops female characteristics. The sex of the individual is therefore **female.**

If the genotype is **XY,** the individual develops male characteristics. The sex of the individual is therefore **male.**

Chromosomes (Genotype)	**Examples of sexual characteristics developed**	**Phenotype (Sex)**
XX	• Ovaries • Uterus • Vagina	Female
XY	• Testes • Penis	Male

Table 5.6: Sex determination in humans.

From the crossing, we see that the ratio of males to females is 1:1. In other words, chances of either a male or female child being born is a half. This means that the chances of getting either a boy or a girl for every conception is the same.

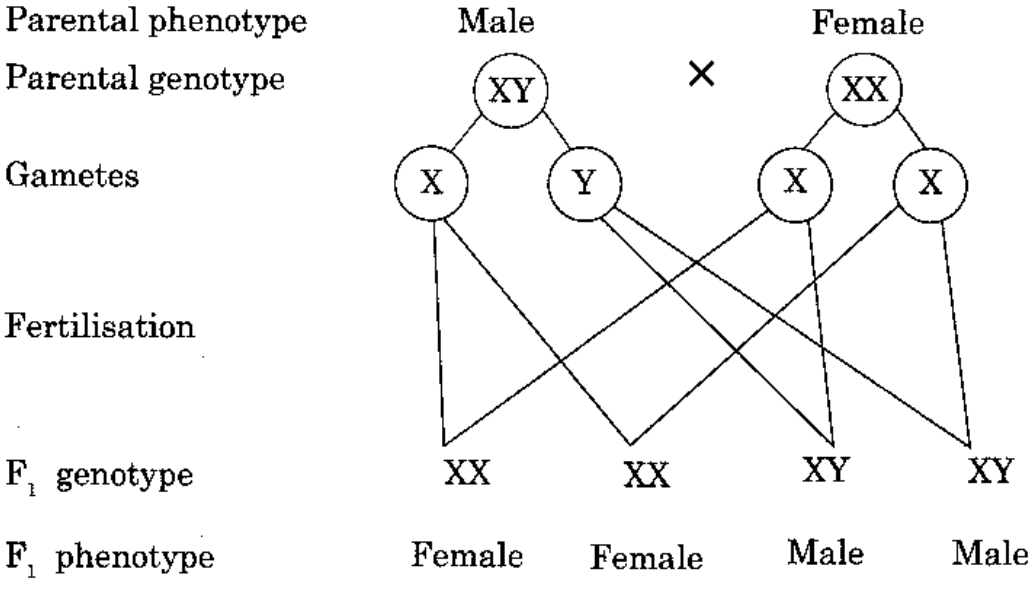
In the cross above, we can also see that the female produces gametes that always have the X-chromosome. The female is therefore said to be **homogametic.**

On the other hand, the male produces gametes that have an X-chromosome and others that have a Y-chromosome. The males are therefore said to be **heterogametic.** Note that a female passes the X-chromosome to her son while the daughter receives an X-chromosome from the father.

Linkage

'Linkage' comes from the word 'link' which means 'joined together'. We learnt that chromosomes consist of several genes located along it's length.

The following examples show a cross between a male and a female.



Genes carried on the same chromosome are inherited together by the new individual.

Since the genes are located on the same chromosome, they are said to be linked. The location of genes on the same chromosome is referred to as **linkage**. The linked genes are always inherited together.

The following illustration gives an idea of linked genes on a homologous chromosome.

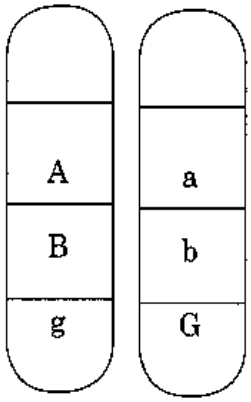


Fig. 5.3: Homologous pair of chromosomes showing linked genes.

The genes represented by letters **A, B** and **g** are **linked** because they are found on the same chromosome. Genes **a, b,** and **G** are also linked because they are found on the other chromosome.

The genes found on different chromosomes such as A and a, or A and G, are **not linked** because they are found on different chromosomes.

Sex-linked genes

We learnt earlier that the sex of a given individual is determined by genes found on the sex chromosomes. We also noted that the sex-chromosomes carry genes that do not determine the sex of the individual. Since these genes are found on the same chromosome, they are linked and are therefore inherited together. These genes that are found on the sex chromosome are said to be **sex-linked genes.**

The characteristics which develop in an individual because of these genes are called **sex linked characteristics.** Let us now look at some of these characteristics.

Sex–linked characteristics

We learnt earlier that the Y chromosome is shorter as compared to the X-chromosome. Therefore, the X-chromosomes bear genes that have no corresponding alleles on the Y chromosome. This is because only a small portion of X-chromosome is homologous to the Y chromosome as shown below.

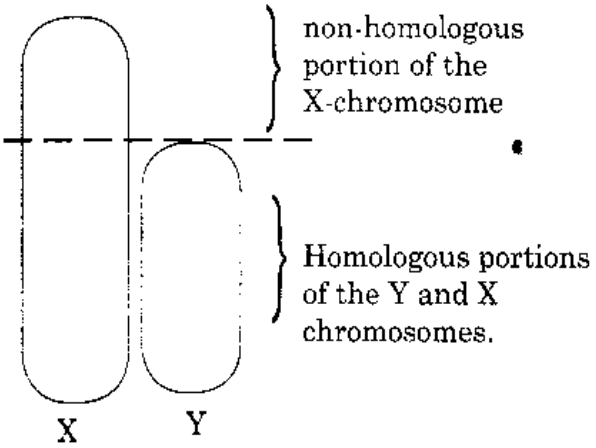


Fig. 5.4: Homologous and non homologous portions of the sex chromosomes.

Genes located on the non-homologous part of the chromosome determines certain characteristics which are referred to as **sex-linked characteristics** or traits. Examples of these traits are **colour blindness, haemophilia, hairy ears and hairy nose.**

When studying sex-linked characteristics, it is important to note that we are interested in the inheritance

of the sex of the individual as well as the inheritance of the sex linked characteristic. The genotype of the individual is written as XX or XY. Since the genes that determine the **sex-linked traits** are located on the unpaired part of the X-chromosome, this linkage is shown in the genotype by a letter representing the gene as a superscript on the X-chromosome.

If the superscript is capital, it denotes a dominant gene for example, $\mathbf{X^H}$. If it is small letter, it denotes a recessive gene for example, $\mathbf{X^h}$.

Let us now learn about some sex-linked characteristics.

(a) Haemophilia

We learnt earlier that blood clotting is important in preventing excessive blood loss from the body after an injury. If the blood fails to clot or takes long to clot, the person is said to suffer from a disease called **haemophilia.** The clotting of blood after injury is influenced by many factors including a protein known as blood clotting factor VIII. The inheritance of this factor is determined by two alleles. One allele determines the production of normal clotting factor. This allele is dominant. The other alleles influence formation of a defective clotting factor. This allele is recessive. When the normal clotting factor is present, the blood clots normally after an injury. When the defective clotting factor is present, the blood is slow to clot or does not clot at all. The dominant allele is expressed with a capital H while the recessive allele is expressed by h. These alleles are located on the unpaired part of the X-chromosome.

In females, the possible genotypes are $X^H X^H$, $X^H X^h$ and $X^h X^h$. If the female, has genotype $X^H X^H$ or $X^H X^h$, the normal clotting factor is produced. Such a person is phenotypically a **normal female.**

If the female has genotype $X^h X^h$, the defective clotting factor is produced and the blood is slow to clot or does not clot at all. Such a person is phenotypically a **haemophiliac female.**

In males, the possible genotypes are X^HY and X^hY. If the male has genotype X^HY, the normal clotting factor is produced. The blood clots normally. Such a person is phenotypically a **normal male.** If the male has a genotype X^hY, the defective clotting factor is produced. The blood is slow to clot or does not clot at all. Such a person is phenotypically a **haemophiliac male.**

The relationship between the genotypes in the inheritance of haemophilia is given in the table below.

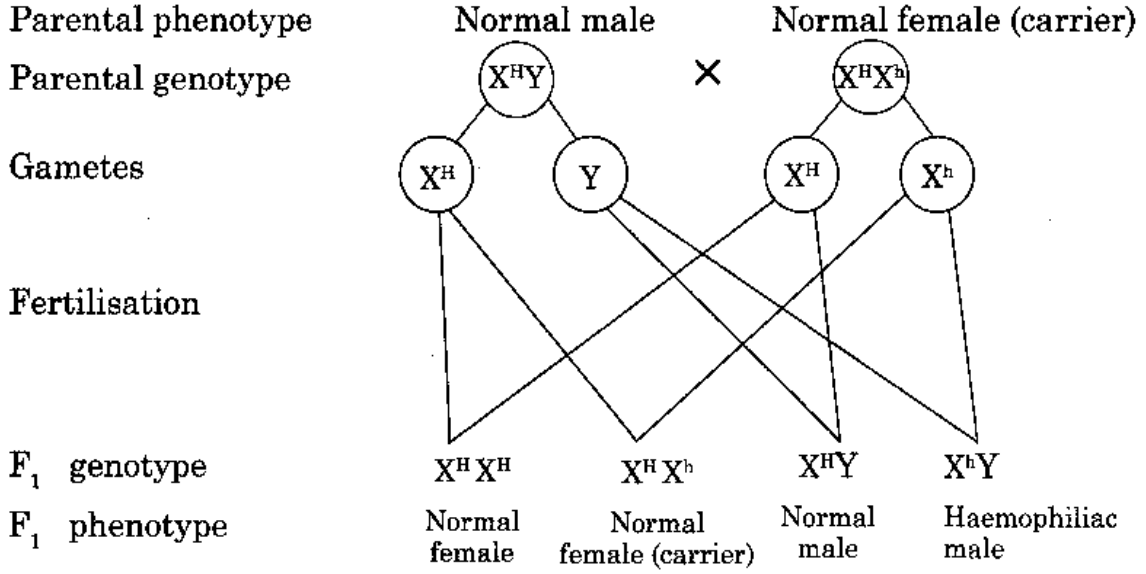
Possible genotype	**Clotting factor**	**Phenotype**
$X^H X^H$	Normal	Normal female
$X^H X^h$	Normal	Normal female
$X^h X^h$	Defective	Haemophiliac female
$X^H Y$	Normal	Normal male
$X^h Y$	Defective	Haemophiliac male

Table 5.7: Relationship between genotypes and inheritance of haemophilia.

From the table, it can be noted that the male require only one recessive allele to be haemophiliac, while the female require two recessive alleles to be haemophiliac. In a population therefore, the chances of males being haemophiliacs are higher than that of females.

The heterozygous female ($X^H X^h$) is also referred to as a **carrier.** This is because

she has a recessive allele for haemophilia which does not show phenotypically. Let us now carry out a cross between a normal male and a carrier female.



(b) Red-green colour blindness in humans

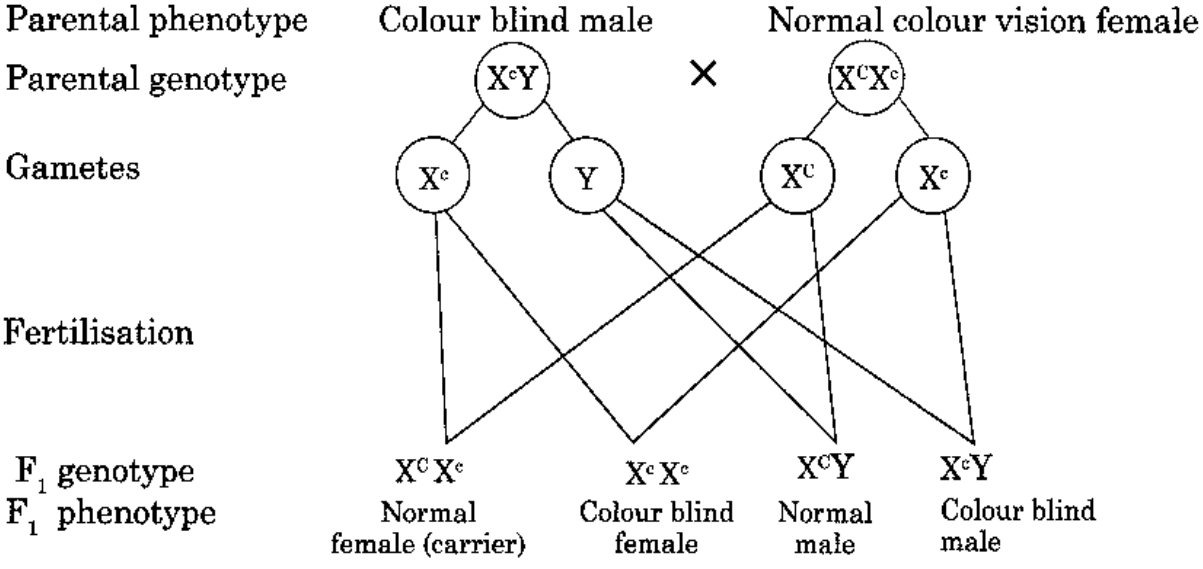
Colour vision is determined by a pair of genes. The gene for normal colour vision is dominant. A normal vision is a situation whereby the individual is able to distinguish all the colours of a given object. The gene for abnormal colour vision is recessive. It brings about a condition known as **red-green colour blindness.** This is the inability of a given individual to distinguish red from green colour. The alleles for colour vision are sex linked. They are found on the X chromosome and are absent on the Y chromosome.

The dominant allele is expressed with a capital **C** while the allele for abnormal colour vision (colour blindness) is expressed with a small letter **c.**

In females, the possible genotypes are X^CX^C, X^cX^c and X^CX^c.

In males, the possible genotypes are X^CY and X^cY.

Let us now carry out a cross between a colour blind male and a carrier female.



The relationship between the genotypes in the inheritance of colour blindness is given in the table below.

Possible genotype	Phenotype
$X^C X^C$	Normal female
$X^C X^c$	Normal female (heterozygous)
$X^c X^c$	Colour blind female
$X^C Y$	Normal male
$X^c Y$	Colour blind male

Table 5.8: Colour blindness.

(c) Hairly nose and ears

This is a condition whereby a male is found to have long turfs of hair growing on the pinna of the ear. Also, hair sprouts from the inner part of the nose as shown below.

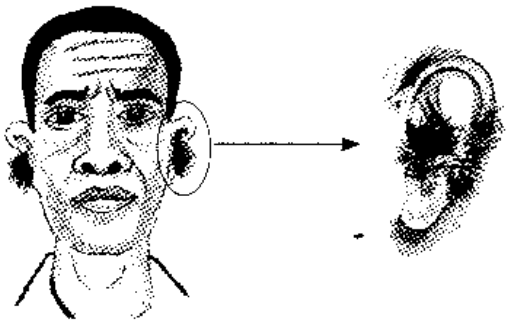


Fig. 5.5: Hairy nose and ears.

The allele that causes this is believed to be linked to the Y chromosome only.

The allele is absent in the X-chromosome and this means that it can only be transmitted by the father to the sons only.

Premature baldness in males is also sex-linked. It is carried by the Y chromosome only.

Composition of chromosomes, DNA and proteins

In Form One, we learnt that cells contain a nucleus which controls and regulates all the activities of the cells, and heredity, (passing on characteristics from parents to offspring). The nucleus is able to do all these because it has structures called chromosomes. Chromosomes are thread-like structures in the nucleus of plant and animal cells.

All cells are formed from already existing cells by a process of cell division. When a cell is not dividing to form new cells, its chromosomes are not visible under the light microscope. It is said to be at rest.

The chromosomes become visible only during cell division. This is because before the cell divides, each chromosome thread coils up to form a compact chromosome. When stained, such chromosomes are visible under the light microscope as shown in the diagram below.

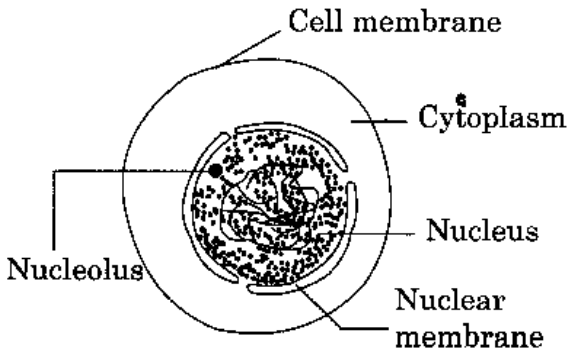


Fig. 5.6: Chromosomes in a cell.

The thread-like chromosomes coil up tightly to form thicker, shorter and more compact chromosomes. Just before cell division, they also appear to have split along their lengths to form two similar strands joined at their centres.

These two strands are called **chromatids** and they are joined at a point called the **centromere** as shown in the following figure.

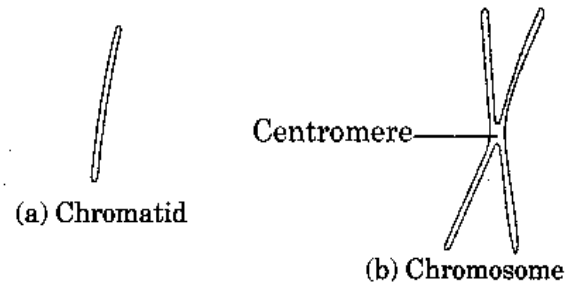


Fig. 5.7: A chromosome and chromatids

Note:
When the two strands are attached at the centromere they are chromatids of the same chromosome. When they are separate, each is called a chromatid.

The two chromatids are exact copies of each other. During the process of cell division, the two chromatids separate with each going into a separate cell as we shall see later.

The number of chromosomes in the nucleus of a plant or animal cell varies according to the species. For example, in humans, it is 46 in the body cells (23 pairs).

Chromosomes are present in the nucleus in pairs. These pairs are called **homologous pairs.**

Homologous pairs of chromosomes have the same length and shape but with different genetic composition.

Chromosome numbers also vary according to the type of cells in the organisms. The difference in number of chromosomes in the same organisms depends on if the cell is a normal body cell, or a reproductive cell. Reproductive cells are called gametes, examples include; sperms and ova in humans.

The body cells are sometimes called somatic cells. These are cells like nerve cells, blood cells, bone cells, muscle cells among others in humans.

In every organism that forms reproductive cells or gametes, the number of chromosomes in the nuclei of the gametes is always half of that in the body or somatic cell. For example, in humans, the body cells have 46 chromosomes, then the sperms or ova have 23 chromosomes.

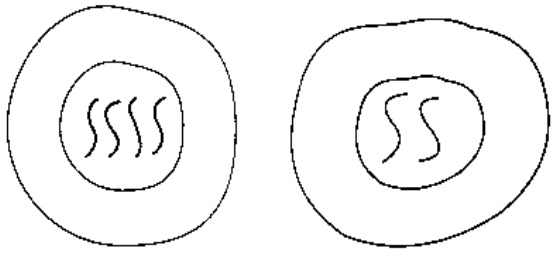
Every species of organisms has a constant number of chromosomes in its normal body cells (somatic cells). This number of chromosomes vary from one organism to another.

The number of chromosomes in somatic cells is referred to as the **diploid** number of chromosomes. It is denoted by **2n.**

This diploid number or condition in organisms is known as **diploidy.**

During sexual reproduction, cell division by meiosis takes place. Meiosis leads to production of gametes. The gametes contain half the number of chromosomes that are in the normal body cells. For instance, gametes in humans (sperms and ova) carry 23 chromosomes (half the number in the somatic cells). The gametes are, therefore, said to be **haploid.** A haploid number of chromosomes is denoted by **(n).** This condition is known as **haploidy.**

The figure below illustrates diploidy and haploidy in somatic and gamete cells in an imaginary cell.



(a) Somatic cells are diploid (b) Gametes are haploid

Fig. 5.8: Diploidy and haploidy.

DNA and proteins

We have learnt that inheritance of characteristics is determined by structures known as chromosomes found in the nucleus.

We have also learnt that chromosomes contain units or small portions known as genes which carry instructions or information on how particular characteristics develop. **The gene is therefore the basic unit of inheritance.** The chromosomes carry hundreds of genes representing all the characteristics of the individual.

A given characteristic can be controlled by one gene or a number of genes. Each gene occupies a given part along the chromosome. The specific location of a gene on the chromosome is referred to as the **gene locus** (plural–loci).

Genes influencing the same characteristic are found at the same loci on separate homologous chromosomes.

The figure below illustrates examples of gene loci of some imaginary genes coding for different traits, that is, height, skin colour and eye colour; on homologous chromosomes.

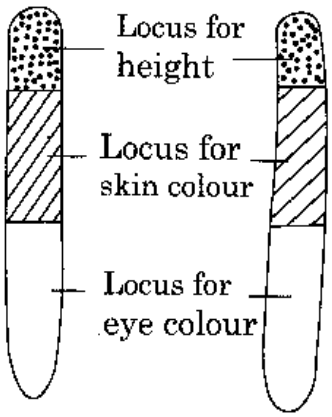


Fig. 5.9: Gene loci in a pair of chromosomes.

Genes are made up of deoxyribonucleic acid (DNA).

DNA belongs to a group of chemical compounds called **nucleic acids.** They are so named because they are found in the nucleus. DNA is a polymer made up of nucleotides (monomers). Each monomer is made up of:

- Pentose sugar.
- Nitrogen containing base.
- Phosphate group.

A chromosome is composed of one very long DNA molecule made up of two strands arranged parallel to each other. They are twisted to appear like a coiled ladder, a shape known as the **double helix.**

Fig. 5.10: Double helix structure of DNA.

Mutations

We have learnt that organisms show variation in characteristics. These variations are caused by various factors. The variations can be caused by the influence of the environment on the organisms. Such variations are not inheritable.

The variations can also be due to the crossing over during meiosis and recombination of alleles from different gametes at fertilisation. Such variations are inheritable.

However, variations can also be caused by changes in the structure of genes and chromosomes. These changes are inheritable. Such changes are referred to as **mutations.**

Mutations can be defined as the sudden changes in structure or amount of genetic material in an organism.

Mutations are spontaneous and rare in a population.

Types of mutations

We said that mutations occur on genes and on chromosomes. On this basis, we have two types of mutations:

- Chromosomal mutations
- Gene mutations

Causes and consequences of chromosomal mutations

Chromosomal mutations involve changes in structure of a chromosome or a change in the number of chromosomes in a given individual.

Mutations are caused or influenced by factors known as **mutagens**. Like any other type of mutations, chromosomal mutations are caused by radiations such as gamma rays, X-rays, beta-rays and chemical substances such as colchines, mustard gas and formaldehyde.

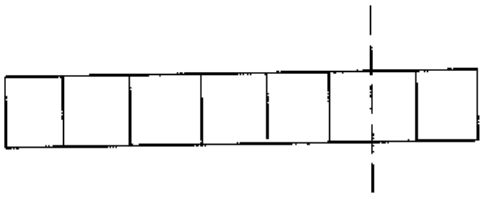
Types of chromosomal mutations

Chromosomal mutations occur in several ways. Some forms of mutations cause changes in the structure of a chromosome. These types include; deletion, inversion, translocation and duplication.

Other forms of mutations cause changes in the number of chromosomes in the nucleus. The most common of such mutation is non-disjunction.

(i) Deletion

This is where a part of a chromosome breaks away. This results in loss of some genes.



Part breaks and is lost

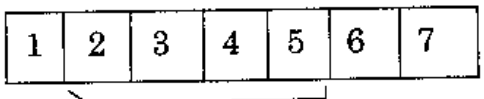
(ii) Translocation

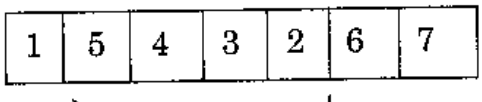
This involves attachment of a portion of a chromosome to another chromosome that is not similar. This results to addition of genes.

Added portion from another chromosome

(iii) Inversion

This is where a middle part of a chromosome breaks off and rotates 180^0, causing change in gene sequence.

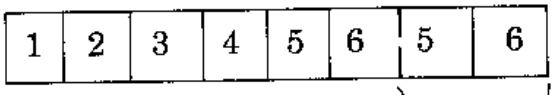




Inverted portion

(iv) Duplication

This is where a portion of the chromosome replicates itself.



Duplicated portion

(v) Non disjunction

This is where homologous chromosomes fail to separate during anaphase I of meiosis. It results to some daughter cells carrying more number of chromosomes while others carry fewer.

Effects of chromosomal mutation

1. **Failure of development of some important body parts.** This may occur when part of a chromosome breaks off and is lost. The lost part may have carried genes important in the development of a given body tissue, gland or organ. In the absence of such genes, the body part does not develop in the new individual.
2. **Additional chromosomes in the cell leading to disorders such as Down's Syndrome.** Due to non-disjunction, the individual produces some gametes with an extra chromosome and others with less chromosomes in their nucleus. When such gametes are involved in successful fertilisation, the zygote formed has an extra chromosome or has one less chromosome in its nucleus.

   An individual with Down's syndrome is characterised by poor mental development. The individual has slit eyes and a thick tongue. Other disorders caused by disjunction include **Klinefelter's Syndrome** and **Turner's Syndrome.**
3. **Polyploidy:**

   The occurence of additional chromosomes is also possible in plant cells. This leads to a condition known as **polyploidy.** This condition is caused by non-disjunction during mitotic cell division.

   As we learnt in Form 3, during mitosis, the chromosome number in the cell is first doubled and then divided into two to result to two cells with the same number of chromosomes as the original cell. Therefore, after doubling occurs and then non-disjunction follows, the doubled number of chromosomes is retained in the cell. The chromosomes in the cell fail to separate due to failure of formation of the spindle. The cell therefore has double the number of chromosomes. The cell will be 4n instead of 2n.

   If this cell now undergoes meiosis, it will produce diploid gametes that is, if the diploid gamete is involved in successful fertilisation, a zygote with multiple number of chromosomes is formed instead of a diploid zygote, 2n + 2n = 4n. Such a zygote with four sets of chromosomes is said to be **tetraploid (4n).** Such a zygote develops into an individual known as a **polyploid.** This is an organism with more than two sets of chromosomes. The condition is referred to as **polyploidy.**

Polyploid plants are usually larger in size and produce larger fruits or seeds, high yields, resistance to drought, pests and diseases and are early maturing. Plant breeders have applied this idea of polyploidy by manipulating meiotic cell division to produce polyploid plants. Such plants include the modern bread wheat (*Triticum aestivum*). The wheat produce large seeds and has more wheat proteins that form more gluten needed in bread making.

4. **Over emphasis of particular traits.**
   Over emphasis of some characteristics can occur in an individual when a portion of a chromosome is doubled or is replicated. The replicated portion of the chromosome adds extra genes to the existing ones in the nucleus. These genes may lead to an increased influence in the development of a given characteristic.
5. Other effects of chromosomal mutations include development of tumors due to mutation of somatic cells. Some tumors develop into cancer.

Gene mutations or point mutations

Gene mutations involve changes in the structure of a gene. These changes result to alteration of the sequence forming a gene. This results to formation of different proteins from the intended ones, leading to disorders and defects in an organism's body.

Types of gene mutations

They include:
(i) Substitution.
(ii) Deletion.
(iii) Insertion.
(iv) Duplication.

(i) Deletion
This is where one part of a gene sequence breaks off and is lost. This distorts protein formation. For example, in a word GOING, if letter I is deleted, the word changes to GONG. This distorts the intended information.

(ii) Duplication
This is where a given part of a gene sequence is doubled, or a given gene is duplicated. This results to two genes of the same type.

(iii) Insertion
This is where an extra unit is added in a gene sequence. This distorts the whole gene sequence. For example, in a sentence such as: HE IS EATING, if you add the letter H to the word EATING, the meaning is distorted to HE IS HEATING.

(iv) Substitution
This is where a unit in a gene is replaced with another unit. The gene is changed or distorted. For example, in the word: COW, if you substitute W with B, the whole meaning is distorted to COB.

Gene mutations in humans are associated with certain genetic disorders. Some of these disorders include:

- Albinism.
- Sickle cell anaemia.
- Haemophilia.
- Colour-blindness.

Let us now learn about some of the disorders.

