Biology and Health Sciences

For Rwandan Schools

Senior 3

Student's Book

Contents

Unit 1

Interdependence among organisms in an ecosystem

Key unit competence

After studying this unit, I should be able to classify examples of species interactions.

Learning objectives

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

- Define and differentiate between intraspecific and interspecific relationships in ecosystems using relevant examples.
- Discuss positive and negative effects of competition among individuals of the same species and between those from different species.
- Identify features that allow a predator to kill and feed on its prey.
- Interpret graphs and data for predator-prey relationships in an environment.
- Appreciate the interdependence of living organisms in an environment.
- Illustrate commensalism and amensalism.

Introductory Activity

Look at the pictures below. Can you identify the types of relationships exhibited?

A

B

C

Fig 1.1: Interactions in the environment

What do the activities in the pictures tell you about how organisms relate? Predict what you will learn in this unit based on the activities in the pictures.

1.1. Meaning of intraspecific and interspecific interactions in organisms

We already know that the universe is inhabited by millions of species of organisms. However, none of these organisms is self-reliant. They all depend on each other. For example, they depend on each other for **food**, **shelter** or even **mates**. This is called **interdependence**. Sometimes the interdependence does not seem obvious with some organisms. It may be direct or indirect depending on the relationship between the organisms in question. Also, some relationships have mutual benefits while others do not.

Activity 1.1: Investigating interactions between living organisms

1. Take a walk and observe an anthill.
    - Observe what happens when termites are building the anthill.
    - Note down the various activities carefully.
2. Come up with a list of roles of different types of termites during the construction work. Fill the following table.

Table 1.1: Interactions in the environment

	Type of termite	Role played
1		
2		
3		
4		
5		
6		

3. Watch the video on worker bees. Note the roles of the various bees in the video. Write them down in a table like the one above.
4. Now, look at the photograph of a pride of lions scrambling for meat of a zebra. Watch a video on the same.
5. Compare what you have seen happening in procedures 1, 2 and 3. What can you conclude about animal interaction in the scenarios given?

The facts

We have already seen that organisms depend on one another in an ecosystem. There are two types of dependencies:

- One in which organisms belonging to the same species depend on each other. This is known as **intraspecific interaction**.
- The other in which dependence is between organisms of different species. This is known as **interspecific interaction**.

1.2. Intraspecific relationships

This type of relationship involves interaction between organisms of the same species. In lions, for example, the females are the hunters while the males are required for protecting the family. In bee colonies, we have the worker bees and those in charge of protecting the queen bee, they are known as soldier bees. Can you think of similar relationships in other organisms?

Activity 1.2

1. Watch a video on relationships of organisms with one another:
2. From the video, come up with the definition of intraspecific interactions and give the examples of intraspecific interactions. Come up with a table like the one below.

Table 1.2: Interspecific interaction

	Intraspecific interaction
Definition	
Examples	

The facts

Intraspecific relationships are of two types: **competition** and **cooperation** interactions.

(a) Competition

Competition is a relationship that occurs between two organisms either of the **same** species or **different** species that require or use the same resources. They depend on the same resources found in the ecosystem, for example, food, space, water and shelter. When this happens between organisms in the same species, it is intraspecific competition. If it happens between organisms of different species, it is interspecific competition. Wildebeests and zebras in the savannah both eat grass. This is an example of interspecific competition.

Competition is only found in organisms in the same ecological **niche** or closer niches. For instance, there may not be any competition between an elephant and a rabbit. Though they are found in the same habitat, they do not depend on the same food. Also, there will be no competition between spiders and lions, though both are carnivores. However, grazers eat the same food i.e. grass. They therefore compete for food. This has brought conflict between livestock and wildlife near human settlements. In some areas, livestock must compete for the limited grass with wild grazers such as zebras and gazelles.

The more similar two kinds of organisms are, the more intense the competition between them. If one of the two competing organisms is better adapted to live in the area than the other, the less fit organism must migrate, die or shift to a slightly different niche in order for it to survive.

- Competition for the same resource by two organisms of the same species is referred to as **intraspecific competition**. Normally, male animals of the same species compete for the female animals.

Fig 1.2: Intraspecific competition

- Competition for same resource by organisms from different species is called **interspecific competition**. Cheetah and lion compete for flesh.

Competition is an instinct in all organisms for their survival. Organisms tend to compete for resources when the supply is not enough.

Fig 1.3: Interspecific competition

(b) Cooperation

This is a kind of interaction in which organisms of the same species live together and share work between themselves. Every member of the species has a diverse role and they closely work together for their own group benefit. This kind of relationship can be observed in social insects such as ants, termites, bees among other groups of organisms.

(a) Bees in a hive

(b) Termites

Fig 1.4: Examples of social insects

Self –evaluation Test 1.1

1. What is intraspecific competition?
2. Why is competition among organisms of the same species healthy?
3. Give the importance of cooperation among organisms living together in a community.

1.3. Interspecific relationships

This type of relationship involves the interaction between organisms belonging to different species.

Activity 1.3: Investigating interspecific relationships

1. Observe the pictures of these animals:

Ticks

Mites

Lice

Fleas

Tsetse Flies

2. Where do you think these animals are usually found? How do they get their food?
3. Bees, butterflies and birds are often seen visiting flowers. What do you think they do on the flowers? Is this important or not?
4. What do the above observations tell you about interspecific relationships between organisms?

The facts

There are many types of interactions between different species of organisms. Examples include: parasitism, predation grazing, competition, mutualism neutralism, commensalism, amensalism and allelopathy.

Have you ever heard of these terms? In the next section, you will study about these types of interactions in detail.

(a) Parasitism

This is a non-mutual relationship between different species of organisms. In this type of relationship, one species benefits while the other suffers. The organism that benefits is the **parasite.** It obtains nutrients from another organism called the **host.** Can you give examples of parasites and their hosts in real life?

Adaptations of the parasites include:

(a) Being smaller than their hosts.
(b) Reproducing relatively faster.
(c) Having penetrating and attachment organs.
(d) Surviving in areas with low oxygen concentration.

These adaptations enable them to survive in or on the host. They usually have no intention of killing their hosts. However, they end up harming or even killing the host.

Further, parasites can either live inside or outside the host. When the parasite lives inside the body of the host, it is called an **endoparasite**. Examples of endoparasites are tapeworms, trypanosomes, liver flukes and roundworms.

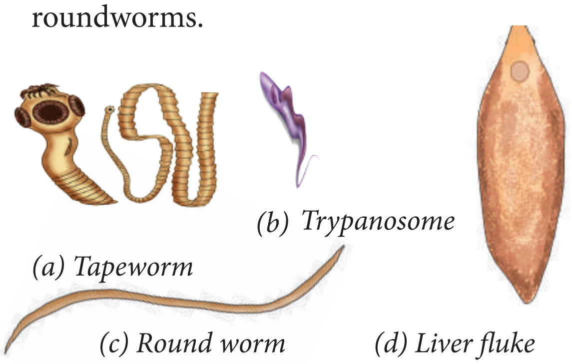
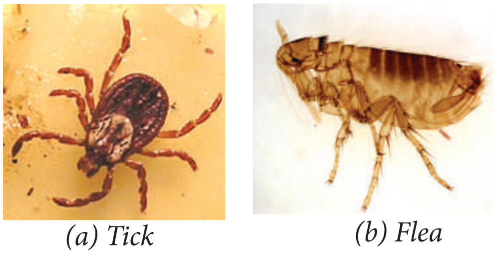


Fig 1.5: Examples of endoparasites

When the parasite lives outside the body of the host, it is called an **ectoparasite**. Examples of ectoparasites are ticks and fleas.



(a) Tick *(b) Flea*

Fig 1.6: Examples of ectoparasites

Effects of parasites

Many diseases which affect humans, domestic animals and crops are caused by parasites. Also, all fungi which are not saprophytic are parasitic. Diseases such as potato blight in plants and ringworms in human beings are caused by fungi which are parasitic. We have already seen that parasites can either kill or interfere with the health of their hosts. Parasites that do not kill their hosts may also reduce their rate of growth.

A reduced growth rate will result in a slow increase in the population of the host.

Did you know?

Mosquitoes are temporary parasites.

(b) Predation

Predation is the hunting, killing and eating of one organism by another for food. A **predator** is an organism that kills and eats the other. A **prey** is an organism that is killed and eaten by the predator.

Fig 1.7: Predator and prey interaction

Can you give examples of other animals that are predators or preys?

Predators have many feeding adaptations. For example:

(a) They have acute senses that locate and identify a prey. Many have structures such as claws, teeth, fangs and stings that they use to catch and subdue or poison the prey. Examples are rattlesnakes, which locate their prey with special heat-sensitive organs located near their eyes, they kill small birds and mammals by injecting them with toxins through their fangs.

(b) Predators that pursue their prey are fast and agile. Those that lie in ambush, for example lions, are often camouflaged in their environment. Preys that do not move usually protect themselves chemically (by possessing toxic chemicals) or physically (by having hard shells, spines or thorns).

(c) Mobile prey depend mainly on their ability to escape from their predators. Preys also camouflage from predators. This makes it difficult for predators to locate them, for example chameleons.

(d) Some predators such as frogs and chameleons have long tongues to help them catch insects.

(e) Predators such as eagles have sharp eyes facing forward thereby giving them greater sense of sight which aids in locating their prey.

Some examples of predator-prey relationships are:

- A spider preying on an insect.
- A lion preying on a gazelle.
- A lizard preying on an insect.

Effects 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 left with less and less food to eat and their population size decreases due to starvation. This gives the prey time to increase in population. In a stable predator-prey relationship, the populations of the predator and the prey are regulated by each other.

This is well illustrated in fig 1.8 showing the relationship between the impala which is the prey and the lion which is the predator. Analysis of the graph shows that when impala increase in number, food become abundant to lions and they start to increase in numbers. When the number of impala start to decline, competition for food among lions increases something which makes lions to starve and die. The cycle of interdependence starts again.

Therefore, predation brings about population balance in an ecosystem. In order to avoid predation, preys exhibit different kinds of behavioural adaptations. Examples include avoiding predators, fleeing from enemies or defending themselves.

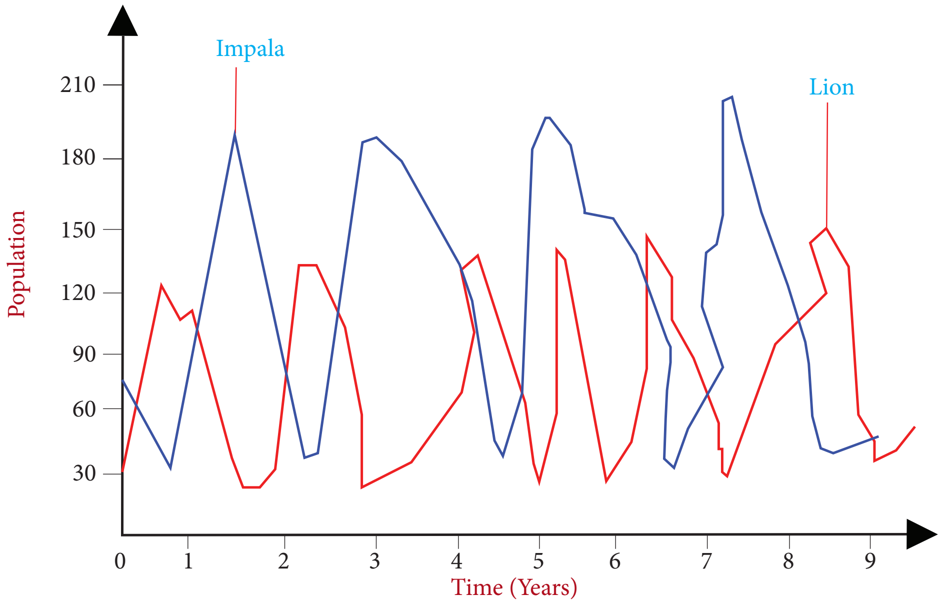


Fig 1.8: Predator – prey relationship between a lion and an impala

Activity 1.4: Interpreting data on predator – prey relationships

The following table shows hypothetical data on the populations of lions, zebras, antelopes and leopards in three national parks in Rwanda, namely Akagera, Nyungwe and Virunga.

Table 1.3: Population of wild animals in national parks

National Park	Population			
	Lions	Zebras	Leopards	Antelopes
Akagera	21	82	32	118
Nyungwe	9	11	7	40
Virunga	13	144	24	18

1. Identify predators and preys from the table.
2. Come up with bar graphs on the population distribution of the animals in the three national parks.
3. Assuming that lions eat zebras only and leopards eat antelopes only, comment about the population of the various animals in the parks.
4. If you were a conservationist, what would you do in the three parks?

(c) Grazing

This is a method of feeding in which herbivores like cows, sheep and goats feed on grasses and plants. Look at the following picture. What is going on in the picture?

Fig 1.9: Cattle grazing

Some domestic animals eat grass and plant parts. They are known as **herbivores**. Herbivores occupy the first level of feeding as **primary** consumers. They transfer energy from **producers** to the **secondary** consumers. **Grazing** is the eating of grass while **browsing** is eating parts of woody plants and leaves.

Did you know: Animals grazing is not seen as predation because plants are not killed by the grazers. It is also not parasitism because a parasite is always with the host either inside or outside. Grazers are not always with the plants they feed on.

(d) Mutualism

Mutualism refers to an interaction between organisms of two different species where both benefit. Through this relationship both species enhance their survival, growth or fitness. It is the opposite of parasitism where only one species benefits and the other is harmed. Examples of mutualism include:

- The relationship between ungulates like cows, goats, sheep and some bacteria found within their intestines. The ungulates manage to use cellulose which is broken down by cellulase enzyme produced by the bacteria. The bacteria benefits by getting nutrients and shelter whereas the ungulate is able to obtain energy from the cellulose broken down.
- The relationship between a buffalo or a cow with the white egret which eats ticks from the buffalo or cow. The buffalo or cow benefits when ticks (parasites) are removed from its body while the birds benefit when they get food (ticks).
- The relationship between bees and flowering plants. The bees get nectar as food while the flowers are pollinated by the bee.

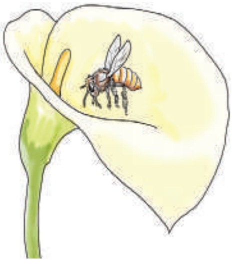


Fig 1.10: (a) A bee in a flower

Fig 1.10: (b) A zebra grazing with a bird picking parasites on it

(e) Neutralism

Neutralism is a term that describes the relationship between two species that interact but do not affect each other. It describes interactions where the health of one species has absolutely no effect whatsoever on that of the other. However, it is not easy to prove that the health of both species is not affected. This term is usually applied to relationships which are insignificant. An example is in a grassland ecosystem where hares, deers, frogs, live together without affecting one another.

(f) Commensalism

Commensalism is a relationship between two organisms where only one benefits while the other is not affected. In other words, one organism benefits while the other neither benefits nor gets harmed. Examples include:

- A fish known as **Remora** follows a shark wherever it goes so that when a shark kills a prey and eats it, there are some leftovers which are eaten by a Remora fish. Since only leftovers are eaten, the shark is not deprived of its food, neither does it get harmed in any way.

Fig 1.11: Remora fish and shark

- Mites will attach to wasps, flies or beetles for transportation.

Can you think of other examples of commensalism? List them down in your notebook.

(g) Amensalism

Amensalism is any relationship between organisms of different species, whereby one organism is inhibited in terms of growth or is destroyed completely while the other organism remains unaffected. Examples include:

- Hooves of cattle trampling grass and other plants. The grass and the plants are crushed and may die while the animal remains unaffected.
- Plants with thick canopy block sunlight and prevent other plants beneath from growing.

Fig 1.12: Plant canopy in a forest

- Think of other examples of ammensalism. Write them down in your notebook and share with other members of your class.

(h) Allelopathy

Activity 1.5: Observing how some plants affect others

1. Look at the plants below. Do you know them?

(a)

(b)

(c)

2. Visit a place where the plants above are growing.
3. Observe the trend in the growth of other plants around the area. What can you conclude?

Allelopathy is a biological phenomenon where one plant chemically inhibits the growth of another. In essence, plant allelopathy is used as a means of survival in nature, reducing competition from plants nearby.

The facts

Some plants produce chemicals known as **allelochemicals.** These chemicals influence germination, growth, survival, and reproduction processes of other plants. These chemicals can work in two ways. They can affect another organism positively or negatively. This means an organism that receives the biochemical can benefit or be harmed. Those plants that produce chemicals that harm others are said to be **allelopathic**.

Trees are good examples of allelopathic plants. For instance, eucalyptus use allelopathy to protect their space by using their roots to pull more water from the soil so that other plants cannot thrive. Some like the maple plant use their allelochemicals to inhibit germination or impede development of nearby plant life. Most allelopathic trees release these chemicals through their leaves, which are toxic once absorbed by other plants. Trees that are known to exhibit allelopathy include maple, pine and eucalyptus.

Maple

Pine

Eucalyptus

Fig 1.13: Examples of allelopathic

Self-evaluation Test 1.2

1. Suggest biological methods of controlling:
   (a) Weeds in the farm.
   (b) Invasive species in a field.
2. What kind of relationship is portrayed in the following interactions?
   (a) Worms in human intestines
   (b) A cat catching a mouse
   (c) Lions fighting over buffalo carcass
   (d) Cows grazing in a field
   (e) Insect in a flower
3. The data below shows imagined numbers of how a predator and a prey affect each other's populations in an ecosystem over a period of several years.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Carrying capacity	35	35	35	35	35	25	15	15	15
Actual number of antelopes	15	15	20	35	55	100	45	15	15
Cheetah population	10	25	20	15	10	0	0	0	0

   (a) What conclusion can you make about the effect of the predator on the population of the prey?
   (b) In what way does the population of prey affect the population of the predator?
   (c) What would happen if all the predators died of a disease?
   (d) How can a farmer apply the knowledge about the relationship between predators and preys?
   (e) Draw a graph to represent the above data.

Unit summary

- Interdependence is mutual dependence between organisms.
- Interspecific relationships are the relationships that show the interactions between the organisms belonging to different species.
- Intraspecific relationships are the relationships that show the interaction between organisms that belong to the same kind of species.
- Parasitism is a relationship in which one organism benefits from the relationship while the other is harmed.

- Predation is a kind of relationship in which one form of species serves as food to the other species. This involves a predator and prey relationship where one specie is hunted by the other as food to eat.
- Competition is a relationship in which the two or more species are competing with each other to utilise the same limited resources that are necessary in order for them to survive.
- Amensalism is a kind of relationship in which the population of one species is inhibited while the population of another species is not affected.
- Neutralism is a kind of relationship in which population of does not affect the other.
- Commensalism is a relationship between species in which one of the organisms benefits from the relationship while the organism is neither benefited nor harmed.
- Allelopathy refers to the chemical inhibition of one species by another.
- Grazing is a method of feeding in which a herbivore feeds on plants such as grasses.

End Unit Assessment 1

1. Symbiosis is a mutually beneficial relationship between different organisms. Which among the following interactions is it closely related to?
   A. Neutralism
   B. Mutualism
   C. Commensalism
   D. Grazing
2. What is interdependence?
3. Indicate whether the relationships below are commensalism or amensalism.
   (a) Barnacles attached to the sides of a whale.
   ____
   (b) Cattle egrets: birds that follow grazing cattle.
   ____
   (c) A flatworm attached to a horseshoe crab
   ____
   (d) A donkey grazing in a field.
   ____
4. Differentiate between intraspecific and interspecific relationships using examples.
5. Explain why a predator is a factor in determining the population of the species it eats, but a scavenger is not.
6. Look at the photograph of a lion below. Identify features that makes the lion a good predator.

7. What are the economic benefits of weeds and pests?

8. What is the main disadvantage of allelopathy in plants?
9. How are predators and their preys adapted to their environments?
10. In your opinion is parasitism beneficial? Why?
11. With reference to interdependence in plants and animals, explain why environmental conservation is important to the economy of Rwanda.
12. The data in the following table shows the relationship between predator and prey in an area of savanna grassland. Use it to answer the following questions.

Time elapsed (years)	Population of the prey (thousands)	Population of predator (hundreds)
0	20	10
2	55	15
4	65	55
6	95	60
8	55	20
10	5	15
12	15	10
14	50	60
16	75	60
18	20	10
20	25	5
22	15	25
24	70	40
26	30	25
28	15	5

(a) Draw a graph to represent the data in the above table.
(b) Explain the population dynamics in the table.
(c) Suggest animals that could depict such relationship.
(d) What is the impact of predator –prey dynamics in the ecosystem?

Unit 2 Population size

Key unit competence

After studying this unit, I should be able to analyse and interpret population curves.

Learning objectives

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

- Define population.
- State the factors affecting the rate of population growth of an organism.
- Identify phases in the sigmoid population curve and give explanation for each phase.
- Describe the increase in human population size over the past 250 years and its social and environmental implications.
- Explain the need for family planning with reference to social and resource demand of the human population and harmful effects.

Introductory Activity

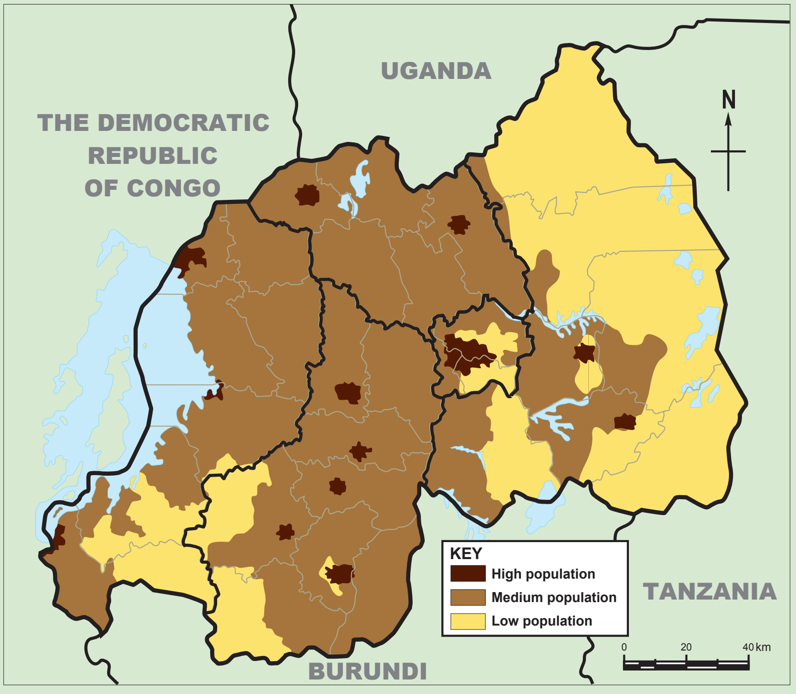


Fig 2.1: Map showing human population in Rwanda

Two hundred years ago, there were less than one billion human beings living on Earth. Today according to UN estimates, there are over 7 billion human beings on earth. According to the 2012 census the population of Rwanda is 11.92 million. This makes 0.16% of the total world population.

- How is this increase in human population important?
- How can this doubling of population affect the environment on earth?
- Would this doubling of populations be a challenge if not controlled?
- What factors might most affect the growth of future populations?

2.1. Environmental factors that limit population size

Population is the total number of all the organisms of the same species living in a specific area at a particular time. **Population size** on the other hand is the actual number of individuals in a population.

Activity 2.1: Research and discussion

Using the Internet, answer the following questions.

1. What is population growth?
2. Which factors affect the rate of population growth of an organism?
3. What is the importance of the factors described in (2) above?
4. What happens when there are no sufficient resources to support the population?

The facts

Population growth is the rate at which the number of individuals in a population increases in a given time period, expressed as a fraction of the initial population. For a population to be healthy, factors such as food, water and space, must be available. The rate of population growth can be slowed down by environmental factors such as low food supply, predation and disease. These factors can lower birth rates, increase death rates or lead to emigration.

The rate of growth of a population depends on:

- Food supply
- Predation
- Disease

a) Food supply

Abundant food will enable organisms to breed more successfully and produce more offspring. Shortage of food on the other hand can result in starvation and less energy for survival or force emigration hence reduction in population.

b) Predation

Heavy predation of a population may reduce its size. This can happen if the breeding rate is not sufficient enough to replace the organisms eaten. Predators such as lions, cheetahs and hyenas tend to migrate from one area to another as prey density increases or decreases. The predators respond to the number of prey.

There tends to be a time lag in population size change for predators and their prey: as predator number increases, prey number drops; and as predator numbers drop, prey number rises again (unless there are other limiting factors).

Fewer predators have abundant food which favours reproduction and growth of younger ones. As the number of predators increases, they feed on the prey whose number reduces. Hence little food for the predators.

(c) Disease

This is a serious problem in large populations, because diseases can spread easily from one individual to another. Epidemics can reduce population sizes very rapidly. Take an example of cholera, which is highly contagious, it spreads very quickly in refugee camps due to high density of people. Therefore, a large dense population, is usually more susceptible to the spread of parasites or contagious disease than a small, sparse population.

Did you know?

Availability of food and low predation may favour high birth rate and an increase in population density. The scarcity of preys may increase death rate of the predators thereby lowering the population density.

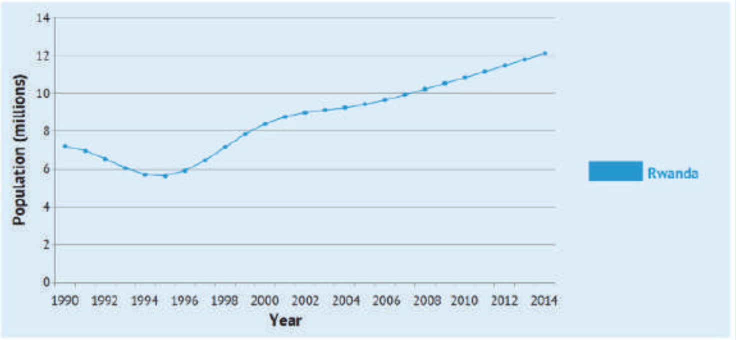
Self-evaluation Test 2.1

1. What do you understand by the word population?
2. Describe the predator-prey relationships using a graph.

2.2. Population growth curve

All populations increase over time. **Population growth** is the increase of individuals in a certain area over a unit time. The growth of population can be measured or estimated by determining population density.

Activity 2.2: Investigating population growth in Rwanda



Source: World bank, 2015

a. Discuss the shape of the population growth curve provided over the years in Rwanda.

b. Write a report about the population dynamics in Rwanda and present your findings

The facts

Population density of any species is controlled by:

- Birth rate (natality rate) - the number of live births per thousand of population per year.

Simple formula to calculate birth rate is:

$$\text{Birth rate} = \frac{\text{Number of births}}{\text{Number of adults in population}} \times 1000$$

- Death rate (mortality rate) - the ratio of deaths to the population of a particular area during a particular period of time, usually calculated as the number of deaths per one thousand people per year.

Simple formula to calculate death rate is:

$$\text{Death rate} = \frac{\text{Number of deaths}}{\text{Number of adults in population}} \times 1000$$

- Immigration - the movement of individuals into a specific area.
- Emigration - the movement of individuals out of a specific area.

Population growth is influenced by the **biotic** and **abiotic** factors. Biotic are living factors like: food, relationships (predators, competition, preys, parasites) and sex mates while the abiotic are the non-living factors such as rain, temperature and soil pH.

Under favourable environmental conditions, population of a given species will increase in number from generation to generation. Growth is said to be exponential. The J-shaped curve in figure 2.2 represents a typical form of an exponential growth curve.

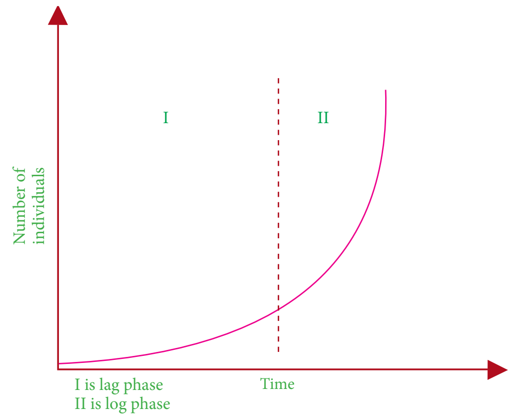


Fig 2.2: Exponential growth curve

The exponential growth cannot continue indefinitely in a resource-limited environment. This happens when the environment has reached its carrying capacity.

As population density approaches the carrying capacity, competition becomes more intense, mortality increases, the birth rate drops and any of the following can happen.

(a) The population may stabilise below the carrying capacity. This pattern is known as a **logistic** or **sigmoid** (S-shape) growth curve as shown in fig 2.3.

(b) The population may briefly go beyond the carrying capacity and then drop.

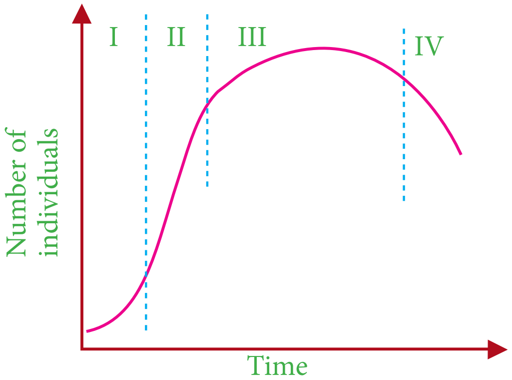


Fig 2.3: Sigmoid growth curve

Population growth in an environment with limited resources

Activity 2.3: Demonstrating population growth pattern of *Drosophila melanogaster* (fruit fly)

Instructions

(a) In this activity, you will collect actual data from a growing population of Drosophila (fruit fly) and create a population curve.

(b) To track population changes for at least three generations of flies, you will collect data once each week over a period of eight weeks.

(c) Grow a population of organisms in the laboratory and plot a population curve based on your laboratory data.

(d) Sketch your predicted population curve.

- What type of population curve do you predict you will see?

Requirements

- Culture stalk and bottle
- Fruit flies (Drosophilame lanogaster)
- Safety glasses and gloves
- Labels
- Anaesthetic

Procedure

1. Label the culture bottle.
2. Create a data table to record and track your population each week for 8 weeks.
3. With the teacher's instructions, administer anaesthesia without killing the flies or letting them escape.

   Caution: Over-exposure to anaesthesia will kill small organisms. Fruit fly exposure to anaesthesia should be relatively short and flies should not be anaesthetised for more than once a day.
4. Carefully remove (if necessary) and count the number of fruit flies. Record the population in your data table.
5. Carefully return the flies to the bottle (if necessary) and make sure the foam plug is securely in place.
6. Tracking the population of fruit flies to be done once a week for 8 weeks.
7. Repeat Steps 3–5.
8. Add additional culture medium to the bottle as necessary.

Analysis questions

(a) What is the purpose of putting the blue culture medium in the bottles?

(b) Plot a graph of time versus population size for your fruit fly population.

(c) Does the graph resemble any of the population curves discussed above? If so, which one?

(d) Interpret your graph.

- What happened to your fruit fly population over the eight-week study period?
- What do you think of the population growth pattern?

(e) What environmental limiting factor do you think is most important in setting the carrying capacity for fruit flies in this experiment? Explain your reasoning.

(f) Does the data support your prediction? Explain.

The facts

There are four stages in the life cycle of the fruit fly: egg, larva, pupa and adult. The time required to complete one life cycle is mainly dependent on the temperature of the surroundings. At a typical classroom temperature of 21°C, it takes about two weeks for a fruit fly egg to mature into an adult fly. The average life span of an adult fruit fly is 40-50 days. One day as an egg, seven days in the larval stage and six days in the pupa stage.

When a limiting factor influences population growth, a sigmoid (S-shaped) curve is obtained.

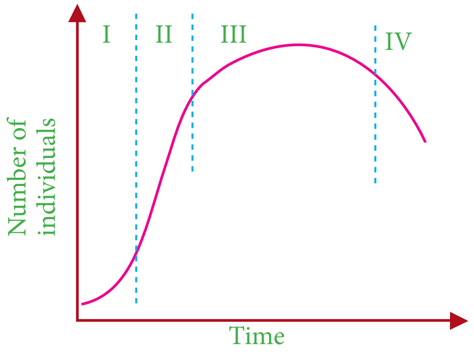


Fig 2.4: Population growth curve for fruit fly

Characteristics of each phase:

i. Lag phase (I)

In lag phase the new population takes time to settle and mature before breeding begins. When this happens, a doubling of small numbers does not have a big impact on the total population size, so the line of the graph rises only slowly with time.

The organisms in this phase do not experience any environmental resistance. There is availability of resources and free space, there is also no competition of any kind. However, increase is not sudden as in the next phase because organisms are still relatively fewer and sex mates are not so many. Therefore, birth rate is still low.

ii. Log (exponential) phase (II)

In this phase organisms increase at a maximum rate. The increase in numbers is exponential: 2 become 4, then 4 become 8, then 8 become 16 and so on. There are no limiting factors hence rapid breeding, which causes a significant increase in numbers. A steady doubling in numbers per unit of time produces a sharp increase in population thus straight line.

All major resources such as food, ability to reproduce and shelter are abundant. The weather or climatic conditions favour the growth of the young ones. Environmental resistances such as unfavourable climatic conditions, lack of space and light, predators, parasites and disease organisms are at minimal while space is large enough to avoid pollution.

iii. Stationary phase (III)

Many organisms produced in the log phase bring about competition for resources. Limiting factors, such as shortage of food, cause the rate of reproduction to slow down.

The three basic requirements are fiercely competed for: food, space (shelter) and sex mates. Young male organisms compete for females to mate with. Sometimes such competitions may result into death. Food becomes scarce to a point where the young ones do not have enough to eat. When food is in scarcity, fertility drops so that birth rate reduces while mortality rate increases steadily.

Population density no longer increases at a faster rate. There is a steady decline in the increase of organisms. Shelter is hard to get during this phase, making the organisms to be exposed to harsh conditions. Pollution becomes a big problem as organisms suffer from many diseases caused by pollution leading to death. Therefore, some organisms are forced to emigrate as environmental resistance is at its maximum.

Fact of life: When the birth rate and death rate are equal, the line of the graph becomes horizontal. Therefore, there is no increase or decrease in the number of organisms. That is why this phase is called a **stationary** phase.

iv. Death phase (IV)

As food runs out, space becomes limited and sex mates are less, more organisms die. Therefore the number of organisms in the population reduces.

Did you know?

If there are no limiting factors, there will be no stationary or death phase – the log phase will continue upwards, instead of the line levelling off.

Rising population growth can lessen the quality of life because it leads to overcrowding and competition for limited resources. Stabilisation of population will have a powerful effect on living standards and the global environment.

Self-evaluation Test 2.2

1. What is the meaning of the term growth?
   (a) Permanent increase in size of an organism.
   (b) Increase in the number of organism.
   (c) Increase in form and complexity of an organism.
   (d) Increase in amount of fat in the body.
2. Explain the factors that lead to the phases in a sigmoid curve of a population growth.
3. Draw graphs on the same plane that show population growth when resources are limited and when they are not.

2.3. Human population growth and its effects

Activity 2.4: Research Activity

1. Using textbooks, journals and the Internet research on the global trends of human population growth and compare it with that of Rwanda.
2. Determine the social and environmental implications of human population growth in Rwanda.
3. Write a report of your findings and present it in class.

The facts

The rapid growth of the world population over the past one hundred years results from a difference between the rate of birth and rate of death. The growth in human population around the world affects all people through its impact on the economy and environment. The current rate of population growth is now a significant burden to our well-being. Understanding the factors which affect population growth patterns can help us improve on our planning.

In the past, infant and child deaths and short life spans used to limit population growth. Currently, due to improved nutrition, sanitation and medical care, more babies survive their first few years of life. The combination of a continuing high birth rate and a low death rate is creating a rapid population increase in many countries.

Did you know?

Over-population is defined as the condition of having more people than can live on the Earth in comfort.

The population of the world was about one billion around 1810. This doubled to two billion people in 1930; then four billion in 1975. The number of people in the world has risen from 4.4 billion people in 1980 to 7.5 billion today. And it is estimated that the population could double again to nearly 11 billion in less than 40 years. The graph below depicts the human population growth over a period of about 200 years in different continents.