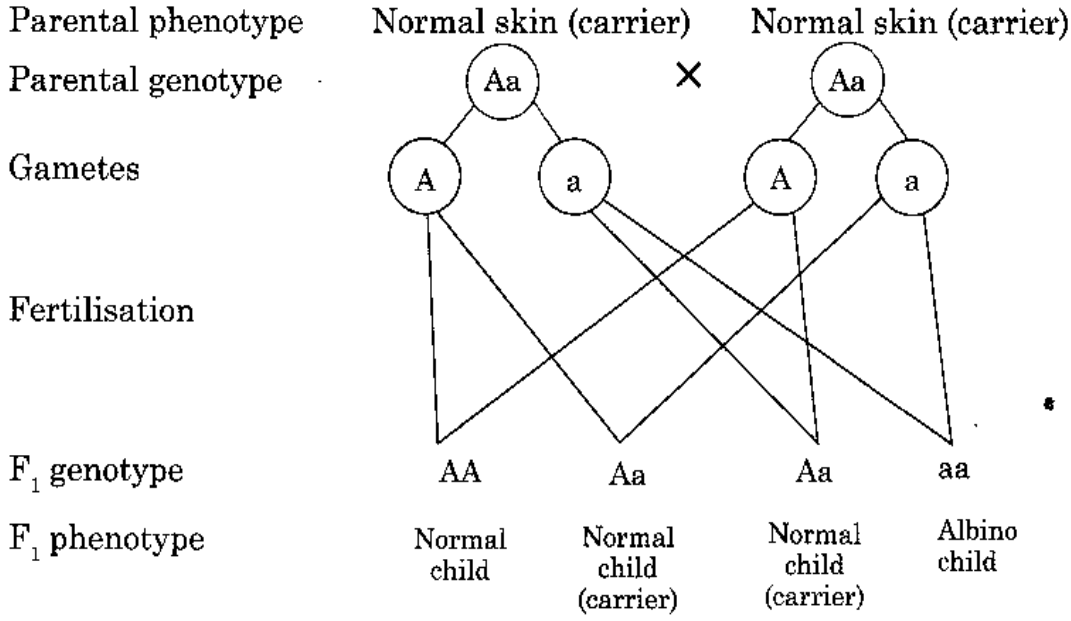
Albinism

Albinism is a condition whereby the skin of an individual fails to produce the skin pigment known as **melanin.**

Melanin gives the skin its colour. It also protects the skin and the eyes against harmful rays such as ultra violet rays from the sun.

A dominant gene influences production of melanin and is denoted by capital letter **A**. The recessive gene prevents the formation of melanin and is denoted by small letter **a**. The two alleles occur in the following genotypes AA, Aa, aa. If the genotype is **AA** or **Aa**, melanin is produced and the individual has a normal skin colour. If the genotype is **aa**, melanin is not produced. The individual is an **Albino**.

Let us now carry out crosses to demonstrate inheritance of this disorder Assuming that a father and a mother are heterozygous for albinism, what is the possibility of the two parents bearing albino children?



From the cross above, we find that the possibility of getting an albino child by two heterozygous parents is 25%. One child in every four children born is Albino.

Sickle cell anaemia

Sickle cell anaemia is a condition whereby red blood cells have an abnormal shape, that is, crescent or sickle shaped. As a result, these cells are not able to transport oxygen efficiently.

The normal shape of red blood cell is a biconcave. This shape makes red blood cells efficient in the transport of oxygen. The shape of the red blood cells is determined by the type of haemoglobin present. The type of haemoglobin produced is determined by two alleles. The two alleles show incomplete dominance.

One allele determines the formation of normal haemoglobin and is denoted by HbA. The other allele determines the formation of abnormal haemoglobin and is denoted by HbS.

The two alleles can occur in the following combinations which are the possible genotypes, HbAHbA, HbAHbS, and HbSHbS. The relationship of genotypes in the inheritance of sickle cell anaemia is given in Table 5.9 below.

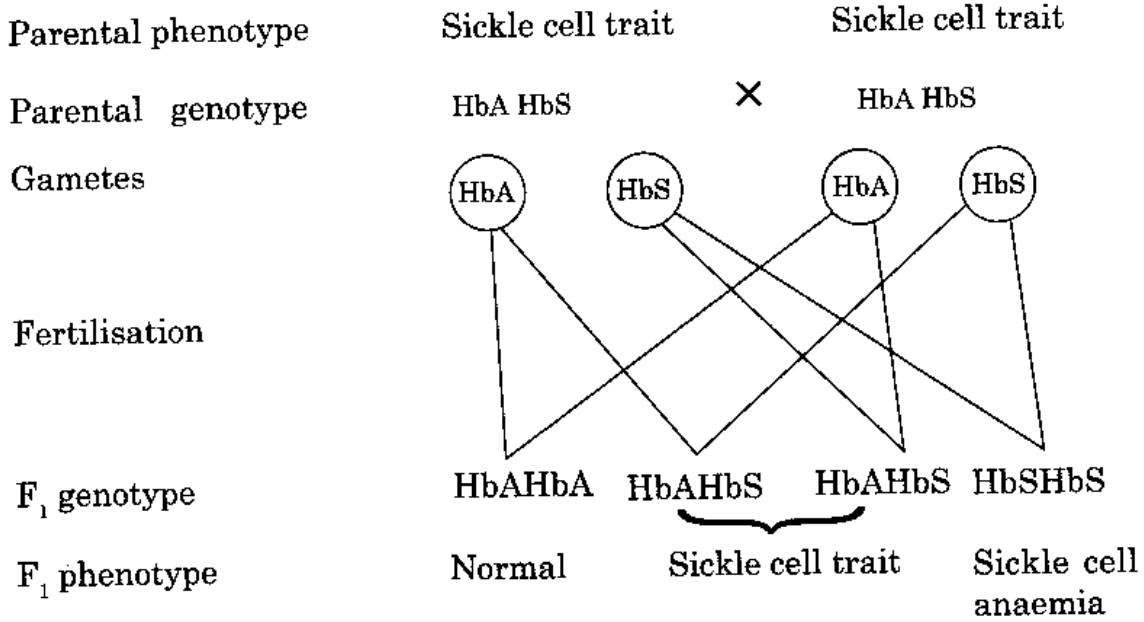
Genotype	Type of haemoglobin	Shape of red blood cells	Phenotype
HbAHbA	Normal haemoglobin	Biconcave disc	Normal
HbA HbS	Normal and abnormal haemoglobin	Biconcave and sickle shapes	Sickle cell trait anaemia
HbS HbS	Abnormal haemoglobin	Sickle shapes	Sickle cell anaemia

Table 5.9: Relationship of genotypes in inheritance of sickle cell anaemia.

If the genotype is HbAHbA, normal haemoglobin is produced. As a result all the red blood cells are biconcave in shape. If the genotype is HbSHbS, abnormal haemoglobin is produced. As a result, all the red blood cells have a sickle shape. The individual suffers from severe **sickle cell anaemia.** A patient with sickle cell anaemia usually requires special medical care which may include blood transfusion to treat the anaemia.

If the genotype is HbAHbS, both normal and abnormal haemoglobins are produced. As a result, some red blood cells have the normal biconcave shape while others have a sickle shape. The individual suffers from mild anaemia and is said to have **sickle cell trait**. In the tropics, individuals with sickle cell anaemia trait are resistant to anaemia. This is referred to as **heterozygous advantage**.

Let us now carry out a cross between two parents with sickle cell trait.



Other disorders brought about by gene mutation include haemophilia and red green colour blindness.

Haemophilia

We had discussed haemophilia as a disorder that is sex linked. The recessive gene that causes the disorder is found on the unpaired part of the chromosome. The occurrence of the recessive gene come about as a result of mutation of the dominant gene.

A case study of inheritance of Haemophilia was observed in the royal family in Britain. A prince by name Albert married Queen Victoria. Queen Victoria was a carrier of Haemophilia. The defective gene was inherited from her across many generations. The pedigree below illustrates the inheritance of haemophilia in the royal family.

Note: A pedigree is a flow diagram that shows record of inheritance of a particular characteristic over several generations.

Red-green colour blindness

We also discussed about colour blindness as a sex-linked trait. The disorder is thought to be caused by the mutation of the normal gene that leads to abnormal colour vision.

Plant and animal breeding in Malawi

With the growing population, demand for food has increased in Malawi. At the same time, climate change has resulted to changes in ecological conditions that do not favour traditional farming any longer.

It is therefore important to come up with ways of increasing food production and at the same time, come up with types of crops and animals that can adapt to changes in climate.

The department of research in the ministry of Agriculture and private research organisation, plant breeders and animal breeders have come up with new livestock breeds and new crop varieties that has boosted food production

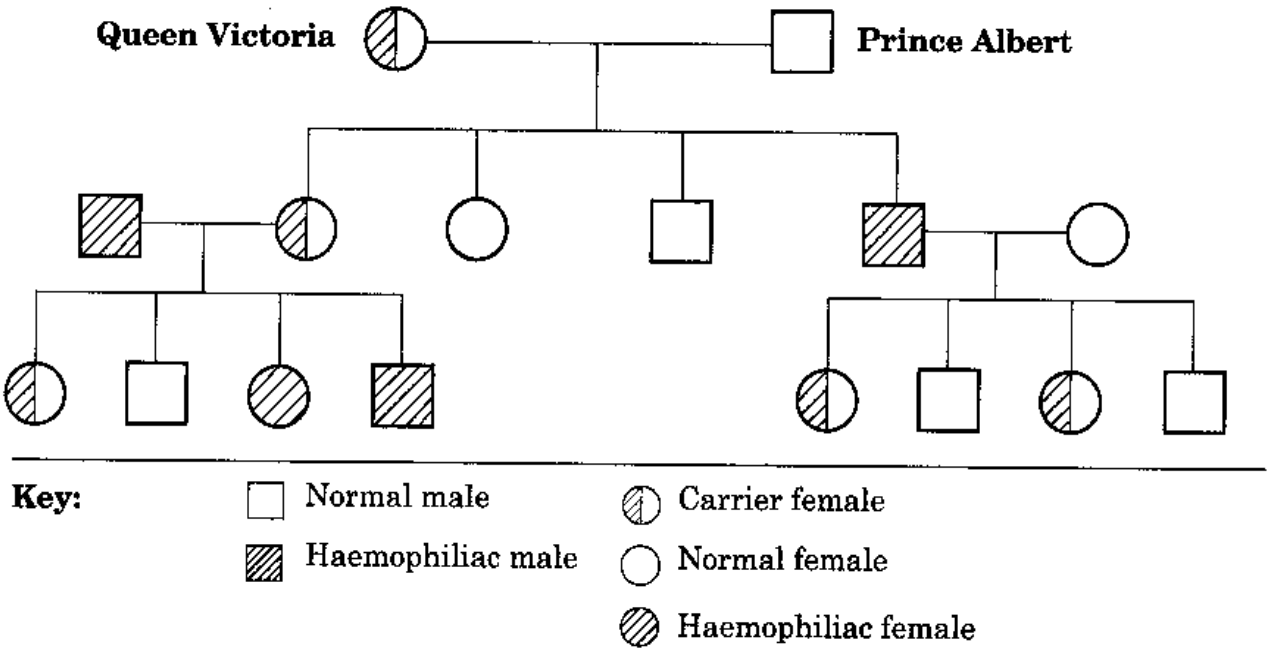


Fig 5.11: A pedigree showing inheritance of haemophilia in the royal family.

in Malawi. Examples include:

1. New maize varieties

These are new varieties produced by companies such as 'Monsanto' and Pannar in Malawi. These maize varieties are produced to suit various ecological regions of Malawi. They include:

- Early maturing varieties for dry lands such as *PAN 3434* that does well in dry lands and responds to irrigation.
- Late maturing varieties for high rainfall areas.
- Varieties with increased or doubled production such as *DK 9089* that is known to produce two cobs per stem thus high production.

Introduction of these varieties and government subsidy on farm inputs such as seeds has made Malawi to be self sufficient in grain production. This has made our country to be an example of other African countries.

2. New dairy breeds

To increase milk production in Malawi, cross breeding of the Malawi zebu with exotic breeds such as the *Holstein* and *Jersey* is being done to produce cross-breeds.

These crossbreeds are well suited to almost all areas of Malawi even where exotic breeds cannot survive.

This has increased milk production.

3. New poultry breeds

Malawi is taking up the keeping of new poultry breeds to replace some traditional poultry breeds such as the *'Kaluta' Yakudia* and *'yoyoha'*

These exotic breeds include: The *hyalines*, *cob*, *cross* and pure breeds such as the *black australop*. The *black austalop* is used to cross breed the local chicken breeds. The cross breeds produced are known to adapt well to the environment and are tolerant to diseases such as Newcastle.

Revision Exercise 5B

1. Define the following terms.
   (a) Genetics (c) Variation.
   (b) Heredity (d) Genes.
2. State two types of variations found in animals.
3. Distinguish between
   (a) Continuous and discontinuous variations.
   (b) Complete and incomplete dominance.
4. State the causes of variation.
5. Explain the meaning of monohybrid cross.
6. In shorthorn cattle, a cross between a pure red line shorthorn with a pure white line shorthorn produced a calf that was neither white nor red. The calf is said to be roan. Make a cross diagram to show the phenotypes of the F_1 and F_2 generations. Show the phenotypic ratio of the F_2 generation.
7. What do you understand by the term test cross?
8. Name the two antigens that determine blood groups in humans.
9. Define the term linkage in relation to heredity.
10. What are sex-linked traits?
11. Give two examples of sex-linked traits.
12. State three disorders in humans brought about by gene mutations.

Unit 6

Ecosystems

Specific objectives

By the end of this unit, you should be able to:

(a) State the components of an ecosystem.

(b) Use ecological methods to study ecosystems.

(c) Describe the physical factors in fresh water and tropical savannah woodland ecosystems.

(d) Describe the plant communities and animal communities in fresh water and savannah woodland ecosystems.

(e) Explain the factors that affect primary productivity in fresh water and tropical savannah woodland ecosystems.

(f) Describe energy transfer in fresh water and tropical savannah woodland ecosystems.

(g) Describe the nutrient cycles in aquatic and terrestrial ecosystems.

(h) Explain the importance of fresh water and tropical savannah woodland ecosystems.

(i) Explain the impact of environmental stress on fresh water and tropical savannah woodland ecosystems.

(j) Explain the impact of human activities on fresh water and tropical savannah woodland ecosystems.

(k) Explain how resources can be managed in fresh water and tropical savannah woodland ecosystems.

Introduction

In Form Two, you learnt about living things and their environment. You learnt that living things live and interact with each other as well as with their physical environment.

In this unit, you will learn about ecosystems and the communities found in fresh water ecosystem and savanna woodland ecosystems.

Meaning of an ecosystem

An ecosystem is a stable unit of nature consisting of all communities interacting with each other and with the physical environment around them.

A community refers to all the populations of organisms in a given area both living and non-living.

Components of an ecosystem

An ecosystem is made up of three components which include:

(a) Physical factors.
(b) Plant communities.
(c) Animal communities.

1. Physical factors (abiotic factors)

These are the non- living factors in an ecosystem that influences the lives of living organisms. These factors include:

(a) Soil

Soil is the natural covering found on the earth's surface. Soil factors are also called **edaphic factors**.

Soil influences a given ecosystem in several ways which include:

(i) Soil is a habitat. It is a home where many living organisms find food and shelter.
(ii) Soil is an important component for growth of plants because it provides support, water and nutrients to plants.
(iii) Soil has productive properties that determines the amount of food that a given ecosystem can produce. In fertile soils, more food is produced hence more organisms are supported.

(b) Rainfall/water

Water is the main resource required by all living organisms. The amount of rainfall or the availability of water determines the type of organisms, their distribution in a given area and the quality of food a given habitat can produce hence the number of organisms it can hold. Water is also a habitat for many living organisms, such as fish.

(c) Oxygen concentration

Oxygen concentration varies in water bodies and up tall mountains.

The concentration of oxygen in water determines the distribution of aquatic organisms. On the mountains, increase in height results to reduced availability of oxygen hence variation in the organisms found in those areas.

(d) Temperature

Temperature influences the distribution of organisms. Up the mountains, the temperatures are very low and in the hot deserts, temperatures are very high hence few organisms are found in these areas. Organisms are many where temperatures are moderate, since enzymes in the body are more active than under low or very hot conditions.

(e) Light

The sun is the main source of light energy in all ecosystems on earth. Light is important in any ecosystem because plants being autotrophs, make their food by the process of photosynthesis using this energy. Heterotrophic organisms in an ecosystem depend directly or indirectly on plants for their food. This means that light energy is incorporated in all living organisms in the form of chemical energy. This chemical energy is found in structural compounds in the bodies of living organisms. Therefore, ecosystems need light to exist. Light intensity affect the type and distribution of organism in an ecosystem.

(f) Atmospheric pressure

Atmospheric pressure is pressure exerted by air on the atmosphere.

Atmospheric pressure affects the amount of oxygen in the air. At sea

level, air pressure is high. Here, air is compressed and has more oxygen and carbon dioxide.

In high altitude areas such as up on high mountains, the air pressure is low. The air is less compressed and has less oxygen and carbon dioxide available for photosynthesis.

There is also less oxygen available for plant and animal respiration. This results in fewer organisms in ecosystems found in high altitudes compared to ecosystems in low altitudes.

(g) Wind

Wind is moving air. Air moves in different directions and speed. These form the two most important aspects of wind. Wind influences environmental factors such as temperature and humidity. In this way, it further influences the ecosystem.

Wind is important in seed and fruit dispersal. It carries a plant seed from one habitat to another. It therefore causes the establishment of plants in totally different areas far from their original habitats. This is also true with spores of some plants. Wind speed and direction influences migration of insects and birds. It helps them to move to far areas. Moist winds bring rainfall to terrestrial habitats hence encouraging growth of plants. Therefore, wind can influence the type and distribution of organisms in a given ecosystem.

(h) Salinity

This is the degree of salt concentration in water. This factor is found in aquatic habitats. Aquatic habitats are divided into three according to their degree of salinity. **Fresh water habitats** have very little salt content almost none. They are mainly fresh water rivers, lakes, ponds and wells. **Marine habitats** have high salt concentration. They include seas, oceans and salt water lakes. **Estuarine habitats** are found at the points where fresh water rivers join salt water bodies. These areas show variation in salt concentrations depending on the tides. During high tides, there is less dilution by the rivers and so high salinity. But during low tides, there is more dilution, hence low salinity.

Salinity determines the type of organisms found in an ecosystem. For instance, tilapia fish is found in fresh water habitats only, while the shark is found in salty water habitats like the oceans. Mangrove trees are found in estuarine habitats only, while the *Salvinia* grows in a fresh water environment.

(i) Humidity

This is the amount of water vapour in the atmosphere. The amount of water vapour in the atmosphere is influenced by other factors such as temperature and wind. Humidity influences evaporation and transpiration. These in turn influence the growth of micro-organisms and distribution of some organisms in different habitats. For, example, organisms like mosses and liverworts grow well in areas with high humidity. Other organisms like termites and millipedes are also found in humid habitats. Humidity is measured using an instrument called a **hygrometer**.

2. Plant communities

These are populations of different species of plants growing in a given area including all other organisms that carry out the process of photosynthesis such as the green algae, spirogyra and planktons found in aquatic habitats.

Plant communities use light energy and simple compounds such as carbon dioxide, water and mineral salts to make food substances. The food substances made by plant communities support all other organisms in an ecosystem. Plant communities are therefore referred to as **producers** in a given ecosystem.

3. Animal communities

These are the population of different animals' species in a given area. They include all organisms that cannot carry out the process of photosynthesis and thus obtain food from plants and other organisms.

Animal communities are **heterotrophs** in that they obtain food nutrients from the bodies of other organisms.

All animal communities are said to be **consumers of energy** because they use energy stored in plants and other animals bodies directly or indirectly.

The animal communities can be divided into groups according to how they obtain food.

(a) **Herbivores** – They obtain food by feeding directly on plants.

(b) **Carnivores** – They obtain food by feeding on other animals.

(c) **Omnivores** – They obtain food from both plants and animals.

(d) **Parasites** – They obtain food and shelter from the bodies of other organisms (hosts). They cause harm to the host.

(e) **Saprophytes/decomposers** – These are organisms that utilise the energy stored in the remains and dead bodies of other organisms. They cause decay or decomposition, for example, bacteria and fungi.

(f) **Detrivores** – These are animals that feed on decomposing materials. They include animals such as beetles, earthworms and cockroaches.

Ecological methods used to study populations

We have learnt how to classify living things into various groups. In order to study such organisms, we first need to collect and count them.

It is impossible to collect all the living organisms in one group. In this unit, we will learn that a few representative organisms in a group that is, samples can be studied at a given time.

Counting organisms in such a small representative group is called **quantitative sampling**.

There are various methods of sampling and collecting living things. The method used should be appropriate to the type of organism being studied.

These include:

(a) Quadrat
(b) Belt transect
(c) Line transect
(d) Capture-recapture
(e) Direct count
(f) Trapping

We will discuss each of the methods above.

(a) Quadrat method

A quadrat is a square frame made of wood or metal. A standard quadrat measures one metre square (1 m^2).

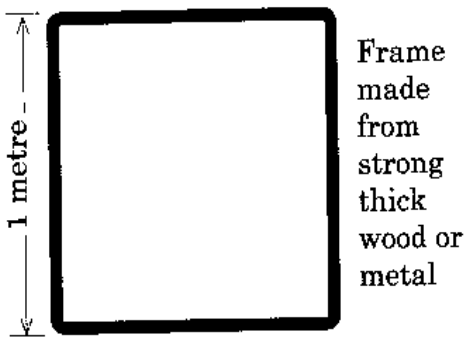


Fig. 6.1: Quadrat frame.

In the quadrat method, a square frame usually of one metre square is thrown randomly to land anywhere in an area in which an organisms population is being sampled.

The following procedure is used to estimate the population of a given organism in an area.

(i) Select an area in which the organism is found. For example, you can sample the population of *star grass* in the school playing field.

(ii) Estimate the size of the selected area in square metres. *For example:* Estimate the size of the school playing field. You can do this by taking or counting steps along the length and width of the field. You will need to know the length of each step in metres. Convert the total number of steps into metres before calculating the area of the field.

(iii) Throw the quadrat randomly into the selected area. This means throwing the quadrat anywhere in the playing field without deliberately deciding where it should land. Do not place it in a place of your choice.
Identify the plants for example, star grass, whose population is being estimated in the quadrat.
Count as many of these organisms as possible.
Record the number of organisms against quadrat throws in your notebook.

(iv) Repeat the third, fourth and fifth steps in the procedure several times and record your results in a table like the one shown.

Quadrat throw	**Number of organisms in quadrat**
1st	20
2nd	2
3rd	100
4th	0
5th	50
6th	8

The number of times of quadrat throws will depend on the size of the whole area. The larger the area, the more times the steps indicated above are repeated.

(v) Calculate the average number of organisms in each quadrat.

The number of organisms for example, the *star grass* may vary in different parts of the school playfield. To get the approximate number of star grasses in one metre square, the number of *star grasses* in each quadrat throw are added up and divided by the total number of throws.

For instance the table shows the number of organisms counted in each throw totalled and divided by the number of throws.

$$\frac{20 + 2 + 100 + 0 + 50 + 8}{6} = 30$$

Therefore, the average number of organisms in one metre square of the area is 30.

Calculate the approximate number of organisms in the whole area by using the formula below:

$$\text{Estimated plant population} = \frac{\text{Average number of plants in a quadrat} \times \text{Total area of the field}}{\text{Area of the quadrat}}$$

Plant population can also be estimated by using proportions.
For example:
Supposing that the area of the playing field is 5000 square metres and the average number of star grass per metre square is 30 then using simple proportion:

$1m^2$ = 30 organisms

$5000\ m^2$ = ?

By cross multiplication;

$$\frac{5000m^2 \times 30 \text{ organisms}}{1m^2} = 150{,}000$$

Therefore the approximate number of organisms in 5000 square metres is 150,000.

The quadrat method of sampling organisms is most suitable for organisms which do not move. For example, plants.

(b) Belt transect method

This method involves the use of two parallel lines, one metre apart. These lines cut across an area in which the population of organisms to be estimated are found.
The length of the belt transect is measured. The whole area of the place where the organism being counted is found is determined. Organisms found between the two lines are counted.

(c) Line transect method

This method involves the use of a straight line cutting across an area in which the population of organisms to be sampled are found.
Quadrats are placed at regular intervals which can be 1 – 3 metres apart along the line.
Each of the quadrats is called a *station.*
The following procedure is used to show how a line transect can be used with a quadrat to sample the organisms in an area.

1. Select the area in which the organisms are found.
2. Estimate the size of the selected area in square metres (m^2) using the same method of estimating the area used in the quadrat method.
3. Take a long rope or string and ask your classmate to hold it at one end. Take the other end of the rope and stretch it across or through the area selected for the study.
4. Select the points along the line transect (stations). The stations should be at regular intervals, 1 - 3 metres apart.
5. Count and record the number of plants every three metres, that is at the stations.
6. Count the number of the plant species you have selected.
7. Record the number of plants counted.
8. Take the quadrat and place it on another station. Count the number of plants in the station and record. Repeat this procedure in all the

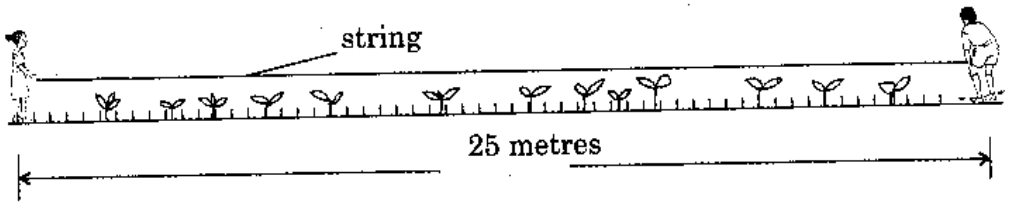


Fig. 6.2: Side view of line transect.

other stations and record your findings in a table.

Station	Number of plants
1st	40
2nd	20
3rd	120
4th	0
5th	5

9. Calculate the average number of plants in one metre square by adding the total number of plants at each station and dividing it by the number of stations. For example, the total number of plants in the table shown above is:

$$\frac{40 + 20 + 120 + 0 + 5}{5}$$

$$= \frac{185}{5}$$

= 37 organisms in one metre square (37 organisms 1 m^2).

(d) Capture-recapture method

Some organisms like birds, crabs, grasshoppers or fish constantly move around in their habitats.

The quadrat and the line transects are not suitable for sampling populations of such organisms. A more suitable method that can be used to sample such animal populations is the **capture-recapture method**. The following procedure is used to sample the organisms by the capture-recapture method.

1. Select a habitat in which the animal is found.
2. Many animals in the area are captured, counted, marked and then released back into the area.

The animals are given time to disperse and mix with the remaining population. After 1–2 days, return to the habitat and capture as many organisms as possible. The number of the marked and unmarked animals in the second capture are counted.

The following formula is then used to estimate the number of animals in the selected area.

Estimated number of organisms.

$$= \frac{FCM \times SC}{SCM}$$

Where:

FCM – Number of animals in the first capture - marked and released.

SC – Total number of animals in second capture. (Both marked and unmarked)

SCM – Number of marked animals in the second capture.

Activity 6.1: To sample the population of grasshoppers in the school playfield using the capture-recapture method

Requirements/materials

- Marker pen.
- Container with a lid.
- Sweep net.

Procedure

1. Use the sweep net to capture as many grasshoppers as possible in the field.
2. Mark all the grasshoppers you have captured. Record their number and code them as FCM.
3. Release the grasshoppers back into the field.
4. After 24 hours, capture as many

grasshoppers from the field. Count and record the number you have collected. Give a code for this count as SC.

5. Count the number of marked grasshoppers in the sample you have marked as SC that is, number of marked grasshoppers in the second collection. Give a code to the number of this marked grasshoppers as SCM.
6. Use the following formula to calculate an estimated number of grasshoppers in the area under study.

   Estimated number of grasshoppers:

$$= \frac{FCM \times SC}{SCM}$$

Area under study	Number of grasshoppers
1st catch	50
2nd catch	45
3rd catch	10
Total	**105**

Discussion

When using this method, four assumptions are made:

1. That no animal moves into (immigrates) or out of the area (emigrates) where the animals are being captured, released and recaptured. If this happens, the accuracy of the estimate you get will be affected.
2. That the released animals mix at random and evenly with the remaining population. Therefore, this method is suitable for animals that move a lot in their environments, like insects, birds, fish and small mammals.
3. That the markings should not come off or make the organism conspicuous in its environment, or be toxic to organisms.
4. That the population does not vary during the study period.

Activity 6.2

- Use the methods described on quadrats and transects to carry out ecological studies of the following habitat;

  A swamp, for example a mangrove swamp. Set up a transect from the dry land upto the swampy area and find out the effect of waterlogging on the distribution of plants and animals.

(e) Direct count

This is a method in which organisms in a given field are counted one after another. This is carried out for organisms that are large in size. These include animals such as elephants in a national park. This is done by use of a low flying plane. Trees in the schools compound can also be counted directly.

(f) Trapping

Trapping is a process in which animals are caught in a device from which they cannot escape. The caught organisms are counted. Different organisms are trapped using different devices.
Examples of trapping devices include:

(i) Pitfall trap

This is made up of a jar that is sunk on the ground. The animals crawl and fall into the jar. The following figure illustrates a pitfall trap.

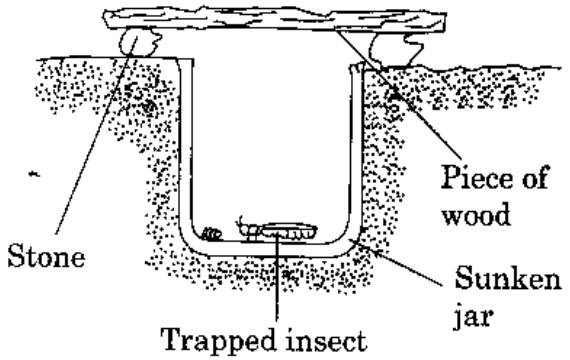


Fig. 6.3: Pitfall trap.

(ii) Pooter

A pooter is used to collect small insects from the ground without hurting or injuring them. Such insects include ants, beetles and aphids. The figure below illustrates a pooter in use.

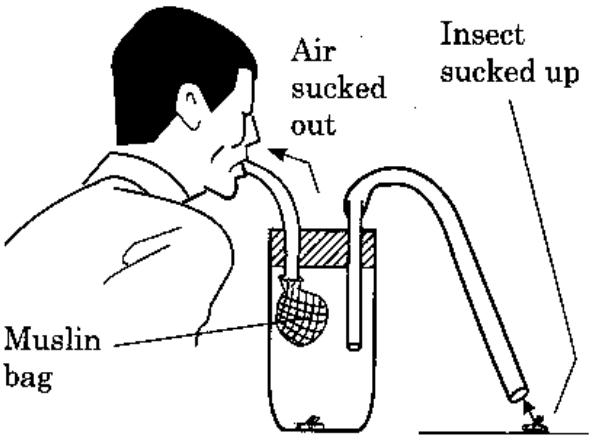


Fig. 6.4: A pooter in use.

As you can see from the figure, the inset tube is placed near the insects. The person then sucks using the tube closed with a muslin bag on one side. The sucking creates a vacuum pressure that sucks in the insects into the jar.

(iii) Sweep net

This is used for capturing flying insects such as butterflies. The figure below illustrates a sweep net.

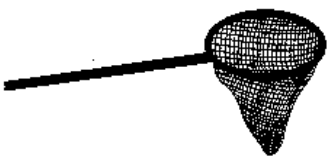


Fig. 6.5: Sweep net.

A sweep net is made up of a finely meshed net with a round mouth held on a long handle.

It is used to capture insects from vegetation especially the flying insects. Such insects include grasshoppers, butterflies, moths, stainers among others.

The insects are captured by swinging the net over the vegetation.

(iv) Tullgren funnel

This is an equipment used for trapping and collecting organisms found in decaying litter such as leaf litter. It is also used to trap nocturnal insects that hide in the litter. Such organisms include spiders, mites, centipedes and larva of insects.

The Tullgren funnel is made of a small funnel held over a jar containing water mixed with alcohol. The funnel is lined with wire gauze to hold the litter. A black polythene bag lines the outside of the funnel to conserve heat. The figure below illustrates a Tullgren funnel.

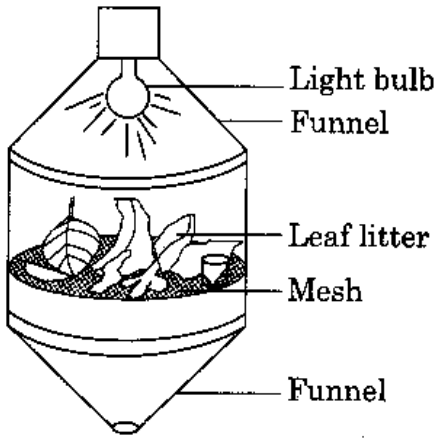


Fig. 6.6: Tullgren funnel.

The Tullgren funnel is kept in a place with strong sunlight for 24 hours.

As the litter dries up, the organisms move deeper into the litter, and pass through the wire gauze. The organisms

are collected by the funnel into the water with alcohol. The water and alcohol is sieved to collect the specimens. The organisms of each type are identified, counted and recorded.

(v) Light trap

A light trap is used to collect flying insect that are attracted to light. The light is provided for by an electric bulb. The type of light selected should be one that attracts insects. Insects attracted by the light move closer to the light source and are trapped by use of a funnel or use of a net. The figure below shows a light trap funnel and bulb.

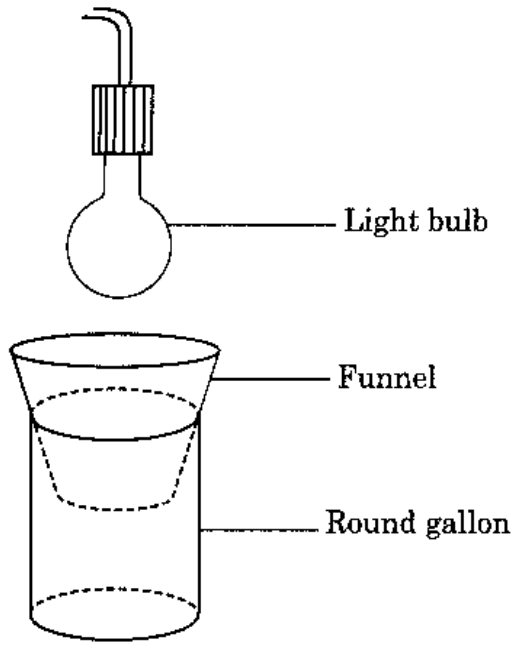


Fig. 6.7: Light trap and bulb.

Plant communities in fresh water ecosystems

In this section, we will learn about physical factors in fresh water ecosystems and the various communities found in it. In our study, we will focus mainly on lake Malawi as an example of a fresh water ecosystem.

Lake Malawi is the 8th largest fresh water lake in the world and it's the most important natural resource to Malawi.

Physical factors in a fresh water ecosystem

Physical factors available in a fresh water ecosystem include:

(i) Fresh water – this is water with very low salt concentration and a relatively neutral pH. (Lake Malawi water is slightly alkaline).
(ii) pH
(iii) Temperatures
(iv) Light intensity depending on depth of light penetration.
(v) Oxygen concentration.
(vi) Nutrient concentration depending on depth.

Near the shore of the Lake we have deep fertile soils due to sediments and deposits from run off water that enters the lake.

Light intensity decreases down the lake. At the bottom of the lake, light does not reach. Oxygen concentration also decreases down the lake.

At the bottom of the lake however, there are debris of plant and animal remains that sinks deep into the water. These materials undergo decomposition.

Plant and animal communities in fresh water ecosystems

The plant and animal communities in a fresh water ecosystem depends on a specific location. These include:

Communities on the shores

As we learnt earlier, the shores of a fresh water lake has deep fertile soils due to deposits. Oxygen is also available and light is abundant.

The shores of fresh water ecosystem attracts plant communities such as:

- Sedges and reeds.
- Abundant floating plants such as water hyacinth, water lilies, salvinia, among others.

Animal communities on the shores of fresh water ecosystems include:

- Earthworms.
- Leeches.
- Crustaceans.
- Insect larva.
- Water snakes.
- Turtles.
- Frogs.
- Flat worms.

Communities in shallow waters

In shallow waters, light and oxygen are readily available but there is no soil for anchorage.

Plant and animals communities found here include:

- Planktons.
- Water insects.
- Fish.
- Crustaceans.
- Water mammals such as the hippopotamus.

Communities in deep waters

In deep waters, oxygen and light availability diminishes. Fewer or no plant communities exist here; only a few species of blue green algae, crustaceans and some algae thrive.

These waters are mainly inhabited by mobile animals such as fish and saprophytic organisms that survive on the decomposing debris at the bottom of the lake.

The deep waters are also hiding and breeding grounds of aquatic animals such as fish. Some of the common types of fish in Lake Malawi are *Mpasia* and Lake Salmon – chilchids.

Adaptation of organisms in fresh water ecosystems

Hydrophytes

Hydrophytes are plants that grow and exist in water or in very wet places. Examples are *Nymphae*, *Salvinia* and water hyacinth.

There are three types of water plants:

(i) ***Emergent plants*** – these have roots and part of stem under water while their leaves are above water. They have a problem of taking in excess water for example, reeds.

(ii) ***Floating plants*** – these float on the water surface with roots in water, for example, water hyacinth.

(iii) ***Submerged plants*** – these are found completely under water for example, spirogyra.

Characteristics of hydrophytes

(a) The cuticle is thin or lacking. This permits the plant to absorb water, minerals and carbon dioxide over its whole surface.

(b) Since some hydrophytes absorb water over their whole body surface, their roots are not well developed. The roots may be used for anchorage for example, in water lily. They are also used for absorption of nutrients.

(c) The presence of many air spaces in the stem and leaf tissue; a special tissue called *aerenchyma* which makes the plants buoyant for support and for gaseous exchange.

(d) They contain little xylem and support tissue. They are supported by aerenchyma and the buoyancy of the water.

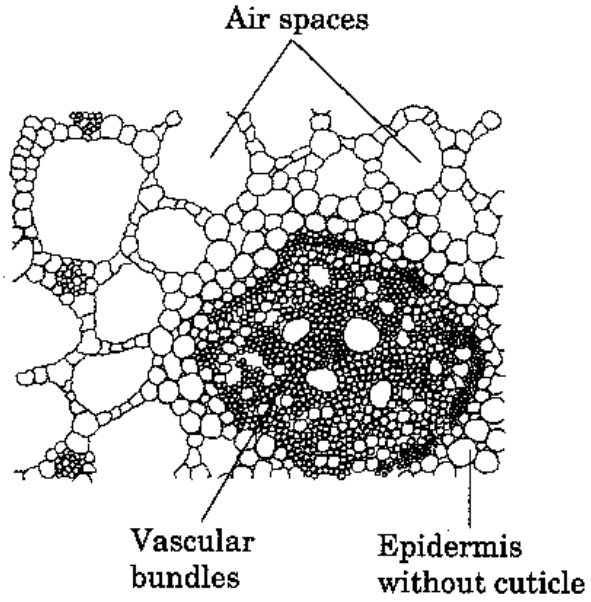


Fig. 6.8: T.S of a hydrophyte plant showing aerenchyma tissue.

(e) Submerged leaves do not have stomata and floating types have many on their upper surface.

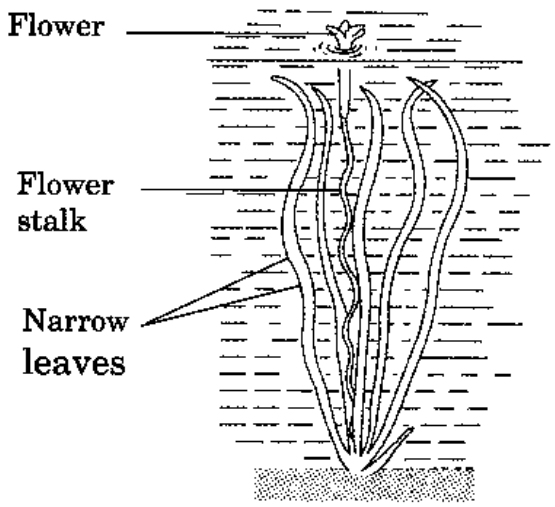


Fig. 6.9: Submerged leaves of Vallisneria gigantea.

Halophytes

These are plants that live in salty places such as rocky shores, seas and sand dunes which occur along coastal regions.

Some halophytes such as *Atriplex* and mangroves, grow near sea water. Therefore, they have a problem of taking up water from their salty surroundings. They have cells that absorb salt. As a result, they create a higher osmotic pressure which enables the plant to absorb water. Because of taking much salt, they excrete excess salts from salt glands. The figure below shows the salt glands of *Atriplex mollis*.

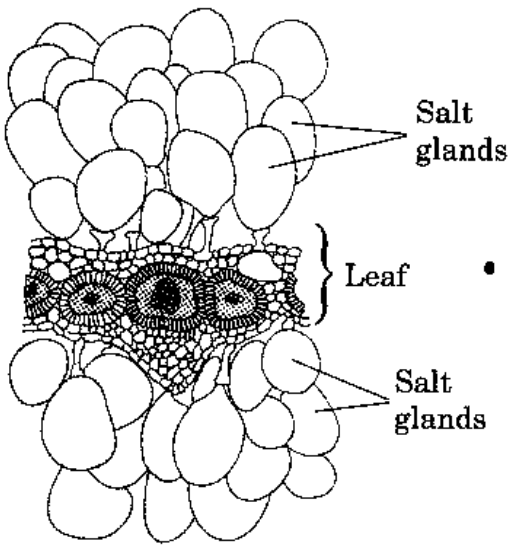


Fig. 6.10: Salt glands on leaf surface of Atriplex mollis.

Animal and plant communities in tropical savanna woodland ecosystems

A savanna is any area that is covered by grass. Savanna woodland combines grass, shrubs and woody trees.

Physical factors in tropical savanna woodland

1. Presence of rainy seasons and

dry seasons. This means that organisms living in these habitats must be adapted to survival in two extreme forms of weather; heavy rains and extreme drought.

2. Presence of fertile soils that support abundant vegetation.
3. Moderate temperatures depending on altitude.
4. Humid conditions during the rainy seasons.
5. Presence of rivers, lakes and streams.
6. Adequate sunshine.

Plant communities in savanna woodland

These include:

- Variety of grasses that covers the entire ground surface. Grass includes tuff grass that grow on the plains and evergreen carpet grass that covers well watered areas.
- A variety of herbs and shrubs.
- Variety of woody tropical trees such as acacia, baobab, brachystegia, mopane, miombo and exotic tree species such as the cypress.

Animal communities found in savanna woodland ecosystem

These include:

- Different varieties of insects.
- Different varieties of rodents.
- A variety of herbivores that inhabit national parks such as Nyika National Park. These include antelopes, zebra, elephant, Kudu, elands, among others.
- Predators such as the lion, leopard and hyena.
- Deep forests animals such as monkeys, baboon, robin, cinnamon dove, water buck, and the reedbuck.

Adaptations of animals communities in the savanna grasslands

Prey-predator adaptation

Predation is the killing and eating of one organism by another. A predator is the organism that kills and eats the other. The prey is the organism that is killed and eaten by the other. (Note that the two organisms are usually of different species).

Predators have many feeding adaptations. They have acute senses that locate and identify prey. Many have structures such as claws, teeth, fangs, stingers and poison to catch and subdue or chew the organisms on which they feed. For example, rattlesnakes locate their prey with special heat-sensitive organs located near their eyes, and they kill small birds and mammals by injecting them with toxins through their fangs. Predators that pursue their prey are fast and agile. Those that lie in ambush for example lions, are often camouflaged in their environment.

Prey that do not move usually protect themselves chemically (by possessing toxic chemicals) or physically (by having hard shells, spines, thorns and so on) Mobile preys depend mainly on their ability to escape from their predators. Preys are also defended by camouflage, which makes it difficult for predators to find them.

Some examples of predator-prey relationships include:

- A spider preying on an insect.
- A carnivore preying on a herbivore.
- A lizard preying on an insect.

Results of predation

Predation helps in controlling the population size of both the predator and the prey. As the population size of the prey decreases, the predators are then left with less food to eat and their population size decreases. When the population size of the prey starts to increase so does the population of the predators. Therefore, in a stable predator-prey relationship, the populations of the predator and the prey are regulated by each other.

Predation also brings about **biological control.** Scientists can use a predator to eliminate the prey. For example, if there were too many locusts destroying crops, then several bird species that prey on them can be introduced into the habitat to reduce the locusts.

Adaptations of communities in terrestrial ecosystems

(a) Xerophytes

Plants that live in dry ecosystems are known as xerophytes.

Adaptations of xerophytes to their habitats

1. Xerophytes have a high ability to absorb water from the soil
   Roots of xerophytes are usually more developed than the shoot. Some xerophytes have long slender roots which grow deep into the soil and extend over a wide area. As a result, the plant has a large surface area for absorption of water and it increases its chances of getting water found deep in the soil. Some xerophytes have superficial roots. The roots grow horizontally close to the soil surface. In this way, they are able to absorb water even from little rain shower.
2. Many xerophytes have *water storage tissues.*
   Many xerophytes have swollen stems or leaves which contain special water storage tissues. Large amounts of water are stored in the stems of the desert cacti. Such plants are called **succulent plants.**
   Xerophytes survive during drought by using the water stored in the stem. Examples of succulent plants are *Bryophyllum*, sisal, cactus, *Euphobia, Opuntia, Aloe,* among others.
   The boabab tree has a thick stem for water storage.
3. Xerophytes reduce water loss through transpiration in many ways:
   (a) They have a *thick waxy cuticle* which prevents excessive water loss through the leaf by evaporation.
   (b) They have *hairs* that keep damp air near the leaf surface. This reduces the diffusion gradient and lowers the rate of transpiration. They also have hairy leaf surfaces which retains moisture in the surface of the leaf reducing transpiration.
   (c) In some xerophytes for example *Nerium oleander,* the *stomata* are found *sunken* in pits. The rate of transpiration is reduced because there is a space containing moist air between the stomata and the atmosphere. *How does the moist air decrease the rate of water loss from the leaf?* Water vapour accumulates

in the pit decreasing the diffusion gradient of water vapour between air spaces in the leaf and the air in the pits.

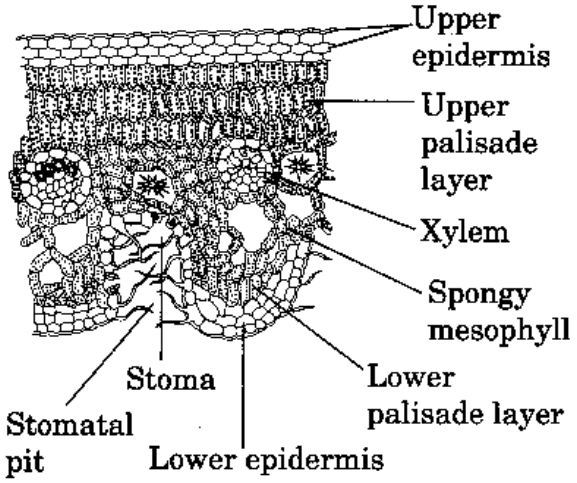


Fig. 6.11: A transverse section of the Nerium oleander leaf.

(d) Many xerophytes have features that *reduce the surface area* over which transpiration occurs:

(i) Many xerophytes have *small leaves*. In some xerophytes, the leaves are reduced to spines, and their succulent stems are green to carry out photosynthesis as shown below.

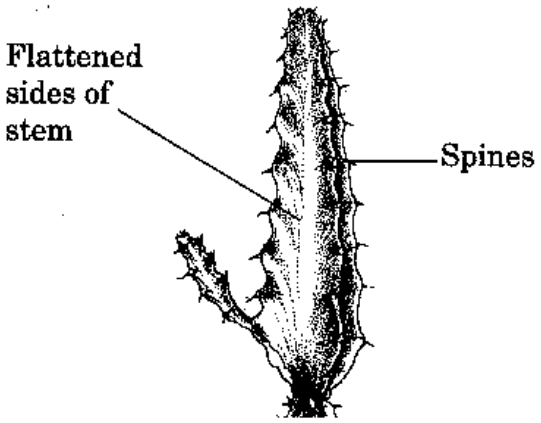


Fig. 6.12: Succulent stem of Euphobia showing spines.

(ii) Some plants *fold or roll up* their leaves to reduce the leaf surface that is exposed to air as shown below.

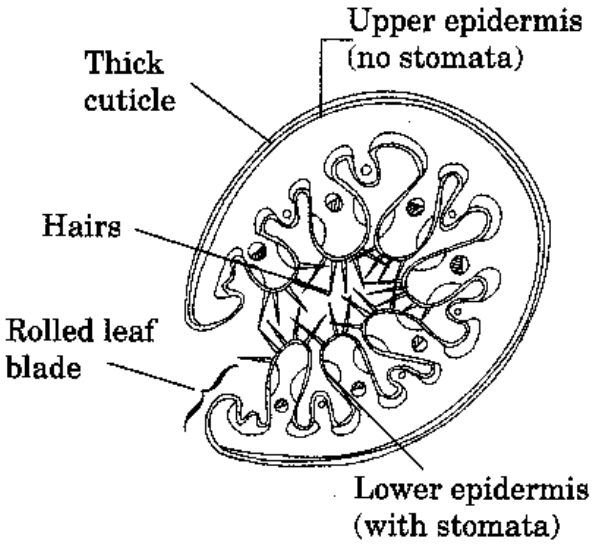


Fig. 6.13: Rolled leaf of murram grass (Ammophila).

(e) Some xerophytes have very *few stomata* which are located on the lower epidermis away from the direct heat from the sun.

(f) Some xerophytes have *reversed stomata rhythm* that is, their stomata opens during the night and close during the day unlike ordinary plants. Less transpiration occurs during the hot day when it is usually hot.

4. Some xerophytes have *life cycles* that enable them to evade dry seasons. For instance:

(a) Some have very short life cycles. They grow very fast during the short rains, produce seeds and then die.

(b) Some xerophytes have seeds that remain dormant in dry periods.
(c) Others have perennating organs such as bulbs, corms and rhizomes to store food and water and also produce new offspring.

(b) Mesophytes

Mesophytes are plants found growing under average conditions of water supply and temperature. These plants grow very well on land and develop into forest and grasslands.

Adaptations of mesophytes to their habitats

- They have *thin leaves*. This ensures rapid diffusion of gases from the stomata to the photosynthetic cells.
- They have *broad flat leaf blades* to provide a large surface area for absorption of light and carbon dioxide.
- *Mosaic arrangement* of leaves on the plant make sure that each leaf receives maximum amount of sunlight.
- There is presence of *stomates* on the upper and lower leaf epidermis to allow for efficient gaseous exchange and also for transpiration.
- Their mesophyll layer in the leaves have *air spaces* that allow free circulation of gases.
- Their leaves have cells with *chlorophyll* so that photosynthesis takes place.
- They have *thick transparent* cuticles to prevent water loss.
- They have a well *developed root system* with long tap or fibrous root and root hair cells for absorption of water.

Factors affecting primary productivity in fresh water and tropical savanna woodland ecosystems

Primary productivity is the quantity of energy that producers in an ecosystem store during photosynthesis and make it available to other organisms in the ecosystem.

It is measured by the biomass of producers in the ecosystem. **Biomass** refers to dry weight of all organisms in a given trophic level.

For an ecosystem to be said to be productive, the biomass of producers must always be higher than that of the consumers. This ensures that the producers supports themselves and at the same time sustains the consumers.

Primary productivity of an ecosystem is influenced by:

- Light.
- Water.
- Temperature.
- Mineral content.

Light

Light influences the rate of photosynthesis.

Abundant light availability to plants results to increased rate of photosynthesis.

This results to more food production in an ecosystem.

In shaded areas, plants grow thin and long and have lower biomass hence lower productivity.

Water

Availability of water results to faster

and vibrant plant growth.
Areas in an ecosystem that receive more rain or are adjacent to water bodies have abundant plant vegetation. This results to more plant hence higher biomass.
The more the plants the more the food in them. This increases primary productivity.

Temperature

Temperature increases the rate of plant growth up to a given level.
Extreme temperatures results to reduced plant growth hence lower productivity as seen in desert conditions where temperatures are very high.

Mineral content

Mineral content in a given ecosystem determines the rate of growth of plant communities.
Abundant mineral nutrients along the shores of water bodies and in deep forests results to abundance of plant life.
This increases productivity and hence more support for consumers in an ecosystem.

Energy transfer in fresh water and tropical woodland savanna ecosystems

We have learnt that inter-relationships in ecosystems involve food. We have also seen that nutrients like proteins can be passed on from one organism to another through some feeding inter-relationships.
In these feeding inter-relationships, it is not only nutrients that are passed on from one organism to another, but also **energy** contained in food in form of chemical energy.

In this section, we are interested in:
1. Where this energy comes from.
2. How the energy flows from one organism to another.
3. How some of the energy is lost or released from the organisms into the surroundings.

The main source of energy in an ecosystem is the sun. The sun produces solar energy. Light energy from the sun is trapped by **green plants** and used in the process of photosynthesis to form carbohydrates. The light energy is thus converted to chemical energy and stored in the plant. This explains why plants are termed **primary producers** in an ecosystem.
Some organisms such as herbivores feed directly on the plants to obtain energy. Other organisms obtain this energy indirectly by feeding on the herbivores. Collectively, these organisms are called **consumers** because they cannot make their own food.
When an organism dies, some of the chemical energy in the organism is released into the surrounding during decay. Some energy in animals is also lost as heat energy in breath, urine and faeces.

How energy flows in an Ecosystem

Energy from the sun flows through producers to the consumers.
Therefore, not all energy from the producers is transferred to the consumer. The flow of energy from producers to consumers in an ecosystem is known as **food chain**. The following figure shows how energy flows in an ecosystem.

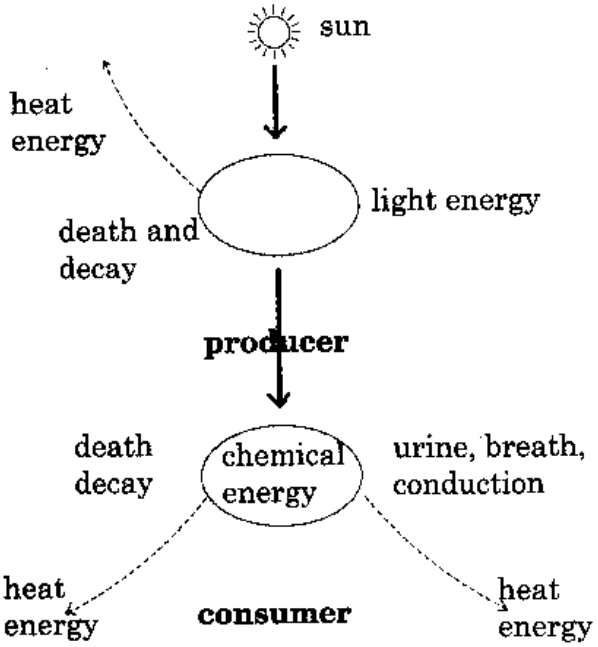


Fig. 6.14: Energy flow in an ecosystem.

Food chains

A food chain is a sequence used to describe a feeding relationship between producers and consumers.

Energy in an ecosystem can be passed on from the sun through several organisms.

Insects like grasshoppers feed on grass. The *grass is the producer* because it makes its own food. The *grasshoppers are the primary consumers* because they obtain chemical energy directly from the plants. The insects are eaten by birds which obtain chemical energy from them. The *birds are the secondary consumers*. If the bird is eaten by a mongoose, the *mongoose is the tertiary consumer*. If the mongoose is eaten by a wild dog, then the *dog is the quaternary consumer*. This is an example of a **food chain**.

A food chain can be represented as follows:

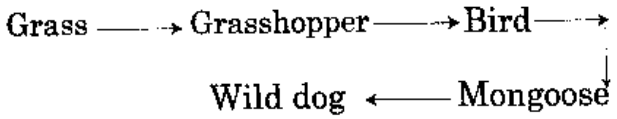


Fig. 6.15: A food chain.

The arrows in the food chain indicate the flow of energy.

If any of these organisms dies, then saprophytes like fungi and bacteria decompose it to obtain food nutrients. The saprophytes are described as **decomposers**. They too obtain chemical energy through food chains. Some energy is released into the ecosystem.

There are three main levels that the energy must pass through in a food chain. These are referred to as **trophic levels**. Trophic means nourishment and so we can also call them nutritional levels. They include:

(a) Producers

They are capable of making their own food by trapping energy from the sun.

(b) Consumers

They depend on the producers for their food either directly or indirectly.

We therefore have **direct** consumers or **primary** consumers, which feed on plants. Then we have **secondary** and **tertiary** consumers, which depend on the primary consumers.

(c) Decomposers

These are saprophytic organisms that act on the dead remains of organisms in all the other levels. The amount of energy passed on by a trophic level to another is always less than the amount of energy that the trophic level received.

This is due to the loss and usage of energy at subsequent levels.

Food chains in ecosystems rarely go beyond the quaternary consumer level because there is very little energy available from the preceding level to support them.

Activity 6.3: To investigate trophic levels occupied by organisms

- Make an excursion to the school compound or to the area around the school.
- List all the organisms found in the school compound. Group the organisms according to their trophic levels.
  (a) Record your work in a table.
  (b) Construct several food chains using the organisms you have listed.

Questions

1. How are the organisms in one trophic level related to the next level?
2. From the food chains, identify organisms that can be eaten by more than one organism.
3. Suggest where decomposers can be fitted in the food chain.

Discussion

The food chains reveal that an organism can transfer energy to more than one organism. So the food relationships are complex. Plants will be eaten by many herbivores while many carnivores will eat herbivores. Also, we get to see the importance of the plants as producers. All food chains must include producers.

However, it may not be easy to fit in decomposers in the food chain. After considering all the food chains in the school compound, you may have realised that they form a network. This network of food chains is called a **food web.** Suggest why the network is given that name.