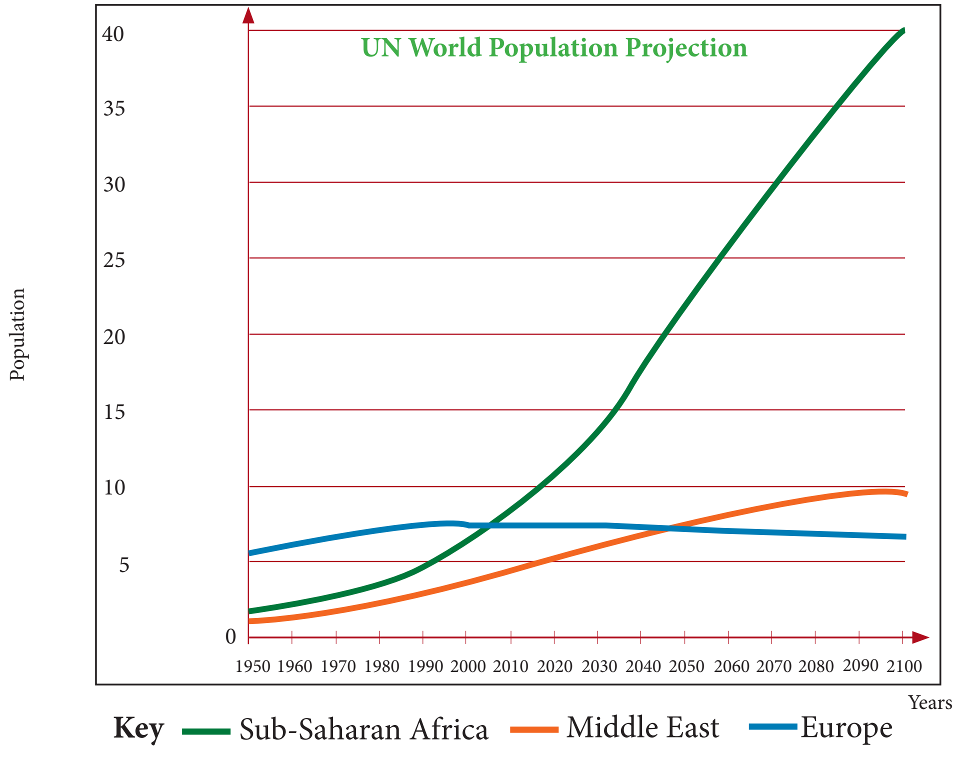


Fig 2.5: Graph of world population growth projections

The population of Rwanda represents 0.16 percent of the world's total population which arguably means that one person in every 637 people on the planet is a resident of Rwanda. The total population in Rwanda was estimated at 11.3 million people in 2016. Looking back, in the year 1960, Rwanda had a population of 2.9 million people.

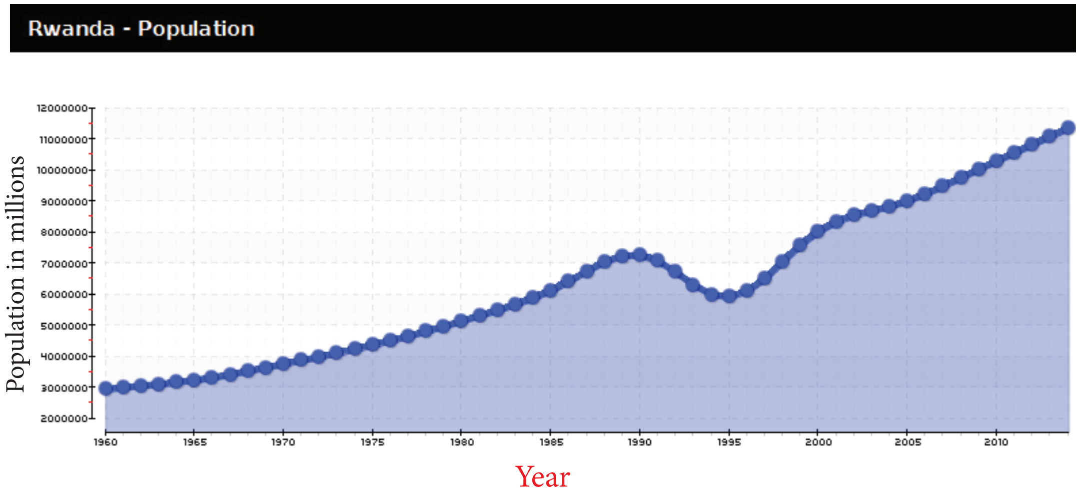


Fig 2.6: Rwanda population growth curve

Education and Money matter

The priorities for getting rid of poverty, improving food supply, ending malnutrition and providing adequate housing are required for a balanced population growth.

Causes of rapid population growth

(a) Food production and distribution

Agricultural practices have improved in many countries due to advancement in technology. This has enabled farmers to increase food production due to availability of faster maturing seeds, chemical fertilisers, pesticides and more sophisticated machinery. The use of technology has made possible the rapid expansion of agriculture in many countries.

(b) Improvement in public health

Scientists have invented ways of preventing and curing many types of diseases. Thus, millions of people who would have died of disease are more likely to live to old age. The most effective tools in the conquest of disease have been improved knowledge about nutrition, vaccinations, better public health practices and the development of new medicines.

(c) Gains in education and standards of living

Through education, many people are able to appreciate the importance of having a better standard of living that improves the quality of life.

Did you know?

Different populations grow at different rates around the world. This depends on how many children families have and life expectancy. Developing countries tend to have shorter lives and higher infant death rates as compared to developed countries.

Consequences of rapid population growth

(a) Scarcity of food

Increased population means more people to feed, leading to food scarcity. This affects a country's economy. Inadequate supply of food leads to undernourishment of the people which lowers their productivity. This further reduces the production capacity of the workers. Deficiency of food also leads to food importation, which also places unnecessarily strain on foreign exchange. This results to unbalanced trade.

(b) Poverty

Rapid growth of population is largely responsible for poverty. Many people spend a major part of their income on bringing up their children. Therefore, no improvement in agricultural and industrial technology, shortage of essential commodities, low standard of living and mass unemployment. As a result the entire economy of a country is surrounded by the vicious circle of poverty. The standard of living also reduces.

(c) Unemployment

A fast growth in population means a large number of persons coming to the labour market. The number of job seekers is expanding so fast that despite all efforts towards planned development, it has not been possible to provide employment to all.

(d) Environmental effects

Rapid population growth leads to drastic changes in the environment. It pushes people to practise farming in ecologically sensitive areas such as, riverbanks, riparian zones, natural reserves and tropical forests. Clearing of forests and encroachment of ecological sensitive areas leads to imbalance of nature, which if not corrected destroys the environment. Changes in the environment leads to climate change that affects organisms through global warming.

Besides all this, the increasing population growth leads to the migration of a large number of people to urban areas with industrialisation. This results in polluted air, water, noise and soil in big cities and towns.

Advocating for family planning programmes

The problem of uncontrolled population growth is worldwide. It's more pronounced in developing countries. The most effective method of controlling population growth is **family planning**. Family planning is the practice of controlling the number of children in a family and the intervals between their births. Family planning allows people to attain their desired number of children and determine the spacing of pregnancies. It is achieved through use of contraceptive methods and the treatment of infertility. Family planning services include educating masses so that people can understand the advantages of family planning and comprehensive medical activities which enable individuals to determine the number of their children freely especially women. The world organisation responsible for family planning is UNITED NATION FAMILY PLANNING ASSOCIATION. World contraception day takes place on September 26th of every year. The annual worldwide campaign centres around a vision where every pregnancy is wanted. It was launched in 2007.

Family planning activities have clear economic benefits and can help countries to have fewer dependents. Many social problems can be solved using family planning. The government of Rwanda took cognisant of this and came up with a national family planning policy in 2012. The aim of the policy is to tackle poverty by controlling population levels.

Self-evaluation Test 2.3

1. Suggest ways of reducing environmental effects due to overpopulation.
2. Compare the growth curves of world population (Fig 2.5) and Rwanda population. (Fig 2.6).

Unit summary

- Population is all the inhabitants of a particular place at a particular time.
- Population growth rate (PGR) is the increase of a population during a period of time.
- Population size is the actual number of individuals in a population.
- Limiting environmental factors that affect the rate of population growth of an organism include food supply, predation and disease.
- Population growth curves are used to show the type of growth pattern organism's exhibit.
- S-shaped growth curve (sigmoid growth curve) is pattern of growth in which, in a new environment, the population density of an organism increases slowly initially, in a positive acceleration phase; then increases rapidly approaching an exponential growth rate as in the J-shaped curve; but then declines in a negative acceleration phase until at zero growth rate the population stabilises.
- The human population growth rate has been declining since its peak in 1960s.
- Over population leads to climate change, pollution, competition for resources hence conflicts.

End Unit Assessment 2

1. (a) What is overpopulation?
   (b) Discuss why we are talking of overpopulation yet we still have vast open spaces on earth?
2. Suggest ways of combating inequality in distribution of resources in the world.
3. Why are developing countries experiencing rapid population growth while developed countries are growing more slowly or not at all?
4. How does the HIV and AIDS epidemic affect global population?
5. The graph below shows the population growth curve of Rwanda from 1961-2003. Study the graph and use it to answer the questions that follow.

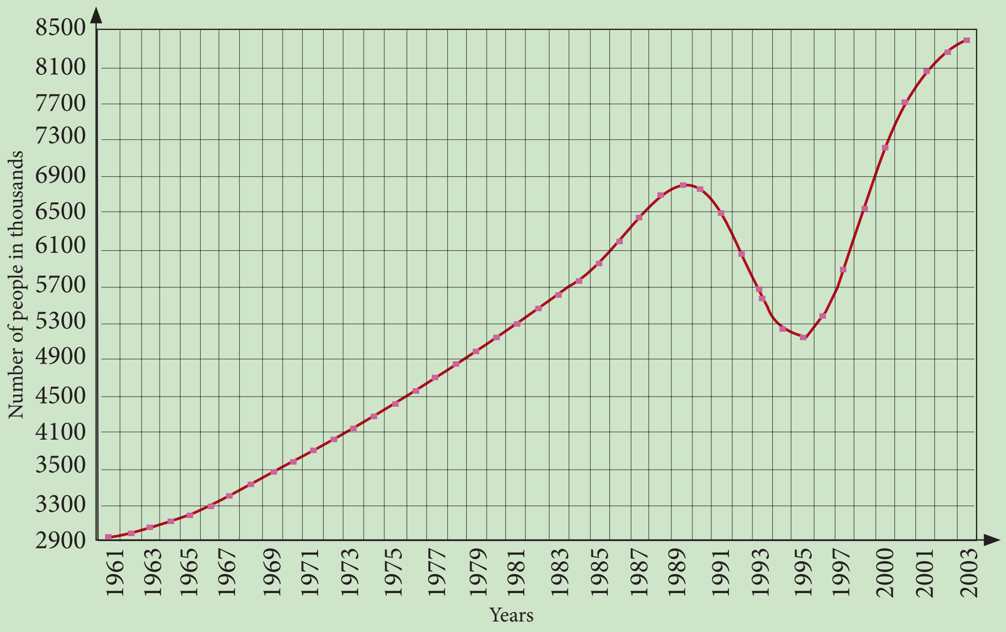
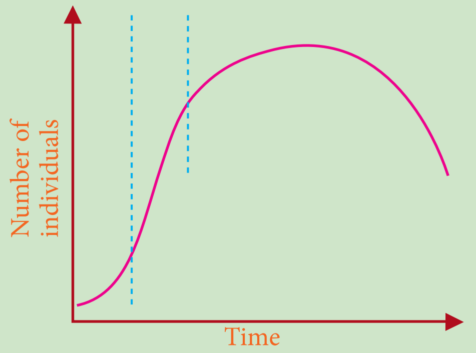


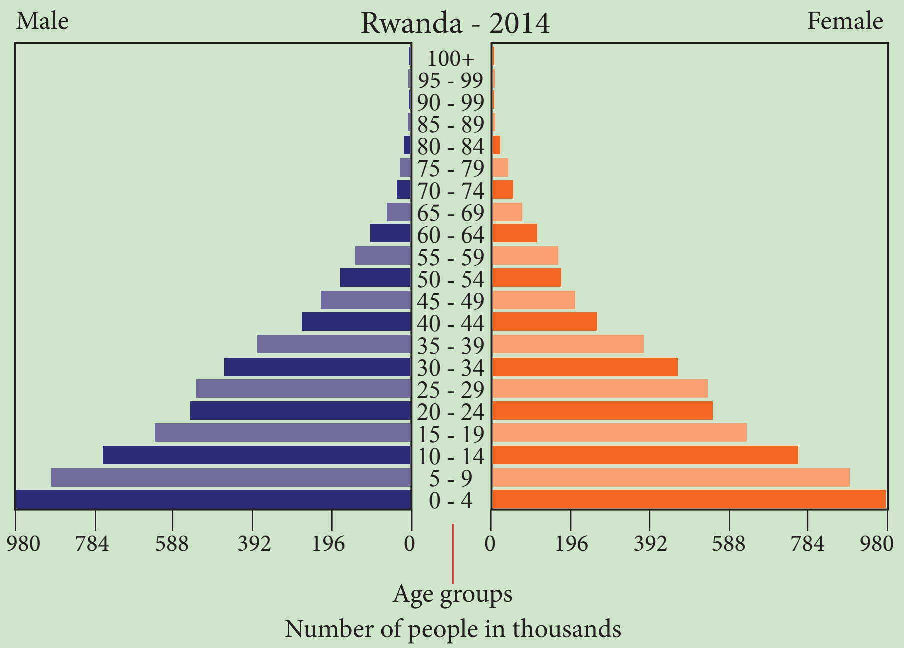
Fig 2.7: Rwanda population growth curve

   (a) Describe the shape of the graph.
   (b) What can you attribute the increase in population to?
   (c) What do you think caused a decline in population as shown on the graph?
   (d) What can you do as an individual to prevent (c) above from happening?
6. The rate of growth of a population depends on
   A. Food supply, predation, disease
   B. Food supply, shelter, disease.
   C. Disease, shelter, predation.
   D. Disease, food supply, prey

7. Which one of the following is a biotic factor that influences population growth?
   A. Rain   B. Oxygen   C. Sex mates   D. Soil
8. In which phase of population growth graph does the rate of population growth highest?
   A. Lag phase   B. Log phase   C. Stationary phase   D. Death phase
9. The following graph shows a population growth pattern.



   (a) Indicate growth phases on the curve.
   (b) Describe the growth phases.
10. Explain the factors that affect the rate of population growth of an organism.
11. The graph below shows the age structure of the Rwanda population in the year 2014.



   (a) Comment on the shape of the graph.
   (b) Do you see a problem with population distribution of the ages?
   (c) Suggest ways of reducing problems associated with such age group distribution in a population.
   (d) In what ways can the human population be controlled?

Unit 3

Nutrient cycles

Key unit competence

After studying this unit, I should be able to explain the water, carbon and nitrogen cycles.

Learning objectives

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

- Describe the water, carbon and nitrogen cycles in nature.
- Interpret charts of nitrogen, carbon and water cycles.
- Explain the effects of burning fossil fuels and deforestation on concentration of oxygen and carbon dioxide in the atmosphere.
- Explain how human activities affect the carbon cycle.
- Justify the use of leguminous plants in crop rotation.
- Acknowledge the role of microorganisms in nutrient recycling.
- Give reasons why tree planting programs at home and school are important.

Introductory Activity

Study the chart below carefully. Try to understand what is going on.

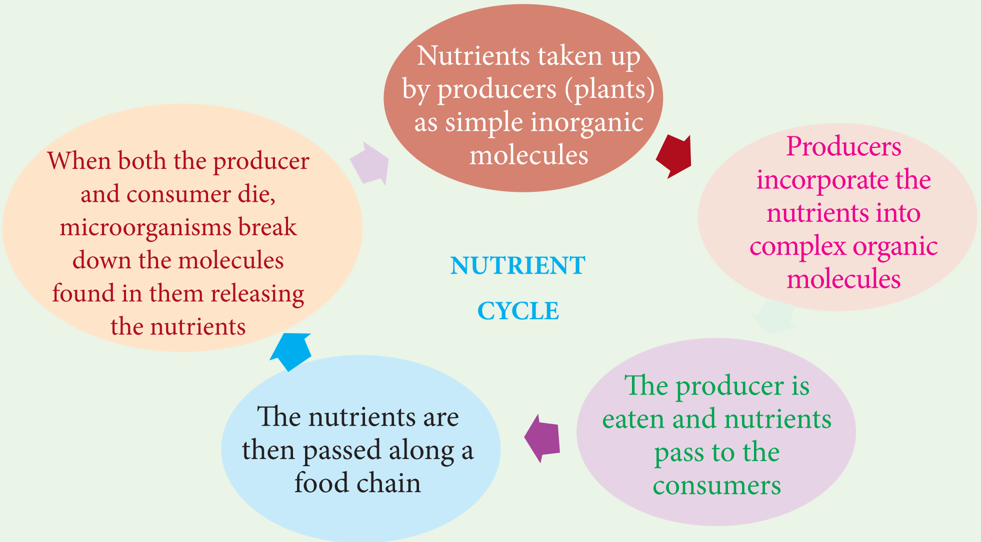


Fig 3.1: Cycling of nutrients in nature

For each level, give a list of organisms or processes that are involved. What is the significance of these processes? What materials are involved? What does this tell you about nutrients and what you will learn in this unit?

Introduction

Plants and animals need nutrients in order to survive. The nutrients are largely obtained from the environment where the plant or animal is located. Some nutrients are required in large amounts, for example, calcium, potassium, sodium and magnesium. They are known as **macronutrients.** Other nutrients such as sulphur, zinc and copper are needed in small amounts. They are known as **micronutrients**. Some compounds such as carbon and water form the bulk of plants and animals. How do plants and animals get these nutrients and compounds from the environment? How are these nutrients taken back to the environment? The flow or circulation of nutrients in the environment and through organisms is what forms **nutrient cycles**. This makes the ecosystem self-sustaining. Energy is non-cyclic. It is constantly lost from the ecosystem and replaced by radiant energy from the sun. Chemical elements in the biosphere cannot be created nor destroyed; they can only be recycled in different chemical forms and combinations.

In this unit you will learn about nitrogen, carbon, water and phosphorous cycles.

3.1. Water cycle

How do you suppose water circulates in nature? The following experiment will help you understand the processes involved.

Activity 3.1: Demonstrating processes involved in cycling of water cycle

A. Experiment

Requirements

- Water
- Kettle
- Source of heat
- Soil
- Plate
- Glass container

Procedure

1. Fill a kettle halfway with water and cover it with a lid.
2. Boil the water then remove the kettle lid.
    - Observe what is underneath the lid.
3. Let the droplets of water underneath the kettle lid fall onto a plate containing soil.
4. When the soil on the plate is fully soaked, cover it with a glass container and place it in the sun.
    - Observe
5. Write a report on your findings.

B. Look at the following diagram and answer the questions that follow in connection with Activity 3.1.

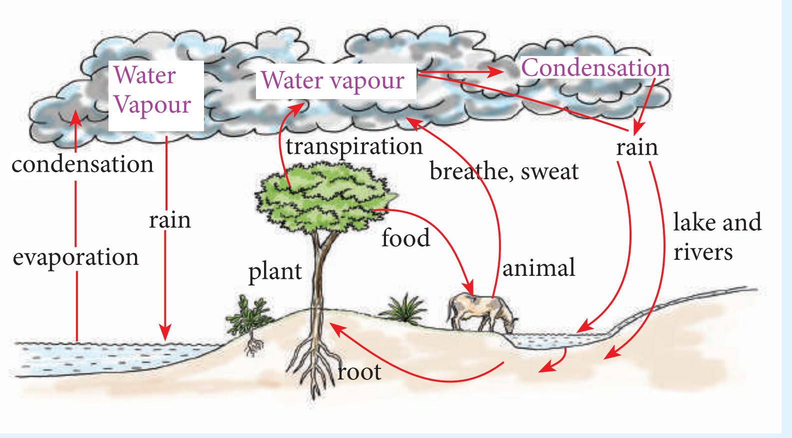


Fig 3.2: The water cycle

Study questions

(i) Name the process that took place in procedures 2, 3 and 4 in Activity 3.1.

(ii) Identify processes that:

- Release water back into the atmosphere.
- Take water from the atmosphere.

(iii) How is water maintained in the environment?

(iv) How does pollution of water interfere with the water cycle?

The facts

The water cycle is also known as the **hydrological cycle**. It describes the continuous movement of water from the atmosphere as rain to the surface of the earth, to bodies of living organisms, to water bodies and then release of water vapour back to the atmosphere. This continuous circulation of water ensures that the mass of water on earth remains fairly constant over time. The cycle involves the following processes: evaporation, condensation, precipitation and infiltration.

(a) Evaporation-Transpiration

Liquid water from bodies of living organisms, the earth's surface and water bodies heats up and Vaporises. When plants transpire, water vapour escaping through the stomata evaporates to the atmosphere. Animals release wastes with some moisture. Due to the warmth in their bodies, some of the water is converted into water vapour, which evaporates to the atmosphere. Animals also lose water from the surfaces of their bodies through sweating and through evaporation. This water rises up into the atmosphere as water vapour.

(b) Condensation

In the atmosphere, the water vapour undergoes condensation (the conversion of a vapour or gas to a liquid) to form clouds.

(c) Precipitation

Condensed water is released back to the earth in form of rainfall. This is called **precipitation**. Rainfall therefore returns the greatest part of water back to the earth.

(d) Infiltration

After rain falls, water goes to the ground. Some seeps underground where it is stored. The underground water comes out to form rivers, springs and wells. Excess water that cannot infiltrate into the soil flows on the ground due to gravity. This water forms surface runoff. It flows into rivers that direct it to large water bodies such as lakes and seas.

Some of the water is taken by living organisms for use in their bodies. All living organisms take in water for physiological processes in their bodies. Some organisms have water as their habitat.

The flow of water over the whole environment forms a **continuous cycle**.

Self–evaluation Test 3.1

1. Where does the energy that powers the water cycle come from?
   A. Plants
   B. Electrical outlets
   C. The sun
   D. Animals
2. What is the correct term for rising water vapour meeting colder air and turning back into a liquid?
   A. Dehydration
   B. Evaporation
   C. Condensation
   D. Precipitation
3. What would happen if there is no water cycle on earth?
4. What is the most important step in the water cycle?

3.2. Carbon cycle

Activity 3.2: Investigating the presence of carbon dioxide in a living organism

A. Experiment

Requirements

- Eye protection
- Crushed natural chalk
- Vinegar or hydrochloric acid
- Flask
- Balloon
- Test-tube
- Limewater (calcium hydroxide solution)

Caution: Wear eye protection

Procedure

1. Pour limewater into a test tube.
2. Place crushed chalk into a flask and add vinegar or hydrochloric acid to the flask.
3. Place a deflated balloon tightly over the flask neck so that no gas can escape.
4. When the reaction has stopped, pinch the balloon tightly at the balloon neck, so that no gas escapes.
5. Remove the balloon from the flask and place it over to the test tube then squeeze it so that the gas goes into the limewater.

- Observe and record your observations.

Alternatively you can breathe out into limewater using a straw.

Study questions

(i) What colour was the limewater before the reaction?

(ii) What happened to the limewater when you added the gas from the balloon?

(iii) Where did the gas in the balloon come from?

(iv) What reaction was responsible for creating it?

(v) What gas was released from the chalk by the reaction?

B. Look at the diagram below and answer the questions that follow.

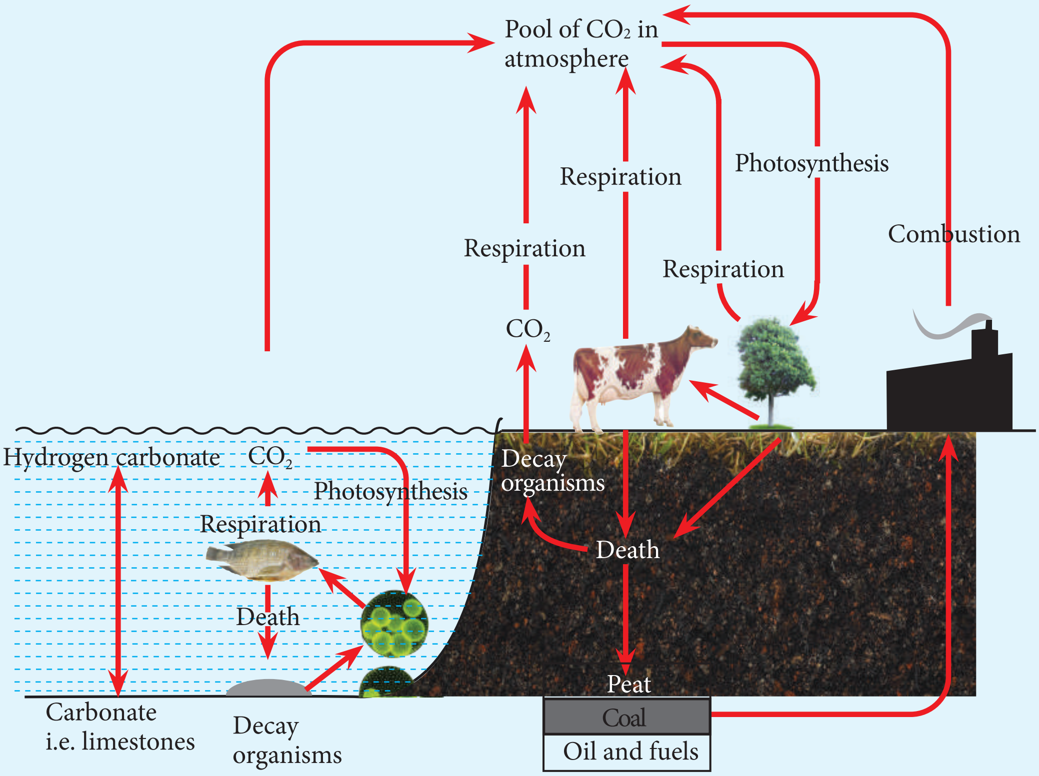


Fig 3.3: The Carbon cycle

(i) What processes are involved in the carbon cycle?

(ii) How are these processes interrelated?

(iii) Identify processes that:

- Increase carbon dioxide in the atmosphere.
- Reduce carbon dioxide from the atmosphere.

(iv) Which human activities increase the amount of carbon dioxide in the atmosphere?

The facts

The carbon cycle explains the flow of **carbon** through the atmosphere in oceans, in soils and in communities of living organisms.

Carbon is found in form of carbon dioxide in the atmosphere. The atmosphere contains 0.03% carbon dioxide. Carbon dioxide is also found dissolved in water. Chains of carbon atoms make up the body of all living organisms. 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 in transfer of carbon. Some carbon dioxide is dissolved in rainwater forming a weak carbonic acid. This dissolves into the soil or into water bodies. The food substances in the plant tissues are 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. Carbon is released back into the atmosphere in the following methods.

(a) Respiration

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.

(b) Decomposition

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

(c) Combustion

(a) Human activities are known to release a lot of carbon dioxide into the atmosphere. These activities include:
- Use of fuels in homes for cooking. Fire is used to burn fields, vegetation and wastes.
- Heating and burning fossil fuels especially in industries and fuels in engines of vehicles. Fossil fuels are formed deep into the earth crust by deposits of remains of living organisms. They contain carbon which when burned releases carbon dioxide into the atmosphere.
- Use of limestone in industries. Limestone is formed deep in seas and oceans where 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, the carbon in it is released back into the atmosphere.

(b) During volcanic activities gases locked up below the earth's surface are released into the atmosphere.

Effects of human activities on the carbon cycle

The carbon cycle involves the movement of carbon between the atmosphere, oceans and land. The carbon cycle is affected when carbon dioxide is either released into the atmosphere or removed from the atmosphere. The natural amount of carbon dioxide produced by organisms is normally utilised in the carbon cycle by vegetation to produce oxygen.

Human activities contribute to the addition of carbon dioxide in the atmosphere without removing an equal amount. This extra carbon dioxide is proving too much for the carbon cycle to handle. It cannot all be moved out of the atmosphere, so it is causing **global warming**. Human activities that affect the carbon cycle include:

(a) Burning of fossil fuels

When oil or coal is burned, carbon is released into the atmosphere at a faster rate than it is removed. The carbon released combines with oxygen to form carbon dioxide. As a result, the concentration of carbon dioxide in the atmosphere increases. Natural gas, oil and coal are fossil fuels that are commonly burned for energy production in industries, transport and for domestic use. The primary industrial activities that emit carbon dioxide and affect the carbon cycle are petroleum refining, paper, food production and mineral production, mining and the production of chemicals.

(b) Deforestation

Deforestation is the permanent removal of trees from forests. Permanent removal of the trees means new trees will not be replanted. This large-scale removal of trees from forests by people results in increased levels of carbon dioxide in the atmosphere because trees are no longer absorbing carbon dioxide for photosynthesis. As a result, the carbon cycle is affected. Farmers remove trees on a large-scale basis to increase acreage for crops and livestock.

(c) Acid rain

Large quantities of atmospheric carbon dioxide could lead to acidic rain. The process begins when carbon dioxide dissolves in droplets of water, in the clouds. The resulting solution, which reaches the surface as rainwater, is weakly acidic:

$$\text{Carbon dioxide} + \text{water} \longrightarrow \text{carbonic acid}$$

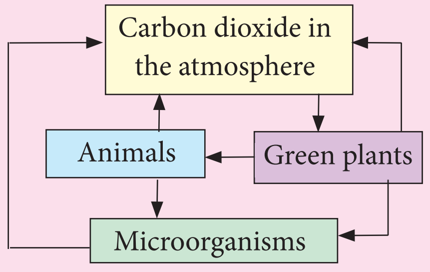
$$CO_2\,(g) + H_2O\,(l) \longrightarrow H_2CO_3\,(aq)$$

Rainwater containing carbonic acid is able to react with most minerals at varying rates according to their chemical stability. The acidic rain may affect plants and building structures through corrosion.

Fact of life: Management of farmland or forests affects the amount of carbon dioxide removed from the atmosphere by plants. These sinks of carbon dioxide affect the carbon cycle by decreasing the amount of carbon dioxide in the air.

Self-evaluation Test 3.2

1. The diagram shows part of the carbon cycle.



Describe how living things are involved in the constant cycle of carbon.

2. Which activity will add more carbon dioxide into the atmosphere?
   A. Combustion of fossil fuel
   B. Animals breathing in
   C. Decay of plants
   D. Volcanic activity
3. Suggest alternative forms of energy to be used rather than fossil fuels.

3.3. Nitrogen cycle

The circulation of nitrogen in the environment through organisms, either when combined in different compounds or free, is termed as the **nitrogen cycle**. All living things need nitrogen-containing compounds which include **proteins** and **nucleic acids**. Nitrogen is found in the atmosphere as nitrogen gas (N_2).

Even though nitrogen gas is abundant in the atmosphere, organisms rarely absorb it in its gaseous state. Plant, for example, cannot use nitrogen directly from the air. This is because nitrogen gas is **inert**. A lot of energy is required to break the bonds in nitrogen gas. Only a few bacteria are capable of splitting the nitrogen molecule. Once broken down, the nitrogen atom can then combine with other compounds so that plants are able to take it up.

Activity 3.3: Examining roots of legumes taken from fertile and infertile soils to compare the number of root nodules

A. Experiment

Requirements

- Bean seeds
- Rich garden soil, soil mixed with manure, poor soil or sand
- Beakers/pots/boxes

Procedure

1. Place some rich garden soil in one box and sand in another box.
2. Plant beans in each container and water with just enough water.
3. Allow the bean to germinate and grow until it matures i.e. forms flowers.
4. Uproot the bean plants carefully without destroying the roots.
5. Count the number of nodules on the roots of several bean plants grown on the fertile soil.
6. Calculate the average number of nodules in each soil.

Study questions

(i) Which bean seedlings had a higher number of nodules.

(ii) Account for the number of nodules in the two plants.

B. Look at the diagram below and answer the questions that follow.

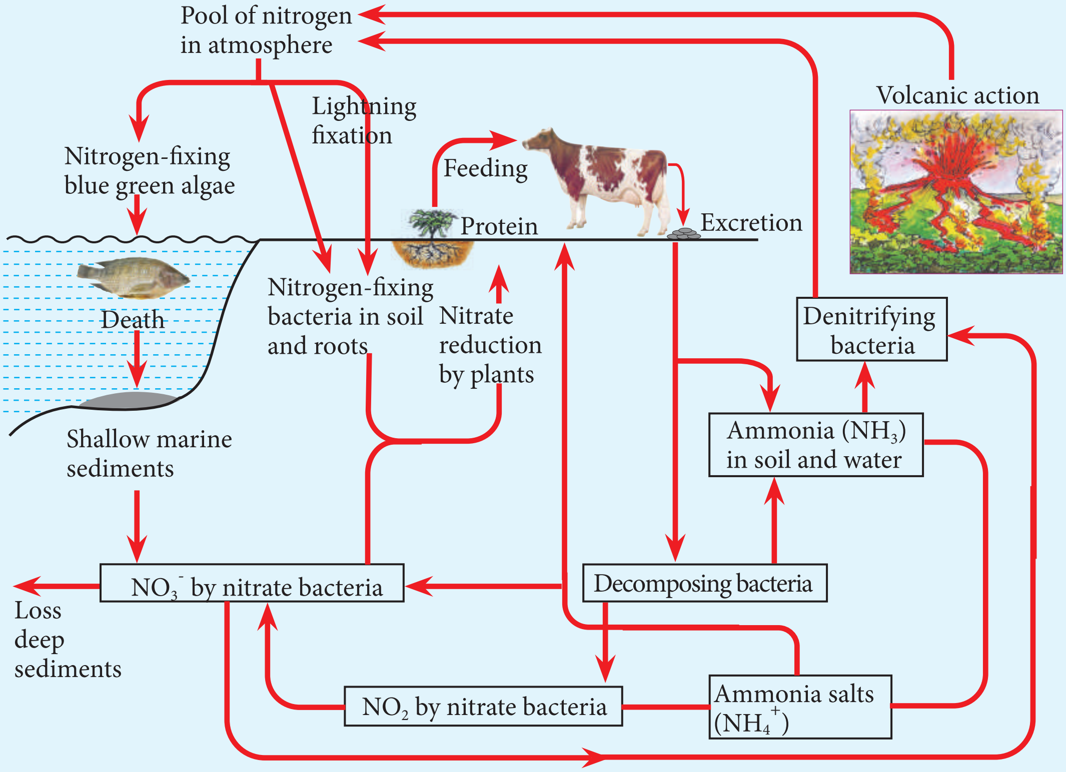


Fig 3.4: The Nitrogen cycle

(i) Identify organisms and processes that:

- Increase nitrogen into the atmosphere.
- Reduce nitrogen from the atmosphere.

(ii) Why do you think nitrogen is abundant in nature but it is not readily available to organisms?

(iii) Ammonium ions (NH_4^+) stay in the soil, while nitrate ions (NO_3^-) are easily leached out. Why do they behave so differently?

(iv) Nitrogen accounts for nearly 79% of air by volume. Still nitrogen is a limiting nutrient for plant growth. Why?

(v) Name substances that contain nitrogen.

The facts

The nitrogen cycle is an important nutrient cycle that describes how nitrogen is stored and transferred. Without nitrogen, plants cannot make proteins and therefore cannot grow. This in turn affects organisms that depend directly or indirectly on plants.

Most plants use nitrogen in two forms, either as ammonium (NH_4^+) or as nitrates (NO_3^-). Usually, nitrates in the soil are the major source of nitrogen for plants. Using ammonium 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.

There are five main processes in the nitrogen cycle. These are:

(i) Nitrogen fixation
(ii) Assimilation
(iii) Ammonification
(iv) Nitrification
(v) Denitrification

(a) Nitrogen fixation

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 in the soil.
- Oxidation of nitrogen by lightning.

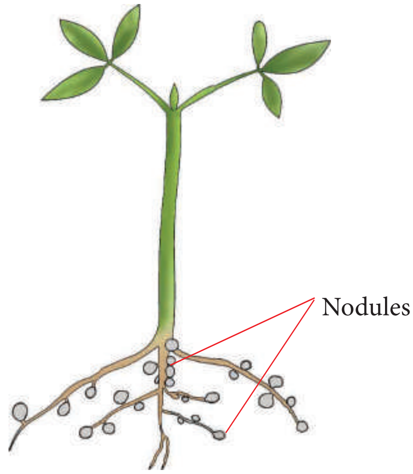


Fig 3.5: Nodules on roots of a legume that contain bacteria that fix nitrogen

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 waterlogged soils. These bacteria absorb nitrogen from the atmosphere and use 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. Plant roots absorb these nitrates to make proteins for the plant.

During heavy rains with lightning and thunderstorms, the energy of lightning 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.

(b) Assimilation

Plants absorb nitrates from the soil and use them to form amino acids, which build up into proteins and other compounds. The proteins formed are referred to as **plant proteins**. When eaten by animals, they are first broken down into amino acids, and then assimilated to form **animal proteins**. In animals, the proteins are used in the formation of new tissues, repair of worn out tissues, making of enzymes and hormones, among others.

(c) Ammonification

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 has nitrogen. When 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.

(d) Nitrification

When plants and animals die, they undergo a process known as **putrefaction**. This is simply referred to as decay or decomposition. Saprophytic bacteria and fungi carry out the process. The putrefying bacteria break up complex proteins into simpler compounds like ammonia.

Some of the compounds formed from putrefaction like ammonia and nitrites are later converted to nitrates. This process of converting ammonium compounds to nitrates is called **nitrification**.

Bacteria called **nitrifying bacteria** carry out the process. These are:

- Nitrosomonas and Nitrococcus (Nitrate bacteria). They convert ammonium compounds to nitrates.
- Nitrobacter (Nitrate bacterium) converts nitrites to nitrates.

(e) Denitrification

The nitrogen cycle involves a number of organisms and a variety of pathways. There is no single nitrogen cycle but a group of cycles that interact with each other. The nitrogen, removed from the atmosphere, is recycled back to it. This occurs in three main ways.

(i) 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*.

(ii) Volcanic activities release trapped nitrogen back into the atmosphere.

When plants and animals die they release nitrogen back into the atmosphere in form of ammonium compounds.