Food webs

This is a series of interconnected food chains showing feeding relationships between various species of organisms in a given community.

A food web is composed of all possible food chains in a given ecosystem. It is a system of all the food chains in a community. In nature, the relationships between organisms in a community are more complex than simple chains of particular kinds of plants and animals. In a community, there are several kinds of producers for example grasses, shrubs and trees which are eaten by several kinds of primary consumers. Some animals might feed on several kinds of insects. All the feeding relationships in a community form a food web.

In order to find out what an organism eats, its stomach contents can be analysed or observations of the organism can be made in the field. Let us now study the following terrestrial food web.

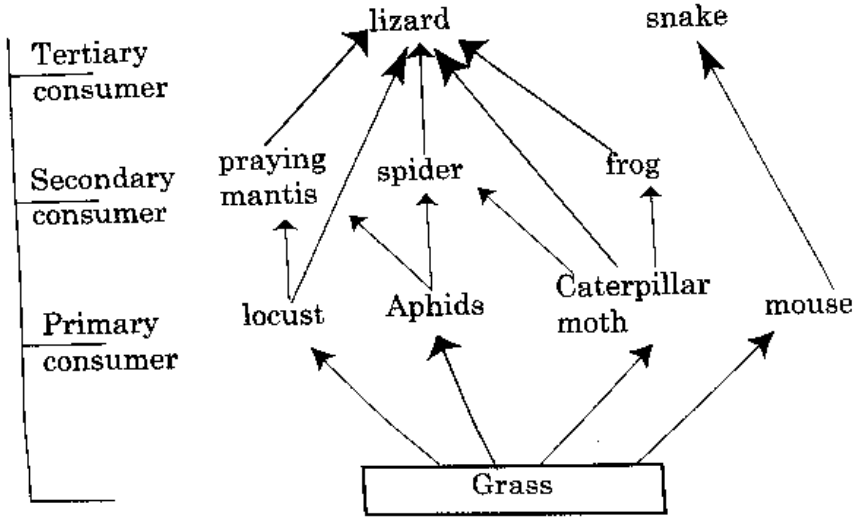


Fig. 6.15: A food web.

In the food web, identify as many food chains as possible. Note that the higher organisms such as the snakes and the owls depend on more than one particular food.

Note that decomposers such as the bacteria and fungi are involved in all parts of the food web.

The food web comprises of the relationships within a community.

It is easily made by arranging organisms in their trophic levels.

From the food web, we note that one organism can provide energy to more than one trophic level.

For example, a caterpillar moth can be eaten by a frog, a spider and a lizard. The frog and the lizard are not in the same trophic level.

In every ecosystem, there are consumers that feed on dead organisms.

Scavengers are carnivores that feed on dead bodies and carcasses left by other carnivores. Examples of scavengers include vultures and hyenas.

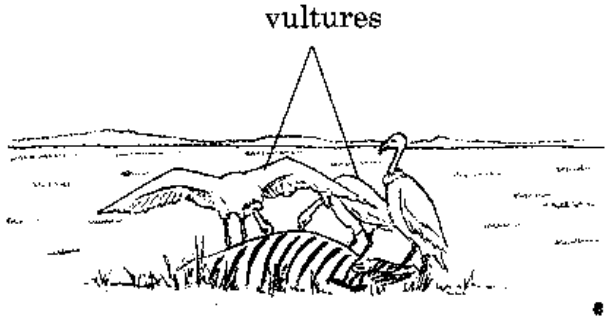


Fig. 6.17: Scavengers feeding on animal remains.

Scavengers move from place to place where they can find remains of prey left by predators. In most cases, the scavengers cannot kill prey by themselves.

Detrivores are organisms that feed on dead plant material which is undergoing decomposition. Examples of detrivores are cockroaches, termites, earthworms, some beetles and some ants.

Some of them like termites, have the ability to digest complex food materials like fibres in wood that cannot be digested by other organisms.

Food pyramids

Every transfer of food in a food chain results in a great loss in energy. This can be up to 90% loss. This is because the energy in food consumed by animals is lost due to respiration, excretion and in indigestible material in faeces. This energy does not reach the next trophic level. It is released into the environment.

A food chain can be expressed in a measurable way such as a **pyramid of numbers** and a **pyramid of biomass.**

Pyramid of numbers

The number of all organisms at each trophic level of a food chain can be counted. These numbers can be used to draw a type of diagram called a **pyramid of numbers**.

The number of organisms in each level can be obtained by totalling the population of all the species making up that level. For instance:

- Total number of plants. (Producers);
- Total number of herbivores. (Primary consumers);
- Total number of carnivores (Secondary consumers).

The pyramid is therefore a diagramatic representation of numbers of organisms in each trophic level in a food chain.

In this way, it is possible to know the number of organisms that are capable of transferring energy from one trophic level to the next.

The following figure shows a pyramid of numbers.

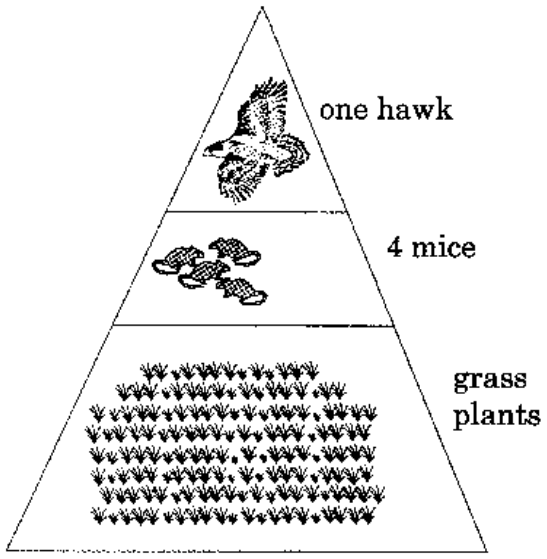


Fig. 6.18: A pyramid of numbers.

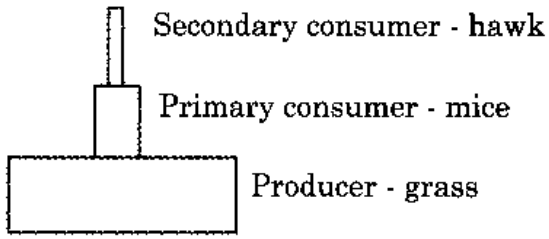


Fig. 6.19: Upright pyramid of numbers.

Its shape as we can see is like that of a pyramid. This is called an **upright pyramid**.

The pyramid indicates that organisms transferring energy to the next energy levels decrease as we rise up.

Sometimes the pyramid is not upright for instance if you were to construct a pyramid of numbers using the tree as a habitat, the tree would be the only producer and the consumers such as caterpillars and birds would be many. If we were to construct a pyramid of numbers, the smallest box would represent the tree. It would be at the bottom and not the top.

The shape of this pyramid would be inverted as can be seen in the following figure.

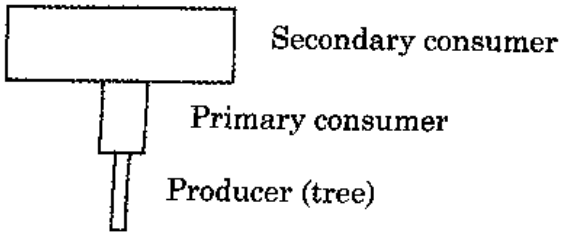


Fig.6.20: An inverted pyramid of numbers.

Pyramid of biomass

A pyramid of biomass is a diagramatic representation of mass or weight of organisms in each trophic level in a food chain.

If the dry mass of all organisms at each trophic level of a food chain is weighed the mass can be used to draw a type of diagram called a **pyramid of biomass**.

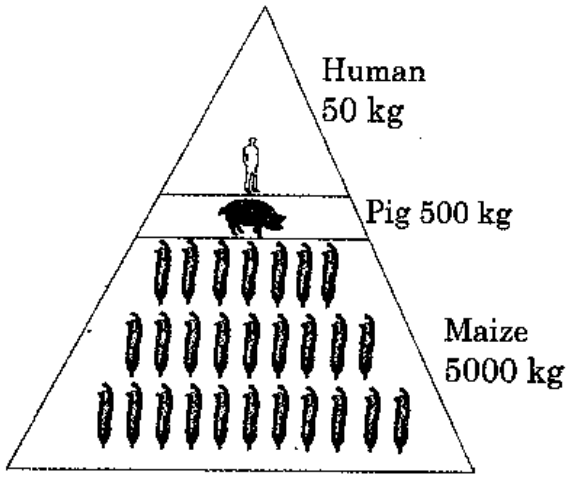


Fig. 6.21: A Pyramid of biomass.

The biomass refers to the total dry weight of organisms making a given trophic level. It represents the mass of the tissue only without any water.

So, the biomass at the following levels may be taken:

- Biomass of all producers.
- Biomass of all herbivores.
- Biomass of all carnivores.

Instead of using numbers, we can use the dry weights of organisms in each trophic level to make a pyramid. Let us now make a simple pyramid for an imaginary habitat using the following data.

- Producers 200 kg.
- Primary consumers 144 kg.
- Secondary consumer 80 kg.

Note that when making a pyramid of biomass, you must use a scale. For example, for this data we can choose a scale of 1 cm = 40 kg. We can then draw boxes whose length represents the number of organisms. The height of the boxes should be the same. The length of the box representing the producers using the above scale will be 5cm, that of primary consumers 3.6 cm and secondary consumers 2 cm.

The biomass of an organism for example grass, is determined by heating a certain amount of grass at 100°C in an oven or in the hot sun for several days to remove water. The sample of grass may be heated for 24 hours and then reweighed. The weight is recorded. The grass is heated in the oven and weighed until a constant weight is obtained. From this, make a simple pyramid.

Nutrient cycles in aquatic and terrestrial ecosystems

Nitrogen cycle

In Form Two, we learnt that nitrogen is an essential element found in amino acids, which form proteins in both plants and animals.

Nitrogen is also found free in nature in its gaseous state (N_2). Even though nitrogen gas is abundant in the atmosphere, organisms rarely absorb it in its gaseous form. Plants for example, cannot use nitrogen from the air. This is because nitrogen gas is inert. A lot of energy is required to break the bonds in nitrogen gas. A few bacteria are also capable of splitting the nitrogen molecule.

In this way, the nitrogen atom can be able to combine with other compounds so that it can be taken up by plants.

The movement or circulation of nitrogen in the environment and through organisms either when combined in different compounds or free is termed as the **nitrogen cycle.**

Without nitrogen, plants cannot make proteins and therefore cannot grow. Without plants, organisms that depend on them directly or indirectly are also affected.

Most plants use nitrogen in two forms either in ammonium (NH_4^+) form or as nitrates (NO_3^-). Usually, nitrates in the soil is the major source of nitrogen for plants. Using ammonia and nitrates, plants can make proteins. Animals cannot use ammonia and nitrate to make proteins. They must feed on plants and animals in order to get the nitrogen they need. Nitrogen gas in the air can be converted to nitrate (NO_3^-). This is known as **nitrogen fixation.** It occurs as follows.

- Fixation of nitrogen by nitrogen fixing bacteria found in the root nodules of plants and in the soil.
- Oxidation of nitrogen by lightning.

There are two types of nitrogen fixing bacteria: The **symbiotic bacteria** found in the root nodules of leguminous plants and the **non-symbiotic** (free-living) bacteria found in the soil.

The most common symbiotic nitrogen-fixing bacteria are the *Rhizobium* species.

The most common free-living bacteria are the *Azotobacter* and *Clostridium* bacteria found in the soil and some algae like *Nostoc* and *Anabaena* found in water-logged soils. These bacteria absorb nitrogen from the atmosphere and uses it to make nitrates. The symbiotic bacteria in the root nodules, pass the nitrates directly to the plants. The free-living bacteria release the nitrates into the soil when they die. All these nitrates are absorbed by plant roots to make proteins in the plant.

During heavy rains with lightning and thunderstorms, the energy of lightening causes some oxygen to react with nitrogen and splits nitrogen molecules to form nitrogen dioxide (NO_2.) Nitrogen dioxide dissolves in raindrops forming nitrous acid and then nitric acid. Nitric acid enters the soil and combines with metallic ions of salts to form nitrites and nitrates.

Plants absorb the nitrates and use them to form amino acids which build up into proteins.

The proteins formed are referred to as plant proteins. When eaten by animals, they are first digested to amino acids, then assimilated to form animal proteins. In animals, the proteins are used in body building, formation of new tissues, repair of worn out tissues, making of enzymes, hormones among others. When the process of excretion occurs in animals, excess proteins eventually form ammonia and urea. Some nitrogen is lost in these excretory wastes, for example, urine has dissolved ammonia which in turn has nitrogen. If the ammonia gets into the soil, it combines with water and other elements to form ammonium salts. These ammonium salts are then converted to nitrates by bacteria.

When plants and animals die, they undergo a process known as **putrefiction**. This is simply referred to as decay or decomposition. It is carried out by saprophytic bacteria and fungi. The putrefying bacteria break up complex proteins into simpler compounds like ammonia. Some of the compounds formed from putrefication like ammonia and nitrates are later converted to nitrates. This process of converting ammonium compounds to nitrates is called **nitrification.** It is carried out by bacteria called **nitrifying bacteria.** These are:

(a) *Nitrosomonas* and *Nitrococcus* (nitrate bacteria). These convert ammonium compounds to nitrates.

(b) *Nitrobacter* (nitrate bacteria). It converts nitrites to nitrates.

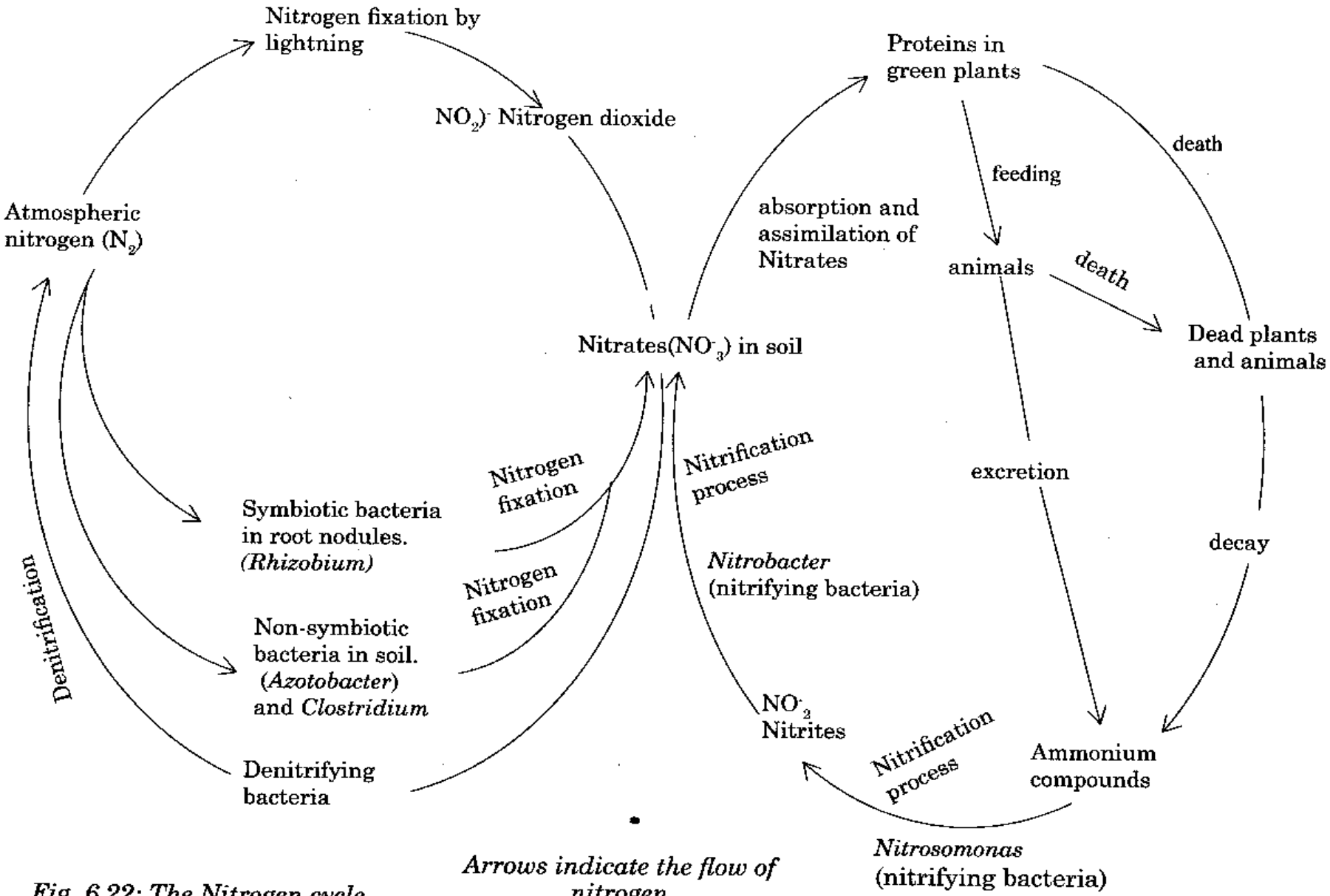
The Nitrogen cycle involves a number of organisms and a variety of pathways. There is no single nitrogen cycle but a group of cycles which interact with each other.

The nitrogen removed from the atmosphere, is recycled back to it. This occurs in three main ways.

Some soil bacteria called **denitrifying bacteria** found in poorly aerated soils and swamps convert nitrates, ammonia and ammonium salts to nitrogen gas. Such bacteria deplete the nitrates in the soil making it less fertile.

Examples of denitrifying bacteria are *Theobacillus denitrificans* and *Pseudomonas denitrificans.*

The diagram below summarises the nitrogen cycle.



Arrows indicate the flow of nitrogen

Fig. 6.22: The Nitrogen cycle

Carbon cycle

This is a cycle that explains flow of carbon through the atmosphere, oceans, soils, and in communities of living organisms.

Chains of carbon atoms makes up the body of all living organisms.

Carbon is found in form of carbon dioxide in the atmosphere.

The atmosphere contain 0.03% carbon dioxide. Carbon dioxide is also found dissolved in water.

Carbon enters the chain through the process of photosynthesis.

Photosynthetic organisms use carbon dioxide to make glucose. Glucose is used to make other complex organic substances.

Food substances contain carbon.

Movement of food substances from one consumer to another results to movement of carbon.

Some carbon dioxide is dissolved in rain water forming a weak carbonic acid. This dissolves into the soil or into water bodies. The food substances in the plant tissues is used by primary consumers. The primary consumers are eaten by secondary consumers such as carnivores. This transfers food substances containing carbon from one trophic level to another.

All living organisms carry out the process of respiration. During respiration, carbon dioxide is produced as a by product. It is released back to the atmosphere.

At the same time, all living organisms produce wastes. These wastes contain carbon compounds.

The wastes are decomposed by decomposers and releases carbon dioxide back to the atmosphere.

All living organisms die, their bodies are made of carbon containing substances. As they decompose, carbon dioxide is released back to the atmosphere.

Human activities are known to release a lot of carbon dioxide to the atmosphere. These activities include:

(i) Use of fuels in engines of vehicles.
(ii) Burning of fossil fuels in industries.
(iii) Use of fuels in homes for cooking.
(iv) Fires used to burn fields, vegetation and wastes.
(v) Heating and burning fossil fuels. Fossil fuels are formed deep into the earth crust by deposits of remains of living organisms. They contain living organisms. They contain carbon which when burned release carbon dioxide to the atmosphere.
(vi) Use of limestone in industries. In seas and oceans, carbon dioxide combines with calcium to form limestone (calcium carbonate). This is used to make shells of sea organisms. Limestone is used in various ways and as a result carbon in it is released back to the atmosphere.

Below is a summary of the carbon cycle.

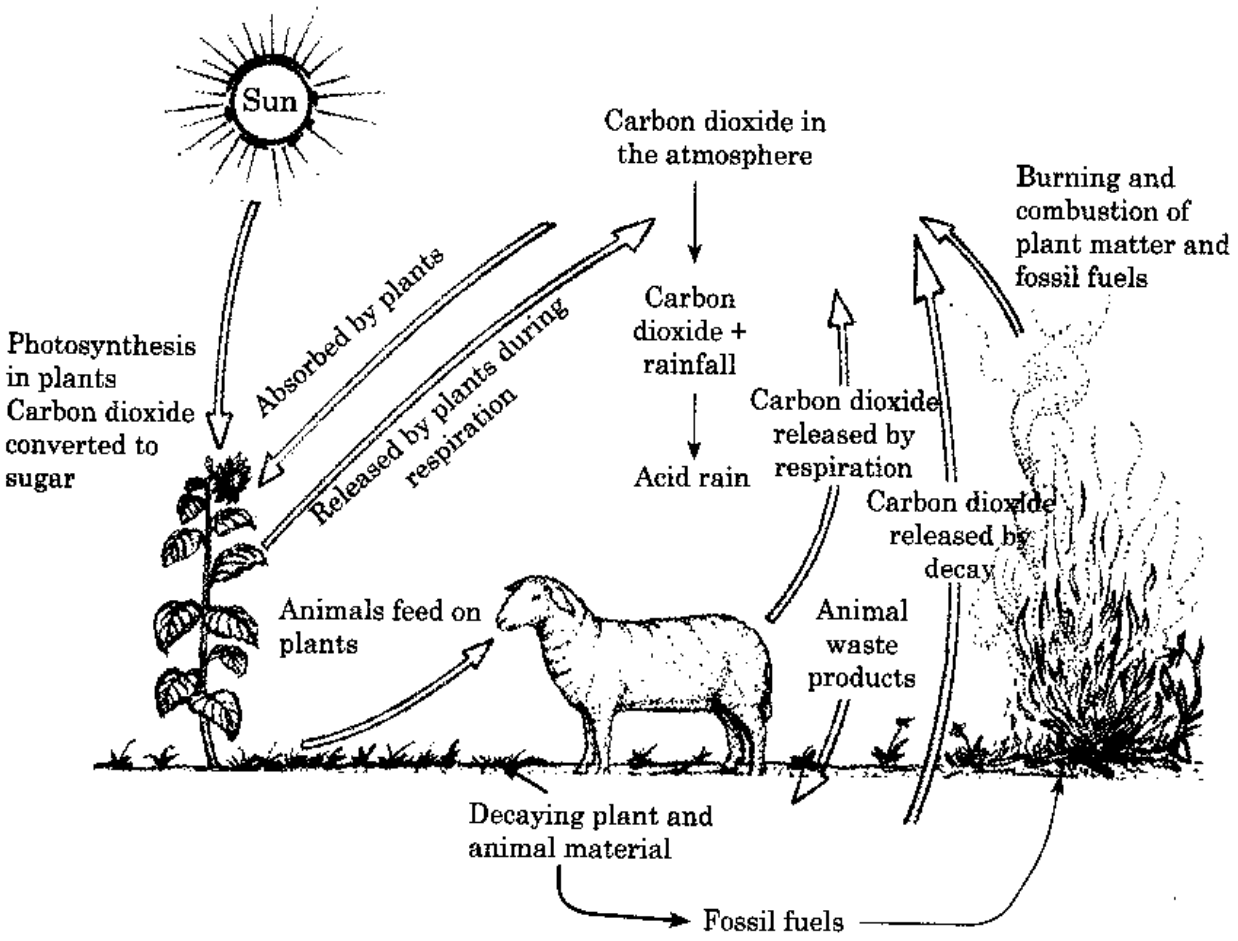


Fig. 6.23: Carbon cycle.

Importance of fresh water and savannah woodland ecosystems

1. They are a source of natural resources such as:
   - Food for animals.
   - Fish.
   - Wood.
   - Minerals.
2. They are tourists attraction sites. In Malawi, almost all the National Parks and Game Reserves are based on savannah woodland ecosystems. Some national parks such as Lake Malawi National Park is attached to lake Malawi, a fresh water ecosystem.
3. They are used for transport for example, in Lake Malawi.
4. They are used for generation of hydroelectric power.
5. They provide water for irrigation.

Effects of environmental stress on ecosystems

Environmental stress are external factors that suddenly bring about changes in an ecosystem. They include floods, drought, fires and disease outbreaks.

(a) Floods

Floods cause erosion of valleys in an ecosystem due to movement of great masses of water. This alters the physical factors in an ecosystem. Deposition of

materials on lowlands interferes with the existing habitats. This may affect animals that depend on the habitat and resulting to death of many animal species. Floods cause displacement of some plant and animal species. The organisms may be transferred to lowlands where they cannot survive once the rains are over.

Deposition of silt into water ecosystems results to physical changes in the water ecosystem. This affects the life of aquatic organisms such as fish.

(b) Drought

This is lack of rain. It causes death of species of plants and animals that cannot tolerate long dry spells. This results to migration of animals to areas near water bodies bringing about depletion of water sources. Destruction of vegetation along river banks and shores of lakes by migrating animals alters the physical factors in an ecosystem.

Death of vegetation in the savannah makes the soil to be bare and vulnerable to soil erosion by wind.

Migration of animals in search food leads to their displacement from their natural habitats.

(c) Fire

Fire results to destruction of large masses of plant and animals species. This lowers the available biomass in an ecosystem. Fire displaces some animals from the natural habitats as they escape from the fire. Fires make soil to be loose and easily eroded by wind and water.

Fire leads to loss of great volumes of wood.

Smoke from fires results to massive air pollution. This is because carbon dioxide is added to the environment.

(d) Diseases

Outbreak of diseases results to death of different species of plants and animals in an ecosystem. The death results to loss of productivity in a given area.

Impact of human activities on fresh water and tropical savanna woodland ecosystem

1. Deforestation

This is the indiscriminate cutting of trees for timber and conversion of forests into farmland.

This has resulted to diminishing of forests cover, destruction of water catchment areas hence global warming.

2. Soil erosion

Poor land use and lack of soil conservation measures in farmland has resulted to loss of top fertile soil. This leads to low production of crops.

3. Overfishing especially in Lake Malawi

This has been caused by rapid population growth around the lake. Communities around the lake use it as a means of livelihood. With increased population and high demand for fish for food and sale, overfishing is taking place even in the breeding grounds of the fish.

4. Introduction of alien plant and animal species

These are species that are not originally from Malawi.

These species are known to have higher competitive ability than the indigenous species.

Their introduction makes the local species to diminish or some resources to be destroyed. Examples are:

- Black wattle tree and the Eucalyptus trees that are known to destroy wetlands.
- Water hyacinth that destroys lakes by massive growth.
- Alien fish species such as the Nile Tilapia and the common carp that are known to predate on the local fish.

5. Pollution

Human activities produce large quantities of wastes. The release of these wastes results to pollution on the environment.

In Form Two, we learnt about the various forms of pollution that include water, air and land pollution. Air pollution causes a phenomenon known as the "Greenhouse effect".

The earth gets its heat from the sun. Most of the heat that reaches the earth is reflected back to outer space.

The atmosphere around the earth acts as an insulating layer, absorbing in some of this heat. This is how the earth is able to maintain its temperature.

Some gases like carbon dioxide and methane, are very good at trapping or insulating most of this heat. They are called greenhouse gases, because they act as greenhouses. The burning of fossil fuels worldwide produces and releases large amounts of carbon dioxide into the atmosphere.

This carbon dioxide would normally be used up by the process of photosynthesis by plants and trees that make up large rain forests all over the world.

This is however not the case because large areas of tropical rain forests have been destroyed (deforestation) and therefore less photosynthesis takes place.

The increased concentration of carbon dioxide traps the radiant energy of the sun in the same way a greenhouse does.

This raises the global temperatures (global warming) by slowing down the loss of heat from the earth's surface to outer space. This can affect weather patterns around the earth.

Management of resources in fresh water and tropical savannah ecosystems

This involves:

1. Preservation of important natural resources. To preserve means to keep without use.
   - Some resources need to be preserved so that they can support production of future resources.
   - A part of Lake Malawi need to be preserved so that it can become a breeding ground for fish.
   - Preserve the islands found in Lake Malawi.
   - Preservation and protection of wetlands needs to be done so that they can continue to be a source of water.
2. Control spread of invasive plant species and alien animal species through proper education and elimination programmes. For example, control of invasion plant species at Mount Mulanje forest reserve.
3. Restoration of damaged habitats by:
   (i) Reaforestation.
   (ii) Soil erosion control and rehabilitation.

(iii) Planting of indigenous trees in their original habitats.
(iv) Restocking of wild life for example, restocking of elephants at Majete game reserve.

4. Conservation of natural resources. This includes:
   (i) Proper conservation of soil in farmlands.
   (ii) Wildlife conservation.
   (iii) Conservation of water catchment areas.
   (iv) Conservation of wetlands such as the Chilwa wetlands.
   (v) Conservation of indigenous species such as Mpasa and chilchid fish in Lake Malawi. This is by keeping off alien species and protecting the fish's breeding grounds.
5. Use of better farming methods.
6. Environmental education in schools and universities.

Revision Exercise 6

1. Define the term "ecosystem".
2. Name the components of an ecosystem.
3. Explain the role played by producers in an ecosystem.
4. Define the following terms:
   (a) Food web.
   (b) Food pyramids.
5. (a) Name different ecological methods used to study population.
   (b) What assumptions are made when one uses capture-recapture method as a way of determining population?
6. Name three devices used to trap animals for counting.
7. Discuss the adaptation of plant communities in fresh water and savanna woodland ecosystems.
8. What is the importance of fresh water and savanna woodland ecosystems?
9. Explain the effects of environmental stress on an ecosystem.

Unit 7

Co-ordination

Specific objectives

By the end of this unit, you should be able to:

(a) Describe the structure of the neurone using a diagram.

(b) State how the neurone functions.

(c) State the functions of parts of a neurone.

(d) Name parts of the central nervous system.

(e) State the functions of parts of the central nervous system.

(f) Give examples of reflex actions.

(g) Describe a reflex arc.

(h) State the significance of reflex action.

(i) Explain how conditioned reflexes develop.

(j) Carry out investigations on co-ordination.

(k) Explain the effects of drugs and alcohol on the central nervous system.

(l) Explain the problems associated with the nervous system.

(m) Explain how hormones co-ordinate processes in the body.

Introduction

In Form 1, we learnt that sensitivity is one of the characteristics of living things. It is the ability of an organism to sense or detect changes in the environment and respond to them appropriately.

In this unit, we will study how animals respond to changes in their external and internal environments. They are able to do this because they have specialised cells called **nerve cells**. We will learn about the structure of these nerve cells and learn the different types of nerve cells. We will also learn about the structure and functions of sense organs that enable these animals to detect the changes in the environment and how the organism coordinates appropriate responses through the nervous system and the hormonal system. Finally, we will study how drug abuse may also interfere with the various body processes.

Structure and functions of neurones

We learnt that the nervous system is made of specialised cells known as nerve cells. The nerve cells are also referred to as **neurones.**

A typical neurone consists of a cell body, which gives rise to a number

of extensions. These extensions can further branch at their ends. One extension which is longer than the rest is called the **axon**. The axon transmits messages away from the cell body. The other extensions are called **dendrons**. They carry messages towards the cell body. Sometimes, other extensions may branch from the dendrons.

The extension that branch from the dendrons are known as **dendrites.**

An axon may be very long. It can for example connect the spinal cord to the big toe. The axon may be surrounded by a sheath of fatty substance called the **myelin sheath.** The axon and the sheath together make a **nerve fibre.** Several nerve fibres put together form a bundle which is referred to as **nerve.** Fig 7.1 and 7.2 show nerve fibres and a cross-section of a nerve respectively.

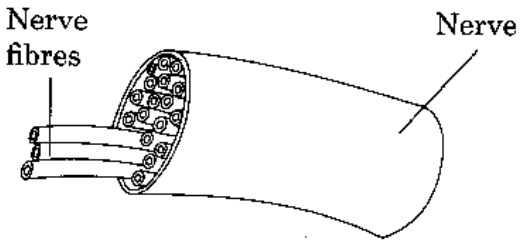


Fig. 7.1:Nerve fibres grouped together forms a nerve.

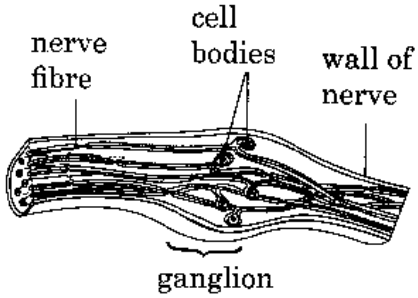


Fig. 7.2: Cross-section through a nerve.

The myelin sheath acts as an insulating material. At certain points along the length of the axon, the myelin sheath is constricted. The constrictions form junctions called **nodes of ranvier.** The nodes of ranvier together with the myelin sheath increases the speed of transmission of impluses. This myelin sheath is formed by cells called **schwann cells.** The schwann cells occur in the outer region of the sheath along the nerve cell (neurone).

Types and functions of neurones

There are three main types of neurones. These are the **sensory neurones, motor neurones** and **intermediate** or **relay neurones.**

Sensory neurones

This is also called **receptor neurone.** These are neurones that carry messages (impulses) from the sensory cells and organs to the central nervous system. The cell body of a sensory neurone is located outside the central nervous system. The cell body gives rise to a nerve fibre that divides into two. The branch which leads to the central nervous system is known as the **axon.** It relays impulses away from the cell body.

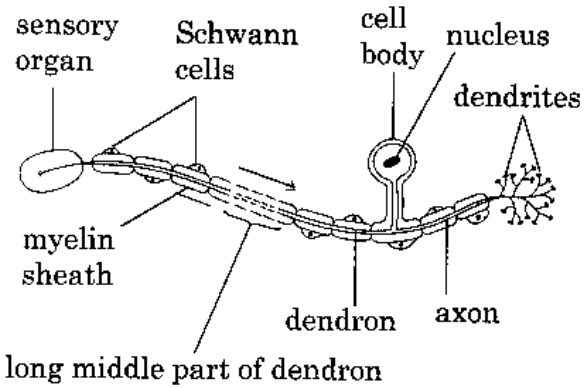


Fig.7.3: Sensory neurone.

The other part of the nerve fibre is called the **dendron.** It relays impulses towards the cell body. There is only one **dendron** and it is longer than the axon.

Motor neurones

These are neurones that carry impulses from the brain and spinal cord to the effectors (muscles and glands) . The cell body of a motor neurone is located in the central nervous system.

Its cell body gives rise to a long axon and many dendrons. The figure below shows a motor neurone.

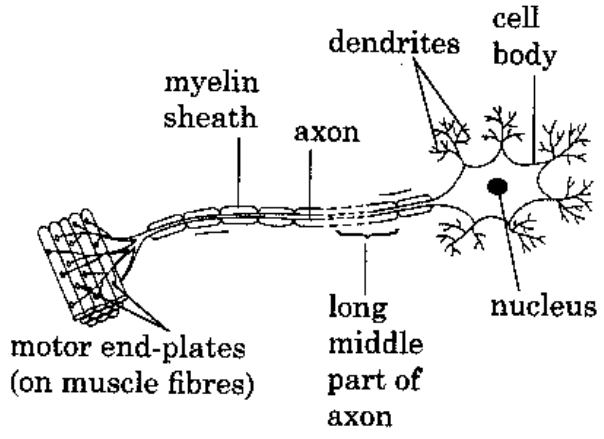


Fig. 7.4: Motor neurone.

Intermediate neurone

These are neurones that relay impulses from the sensory neurones to the motor neurones. They are therefore sometimes known as **relay neurones**.

These neurones are wholly located in the grey matter of the brain and the spinal cord. They have relatively short axons as shown below.

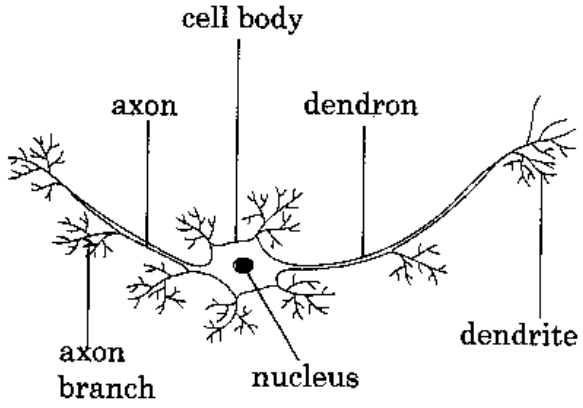


Fig. 7.5: Intermediate (relay) neurone.

Transmission of impulse along the axon

Neurones transmit information from the receptors to the central nervous system (CNS) and from the CNS to the effectors to bring about a response.

The information is transmitted in form of electrical charges along the axons. The information is known as the **impulse**.

When a neurone is not transmitting an impulse, it is said to be in a **resting potential.**

At this time, the surface of the membrane of the nerve cell is usually positively charged while the inside of the membrane is negatively charged. This is due to sodium pump mechanism that pumps dodium ions out of the axoplasm. The neurone at this stage is said to be **polarised** and no impulse is transmitted. When a neurone is transmitting an impulse, it is said to be at **action potential**. At this time, there is no sodium pump mechanism hence an influx of positively charged sodium ions into the axoplasm. The neurone at this stage is said to be **depolarised**.

The neurone is depolarised because the charges outside the membrane are not equal to the charges inside the membrane.
A change in the charges on one part disturbs the next part of the axon causing the disturbance to move along the axon. This transmits the impulse from one end of the neurone to the other end.
After an impulse is transmitted, the neuron becomes repolarised by returning back to a resting potential.

Synapse

In the nervous system, the ends of adjacent neurones are not in actual contact. There is a very small gap found between them. This small gap is called a **synapse.** It is through this synapse that impulses are transmitted from one neurone to another.
A synapse is therefore a junction formed when two neurones meet end to end, or when a neurone meets a muscle.
Each axon of the neurone form a swollen knob called a **synaptic knob.**
The knob contain vesicles that carry a chemical substance that transmits impulses from one neurone to the other.
The chemical substance is called the **transmitter substance.**
The most common chemical transmitter substances are **noraadrenaline** and **acetylcholine.**
Acetylcholine is made of choline and acetic acid.
After transmitting the impulse, the acetycholine is broken into choline and acetic acid by an enzyme called **cholinesterase.** Acetic acid and choline move back to the synaptic knob where they are re-assembled back to acetylcholine.
There are numerous mitochondria at the synaptic knob to provide energy for active transport.
Calcium ions at the synaptic knob influence movement of the vesicles when an impulse reaches the synapse. The figure below illustrates a synapse.

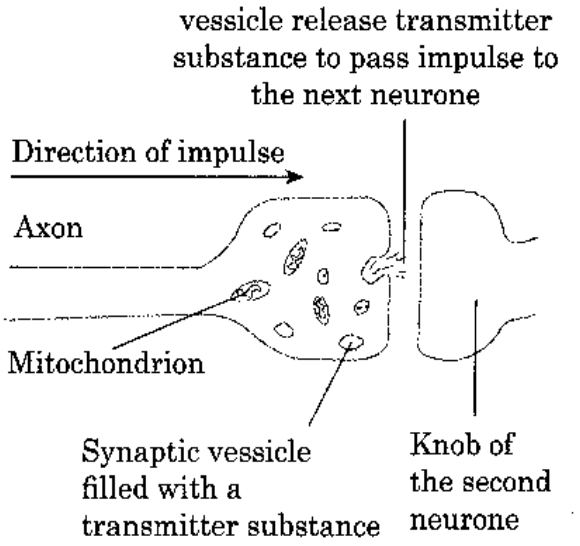


Fig. 7.6: Synapse.

The central nervous system

The central nervous system is made up of the **brain** and the **spinal cord.** The spinal cord is an extention of the brain.

The brain

The brain is made of two halves known as **hemispheres.**

These are the **right hemisphere** and the **left hemisphere.** The two hemispheres are interconnected by a group of nerves called **corpus callosum.**

The right hemisphere controls activities of the left side of the body while the left hemisphere controls

activities of the right side of the body. The outermost part of the brain is called the **grey matter.** Beneath the grey matter is an inner larger part known as the **white matter.**

The brain is covered by two membranes known as **meninges.** The outer membrane is tough and delicate and is known as the **dura matter.** This membrane protects the brain from mechanical damage. The inner membrane is known as the **pia matter.** It is composed of blood capillaries and lymph vessels.

Between the dura matter and the pia matter is a space known as the **arachnoid.** It consists of connective tissues, blood vessels and a fluid known as **cerebro-spinal fluid.** The fluid distributes oxygen and nutrients to the nervous tissues. It also helps to protect the central nervous system against mechanical shock because of its cushioning effect. The fluid also contains lymphocytes which protect the brain against disease infections.

Functions of major parts of human brain

We learnt that, the brain is divided into two hemispheres, the left and the right hemispheres.The hemispheres are organised into a number of parts. These include cerebrum, cerebellum, medulla oblongata, hypothalamus, thalamus, pons and pituitary bodies. Fig. 7.7 shows the structure of the brain.

In this section, we shall discuss the parts and functions of the brain. The main parts include the cerebrum, cerebellum and medulla oblongata.

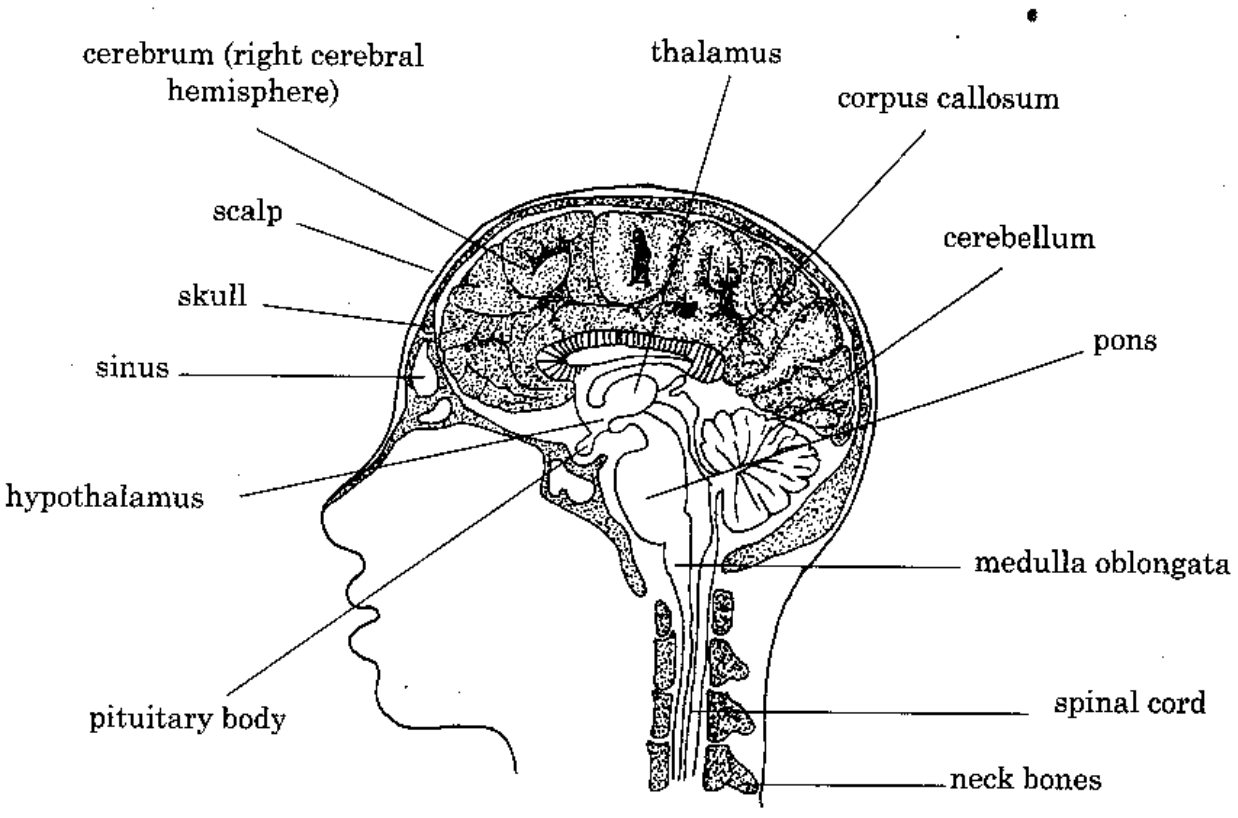


Fig. 7.7: Section through a human head to show the brain.

Cerebrum

This is the largest part of the human brain. It makes up about two-thirds of the brain. Note that it is divided into the right cerebral hemisphere and the left cerebral hemisphere.

The outer layer of the cerebrum is called **cerebral cortex.** It has many folds on its outer layer. These folds increase the surface area and hence a higher number of neurones.

To understand the functions of the cerebrum, let us consider the following situation. When you are practising for your music and drama festivals, you probably recite poems, and act in plays. What do you think these activities involve?

These activities probably involve reading and remembering lines and verses, creating interesting costumes, understanding difficult themes in the play, having confidence to make presentation, learning, and coordinating dance steps among other things.

When you are carrying out all these activities, the part of your brain that is involved is the cerebrum.

The cerebrum therefore has the following functions:

- It is the thinking centre.
- It is involved in learning.
- It is involved in imagination and creativity.
- It is the memory centre.
- It is the intelligence centre.
- It is responsible for personality or character.
- It is responsible for emotions such as joy and sorrow.
- It is involved in voluntary control of body movements such as walking, dancing and jumping.
- It receives and interprets (sorts out) impulses from the sense receptors. These receptors include the eyes, ears, taste buds and nose and receptors for touch, pain, pressure, heat and cold. This means that the cerebrum is responsible for sight, hearing, taste, smell and speech.

Cerebellum

The cerebellum is found below the rear part of the cerebrum. Like the cerebrum, it is divided into two hemispheres; left and right. The cerebellum is smaller in size than the cerebrum. It also has folds on its outer layer that increase surface area and hence a higher number of neurones.

To understand the functions of cerebellum, let us consider the following short story. Assume you are watching a final football match between your school and a neighbouring school. The striker of the opposing team dodges the defence of your team and remains with the goalkeeper. Everyone waits for the goal to be scored. Surprisingly, the goal keeper saves it. What do you think the goalkeeper had to do to save the ball?

The goalkeeper probably had to keep his eyes on the ball to judge the speed and its direction. This way he/she managed to coordinate his/her movements to dive and catch the ball. The part of the brain that was involved in this type of coordination is the cerebellum. The functions of the cerebellum are as follows:

- Coordination of body movements.
- Maintaining body balance and posture.
- Ensuring dexterity in fine movements like using hands and fingers to carry out skilful tasks such as playing a guitar, sewing and typing.

We learnt that a sexually transmitted disease known as **syphilis** can affect the nervous system. The disease in its late stages may lead to madness as a result of the infection of the **cerebellum.** It is therefore important for each one of us to have behaviour change in order to avoid contracting STIs.

Medulla oblongata

The medulla oblongata is located beneath the cerebellum. It is connected to the spinal cord. Consider a situation whereby you hold your breath for some time. How long do you think you can do this? What is it that makes you to gasp for air even if you intended to continue holding your breath for a longer time? Do you gasp for air deliberately or is it something you cannot control?

You gasped for air without your will because you had intended to hold your breath longer. The gasping is a response you could not control. Such a response is referred to as **involuntary action**. If you had not gasped involuntarily, you may have suffocated due to lack of oxygen. Such a response is an example of a vital involuntary action. Such responses are controlled by the medulla oblongata.

The function of the medulla oblongata is to control involuntary responses such as:

- Breathing
- Blood circulation
- Heartbeat, digestion and swallowing.

The spinal cord

As we have mentioned, the spinal cord is an extension of the brain. It extends from the base of the brain as shown in the figure below.

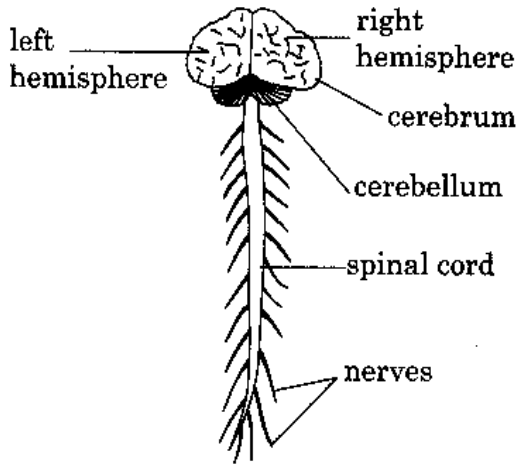


Fig. 7.8: The central nervous system

The outer parts of the spinal cord contains the **white matter** and the inner part contains the **grey matter**. There is a narrow canal called the **central canal** which runs down the spinal cord. The canal is filled with the cerebro-spinal fluid. The spinal cord is also covered by the meninges that protects it against mechanical damage. The functions of the spinal cord include:

(i) Linking the nerves of the peripheral nervous system with the brain.

(ii) Co-ordinating certain automatic responses.

Reflex action

Assume you climb a mango tree to pick a mango fruit. As you reach out for one big, ripe and juicy looking mango, you suddenly spot a snake moving towards the mango. What do you think you would do?

You would probably quickly withdraw your hand and jump down the tree and run away very fast without thinking.

Such a response is an example of a **reflex action.** A reflex action can be defined as a rapid and automatic response to

a stimulus. It usually has a survival value. For example, your behaviour in the cited case involved several actions that helped you escape from the snake and avoid being bitten.
Suggest examples of some other reflex actions you may know and their possible survival values.
Let us carry out an experiment to investigate reflex action.

Activity 7.1: The knee jerk experiment

1. Work in pairs.
2. Ask your partner to sit on a chair with their legs crossed so that one leg hangs freely.
3. Strike sharply the part just below the knee of the hanging leg using a ruler or edge of your hand.
4. Make your observations.
5. Change places with your partner and repeat the activity.

Questions

1. What did you observe when you struck your partner's knee?
2. What type of response is this?

Discussion

You may have noted that the knee kicked or jerked. This sudden response is automatic and is not under the conscious control of the individual involved. It is an example of a reflex action. It is called a **knee jerk action.**
There are two types of reflex actions:
(i) Simple reflex action.
(ii) Conditioned reflex action.

(a) Simple reflex action

In a simple reflex action, a given stimulus always produces the natural or expected reflex response.
Examples of simple reflex actions are shown below:

1. Touching a hot object causes quick withdrawal of the hand. This prevents burning of the hand.
2. Sudden blinking when someone throws an object towards your eyes. This prevents the eye from possible physical injury.
3. Salivation at the sight of food. This prepares the individual for softening and lubrication of food to make it easy to swallow.
4. Sneezing when dust gets into your nose. This helps in releasing and expelling the dust that may contain infectious bacteria.
5. Constriction of the pupil of the eye in response to light intensity. This prevents excessive entry of light into the eye which can damage cells in the retina of the eye.
6. Secretion of tears when an onion is peeled near you. The tears wash away the irritating chemicals that can damage the eye.

During a simple reflex action, an impulse passes through a certain pathway from the receptor to the effector. This pathway usually involves the three neurones we learnt about earlier; the sensory neurone, the intermediate neurone and the motor neurone.

The stimulus is detected by receptor cells which forms an impulse and transmits it to the sensory neurone. The sensory neurone then transmits the impulse to the intermediate neurones in the central nervous system.

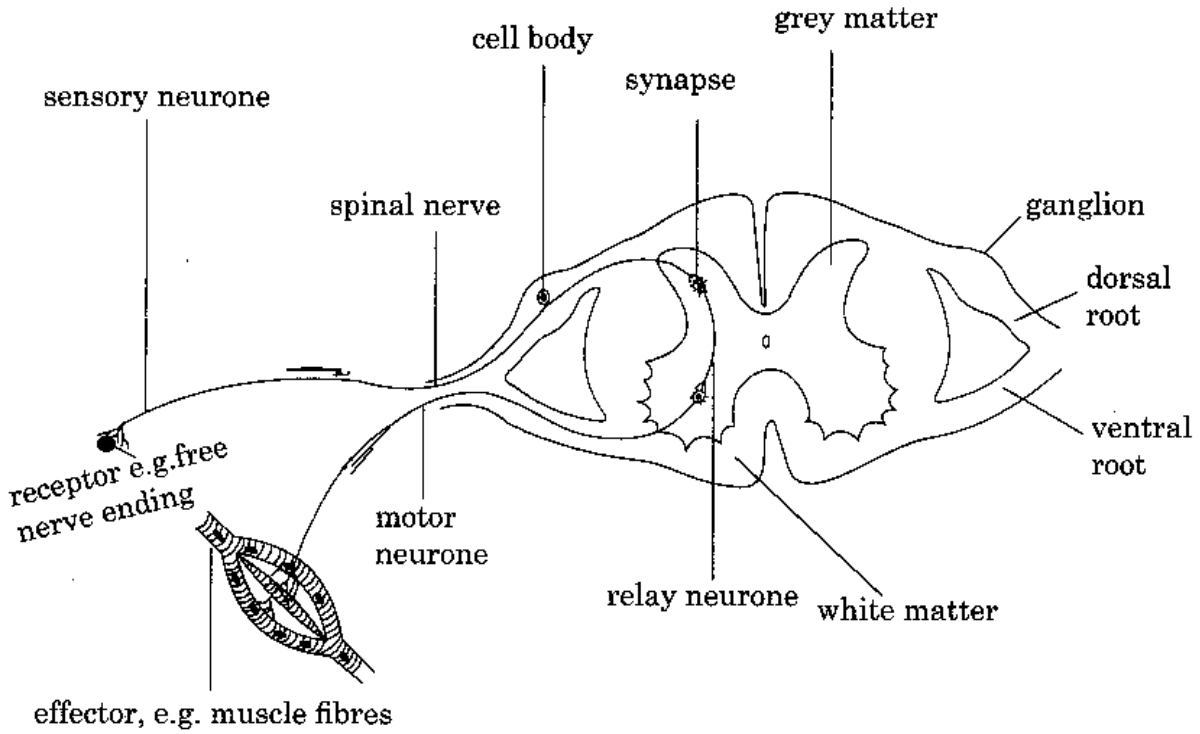


Fig.7.9: The reflex arc.

The intermediate neurones then transmit the impulse to the motor neurones. The motor neurones then transmits the impulse to the organ which brings about a response to the stimuli. This pathway of stimuli that is responsible for bringing about a reflex action is called a **reflex arc.** Figure 7.9 shows the reflex arc.

In the nervous system, the ends of adjacent neurones are not in actual contact. There is a very small gap found between them. This small gap as we learnt earlier is called a **synapse.** It is through this synapse that impulses are transmitted from one neurone to another.

(b) Conditioned reflex action

Assume your name is Fredrick. You are appointed to be the new Captain in your school. You have always responded to the name Fredrick. When the students started calling you Captain, you could not readily respond because you were not used to it. When the students realised this, they started calling you 'Captain Fredrick'. They repeatedly used the two names together. As a result, when the name Captain was subsequently used alone, you were able to respond to it. Why do you think you are now able to respond to the name 'Captain' alone yet you could not respond to the same name before?

At first, the name you were used to was Fredrick and not Captain. You could not respond when called Captain. When the two names were repeatedly used together, you realised that you were the one being referred to. You therefore learnt to associate the name Captain to your name.

So, when the name Captain was used alone, you were able to respond. Your ability to respond automatically to the new name Captain in the absence of your name Fredrick is an example of a

conditioned reflex action.

A **conditioned reflex** action can be defined as an automatic rapid action in response to a stimulus which is substituted for the normal or natural stimulus. This action is also referred to as a learnt response. It involves response to unrealistic stimulus. For this to be possible, the individual must be exposed to the new stimulus repeatedly over a period of time. This is the process of learning or conditioning.

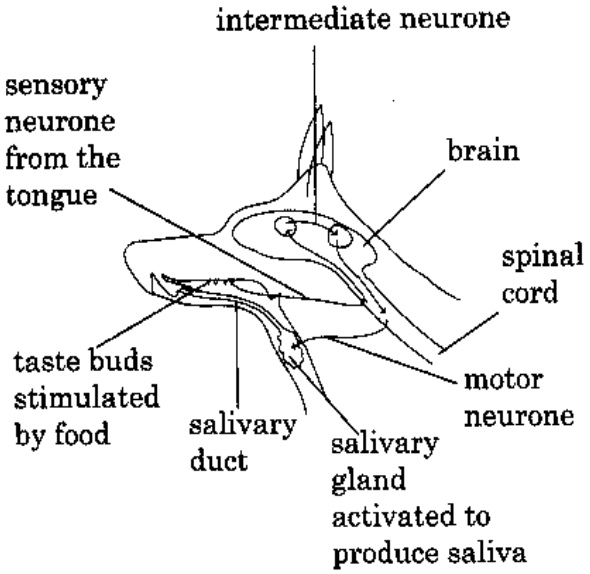
Can you suggest some other examples of conditioned reflex action? Other examples of conditioned reflex action include;

- cycling,
- walking,
- swimming,
- driving,
- training of animals in various skills.

The most famous example of conditioned reflex is that of **Pavlov's experiments on dogs**. Pavlov discovered that by placing food near a dog's mouth, he could cause the dog to secrete saliva. He rang a bell at the same time for several days as he gave the dog its food. Finally, he rang the bell without giving the dog its food and found that the dog still produced saliva. The dog therefore had been conditioned to associate the ringing of the bell with its food. Other animals can also be conditioned to respond to a variety of stimuli.

The following illustrations show:

- The simple reflex pathway when the original stimulus (taste of food) causes salivation in the dog.



- The conditioned reflex pathway when the new stimulus (sound of a bell) caused the same response of salivation.