Self–evaluation Test 3.3

1. Synthetic fertilisers add ________ to the soil.
   A. organic nitrogen
   B. fixed nitrogen (ammonium)
   C. nitrogen oxides
   D. Rhizobium bacteria
2. What is the most common way through which nitrogen fixation occurs?
   A. Lightning
   B. Nitrogen fixing bacteria
   C. Fossil fuel combustion
   D. Forest fires
3. Atmospheric nitrogen (N_2 gas) is easily taken up and used by plants and animals. True or false?
4. In what form does nitrogen re-enter the earth after the process of fixation?
5. How does nitrogen lead to eutrophication of water bodies?

3.4. Phosphorus cycle

Phosphorus is an essential nutrient for plants and animals in the form of phosphate (PO_4^{3-}) ions and hydrogen phosphate (HPO_4^{2-}) ions. Phosphorus forms part of:

- DNA and genes in general.
- Molecules that store energy such as ATP.
- Fats.
- Building blocks of certain parts of the human and animal body such as the bones and teeth.

Activity 3.4: Investigating presence of phosphrous in plants

Requirements

- Pots
- Infertile soil
- Burnt plant ashes
- Bean seedlings
- Burnt insects ashes

Procedure

1. Place infertile soils into 2 pots. Label them A and B.
   - In Pot A, add ashes from plants.
   - In Pot B, do not add anything.
2. Place healthy bean seedlings in each pot and observe for three weeks.
3. Write a report on your findings.

Study questions

1. Where is phosphorus concentrated?
2. How is phosphorus maintained in the environment?

3. After analyzing the diagram below, what are the effects of phosphorous fertilisers to the environment?

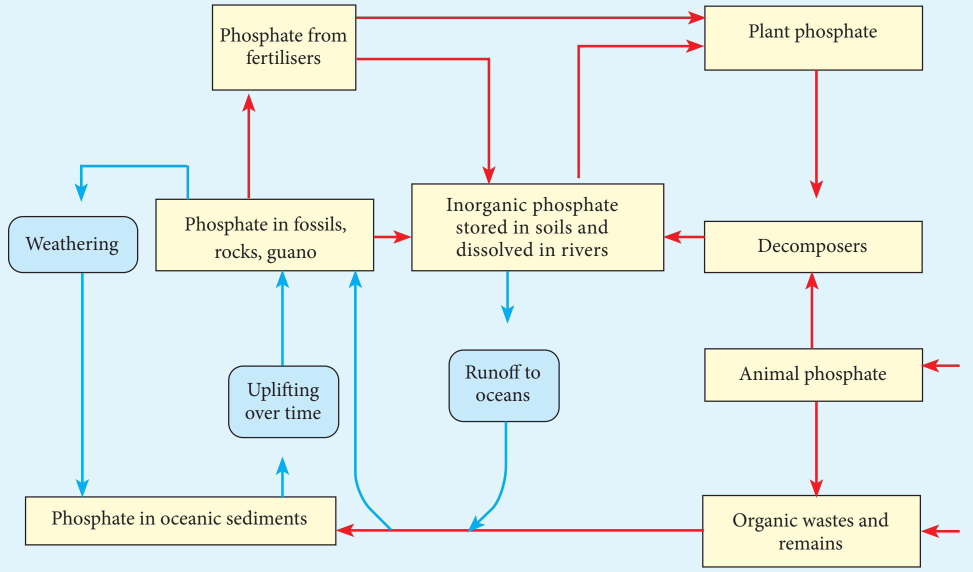


Fig 3.6: The phosphorus cycle

The facts

Phosphorus can be found on earth in water, soil and sediments. Unlike the compounds of other cycles, phosphorus cannot be found in air in the gaseous state. This is because phosphorus is usually liquid at normal temperatures and pressures. It exists mainly in water, soil and sediments.

In the atmosphere phosphorus can mainly be found as very small dust particles.
Phosphorus moves slowly from deposits on land and in sediments to living organisms. It moves much more slowly back into the soil and water sediments. The phosphorus cycle is the slowest of the nutrient cycles.

Phosphorus is most commonly found in rock formations and ocean sediments as phosphate salts. Phosphate salts that are released from rocks through weathering usually dissolve in soil water and will be absorbed by plants.

The quantities of phosphorus in soil are generally small; it is often the limiting factor for plant growth. That is why farmers often apply phosphate fertilisers on farmland. Phosphates are also limiting factors for plant-growth in marine ecosystems, because they are not very water-soluble.

Animals absorb phosphates by eating plants or plant-eating animals. Phosphorus cycles through plants and animals are much faster than those in rocks and sediments. When animals and plants die, phosphates will return to the soils or oceans again during decay. After that, phosphorus will end up in sediments or rock formations, remaining there for millions of years. Eventually, phosphorus is released again through weathering and the cycle starts over.

Supporting tree planting programmes at home and school

Nutrient cycle and trees

It is important to plant trees in school compounds and homesteads so as to enhance nutrient cycles. This is done by transplanting tree seedlings. Trees use carbon dioxide in the atmosphere so that its percentage remains at 0.03%. When this percentage is altered due to deforestation, climate change sets in with dire consequences. Plants are the only organisms that use atmospheric carbon dioxide in substantial amounts thus stopping global warming.

Trees play an important role in phosphorus and nitrogen cycles as well. Atmospheric nitrogen is used by nitrogen–fixing bacteria to form nitrates which are absorbed by plants. The percentage of nitrogen is maintained at a safe percentage, that is 79%. Animals get nitrates from plants. Without plants, nitrates can not be used by animals directly.

Phosphorus is present in small quantities in soil. The plants are the only organisms that can get phosphorus from soil while animals get phosphorus from plants. All nutrient cycles depend on plants to be complete especially the trees and human beings who depend on plants for carbon, nitrogen and phosphorus for their own use. In Rwanda, planting of trees has helped people not only to have fuel such as firewood and charcoal but also to control soil erosion.

Unit summary

- A nutrient cycle is the movement and exchange of organic and inorganic matter back into the production of living matter.
- The water cycle is the cycle of processes by which water circulates between the earth's oceans, atmosphere, and land, involving precipitation as rain and snow, drainage in streams and rivers, and return to the atmosphere by evaporation and transpiration.
- The carbon cycle is a series of processes by which carbon compounds are interconverted in the environment, chiefly involving the incorporation of carbon dioxide into living tissue by photosynthesis and its return to the atmosphere through respiration, the decay of dead organisms, and the burning of fossil fuels.
- The nitrogen cycle is a series of processes by which nitrogen and its compounds are interconverted in the environment and in living organisms, including nitrogen fixation and decomposition.
- The phosphorus cycle is the biogeochemical cycle that describes the movement of phosphorus through the land, water and atmosphere.
- Deforestation is the permanent destruction of forests in order to make the land available for other uses.
- Human activities such as deforestation, burning fossil fuels affect the carbon cycle.

Self-evaluation Test 3.4

1. Energy is released from ATP when ____________.
   A. a phosphate group is added
   B. adenine bonds to ribose
   C. ATP is exposed to sunlight
   D. a phosphate group is removed
2. Phosphorus is difficult for plants and animals to access in nature because
   A. it reacts quickly with other elements, like oxygen.
   B. most phosphorus in the environment is bound to carbon, nitrogen and hydrogen.
   C. it is typically found as a phosphate.
   D. most phosphorus in the environment is stored in reservoirs.
3. Without phosphorus, living organisms cannot grow, reproduce or move. This is because phosphorus
   A. forms part of the structure of DNA and RNA.
   B. provides structure to cell membranes.
   C. is needed for energy transport in cells.
   D. all of the above.

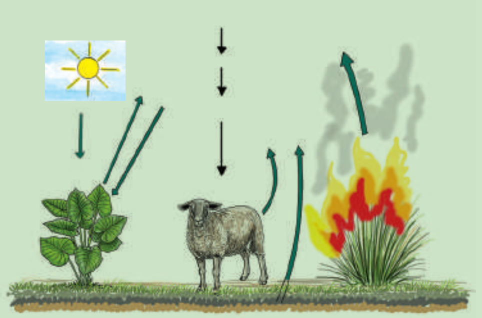
Research activity

1. Explore your local environment.
2. Visit various ecosystems such as wetlands, forests and grasslands.
3. Identify, research and talk to people about the effects of human activities on the nutrient cycles.
4. Write a report and present your findings.

End Unit Assessment 3

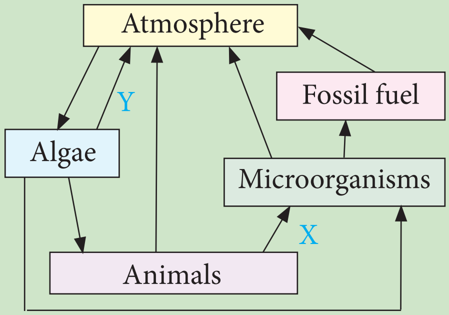
1. What are the four stages of the water cycle?
   A. Condensation, precipitation, hibernation, dehydration
   B. Evaporation, condensation, precipitation, surface runoff
   C. Precipitation, dehydration, evaporation, perspiration
   D. Transpiration, dehydration, condensation, hibernation
2. Which of the following is a component of acid rain?
   A. ammonium
   B. denitrifying bacteria
   C. nitrogen oxides
   D. organic nitrogen
3. (a) How does the phosphorus cycle differ from the carbon and nitrogen cycles?
   (b) How does organic phosphate move through a food web?
   (c) Humans do not influence the phosphorus cycle in any significant way. True or false.
4. Give an example of evaporation at home or in school.

5. (a) Identify leguminous plants from the following list:
Peas, millet, ground nuts, sweet potatoes, cassava and cashew nuts
(b) Why is it important to include leguminous crops in a farm?
6. What does it mean to say that nutrients recycle in an ecosystem but energy flow is a one-way path?
7. The picture below shows the mass of carbon dioxide released into and removed from the air each year.



(a) Describe the processes shown in the picture that exchange carbon dioxide with the air.
(b) Explain the overall effect of these processes on the mass of the carbon dioxide in the air.

8. The diagram shows part of a carbon cycle in a habitat.



(a) Name the processes shown by arrows **X** and **Y**.
(b) Describe the part played by algae in this carbon cycle.
(c) In tropical rainforests, process **X** is much faster than in most other habitats. Suggest why.
9. Ecologists discovered that trout were dying in a stream that ran through some farmland where nitrogen fertiliser was used on the crops.
(a) How might you explain what happened?
(b) Formulate a hypothesis in order to test your idea.
10. Suggest ways of reducing human interference to the nutrient cycles.
11. Briefly describe phosphorus and nitrogen cycle by explaining processes that take place in each cycle.

Unit 4 Effects of human activities on ecosystems 1

Key unit competence

After studying this unit, I should be able to assess the consequences of uncontrolled human activities on ecosystems.

Learning objectives

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

- State how modern technology has resulted in increased food production.
- Describe the negative impacts to an ecosystem of large-scale monocultures of crop plants and intensive livestock production.
- Describe the reasons for habitat destruction limited to agriculture, housing and extraction of natural resources.
- Explain the undesirable effects of deforestation on the environment.
- State the sources and effects of pollution of land and water (rivers, lakes and the sea) by insecticides, herbicides and by nuclear fall-out.
- State sources and effects of air pollution.
- Assess the effectiveness of management of parks and forests by Rwanda government.

Introductory Activity

Study the pictures below. How does the activity taking place in each picture affect the environment?

Fig 4.1: Activities in the environment

Is it good or bad? Why is this the case? Based on what you have seen in the pictures, what do you think you will learn in this unit?

Introduction

When you start a vehicle; the fuel in the vehicle is processed to release energy. This energy is useful in moving the vehicle. However, in the process, harmful gases are released into the environment.

- Have you ever wondered how dangerous these gases are to human beings or other animals?
- What other means of transport can be used that does not release such gases into the environment?
- Which other activities carried out by human beings affect the environment and how?

Human beings affect the environment in many ways. Most of these ways lead to degradation of the environment. Environmental exploitation is the most dangerous human activity. This involves carrying out activities like mining, quarrying, cutting down of forests or deforestation among others. Destruction of the environment by human beings leads to:

- Reduced food supply
- Habitat destruction in general
- Pollution
- Climate change, greenhouse effect and global warming

This unit is about the effect of human activities on the environment.

4.1. Food supply

Activity 4.1: Research activity

1. Use reference textbooks in the library and the Internet to carry out a research about the following:
   i) The challenges facing the world due to population increase.
   ii) The social, environmental and economic implications of providing sufficient food for an increasing human global population.
   iii) The modern technology employed to increase food production.
2. Write a report and present your findings.

The facts

There are a number of agricultural practices in the world that result in increased food production. However, some farming communities still depend on traditional farming methods that yield less food with poor storage facilities. Advancement in science and technology has created new and better methods of food production and storage. This has led to increased food production in the world to feed the ever growing population.

Modern technologies used in agriculture to increase food production include:

- Development and use of chemical fertilisers on farm land to boost levels of nutrients in the soil.
- Development and use of pesticides such as insecticides and fungicides to kill pests that feed and damage crops. The use of biological control methods for pest control as an alternative to pesticides.
- Development and use of herbicides to kill weeds that compete with crops for nutrients, light, water and space.
- Use of modern machinery, such as tractors and combine harvesters that has enabled land and crops to be managed more efficiently.

(a) Tractor tilling land

(b) Combine harvester at work

Fig 4.2: Modern agricultural machinery used to increase food supply

- Selective breeding (artificial selection) to produce varieties of plants that are suited to particular climates and soil types and breeds of animals for specific purpose such as optimum meat, milk and wool production.
- Use of yeast and bacteria in the large-scale production of bread, beer, wine, yoghurt and cheese.
- Use of genetic engineering and cloning techniques to produce organisms that are adapted to the environment and produce better yield.
- Development of systems to water plants in greenhouses automatically and to grow plants in nutrient solutions (a process called **hydroponics**).
- Development of intensive farming and automated feeding mechanisms.

Activity 4.2

Using different references resources discuss the questions below.

- Are genetically modified foods (GMOs) healthy?
- How can agriculture meet the world's growing need for food while doing less environmental harm?
- How can we protect agricultural lands from urban spread?

Self-evaluation Test 4.1

1. How can you assist in developing sustainable food production in your community?
2. Why is excessive use of insecticides bad for the environment?

4.2. Negative impacts to an ecosystem of large scale monoculture of crop plants and intensive livestock production

Activity 4.3: Field study

1. Take a visit to a farm that carries out monoculture and intensive livestock production.
2. During the tour, look out for the following.
   - The type of crops planted or animals reared. Why?
   - What type of chemicals are used on the farm?
   - The challenges the farmer(s) experiences.
   - What are the negative impacts to an ecosystem of monoculture and intensive livestock production?
3. Using photographs related to environmental degradation discuss with a friend the causes, consequences and protective measures for environmental degradation.
4. Which problems contribute to famine?
5. Present your findings for marking.

An **ecosystem** contains numerous different species, each with unique adaptations to its environment. All the species in the environment coexist together for a healthy system. Any change to the system leads to environmental degradation. **Intensive farming** is an agricultural practice that aims to maximise yields from available land through various means, such as heavy mechanisation, use of pesticides and chemical fertilisers.

The facts

Environmental degradation is the changing of the environment in a negative way. The environment can deteriorate due to farming methods used. Some of the farming methods that lead to environmental degradation include monoculture and overgrazing due to intensive livestock production.

Intensive farming is an agricultural practice that aims to maximise yields from available land through various means, such as heavy mechanisation, use of pesticides and chemical fertilisers.

(a) Large - scale monoculture of crop plants

The term monoculture refers to the growing of a single crop over a large area. Monoculture is practised in most large-scale commercial agriculture. The crops most commonly planted are corn, wheat, soybeans, cotton or rice. The crops are planted in the same soil every year with no introduction of a different crop. This creates a system with very little diversity.

The benefits of monoculture include limiting waste from inefficient harvesting and planting, reducing plant competition, controlling unprofitable organisms and allowing production to be standardised.

Monoculture cultivation is mainly practised by cooperative farmers. This can be seen at Mulindi on your way to Rusizi from Kigali city and at Kabuye sugar farms.

Others are:
Maraba Coffee Plantations in Huye District and Sowathe Tea Plantations located at Kinihira, Rulindo District.

Fig 4.3: Large scale sugar plantation

Negative environmental impacts of monoculture

(i) Susceptibility to pests

Monoculture crops have no genetic variability because they are not allowed to reproduce naturally. The pests and weeds that attack them adapt easily to the environment and develop resistance to chemicals used to control them. The only way to control pests in this setup is to use more chemical control mechanisms.

Chemicals that are safe for human consumption or exposure can have negative impacts on the environment. For example, roundup, a widely used herbicide, is much more toxic to amphibians than it is to humans.

(ii) Eliminates biological controls

The lack of diversity in a monoculture system eliminates all the functions that nature provides to plants and the soil. Since there are no varieties of plants that naturally provide nutrients to the soil, such as nitrogen-fixing legumes, or ground cover crops to improve the nutrient content of the topsoil.

There are fewer species of microorganisms such as bacteria, in the soil hence fewer nutrients available for them to survive on. The soil lacks diverse nutrients from not having a variety of plants with different root depths.

(iii) Use of dangerous synthetic chemicals

Farmers use synthetic chemicals in an attempt to prevent damage to crops by weeds, insects and bacteria and to provide sufficient nutrients in the soil for the plants to grow. Not only do these chemicals leave traces on plants that are intended for human consumption, but they can also enter the food chain. They are routinely over-used so that a large proportion of the synthetic material remains in the soil, even after the crop has been harvested.

Most of the chemicals used are inorganic and cannot be processed into organic matter by microorganisms. The chemicals leach through the soil, eventually polluting groundwater supplies and altering ecosystems that may be at a great distance from the original location where the chemicals were used. For instance, inorganic fertiliser runoff has contributed greatly to algal blooms in rivers and lakes. The increased algae blooms become a problem when they die. The aerobic bacteria that decompose them use a lot of oxygen. Organisms such as fish in water bodies may lack oxygen and die.

(iv) Soil degradation

Besides the negative impact the overuse of chemical fertilisers has on the soil, monocultures affect soil health in other ways. Ground cover crops are eliminated, meaning there is no natural protection for the soil from erosion by wind and rain. The soil lack moisture and no plants provide leaf litter mulch to replenish the topsoil. All these combine to continually degrade the soil, often meaning that it becomes unproductive for agriculture.

(v) Use of fuel energy

Many modern monoculture farms use machinery for their operations. The machinery requires large inputs of energy to function. These functions along with the manufacture of packaging materials use fossil fuel energy. In combination with the chemical fertilisers and pesticides, the industrialised mode of food production is a major contributor to climate change.

(b) Intensive livestock production

Intensification of farming is also applied in rearing livestock. Animals such as cows, pigs, goats and poultry among others are being held indoors in what has become known as factory farms.

(a) Rearing of chicken

(b) Pigs

(c) Cattle rearing on large scale

Fig 4.4: Examples of factory farms

Intensive farming practices produce more food per acre. This has helped feed the increasing human population and may prevent surrounding land from being converted into agricultural land.

The practice is designed to produce the highest possible output at the lowest possible cost to the farmer. The negative impacts of intensive livestock farming include:

- The overuse of pesticides. Although pesticides have their benefits, such as controlling or killing potential disease-causing organisms and other pests, there are many drawbacks, such as threat of toxicity to humans and other animals, increased pest resistance and the unintended killing of pests' natural enemies.

- Overgrazing, this is the intensive animal consumption of plants. It is most commonly caused by unsustainable animals on a piece of land. Overgrazing is a significant driver of climate change and major cause of desertification worldwide. Overgrazing also causes soil erosion, reduces the usefulness, productivity and biodiversity of a land.

Monoculture and intensive livestock production are significant contributors to the build-up of greenhouse gases in the atmosphere. They are the biggest threat to the global environment through:

- The loss of ecosystem services and global warming.
- Emergence of new parasites and re-emergence of parasites previously considered to be under control by creating conditions for parasite growth.
- Deforestation of tropical forests.
- Killing beneficial insects such as bees and plants.
- Degradation and depletion of soil.
- Creation of polluted runoffs and clogged water systems, increasing susceptibility to flooding.
- Decreasing biodiversity and destroying natural habitats.

Self–evaluation Test 4.2

1. Monoculture system contributes to the biological diversity of an ecosystem? Discuss.
2. What are the consequences of growing primarily single varieties of common food crops?
3. What causes food insecurity?

4.3. Habitat destruction

Activity 4.4: Field study

You will take a field trip to protected areas such as National parks and Forest reserves such as Akagera National park and Nyungwe forest reserve.

1. Prepare a questionnaire you will use to engage the persons in charge of the park. The questionnaire may include questions such as:
    - How big is the park or reserve?
    - What kind of animals and plants are in the park or reserve?
    - Which organisms are endangered in this park?
    - What security measures are put into place to protect wildlife from poachers?
    - How do the community living around the park benefit from it?
2. Find out any effects of human activity and how these are mitigated.

3. Write a report on your findings.
4. Present your work to the rest of the class.

The facts

A **habitat** is the natural place where plants, animals or other organisms live. This is the living area necessary for an ecosystem to remain healthy. Destruction means to change something so much that it can no longer exist as it once was. Therefore, habitat destruction is the change in the home of a species to a point it no longer exists.

Fig 4.5: A tractor destroying land to give space for road construction

Habitat destruction occurs when enough change has happened to an area that it can no longer support natural wildlife. This change can actually be in many forms, including destruction, fragmentation and degradation. But no matter how it happens, plants, animals and other organisms whose habitat has been destroyed no longer have a home. Destruction of habitats leads to alterations of food webs and food chains found in an ecosystem. This alteration can lead to species extinction due to lack of food or change in food preference hence adaptation.

Effects of altering food web and food chain

When one species in a food web is removed, it has an effect on all other species both up and down the food web. In general, the prey of that species will benefit, at least for a while, and the predators of that species will be harmed, especially if an alternate food source can't be found. For example, if a grasshopper that eats wheat is removed from the food web, the wheat population will probably go up, but the population of birds and mice that eat the grasshoppers will go down. If a species of bird only eats that grasshopper, it may also die off completely.

Changes in habitat, such as those created by climate change or by human development, can help some species while hurting others. When humans drain a swamp to build a city, species that need a swamp habitat may die off or move away, while other species that like living in the city, like pigeons or sparrows, may move in.

Causes of habitat destruction

(a) Agriculture

Agriculture is a major land use. Agricultural ecosystems provide important habitats for many wild plant and animal species. This is especially the case for traditional farming areas that cultivate diverse species, as in the case of subsistence farming. However, rising demand for food and other agricultural products has seen large-scale clearing of natural habitats to make room for intensive monocultures. This ongoing habitat loss threatens entire ecosystems as well as many species.

(b) Housing and road construction

The conversion of lands that once provided wildlife habitat are being used in housing developments, roads and industrial sites. This destroys the habitat. Construction of roads through wildlife zones exposes organisms to habitat change. The organisms become vulnerable to destruction from environmental conditions they are not used to.

(c) Extraction of natural resources

Resource extraction involves any activity that withdraws resources from nature. Extraction produces raw material that are further processed to add value. Examples of extractions are hunting, trapping, mining, oil and gas drilling and deforestation.

Fig 4.6: Mining or quarrying

Natural resources can add substantial amounts to a country's wealth. However, these extractions do not consider habitats of organisms. Organisms that live in areas where extractions occur have to move away, get destroyed or change their way of life.

Undesirable effects of habitat destruction

a) Extinction

Trees serve as habitats for animals. If they are cut down, animals lose their homes and become more vulnerable to predators. The species will die out because they don't have a place to live. This may lead to extinction of plant species as well as animals.

b) Soil erosion

Without trees, the land is uncovered therefore weather conditions such as wind and rain cause soil erosion and flooding which results into soil infertility.

c) Rise in level of Carbon dioxide

Trees uses carbon in photosynthesis and without trees the carbon levels in the atmosphere will rise as there will be photosynthesis taking place.

Self–evaluation Test 4.3

1. How does habitat fragmentation contribute to species extinction?
2. Given the varying reasons for species extinction, how can we as human beings best protect biodiversity?

Disadvantages of environment degradation

Activity 4.5: Research activity

Analyse photographs related to environmental degradation and discuss consequences and protective measures.

During the field trip to protected areas such as national parks and forests like Akagera National park and Nyungwe forest reserve, find out and report back any effects of human activity and how these are mitigated.

Environmental degradation is the changing of the environment in a negative way. The environment deteriorates due to the poor quality of air, water and soil. There are three major causes of environmental degradation which are: population of humans, increase of per capita income and application of depleting and polluting technology. Environment degradation have the following impacts:

a) **Impact on human health:** Human health might be on the receiving end as a result of the environmental degradation. Areas exposed to toxic air pollutants can cause respiratory problems like pneumonia and asthma. Millions of people are known to have died due to indirect effects of air pollution.

b) **Loss of biodiversity:** Biodiversity is important for maintaining balance of the ecosystem in the form of combating pollution, restoring nutrients, protecting water sources and stabilising climate. Deforestation, global warming, overpopulation and pollution are few of the major causes for loss of biodiversity. Removing some organisms and introducing others in an ecosystem alters food chains. In most cases the impact is negative. This is when organisms which were not pests become pests. Monoculture can lead to loss of biodiversity, this can be seen at Kabuye sugar farms. Many organisms are killed and others are displaced in the process of preparing land for planting

c) **Ozone layer depletion:** Ozone layer is responsible for protecting earth from harmful ultraviolet rays. The presence of chlorofluorocarbons land hydro chlorofluorocarbons in the atmosphere is causing the ozone layer to deplete. As it will deplete, it will emit harmful radiations back to the earth.

d) **Loss for tourism industry:** The deterioration of environment can be a huge setback for tourism industry that rely on tourists for their daily livelihood. Environmental damage in the form of loss of green cover, loss of biodiversity, huge landfills, increased air and water pollution can be a big turn off for most of the tourists.

e) **Economic impact:** The huge cost that a country may have to borne due to environmental degradation can have big economic impact in terms of restoration of green cover, cleaning up of landfills and protection of endangered species. The economic impact can also be in terms of loss of tourism industry.

4.4. Pollution

Activity 4.6: Research activity

1. Using textbooks and the internet, carry out research about pollution.
2. Discuss the effects of pollution. Use the following questions as your guide:
   - What is pollution?
   - How does pollution affect the environment?
   - Suggest measures to combat pollution.
3. Compare your findings with the rest of the class.

The facts

Pollution is the addition of substances or energy forms to the environment in quantities that are harmful to organisms and destructive to an ecosystem. The substances that cause pollution are called **pollutants**. They range from toxic chemicals, noise from factories and vehicles, untreated sewage from homes, fertilisers from farms and heat from nuclear plants among others. Pollutants are released into the environment as a result of human activities. Pollution affects air, water and soil which are habitats of a variety of organisms.

Air pollution

Activity 4.7: Investigating effects of air pollution

Requirements

- Petroleum product e.g. tar, used motor oil
- Water
- Containers
- Planted seedlings
- Litmus paper

Procedure

1. Burn some petroleum products in a closed environment.
2. Dissolve the smoke produced in water.
3. Use a litmus paper to test for the pH of the resulting mixture.
   - Note your observations.
4. Pour the mixture on seedlings over a period of time.
   - Note your observations.
5. Write a report of your findings.

The facts

Air pollution is the addition of waste substances into the air. Air pollution occurs from the following sources:

- Factories, in the form of gaseous industrial waste, like carbon dioxide, sulphur dioxide and carbon monoxide. Smog due to smoke produced by factories combining with fog.
- In the burning of fossil fuels such as oil, petrol and wood which produce carbon dioxide and carbon monoxide.
- Motor vehicles which burn leaded petrol to produce car exhaust fumes and carbon dioxide. Motor vehicle exhausts also produce nitrogen oxides and hydrocarbons.
- Soot from burning of fossil fuel especially in cooking.

- Use of aerosols. Aerosols are liquid substances put in cans under high pressure so as to release them as sprays, for example, in pesticides.

Effects of air pollution

Acid rain

Acid rain contains large amounts of oxides of sulphur and nitrogen. This happens when gases, for example, carbon dioxide, sulphur dioxide and nitrogen dioxide are emitted to the atmosphere from factories or when sulphur dioxide and nitrogen dioxide are emitted from car exhausts, they dissolve in the water droplets when it rains to form acidic solutions that fall as acid rain. Acid rain damages plants, kills fish together with their eggs and also causes the corrosion of buildings made from limestone.

Sulphur dioxide and other air pollutants, when inhaled can cause alveoli of the lungs to join together, hence reducing the surface area for gaseous exchange. Some air pollutants cause constriction in the branches of bronchial tubes. This reduces the rate at which air is exchanged between the alveoli and air outside the lungs.

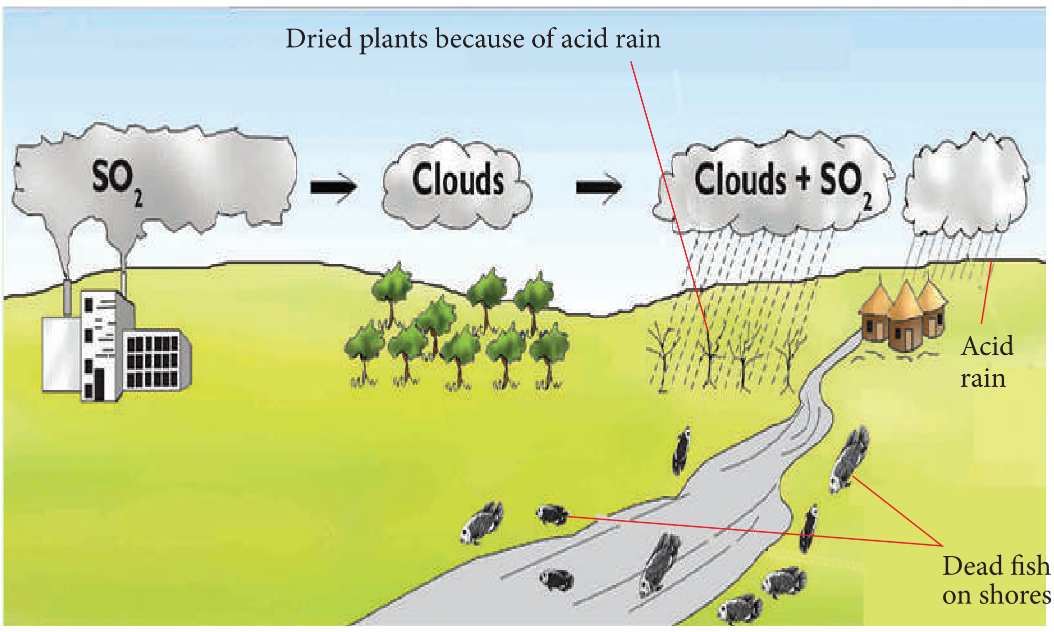


Fig 4.7: Some effects of acid rain

Acid rain can be prevented if:

- Factories that produce sulphur dioxide can be fitted with chemicals called acid scrubbers that absorb acidic gases from fumes before they are released into the atmosphere.
- Cars can be fitted with catalytic converters to clean up their exhaust gases.

Enhanced greenhouse effect and climate change

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 create a greenhouse effect. 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. Heat is trapped in the atmosphere increasing global temperatures by slowing down the loss of heat from earth to outer space. Increased temperature changes climate patterns that lead to typhoons, hurricanes and floods.

In some other areas, semi – arid areas become deserts.

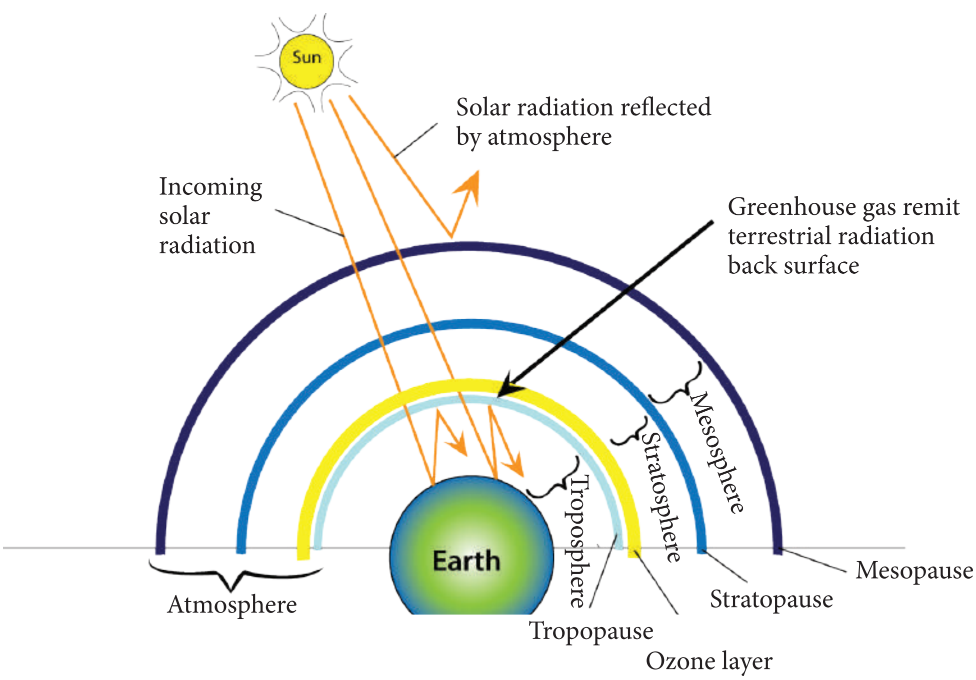


Fig 4.8: The greenhouse effect

This increase in global temperatures may result in the polar ice caps melting. This can raise sea level and it is thought to be responsible for floods in most parts of the low-lying coastal regions of the world today. The solution to this problem lies in the use of energy from non-fossil sources, controlled felling of tropical forests and reforestation of areas where the forests have been depleted.

Water pollution

Activity 4.8: Field study

1. Visit an area with poor sewage system that leads to a river or stream.
2. Follow the sewage system as it leads to a river or stream.
    - Note the activities the communities around do that pollute the river.
    - Ask around if there are diseases prevalent in the area associated with pollution of the river.
    - What is the community doing to prevent further pollution of the river?
    - What would be your suggestion to the community concerning water pollution?
3. Write a report on your findings.

The facts

Water pollution is the addition of harmful substances into water. These substances include toxic metals, pesticides and run off fertilisers. The substances may kill organisms in water or make it less suitable for drinking or for use in agriculture. Other causes of water pollution are wastes and sewage from houses, industrial wastes, agricultural practices and oil spills. Most rivers, lakes and streams are being polluted more and more by human activities.

Fig 4.9 (a): Dumping solid plastic waste in the river

Fig 4.9 (b): Releasing effluent from factory to the lake

Causes and effects of water pollution

(a) Wastes and sewage from homes

The release of organic wastes such as human faeces into water bodies, for example, lakes and rivers causes water pollution. Decomposition of these wastes by micro-organisms uses up oxygen in water. As a result, fish and other aquatic organisms die due to lack of oxygen.

Decomposition of wastes also releases nutrients into the water which cause rapid growth of algal, referred to as **algae blooms**. The large amounts of algae float in water and reduce light to photosynthetic organisms below. As a result, they are unable to carry out photosynthesis and hence die. As they decompose, oxygen is used up from the water causing the death of aquatic animals. This enrichment of the lake with nutrients and its effects is called **eutrophication**.

Untreated sewage also introduces micro-organisms which cause diseases such as typhoid, cholera and dysentery to human beings.

(b) Industrial wastes

Industrial wastes from breweries, tanneries, textile and paper industries contain toxic chemicals. These chemicals are harmful even in small amounts. This is because they can accumulate in fish and other aquatic organisms and then be transferred along the food chain to other organisms including fish-eating birds and human beings.

(c) Agricultural practices

Pesticides and excess fertilisers applied to crops may enter into rivers and lakes through runoff after rain. The pesticides are chemical compounds that are used to kill pests that damage crops. Some of the pesticides contain toxic metals such as copper. Excess fertilisers in water containing nitrates cause eutrophication which in turn causes death of aquatic organisms.

(d) Oil spills

Water gets polluted by oil that spills off from oil tankers in the sea as a result of accidents or poor maintenance. Such oil is toxic to aquatic plants and animals and kills many types of bacteria.

Water birds die when they ingest the oil in trying to clean it off from the feathers. Oil also reduces entry of oxygen into water and this leads to death of aquatic organisms.

Methods used to control water pollution

(i) Treatment of sewage before releasing it into water systems. This is done through water treatment plants which remove pollutants contained in sewage and any other disease causing micro-organisms present.

(ii) Avoid excessive use of chemicals in agricultural practices. Instead, biological control methods should be adopted, as this will reduce accumulation of harmful chemicals in the environment.

(iii) Proper legislation to be put in place by governments to avoid irresponsible dumping of industrial wastes into water bodies. Such legislations should be implemented and followed to the letter.

(iv) Avoiding spillage of oils into water bodies as much as possible. Petroleum companies should put measures in place to avoid unnecessary accidents which usually result to such spillage.

Land pollution

Activity 4.9: Investigating land pollution

Requirements

- Used motor vehicle oil
- Containers
- Grass field

Procedure

1. Pour some used oil on a selected piece of grass field within the school compound.
2. Wait for one week and record observable changes.
   - Are the grasses growing healthy?
   - Is it possible to do a clean up of the area?
   - Which other form of land pollution are you aware of?
3. Note the time it takes to clear the oil from the area.
4. Present your findings.