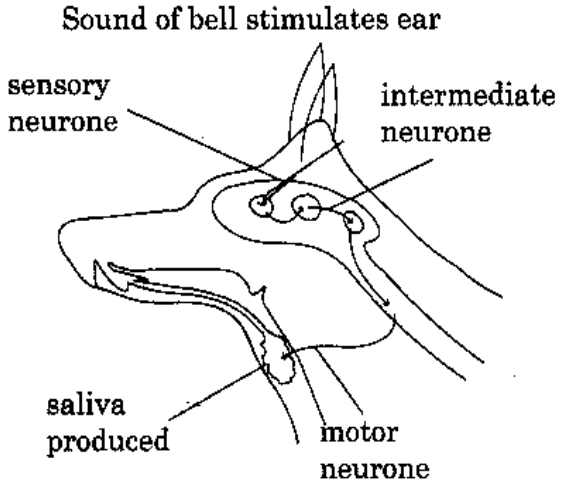


Fig. 7.10: Sequence of events during reflex action.

Significance of reflex actions

1. They enable the body to adjust to changes in its external environment. In this way, the body responds to ensure that the changes in the external environment to do not bring harm.

2. They protect the body against mechanical injuries such as cuts and burns.
3. Some animals use reflex actions to catch prey and obtain food.
4. In humans, reflex action is used in learning of skills such as sewing.

Investigations on co-ordination

Our brains are adapted to coordinate or bring order to all activities that we carry out. However, the working of the brain is also affected by external factors. These factors can improve brain activity or they can slow it down.

Discuss the following questions:

(i) When do you learn better; in the morning or in the afternoon?

(ii) What happens when you want to study but your mind is tired?

(iii) Are you a good football player? What makes one to be a good football player? Is it the talent alone or it's the talent and practice?

Let us carry out the following activities.

Activity 7.2: To investigate effect of time of day on memorising

1. You are provided with a list of 10 words below.
   1. Obama
   2. Mikaya
   3. Nyasa
   4. Kamusu
   5. Lapukeni
   6. Gondwe
   7. Kolonzo
   8. Bakari.

   (i) Memorise the words early in the morning for five minutes.

   (ii) Write down the number of words you can remember at noon tie without reading from the list again.
2. In the evening after school, try to memorise the list below for five minutes and find out how many words you can recall before going to sleep.
   1. Chisoni
   2. Nkhata
   3. Ndengu
   4. Kadawati
   5. Nyasa
   6. Kise
   7. Onani
   8. Kisau
   9. Kisinagu
   10. Kamuzu

Questions

(a) In which time of the day did you recall more words?

(b) Which type of words in the list were easy to recall?

Discussion

From the activity, you may have realised that our ability to recall words in influenced by the time of day.

For instance, in a group of students, it was observed that in a list of ten words they recalled more words after memorising in the morning.

Words memorised in the evening were least recalled and in most cases, the students recalled only the first 2 – 4 words.

This means that depending on the time of the day, our ability to record information changes. In the morning, our minds are least engaged after a

night of rest. There are fewer responses to coordinate hence better memory.

Activity 7.3: To investigate effects of practice on hitting a target

Requirements/materials

- Dart board and arrows.
- A ball.

Procedure

1. Make a mark on the dart board.
2. Aim the work using the arrows or using the ball.
3. Take ten attempts (1round) count the number of hits to target you make.
4. Continue for about 10 rounds (100 attempts) recording the number of hits to target made.
5. Record your work in a table like the one shown below.

Round (10 attempts)	1	2	3	4	5	6	7	8	9	10
No of hits on target										

Questions

1. How many hits did you make at
   (a) 1st round
   (b) 5th round
   (c) 10th round.
2. Why do you think the hits were different at the last round compared to the first round?

Discussion

You may have realised that at the beginning of the experiment, there were few hits on the target.
However, as the rounds continued, hits on the target increased.
This is because the brain was being used to respond towards one target by continuous practice.
Exposure to one stimulus for repeated times make the brain to coordinate the repeated activities faster and more accurately.
That's why there is a saying that practice makes perfect.

Assignment

- Device other activities that involves practice.

Effects of alcohol on the central nervous system

Alcohol affects adults as well as foetus if its taken by pregnant mothers.
Alcohol causes the following effects on the foetus:

(i) Poor mental development by slowing down the rate of development of brain cells in a foetus.
(ii) Development of a small brain and a small head.
(iii) Poor development of the cerebrum leading to birth of children with low levels of intelligence.

In adults, alcohol affects the nervous system in the following ways:

(i) It lengthens the reaction time by reducing the rate at which impulses travel through the nervous systems. An individual takes long to detect and response to a stimulus. This puts the life of the individual in danger. This is the reason why alcoholism results to many road accidents.
(ii) It increases the feeling of aggression resulting to increased violence.
(iii) Alcohol interferes with body balance resulting to convulsions

and unconsciousness.

(iv) Alcohol interferes with the brain causing lack of appetite, loss of control of body processes and loss of memory.

(v) Alcohol results to poor judgment.

Effects of marijuana on the nervous system

Marijuana is the most commonly abused drug among the youth in Malawi and in Africa at large.

The drug is known to cause great harm to the brain. The effects of marijuana to the brain include:

(i) Marijuana interferes with transmission of impulses from one neurone to another. This distorts the response processes. For instance, a response that required an individual to retrieve memory and remember what he was supposed to do, is diverted. That individual cannot remember what was required.

(ii) Marijuana contains chemicals that damage cells in the memory centre of the brain. This makes an individual not to keep memory.

(iii) Marijuana damages the brain cells that control emotions. This results to distorted emotional reactions by an individual. This leads to slow or no emotional feeling in situations where it was needed and feelings of worry and anxiety even where there is nothing to worry about.

(iv) In high doses, marijuana leads to total breakdown of mental coordination. This leads to total loss of efficient coordination leading to madness.

Problems associated with the nervous system

There are many problems that people in Malawi and other African countries face that are related to the nervous system. They include:

1. Polio (poliomyelitis)

This is contagious disease and is classified as one of the most dangerous diseases in the world.

It is caused by a virus. The virus attacks the nervous system causing:

- Paralysis of muscles.
- Paralysis and deformation of the skeleton.

Polio has been successfully eliminated in most countries in the world by use of polio vaccines that are given to all children freely. Mothers should ensure that their newborn babies are immunised against polio.

2. Meningitis

This is a disease that affects the meninges surrounding the brain and the spinal cord.

It causes the meninges to become inflamed. It is caused mostly by a virus that attacks the meninges and in some cases bacteria and fungi.

Symptoms include:

- Headache
- Neck stiffness
- Fever
- Confusion
- Vomiting
- Intolerance to bright light and loud sound.

Meningitis can lead to serious problems such as deafness, epilepsy and even death.

Control

- Prompt treatment
- Vaccination against viral diseases.

3. Leprosy (Hansen's disease)

This is a disease that affects the peripheral nervous system. It is caused by a bacteria called *Mycobacterium leprae.*

It causes permanent damage to the skin, nerves, limbs and eyes. Over the years, World Health Organisation (WHO) is ensuring that the disease is eliminated from the world.

4. Tetanus (Lockjaw)

This is a disease caused by a bacteria called *Clostridium tetani.* The bacteria is present in the soil. It enters the body through cuts.

It causes permanent contraction of muscles by interfering with nervous transmission. This causes the jaws to lock after contraction of muscles.

5. Stroke

This is a condition where the functions of the brain are interfered with by blockage of arteries in the brain or by bursting of a capillary in the brain leading to a blood clot on the nerve cells.

The nerve cells where the blood vessels is affected becomes inactive resulting to distorted responses such as:

- Inability to speak
- Inability to see
- Difficulties in movement
- Death

It is usually encouraged by:

- Old age
- Hypertension
- Diabetes
- Smoking
- Alcoholism
- Injuries on the head.

Stroke can be managed by prompt medical attention to remove the clot.

Other disorders include:

Cerebral palsy

This is a disorder in children whereby the brain is damaged during birth. It results to paralysis, lack of body balance, low intelligence, and impaired speech. It also results to physical body abnormalities. Cerebral palsy is easily prevented by proper medical attention during birth.

Chemical co-ordination

Role of hormones in co-ordination in a mammal

As we mentioned earlier, the endocrine system produce hormones that work together with the nerve cells to bring about co-ordination during the process of irritability in animals. Hormones are chemical substances produced in one part of the body and bring about responses in another part of the body. They are produced by **endocrine glands** also known as **ductless glands.** Fig 7.11 shows various endocrine glands.

On production, the hormones are released into the blood circulatory system. As the blood circulates in the body, the hormones stimulates responses in specific organs. Such organs are called **target organs.**

Some endocrine glands are usually stimulated to release hormones by impulses that originate from the nervous system. Other endocrine glands release their hormones as a result of stimulation by hormones from other

glands. Hormones are produced in very small quantities and stay for a while in the blood. As a result, their effects are felt for a longer time. The figure below shows the endocrine system in humans.

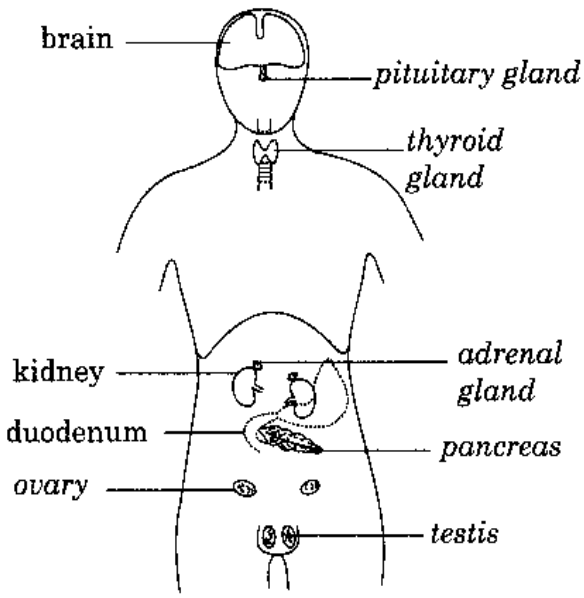


Fig. 7.11: The endocrine system in humans.

Hormones involved in co-ordination are thyroxine and adrenaline. Other hormones secreted by endocrine glands include insulin, glucagon and antidiuretic hormone. Let us learn more about these hormones.

Thyroxine

Thyroxine is a hormone produced by the thyroid glands found in the neck region. Thyroxine is a complex protein compound that contains iodine. It is released by the thyroid glands upon stimulation by another hormone known as the **thyroid-stimulating hormone (TSH).**
The thyroid stimulating hormone is produced by the pituitary gland.

Role of thyroxine

Thyroxine controls the rate of chemical reactions in the body that is, the metabolic rate. It does this because it is able to stimulate the formation of enzymes required for respiration. The energy released during respiration is required by the chemical reactions taking place in the body.

The chemical processes are important in growth and development. Thyroxine is therefore important in regulating rate of growth and development of the organism. In this way, thyroxine helps in coordinating the various processes that lead to normal growth and development.

Thyroxine also controls the basal metabolic rate.

Effects of under-secretion of thyroxine (Hypothyroidism)

Under-secretion occur when thyroid gland produce less thyroxine than the amounts required for normal metabolism, growth and development.

Under-secretion of thyroxine leads to the following conditions:

(a) If there is a deficiency of thyroxine at birth, this will lead to poor growth and mental retardation, a condition known as **cretinism.** If detected early, this condition can be rectified.

(b) If the deficiency occurs in an adult, it leads to a condition known as **myxoedema.** This condition is characterised by slow physical and mental activity in adults. The weight of the person increases due to the formation and storage of a semi-fluid material under the

skin. The skin then becomes coarse and rough. Also, hair is lost from the head. This condition can be rectified by swallowing thyroxine tablets.

The thyroid gland swells to form a disease called **goitre**.

Effects of over-secretion of thyroxine (Hyperthyroidism)

Over-secretion of thyroxine occurs when the thyroid glands produce more thyroxine than required for the normal metabolism, growth and development. It is caused by swelling of the thyroid glands, a condition referred to as **axopthalmic goitre.**

Oversecretion of thyroxine leads to increased metabolic rate in the body which results to the following:

- High body temperatures.
- Increased breathing rate and heart beat.
- Increased rate of breakdown of glucose, glycogen and fats leading to loss of body weight.
- Excess energy production that results to physical and mental restlessness. Such people become nervous and irritable and their hands shake when held out.

The person has protruding eyes.

Note:

A swelling of the thyroid gland (goitre) can be caused by both over activity and under-activity of the thyroid glands. Over-activity may lead to over-secretion of thyroxine while underactivity leads to under-secretion of thyroxine. Goitre is also caused by lack of iodine in the diet.

Adrenaline

Adrenaline is produced by glands known as **adrenal glands** found on the upper surface of the kidneys. The hormone is produced by the inner part of the adrenal glands known as the **adrenal medulla.** The production of adrenaline is stimulated by the nervous system.

The hormone is involved in response to danger, anxiety, excitement and emergency. It is therefore sometimes referred to as the **flight hormone, emergency hormone** or **combat hormone**.

Over-production of adrenaline causes:

- Increased metabolism.
- Increased conversion of glycogen into glucose.
- Increased heartbeat resulting to increased rate of circulation of blood and therefore, the supply of glucose and oxygen to the muscles.
- Blood vessels serving non-vital organs such as the digestive system to constrict reducing blood supply to them.
- Blood vessels serving vital organs such as the lungs and the brain to dilate hence increasing blood supply to them.
- Increased rate of breathing to supply oxygen required for more energy production.
- Increased rate of muscle contraction enabling rapid movements.

These responses make the body ready to respond to emergency or threatening situations. That is why adrenaline is referred to as the hormone for 'fight' or 'flight'.

Under-production of adrenaline causes:

- Reduced activity
- Fatigue
- Stress and slow response to danger.

Insulin

Insulin is produced by beta cells in the islets of langerhans in the pancreas. It works in the liver.

Functions of insulin

- Insulin decreases glucose concentration in the blood if the concentration rises above normal.
- It also increases use of glucose to eliminate excess glucose in the blood.
- Insulin stimulates conversion of excess glucose to lipids that are then stored by the body.

Deficiency of insulin

- If pancreas produces insufficient insulin, an individual suffers from a disease called **diabetes mellitus** or **sugar disease**.

Diabetes mellitus

This is a condition in which the pancreas fails to produce insulin or produces inadequate amounts. This may be due to hereditary reasons or disease affecting the islets of langerhans. A person with diabetes mellitus has an abnormally high level of glucose in the blood (hyperglycaemia).

Symptoms of diabetes mellitus include:

- Passing urine frequently.
- Constantly feeling thirsty.
- Dehydration.
- Loss of weight.
- Poor resistance to infections.

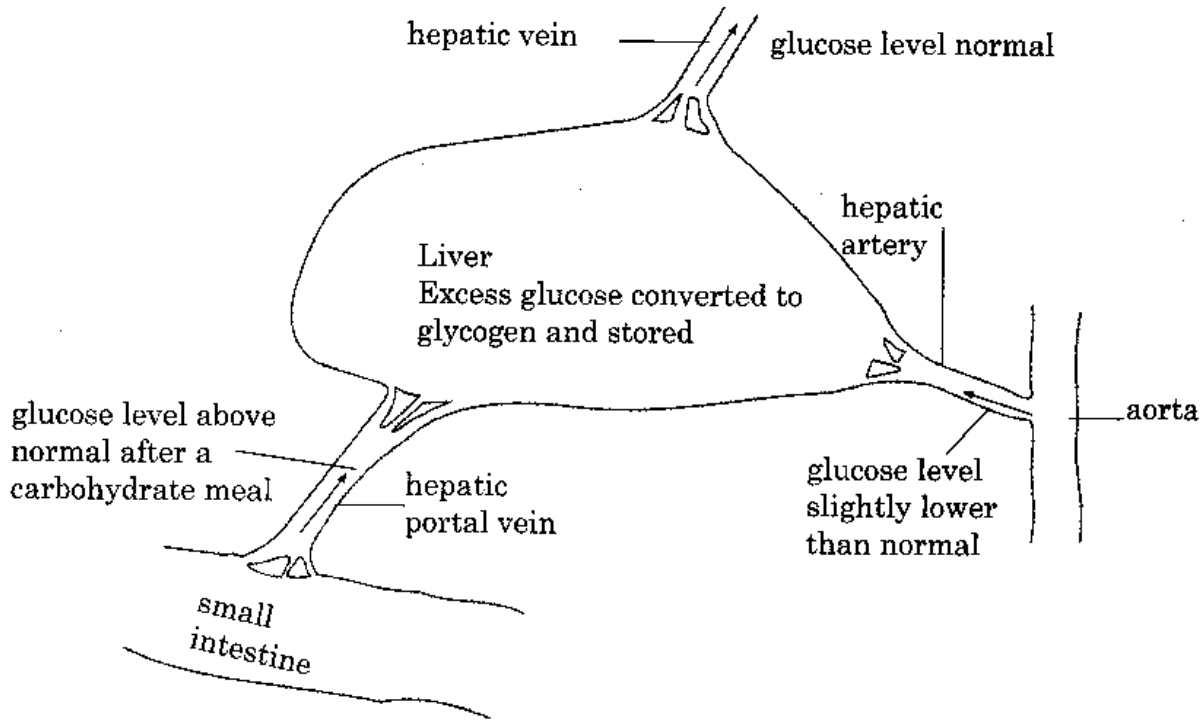


Fig 7.12 : Diagram showing blood vessels connected to the liver and their glucose concentration after a carbohydrate meal.

The kidney eliminates some glucose in the urine which is an unusual condition known as **glycosuria** (sweet urine). It can be managed by administering the hormone insulin, which decreases the glucose level to normal and reduces the symptoms of the disease. Insulin is administered through injection into a vein.

Suggest reasons why insulin is not taken orally.

A diabetic person is advised to limit carbohydrates intake in the diet. This ensures that blood sugar level is manageable.

Diabetes mellitus is becoming common today because of poor diets and alcoholism.

Be careful on your diet and avoid alcohol and other drugs.

Antidiuretic hormone (ADH)

ADH is also called **Vasopressin**.
It is produced by the posterior lobe of the pituitary gland.
ADH is involved in osmoregulation. It stimulates the walls of the collecting ducts and distal convoluted tubule to be more permeable to water. More water is reabsorbed from glomerula filtrate back to the blood. This restore blood water level back to normal.
When ADH is produced in less quantities, an individual suffers from a condition called ***Diabetes insipidus***.

Diabetes insipidus

When the pituitary gland releases very little ADH or fails to release it completely, the kidney nephrons are unable to reabsorb the required amounts of water. This leads to the production of excessively large volumes of dilute urine. This is known as **diuresis**. The urine can also be described as being "tasteless" or **insipid** thus the name diabetes insipidus. This condition may be caused by disease or injury. Diabetes insipidus can quickly lead to dehydration. People with this condition therefore drink lots of water.

Functional differences and similarities between the endocrine and nervous systems

As we had said earlier, both the nervous and the endocrine systems are involved in linking co-ordination.

Since the two systems are involved in co-ordination, they therefore have some similarities and some differences.

The following are the functional similarities between the endocrine and the nervous system.

1. Both stimulate responses to specific stimuli. These responses are of survival value to the organisms.
2. Both are involved in co-ordination of body activities.
3. Both stimulate responses that have survival value to specific stimuli.

However, the two systems have several differences related to how they function. These differences are summarised in the table below.

Endocrine system	Nervous system
1. Uses chemical substances or hormones to relay impulses.	1. Uses electrical charges caused by concentration of chemical substances to relay impulse.
2. Hormones are transmitted through the blood.	2. Impulses are transmitted through nerve cells.
3. Hormones reach all parts of the body.	3. Nerve impulses are transmitted through nerve cells connected to specific parts of the body.
4. Hormones stay longer in the blood and as a result, their effects last longer.	4. Impulses are short lived and as a result, their effects last for a short time.
5. Mostly involved in growth responses and some muscle activity.	5. Mostly involved in muscle contractions and stimulation of hormone secretion.
6. Responses are usually slow.	6. Responses are usually fast.

Table 7.1: Functional differences between the endocrine and the nervous systems.

Revision Exercise 7

1. What are neurones?
2. State four main parts of a neurone.
3. What is the main difference between an axon and a dendron?
4. State the role of the following parts of a neurone.
   (a) Node of ranvier.
   (b) Myelin sheath.
   (c) Schwann cell.
5. (a) State the three types of neurones.
   (b) The diagram below shows a neurone.

   (i) What type of a neurone is shown above?
   (ii) Give a reason for your answer.
6. What do you understand by the term reflex action?
7. State two types of reflex actions.
8. Distinguish between the two types of reflex actions named above.
9. What is a reflex arc?
10. What is the effect of marijuana on the nervous system?
11. List down the effects of over-secretion of thyroxine hormone in adults.
12. Explain how the following hormones work.
    (a) Insulin. (b) Glucagon.
13. Name three diseases associated with the nervous system.

Unit 8

Immunity

Specific objectives

By the end of this unit, you should be able to:

(a) Define immunity.

(b) Explain how the first line of defence works.

(c) Distinguish between natural and artificial immunity.

(d) Explain how HIV weakens the immune system.

(e) Describe the ABO blood group.

(f) State factors to consider before blood transfusion.

(g) State factors to consider before an organ transplant.

(h) Explain the importance of immunisation.

Definition of immunity

Immunity is the condition in which an organism can resist diseases. This means a person can be exposed to factors or organisms that cause a disease, yet they do not become sick.

How first line defences work

A defence is a way that an organism protects itself from something harmful. Organisms must find a way of defence against harmful micro-organisms like viruses, bacteria and fungi. If this was not the case, these harmful organisms would reproduce themselves inside the body of other organisms and cause diseases or even death.

The body has many ways of defending itself from such harmful micro-organisms. Such defence can be **first line** or **second line**. The first line of defence prevents harmful micro-organisms from entering the body. The body does this by creating various mechanisms that intercept or create entry barriers. The following are the first line defences in the human body:

- The skin.
- Mucus.
- Tears.
- Blood clotting.
- Cilia.
- Symbiotic defence.

The skin

The skin is an excellent first line defence because harmful micro-organisms cannot pass through it. It therefore creates a barrier that protects the cells inside the body from harmful micro-organisms in the external environment.

Mucus

Mucus is a sticky watery or liquid found in certain body openings like the nose and throat. It is secreted by

cells that line these openings. It traps micro-organisms entering through these openings. The trapped micro-organisms can be expelled by the process of sneezing if it is in the nose and therefore prevents the trapped micro-organisms from invading and infecting the body cells. It contains an enzyme called lysozyme that destroys certain bacteria.

Tears

Tears are a watery secretion produced by tear glands located in the outer eye. They contain a powerful enzyme that can digest and break down harmful micro-organisms into harmless substances. Therefore, harmful micro-organisms cannot enter the body through the openings around the eye.

Cilia

Cilia are tiny hair like structures that line the inside of some parts of the body. An example is in the respiratory or breathing system. Certain cilia line the trachea. They can move back and forth to trap and sweep micro-organisms in such openings and prevent them from entering the lungs. Then when combined with mucus, the process of coughing and sneezing expels the harmful organisms from the body.

Blood clotting

We learnt that clotting of blood occurs when an open cut or wound exposes blood to air through the process of bleeding. Such a cut causes a break in the barrier caused by the skin and can expose the body to harmful micro-organisms that can enter the body and cause infection and disease. When a clot forms, it seals the opening and enables the wound to heal thus preventing the entry of these infectious agents.

Symbiotic defence

Symbiotic is a relationship whereby two organisms live together and benefit from each other. For example, a bacteria called *Escherichia coli* lives in the intestines of a baby. The bacteria benefits from food, warmth and shelter from the intestines of the baby.

On the other hand, the bacteria makes vitamin K that is used by the baby. The bacteria also fights other bacteria that may enter the intestines to cause diseases. This makes the body of the baby be able to fight some diseases in the intestines. This is called symbiotic defence.

Natural and artificial immunity

1. Natural immunity

This is immunity that comes from the body itself. It is divided into two:

(a) Active natural immunity.

(b) Passive natural immunity.

(a) Active natural immunity

It may develop after recovering from a disease. The organism makes its own antibodies as a result of contact with the antigen from the disease-causing pathogen. Once the organism recovers from the disease, it can produce antibodies very quickly should the pathogen invade it again. This makes the organism **immune** in the sense that it cannot fall sick due to invasion by the same pathogen. Since this happened naturally, it is therefore known as **active natural immunity**. For example, if a

person gets infected with measles and gets healed and measles attacks the person again, the person is not affected by the disease. This is because as the the pathogen enters the body, the helper T-cells recognise it and killer T-cells are produced that destroy infected body cells.

(b) Passive natural immunity

This is immunity acquired by the foetus from the mother through the placenta and also through breast milk. This type of immunity is short-lived.

2. Artificial immunity

This is immunity that is obtained by introducing antigens into the body of an organism to protect the organism from a disease. It is divided into two:

(a) Passive artificial immunity.

(b) Active artificial immunity.

(a) Active artificial immunity

Active immunity is induced by introducing antigens into the body of an organism through the use of a **vaccine**. A vaccine contains antigens composed of living, dead or weakened pathogens. They are used to stimulate the body to recognise certain disease antigens and to respond to them. Vaccines usually do not cause the disease.

(b) Passive artificial immunity

This is the transfer of immunity in the form of ready made antibodies. This is immunity that comes from using antibodies produced in one organism to protect another organism from a specific disease. These antibodies are usually extracted from the **serum** of an animal that has recovered from the disease. Such immunity does not last long. Serum refers to plasma without the soluble protein fibrinogen.

How the HIV weakens the immune system

HIV infects cells in the immune system. One of the main types of cells that this virus infects is a type of lymphocyte called a Helper T cell. These cells play a key role in the immune system. HIV destroys and depletes Helper T cells population in the body. The body cannot launch an immune response and become susceptible to disease.

Helper T–cells

These are a type of white blood cells called **lymphocytes**. These cells activate and direct the immune cells to destroy disease causing organisms. HIV infects the Helper T–cell because it has the protein CD4 on its surface with which HIV uses to attach itself to the cell before gaining entry.

Killer T–cells

These are lymphocytes or white blood cells that destroy a cell that has been infected with the HIV virus. These cells help to stimulate the immune system.

Onset of AIDS

- AIDS is the last stage of HIV infection. It occurs when a person has lived with HIV and AIDS for long and the damage to the immune system is great.
- At this stage, the body becomes easily affected by other diseases because the immunity is very low.
- The disease affects the body of the patient causing what is referred to as full blown AIDS.

ABO blood group system

Everybody's blood is classified into a blood group or blood type. Do you know your blood group? What about those of your family members and friends? What does it mean to have a given blood group?

The red blood cells of humans have special types of proteins called **antigens**.

There are many types of such antigens, including **antigen A** and **antigen B**. Antigens determine the **blood type or blood group** of a person. People with only antigen A on their red blood cells are said to belong to **blood group A**. People with antigen B only belong to **blood group B**. Sometimes both antigens A and B are found on the red blood cells of the individual. In such a case, the person is said to belong to **blood group AB**. In other people, the blood has no antigens on the red blood cells. Such people have blood group **O**. Study the table below.

Antigen present on red blood cell	**Blood group**
A	A
B	B
A and B	AB
None (no antigens)	O

Table 8.1: Antigens and blood groups.

In addition to the antigens on the red blood cells, blood plasma contains other types of proteins called **antibodies**. These are complementary to the antigens A and B. Antibodies are named **a** and **b**, respectively. Antigens and antibodies that correspond to each other are never found together in the same individual. For example, **antigen A** and **antibody a** or **antigen B** and **antibody b** cannot be found in the blood of the same individual. If found together, a process known as **agglutination** (sticking together or clumping of the red blood cells) occurs and can block the blood vessels.

Instead, a person with antigen **A** will have antibody **b** in the plasma. A person with antigen **B** will have antibody **a** in the plasma. If both antigens are present, as is the case with blood type **AB**, then no antibodies will be present in the plasma. If none of the antigens is present, then both antibodies are present. This is the case with blood type **O**. Study Table 8.2 for a summary of the blood groups.

Blood group	A	B	AB	O
Antigen(s)	A	B	A and B	None
Antibody(s)	b	a	None	ab

Table 8.2: Antigens, antibodies and blood groups.

Blood transfusion

You may have heard of a situation where someone was hospitalised and needed blood. May be that person was you, a close friend or a relative. Have you ever donated blood during a blood donation week at school? Why was this necessary? Explain some of the situations that cause a person to require blood from another person.

A **blood donor** is a person who voluntarily goes to a hospital or a health centre to give blood. Blood is taken from the donor through a vein in the arm,

and passed into a bag containing anti-clotting substances. This blood is kept in a blood bank under suitable conditions, awaiting to be given to a patient who needs it.