The facts

Land pollution is the addition of harmful substances into the soil. The main sources of soil pollutants are agricultural chemicals and disposal of solid wastes. Another form of land pollution is linked to nuclear fallout from destroyed nuclear plants, for example, in Chernobyl (Ukraine) and Fukushima (Japan). The land was totally polluted after the accident.

Fig 4.10: Land pollution

Causes and effects of soil pollution

(a) Agricultural chemicals

Agricultural chemicals refer to pesticides and fertilisers used by farmers in order to increase food production. Some pesticides, for instance copper sulphate used to control fungi in fruit orchards, are insoluble. Therefore, they accumulate in soil and reach levels that kill soil organisms especially the nitrogen-fixing bacteria. Some pesticides containing mercury are applied on seeds to prevent fungal diseases of newly germinated seedlings. Wild birds and mammals that consume these seeds get poisoned and killed. When fertilisers are used in the farms, they are washed down by rainwater into the rivers and lakes, where they cause eutrophication and lack of oxygen.

(b) Solid wastes

There are two main types of solid wastes. These are **biodegradable** wastes such as potato peeling wastes and cabbage pieces and **non-biodegradable** wastes such as plastic containers and scrap metals.

When biodegradable waste is not properly disposed, it rots and attracts flies. These flies breed in the wastes and become a threat to human health. The flies can spread diseases such as cholera or transfer microorganisms from the wastes of an infected person to the food of another healthy person. Solid waste dumping sites can be a habitat for rats, which can spread diseases such as plague.

Some of the non-biodegradable wastes can be a breeding ground for mosquitoes, which spread malaria besides being an eyesore.

Control of soil pollution

Many chemical pesticides are not easily broken down and tend to accumulate in the environment. A number of methods can be used to reduce or solve the problem created by pesticides and solid wastes. These are:

- Use of biodegradable pesticides, which break down to harmless substances within a few days. These pesticides will not accumulate in the soil.
- Controlling pests biologically is better than using chemical pesticides. One biological method is the use of natural enemies of the pests: predators and parasites of pests for example bacteria and viruses are common parasites of most pests. Crop rotation can also be used to kill pests naturally.
- Biodegradable wastes can be broken down by bacteria, they can be managed through compositing. This is the decomposition of biodegradable waste under aerobic conditions. The solid wastes may be household waste or industrial or agricultural waste.
- Non-biodegradable wastes cannot be broken down by bacteria, they can be managed through reusing and recycling. We can also reduce the amount of waste we produce.
    - **Reuse of waste:** This involves using a product or packaging material more than once in the same system e.g. re-usable glass milk bottles.
    - **Recycling:** This is using wastes to make new products or something different, for example Polyvinyl chloride (PVC) bottles are recycled into garden furniture or insulation material for clothing. Materials that can be recycled are collected from the households or industries and transported to factories where they are processed.
- **Incineration:** This is the burning of some types of non-biodegradable waste, for example medical wastes. This reduces the amount of wastes that need to be disposed of.

Fig 4.11: Burning wastes in incineration

Nuclear fallout

Nuclear fallout are particles of matter in the air made radioactive from a nuclear explosion or leakage. Some of these particles fall in the immediate area and some get blown away by upper winds many thousands of miles. Eventually they fall to the earth. This is called **fallout**.

A detonated nuclear bomb produces a fireball, shockwaves and intense radiation. A mushroom cloud forms from vaporised debris and disperses radioactive particles that fall on earth. When carried by wind currents, fallout can cause far-reaching environmental damage.

Fig 4.12: Nuclear fallout

Detonation of nuclear bombs above the ground can inject radioactive particles into the atmosphere causing global fallout. Any contact between the particles and organisms leads to radiation. Radiation has long term effects on human health. It has been linked to leukemia, bone, lung and breast cancer.

Self–evaluation Test 4.4

1. Who do you think is more responsible for pollution, individual people or the government? Explain.
2. What are some of the ways that you can use to reduce pollution in Rwanda?
3. Do you think nuclear power is safe? Explain

Activity 4.10: Project

1. Write a project for recycling paper and plastic bottle within your community.
2. Present your project findings.

Pollution by methane gas

Methane is a colourless and odourless gas at low concentrations but with sweet smell at high concentrations. It is highly combustible with mixtures of betweeen 5 to 15 percent in air being explosive. Upon release into the atmosphere, methane is destroyed by reactions with other chemicals giving it a lifetime of about 10 years.

As the major constituent of natural gas, methane is burned to directly heat homes and other commercial buildings. It is also used as a fuel in power stations to produce electricity. Methane is used widely in the chemical industry in the production of more complex chemical compounds. Methane occurs naturally in the environment. One of its major sources is from decomposition of plant and animal matter by methane-producing bacteria. These occur in airless environments such as marshes and in the gut of some animals and landfills. Methane is also trapped in small quantities within the earth's crust and is released during the mining of fossil fuels. On a global scale, the human activities that result in methane emission, in descending order of importance are: livestock farming, production of fossil fuels, wet rice cultivation, biomass burning, landfill and domestic sewage.

Excessive exposure to methane may affect the brain and ultimately leads to suffocation. Also, methane gas build-up from landfill sites is a potential explosion hazard. In the past, this has resulted in a few temporary evacuations of residents in housing estates built on top of old landfill sites that have not sufficiently vented the methane. As a volatile organic compound, it has been determined to have negligible photochemical reactivity and is unlikely to contribute significantly to the formation of harmful ground level ozone or photochemical smog.

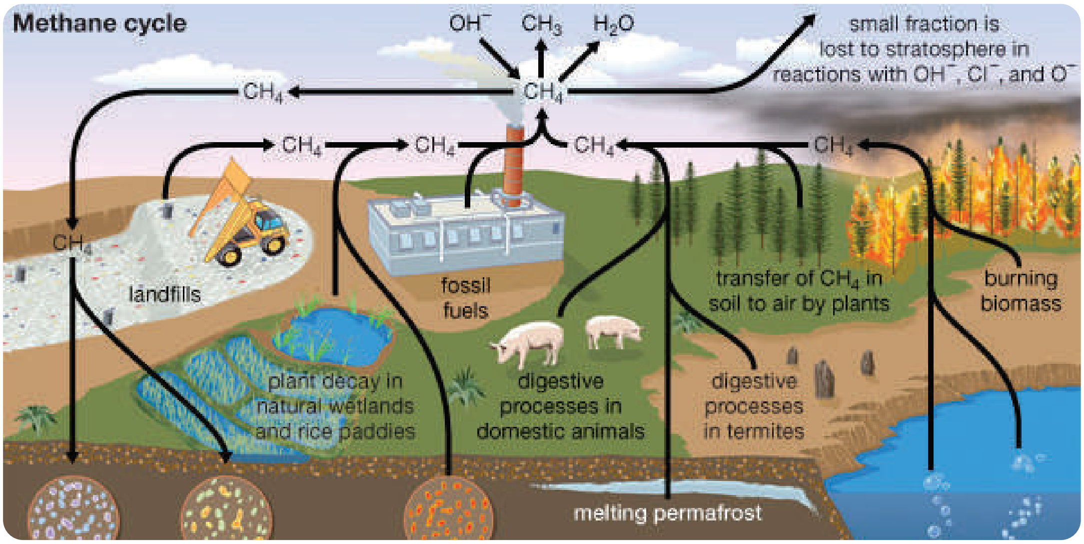


Fig 4.13: Diagram showing methane pollution

The main environmental concern with methane is the role it plays as a greenhouse gas influencing climate change. The concept of global warming potential has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. Although less methane is emitted into the environment, the global warming potential of methane is 21 times that of carbon dioxide for over 100 years.

Measures taken by Rwandan government to protect the environment

In order to find solutions to the environmental problems and ensure the protection and sustainable management of the environment, ten principles have been developed by the Rwanda government. The principles are:

1. Every individual has the right to live in a healthy and balanced environment and has the obligation of safeguarding environmental health.

2. Economic growth in Rwanda should be based on a more rational utilisation of resources and take into account the environment protection measures.
3. Active and effective participation of the entire population in the protection and management of the environment.
4. Special attention should be paid to educational and awareness creation programmes in environment at all levels with a greater involvement of women and the youth.
5. Introduction of the principle of prevention; this is aimed at preventing environmental issues rather than curing them.
6. Introduction of the principle of polluter-pays. This will help to deter environmental polluters.
7. Environmental impact should be analysed during consideration of developmental projects;
8. The principle of equality among generations and fair share in the utilisation of resources should be respected;
9. Establishment of a favourable social and economic environment for the utilisation of natural resources
10. Recognition of sub - regional, regional and global environmental interdependence and therefore working closely with other international players in managing environmental issues.

- In addition, the Rwandan government has set up institutions such as Rwanda Environmental Management Authority (REMA) which coordinates the implementation of Government policies or environmental issues. REMA also advises the Government on legislations and other measures relating to environmental management or to the implementation of relevant international conventions, treaties and agreements.

- Further, the Rwandan government is involving civil Society and private sector in the implementation of the environment policy. This is done through Non-Governmental Organisations which play a vital role in mobilisation and awareness creation among the population on environmental issues. The private sector too is required by law to take a more active role in the protection of the environment.

Unit summary

- Use of modern technology in agriculture has resulted into increased food supply. This is due to the use of chemical fertilisers, herbicides and selective breeding, among others.
- Monoculture is the use of land for growing only one type of crop.
- Intensive animal farming is a modern form of intensive farming that refers to the keeping of livestock, such as cattle, poultry and fish at higher stocking densities.
- Habitat destruction is the process in which the natural habitat is rendered unable to support the species present.
- Organism's habitats are destroyed due to increased areas for food and livestock production, construction of houses and roads, and extraction of natural resources.
- Pollution is the introduction of a substance(s) that has harmful or poisonous effects to the environment.
- Air pollution the presence in

or introduction into the air of a substance which has harmful or poisonous effects.

- Water pollution is the contamination of water bodies.
- Land pollution is the degradation of earth's land surfaces often caused by human activities and its misuse.
- Nuclear fallout, or simply fallout, is the residual radioactive material propelled into the upper atmosphere following a nuclear blast or a nuclear reaction conducted in an unshielded facility, so called because it "falls out" of the sky after the explosion and the shock wave have passed.

End Unit Assessment 4

1. Environmental degradation is disadvantageous in all the following ways except:
   A. affects the recycling of materials
   B. it preserves the natural resources for a longer time
   C. destroys habitats for organisms
   D. kills organisms
2. Describe the effects of acid rain.
3. (a) Explain how pollution affects our country.
   (b) Which form of pollution is widespread in Rwanda?
   (c) What should we do to increase awareness about environmental pollution?
4. (a) What are the effects of deforestation on the environment?
   (b) How can parks and forests in Rwanda be managed to keep them safe from poachers?
5. Explain the reasons for habitat destruction.
6. Discuss briefly the following:
   (a) Should we focus on controlling nature to satisfy our food requirement or work with it?
   (b) How does maintaining biodiversity play a role in food security?
   (c) Which benefits are realised by protecting the environment?
   (d) If you could choose one alternative energy source to develop, which one would you choose? Why?
   (e) Do you think recycling is an important environmental issue? Explain your answer
   (f) Should global warming be a major concern to the world? Why?
7. You are a member of the environment club in your school.
   (a) What is the importance of being a member of a club in school?
   (b) How can you impact your community with the knowledge obtained from the club activities?
8. There are scientists in laboratories all over the world working to develop better ways of making food. Do you think science can fix today's food problems?
9. Describe the effects of methane pollution to the environment?
10. Rwanda has put in place a body known as Rwanda Environmental Management Authority. What measures has REMA put in place to solve the issues related to environmental degradation in Rwanda?

Unit 5

Effects of human activities on ecosystems 2 (conservation and sustainability)

Key unit competence

After studying this unit, I should be able to assess the outcomes of conservation measures.

Learning objectives

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

- Define the terms sustainable resource and sustainable development.
- Explain the need to conserve non-renewable resources, limited to fossil fuels.
- State that some resources can be maintained, reused or recycled.
- Outline how sewage is treated to make the water that it contains safe to return to the environment or for human use.
- Explain why organisms become endangered or extinct and describe how endangered species can be conserved.
- Explain how forests and fish stocks can be sustained using education, legal quotas and re-stocking and give requirements for sustainable development.
- Organise clubs, design projects, conduct shows and plays on wildlife conservation aiming at environmental education and wildlife protection.
- Make research on the endangered species in Africa as a result of human activities.

Introductory Activity

Study the diagram alongside carefully.

Does the symbol look familiar? Find out the importance of the symbol and how it can affect our lives. Based on your answers predict what this unit is about.

Fig 5.1: 3Rs of conservation

Introduction

In your community, you have heard of the term *'Kwita Izina'*. What does it mean?

"Kwita Izina" is a uniquely Rwandan event launched in the year 2005. It is a naming ceremony for newly born mountain gorilla babies. The ceremony was created as a means of highlighting the importance of protecting the mountain gorillas and their habitats.

A gorilla is an example of an endangered species. Others are rhinos, elephants and hippos.

Fig 5.2: Gorilla beringei–endangered animal in the world.

Did you know?

Endangered organisms have to be protected from extinction in order to preserve them for future generations.

5.1. Sustainable resources and development

Activity 5.1: Research Activity

1. Using the Internet and text books carry out research on sustainable resources and development in Rwanda.
2. Talk to a friend about sustainable resources and development. Use the study questions below.

Study questions

(i) What does the term sustainable resources and development mean?

(ii) How do sustainable resources affect social, economic and ecological well-being of a country?

(iii) Distinguish between renewable and non-renewable resources.

(iv) How can we sustainably use fossil fuels?

(v) What is the importance of conservation?

The facts

Sustainable development refers to the type of development that meets the needs of the present without compromising the ability of the future generations to meet their own needs.

Sustainable resources on the other hand are those which are used or harvested in such a way that they are not depleted or permanently damaged, for example agriculture development of a country depends on the natural resources it can harness. Human beings need resources for social and economic development. Therefore, sustainable social, economic and ecological growth is a result of managing available resources efficiently without damaging the ecosystem. The natural resources include plants, animals, fossil fuel and minerals salts.

Conservation and preservation of natural resources are the principle guidelines for sustenance. Conservation of natural resources is the use of nature for social and economic development without wasting the resources and polluting the environment, while preservation of natural resources is the protection of the environment in its natural form at all costs.

A balance must be struck between conservation and preservation when developing social and economic factors. A program such as the Rwanda gorilla conservation is striving to maintain ecosystems by protecting endangered species and vulnerable environments.

Fig 5.3: Restoration of vulnerable environments in Gishwati Rwanda

Activity 5.2: Designing a poster

1. Design a poster for the wildlife club.
2. In your poster show how the clubs activities will be organised to propagate conservation ideas to the students and community around the school.
3. Present your poster for assessment.

Non–renewable resources

Activity 5.3

Discuss the questions below.

- Why is conserving the environment necessary?
- How can we use fossil fuels sustainably?

Sustainable resources should be used to meet short and long term benefits for the people. This is true for the use non-renewable resources. Non-renewable resources are resources which cannot be renewed to sustain social and economic development.

Non-renewable resources include ground water, metal ores and fossil fuels such as natural gas, coal and petroleum. Fossil fuels were made from the remains of organisms which died long time ago. These dead organisms were exposed to intense heat and pressure to form the fuels.

Fig 5.4: Mining tungsten in Rwanda by Bugarama Mining Company

Fossil fuels are the main source of energy for industries, motor vehicles and other machineries. Most of the energy used in the world today comes from fossil fuel. Therefore, there is a need to conserve fossil fuels. Conservation of fossil fuels can be done by exploring alternative sources of energy which are renewable. Renewable energy sources include hydroelectricity, wind, geothermal, thermoelectricity from hot springs, alcohol from sugar cane and sugar beets.

Use of fossil fuel as source of energy has been shown to lead to climate change and a contributor to global warming. Fossil fuels on combustion emit huge amounts of carbon dioxide and carbon monoxide into the atmosphere. High levels of carbon in the atmosphere coupled with deforestation is dangerous. Conserving fossil fuel helps to reduce greenhouse emissions thereby lowering global warming.

Some resources such as forests and fish stocks can be replenished if they run out. A destroyed forest can be replanted in a process known as **reforestation**. Diminished fish stock in a pond or water body can be replenished by introduction of fishling, which will repopulate the stocks.

Self–evaluation Test 5.1

1. Define sustainable development and discuss some of the key issues that are essential in such a process.
2. How does sustainable development make economic sense for society?
3. What can you do as a citizen for development to be more sustainable?

5.2. Reuse or recycling and sewage treatment

Activity 5.4: Field study

1. Go for a field trip to a recycling plant.
   - *Design a questionnaire you will use to gather information.*
2. Use internet and textbooks to find out about recycling.
3. Design a project for recycling papers, plastics and steel solid waste.
4. Share your findings with the rest of the class.

The facts

Recycling is the conversion of waste material into other materials that can be used (reused). This method is very useful in conservation of resources as it reduces use of new raw material. The environment is also protected indirectly. Waste material which is usually dumped in the environment can be recycled. Burning or dumping waste instead of recycling can lead to air, water or land pollution.

Recyclable material include: papers, glasses, plastics and metals. To recycle these materials, they are sorted and washed with water to remove all dirt. Then they are reprocessed into new materials for manufacturing other items.

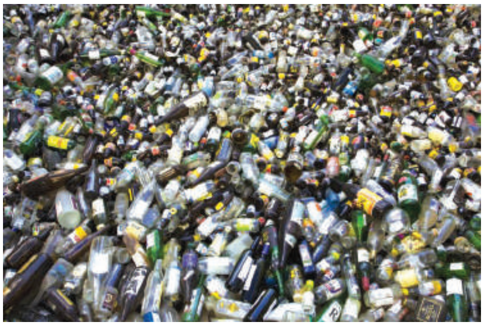


Fig 5.5: Materials that can be recycled

Recycling of waste materials has created jobs for many people in Rwanda. It has also reduced foreign exchange since fewer new products are imported. In Rwanda, many plants for recycling waste products have been established. Examples include:

- **Ecoplast**–located at Mageragere in Nyarugenge District. The plant recycles plastic materials such as plastic bags, used water bottles among others.
- Coped (Company for Environment and Development) – is a recycling company which deals with organic wastes. Hospitals, schools and residents are the major suppliers of organic wastes.

Sewage treatment on the other hand is the process of cleaning waste water from homes and industries by removing organic wastes. It involves three processes i.e biological, chemical and physical processes.

Fig 5.6: Sewage treatment plant in kigali city

At the end of all the processes, safe and clean water is obtained for domestic use while solid remains can be used to make manure for use in the farms.

Self-evaluation Test 5.2

1. Using old jericans to store water is an example of __________.
   A. recycling
   B. reusing
   C. reducing
   D. refusing
2. Which one of the following takes the most time to dissolve in nature?
   A. A bus ticket
   B. A plastic bottle
   C. A bottle of glass
   D. A woollen cloth
3. Why should industrial plants treat their waste water before dumping in water bodies?

5.3. Conservation of endangered species

Activity 5.5: Research activity

1. Using the internet and textbooks carry out research on the endangered species in Africa as a result of human activities. What do we call endangered species?
2. How can endangered species be conserved?
3. Identify some endangered plant and animal species in your community.

The facts

Endangered species are both plants and animals although most emphasis is put on animals. This is because animals are disappearing much faster than the plants. An organism becomes an endangered species when it is likely to become extinct. All countries in the world are required to conserve all endangered species.

Natural causes can also lead to extinction of organisms. Such causes include:

- Rapid changes in temperature and climate that affects organisms.
- Changes in sea level and water currents.
- Acid rain which increases the acidity of the soil which affects plant life. It can also disturb rivers and lakes.
- Diseases and epidemics.
- Invasive species that invade foreign territory. They use resources that the other species depend on. Once competition gets too great, the survival of the fittest begin, and one of the species, usually the less adapted one, will die off.

Human activities contribute to the extinction of organisms. This is through:

- Uncontrolled population increase.
- Destruction and fragmentation of habitats.
- Pollution of the environment.
- Climate change or global warming.

Extinctions caused by humans are generally considered to be a recent phenomenon.

Fig 5.7: Deforestation

Conservation of endangered species

Activity 5.6

1. Dramatise wildlife conservation.
2. In your skit, include human effects on protected and unprotected areas.
3. Rehearse your skit and present a performance to the school.

An endangered species is at risk of becoming extinct, for example, the gorilla are endangered and may become extinct. A species is endangered when its population falls below a critical level.

It is important to conserve the variety of living things on earth. We have moral and cultural reasons for conserving endangered species. Conservation seeks to:

- Maintain the future possibility that plant species might be identified for medicinal value.
- Keep damage to food chains and food webs to a minimum.
- Protect our future food supply.

Conservation measures for endangered species include:

(i) Monitoring and protecting species and habitats

Habitat monitoring is an important tool for assessing the threat and conservation status of species and protected areas. This can be done at global and regional levels, where data is available. Habitat indicators are used to assess the threat to endangered species.

Assessment of species threat is done and threat levels estimated by an international body known as International Union for Conservation of Nature (IUCN). The body recommends action to be taken to preserve an endangered species.

(ii) Education programmes

Providing education programmes to communities living around a conservation area about the importance of conservation will assist in protecting such organisms. The community becomes aware and gets involved in such initiatives. The public can be educated through the following methods:

- Distribution of information packets or flyers.
- Contacting local schools to organise educational sessions for pupils.
- Advertising in local newspaper(s) or regional newsletter.
- Giving presentations at village gatherings.
- Setting up interviews in local radio and television stations.
- Posting relevant videos and messages on social media sites, local public information channels or websites.

(iii) Captive breeding programmes

Captive breeding provides a means for conserving species that may not survive in the wild. Captive populations are established for many reasons such as conservation education, exhibition of interesting species and research purposes. Establishing captive populations for saving species from extinction is an important contribution of zoos to conservation. The aim of captive breeding is to establish captive populations that are large enough to be stable and genetically healthy or to reintroduce animals back to the wild.

Fig 5.8: Mountain Gorilla in Volcanoes National park

(iv) Seed banks

A seed bank is a store for seeds preserved for genetic diversity; a type of gene bank. Seed banks are useful because they provide: genes that plant breeders need to increase yield, disease resistance, drought tolerance and nutritional quality. They are also used to store seeds in case of genetic diversity loss in endangered plant species in an effort to conserve biodiversity. Seed banks offer a way to preserve historical and cultural value.

In Rwanda, Gishwati Forest Reserve (GFR) was set up to help in conservation. The major reason for conserving Gishwati is the endangered species that are found there. It is hoped that Gishwati forest will join Nyungwe forest as many trees have been planted between the two forests. This will provide the Rwandan economy with benefits from ecotourism from the biodiversity found in the area.

Another initiative by the Rwanda government was the gorilla naming ceremony that was initiated in 2005. This activity has developed to be the country's biggest tourist attraction.

It is named ***Kwita Izina*** after the traditional child naming ceremony.

Observation of mountain gorilla in Virunga forest reserves and Bwindi in Uganda indicate an increase in their number.

Fig 5.9: Kwita Izina ceremony

Further Activity

Attend a Kwita Izina ceremony and compare it to the traditional child naming ceremony.

Self –evaluation Test 5.3

1. Why are some species termed as endangered?
2. Why should endangered species be protected?
3. Give the difference between a threatened species and an endangered species.

5.4 Requirements of sustainable development

Activity 5.7: Field study

1. Identify organisations and projects in Rwanda that are dedicated to sustainable development such as Rwanda Initiative for Sustainable Development (RISD).
2. Plan to visit such organisations to carry out a study.
3. Make the questionnaire you will use to engage the officers involved.
   - How do the projects help the community around?
   - Have the projects achieved their objectives?
   - Suggest changes you can introduce to the projects to make them sustainable.
2. Compare effects of human activities on protected and unprotected areas.
3. Write a report on your findings.
4. Share your work with the rest of the class.

The facts

There are three factors that affect sustainable development which must be addressed, **economic growth**, **environmental awareness** and **social issues**. Sustainable development requirements include a strategy that will develop the social, financial and environmental resources to meet the needs of people. It should be implemented in such a way as to meet the needs of future generations.

An increasing global population needs more resources. At a basic level the following are required: uncontaminated food and water supplies, shelter, clothing and good health. All these requirements are obtained from natural resources.

The natural resources have increasing demands upon them and can be difficult to manage. Sustainability aims to preserve the environment and retain resources for future generations to enjoy.

To conserve natural resources for future generations, sustainable management of the natural environment is necessary. Alternative resources might be developed in order to ease the strain on non-renewable resources. However, alternative resources can be expensive and take time to develop. Existing resources could be used more efficiently, to prevent non-renewable resources being used up so quickly.

Fig 5.10: Solar power as an alternative source of energy

Nature conservation and its place in sustainable development is one of the major challenges facing humanity. Global conservation cannot be resolved by one country acting alone. Each country has to contribute to this international effort.

Each country must ensure international cooperation; promote cooperation towards conserving the environments of developing regions and equip its citizens in doing the same.

To promote international cooperation, the government has to guarantee international cooperation in research, observation and monitoring conservation activities.

The government has to encourage activities by local organisations and private organisations. When coming up with policies, the government has to keep in mind the conservation of the environment.

In Rwanda the government has put in place measures for sustainable development in a document known as Rwanda's Vision 2020 programme. The following are the major requirements of sustainable development in Rwanda.

(a) Methods to reduce poverty using cooperatives.
(b) To improve health services in order to reduce infant mortality rate.
(c) Reduction of HIV and AIDS.
(d) Eradication of Malaria.
(e) Education for sustainable development.
(f) Participation of people in decision making by empowering them.

Education is necessary for sustainable development. It is critical in promoting and improving the understanding of people when addressing environmental issues connected with development. It is important to change people's attitude through information so that they can assess and solve sustainable development concerns. What is important is to achieve environmental and ethical awareness, values, and skills and culture which are consistent with sustainable development.

Self–evaluation Test 5.4

1. What actions can be taken to promote international cooperation in conserving biodiversity?

2. Suggest measures to be taken to control wildlife trafficking.
3. How do you suppose the Rwanda government will achieve Rwanda's Vision 2020 programme?

5.5 Benefits of conservation programmes

Activity 5.8: Interactive talk

1. Listen to the public speaker.
2. Prepare a questionnaire you will use to engage the speaker.
3. Listen and ask questions during the presentation.
    - What are the effects of conservation in nature?
    - How do we gain from conserving the environment and organisms?

The facts

Conservation programmes aim to preserve the natural environment, keeping it from harm or damage for later use. Conservation also aims at maintaining quantity, management, protection and wise use of natural resources to support life. The benefits of conservation include:

- Reducing extinction of species.
- Protecting vulnerable environments.
- Maintaining ecosystem functions.

(a) Reducing extinction of species

The extinction of plants and animals is not new. It has been happening as a natural part of the process caused by natural disasters such as disease or drought. In recent times, human activities have contributed to the extinction of many species of plants and animals. The activities include collecting, hunting and trading of plants and animals parts. However, the main cause for concern is habitat destruction.

Once a species becomes vulnerable, almost any level of environmental change or disturbance can affect its status. Through conservation strategies, many species of plants and animals have been maintained and saved from extinction.

(b) Protecting vulnerable environments

Environmental vulnerability is an estimate of the inability of an ecosystem to tolerate stress over time. Vulnerable environment include forests, natural reserves and game parks bordering human occupation, water bodies near oil exploration sites and soils near nuclear sites.

Through conservation measures, vulnerable environments have been protected and effects reduced.

Fig 5.11: Nyungwe forest is an example of vulnerable environment in Rwanda

(c) Maintaining ecosystem functions

Ecosystem function refers to the biological and physical processes and components that take place or occur within an ecosystem. Ecosystem function relates to the structural components of an ecosystem and how they interact with each other within the ecosystem and across ecosystems.

Maintaining ecosystem function is important in sustaining the capacity of an area. Conservation measures seek to prevent environmental degradation hence maintain a healthy ecosystem function.

Comparison of human effects on protected to unprotected areas

Activity 5.8: Research activity

Organise a field study to compare human effects on protected and unprotected. Find out and report back any effects of human activity on protected and unprotected areas and how these are mitigated.

A protected area is a geographical space, recognised, dedicated and managed through legal or other effective means to achieve conservation of nature while an unprotected area is a geographical space which lacks restriction and can be accessed by anyone without seeking legal permission. The areas which are protected by the Rwandan government are mainly three, namely: The Akagera National Park that covers an area of 108, 500 ha. There are several endangered plant species in Akagera, including *Markhamia lutea* and *Eulophia guineensis.* Nyungwe National Park has an area of 101,900 ha and Volcanoes National Park has an area of 16,000 ha. In addition, the forest reserves are the Gishwati Forest Reserve (700 ha), Mukura Forest Reserve (1600 ha), Busaga Forest Reserve (150 ha) and Buhanga forest and gallery forest in the eastern province of about 160 ha. The protection of the reserves has done wonders as Gishwati forest reserve is transforming to its former biodiversity. It's the same thing with Nyungwe National park. It can be that all areas which are near protected areas lack the biodiversity which is in the protected areas. Take an example of the three districts in which Akagera National park is found. People around the park carry out various activities such as farming, fishing and burning charcoal which reduce the biodiversity enjoyed in the protected area. Cutting down of trees, domestic animals encroachment, poaching and introduction of new species that never existed before are some of the ways in which human beings affect protected areas as they interfere with the abundance and diversity. Humans also affect the unprotected area majorly by polluting air, soil and water.

Fig 5.12: Nyungwe forest reserve

Self–evaluation Test 5.5

1. How can we conserve the environment better?
2. What kind of challenges do you think conservationists face?
3. Sustainable development will not aim at:
   (a) Social economic development which optimises the economic and societal benefits available in the present, without spoiling the likely potential for similar benefits in the future.
   (b) Reasonable and equitable distributed level of economic well-being that can be perpetuated continually.
   (c) Development that meets the need of the present without compromising the ability of future generations to meet their own needs.
   (d) Maximising the present day benefits through increased resource consumption.

Project Work

1. Design and execute a project for recycling papers, plastics and steel solid waste in your community.
2. Present your report to the teacher for assessment.

Unit summary

- Sustainable resources are those resources that are replenished at a rate equal to, or greater than the rate of consumption.
- Renewable and sustainable resources are not the same thing. Unlike a renewable resource, a sustainable one does not have to be replenished quickly, as long as it is consumed slowly.
- Sustainable development is an economic development that is conducted without depletion of natural resources.
- Non-renewable resources are resources for which have limited supply. The supply comes from the earth itself and, as it typically takes millions of years to develop.
- Fossil fuels are natural fuels such as coal or gas, formed in the geological past from the remains of living organisms.
- The most effective way to reduce waste is to not create it in the first place. Reduction and reuse are the most effective ways you to save natural resources, protect the environment and save money.
- Sewage treatment is the process of removing contaminants from wastewater, primarily from household sewage.
- Extinction is the act of ending the existence of a plant or animal.
- Endangered species is a species of animal or plant that is seriously at risk of extinction.

- For sustainable development to be achieved there has to be management of conflicting demands and cooperation at local, national and international levels.
- Conservation programmes reduce extinction, protect vulnerable environments and maintaining ecosystem functions.

End Unit Assessment 5

1. (a) Define sustainable resources and sustainable development.
   (b) Which one of the following is **NOT** an example of sustainable resources?
      A. Recycling
      B. Reducing
      C. Reusing
      D. Removing
2. Which of the following cannot be recycled?
   A. Paper
   B. Organic waste
   C. Glass
   D. Metal
3. Which of the following statements in relation to sustainable development is not true?
   (a) Sustainable development is defined as the development that meets the needs of present without compromising the ability of our future generations to meet their own needs.
   (b) Sustainability has the main objective of purely focussing on the natural environment.
   (c) Sustainable development of various countries and the entire world is the only solution left with mankind to survive for a longer period on Earth.
   (d) Sustainable development not only considers the protection of the environment but also the maintenance of economic viability as well as the social and ethical considerations.
4. The human activity, among the following, which causes maximum environmental pollution having regional and global impacts, is:
   (a) Urbanisation
   (b) Industrialisation
   (c) Agriculture
   (d) Mining
5. (a) Why should non-renewable resources be conserved?
   (b) What are the challenges faced in treating wastewater?
6. (a) Suggest ways you as an individual can help conserve endangered species.
   (b) Which human activities can lead to species extinction?
   (c) What is the point of saving endangered species?
7. Differentiate between conservation, restoration and stabilisation.
8. Explain how captive breeding programmes help in conservation of endangered species.
9. Describe how sustainable development leads to conservation.
10. Explain how human activities affect areas that are protected.

Unit 6

Mitosis and meiosis

Key unit competence

After studying this unit, I should be able to explain the different processes of cell division and their implications on living organisms.

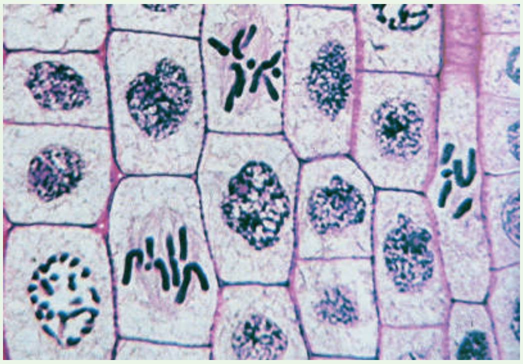
Learning objectives

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

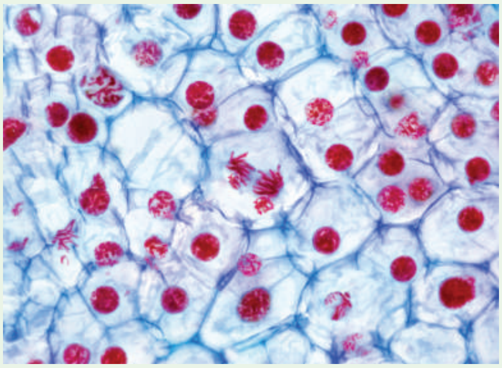
- Recall DNA, chromosome and cytokinesis.
- Explain the role of mitosis, meiosis and duplication of chromosomes.
- Outline the stages of mitosis and arrangement of chromosomes.
- State that meiosis is involved in gamete formation in sex organs.
- Compare mitosis and meiosis.
- State significance of meiosis division.

Introductory Activity

1. Study the photomicrographs below.



A



B

Fig 6.1: Cell division in plant cell

Research about what is going on in each photomicrograph. How do they relate to mitosis and meiosis?

2. Study the flow-chart below.

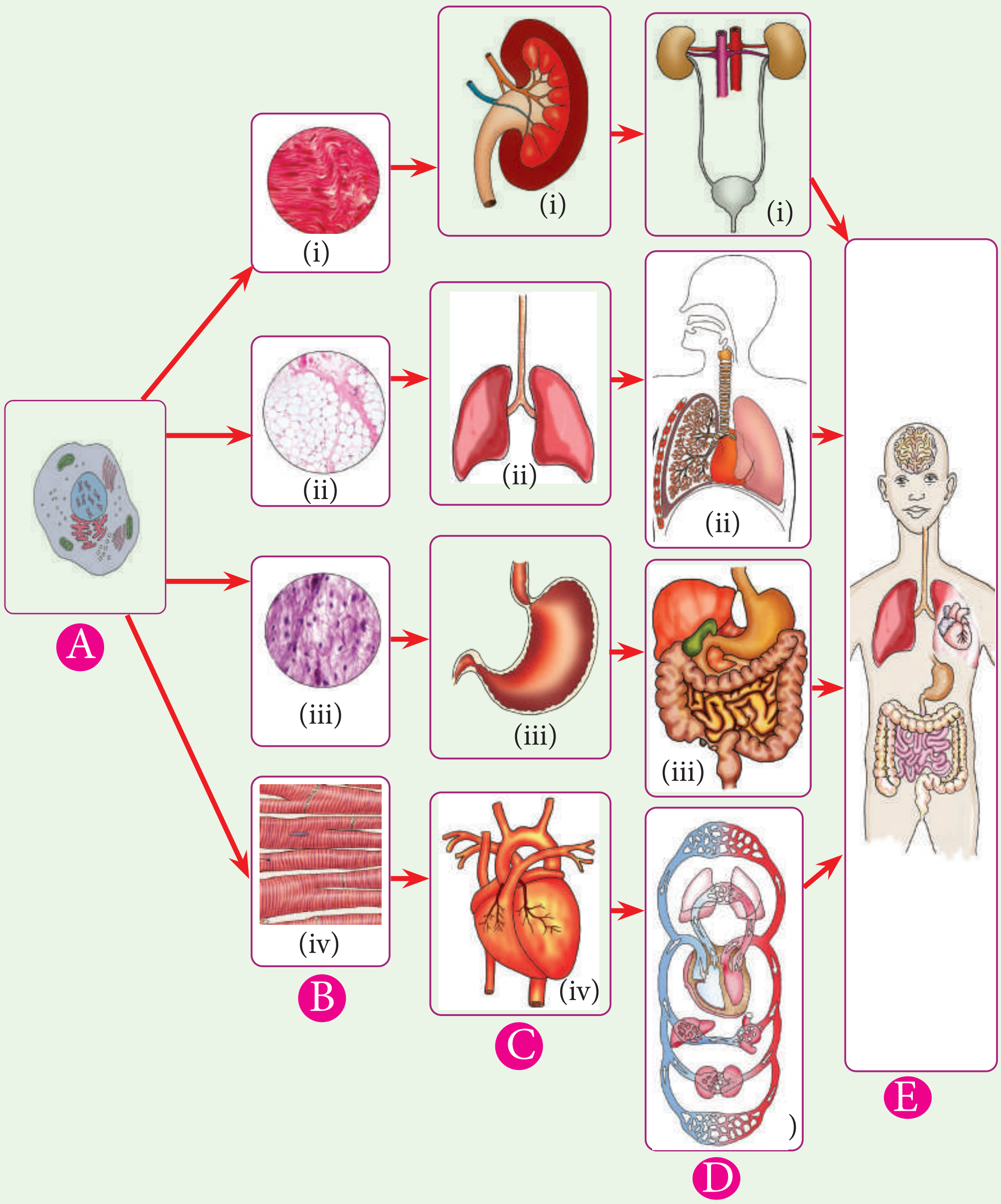


Fig 6.2: Organisation structure of a multicellular organism

Identify what **A**, **B**, **C** and **D** represent. What does the diagram tell you about how organisms come into existence? Use this information to predict what you are likely to learn in this unit.

Introduction

Each one of us began as a single cell. This cell could not move, talk or think like we do. However, there was one thing it could do very well: **divide**. Divide it did! Several times! The single cell became two, then four, then eight and so on. With time, it became the person that you are now! You can now think on your own, talk, work and move your body parts. This is the amazing result of cell division. The processes of **mitosis** and **meiosis** happen during cell division.

6.1. Chromosomes

Activity 6.1 Research Activity

Carry out a research about chromosomes.

1. Use the following lead questions:
   (a) What are chromosomes?
   (b) How are they formed?
2. Watch the video through the Youtube link: Division of chromosomes then answer the above questions.

The facts

Cells contain a **nucleus** which controls and regulates all the activities of the cell 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.

Chromosomes occur in the nucleus in pairs. These pairs are called **homologous chromosomes**. Homologous pairs of chromosomes have the same length and shape but with different genetic composition. Chromosome numbers also vary according to the type of cell in the organisms. The difference in number of chromosomes in an organism depends on whether the cell is a normal body cell or a reproductive cell. The number of chromosomes in the nucleus of a plant or an animal cell varies according to the species, for example, in human beings, there are 46 chromosomes in the body cells (in 23 pairs).

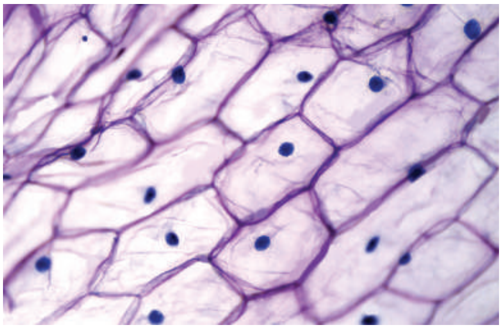


Fig 6.3: Onion cells under a light microscope- before dividing

All cells are formed from already existing cells through **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 structure. When stained, such structures are visible under the light microscope.

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 where they join is called **centromere.**

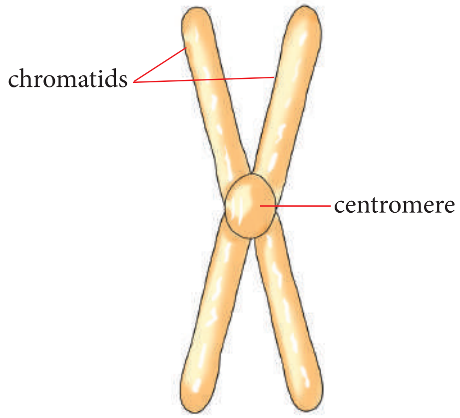


Fig 6.4: The structure of a chromosome

6.2. Cell division

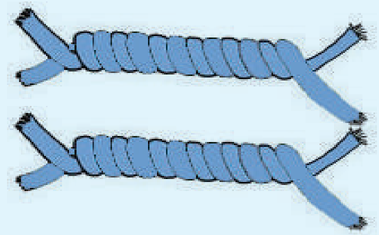
Growth is one of the characteristics of all organisms. It is the irreversible increase in mass. It occurs because of **cell division.** (Remember, cells originate from pre-existing cells). During growth, the cells increase in number through cell division. The two types of cell division are **mitosis** and **meiosis**.

During cell division, the two chromatids in a chromosome separate with each going into a separate cell as you shall learn later.

Activity 6.2: Analogy of replication of chromosomes during cell division

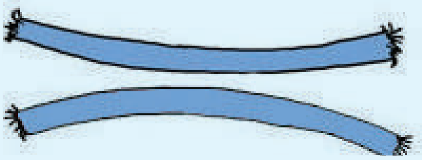
Requirements

- Two twisted ply wool (a rope or twine may also be used)

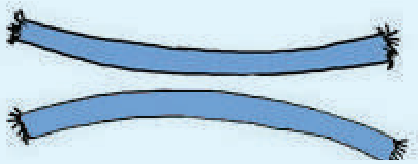


Procedure

1. Untwist the first wool or rope from one end as shown below.



2. Untwist the second wool or rope from one end as shown below.



3. Answer the questions below.
   (a) How many sets of twisted coloured ply wool did you start with?
   (b) How many sets of untwisted wool did you end up with?
   (c) Relate your findings in this activity to what happens inside the nucleus of a cell.

Self-evaluation Test 6.1

1. A human being has _____ number of chromosomes.
   A. 23
   B. 46
   C. 12
   D. 28
2. Each chromosome consists of two identical__________.
   A. genes
   B. nuclei
   C. chromatids
   D. bases
3. Which of the following is correct?
   A. The chromosome number is constant within individuals in a species in an ecosystem.
   B. The chromosome number is constant within different species in an ecosystem.
   C. The chromosome number is constant within somatic cells of an organism.
   D. None of the above.

6.3. Mitosis

Activity 6.3: Examining the stages of mitosis using squashed young onion root tip

Requirements

Germinating onions, 1M HCL
Test-tube, microscope
microscope slide, water
orcein dye (for staining), white tile
scalpel, glass rod, cover slip
blotting paper and forceps.

Procedure

1. Cut off 0.5 cm from the end of a root tip of the onion.
2. Place it in a little 1M hydrochloric acid which has been heated to 60°C in a test-tube.
3. Leave it for 10 minutes. Remove the piece of root tip using forceps and wash it in running water.
4. Place the root tip on a microscope slide and remove excess water using the blotting paper.
5. Place a small drop (0.5 cm diameter) of orcein stain on the tip just enough to prevent it from drying up.

   Note: Orcein dye is used to stain chromosomes to make them visible.
6. Tap the root tip gently with a glass rod until no particles are seen. Remove any particles big enough to be seen. What is left should be a suspension of separated cells.
7. Lower the cover slip on the slide and leave for 10 minutes.
8. Use blotting paper to absorb any excess liquid. (Avoid lateral movement of the slide.)
9. Examine the slide carefully under the low power then high power objective lens of the microscope.

Study questions

(a) Can you see any chromosomes? What is the appearance of the chromosome?

(b) Try to count the number of chromosomes in the cell in your preparation. Record it down.

(c) Notice cells at different stages of development. Notice any patterns.

(c) Draw one cell in each of these stages, arrange the drawings in their correct sequence beginning with the first stage to the last.

The facts

Mitosis is the process by which the nucleus of the cell first divides into two daughter nuclei. Each daughter nucleus ends up with a set of chromosomes, which are identical. After the nucleus divides, the cytoplasm then divides. This results in two cells that can exist independently. A simple way of understanding mitosis is by first following what generally happens to the chromosomes in the nucleus before following it up with what is also going on in the entire cell.

The following is an outline of the main events that involve only the chromosomes in an imaginary cell with two chromosomes.

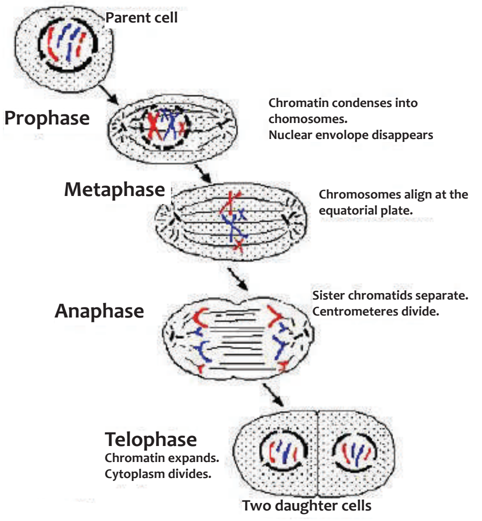


Fig 6.5: A generalisation of the process of mitosis

This way, it is possible for one set of chromosomes to be apportioned into each daughter cell that is formed when cells divide by mitosis. This means that each daughter cell can retain the original number of chromosomes in its nucleus.

Stages of mitosis

The process of mitosis is an orderly sequence of events that happens to the whole cell. This sequence of events can be categorised into four stages with a resting phase in between. Even though they can be studied separately, each stage is a continuation of the other. They therefore, form a cycle of events.

The main stages of mitosis are:

- Prophase
- Metaphase
- Anaphase
- Telophase

Prophase is preceded by a resting phase called **Interphase.**

(a) Interphase

Interphase is the interval in the cell cycle between two cell divisions when the individual chromosomes cannot be distinguished. It was once thought to be the resting phase but actually it is the time when DNA is replicated in the cell nucleus.

In this phase, chromosomes are not visible under the light microscope. They appear as a twisted mass of thread-like structures called **chromatin**. During this stage, there is high metabolic activity as the cell generates energy in preparation for cell division. It is at this stage that the genetic material i.e. DNA replicates. As a result, each chromosome doubles itself into two sister chromatids. New cell organelles are then formed.

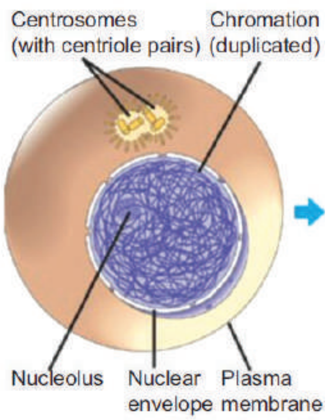


Fig 6.6: Interphase stage of mitosis

(b) Prophase

During this phase, the chromosomes become visible as long, thin entangled threads. They gradually start to shorten and thicken and can be seen to comprise of two chromatids joined at the centromere. The centrioles, which are tiny structures that lie just outside the nucleus move to opposite poles of the cell. (Note that plant cells do not usually have centrioles). From these centrioles, strands appear. They form a star like structure. These strands are called **spindle fibres** and spread from one pole to the other.

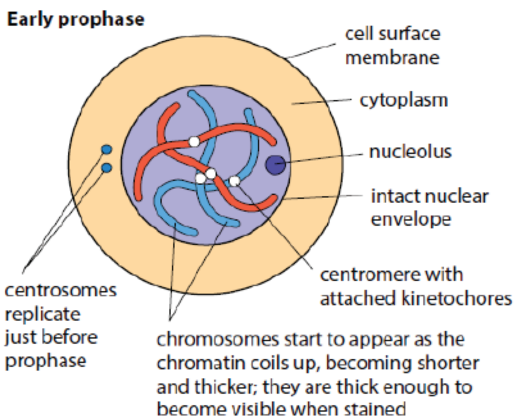
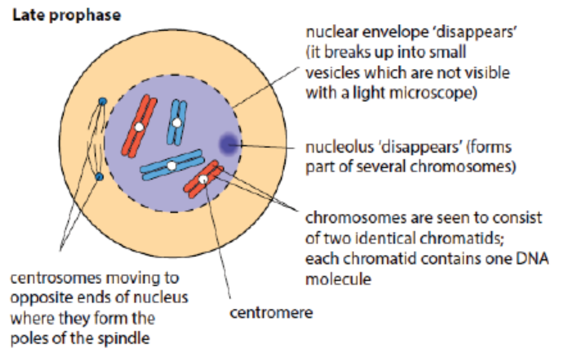


Fig 6.7: Early prophase



At late prophase the nucleolus disappears and the nuclear membrane breaks down leaving the chromosomes within the cytoplasm of the cell.

(c) Metaphase

During metaphase, the chromosomes arrange themselves at the centre or the equator of the spindle. They become attached to certain spindle fibres at the centromeres. These spindle fibres contract a little, separating the chromatids slightly. The following diagram shows chromosomes lined up at the equator.

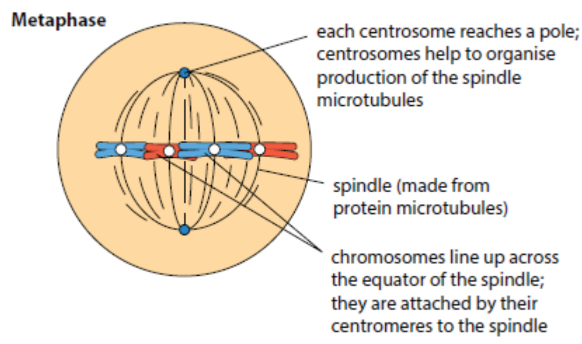


Fig 6.8: Metaphase

(d) Anaphase

During anaphase, the centromeres split and the spindle fibres shrink or shorten even more causing separation of the two chromatids. They move towards opposite ends or poles of the cell.

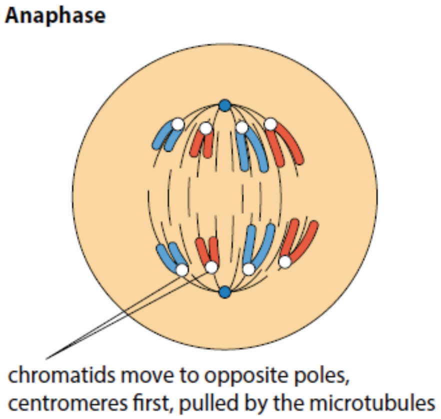


Fig 6.9: Anaphase

(e) Telophase

During telophase, the chromatids reach their respective poles and become chromosomes. A new nuclear envelope forms. The spindle fibres disappears and a new nucleolus forms in each new nucleus. The cytoplasm divides and the cell separates into two daughter cells. This is known as **cytokinesis**. Each daughter cell has the same number of chromosomes as the original parent cell. Chromosomes regain their thread-like appearance and return to the interphase stage.

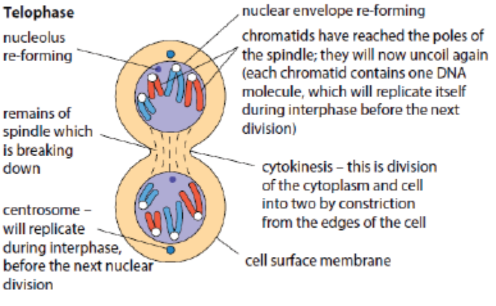


Fig 6.10: Telophase

Importance of mitosis

Mitosis is important because it is responsible for:

(i) The process of asexual reproduction. This is due to the formation of new cells which retain the same number and exact copies of chromosomes as the parent cell. Asexual reproduction gives the ability to produce large quantities of offspring in a short period of time. However producing large number of similar organisms by mitosis can lead to the competition and less resistance to the environment changes and might not survive.

(ii) Growth in organisms. New cells are formed through mitosis. This increases number of cells in an organism leading to growth of an organism.

(iii) Replacement of damaged or worn out cells in the body. Cells are replaced by existing cells that divide through mitosis.

Facts of life

- Most animal cells are capable of dividing by mitosis when the need arises. Plant cells however are not all capable of dividing by mitosis. Only a specialised group of plant cells called meristematic cells are able to do so.
- In specialised tissues like nerve tissue, division of cells stops once the cells mature. This explains why injuries to the spinal cord and the brain sometimes leave the patient paralysed permanently.

Self-evaluation Test 6.2

1. Why does mitosis result in daughter cells with nuclei identical in chromosomal number and composition to the parent nuclei?
2. The spindle fibres are produced by the __________.
   A. centrioles
   B. nucleus
   C. chromosomes
   D. chromatin
3. Which of the following is correct?
   A. The chromosomes shorten and thicken during prophase.
   B. The nucleolus re-appears during telophase.
   C. Interphase is characterised by little cellular activity, as the cell is resting to prepare for the next mitotic event.
   D. All of the above
4. A cell with 10 chromosomes undergoes mitosis. How many daughter cells are produced? Each daughter cell has ___ chromosomes.

6.4. Meiosis

Activity 6.4: Examining stages of meiosis in the anthers of a flower

Requirements

- Immature anthers (still enclosed inside the flower buds, for example, lily)
- Acetic orcein dye (ten parts dye to one part HCl); Slides and cover slips, mounting needles, white tile, hand lens, glass rod, filter paper/tissue, source of heat, forceps and microscope.

Procedure

1. Take a flower bud and remove the enveloping sepals and petals. Expose the anthers. Do this on the white tile using a needle and forceps.
2. Use the hand lens to help you identify the anthers.
3. Remove one anther and place it onto the microscope slide.
4. Add two drops of acidified acetic orcein dye.
5. Squash the anther with a glass rod for a while and leave for a minute for the stain to penetrate the tissue.
6. Place a cover slip and press downwards gently. Remove excess liquid using a filter paper.
7. Examine the slide and look out for cells that have nuclei that is under cell division.
8. Try to locate and identify the chromosomes in different cells.

Study questions

(a) Are there chromosomes that appear to have replicated?

(b) What similarities and differences do you notice in the various cells?

The facts

Meiosis is a type of cell division that occurs in the reproductive cells. It reduces the number of chromosomes in a cell by half. It is important in the formation of gametes i.e. sperms and ova. During this process the original cell first divides into two. Each cell then divides further into two cells forming a total of four cells. Each of the four cells has half the number of chromosomes as the original. It is said to be **Haploid (n).** A case where a cell has full number of chromosomes it is known as **Diploid (2n).**

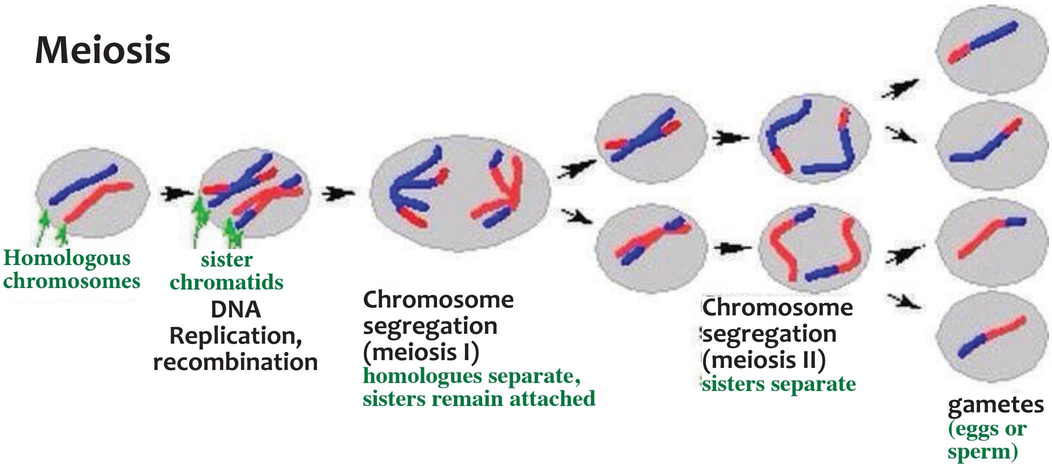


Fig 6.11: A generalisation of the process of meiosis

Meiosis also allows exchange of portions of chromosomes during division. This leads to genetic variation in offspring.

The stages of meiosis

The stages of meiosis form a cycle of events which can be divided into Mitosis and mieosis II.

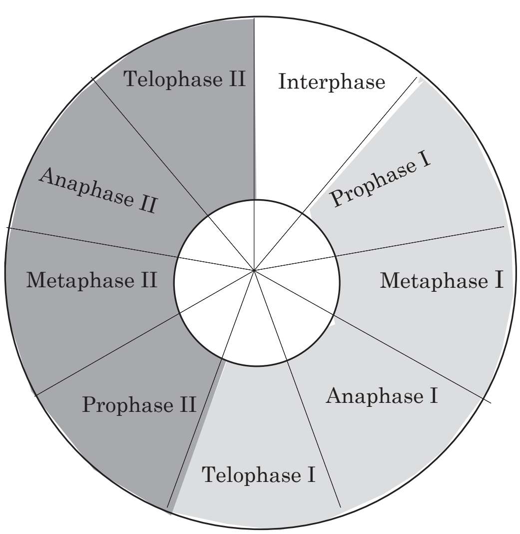


Fig. 6.12: The cycle of meiotic division and stages that occur during meiosis

(a) First meiotic division (Meiosis I)

This is divided into:

Prophase I

Metaphase I

Anaphase I

Telophase I

(b) Second meiotic division *(Meiosis II).*

This is divided into:

Prophase II

Metaphase II

Anaphase II

Telophase II

Interphase stage occurs between the two meiotic divisions.

Interphase

In interphase, as shown in mitosis, the cell is not dividing. The chromosomes are not visible.

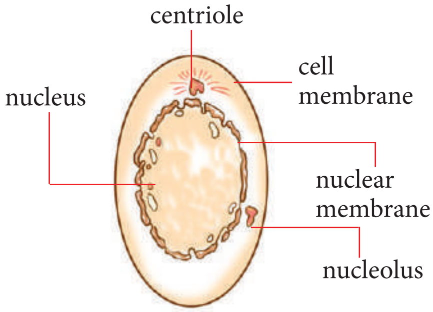


Fig. 6.13: Meiotic interphase

The chromosomes and cell organelles replicate.

Prophase I

Prophase I starts when the chromosomes contract and shorten becoming more clearly visible. The nucleolus disappears. The homologous chromosomes pair up. Each pair is called a **bivalent**. After that, each chromosome is seen to be clearly made up of two chromatids which are not clearly visible during interphase as shown in the following two diagrams.

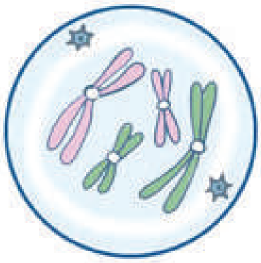


Fig. 6.14 (a): Chromosomes visible

Chromatids of homologous chromosomes may then wrap around each other and become joined at certain points called chiasmata (Singular: chiasma).

One (or both) of the chromatids of the two homologous chromosomes may break at these points and link up with the chromatid of the other chromosome in the bivalent at points called **chiasmata**.

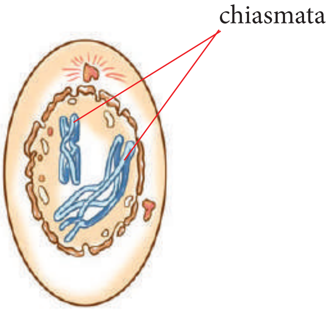


Fig. 6.14 (b): Chromatids of separate homologous chromosomes linked at chiasmata during crossing over

Formation of chiasmata ensures that the portions of chromosomes are exchanged in a process called **crossing over.**

Metaphase I

In metaphase, the spindle is fully developed. The bivalents (pairs of homologous chromosomes) move to the equator of the spindle and arrange themselves as pairs. (**Note:** Some have exchanged portions.)

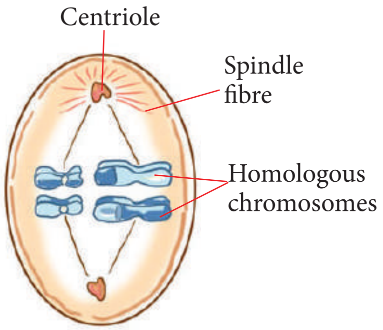


Fig. 6.15: Metaphase 1

Anaphase I

The spindle fibres which are attached to the centromeres contract. The homologous chromosomes (bivalent pairs) are pulled apart and separated because of the action of the spindle fibres. One chromosome in each pair of chromosomes is pulled towards one pole and the other to the other pole. **Note:** Each chromosome is replicated to form chromatids.

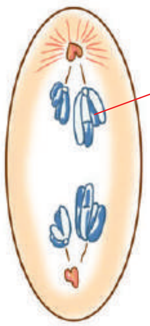


Fig. 6.16: Anaphase I

Telophase I

The spindle fibres disappear. The nuclear membrane may reform around the two sets of chromosomes. When the chromosomes reach the poles, the cell divides into two new cells, each with half the number of chromosomes as the original cell as shown in the diagram below.

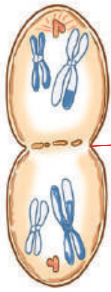


Fig. 6.17: Cell divides into two new daughter cells

Sometimes the nuclear membrane does not form around the two sets of chromosomes at the poles and prophase II follows immediately. At other times the daughter cells go into a short 'resting' interphase.

Prophase II

At this point, let us note that the first meiotic division separates the homologous chromosomes into two daughter cells.

At this point, the appearance of the chromosome is as would be expected in prophase during mitosis i.e. replicated into chromatids.

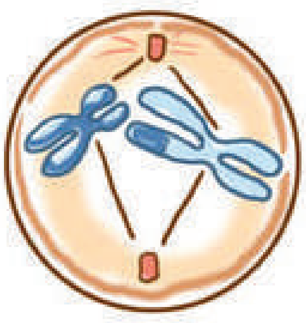


Fig. 6.18: Prophase II

Metaphase II

The centrioles replicate and new spindle fibres are formed in each new cell. The chromosomes (with their chromatids) arrange themselves singly on the equator of the cell. The spindle fibres attach themselves to the centromere of each chromosome.

Note: The chromatids are still attached to each other at the centromeres.

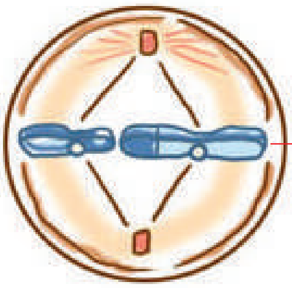


Fig. 6.19: Metaphase II

Anaphase II

Chromatids of each chromosome separate and are pulled to opposite poles of the cell.

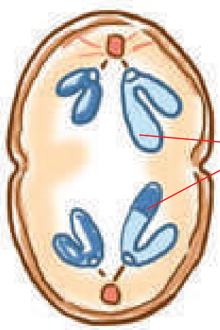
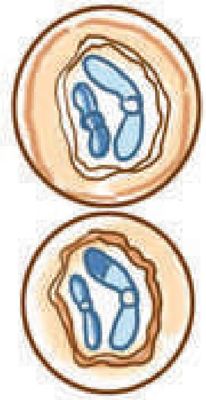


Fig. 6.20: Anaphase II

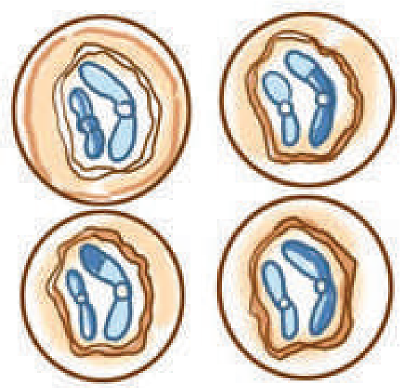
Telophase II

The cell constricts along the middle and two new cells form. The nuclear membranes and nucleoli reform. The chromatids are now chromosomes. They unwind and soon become thin and indistinct. The spindle fibres disappear. The daughter cells have half the number of chromosomes of the original parent cell.

Note: At this point, the second meiotic division separates the chromatids from each other into new cells (just like in mitosis). The result is four new daughter cells each with half the number of chromosomes of the original parent cell.



(a) One daughter cell splits into two cells



(b) Each cell finally divides into two resulting to four haploid daughter cells.

Fig. 6.21: Telophase II

The four daughter cells formed at the end of the process of meiosis are not yet gametes. They undergo the process of differentiation to form specialised cells or gametes i.e. sperms and ova.

In flowering plants, the daughter cells form ovules in the female part of the flower and pollen grains in the male part of the flower.

Significance of meiosis

Meiosis is important for various reasons:

1. Meiosis reduces the chromosome number by half-producing daughter

cells with half as many chromosomes as the parent cell. This is important because it prevents the chromosome numbers from doubling in the next generation i.e. (the daughter cells have haploid number of chromosomes).

2. It ensures that when sexual reproduction takes place, genetically varied offsprings that are different from parents, and from one another, are formed. A different trait in an offspring may enable it survive better than the parents when environmental conditions become adverse. This is possible because genetic variability results from:
   (i) random fertilisation of eggs by sperms.
   (ii) large numbers of possible arrangement of chromosome pairs at metaphase I which increases the possible combinations of chromosomes in the gamete cells produced.
   (iii) crossing over during prophase I, which enables the exchange of corresponding segments between two homologous chromosomes.

Comparison between mitosis and meiosis

(a) Similarities

1. Both mitosis and meiosis involve nuclear division that results in the formation of new cells.
2. DNA should be replicated before both meiosis and mitosis.
3. Both have the same stages (prophase, metaphase, anaphase and telophase). But there occurs some specific events like crossing over (recombination) in meiosis.
4. Fundamental events and processes are same in both meiosis and mitosis.
5. Both mitosis and meiosis are associated with cytokinesis. Cytokinesis occurs during telophase stage.
6. Meiosis II is similar to mitosis.
7. Both start from diploid cells

(b) Differences between mitosis and meiosis

The following table shows the differences between mitosis and meiosis:

Table 6.1: Differences between mitosis and meiosis

Mitosis	Meiosis
It produces daughter cells and is responsible for: • growth • repair • asexual reproduction	It produces gametes with half the chromosome number (haploid). This: • Ensures that organisms formed due to sexual reproduction retain cells with the double number of chromosomes. • Brings about genetic variation.
Two daughter cells are formed.	Four daughter cells are formed.
Daughter cells are identical to the parent.	Daughter cells are not identical to the parent.
The number of chromosomes is retained.	The number of chromosomes is halved.
Homologous chromosomes do not pair up.	Homologous chromosomes pair up in prophase I.
Chiasmata do not form. No crossing over occurs.	Chiasmata is formed and crossing over may occur.

Self-evaluation Test 6.3

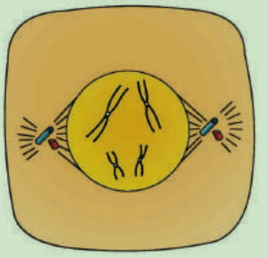
1. Why does meiosis result in a daughter nucleus that is different from the parent nucleus?
2. Crossing-over occurs during:
   A. anaphase 1
   B. metaphase 1
   C. prophase 1
   D. prophase 2
3. Which of the following distinguishes prophase 1 of meiosis from prophase of mitosis?
   A. homologous chromosomes pair up
   B. spindle forms
   C. nuclear membrane breaks down
   D. chromosomes become visible

Unit summary

- Chromosomes are fine coiled and threadlike structures in the nucleus of a cell. They contain heredity information on how characteristics in the organism develop.
- Mitosis is the cell division responsible for growth and asexual reproduction and produces identical diploid cells.
- Meiosis is the cell division that forms gametes, each of them different and haploid.
- In both mitosis and meiosis the following processes take place: prophase, metaphase, anaphase and telophase.
- Meiosis takes place in two distinct cycles i.e. meiosis I and meiosis II.
- The significance of mitosis is that all the body cells of a plant or animal have identical sets of chromosomes i.e. the same sets of chromosomes that were present in the zygote.
- The significance of meiosis is that it makes it possible for organisms to differ in their genetic make up. This is because organisms which reproduce sexually show variation because gametes differ in their genetic makeup. This gives organisms a higher chance of survival because they are not identical.

End Unit Assessment 6

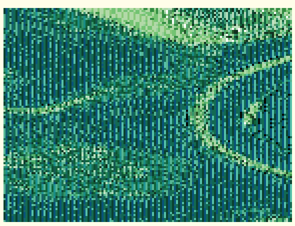
1. Arrange the following in an **ascending** order.
   A. Gene, chromosome, cell
   B. Chromosome, gene, cell
   C. Nucleus, gene, chromosome
   D. Cell, gene, chromosome
2. Which of the following statements is incorrect?
   A. The chromosome number is constant within individuals in a species in an ecosystem.
   B. The chromosome number is constant within different species in an ecosystem.
   C. The chromosome number is constant within somatic cell in an organism.
   D. All the above
3. In what phase do cells spend most of their time?
   A. Cytokinesis
   B. Prophase
   C. Mitosis
   D. Interphase
4. Which of the following is true of mitosis in a diploid cell?
   A. It results in 2 haploid daughter cells.
   B. It involves replication of the cell's DNA.
   C. It results in daughter cells which are genetically identical, but physically smaller, than the original cell.
   D. It occurs in two phases.
5. What stage of mitosis is this cell representing?



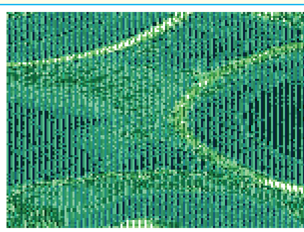
   A. Anaphase
   B. Telophase
   C. Prophase
   D. None of the above stages

6. Match the terms with the appropriate stages in the answer:
Migration, Shortening and Thickening, Cytokinesis, Prophase
   A. Telophase, Anaphase, Prophase, centrioles forming
   B. Anaphase, Prophase, Metaphase, microtubules
   C. Anaphase, Prophase, Telophase, centrioles forming
   D. Metaphase, Anaphase, Telophase, microtubules

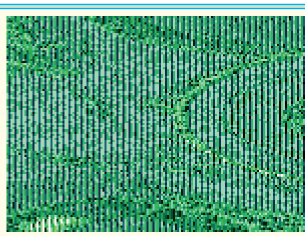
7. Rearrange the photographs below in the correct chronological order.



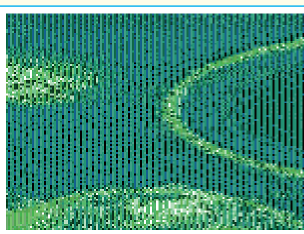
(i)



(iii)



(ii)



(iv)

8. A diploid female lizard produces diploid offspring that are genetically identical to herself. This type of reproduction requires:
   A. meiosis
   B. mitosis
   C. mitosis, then meiosis
   D. none of the above

9. The main difference between meiosis and mitosis is that ______ .
   A. DNA replicates during mitosis, but does not during meiosis.
   B. during mitosis, sister chromatids separate; they do not during meiosis.
   C. mitosis makes genetically identical copies; meiosis does not.
   D. mitosis increases chromosome number in each cell, while meiosis decreases it.

10. Which of the following happens during both meiosis and mitosis?
   A. Crossing over
   B. Random alignment of homologous chromosomes
   C. Sister chromatids separate.
   D. Homologous chromosomes separate.

11. (a) Outline the difference between mitosis and meiosis.
   (b) Explain the significance of mitotic cell division.

(c) How is meiosis involved in gamete formation?

12. If a parent cell contained 30 chromosomes, its daughter cells would contain___________ chromosomes following _________ cell division.

13. Indicate whether the following statements are **true** or **false** by placing a tick (√) in the appropriate box in each case.

	Description	True	False
a.	Meiosis is an important source of variation.		
b.	Mitosis occurs in mature red blood cells in human beings.		
c.	During mitosis the nuclear membrane temporarily disappears.		
d.	Meiosis gives rise to the haploid condition.		
e.	In multicellular organisms mitosis functions primarily in growth.		
f.	In plants, a cell plate forms during telophase of mitosis.		
g.	The human zygote divides by meiosis.		

14. Define the following terms as used in cell division
    (i) Meiosis
    (ii) Mitosis
    (iii) Haploidy
    (iv) Diploidy
    (v) Cytokinesis

Unit 7 Heterotrophic nutrition

Key unit competence

After studying this unit, I should be able to compare forms of heterotrophic nutrition and explain the process of digestion in humans.

Learning objectives

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

- Identify the different forms of heterotrophic nutrition.
- Describe the proper care of teeth in terms of diet and regular brushing.
- Identify the types and functions of human teeth and the causes and preventative measures of dental decay.
- Describe the process of digestion in various parts of the alimentary canal.
- Explain absorption and assimilation.
- Show the difference between the alimentary canal of human beings and cattle based on the type of food they eat.
- Suggest the healthy practices for the proper care of teeth.
- State the forms of feeding shown by different organisms.

Introductory Activity

Study the jaws below carefully.

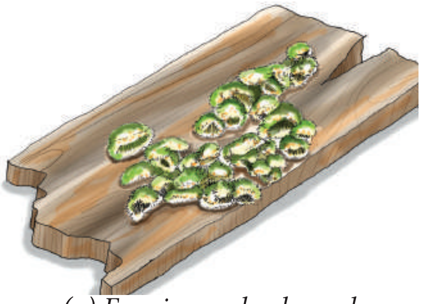
Fig 7.1: Different types of jaws

Research about the types of animals with each type of jaw. What do they feed on? From the structure of the jaws, say how each category of animals is adapted to its feeding habits. Use the information you have found out to predict what you will learn in this unit.

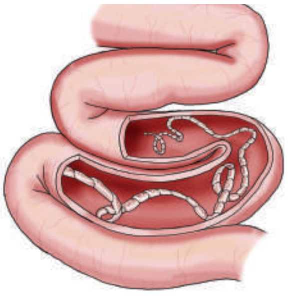
Introduction

Nutrition is the intake of nutrients and other substances into the body and making it part of body tissues.

Earlier you learnt that green plants make their own food materials from simple inorganic substances like CO_2 and water. This type of nutrition is called **autotrophism**. The opposite of autotrophism is **heterotrophism**. Look at the pictures below.