Donated blood is introduced into the arm of the person receiving it through a vein. It is allowed to move slowly into the person receiving the blood, known as a **recipient**. The process of putting donated blood into the recipient is known as **blood transfusion**.

Perhaps you may have heard a radio announcement asking for blood donations for specific groups of blood. This means that only specific blood groups can be transfused into recipients with specific blood groups. We shall soon see why this is so.

A blood transfusion may be necessary in situations such as the following:

(i) When a person loses too much blood due to an injury that may result from a motor accident, a fall, war or a fight.

(ii) When a person becomes anaemic due to a disease such as malaria.

(iii) When a woman loses too much blood after childbirth.

(iv) A patient may sometimes need a blood transfusion during surgery.

Some of the situations that may cause one to need blood are preventable. Young children and expectant mothers catch malaria more easily. They should be encouraged to sleep under treated mosquito nets.

A successful blood transfusion is one in which the recipient's body will accept donated blood without agglutination or clumping of red blood cells taking place. This means that antigens and antibodies that match should not be brought together in a recipient. For instance, antigen A blood should not be given to a recipient who has antibody a.

Suppose you had blood group A, study Table 8.2 and suggest the blood types that your body can accept or reject. Discuss this with your friend in the class who you will assume has blood group B. Suggest suitable blood types for your friends as well.

Now study Table 8.3 below and compare it with the conclusions of your discussion. Did you pick the right blood groups for yourselves? If not, find out where you went wrong.

Donor \ Recipient	Blood group O	Blood group A	Blood group B	Blood group AB
Blood group O	Yes	Yes	Yes	Yes
Blood group A	No	Yes	No	Yes
Blood group B	No	No	Yes	Yes
Blood group AB	No	No	No	Yes

Table: 8.3: Compatibility of blood groups.

We can see from Table 8.3 that a person with blood group O can **donate** blood to recipients of all the four blood groups. This is because type O blood lacks antigens on the red blood cells that could be agglutinated by the antibodies from the recipient's plasma. People with blood group **O** are therefore described as **universal donors.**

Individuals with blood group AB can **receive** blood from all the blood groups. This is because **AB** blood group has no antibodies to agglutinate the recipient's blood. People with **AB** blood group are therefore described as **universal recipients.**

Factors to be considered before a blood transfusion

Several considerations or precautions have to be taken to ensure that a recipient does not suffer any harm as a result of blood transfusion. These are as follows:

(a) ABO blood group compatibility

A recipient must be given compatible blood. This means that blood received by the recipient should not agglutinate. Compatibility of blood is determined by the rhesus antigen as well as the A and B antigens.

Any blood from a donor is first screened before it is kept in a blood bank or transfused into a recipient. During screening, the doctors test blood for several things including the blood group it belongs to.

(b) Human Immunodeficiency Virus (HIV)

Only blood from a healthy person is kept for future use. Any blood found having disease causing organisms in it is destroyed.

(c) The rhesus factor

There is another type of antigen found in the red blood cells of some people. This antigen is called the **rhesus antigen** or the **rhesus factor**. Individuals with this antigen on their red blood cells are described as **rhesus positive** and those without the antigen are said to be **rhesus negative.** This is the reason why blood is described as + or – in addition to the blood type. For example, A^+ or A^-, B^+ or B^- among others. A^+ blood has the Antigen A as well as the rhesus antigen. A^- blood lacks the rhesus antigen but has antigen A.

Rhesus negative blood does not normally contain antibodies against the rhesus antigen. Compare this with the blood groups. However, when rhesus positive blood is introduced into a rhesus negative individual, the presence of the foreign rhesus antigens is immediately recognised by the recipient's body and antibodies are formed to counter their presence. In a single blood transfusion, only minor agglutination will take place. If the rhesus negative individual is given a second blood transfusion with the same rhesus positive blood, then the anti-rhesus antibodies already present in the blood would cause the agglutination of the incoming transfused blood. This can cause blocked blood capillaries and could lead to the death of the person.

In a blood transfusion therefore, it is important to consider the blood group antigens and antibodies, the rhesus antigens and the safety of the blood with regard to infectious diseases that are transmitted through blood.

(d) Hepatitis

Blood from individuals suffering from hepatitis should not be used for transfusion. This is because hepatitis virus can be transmitted through blood.

(e) Syphilis

Bacteria causing syphilis *(Treponema pallidum)* is found in the blood. Blood from a person suffering from syphilis should not be used for transfusion.

(f) Anaemia

Anaemia describes the condition in which the number of red blood cells in the blood is low. For this reason, doctors sometimes describe someone with anaemia as having low red blood cells count. A person who has anaemia is called **anaemic**.

An anaemic person cannot donate blood due to low red blood cell count with low haemoglobin content.

Factors to consider before an organ transplant

Organ transplanting

Sometimes an organ in the body for example the kidney or heart can fail to work properly due to infection or injury. Due to the need to save the persons life, a healthy organ can be moved from one person's body (the donor) to replace the damaged organ in the recipient.

Organ transplant is therefore the moving of an organ from one body to another to replace a damaged or absent organ. Examples of organs that can be transplanted are the heart, kidneys, eyes, liver, lungs, and pancreas among others. Kidneys are the most commonly transplanted organs followed by the liver then the heart.

One of the main difficulties of a successful organ transplant relates to the problem of the organ being rejected by the recipient. The body of the recipient responds to the transplanted organ through an immune response. It is able to recognise the foreign antigen in the organ. This can cause the transplant to fail and require the immediate removal of the organ from the recipient's body.

Several factors have to be considered before an organ transplant to avoid or reduce transplant rejection. They include:

- The blood type of the donor.
- Health condition of the donor.
- The age of the donor.

Importance of immunisation

We have seen that vaccines are antigens that are artificially introduced into the body of an organism to start an immune response. This gives protection to the organism against certain diseases, sometimes for life. The antigens are introduced into the body by injection or orally by mouth in a process called **immunisation** or **vaccination**. In children, some diseases are life threatening and the Malawian government has prepared a proper programme of immunisation to protect them from such diseases. It is necessary that all children are vaccinated against **polio, diphtheria, tetanus, whooping cough** and **tuberculosis**. You must have been vaccinated as a child. Here is a quick way of finding out. Look for the scar on the outer part of your left arm. See if your neighbour has a similar one. This scar comes from

immunising children with BCG vaccine. Are your younger brothers and sisters vaccinated? What about other children in your locality? Find out and mention the importance of vaccination to parents whose children you suspect are not vaccinated. Sometimes, people who go to a foreign country are immunised against **yellow fever**. In the case of an outbreak of a disease such as cholera or typhoid, mass vaccinations are carried out to prevent many deaths from taking place. Table 8.4 is a schedule of immunisation that a child gets from birth to 9 months.

Age	Vaccination
Birth	• BCG; prevents tuberculosis. • Oral polio vaccine:protects against poliomyelitis (polio).
6 weeks	• Diphtheria/whooping cough/tetanus/Hepatitis B/Haemophilus influenza type B. • Oral polio vaccine.
10 weeks	• Oral polio vaccine • Diphtheria/whooping cough. • Tetanus/hepatitis B/ Haemophilus influenza type B.
14 weeks	• Oral polio vaccine • Combined diphtheria/ whooping cough/tetanus/ Hepatitis B/Haemophilus influenza type B.
9 months	• Measles

Table 8.4: Immunisation schedule for children.

The diseases mentioned in the table are called **childhood immunisable diseases**. They can be greatly reduced or even eradicated if the immunisation schedule is followed. The immunisation is given free of charge in government hospitals. On the other hand, these diseases can be fatal if children are not immunised against them.

In addition to the schedule shown in Table 8.4, booster vaccines aimed at completely eradicating these diseases may be given. These are given to all children below a certain age irrespective of whether or not they have been immunised before.

Massive campaigns for parents to take children for immunisation usually accompany the exercise for administering the booster vaccine.

Revision Exercise 8

1. Define the following terms:
   (a) Immunity.
   (b) Defence.
   (c) First line defence.
2. Describe the first line of defences in the human body.
3. What is symbiotic defence?
4. State three factors that are considered before blood transfusion is done on a person.
5. Name four childhood immunisable diseases.

Unit 9

Cancer

Specific objectives

By the end of this unit, you should be able to:

(a) State the causes of cancer.

(b) Describe the effects of cancerous cells.

(c) State factors which increases the risk of cancer.

(d) Describe ways of preventing and controlling cancer.

Meaning of cancer

Cancer is a condition characterised by uncontrolled cell division in the body. Cancer is not a single disease. More than 200 types of cancer are known. Cancer if untreated causes death. Breast cancer is the most common cancer in women and lung cancer in men. The common cancers are for; skin, stomach, colon, bladder, blood, among others.

Causes of cancer

We learnt that growth in the body of an organism is as a result of new cells being formed by the cell division process of mitosis. Sometimes, this process in which cells divide to form new cells gets out of control. This abnormal multiplication of cells in the body is due to mutation. A mutation is an abnormal activation of the gene processes which controls cell division. The cells therefore undergo uncontrolled cell division. The extra cells form a mass of cells called **tumor**. The following are other causes of cancer:

1. Diet, physical inactivity and obesity. This is because obesity has negative effects on immune and endocrine system.
2. Infections by micro-organisms. For example, a virus known as **oncovirus** can cause cancer.
3. Radiation: If an organism's body is exposed to some types of radiation such as gamma rays, they can get cancer. This is because the rays penetrate the body cells where they interfere with the chromosomes.
4. Heredity: Some people get cancer because of an inherited genetic deffect.

Examples of cancer include:

Colon cancer: This is cancer of the large intestines. This can cause bleeding or obstruction of the colon.

Lung cancer: This occurs in the lungs.

Breast cancer: This occurs in the breast.

Effects of cancerous cells in the body

The effects of cancerous cells in the body are as follows:

1. They form lumps or masses of tissue called tumors. Tumors can grow and interfere with the various systems in the body. Some of the systems that are affected are the digestive, nervous and circulatory systems.
2. Some cancers can release chemical substances called hormones which can alter body function. There are two types of tumors. Tumors that stay in one place and show limited growth are said to be **benign**. Some cancerous cells move throughout the body. Such cells invade other cells, and even destroy healthy cells. Such cancers are said to be **malignant**.

The following are the common effects of cancerous cells in the body.

- Competition for nutrients.
- Malfunctioning of organs.
- Eventual death if unmanaged.

Factors that increase the risk of cancer

We learnt that cancers are as a result of mutation or changes in the genes. Any factor which causes mutations or increases the chances of mutation occurring, also increases the risk of cancer.

The following factors are known to increase the risk of cancer.

- Smoking.
- Excess alcohol consumption.
- Over-exposure to radiation.
- Some viral infections.
- Some chemicals.

(a) Smoking

Smoke from cigarettes contains a substance called **tar**. Tar contains substances called **carceinogens** that are known to initiate cancer in the lungs, mouth and throat.

(b) Excess alcohol consumption

Alcohol damages liver cells making them to develop cancer. It is also converted to other chemicals that initiate cancer in the liver and the throat.

(c) Over-exposure to radiations

Some radiations such as X-rays increases chances of development of cancer in the cells. Strong sun rays can cause skin cancer.

(d) Viral diseases

Some viral diseases such as hepatitis increase chances of cancer in the liver. *Human papilloma virus* causes cervical cancer.

(e) Chemicals

Chemicals such as mercury are **carcinogenic** and hence initiate cancer in the body.

Ways of preventing and controlling cancer

There are many factors that go into causing cancer in and individual. One of them is genetic because some cancers run in families.

(a) Living a healthy lifestyle

Here are some suggestions.

- Avoid smoking to reduce cancers of the lungs, mouth, oesophagus and larynx. Substance in cigarette smoke inhaled can cause cancer.
- Stay active and maintain a healthy weight.
- Eat plenty of plant foods such as fruits and vegetables.
- Get immunized for Hepatitis B to limit liver cancer and HPV (*Human papilloma virus*) that leads to cervical cancer.
- Reduce stress.
- Eat a diet high in antioxidants like beta-carotene, vitamin C and vitamin E.
- Limit fat in the diet. Choose fewer high fat foods because they have high calories and may increase the risk of overweightness which in turn can increase risks of cancer attack.
- Avoid drinking alcohol. The risk of various types of cancer, including cancer of the breast, colon, lung, kidney and liver increases with the amount of alcohol taken and length of time a person has been drinking.
- Protect yourself from strong sunlight. It is known to contribute to skin cancer.

(b) Avoid risky behaviour

Some sexual transmitted infections may increase the risk of cancer. For example HIV. People who have HIV and AIDS have a higher risk of cancer of the anus, cervix, lungs and immune system.

HPV – *Human papilloma virus* is associated with cervical cancer, but it may also increase the risk of cancer of the anus, penis, vulva and vagina.

Sharing needles with infected people can also expose someone to HIV as well as hepatitis B and hepatitis C which can increase the risk of liver cancer.

Cancer screening

This is a process by which cancer is detected after it has formed but before any noticeable symptoms appear. This may involve physical examination, blood or urine tests and medical imaging such as x-ray.

Revision Exercise 9

1. What is cancer?
2. Explain the causes of cancer.
3. Explain the factors that increase the risk of cancer?
4. What are the ways of preventing and controlling cancer?

Unit 10

Evolution

Specific objectives

By the end of this unit, you should be able to:

(a) State Darwin's theory of evolution.

(b) Describe evidence of evolution.

(c) Describe examples of natural selection.

(d) Explain how speciation occurs.

Introduction

The meaning of evolution

Imagine yourself living on earth millions of years ago. What kind of animals and plants do you think existed then? How do you think human beings looked like 20 million years ago? Think of an organism that:

- No longer exists, or is extinct.
- That may have changed over time.
- That may have remained unchanged over time.

How do you think humans will be like 20 million years from today? Will they still exist? Will they remain the same? With mutations occurring over time, how do you think humans will look like? They would probably look like what is shown in Fig 10.1.

The term evolution is formed from the word 'evolve' which means 'gradual change over a long period of time'. Evolution is a theory. The evolution theory tries to explain how the great diversity of animals and plants that exist on earth today has come to be. It suggests that life on earth began from simple forms which then slowly evolved into the present day organisms.

This was because the original simple forms of organisms underwent small changes that accumulated over millions of years. This led to the great variations of complex plants and animals we have today.

Darwin's theory of evolution

Natural selection is one of the theories which explains how new species arise from pre-existing species. When you look around your environment, you realise that plants and animals live or die according to their ability to survive in that environment. For example, plants are always competing with others for light and water. Animals compete for food, space, mates and shelter. In the process, some survive, while others die. **Natural selection** is, therefore, a process whereby organisms with favourable variations survive and produce more offsprings than organisms with less favourable variations. This is also called **survival for the fittest**.

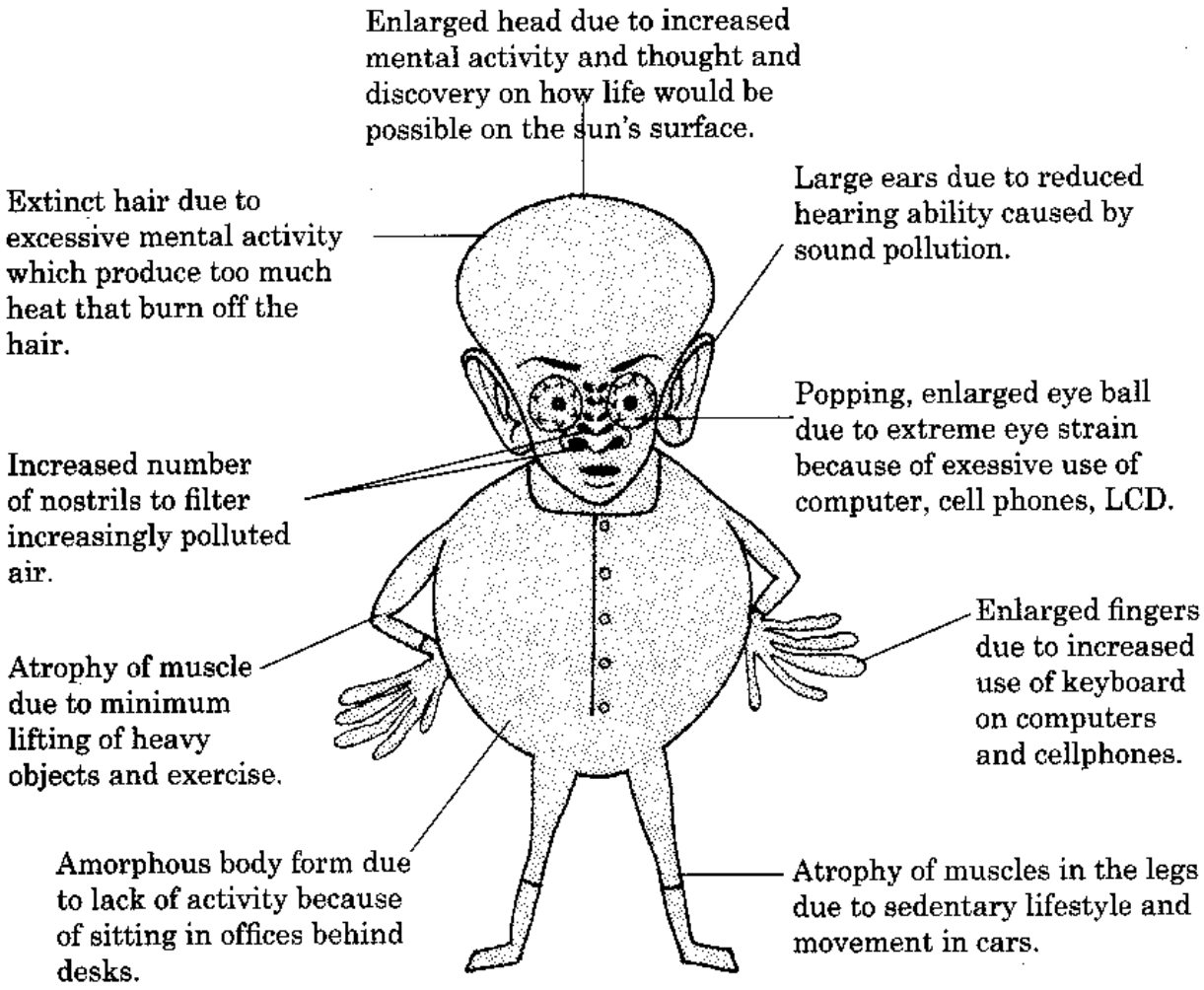


Fig. 10.1: Will the human being look like this 20 million years from now?

In any population of organisms, many new individuals are always produced. However, it is observed that the population of these organisms remain more or less constant. The reason for this is that some natural factors in the environment cause the death of some organisms. Such factors include insufficient food and diseases among others. These can be caused by **overcrowding/overproduction** and competition between the organisms. This creates a **struggle for existence.**

These cause some organisms to die and others to survive. The reason why not all organisms survive in this competition is because their characteristics are not the same.

There is variation in the characteristics of the species. These variations are of two types. Those variations that enable the organisms to compete effectively are referred to as ***beneficial, favourable or advantageous variations***. Those variations that do not enable the organism to compete effectively are referred to as ***non-beneficial or disadvantageous variations.***

The beneficial variations are also referred to as ***adaptations.*** An

adaptation is an inheritable characteristic that improves the organism's chances of survival in an environment. This creates **survival for the fittest**.

In nature, environmental conditions keep changing. Organisms that have adapted to the changes in the environment will always survive. Those organisms that have not adapted to the changes in the environment will gradually be eliminated.

This way, beneficial variations or adaptations enable organisms to survive competition and grow to maturity. These organisms pass on the variations to their offsprings. As a result, the organisms with beneficial variations increase in number in a given population.

The organisms with non-beneficial variations do not survive the competition. As a result, they do not grow to maturity to reproduce and pass on their characteristics to the offsprings. Organisms with non-beneficial variations therefore reduce in numbers in a given population. It is as if nature is selecting some organisms to live and some to die. This is referred to as ***natural selection.***

A famous scientist; *Charles Darwin* studied this phenomenon of natural selection which later came to be called **Darwin's theory of natural selection**. Darwin worked together with Alfred Wallace to formulate this theory.

Natural selection causes evolution because with time and over many generations, favourable adaptations gradually accumulate in the species while the unfavourable ones disappear. This leads to a change or evolution in the species.

Sometimes, the accumulated changes become so many that the eventual outcome may be a species that cannot reproduce and have viable offsprings with the original one. This means that the gradual changes have led to the formation of a new species. This is called ***speciation.***

Evolution occurs slowly and continuously over millions of years by natural selection. Other sources of variations that contribute to natural selection in a species include:

- Mutations.
- Recombination of genes as a result of sexual reproduction.
- Migration of individuals between populations which lead to introduction of new genes in the population.

Evidences for organic evolution

Evidence is information that is used as proof that a given idea is true or not true. For example, if you saw an old woman walking with a very young boy, you may assume that the old woman is the grandmother of the boy. This is however just an assumption that may or may not be true. To be certain that indeed it is the case, you may need to show reasons or proof for this assumption. The proof is theoritised as evidence for the relationship. In the same way, before scientists proposed the theory of evolution and it's mechanisms, they needed some proof or evidence for it. In this section, we shall study different sources of evidence for the theory of evolution which include:

- Fossil records.
- Geographical distribution.
- Comparative embryology.
- Comparative anatomy.
- Cell biology.

1. Fossil records

Fossils are the remains of plants and animals which used to live millions of years ago. There are three main ways in which fossils can be formed. Most fossils are formed from the hard parts of animals like bones, teeth and shells. When an animal dies, these parts do not readily decay. They eventually get buried in the soil or ground or in the sea. As the soft parts of the tissue of these structures decay, they are replaced by minerals forming a rock-like structure. Such structures retain the shape or form of the original hard part of the organism, that is, bone.

The soil or sediment in which these structures are buried eventually hardens into rock. The structure is then called a **fossil**. The fossil remains distinct in the rock. Fig. 10.2 below shows fossils of organisms called trilobites which are distant relatives of insects.

Fig. 10.2: Fossils of trilobites.

Sometimes, the softer parts of the organism decay slowly and the tissue may get replaced by minerals forming a hard structure. This process is known as **petrification.** Petrification is, however, rare. Sometimes, an organism may die yet not undergo decay because it is in a medium that cannot allow activity of micro-organisms that cause decay. Such media include ice and amber. Amber is a plant resin. Insects and leaves are found preserved in amber which hardens to a stone. This preserves the organism intact as a fossil for thousands of years as shown in Fig. 10.3 below.

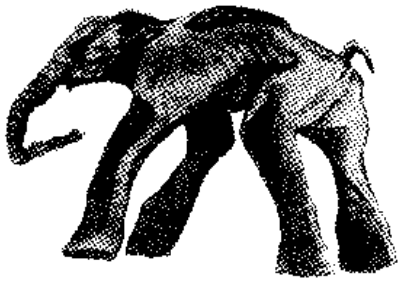


Fig. 10.3: A fossil of a mammoth a distant relative of elephant.

Fossils are studied by scientists called ***Palaeontologists***. Palaentologists put together fossil information of related organisms by arranging them in such a way that they form a series according to their age starting from the oldest to the most recent. This is referred to as a ***fossil record***.

From such fossil records, differences are usually noted between related fossils. These specific differences reveal changes of development from one form of organism to another. These changes are believed to have occurred slowly over time during the life of the organism. In this way, fossil records offer very good evidence for evolution.

In summary, fossil record reveals the following:

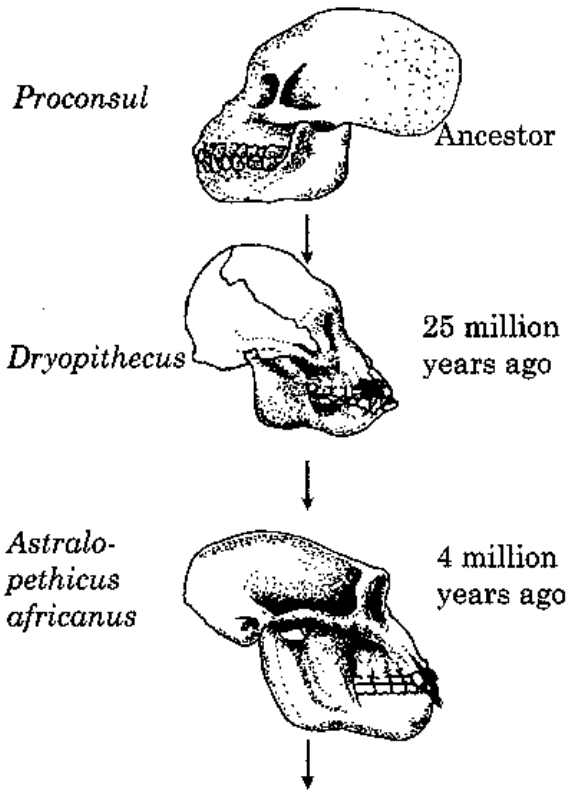
- The *extinction of organisms* due to presence of fossils of organisms that do not exist today.

- Evidence of *progressive change* within forms of organisms.
- The existence of *transitional forms* between groups of organisms.

> ***Note***
>
> **It is important to note that only few fossil records are available because many remains are lost through decay, fires, volcanic activities and through scavengers.**

Human evolution

A good example of a fossil record as evidence of evolution is that of human evolution. Fossil records of skulls and bones reveal that at one time, there existed intermediate forms between humans and their ancestors. When these fossils are arranged in series according to their age (oldest first) to form a fossil record, a pattern of human evolution is revealed. The pattern is as illustrated in Fig 10.4.



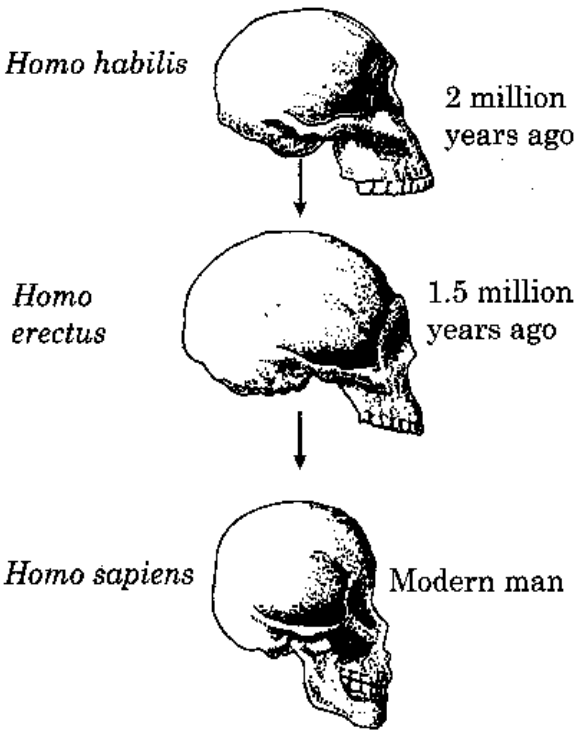


Fig. 10.4: Skulls showing the transition of human beings from ancestral form to modern man; an example of a fossil record.

Study these skulls carefully. Point out some of the changes that you can note from one type of the skull to the next. Suggest some ways in which the human may have evolved over time by looking at these fossils.

The illustration reveals progressive changes that have occurred during human evolution.

> **Activity 10.1: Educational tour to an archeological site/local museum**
>
> - Draw fossils if present.
> - Identify present types of fossils.
> - Study the evolution of man.
> - Make a presentation to the class on the tour.

2. Geographical distribution

What is geographical distribution of organisms? It is the present day dispersion and location of plants and animals in specific geographical regions of the world.

Observation of organisms living in the world today show that some plants and animals living in different parts of the world have many similarities in common. For example, the leopard is similar to certain animals like cat and the lion.

Organisms with similar characteristics are believed to have evolved from the same ancestral group or species.

The question is: Why do some of these organisms with many similarities live in natural habitats that are so far apart?

For example, the camel and the llama are classified in the same family *Camelidae*. They are, however, geographically distributed in two separate regions of the world.

If it is true that these two organisms evolved from the same species of organism, how is it that their natural habitats are so far apart? In other words, why is it that present day organisms are geographically distributed in specific regions of the world and not evenly distributed in different parts of the world?

Fossil evidence shows that it was not always the case for some organisms to be confined to one region only. In some cases, there is fossil evidence that some organisms had a continuous distribution over more geographical regions than noted today. This could be true because there was free migration of animals from one region to another. Organisms remained confined to one region only due to geographical barriers that prevented their movement.

Such barriers include mountains, oceans, deserts and rivers which have influenced the distribution of species. These barriers have isolated populations of organisms thereby preventing them from interbreeding.

As a result, over time, the isolated species underwent separate change or evolution. This would explain the similarities in related groups of organisms found in separate regions.

The continental drift

At one time, it is believed there was only one continent, the continent of **Pangaea**. This made it possible for animals to migrate freely over the continent. Pangaea broke into **Laurasia** and **Gondwanaland** continents as shown in Figs. 10.5 and 10.6.