(a) Fungi on a dead wood



(b) Tapeworms in the intestines

Fig 7.2: Feeding in animals

The pictures show heterotrophic nutrition which is the concept you will learn in this unit.

7.1. Forms of heterotrophic nutrition

Activity 7.1: Research Activity

1. Observe how the following animals obtain their food:
    - Cockroaches
    - Spiders
    - Butterflies
    - Frogs
2. Relate your observations to what happens in human beings.
3. Find out the different modes of feeding in animals.
4. Write short notes and present to your classmates.

The facts

Heterotrophism is the type of nutrition in which animals obtain ready-made food materials from their environment. Such organisms are called **heterotrophs**. They obtain nutrients by digesting organic compounds. Example of heterotrophs include: human beings, fungi such as mushrooms and some protists like plasmodium, amoeba and paramecium. All heterotrophs depend on autotrophs for their nutrition.

Heterotrophic nutrition involves digestion of food so that insoluble complex food substances can be changed into soluble simple molecules that can be absorbed. There are three main types of heterotrophic nutrition. These are:

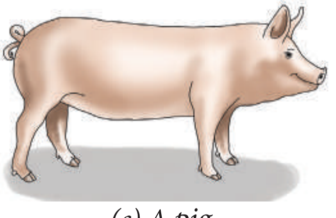
- Holozoic nutrition
- Saprophytic nutrition
- Parasitic nutrition

(a) Holozoic nutrition

This type of nutrition involves organisms with a developed digestive system. Food materials are ingested, digested, absorbed, assimilated and thereafter undigested food is egested. During these steps, complex insoluble food substances are broken down to simple soluble compounds. Examples of holozoic animals are carnivores, such as eagle, lion and tigers, herbivores such as cattle, goat and antelopes and omnivores such as human beings and pig.

(a) A lion

(b) A zebra



(c) A pig

Fig 7.3: Holozoic animals

(b) Saprophytic nutrition

This is the type of nutrition found in saprophytes which obtain their food from dead and decaying organic material. Examples of saprophytes include some fungi such as mushrooms and mucors (Rhizopus) and bacteria. The saprophytes release enzymes which break down the decomposing food material into simple food substances that are easily absorbed into their bodies.

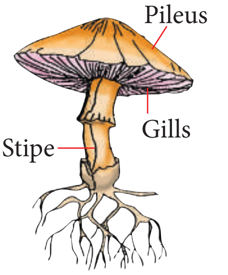


Fig 7.4: Mushroom

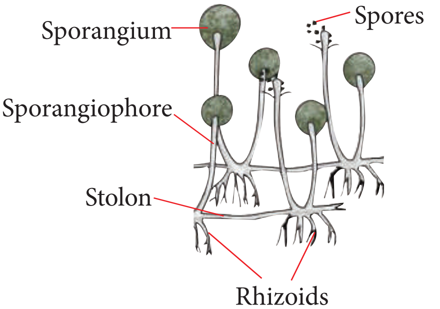


Fig 7.5: Mucor (Rhizopus)

(c) Parasitic nutrition

This is the type of nutrition found in parasites which obtain their food material from other living organisms. Parasites obtain nutrients from other living organisms which are referred to as **hosts.** The host is always on the losing side as it does not benefit from the parasite. Parasites have no intention of killing the host although sometimes a host may die due to the activities of parasites. The food material is easily absorbed because it is already in simple form.

Parasites living inside organisms are called **endoparasites,** for example, tape worm and liver fluke. Parasites which live on the outside of an organism such as ticks and lice are called **ectoparasites.** All these suck food materials and blood from the organism.

Self–evaluation Test 7.1

1. What is heterotrophic nutrition?
2. How can you preserve bread for longer without it growing mould?
3. Unscramble the following to form terms related to modes of feeding.
   A. raspaeit
   B. ropehytsap
   C. torophaut
   D. sibiomsys
4. Suggest ways a farmer can use to control parasites in livestock.

7.2. Structure and functions of human teeth

Activity 7.2: Investigating the human teeth

Requirements

- Teeth and jaw models
- Charts and diagrams

1. Observe a jaw model or chart showing arrangement of teeth.
   - What can you see?
   - What is the colour of the teeth?
   - How many types of teeth can you observe?
   - Do you have all your teeth present? What happened if some are missing?
   - What is the importance of keeping good dental hygiene?
2. Compare your observations with the teeth and jaw models and the diagrams on the charts.
   - Draw the teeth you have observed.
3. Share your findings with the rest of the class.

The facts

Human beings feed on a mixed diet of animal flesh and vegetable matter. They therefore have differentiated teeth. The different types of teeth found in mammals have different functions, for example, chewing, biting and grinding. When teeth are of different types and sizes, the dentition is termed **heterodont** while dentition in teeth similar in structure and size, is termed as **homodont**.

The structure of each type of teeth is adapted to its specific function. The teeth are used to break down large pieces of food to smaller pieces to increase the surface area for digestive enzymes to act. Like other mammals, humans have two jaws, each with a set of teeth. The number, size and shape of these teeth is determined by the omnivorous diet of human beings. Each type of tooth has a basic structure and function.

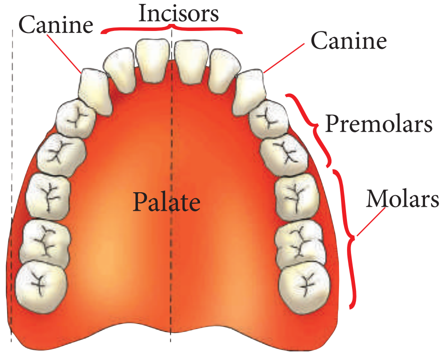


Fig 7.6: Upper jaw showing human dentition

The different types of teeth in human being dentition are incisors, canines, premolars and molars.

(a) Incisors

They are located at the front of the jaws. They are shaped like a wedge or chisel, see fig 7.7. This creates a flat surface with a sharp edge that makes incisor teeth suited for cutting and biting.

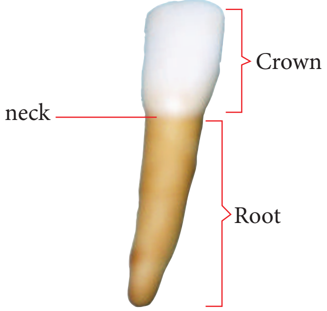


Fig 7.7: An incisor

(b) Canines

They are located on the left and right of the incisors. Canines are pointed teeth as shown in fig 7.8. Their basic function is to pierce and hold food. In human beings, canines are poorly developed and are rarely used.

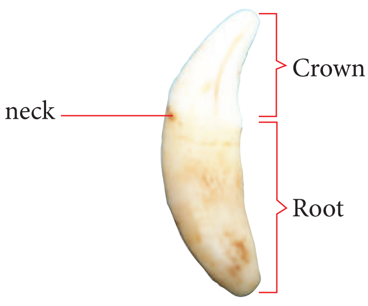


Fig 7.8: A canine

(c) Premolars

They are located after the canines, towards the back of the jaw. They have broad top surfaces usually with two projections called cusps that give them a ridged appearance. Fig 7.9 illustrates a premolar tooth. They are used to crush and grind food.

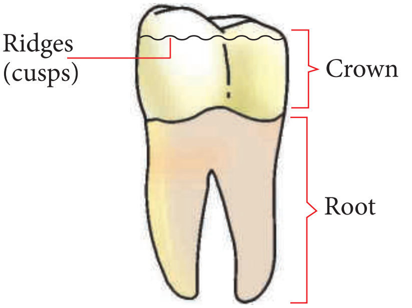


Fig 7.9: A premolar

(d) Molars

They occupy the back of the jaw, in the cheek. They too have broad top surfaces with four or five cusps, which form a ridged surface as shown in fig 7.10. They are also used to crush and grind food.

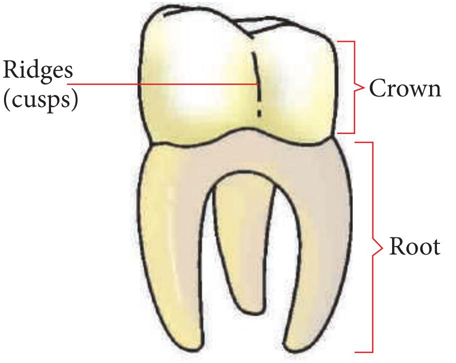


Fig 7.10: Molar tooth

Human beings have two sets of successive teeth. The first set is known as the **milk set** or **deciduous teeth**. They form in the jaw before birth. In a new-born baby, the teeth are not visible above the gum. They erupt out of the gum at about five months. At two years, the baby has all the teeth in the milk set, usually 20. Milk teeth are shed from the age of about seven years. They are replaced by a second set of teeth which are larger and more permanent. These are permanent teeth. An adult has

32 permanent teeth. The last molars to appear are called **wisdom** teeth. They erupt any time between 17 and 25 years.

The dental formular in human is as follows:

$$\frac{2I\ +1C\ +2P+3M}{2I\ +1C\ +2P+3M}\ X2 = 32$$

(I= Incisors; C= Canine; P=Premolar; M=Molar)

Structure of the tooth

Activity 7.3: Investigating the structure and function of human teeth

1. Observe carefully the models, charts and diagrams showing the structure of human teeth and rabbit teeth.
    - How do the human and rabbit teeth differ?
    - How are they similar?
2. Label the different parts shown and suggest their functions.
3. Compare your drawings with the rest of the class.

The facts

A tooth has three regions. These are the **crown**, **root** and **neck**. The crown projects above the gum, the root is fixed in a socket in the jaw-bone and the neck is the narrow part which lies between the root and the crown.

When a tooth is cut longitudinally into two, we can observe and study the internal parts. The internal structure of a tooth is shown in the following diagram.

(a)

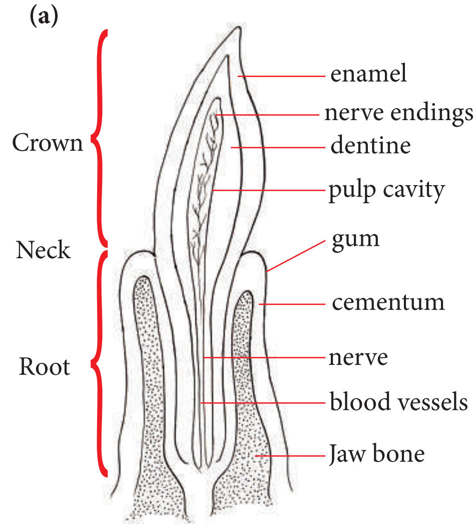


Fig 7.11: Longitudinal section of a canine tooth

Enamel

The enamel is the outer part of the tooth. It is the hardest substance in the human body. It is made up of non-living tissue. The function of the enamel is to:

- Protect the inner parts of the tooth from infection by bacteria and other micro-organisms. It also protects the inside of the tooth from mechanical damage by hard food material such as bones.
- Provide a hard biting surface.

Dentine

This is the part of the tooth found immediately beneath the enamel. It is not as hard as the enamel. It is made up of living cells. The dentine:

- Forms the bulk of the tooth.
- Replaces worn out enamel.
- Prevents the teeth from cracking.

Pulp cavity

It is found at the centre of the tooth. The pulp cavity contains numerous blood capillaries and sensory nerves. These enter the pulp cavity through a small opening at the bottom part of the root. The blood capillaries supply nutrients and oxygen to the cells of the pulp cavity. They also transport waste material and carbon dioxide from the tooth. The sensory nerve fibres have nerve endings that make the tooth sensitive to temperature and pain. Special cells in the pulp cavity produce dentine which forms the bulk of the tooth.

Cement

It is similar to a bone in structure. It lines the root and holds the tooth in its socket in the jaw.

Periodontal membrane

This membrane is found between the cement and the jaw bone in the socket of the tooth. It contains cells that secrete cement. It also allows the tooth to move slightly to avoid breaking during chewing.

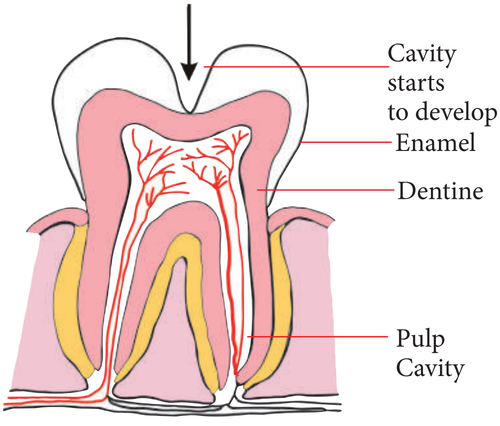
Common dental diseases

The mouth cavity is a habitat for bacteria and other micro-organisms. These micro-organisms feed on the food particles that remain trapped between the teeth after eating. Bacteria and their activities can be a source of disease to both the teeth and the gum. Bacteria cause two major dental diseases; **dental caries** and **periodontal** disease. Lack of proper care of the teeth also contributes to this problem.

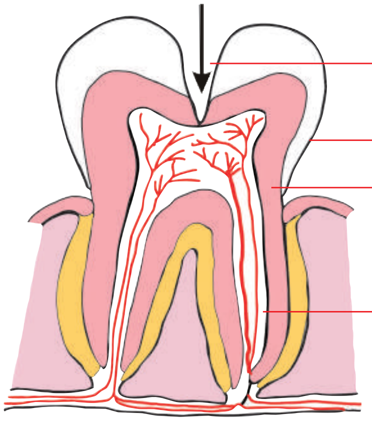
Dental caries

This is also called **dental cavities**. It is a dental disease that is caused by plaque found on the surface of the teeth and also between the teeth. Plaque is made up of bacteria mixed with saliva. The bacteria feed on sugary substances in the food left between the teeth in order to produce energy for them. An acid is formed as a by-product of this process. This acid slowly dissolves or corrodes part of the tough tooth enamel. This is the beginning of the formation of a tiny hole called a **cavity**, which does not cause any pain.

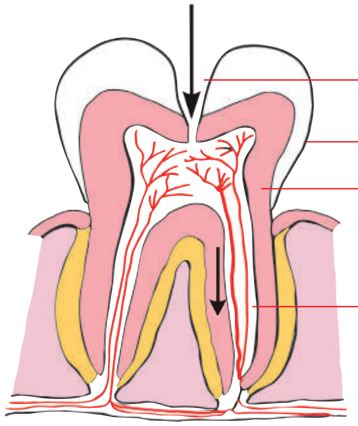
The cavity traps more food and bacteria. Further bacterial action on the food causes the cavity to become deeper, exposing the dentine. At this point some pain is felt. If the cavity becomes deep enough to reach the pulp cavity, severe pain is felt due to exposure of the nerve endings. At this point, this pain is called a **toothache**. Dental cavities can form in the grooves on the top surface of teeth, e.g. molars. They can also form at the junction between the neck and the root of any tooth.



(a) A cavity begins to form in enamel



(b) Cavity deepens to reach dentine



(c) Cavity further deepens to reach pulp cavity

Fig 7.12: Stages in the formation of dental cavity

Health check!

It is advisable to clean teeth a minimum of two times a day.

Care of teeth

Activity 7.4: Research Activity

1. Devise an experiment to investigate the effects of hydrochloric acid, lemon juice and fizzy drinks on egg shells.
2. Share your findings with the rest of the class.

Most dental diseases can be prevented with proper care of the teeth and gums. This would require a proper diet and good oral hygiene and other measures.

The following are some useful measures in preventing dental diseases.

(i) A diet rich in calcium and vitamin D is important in the growth of strong and healthy teeth. This is especially important in pregnant mothers, breast-feeding mothers and children.

(ii) Brushing the teeth regularly, particularly after meals and before going to sleep to remove food particles and to reduce the accumulation of plaque. Food particles that are stuck between the teeth can also be removed by inserting a strong nylon thread into the gaps between the teeth and pulling the thread upwards. Thread used in this way is called **dental floss**.

(iii) Avoiding sweet and sugary food in order to prevent multiplication of bacteria on the teeth.

(iv) Eating food that contains enough fibrous material to stimulate blood circulation in the teeth due to the chewing process. Efficient blood circulation supplies the teeth with the necessary nutrients required for maintenance of strong and healthy teeth. Examples of food rich in fibrous material are nuts, sugarcane, pear and raw carrots.

(v) The teeth should not be used to remove bottle tops or crack nuts. Such use of teeth could cause cracks in them. Food particles and bacteria could occupy the cracks and cause dental cavities.

(vi) Occasionally, when brushing is not possible, the mouth should be rinsed thoroughly with water to remove food particles between the teeth.

(vii) Taking water with minute quantities of fluoride and using toothpaste with small amounts of fluoride could prevent dental cavities. Fluoride helps in the formation of hard, strong teeth.

(vii) Regular visits to a dentist will help in the detection of cavities and diseases of the gum at an early stage.

Self-evaluation Test 7.2

1. The outer layer of the crown of a tooth is resistant to attack by bacteria.
   (a) Name this outer layer.
   (b) State the minerals and the vitamins needed in the diet for the healthy development of this layer.
   (c) Explain how bacteria can gain entry through this layer into the tooth and cause dental decay.
2. How do the functions of teeth contribute to the process of digestion?

7.3. The digestive system

Activity 7. 5: Dissection of a rabbit to observe the digestive system and compare it to the human digestive system

Requirements

- Charts and models of the human digestive system
- Rabbit (preserved or just killed)
- Dissecting instruments
- Cotton
- Dissecting board or tray
- Pins

Procedure

1. Place the rabbit on its back on the dissection board and stretch out the body by tying the limbs to the sides of the board with a pin.
2. Wet the fur and then pinch up the skin in the middle of the abdomen.
3. Insert the point of your scissors, cut skin upwards along the midline to the neck, downwards near the reproductive opening and outwards along the four limbs.
4. Separate the skin from the underlying muscle with your scalpel and pin it out on either side of the body.
5. Open up the abdominal cavity by holding your scissors horizontally and carefully cutting through the muscle layers along the mid-ventral line, forwards to the start of the breastbone and backwards to near the reproductive opening.
6. Cut across the body muscle immediately behind the ribs and towards the rear of the abdominal cavity.
7. Pin back the body flaps.
8. Locate the following organs: liver, stomach, small intestine (much coiled), caecum, colon or large intestine, rectum, bladder (bag-like).
9. Without disturbing the organs, make a drawing of the abdominal cavity.
10. Observe the charts and models of human digestive system.
    - Name all the parts of the digestive system.
    - What are the functions of parts of the digestive system named?
11. Compare the diagram drawn of the digestive system of the rabbit and with the model of the human digestive system.

The facts

Human beings take in solid or liquid food material. The teeth mechanically break down food into smaller pieces. Such food is easy to swallow. However, it is still complex and the body cells cannot use it in this form. It needs to be broken down further by enzymes. The breaking down process changes the food materials from complex compounds to a simple compound which can easily be absorbed by the human body. This process is known as **digestion**. It takes place along the digestive system.

You will remember that an organ system is a group of different organs working together to carry out a particular function. The digestive system is such a system. The main function of the digestive system is to break down complex food material into simple soluble substances that the cells can use. Both mechanical and chemical breakdown of food take place in the digestive system.

The parts that make up the digestive system are the alimentary canal, liver, pancreas, gall bladder and salivary glands.

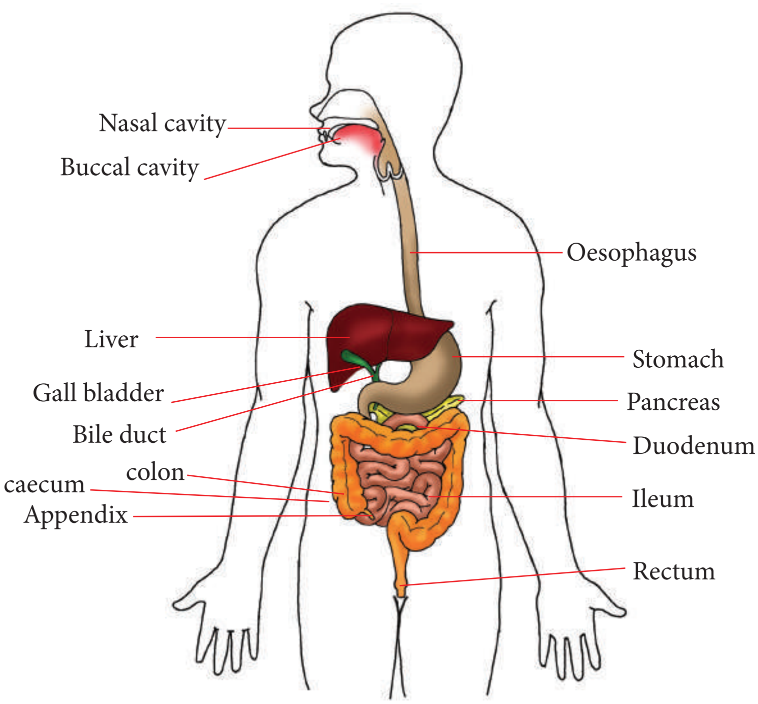


Fig 7.13: The human digestive system

The alimentary canal

The alimentary canal is also known as the gut. It is a muscular tube that runs from the mouth to the anus. The walls of the alimentary canal are lined with glands and blood vessels. As food passes through this tube, it undergoes the process of digestion. Digested food material is then absorbed into the blood system. Food that is not digested or cannot be digested (indigestible) leaves the gut via the anus. The different parts of the alimentary system include the mouth, oesophagus, stomach, small and large intestines. There are organs associated with the alimentary canal in relation to digestion.

The mouth

The mouth opens into a large space or chamber called the **buccal cavity**. Once food is taken into the mouth, several things happen to it. The teeth chew and break up the food into smaller particles. This creates a large surface area for enzyme action.

The tongue, which is a long muscular organ on the floor of the mouth contains taste buds for tasting food. It also moves food around inside the mouth. This allows the food to mix with saliva which is secreted from the salivary glands.

Saliva contains a substance known as mucin which moistens, softens and lubricates food. This makes dry food easy to swallow. The food particles are also able to stick together to form balls called **boluses** (singular: bolus). Mixing of food also allows the enzymes such as salivary amylase that aids in converting starch in the food to maltose to mix with the food. The optimum temperature for salivary amylase ranges from 32°C to 37°C and the optimum pH is between 6.5 to 7. Three pairs of salivary glands inside the mouth cavity secrete saliva into the mouth through short tubes called **ducts**.

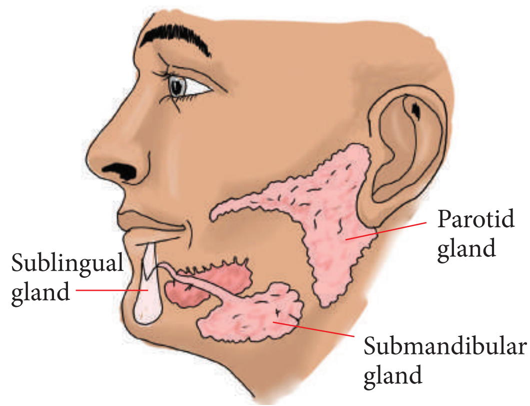


Fig 7.14: Diagram showing the salivary glands

The salivary glands in the mouth are as follows:

- Two parotid glands located on each side of the mouth in front and below the ear.
- A pair of submaxillary glands located below the jaws.
- Sublingual glands located below the tongue.

Fact of life: Mumps is a viral infection of the salivary glands.

Further Activity

1. Compare the digestive system of a ruminant and non-ruminant.
2. Present your work for assessment.

Activity 7.6: To show the effect of ptyalin on starch

Requirements

- Starch solution
- Iodine solution
- Benedict's solution
- Test tubes
- 1% ptyalin enzyme
- Beaker of water (water bath) maintained at 37°C
- White tile
- Dropper
- Thermometer

Procedure

1. Put 2 cm^3 each of starch solution into two test tubes and label them 1 and 2.
2. Into test tube 2, add 5 cm^3 of starch solution then 1 cm^3 of a solution of the enzyme ptyalin.
3. Place the two test tubes into the water bath maintained at 37°C for 10 - 15 minutes.
4. Using a pipette or dropper, place one drop of the contents of test tube 1 onto the tile then add a drop of iodine solution. Repeat this procedure with contents of test tube 2.
5. Take the remaining contents of test tube 1 and 2, add 2 cm^3 of Benedict's solution to both and boil. Record your observation and conclusions as shown in the following table.

Table 7.1: Results for test for starch

Test tube	Test with Iodine		Test with Benedicts solution	
	Observation	Conclusion	Observation	Conclusion
Starch alone				
Starch + ptyalin				

Study question

1. Why was the water bath maintained at 37°C?
2. Suggest a pH level suited for the enzyme. Give reasons.

Oesophagus

When food has been chewed enough, the tongue rolls the bolus against the soft palate of the mouth to the back of the throat or **pharynx**. This starts the process of swallowing which forces food into the oesophagus.

The tube adjacent to the oesophagus is the trachea which leads to the lungs. During swallowing, a flap of tissue above the trachea, called the **epiglottis**, closes and prevents food from entering the trachea. The **uvula** or soft palate also closes off the internal opening to the nose. These two actions temporarily stop the breathing process.

Swallowing is a deliberate action but

once the process begins, it cannot be stopped. Once the swallowing process is complete, the epiglottis and uvula open the air passages and breathing continues. If you eat and talk at the same time, some food might get into the entrance of the trachea. This causes violent coughing to remove the food.

We mentioned earlier that the alimentary canal is a muscular tube. It contains circular and longitudinal muscles which form part of the tissue of its walls. Circular muscles are arranged in a circular manner inside the wall of the alimentary canal. Longitudinal muscles are arranged along the length of the alimentary canal.

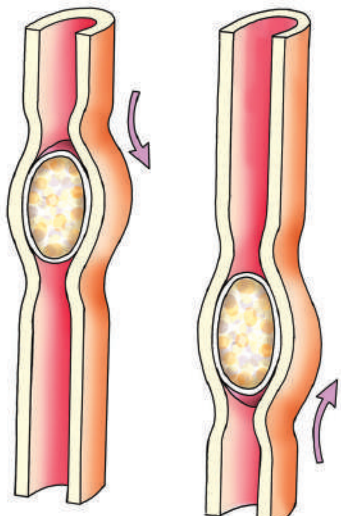


Fig 7.15: Diagram showing the arrangement of muscles in the wall of oesophagus

When the food bolus is in the oesophagus, muscles in the oesophagus walls contract and relax in a wave-like manner to squeeze it along. This process is known as **peristalsis**. During peristalsis, the circular muscles behind the food bolus contract causing narrowing of the oesophagus in this area. This creates pressure that squeezes the bolus into the oesophagus. Here, circular muscles relax allowing the oesophagus to receive the bolus. The alternate contraction, constriction and relation of the circular muscles in the oesophagus enables the food to be propelled into the stomach.

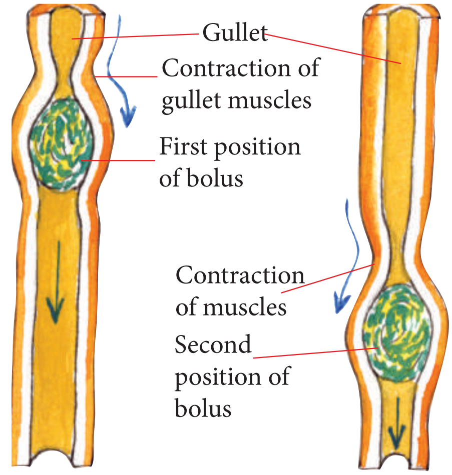


Fig 7.16: Peristalsis

Digestion in the stomach

The stomach is a thick-walled muscular bag that stretches as it fills with food. It is located on the left side of the abdomen just below the diaphragm. A ring of muscle called a **cardiac sphincter** is found at the point where the oesophagus opens into the stomach. There is another ring of muscle at the lower end of the stomach. This is known as the **pyloric sphincter**. The two sphincter muscles control the movement of food into and out of the stomach respectively. They help to retain the food for long periods in the stomach which can store food for 2 to 6 hours.

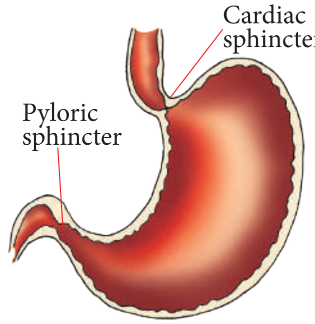


Fig 7.17: The position of the cardiac and pyloric sphincter muscles

When food reaches the stomach, the stomach walls begin wave-like contractions similar to peristalsis which churn or mix the food. This continues the mechanical breakdown of food that started in the mouth.

Churning changes the food into a semi-liquid form called **chyme**. After 2 - 6 hours of churning and digestion, the chyme is gradually released in small amounts into the duodenum through the pyloric sphincter muscles which relax at intervals.

The stomach lining has many openings known as **gastric pits**. These originate from gastric glands in the walls of the stomach. Gastric glands produce a liquid known as **gastric juice** into the stomach. It is mixed with food during churning. Production of gastric juice is stimulated by a hormone called **gastrin** produced by cells in the stomach walls. Gastric juice is also released when one smells or tastes food.

Gastric juice contains three important substances, namely: **pepsin, rennin** and **dilute hydrochloric acid**. Each of these substances is released by different cells lining the inside of the gastric gland.

The walls of the stomach also have special epithelial cells, which release mucus that forms a shield between the stomach wall and the gastric juice. It prevents digestion of the stomach lining by the enzymes in gastric juice.

Fact of life: Certain substances such as alcohol and drugs are absorbed directly into the blood circulatory system from the stomach. However, most of the food substances are not usually absorbed in the stomach.

Functions of the components of gastric juice

1. Dilute hydrochloric acid

This acid has several functions in the stomach.

(a) It kills bacteria that may be present in food. In this way, it helps to protect the body against some bacterial infections.

(b) It changes the inactive **pepsinogen** to the active enzyme, **pepsin.**

(c) Its pH is between 1 and 2.5. This is the optimum pH for the enzyme pepsin to be most active. Therefore, hydrochloric acid creates a suitable pH medium for pepsin to work.

2. Pepsin

It is an enzyme which catalyses the breakdown of proteins into smaller polypeptides through hydrolysis. Pepsin is secreted in an inactive form called pepsinogen by special cells in the gastric gland. This protects the enzyme producing cells from being digested. Once in the stomach, pepsinogen is converted to active pepsin due to presence of hydrochloric acid.

$$\text{Proteins} \xrightarrow{\text{pepsin}} \text{smaller polypeptides}$$

3. Rennin

Its function is to make liquid milk to curdle. This is described as the coagulation of milk. It does this by converting a soluble milk protein called **caseinogen** into an insoluble form called **casein**. Pepsin can only act on milk protein when it is converted to casein. Coagulation of milk by rennin is also important because the solid milk stays in the stomach longer for digestion to occur. Rennin is found mainly in young mammals and may be absent in adults. This is because the diet of young mammals mainly consists of milk.

The small intestine

The small intestine is about 6 - 7 metres long in an adult human being. It is made up of the **duodenum** and the **ileum**.

Digestion in the duodenum

The duodenum is the first part of the small intestine. It is about 25 - 30 cm long and is shaped like the letter C. The pancreatic duct and bile duct open into the duodenum.

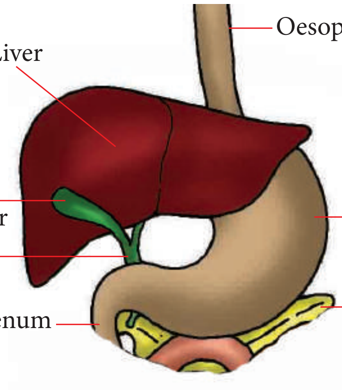


Fig 7.18: Diagram showing the relationship between liver and digestion

The pancreatic duct carries pancreatic juice from the pancreas. The bile duct carries bile from the gall bladder. Bile is made in the liver and stored for a short while in the gall bladder. The two ducts join and form a common duct that empties its contents into the duodenum.

Functions of pancreatic juice

Pancreatic juice contains the enzymes pancreatic lipase, pancreatic amylase, trypsin and chymotrypsin. These enzymes digest the following food substances:

- Lipase converts lipids into fatty acids and glycerol.
- Pancreatic amylase breaks down any undigested starch into maltose.

Did you know?

Some starch is digested in the mouth by salivary amylase.

- Trypsin breaks down proteins to peptides. It is released in the inactive form called trypsinogen.
- Chymotrypsin breaks down proteins to peptides. Its inactive form is chymotrypsinogen.

Fact of life: Trypsinogen and chymotrypsinogen are both activated by an enzyme called enterokinase.

Pancreatic juice also contains sodium bicarbonate (sodium hydrogen carbonate). This creates an alkaline medium of pH 8.8. This medium is suitable for the enzymes found in pancreatic juice. It also neutralises the acidic content of food from the stomach.

Table 7.2: Digestive enzymes and products of digestion in the duodenum

Substance / enzymes	Function
Trypsin	Hydrolyses proteins to peptides
Chymotrypsin	Hydrolyses proteins to peptides
Lipase	Hydrolyses lipids to fatty acids and glycerol
Pancreatic amylase	Hydrolyses starch to maltose
Sodium bicarbonate	Neutralises the acid in the chyme. Creates an alkaline medium for the action of the pancreatic enzymes
Bile: bile salts	Emulsification of lipids

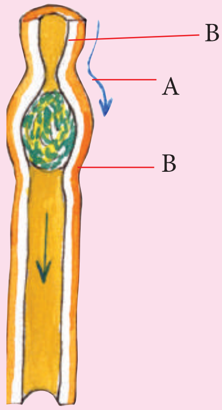
Bile

Bile is a greenish liquid. It contains bile salts including sodium hydrogen carbonate. It also contains bile pigments. The bile salts split up fat into tiny droplets which expose a larger surface area of the lipid for digestion. This process is called **emulsification**. It prepares the lipids for digestion by lipase enzyme.

Self-evaluation Test 7.3

1. (a) Define the term digestion.
   (b) What is the role of hydrochloric acid in the stomach?
   (c) What prevents this acid from corroding the stomach walls?
   (d) Name the enzymes produced in the stomach and give their function.
2. Digestion begins in the mouth. Which of the following statements is incorrect?
   A. The tongue aids in the digestion of the food.
   B. The saliva changes some of the starches in the food to sugar.
   C. The tongue keeps food in place in the mouth while the food is being chewed.
   D. The digestive juices can react more easily with the food when chewed.

3. Study the following diagrams?



(a) Name the process that the above diagram illustrate.

(b) State the condition of the ring of muscles at:

(i) A

(ii) B

(c) Name the two types of muscles in this part of the alimentary canal.

(d) The stomach wall has powerful muscles. After a meal, they become increasingly active. What is the importance of this activity?

7.4. Digestion in the ileum and large intestine

Activity 7.7: Investigating absorption and assimilation of food

1. Watch computer simulations and animations of the digestion process involving absorption and assimilation.
2. Also critically observe the charts and pictures showing the structure of the ileum.
   - How does absorption and assimilation of food materials take place in the ileum and colon?
   - What happens to materials that are not absorbed?
3. Share your findings with the rest of the class.

Digestion in the ileum

The ileum is the second part of the small intestine. The ileum has two main functions.

- To complete breakdown of food.
- It is the site for absorption of digested food into the blood.

The epithelial lining of the small intestine has special cells called **goblet cells** that secrete mucus. This mucus protects the intestine wall from protein digesting enzymes. Secretory cells in the intestine wall also release intestinal juice or **succus entericus**. Intestinal juice is a slightly alkaline liquid with a pH of about 8.3.

It contains water, mucus and enzymes. Intestinal juice increases the volume of the fluid in the gut. It also creates the right pH for the intestinal enzymes to function well. Intestinal juice contains the following digestive enzymes: peptidase, sucrase, lactase, maltase and lipase.

Table 7.3: Components of intestinal juice and products of digestion in the ileum

Enzyme	Food substrate	Final product
Sucrase	Sucrose	Glucose and fructose
Maltase	Maltose	two Glucose molecules
Lactase	Lactose	Glucose and galactose
Peptidase	Polypeptides	Amino acids
Lipase	Lipid	Fatty acids and glycerol

At this point, the products of digestion are small enough to be absorbed across the ileum walls to the blood.

Absorption of digested food in the ileum

Most absorption of digested food takes place in the ileum. This is because the structure of the ileum is suitable for rapid and efficient absorption as illustrated in *Fig 7.19*. It has the following characteristics.

- A large surface area over which absorption can take place. This is created by the long length of the ileum, folding of its inner wall and presence of numerous villi and microvilli.
- A thin epithelium through which the digested food materials diffuse into the blood.
- Many blood capillaries to rapidly transport from the small intestine the digested food materials that diffuse through the epithelium.

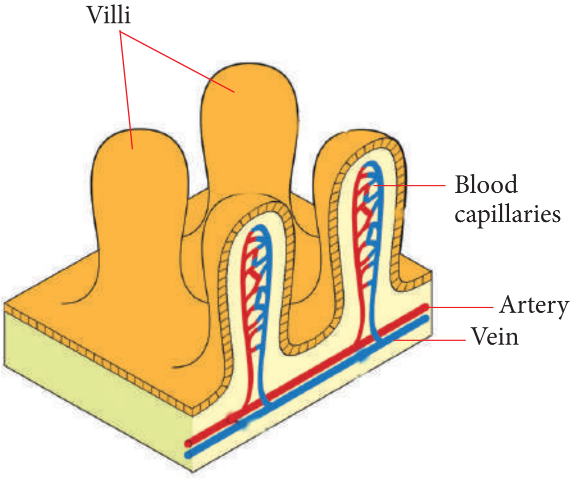


Fig 7.19: Villi emerging from the walls of ileum

During absorption, digested food materials move across the epithelium by simple diffusion. However, this may not be the only process. The substances sometimes move by active transport because absorption may take place against a concentration gradient.

Table 7.4: Food materials and the form in which they are absorbed

Food material	Form of absorption
Carbohydrates	Monosaccharides such as glucose, fructose and galactose
Proteins	Amino acids
Lipids	Fatty acids and glycerol

The blood transports the digested food substance to the liver via the hepatic portal vein. Some fatty acids and glycerol are absorbed into the blood capillaries together with other products of digestion. However, fats which have not been digested are absorbed into the lacteals, located in the villi.

The diet in most cases also contains other substances which are useful to the body. Examples of these substances are vitamins, dissolved mineral salts and water. These remain unchanged because they are simple enough for absorption without being digested first. They are absorbed directly into the blood capillaries in the villi.

Fat soluble vitamins like A, D, E and K are absorbed with the fat, into the lacteals. Absorption of water occurs by osmosis.

On average, the food material spends three to four hours in the small intestine before passing into the large intestine. The length and folds in the ileum allows food to stay in it for longer periods. This gives more time for digestion and absorption. Any food material that is not digested or absorbed in the ileum moves on to the large intestine. This is controlled by the **ileo-colonic sphincter muscle**.

Adaptations of the ileum for digestion and absorption of food

The structure of the ileum is well suited to its two functions in the following ways.

1. The ileum is long to increase the surface area for absorption.
2. The inner walls of the ileum are highly folded to increase the surface area for absorption.
3. They have many finger-like projections called **villi** (singular villus) which increase their surface area. Each villus is about 1mm long. Each square millimetre of small intestine has up to forty villi. This means that there are over 5 million villi in the small intestine. The surface area of each villus is increased even more by the folding of the membrane of each villus cell into microscopic microvilli. There are about 5,000 microvilli per cell, which are visible only through an electron microscope. Thus, the folds of villi and microvilli greatly increase the surface area of the lining of the ileum for absorption of digested food.

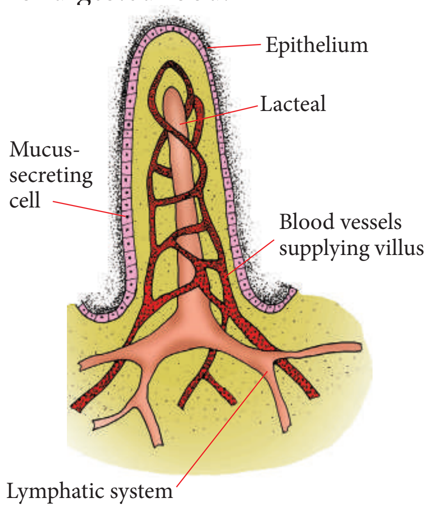


Fig 7.20: Longitudinal section through a villus

4. Each villus has a network of blood capillaries and a lacteal in the centre. The presence of many blood vessels in one villus and the fact that there are over 5 million villi in the small intestine means that the intestine is served with millions of blood capillaries. The blood capillaries from the villi join to form a blood vessel known as the hepatic portal vein which takes blood to the liver. This large number of blood capillaries results in a large amount of absorbed digested food materials being carried away from the small

intestines in a very short time.

5. The small intestine also has a thin epithelial lining, which is one cell thick. It allows rapid diffusion of digested food material from the intestinal space (lumen) into the blood vessels.
6. Contraction of muscles in the walls of the small intestine cause continuous movement of the fluid like material in the lumen of the small intestine. These movements mix the enzymes with food substances thoroughly and expose the villi to digested food. This speeds up the process of digestion as well as absorption of the digested food material.

The large intestine

The large intestine is about 1.5 metres in length and is composed of the caecum with the appendix, the **colon** and the rectum. The walls of the large intestine have no villi. They have mucus secreting glands.

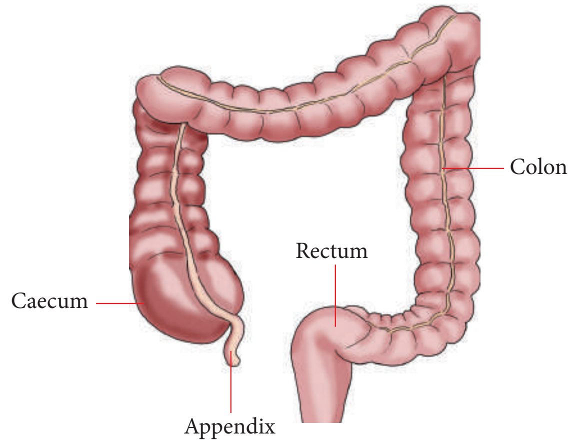


Fig 7.21: Structure of large intestine

Functions of the large intestine

i. The main function of the large intestines is absorption of water. This makes the contents of the large intestine to become more solid. At this point; this material is known as **faeces**.
ii. The mucus-secreting cells in the walls of the large intestines produce mucus to lubricate the passage for easy movement of faeces. Faeces is composed of undigested roughage material, food which may not have been digested (undigested material), dead cells from the lining of the alimentary canal, unwanted mineral salts, bile pigments, living and dead bacteria.

iii. Some bacteria in the large intestines produce **vitamin K**, which is useful to the body. Other bacteria in the large intestine form a gaseous mixture of nitrogen, hydrogen sulphide and flammable hydrogen and methane. The accumulated gas called **flatus** is eliminated through the anus.

iv. The rectum stores faeces until powerful peristaltic waves cause the sphincter muscles in the rectum to relax and the faeces are released in a process known as **defecation**. Faeces may take 12 - 24 hours and even up to three days or more to pass to the rectum.

   A sphincter muscle at the entrance to the rectum prevents faeces from entering the rectum until it is ready for elimination. Two sphincter muscles control elimination of faeces. When the rectum is distended with faeces, its muscles contract and the inner anal sphincter relaxes. The relaxation of the inner anal sphincter is not under our control. The relaxation of the outer anal sphincter is what is under our control. It remains in contracted condition until we decide to have it relaxed in order to defecate.

v. In the large intestines, the **caecum** is large in diameter. It has an **appendix** which forms a small projection with a blind end. In some animals like the rabbit, the caecum and appendix are enlarged and contain bacteria which release an enzyme called **cellulase**. Cellulase digests the cellulose material found in the cell walls of plant material. In human beings, the caecum and appendix are small, and do not have any function.

Fact of life: Sometimes, food may get trapped in the appendix. It decays and causes an infection called appendicitis.

If the infection is very severe, doctors remove the appendix.

Difference between the alimentary canal of human beings and cattle based on the food they eat.

Unlike to human beings, herbivores animals (cows, sheep, giraffe…) eat mainly grass and other plant leaves as food. Plant leaves are rich in a carbohydrate called **cellulose**.

The cellulose can be digested by the action of bacteria, which are present only in the stomach of ruminant like cattle. Goats etc. Ruminants has stomach that consist of four chambers.

The first chamber is the **rumen** which contains symbiotic bacteria secreting **cellulase** enzyme that digest cellulose. Thus the grass is partially digested in the rumen. The partially digested grass are called **cuds**.

The second chamber of ruminant stomach is the reticulum from where the cuds are regurgitated for thoroughly re-chewing. After some time when the ruminant (cow)is resting, the cuds from rumen are brought back to the mouth of the cow in small amount then are chewed thoroughly this is why many times we see a cow moving its jaws from side to side and chewing continuously even when it is not eating grass. This process is called rumination

The third chamber of ruminant stomach is the **omasum** where food is churned and more water is absorbed and the fourth and last chamber of ruminant stomach is the **abomasum**. This is regarded as the true stomach of ruminant since it secretes the gastric juice

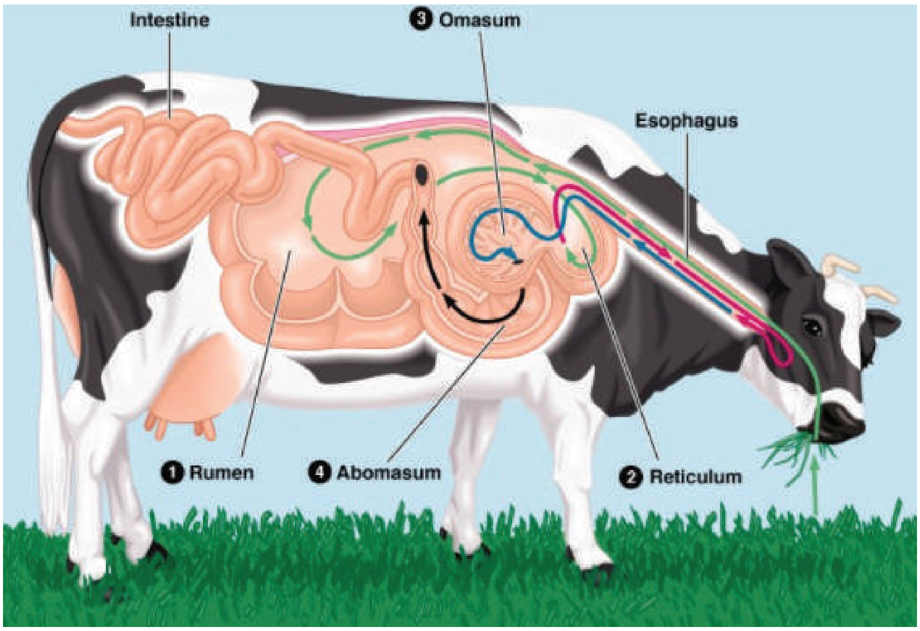


Fig: Alimentary canal of cattle

Self-evaluation Test 7.4

1. Movemens in the small intestine that churn the materials being digested and mix them with intestinal secretions are called _________.
   A) peristalsis
   B) pendular motility
   C) segmentation
   D) churning
2. What is the function of the villi in the small intestine?
   A) To decrease the amount of exposed surface
   B) To facilitate enzyme retention and dispersal
   C) To increase the surface area or absorption and secretion
   D) To sweep particles across the surface with wavelike actions
3. Write **true** or **false** for each of the following:
   A) The optimal pH for pepsin is about 2.0.
   B) The muscularis mucosae is composed of smooth muscle fibres.
   C) Another term for canine teeth is bicuspid teeth.

D) Each small intestinal microvillus contains a lymphatic vessel called a lacteal.

E) Each small intestinal microvillus contains a lymphatic vessel called a lacteal.

F) Another term for swallowing is deglutition.

7.5. Digestive disorders and good health

Activity 7.8: Research Activity

1. Share experiences about the kind of digestive disorders each one has ever experienced.
   - What caused the disorder and how was it treated?
2. Using the Internet and text books research on other digestive disorders.

The facts

A digestive disease is any health problem that occurs in the digestive tract. Conditions may range from mild to serious. Some of the digestive disorders include: constipation, diarrhoea, heart burn, bloating and nausea and vomiting.

(a) Constipation

Constipation is most often defined as having a bowel movement less than 3 times per week. It is often associated with hard stools or problems passing stools. You may have pain while passing stools or may be unable to have a bowel movement after straining or pushing. Constipation is most often caused by:

- Low-fibre diet.
- Lack of physical activity.
- Not drinking enough water.
- Delay in going to the bathroom when you have the urge to move your bowels.
- Stress and travel can also contribute to constipation or other changes in bowel habits.

Constipation is controlled and prevented through:

- Drinking plenty of fluids each day (drink at least 8 glasses of water).
- Eating a lot of high fiber-foods such as fruits and vegetable or root crops.
- Exercising regularly.
- Using the toilet when you feel the urge. Do not delay.

(b) Diarrhoea

Diarrhoea is a condition associated with passing of loose or watery stool. In some people, diarrhoea is mild and goes away in a few days. In other people, it may last longer. Diarrhoea can make you feel weak and dehydrated.

The most common cause of diarrhoea is the stomach flu *(Viral gastroenteritis)*. This mild viral infection goes away on its own within a few days. Eating or drinking food or water that contains certain types of bacteria or parasites can also lead to diarrhoea. This problem is often called food poisoning. Most times diarrhoea is treated at home by oral rehydration therapy (ORT).

ORT is the giving of fluid by mouth to prevent or correct the dehydration that is a result of diarrhoea. As soon as diarrhoea begins, treatment using home remedies to prevent dehydration must be started. If adults or children have not been given extra drinks, they must be treated with a special drink made with oral rehydration salts (ORS).

Activity 7.9: Preparation of ORS

Requirements

- Six (6) level teaspoons of Sugar
- Half (1/2) level teaspoon of Salt
- One litre of clean drinking or boiled water and then cooled - 5 cupfuls (each cup about 200 ml.)

Preparation

1. Stir the mixture till the salt and sugar dissolve.
2. Give the patient the mixture.

Note: ORS packets are available from health centres, pharmacies, markets and shops.

In this case prepare the mixture as follows:

1. Put the contents of the ORS packet in a clean container.
2. Check the packet for directions and add the correct amount of clean water. Too little water could make the diarrhoea worse.

Caution: Add water only. Do not add ORS to milk, soup, fruit juice or soft drinks. Do not add sugar.

3. Stir well and feed it to the child from a clean cup. Do not use a bottle. Encourage the child to drink as much as possible.

(c) Heartburn

Heartburn is a painful burning feeling just below or behind the breastbone. Most of the time it comes from the oesophagus. The pain often rises in your chest from your stomach. It may also spread to your neck or throat.

Normally when food or liquid enters your stomach, a band of muscle at the end of your oesophagus closes off the oesophagus. This band is called the **lower oesophageal sphincter** (LOS). The band has to close tightly enough or food and stomach acid can back up (reflux) into the oesophagus. The stomach contents can irritate the oesophagus and cause heartburn and other symptoms. Heart burn is treated through diet change or medication.

(d) Abdominal bloating

Abdominal bloating is a condition in which the belly (abdomen) feels full and tight. Your belly may look swollen (distended). This condition can be caused by swallowing air, constipation and overeating.

(e) Nausea and vomiting

Nausea is feeling an urge to vomit. It is often called "being sick to your stomach." Vomiting or throwing-up is forcing the contents of the stomach up through the esophagus and out of the mouth. Many common problems that may cause nausea and vomiting include:

- Food allergies.
- Infections of the stomach or bowels, such as the "stomach flu" or food poisoning.
- Morning sickness during pregnancy.

If the protective mucus layer breaks down, part of the stomach lining wall may be digested. This causes a painful ulcer to develop. Some ulcers are caused by excess secretion of gastric juice due to nervousness or stress. Ulcers are treated by diet, medication or by surgery in severe cases.

7.6. Health practices for the digestive system

Activity 7.10: Discussion Activity

1. Suggest healthy practices for the digestive system.
2. Let each one come up with practices that enhance good health.
3. Note down the points raised.

The facts

Digestion begins in the mouth when you begin to chew. The act of chewing thoroughly helps the digestive system to activate your body enzymes to help digestion. Good health of the digestive system includes:

(i) Eating high fiber foods which add bulk to the diet, making you feel full faster. Fibers are found in fruits, vegetables, nuts, seeds, bran and barley. They speed up the movement of food through the intestines and stomach, adding bulk to the stool.

(ii) Eating small and regular meals throughout the day. This make food move smoothly through the digestive tract.

(iii) Maintaining a regular schedule for excretion when you feel the urge.

(iv) Drinking adequate water as it plays a very important role in the process of digestion. Water is needed to create hydrochloric acid in the stomach and mucous lining the stomach walls. Hydrochloric acid is vital for digesting proteins, which activates digestive enzymes. Water also softens the stools and lubricates the digestive system.

(v) Regular exercise can keep food moving smoothly through the digestive system.

(vi) Avoiding caffeinated and carbonated drinks, greasy foods, too much spice, dairy products (if lactose intolerant), alcohol and smoking.

Food contamination

Activity 7.11: Research

1. Research on food contamination. You can use the Internet or textbooks.
2. Record your findings then share with the rest of the class.

The facts

Food contamination refers to the presence of harmful chemicals and microorganisms such as bacteria, viruses and parasites in food which can cause illness. Toxins produced by certain bacteria can cause food poisoning. Food contamination can be caused by:

- Chemicals such as pesticides, certain cleaning compounds and sometimes by use of improper containers for cooking or storing food.
- Improper handling, preparing and storing of food.
- Poor personal hygiene habits.
- Improperly cleaned and sanitised eating and cooking utensils and equipment.
- Contamination of food, utensils and equipment from flies, roaches and other insects and pests.
- Use of foods from unapproved sources.

Self-evaluation Test 7.5

1. (a) What does it mean to eat healthy?
   (b) Why is food contamination bad for our health?
2. How can you help prevent diarrhoeal diseases in your community?

Unit summary

- The human digestive system begins at the mouth. The teeth break up food by mechanical means, increasing the surface area available for the action of digestive enzymes.
- There are four types of teeth. The chisel-shaped incisors are used for biting; the pointed canines for tearing, and the flattened, ridged premolars and molars are used for grinding and crushing food.
- Gastric juice is a mixture of hydrochloric acid and enzymes that further digest the food. Gastric juice and mucus are secreted by gastric glands in the lining of the stomach. The enzymes in gastric juice are rennin and pepsin.
- The mucus helps to protect the stomach wall from its own digestive enzymes and acid.
- The first part of the small intestine is called the duodenum.
- In the duodenum, bile from the liver is mixed with pancreatic juice from the pancreas.
- Small finger-like projections, called villi, line the small intestine. They greatly increase the intestinal surface area. Most of the nutrient absorption takes place through the villi.
- The small intestine joins the large intestine (colon) at the caecum. The caecum is a blind sac that has the appendix protruding from one side. Both the appendix and caecum are functionless in humans.

- The large intestine has the function of removing water from the undigested, unabsorbed material.
- Large numbers of bacteria exist in the colon. They are involved in the synthesis of vitamin K which is necessary for the process of blood clotting.
- The last section of the colon, called rectum, stores faeces until it is expelled through the anus.

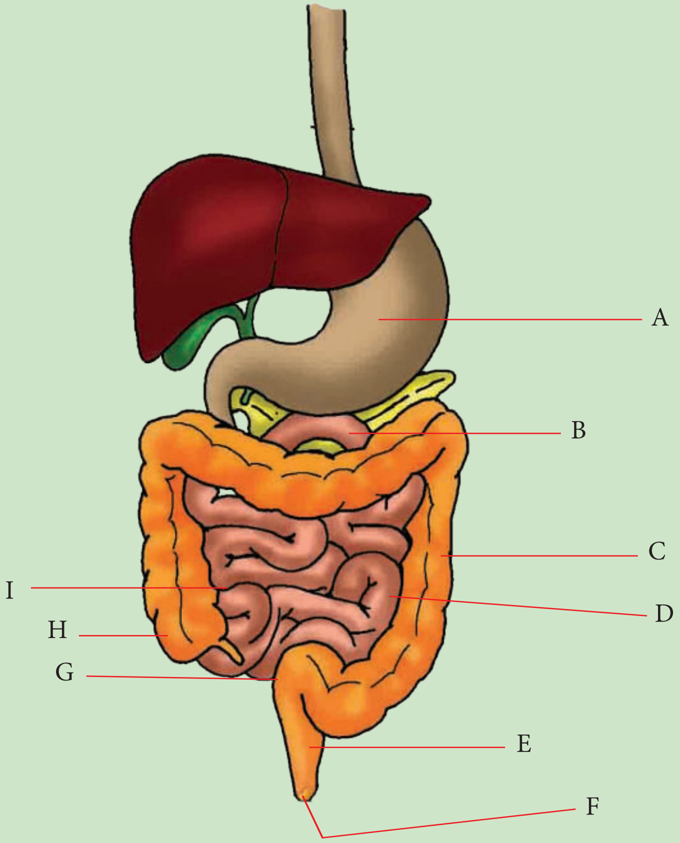
End Unit Assessment 7

1. Two cellular activities that support human life are absorption and assimilation. What is needed for assimilation but not for absorption?
   A. Enzymes to synthesize new molecules
   B. Blood capillaries
   C. Dissolved nutrients
   D. Microvilli
2. Digestive functions of the tongue include ____________.
   A. manipulating and mixing ingested materials during chewing.
   B. helping compress partially digested food to form a bolus.
   C. assisting in the swallowing process.
   D. all of the above.
3. Spot as many organisms as possible in the following grid by encycling them. Categorise the organisms into autotrophs or heterotrophs. Categorise heterotrophs further as either carnivorous, omnivorous or herbivorous.

B	R	O	S	E	A	T	C	R	O	W
A	A	G	N	B	H	I	N	D	I	B
N	B	N	G	I	N	G	E	R	C	L
Y	B	A	N	H	B	E	C	O	W	F
A	I	M	U	S	H	R	O	O	M	F
N	T	G	B	E	R	M	W	F	I	O
E	L	E	P	H	A	N	T	S	C	X
T	S	A	E	Y	N	P	H	B	E	E
C	A	R	R	O	T	U	L	S	I	X

4. Mark the following statements as either true or false. If false write the correct statement.
   A. Tongue is attached to the roof of the mouth cavity at the back.
   B. The large intestines are longer and wider than the small intestines in human beings.
   C. Mucus protects the large intestines from damage.
   D. Heterotrophs have a similar basic process of nutrition.

5. (a) Name the parts in the diagram below.



b) Identify:

(i) The largest gland in the body. __________

(ii) The organ where protein digestion begins. __________

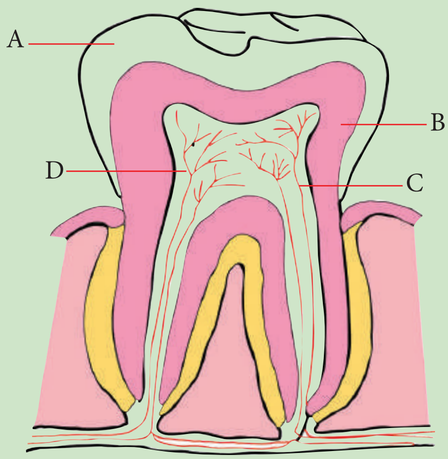
(iii) The organ that releases digestive juice into the small intestine. ______

(iv) The organ where bile juice is stored. __________

6. Match what is in column A with B.

Column A	Column B
Rectum	Mucus
Gall bladder	Villi
Stomach	Taste buds
Tongue	Faeces
Small intestines	Bile juice

7. Paul took some grains of boiled rice in test tube A while John took boiled and chewed rice in test tube B. Both of them poured 1-2 drops of iodine solution into their test tubes and observed colour change. What colour change would they be expecting? Give reasons for your answer.
8. What features of the teeth lead to their effectiveness?
9. Study the diagram below then answer the questions that follow.



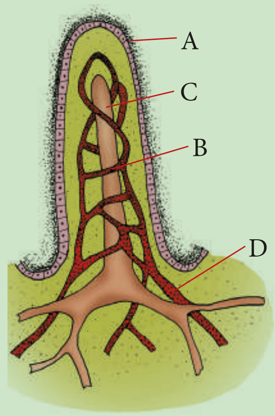
   (a) Name the parts labelled A,B,C,D.
   (b) Identify the type of tooth and give one reason for your answer.
   (c) What organism is responsible for decaying teeth?
   (d) What are the effects of tooth decay?

10. Fill the gaps in the table below.

Name of enzyme	Gland secreting the enzyme	Substrate	Products	Optimum pH
Amylase		Starch	Maltose	
Pepsin				
		Triglyceride	Glycerol and fatty acids	

11. Besides being necessary for the activation of the main gastric digestive enzyme, how is HCl directly involved in digestion?
12. Explain the following terms: ingestion, absorption, assimilation, excretion and egestion.

13. The diagram below shows the structure of a villi.



(a) Label the parts A, B and C.

(b) Name places in the human body where villi are found.

(c) How are the villi suited to their function?

14. The table below shows some average daily dietary requirements of certain individuals.

Diet content	Boy (12-15 Yrs)	Girl (12-15 Yrs)	Man (moderately active 18-35Yrs)	Woman (moderately active18-35 Yrs)
Energy (joules)	11.7	9.6	11.6	9.2
Proteins (g)	70	58	75	55
Calcium (g)	700	69	510	510
Iron (g)	14	14	10	12

(a) Give one reason why the protein requirements of the boy and girl are different.

(b) Give one reason why the iron requirements of the man and woman are different.

(c) Suggest two circumstances when a woman's need for calcium would be increased.

15. Outline ways in which food can be contaminated.

16. (a) Describe the following types of nutrition. In each type, give an example of an organism or organisms in which it takes place.

(i) Holozoic nutrition

(ii) Saprophytism

(iii) Parasitism

(b) (i) Human salivary glands produce amylase.

Name one other organ in humans that produces amylase.

(ii) What is the role of amylase in humans?

(iii) In an experiment with salivary amylase, a student investigated the effect of increasing the temperature from 0°C to 60°C. How would you expect the activity of the salivary amylase to change over this range of temperature?

(c) Explain why most food eaten by humans needs to be digested before it can be absorbed.

Unit 8 Circulatory system in humans

Key unit competence

After studying this unit, I should be able to relate the structure of the circulatory system to its functions.

Learning objectives

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

- Define the circulatory system as a system of blood vessels with a pump and valves to ensure one-way flow of blood.
- Describe the single circulation of a fish and the double circulation of a mammal.
- Identify the structures of the mammalian heart.
- Explain how blood is pumped away from the heart and returns through the veins.
- Describe coronary heart disease in terms of the blockage of coronary arteries and state the possible risk factors.
- Explain how the structures of arteries, veins and capillaries are adapted for their functions.
- Outline the components and the functions of the lymphatic system.
- Demonstrate the effect of physical activity on the pulse rate.
- Compare the components of a blood smear.
- Adopt a culture of maintaining a physical fitness and health.

Introductory Activity

Study the following diagram which is a hot water supply system in a typical house.

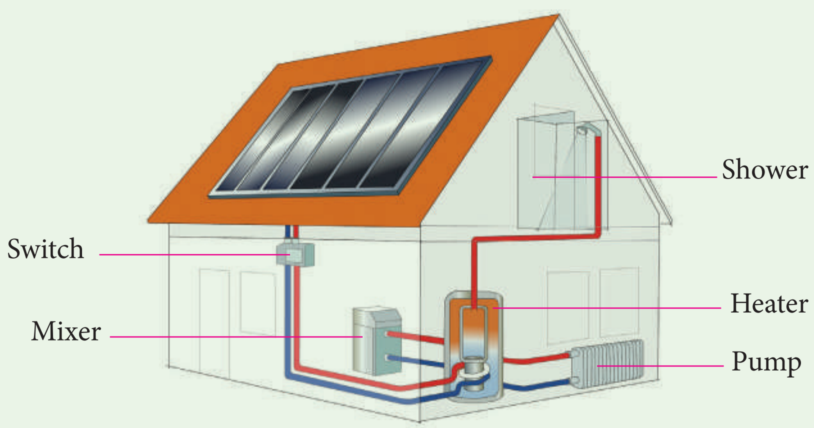


Fig 8.1: Hot water supply system in a house

Note: The blue pipes in the diagram convey cold water whereas the red pipes convey hot water.

Based on this diagram, predict how the circulatory system of human beings works.

Introduction

The human circulatory system is responsible for pumping blood throughout the body. The heart acts as the pump for the blood.

Human intelligence is yet to device a more reliable and efficient machine than the heart. Even when the body is at rest, this incredible organ pumps more than 6,000-7,500 litres of blood daily. The heart works closely with blood vessels which convey blood to the various body organs.

In this unit you will learn about the functioning of the circulatory system in human beings.

8.1. Types of circulation

Activity 8.1: Determining the types of circulatory systems

1. Watch the video on circulation of blood.

   Identify the organs involved and the path of blood from the heart to all the other organs. Sketch the path of blood in your notebook.
2. Observe the charts and pictures of the different types of circulatory systems. Can you identify the types of circulatory systems shown?
   (a) Which animals exhibit each circulatory system.
   (b) How are the circulatory systems suited for the animals?
3. Come up with a list of the similarities and differences between the various types of circulatory systems.

The facts

There are two types of circulatory systems in animals: **closed circulatory system** and **open circulatory system.**

Open circulatory system

This is a circulatory system in which blood is in contact with body cells.

In the open circulatory system, blood does not stay inside the vessels all the time because they are open-ended.

Instead, the blood is pumped out of the vessels by a **heart** or pumping organ into a space within the body known as the **haemocoel**. This means that blood is in direct contact with the cells. The cells exchange materials directly with the blood. This blood eventually flows back into the heart due to the movement of the body muscles of the organism.

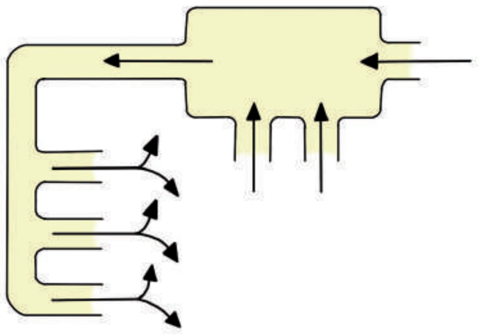


Fig 8.2: Open circulatory system

Insects' circulatory systems consist of a long tubular heart along the back side (dorsal) of the organism. When the heart contracts, blood in it is forced out at its front end. The blood then flows into the haemocoel or body space where exchange of materials with the tissues takes place. It then re-enters the heart through openings called **ostia**.

The open circulatory system works best in organisms with a small body cavity, for example, insects. It is not efficient for large organisms such as vertebrates.

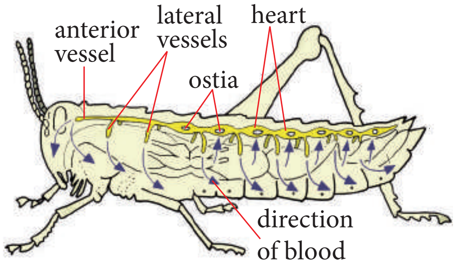


Fig 8.3: Open circulatory system in a grasshopper

Closed circulatory system

This a circulatory system in which blood remains enclosed in a sytem of vessels. It circulates within these vessels due to the pumping action of the heart which is part of the system. In this way waste substances from the tissues enter the blood vessels, while food substances from the blood vessels enter the tissues.

The closed circulatory system is found in annelids and vertebrates like mammals. It has an advantage over the open circulatory system because the pressure of blood in it is high. This means that blood circulates faster and hence transports substances to and from the tissues faster than in the open system.

Activity 8.2: Comparing circulation systems of fish and mammals

1. Compare open and closed circulatory system.
   - What are the similarities?
   - How do they differ?
   - How is the circulatory system suited to the organisms?
   - What are the advantages and disadvantages of each of circulatory systems?

A closed circulatory system is a characteristic of vertebrates. However, there are significant differences in the structure of the heart and the circulation of blood among the different vertebrate groups due to adaptation and internal body structure (anatomy). There are two types of closed circulatory systems: **single** and **closed circulatory system.**

a. Single circulatory system

This is a type of circulatory system in which blood passes through the heart once before it goes to the body. It is found in animals such as fishes.

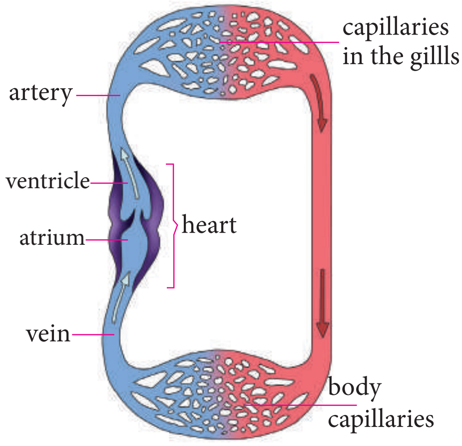


Fig 8.4: Single circulatory system (fish)

Fishes have a single circuit for blood flow and a two-chambered heart that has only a single atrium and a single ventricle.

The atrium collects blood that has returned from the body, while the ventricle pumps the blood to the gills where gaseous exchange occurs and the blood is re-oxygenated; this is called **gill circulation**. The blood then continues through the rest of the body before arriving back at the atrium; this is called **systemic circulation.**

This unidirectional flow of blood produces a gradient of oxygenated to deoxygenated blood around the fish's systemic circuit. The result is a limit in the amount of oxygen that can reach some of the organs and tissues of the body, reducing the overall metabolic capacity of fish.

b. Double circulatory system

This is the type of circulatory system in in which blood passes through the heart twice before completing a full circuit. It is found in the body of mammals and birds.

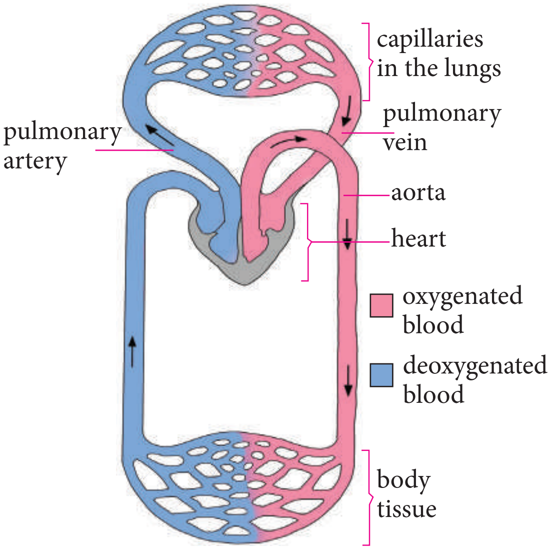


Fig 8.5: Double circulatory system (mammal)

In this type of circulation, the pulmonary circulation is separate from the systemic circulation. Pulmonary circulation carries deoxygenated blood away from the heart to the lungs and returns oxygenated blood back to the heart.

Systemic circulation carries oxygenated blood away from the heart to the body, and returns deoxygenated blood back to the heart.

Advantages of double circulatory system over the single circulatory system

- Blood flows into and from the body at relatively higher pressure therefore, blood can be pumped for a long distance.
- Oxygen and nutrients plus hormones are delivered to tissues at higher speed than in the single circulatory system.
- Waste products are removed at relatively higher speed from tissues to excretory organs.

Self-evaluation Test 8.1

1. (a) What is the alternative means of transport in animals without a circulatory system?
   (b) Why is blood important as a means of transport for larger animals?
2. Flying insects such as flies beat their wings at a great speed despite having an open circulatory system. Explain.

8.2. Human circulatory system

The mammalian circulatory system consists of a **heart** which pumps blood to circulate through a well-defined network of vessels (arteries, veins and capillaries) throughout the body.

Structure of the heart

Activity 8.3: To examine the structure of a sheep or goat's heart

Requirements

- Sheep's or goat's heart with all parts and vessels intact
- Hollow tubing
- Flat wooden board
- Forceps
- Diagrams and pictures of circulatory system

Procedure

1. Place the heart on the dissection board and examine it closely. Identify the following parts:
   i. Various blood vessels.
   ii. Pericardium (membrane covering the heart).
   iii. The heart chambers.
   iv. Any fat surrounding the heart.
2. Using the scalpel, scissors and the forceps, carefully remove the pericardium and the fat.
3. Cut and expose the internal parts of the heart.
4. Identify the atrioventricular valves i.e. bicuspid and tricuspid. Note the tendons and the muscle thickness of both the left

and right lower chambers and compare their sizes.

(a) Explain the function of the valve tendons.

(b) Account for the differences in muscle thickness of the left and right lower chambers.

(c) Name the wall between the right and left chambers. Suggest its importance.

(d) Identify the two blood vessels that take blood away from the two ventricles.

5. Draw a sketch of the external structure of the heart.

The facts

The heart is a muscular organ about the size of the fist. It lies inside the chest cavity between the two lungs.

Internally, the heart is surrounded by a tough membrane called the **pericardium** which covers and protects it. The heart is divided into two sides, the left and the right side which are completely separated by a wall called the **septum**.

The septum prevents blood on the right side from mixing with that on the left side. Each side consists of a small upper chamber called the **atrium** (plural atria) and a larger lower chamber called the **ventricle**. This makes the mammalian heart a four-chambered organ. The atria (also called auricles) are thin walled and receive blood into the heart which they pump to the ventricles. The ventricles are thick walled and pump blood out of the heart.