Fig. 10.5: Laurasia and Gondwana land at the start of the drift after splitting of Pangea.

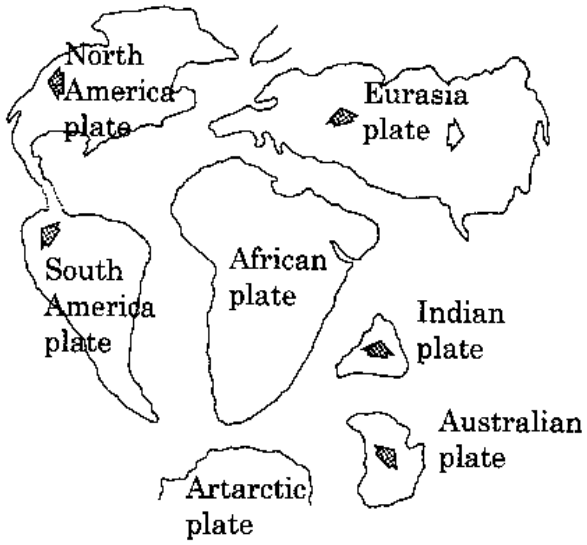
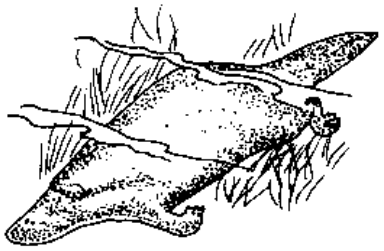


Fig. 10.6: Drifting of Gondwanaland and Laurasia led to the present day seven continents.

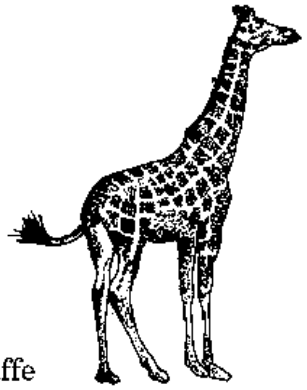
These two broke up into the seven continents we know today. Today, these continents are still slowly drifting further apart. Such movement is evidenced by the movement of the Indian Ocean floor that caused the giant tsunami tidal waves. This killed so many people on the surrounding coasts in December 2004. **Continental drift** is the slow movement of continents away from each other into new positions or into each other.

In this process, new physical barriers like large water bodies such as gulfs, seas and oceans are formed. The barriers, as a result, prevent free migration freely as before. The populations are said to have undergone **geographic isolation**. The separated population groups cannot interbreed. Over a long period of time, each group undergoes separate changes. These changes make it better for them to survive in a particular environment. If this occurs over a period of thousands of years, the original species may evolve into different species each living in a new environment. This process is known as **adaptive radiation.** Fig 10.7 shows examples of animals that have arisen due to this process.

Spiny ant eater



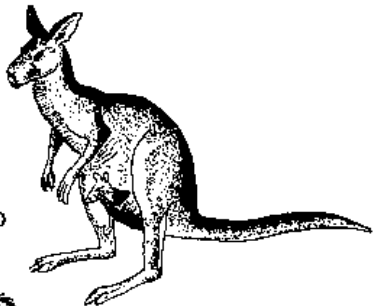
Duck billed platypus



Giraffe

Bat

Whale



Kangaroo

Koala

Fig. 10.7: Examples of animals that have arisen through adaptive radiation in different geographical regions.

This explains the geographical distribution of organisms as they now are on different continents. For example, monotremes (mammals that lay eggs) are found only in Australia and New Guinea. Examples are the duck-billed platypus and spiny ant eaters. They are thought to have evolved from reptilian stock. They have retained the reptilian characteristic of laying eggs.

3. Comparative embryology

During the study of reproduction in Form Three, we learnt that when eggs or ova are fertilised, they develop into embryos. Comparative embryology is therefore the comparative study of embryos of different animals.

When the development patterns in embryos of vertebrates are compared, many similarities are noted in the early stages of embryonic development.

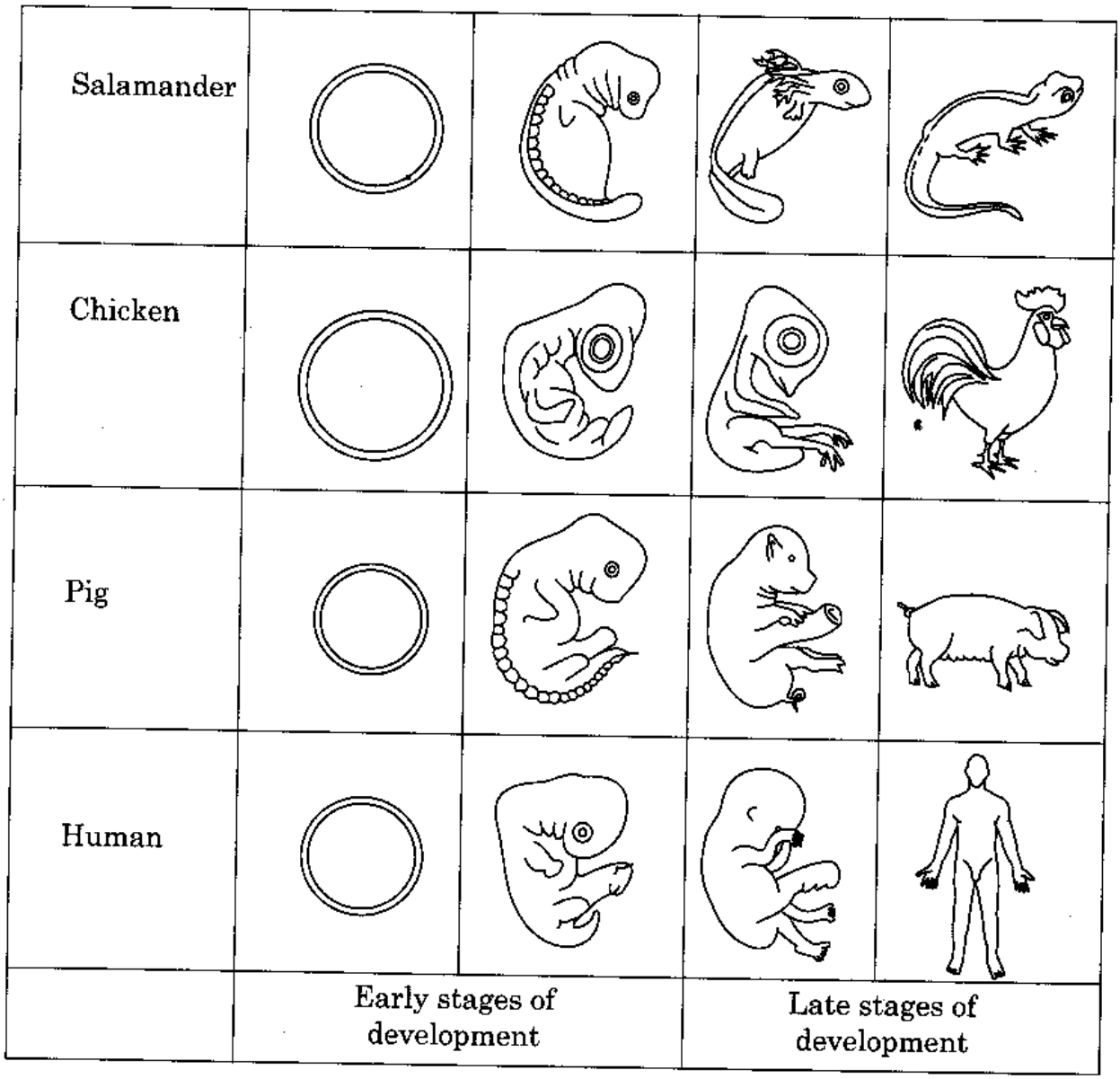


Fig 10.8: Embryonic comparison in four animals; similarities indicate a common evolutionary origin.

These suggest a common ancestor for these vertebrates. In other words, embryos of closely related species show similar patterns of development. These similarities support the idea that these organisms have a common evolutionary origin. As development continues, the embryos of each species begin to resemble the adults of their own species.

Thus, embryo development can be used as evidence for evolution. Fig. 10.8 shows stages of embryo development in some selected vertebrates.

4. Comparative anatomy

Anatomy is the study of the structure of living organisms. **Comparative anatomy** is the study of the structural similarities and differences between organisms. Certain structures when compared, suggest evolution from the same ancestor. Such evolution can be described as **divergent evolution**. Some other structures when compared, suggest evolution from different ancestors . Such evolution is referred to as **convergent evolution**. We will now discuss these two forms of evolution.

Divergent evolution

If you were to study and compare the anatomy of adult vertebrates, you would observe that the forelimbs contain the same number and types of bones. These bones are arranged in a similar way or pattern. The external and general appearance of these structures is however very different.

Let us now carry out the following activity to compare vertebrate limbs.

Activity 10.2: Comparing vertebrate limbs

Requirements/materials

- *Specimen:* Wings with feathers of a chicken or a suitable bird, leg of a goat, cow or sheep, pictures of an arm of a human, foot of a cat or dog, leg of a frog, leg of a rabbit, scalpel, mounting needles,

Procedure

1. Study the external appearance of each vertebrate limb. Draw the external appearance of each limb.
2. Compare the limbs and note any external similarities or differences.
3. Cut open each limb and expose the arrangement of the bones.
4. Draw the limbs and show how the bones are arranged.
5. Compare the arrangement of bones in different limbs and note any differences and similarities.

Questions

1. Are the external appearances of the limbs different or similar?
2. From the external appearance of the limbs, suggest what use it is put to. Suggest how each limb is suited to this use.
3. What are the similarities and differences in the arrangement of bones in these limbs?
4. Do you think the animals from which these limbs were obtained could be related in any way? Explain your answer.

Discussion

The external appearance of the limbs in vertebrates is quite different. Some vertebrates like the birds have forelimbs that have feathers and have a flat shape. The goats, sheep or cows have hooves. The cat has paws with claws while human beings have fingers. The birds use the wings to fly, humans use fingers to grip. Goats, sheep and cows have limbs which are good for walking due to the strong hoofs on them.

The bones in these limbs have the same pattern of arrangement, one long bone is next to the end of two long bones and several small bones arranged close to each other, at the end of the two long bones. The organisms could be related because they have similarities. This indicate a common group of organisms from which they could have evolved from.

Let us now study the following illustration that shows the arrangement of bones in forelimbs of selected vertebrates.

Note that all these limbs have a common plan. This plan in vertebrate limbs is called the **pentadactyl limb plan.** (*Penta* means five and *dactyl* means digit.) The word Pentadactyl therefore means five digits. The ancestors of all these animals had a limb whose basic plan was similar to the one shown below.

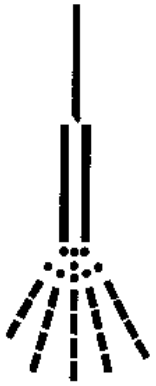


Fig. 10.10: Pentadactyl limb plan.

As a result of evolution, changes occurred in the structure of the limbs enabling each limb to be put to different use.

For instance, the bird and bat use their

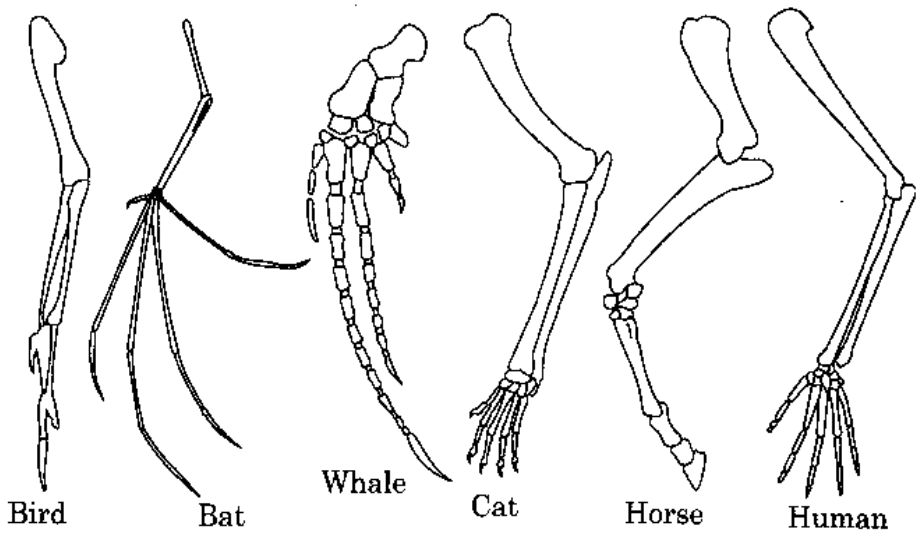


Fig. 10.9: Forelimbs of different vertebrates adapted to different functions.

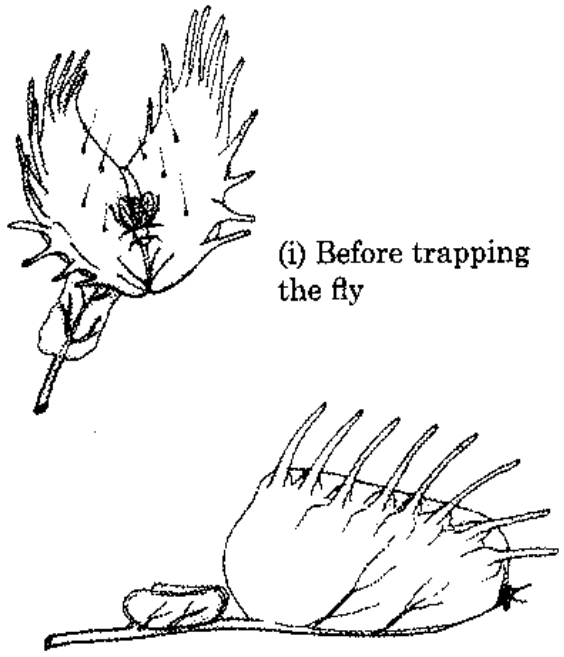
forelimbs for flight, the whale uses its flipper for swimming, the cat for walking, the horse for galloping over long distances and that of the human for grasping.

Body parts that have similar structures but different functions are termed **homologous structures.** The presence of homologous structures suggests that the organisms are related to each other. If all vertebrates descended from a common ancestor, then the limbs are adapted to different functions because each evolved separately. This type of evolution is called **divergent evolution**. This is observed between closely related groups of organisms which have diverged from each other during evolution.

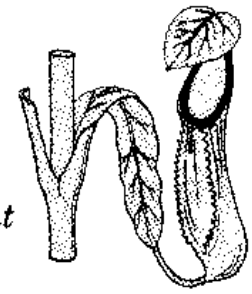
Divergent evolution results in organisms which have adaptations that enable them to exploit different ecological niches in a process called **adaptive radiation.**

Fig 10.11 illustrates homologous structures in plants. Note that each illustration is that of a leaf.

They are leaves of venus fly trap (a) and pitcher plant (b). The leaves have been modified in shape in order to trap insects which the plants use as a source food. Other types of plants also have their leaves modified to serve different functions. Other examples of modified leaves are those of *Poinsettia* which has bright red leaves that look like flower petals and the cactus leaves which are modified into small spines to reduce water loss. The leaves demonstrate adaptive radiation.



(a) Venus fly trap



(b) Pitcher plant

Fig. 10.11: Adaptive radiation in plants.

Convergent evolution

If you were to observe and compare the anatomy of some organisms, you may observe that some structures have the same function but appear different. Let us now carry out the following activity to compare such structures.

Activity 10.3: To compare wings of birds and insects

Requirements/materials

- Winged insects such as butterflies, moths and houseflies.
- Wings of birds such as chicken (wings must have feathers on them).
- Hand lens.

Procedure

1. Examine the wings of the insects using a hand lens and write down observable features.
2. Draw and label a single wing from an insect.
3. Examine the external features of the wing of the chicken. Write down all the observable features noted.
4. Draw and label a single wing from a bird.
5. Cut up and expose the internal structure of the wing of the bird. Note how exceptionally different the structure is from that of an insect.
6. Describe what you see. Draw and label the internal structures of the wing from the bird.

Questions

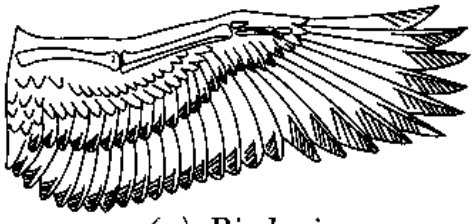
1. What are the observable features of insect wings?
2. What are the external and internal features of the bird wings?
3. What do the wings of insects and birds:
   (a) Have in common?
   (b) Not have in common?
4. Do you think that the animals from which these specimens were obtained could be related? Explain your answer.

Discussion

Wings of insects are made up of stiff membranes, with veins running through them. The veins are hard and made of materials called **chitin.** The wings of the bird have an internal arrangement of bones and muscles. It is covered by skin and feathers. They both have a wide surface which is flat. The species from which these specimens were collected are probably unrelated because their wing structure is different.

When you examine the internal structures of the birds and insect wings, you note very few similarities. For example, both wings are broad and flattened because they are both adapted to fly. However, their internal structures are completely different.

Study the illustrations below and note the similarities and differences between the two wings.



(a) Bird wing

(b) Insect wing

Fig 10.12: Wings of a bird and an insect.

Body parts of organisms that have similar functions but different structures are called ***analogous structures***. They are considered evidence for a different kind of evolution. They show that during evolution, dissimilar structures can become modified to suit a particular function. This kind of evolutionary change is called **Convergent evolution.**

In convergent evolution, different groups of organisms develop the same adaptations because they exist in the same type of environment. Analogous structures do not indicate close relationships. They suggest that organisms with such structures have evolved from different ancestors.

It is known that weight lifting exercises in men cause muscles to grow bigger. But does this mean that the children of such men are also born with big bulging muscles? Explain.

5. Cell biology

Cell biology is the study of the cell. Studies on different types of cells from different organisms may reveal some similarities and differences between them. This knowledge can then be used to provide evidence on evolution.

In this topic, we will study cell organelles and blood pigments and use the information obtained to provide evidence for evolution.

(a) Cell organelles

The study of cell organelles reveals similarities and differences between cells. For example, cells without true nucleus and nuclear membrane, are **prokaryotic cells** and those with the nucleus and nuclear membrane are **eukaryotic cells.**

This grouping already suggests that *organisms with prokaryotic cells* such as the bacteria and blue green algae are more closely related. In the same way, *organisms with eukaryotic cells* are also closely related. Therefore, bacteria and blue green algae though different, show similarity because they evolved from a common ancestry.

Organisms that share similar cell organelles like mitochondria, ribosomes and Golgi bodies for example eukaryotes have a common evolutionary origin.

Cell organelles and structures like chloroplasts and cellulose cell walls indicate a common evolutionary origin only shared by plants and not by animals.

(b) Blood pigments

In transport in animals, we learnt about haemoglobin as a blood pigment. This is not the only blood pigment that exists in kingdom Animalia, there are four other blood pigments. These are:

- haemoglobin
- haemocyanin
- haemoerythrin
- chlorocruorin

When the blood of different animals are analysed, it is realised that the blood pigments are distributed among specific groups of organisms in the animal kingdom. This indicates that the groups that share similar blood pigments are the most closely related. Such groups, it is believed, also share the same

evolutionary ancestry. Most likely they are related because they evolved from the same group of organisms.

Haemoglobin for example, is found in all vertebrates which suggests that they share the same evolutionary origin.

Many invertebrates also have haemoglobin as their blood pigment which makes them more closely related in evolutionary history. These invertebrates may also share some evolutionary relationships with vertebrates.

Only closely related groups of organisms in the animal kingdom share the same blood pigment due to the evolutionary line. This is how blood pigments can be used to show evidence of evolution.

Natural selection in action

1. The peppered moth (Industrial melanism)

We have learnt that evolution can occur by natural selection. We have also learnt that natural selection may take thousands of years to produce a change in a population. In this sub-topic, we will study an example of natural selection in action. Natural selection in action is exhibited by the peppered moth, ***Biston betularia.*** This is a moth commonly found in England. There are two types of such moths which vary in body colour. These variations in colour are; light body colour and dark body colour. The variations are genetically determined. The dark body colour in the moth is due to a pigment called **melanin** whose occurrence is caused by a mutation. The moth with this body colour is called the ***melanic form.*** This type was very rare in England before industrialisation. After industrialisation, it was observed that the number of the melanic forms increased around the areas with the development of industries. Table 10.2 shows various stages of moth during industrial melanism.

Scientists use the theory of natural selection to explain this observation.

The explanation is as follows: In a natural setting, the tree trunks are covered by light coloured lichen which grows on them. Light coloured moths are camouflaged against light coloured lichens. As a result, they are not readily seen and eaten by predatory birds.

The light colour of the moth is a beneficial variation to the moth. However, the dark coloured moths do not blend or camouflage against the light coloured lichen. As a result, dark coloured moth were readily seen and eaten by predatory birds. The dark colour of the moths is a disadvantage to their survival.

As a result of this selection, the light coloured moths are many and the dark coloured moths are few. This is because the light coloured moths survive and reproduce more. Light coloured moths and are therefore, better adapted to this environment compared to melanic forms.

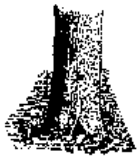
Natural setting	Polluted setting (industrialised)
 *Light coloured moth*	 *Melanic form*
 *Tree trunks with light coloured lichen.*	 *Tree trunks blackened with soot and smoke.*
 *Light colour of trunk camouflages the light coloured moth. Melanic form is exposed to predation.*	 *Dark colour camouflages the melanic form but exposes the light coloured moth.*

Table 10.1: Stages of moth during industrial melanism.

As a result of industrialisation, a lot of soot and smoke is released into the natural environment. This kills the light coloured lichen growing on the trunks and blackens the trunks.

In this new environment, the dark form of moth is better adapted.

Its colour is an advantage because it blends well against the black background. Predatory birds do not see it readily and it is not quickly eaten. The light coloured moth is disadvantaged by its colour because it does not blend well against the blackened tree trunks. It is readily seen and eaten by predatory birds. Due to this form of selection caused by the change in the environment, more dark coloured moths survive and reproduce themselves than light coloured moths. This is what is known as **industrial melanism**.

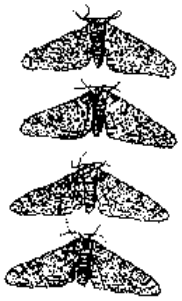
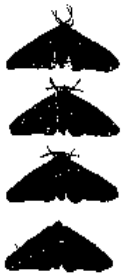
 *Fewer light coloured moths preyed on. They survive and increase in number by reproduction.*	 *Fewer melanic form moths preyed on. They survive and increase in number by reproduction.*
 *More melanic form moths preyed on. They decrease in population despite reproduction.*	 *More light coloured moths preyed on. They decrease in number despite reproduction.*

Table 10.2: Industrial melanism in peppered moth.

2. Resistance to drugs, pesticides and antibiotics

Drug resistance refers to the ability of a pathogen to survive in the body of an organism even when drugs intended to kill it are introduced into the body. The pathogen withstands the presence of the drug.

When we fall sick, we see a doctor. The doctor may prescribe medicine for us.

This medicine probably made you feel better. What do you think was the problem with the first medicine prescribed? The medicine that you took is an example of a **drug**. In this section, we try to understand why chemicals such as drugs, pesticides and antibiotics sometimes fail to work as intended.

Medicines are drugs that are used to cure diseases. They work by killing the organisms that cause the disease. For example, in the treatment of malaria, drugs such as chloroquine and Fansidar are used. The drugs work by killing the *plasmodium* found in the blood. The *plasmodium* causes malaria.

Antibiotics are drugs that specifically kill bacteria. Bacteria cause diseases like Pneumonia, Tuberculosis (TB) among others. An example of an antibiotic is *Penicillin.*

Pesticides are chemicals that are used to kill pests. Examples of pests are insects like mosquitoes that transmit malaria, locusts and armyworms which destroy food crops causing food shortages.

Sometimes, the organisms that are meant to be killed by the drugs, pesticides and antibiotics do not die. This is because the organisms are resistant to these substances. As a result, the drugs, pesticides and antibiotics are rendered useless.

Research scientists become interested in finding out the cause of the resistance and they try to formulate new drugs, antibiotics and pesticides to combat the resistant organisms. The reason for the resistance above may be due to development of new varieties of the organisms that cannot be killed by the available pesticides, drugs and antibiotics.

The reason for this resistance is because new forms of organisms evolve from pre-existing ones by either mutation or natural selection. Mutation in bacterial cells can cause the bacteria to suddenly be able to survive the hostile antibiotic environment. Another possible reason may be that the chemicals act as selecting agents.

For example, during medical treatment by antibiotics, several strains or types of bacteria may exist in the sick person, causing the same disease.

Some strains may be resistant to the antibiotic and are not killed by it. Other strains may be non resistant to the antibiotic and die.

Since bacteria reproduce rapidly, the resistant bacteria that survive in the presence of antibiotic increase in number. The antibiotic is ineffective (not effective) on them.

The person under treatment does not get better and may even get worse. This process is like natural selection whereby the antibiotic is the selecting agent.

Due to this possibility occurring, doctors stress on minimal use of antibiotics especially in ailments that the immune system can naturally handle for example, common cold. If the situation demands the use of an antibiotic, the doctor may prescribe a "broad spectrum" antibiotics. This refers to an antibiotic that can kill a variety of different strains of bacteria, the resistant ones as well as the non resistant ones.

It is now recognised that the indiscriminate use or misuse of some drugs, antibiotics and pesticides has caused some organisms like *Plasmodium*, some bacteria and insects to become resistant to these drugs.

You may have noticed that some insecticides that previously killed cockroaches in the house are no longer effective.

Under all circumstances, resist the habit of buying medicines without a doctor's prescription.

Also, complete the full dose as indicated on the prescription even if you start to feel better. This ensures that all the organisms are adequately killed by the medicine leaving no resistant strains.

Today, resistance of plasmodium to drugs like chloroquine and Fansidar, is evident. This is caused by such misuses of drugs as mentioned above. This makes the fight against malaria more difficult.

3. Sickle cell anaemia

We mentioned earlier that sickle cell anaemia is a genetic disorder which brings about production of defective red blood cells. We found out that there are three types of individuals in relation to sickle cell anaemia. There are the normal individuals whose red blood cells are all normal. Sickle cell anaemic individuals whose red blood cells are all sickle shaped and sickle cell trait individuals whose red blood cells are

a mixture of normal cells and sickle shaped cells.

The development of sickle cell individuals is influence by natural selection.

Individuals who have sickle cell anaemia are said to be carrying a less favourable variation. The sickle cells interfere with blood circulation. Without proper blood circulation and with low oxygen supply, the individual grow slowly and often die before reaching maturity. Nature therefore eliminates the individuals ensuring that they do no pass the defective genes to any generation.

On the other hand, individuals with sickle cell traits are known to survive better than normal individuals in malaria prone areas.

This is because the malaria parasite attacks and reproduces inside normal red blood cells only.

The red blood cells in this case become a less favourable variation. They encourage rapid multiplication of malaria parasite resulting to rapid progression of the disease. If treatment is delayed these individuals die faster.

In individuals with sickle cell trait, half of their red blood cells are sickle shaped. These cells cannot be attacked by the malaria parasite.

The trait in this case becomes favourable feature. The parasite attacks the normal red blood cells because the cells are fewer; the rate of multiplication of the parasites is also lower. Malaria symptoms progresses slowly in such individuals and because the sickle cells are still transporting some oxygen to the cells, the individual is able to seek treatment on time.

Individuals with the trait therefore have lower chances of death due to malaria.

In this case, nature selects individuals with sickle cell trait because of their favourable traits.

Speciation

This is a process whereby gradual changes brought about by natural selection results to production of new species of organisms different from the original parent species.

Natural selection causes evolution because with time and over many generations, favourable adaptations accumulate in a given group of organisms while the unfavourable variations slowly disappear. This leads to distinct differences between a particular species and its ancestors.

The species cannot fit into the features of its ancestors and hence it develops into a new species.

At the same time, speciation can occur when a group of animals become separated by geographical barriers.

Organisms of some species that used to live in one habitat ends up being taken to different habitats. The organism does not meet and over a long time each group adapts differently to suit a particular habitat.

Differences in climatic and environmental conditions makes the organisms to adapt differently and acquire different reproductive behaviours.

Over time the two groups cannot interbreed even if they were brought together. They have evolved into two distinct species.

Revision Exercise 10

1. What is evolution?
2. What is the meaning of the word evidence?
3. List five evidences of organic evolution.
4. (a) What is a fossil?
   (b) Give an example of a fossil.
5. What is a fossil record?
6. Explain the meaning of geographical distribution of organisms.
7. What is adaptive radiation?
8. What is embryology?
9. How is comparative embryology evidence for evolution?
10. Give examples of natural selection in action.