The heart is made of special muscle called cardiac muscle. This muscle is special in two ways:

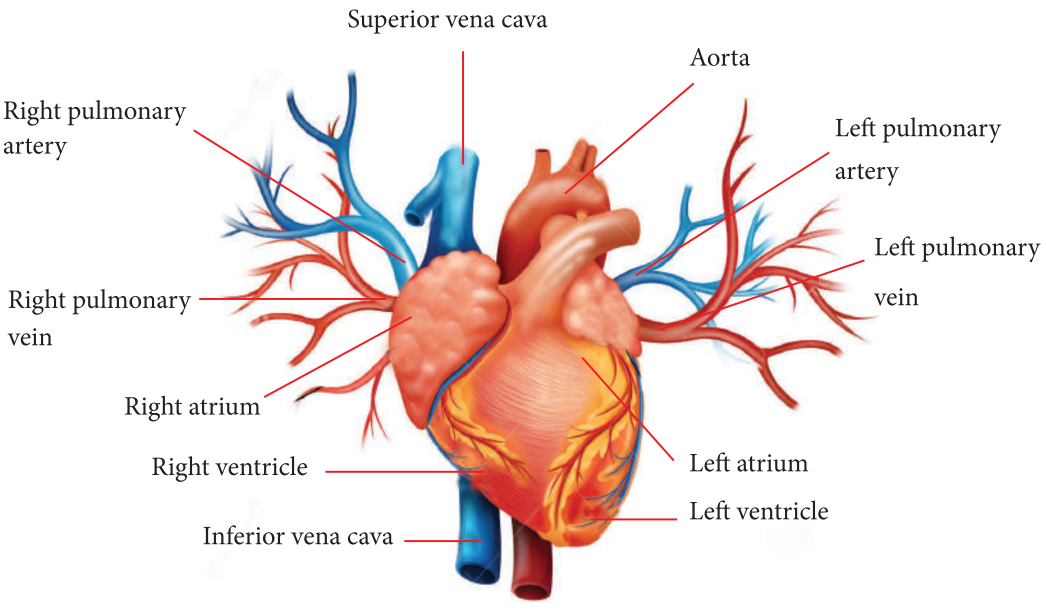


Fig 8.6: External structure of mammalian heart

- The heart can contract continuously without fatigue. Therefore can beat for a lifetime without taking a rest.
- Cardiac muscle is also **myogenic**, which means that its contractions are started by the muscle itself and not by nerves as is the case with other muscle tissue in the body.

Did you know?

The heart tissue itself receives food nutrients and oxygen via a vessel known as the coronary artery which branches from the aorta and spreads through the heart muscle.

Heart valves

Four flap-like valves control the direction of blood flow inside the heart.

- Two of these valves are called the **atrioventricular** valves, which allow the blood to flow only from the atria to the ventricles. The one found in the right side of the heart is called the tricuspid valve because it has three flaps. In the left side of the heart is the **bicuspid** valve. It is also known as the mitral valve.
- The other two valves found in the heart are the **semilunar valves.** When open, they allow blood to move from the ventricles into the arteries and away from the heart.

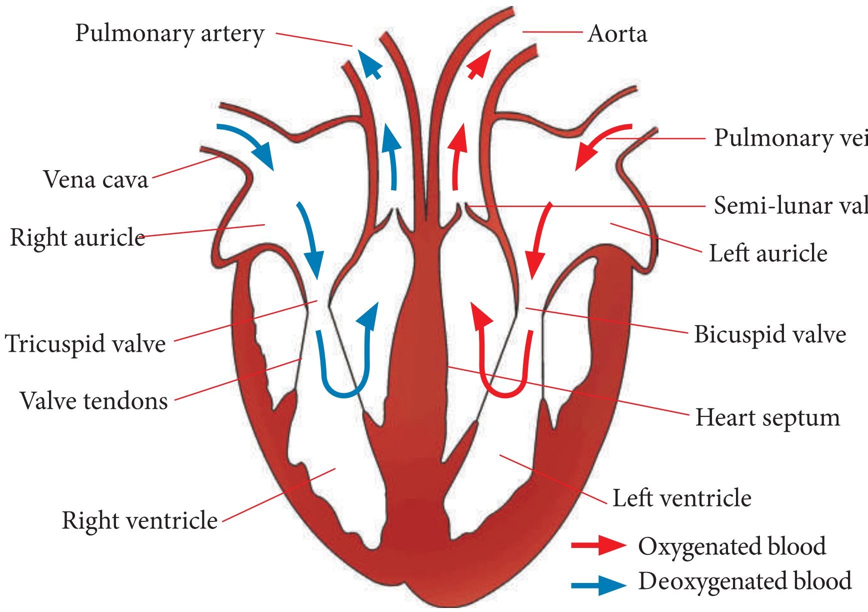


Fig 8.7: Internal structure of the mammalian heart showing direction of blood flow

Circulation of blood in the heart

Activity 8.4: Investigating circulation of blood in the body

1. Using charts, illustrations or computer animations provided, examine the circulation of blood in the heart.
2. Trace the path taken by the red blood cell in a complete circuit.
3. Share your findings with the class.

The facts

The function of the heart is to receive and pump blood. The heart receives blood when its muscles relax. It pumps blood when its muscles contract. These two processes take place in a repeated sequence or cycle known as the heart or **cardiac cycle**. The cardiac cycle has two alternating phases known as **systole** and **diastole**. During systole, the muscles of the heart chambers contract to pump out blood. During diastole, muscles of the heart chamber relax for them to receive blood.

The right atrium receives blood coming from the body tissues through the vena cava. This blood has very little oxygen dissolved in it because most of the oxygen has been taken up for respiration by the tissues. It is however rich in carbon dioxide and appears dull red in colour. This blood is described as **de-oxygenated blood.**

The right atrium then pumps the blood into the right ventricle via the tricuspid valve. When full, the right ventricle lets blood into the pulmonary artery. Semi-lunar valves at the opening of this artery prevent back flow into the right ventricle. At the same time, the tricuspid valve prevents any back flow of blood into the right atrium.

The pulmonary artery carries blood to the lungs. In the lungs the blood picks up oxygen and gives up carbon dioxide. It is now said to be **oxygenated** and is bright red in colour. It goes to the left atrium of the heart via the pulmonary vein.

The left atrium lets blood into the left ventricle via the bicuspid valve. The left ventricle pumps blood to all parts of the body, except the lungs. This blood leaves the left ventricle through the **aorta**. Semi-lunar valves that open into the aorta prevent back flow of blood.

The left ventricle walls are much thicker than the right ventricle walls in order to develop a high enough pressure to pump blood to all parts of the body.

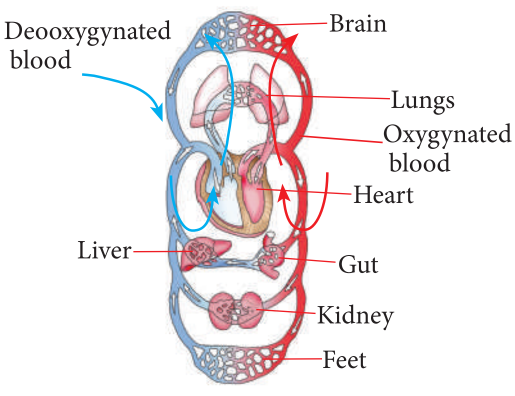


Fig 8.8: Circulation of blood in the body

Self-evaluation Test 8.2

1. What is the main function of the circulatory system?
2. Distinguish between single circulation and double circulation.
3. Which is the most powerful chamber in the heart and why?
4. What is the correct route for blood flow in a human heart?
   A. Right atrium → right ventricle → left ventricle → left atrium → lungs
   B. Right atrium → right ventricle → lungs → left atrium → left ventricle
   C. Left atrium → left ventricle → lungs → right ventricle → right atrium
   D. Left atrium → left ventricle → right ventricle → right atrium → lungs

8.3. Effect of physical activity on heart rate

Activity 8.5: Investigating the pulse rate at the wrist before and after vigorous activities

Requirements

- Stop watch
- Sphygmomanometer

Procedure

1. Take your pulse by placing three fingers firmly on your partner's wrist.

   Shift the position of these fingers until you feel some beating movement against your fingers. This is the pulse. Alternatively you can use a sphygmomanometer when it is available.

Fig 8.9: Taking a pulse

2. Count the number of times you feel these beats in a minute and record them in a table like the one shown below.
3. Repeat this procedure.

Table 8.1: Results for pulse rate

Activity	Pulse rate (beats per minute)		
	1	2	Average
Standing			
Walking			
Running			

4. Ask your partner to walk round the classroom block. Take the pulse again and record. Repeat and record.

5. Ask your partner to run round the classroom block and take the pulse once more and record.

Study questions

1. Why is it necessary to know your pulse rate?
2. Give situations where your pulse rate can increase without any physical activity.
3. What other situations can cause the pulse rate to increase?

The facts

The normal average heartbeat of an adult at rest is 72 beats per minute. This is also known as the pulse rate. It increases during vigorous activity. An increased heartbeat circulates blood with oxygen and glucose needed to produce energy for the vigorous activity in the muscle tissue faster and takes away carbon dioxide and other wastes away from the tissue. The pulse rate also increases during situations of fear or excitement.

Apart from measuring heart rate by pulse rate, the activity of the heart can be monitored by listening to heart sounds caused by the closing of valves and Electrocardiogram (ECG) as shown on below diagram.

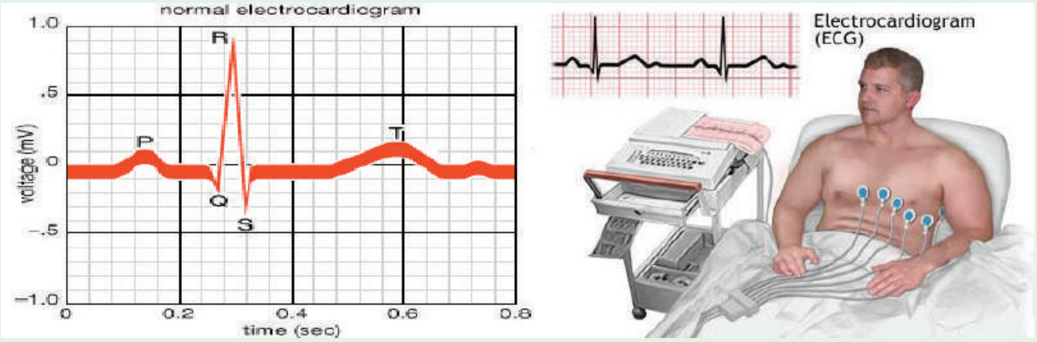


Fig8.10: Use of Electrocardiogram

Further activity: Planning a fitness program

1. Plan out a fitness program that will help have a healthy heart.
2. Present your plan to the class.

8.4. Coronary heart disease

Activity 8.6: Research Activity

Using textbooks, carry out a research about coronary heart diseases.

You can also use this website link http://www.nhs.uk/conditions/coronary-heart-disease

1. Use the following guide questions.
   - What causes the diseases?
   - What are the risk factors of the diseases?
   - How can the diseases be prevented?
2. Share your findings with the rest of the class.

The facts

There are certain diseases and conditions which may interfere with the proper functioning of the heart and blood vessels. Coronary heart disease is the term that describes what happens when the heart's blood supply is blocked or interrupted by a build-up of fatty substances in the coronary arteries. These arteries supply the heart with blood. It is one of the most common cardiovascular diseases that cause death. Coronary heart disease manifests in many ways, for example thrombosis, arteriosclerosis, atherosclerosis and varicose veins.

a. Thrombosis

Under normal conditions, blood flowing in the blood vessels is in a fluid state. Sometimes, blood may clot or form lumps in the vessels. Why do you think this is a problem?

When a blood clot forms inside a vessel, it is called a **thrombus**. The process of its formation is called **thrombosis**. Sometimes the clot or part of it is carried by the blood into the general circulatory system. If it gets into a narrow capillary, it blocks the vessel and stops the flow of blood to the tissues served by that vessel. The movement of the thrombus and its stoppage causes is called an **embolism**. The cells in the affected tissue will not receive oxygen and nutrients and they finally die.

A thrombus in the coronary artery which supplies the heart with oxygen and nutrients is the main cause of a **coronary heart attack**.

A thrombus in a blood vessel supplying the brain leads to a **stroke**. It is now known that long distance travelling, for instance in planes, with little physical activity can set off the formation of a thrombus. Have you heard of anybody who has suffered a stroke? Have you seen them? What are some of the effects of a stroke on a person?

b. Arteriosclerosis

This is hardening of the arteries due to deposition of cholesterol and calcium in their walls. This causes them to thicken and harden and to become less flexible or less elastic: they become sclerotic. This forces the heart to work harder in order to pump blood efficiently throughout the body. It also causes an increase in the blood pressure. High blood pressure can lead to a stroke or a heart attack.

c. Atherosclerosis

It is a condition similar to arteriosclerosis but occurs when cholesterol, fat and calcium are deposited along the inner walls of the arteries. This reduces the diameter of their lumen and causes high blood pressure as the heart is forced to pump harder.

If atherosclerosis takes place in the arteries which supply the brain, the person may suffer a stroke.

Factors that increase the risk of atherosclerosis are:

- High levels of blood cholesterol
- Smoking
- Obesity
- Diabetes
- A sedentary lifestyle which does not involve much physical activity of the body.

  Leading a lifestyle that reduces the risk factors will prevent atherosclerosis.

d. Varicose veins

These are enlarged veins and their branches found near the surface of the skin in the lower parts of the leg. When the valves in these veins do not work properly, blood tends to build up inside the veins. The walls of the veins become stretched and lose their elasticity and are unable to regain their normal size.

Preventing heart diseases

- Avoid smoking.
- Reduce the amount of high-cholesterol foods by eating less fatty meat, chicken and fish but more of fresh fruits and vegetables.
- Reduce salt intake to prevent high blood pressure.
- Exercise regularly to strengthen the heart and improve the circulation.
- Avoid obesity because it causes the heart to overwork.
- Learn to be organised to avoid stress.
- Avoid alcohol.

Self-evaluation Test 8.3

1. Is coronary heart disease inherited? Explain.
2. Explain why your heart beats faster during exams.
3. How does physical exercise contribute to preventing coronary heart disease?

8.5. Blood vessels

Activity 8.7: Observing prepared slides of blood vessels

Requirements

- Microscope
- Prepared or permanent slides of blood vessels
- Diagrams and charts

Procedure

1. Set up the microscope.
2. Mount the prepared slides and observe.
3. Make drawings of your observations.

Study questions

1. How many types of blood vessels did you observe?
2. Compare the structures of the blood vessels.
3. How are the blood vessels suited for their functions?

The facts

Blood vessels are tube-like structures which form continuous channels through the body. They transport blood to and from the heart to the body tissues. There are three major types of blood vessels: **arteries**, **veins** and **capillaries**. The figure below illustrates the relationship between these three main vessels.

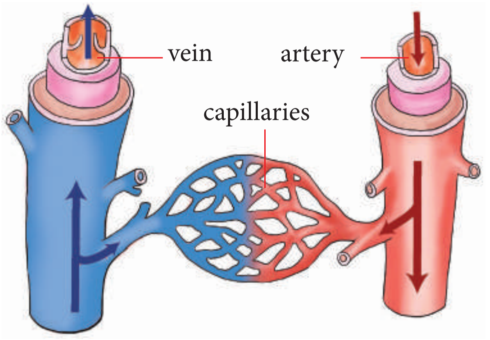


Fig 8.10: Relationship between arteries, capillaries and veins

Arteries

The heart pumps blood into vessels called arteries. Arteries carry blood away from the heart to various parts of the body. Due to the pumping action of the heart, blood from the heart enters the arteries at high pressure. Therefore, the structure of the arteries enables them to withstand the high pressure of blood flowing in them.

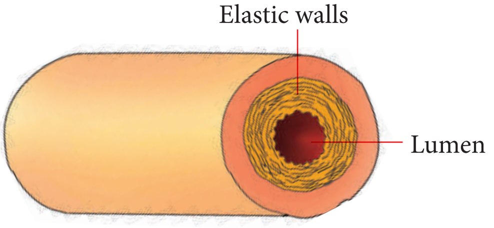


Fig 8.11: Transverse section of an artery

Arteries have the following properties.

- Thick muscular walls to withstand and maintain higher pressure of blood.
- An outer fibrous coat for strength and protection.
- A thick layer of muscle and elastic fibres which contract and relax to adjust their diameter as blood flows through them. Arteries have an inner lining of cells known as an **endothelium**.
- A narrow lumen to maintain the pressure of blood inside them.
- Arteries are located deep within our bodies.
- All arteries **carry oxygenated** blood except the pulmonary artery which carries deoxygenated blood.

The size of the lumen in arteries can be adjusted by the muscles in their walls, for example, the amount of blood passing through arteries can be adjusted during exercise, so that more blood flows to the legs and less blood to the small intestines. This is very important because it ensures that blood is supplied to parts of the body that need it most. Pumping of the blood can be felt on an artery if pressure is put on it with a finger. This is known as the **pulse**. It is this pressure which makes blood in arteries to flow in only one direction.

Arteries branch out to form narrower vessels called **arterioles**. The arterioles branch further within the tissues into finer vessels called **capillaries**.

Capillaries

Capillaries are fine branching blood vessels that form a dense network between the arterioles and venules.

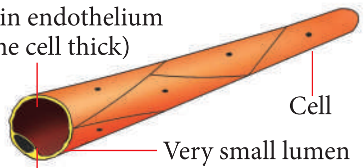


Fig 8.12: Transverse section of a capillary

Capillaries have the following properties.

- They have thin walls to allow for rapid exchange of substances.
- They form a dense network which creates a large surface area over which the exchange of substances takes place.
- Their walls are narrow to allow high pressure build-up within them. This ensures faster movement of substances out of them.
- They have very thin walls made up of only one cell layer for faster exchange of materials.

Capillaries join to form larger vessels known as **venules**. Venules link up to form **veins**.

Veins

Veins carry blood under low pressure from the tissues towards the heart. They have thin walls which are composed of a thin outer fibrous coat, a thin middle layer of muscle and elastic fibres and an inner layer of cells, the endothelium.

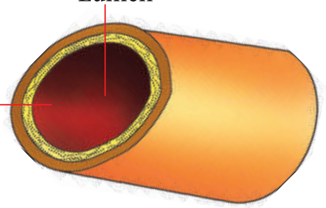


Fig 8.13: Transverse section of a vein

Veins have pocket valves at intervals in their walls which allow blood to flow only in one direction towards the heart. They carry deoxygenated blood except the pulmonary vein which carries oxygenated blood.

Portal veins have capillaries at both ends. They are unique veins that carry blood from one organ to another, for example, the hepatic portal vein which carries blood from the small intestine to the liver.

Activity 8.8: To demonstrate the unidirectional flow of blood in the cutaneous veins in the forearm

Requirement

- Piece or strip of cloth or ribbon

Procedure

1. Work in pairs to carry out this activity.
2. Tie the upper part of your partner's arm just slightly above the elbow with a piece of cloth.
   - What are your observations?
   - Compare your observations with the figure below.

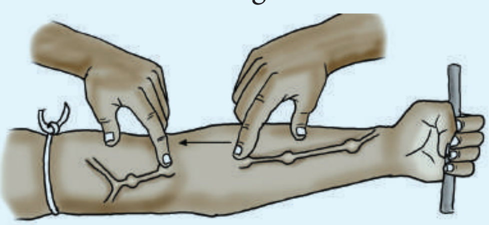


Fig 8.14 (a)

3. Using one finger, your partner will block a raised vein at point B as shown in Fig 8.14 (b).

Using another finger on other hand, your partner will push blood to the swelling at point A. What do you notice happening to the vein? Why is it like this?

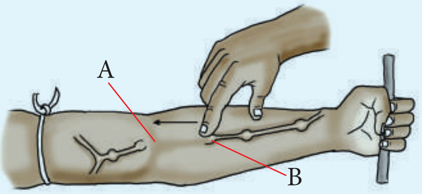


Fig 8.14 (b)

4. Remove the finger at A and leave the finger at point B as shown in Fig. 8.14 (c) below.

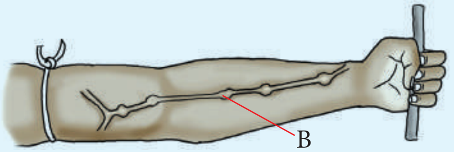


Fig 8.14 (c)

- Describe the appearance of the vein.

5. Now try pushing the blood from point A to B along the vein towards the wrist as in Fig. 8.14 d. Does the blood fill up in the vein?

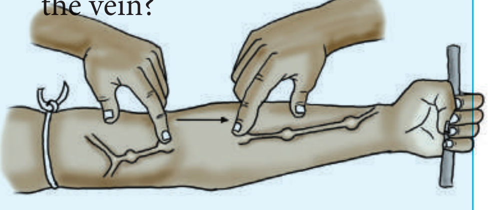


Fig 8.14 (d)

6. Reverse roles and repeat this activity.

Study questions

1. a) What do you think is the normal direction of the blood in the vein? Is it from the wrist to the armpit or from the armpit to the wrist?
   b) Explain your answer using the observation made in the activity.

The facts

Blood flows through all parts of the body in vessels. The vessels form a continuous system so that blood circulates within the body. Blood flows in blood vessels always in the same direction. Arteries convey blood from the heart to the body tissues; veins return blood to the heart from the body tissues; capillaries provide a link between the arteries and veins within the tissues.

Table 8.2: Differences between arteries, veins and capillaries

Arteries	Veins	Capillaries
Carry blood away from the heart	Carry blood towards the heart	Carry blood from the arteries to veins
Carry blood rich in oxygen except the pulmonary artery	Carry blood low in oxygen concentration except the pulmonary vein	Oxygen diffuses into the tissue fluid from them
Blood is under very high pressure	Blood is under low pressure	High pressure of blood for filtration of substances
Blood flows in pulses	Blood flows with no pulse	Blood flows with no pulse
No valves except at the points where arteries leave the heart	Have valves	No valves
Have thick muscular elastic walls	Walls are thin, less muscular and inelastic	Are one cell thick
Have a narrow lumen	Have a larger lumen	Have very narrow lumen (microscopic)
Are located deep in the body	Are located nearer the skin	Are located in all tissues

Self-evaluation Test 8.4

1. Which blood vessels carry blood away from the heart?
2. Blood vessels which absorb strong pressure pulses contain more of __________tissue.
3. What features do veins have that arteries do not have?

8.6. Components of blood

Activity 8.9: Investigating the components of blood

Requirements

- Light microscope
- Micrographs of blood smear
- Diagrams and charts

Procedure

1. Set up the microscope with assistance from your teacher.
2. Mount the micrographs of blood smear.
3. Make drawings of your observations.
4. Compare your drawing with the charts.

Study questions

1. What is the composition of blood?
2. Compare the structures of the blood components.
3. Are there any structural adaptations in the components of blood?

The facts

Blood is the body fluid which transports materials in mammals. It is a liquid tissue that contains suspended substances as well as dissolved substances. Blood has three major functions:

- A medium of transport of materials to and from other tissues.
- Regulation of body temperature and of materials in the body.
- Protection against disease germs.

Composition of blood

The mammalian blood is composed of **cellular components** suspended in a pale yellow watery medium known as **plasma**. The cellular components of blood are the **blood cells** and the **platelets**. There are two main types of **blood cells: red blood cells** also known as erythrocytes and the **white blood cells** also known as leucocytes.

Plasma

Plasma makes up about 55 per cent of the total volume of blood. The other 45 per cent of the blood is made up of the red blood cells, white blood cells and the platelets. Blood plasma is clear and pale yellow in colour when separated from the cellular parts of blood. Ninety per cent of blood plasma is made up of water. The remaining ten per cent consists of a variety of substances that are dissolved in the water. These substances dissolved in plasma include:

- **Food substances** - glucose, amino acids and fatty acids.
- **Vitamins** and **mineral salts** from digestion. The mineral salts are in the form of ions - sodium chloride and hydrogen carbonate ions.
- **Waste substances** - carbon dioxide and urea.
- **Hormones** - adrenaline and insulin among others.

Did you know?

Blood plasma without fibrinogen is called **serum**.

Functions of blood plasma

The plasma transports substances dissolved in it from one part of the body to another.

i. Transportation of carbon dioxide

Carbon dioxide is formed from reactions that release energy in the cells. Carbon dioxide can be toxic to the cells at high concentrations and must be removed before it accumulates.

About 5 – 10% of carbon dioxide from the tissue is transported in solution as **carbonic acid**. The water in plasma acts as the solvent.

Carbon dioxide + water ⟶ carbonic acid

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

The plasma also carries carbon dioxide in form of hydrogen carbonate ions formed from breakdown of carbonic acid in the red blood cells. Most of the carbon dioxide is transported in this way.

ii. Transportation of waste substances

End products of metabolic wastes in the body such as urea, carbon IV oxide and urine are transported to various excretory organs for elimination from the body.

iii. Transportation of heat

Transport of heat by the blood helps distribute it evenly within the body tissues. Most heat originates from an organ like the liver in which many heat-producing chemical reactions occur.

iv. Transportation of hormones

The blood plasma serves as a medium in which hormones are transported from the glands that produce them, to specific target organs on which they act.

v. Transportation of antibodies

Antibodies are chemical substances that protect the body from disease causing micro-organisms. They are transported in the plasma.

vi. Transportation of nutrients

Many of the products of digestion such as glucose and amino acids are dissolved in the plasma before they are transported from the small intestines to the liver either for storage or for further transport to cells in body organs.

Red blood cells (Erythrocytes)

These are very tiny cells. They are **disc shaped** and **biconcave** and appear as discs which are thinner in the centre than around the edge.

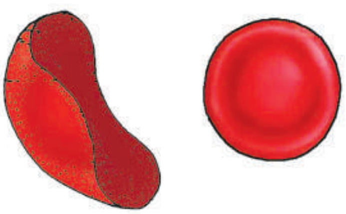


Fig 8.15: Red blood cells

The small size of red blood cells increases their surface area to volume ratio for the diffusion of oxygen. Their cytoplasm contains a red iron-containing pigment called **haemoglobin**. Red blood cells have no nucleus. This creates space for more cytoplasm and therefore more haemoglobin to be packed in them. Red blood cells are also very many in number. There are about five million red blood cells in every cubic millimetre (mm^3) of human blood. However, the number of red blood cells varies depending on any of the following factors:

- Altitude: the higher the altitude the more they will be.
- The state of health of a person: People with severe anaemia or malaria have much fewer red blood cells in their blood.

Red blood cells are made in the red bone marrow of the bones of the sternum and ribs. They circulate for about 100–120 days in the body before their components are destroyed in the liver and spleen. Iron from destroyed cells is reused in the body to make haemoglobin in new red blood cells.

Functions of the red blood cells

The main function of the red blood cells is to transport oxygen from the lungs to the body tissues. The haemoglobin found in these cells readily combines with oxygen when the blood passes through the lungs to form **oxyhaemoglobin**. When the blood reaches a region with low oxygen levels like in the tissues, the oxyhaemoglobin readily gives up the oxygen it was carrying. It then reverts back to haemoglobin. The cells take up the oxygen, while haemoglobin is free to be used again to carry more oxygen.

$$\text{Haemoglobin} + \text{oxygen} \xrightarrow{\textit{tissue}} \text{oxyhaemoglobin}$$

The red blood cells also play an important role in the transport of carbon dioxide. Most of the carbon dioxide from the tissues enters the red blood cells where an enzyme called **carbonic anhydrase** speeds up the dissolving of carbon dioxide to form carbonic acid. This acid dissociates to form hydrogen ions and hydrogen carbonate ions. The hydrogen carbonate ions leave the red blood cell and enter the plasma where they are eventually transported to the lungs. In the lungs, the reverse reaction takes place and the hydrogen carbonate ions are converted back to carbon dioxide. This is released to the air when breathing out.

White blood cells (Leucocytes)

The white blood cells are larger than red blood cells, they are colourless and are fewer in number. There are about 6000 white blood cells per cm^3 of blood. This number increases during infections but reduces in the case of HIV infection. White blood cells have a nucleus and fight disease germs in the body.

There are two main types of white blood cells namely lymphocytes and phagocytes. Others are neutrophils, monocytes, eosinophils and basophils.

i. Phagocytes

Phagocytes are made in the bone marrow of long bones. They have a large lobed nucleus and a cytoplasm containing granules.

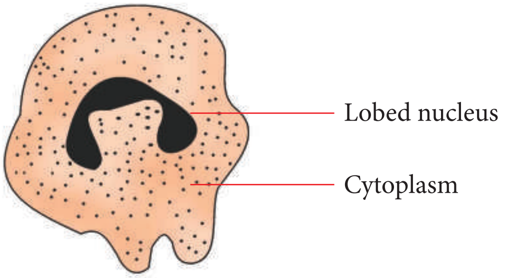


Fig 8.16: A diagram of a phagocyte

They can change their shape as they actively seek, engulf and digest disease - causing micro-organisms therefore protecting the body from infection. They can squeeze through capillary walls in order to reach infected tissue.

ii. Lymphocytes

Lymphocytes have large rounded nuclei. Their cytoplasm is also non granular.

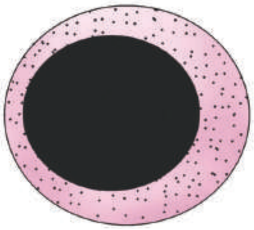


Fig 8.17: A diagram of a lymphocyte

They protect the body from disease by recognising foreign proteins (antigens) in disease-causing micro-organisms that invade cells. They are also able to recognise any chemicals that these micro-organisms produce. Lymphocytes respond by producing chemical substances called **anti-bodies** to destroy the antigen or germs.

iii. Neutrophils

Neutrophils are the most common type of white blood cell in the body. Neutrophils are medium-sized white blood cells with irregular nuclei and many granules. They kill germs by means of a process known as phagocytosis or “cell-eating".

Fig 8.18: Neutrophil

iv. Monocytes

Monocytes are the largest of the types of white blood cells. They have few granules in the cytoplasm when seen under the microscope. Monocytes turn into macrophages when they exit the bloodstream.

As macrophages, monocytes do the job of phagocytosis (cell-eating) of any type of dead cell in the body, whether it is a somatic cell or a dead neutrophil.

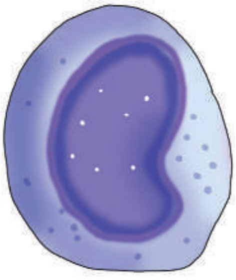


Fig 8.19: Monocyte

v. Eosinophils

There aren't that many eosinophils in the bloodstream—only about 40-400 cells per mm^3 of blood. They have large granules that help in cellular functions. Eosinophils are especially important when it comes to allergies and worm infestations. High eosinophil counts are associated with allergic reactions.

Fig 8.20: Eosinophil

vi. Basophils

Basophils are the least frequent type of white blood cell, with only 0-100 cells per mm^3 of blood. Basophils have the ability to secrete anticoagulants and antibodies that have function against hypersensitivity reactions in the bloodstream.

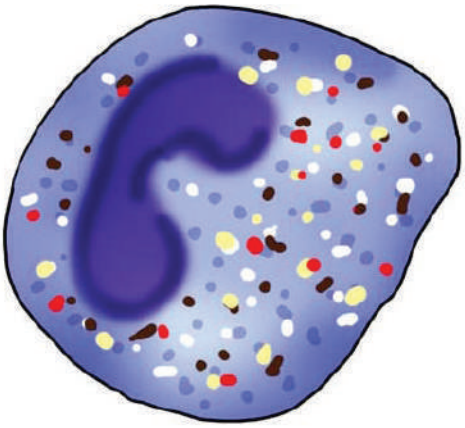


Fig 8.21: Basophil

Platelets

Blood platelets are also known as **thrombocytes**. They are fragments from larger cells. They are very small and have no nucleus.

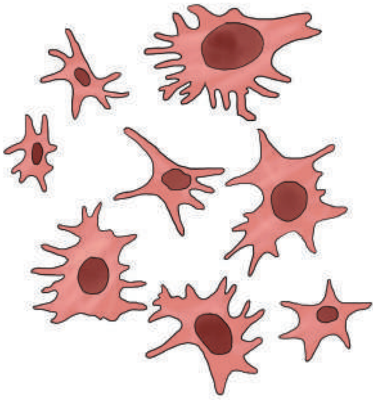


Fig. 8.22: Platelets

Platelets are formed by the pinching off of bits of cytoplasm from large cells inside the bone marrow. Although these bits of cytoplasm contain no nuclei, they are surrounded by a membrane. About 300,000 platelets are found in 1 cm^3 of blood. They live for about seven days. Platelets are involved in blood clotting when an injury occurs on the skin.

Table 8.3: Comparison of red blood cells, white blood cells and platelets

Red blood cells	White blood cells	Platelets
Bi-concave disc in shape	Irregular shape	Cell fragments
Have no nucleus	Have nucleus	No nucleus
Cytoplasm packed with haemoglobin	Several different types, some with granules in the cytoplasm, some without	Composed of cytoplasm surrounded by a membrane
Very many in number. Smaller than white blood cells.	Fewer than red blood cells. Larger than red blood cells.	Few in number Tiny
Made in red bone marrow e.g. ribs and vertebrae	Lymphocytes are made in the bone marrow but migrate to lymph nodes	Made in the red bone marrow
Transport oxygen as oxyhaemoglobin. Also transport carbon dioxide	Some destroy bacteria by engulfing and digesting them; others destroy bacteria by producing antibodies	Responsible for clotting of blood

Blood clotting

Activity 8.10: Determining the process of blood clotting

Using simulations and visual materials.

1. Use the materials to come up with a mechanism involved in the blood clotting process.
2. Discuss your findings with the rest of the class.

Study questions

(a) Have you recently suffered a cut or bruise on any part of your body? In your own words; explain what happened

(b) How long did the injured part bleed?

(c) What did you see at the injury site after the bleeding stopped?

The facts

A blood clot is a seal that forms to close blood vessels that are cut or damaged. This stops further bleeding at the wound and therefore prevents excessive blood loss. It also prevents entry of harmful bacteria into the body through the damaged tissue.

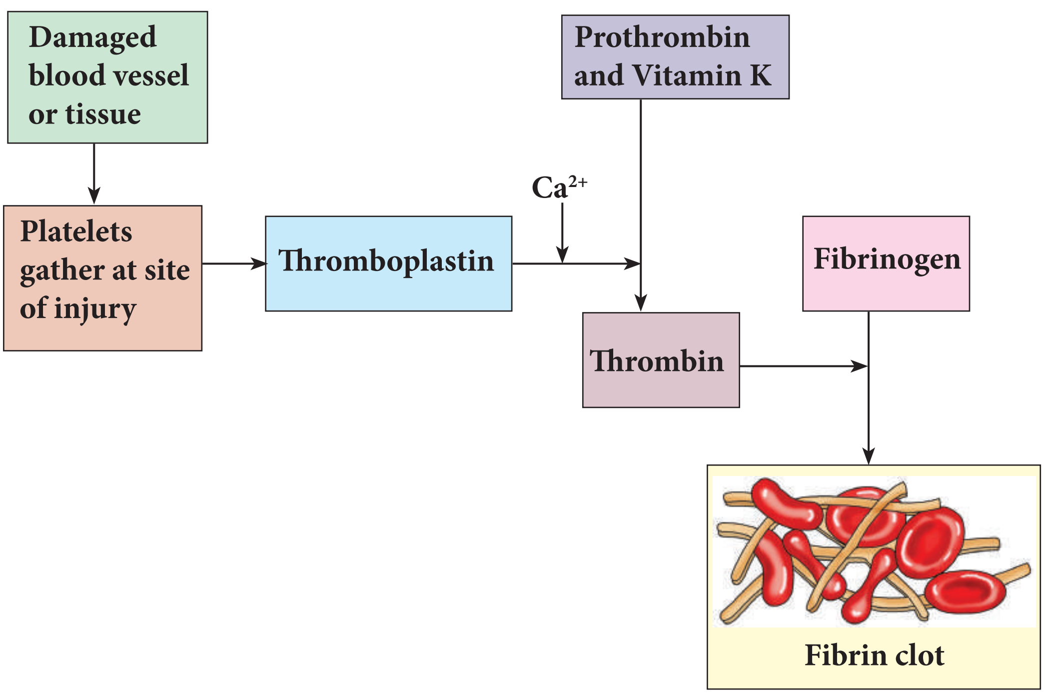


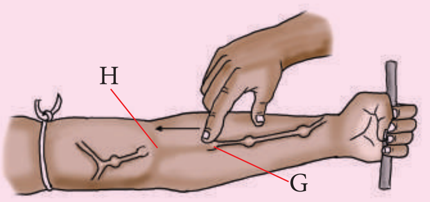
Fig 8.23: The process of blood clotting

When blood vessels are damaged, for example, a cut on the skin, the damaged tissue and platelets release a chemical called thromboplastin (thrombokinase). This substance converts a blood protein called prothrombin to enzyme thrombin. Thrombin in turn changes soluble blood protein fibrinogen into insoluble fibrin, a mesh of fibres which traps red blood cells. This generate a clot which shrinks as it forms hence pulling the edges of the wound together and assists in its sealing. It dries up to form a scab which protects the wound, giving the tissue beneath time to heal. Vitamin K is needed for prothrombin to be formed in the liver.

If a clot forms internally, a condition known as thrombosis occurs. We have seen that thrombosis can be fatal if the clot formed enters and blocks fine capillaries that provide oxygen and nutrients to vital organs like the brain or heart.

Self-evaluation Test 8.5

1. Which of the following statements is true concerning human blood?
   - A. Blood is not a tissue.
   - B. The blood of all normal human beings contains red and white cells, platelets and plasma.
   - C. Some people lack the ability to produce plasma.
   - D. Proteins are not normal components of blood.
2. Write true or false for the following statements.
   - A. Mature red blood cells lack nuclei.
   - B. Red blood cells contain haemoglobin.
   - C. Deoxyhemoglobin carries oxygen.
   - D. Red blood cells lack mitochondria.
3. The ________ produces red blood cells which transport____ and ________.
4. Of what advantage is it for a red blood cell to:
   - (i) have a biconcave disc shape?
   - (ii) have haemoglobin?
   - (iii) lack a nucleus?
5. What is the main function of white blood cells?
6. Study the following diagram showing raised veins in an arm with swellings at pocket valves along the veins.



   - (a) In which direction is the blood flowing in these veins?
   - (b) What is the purpose of tying the band of cloth near the elbow?
   - (c) If the finger is pressed against the vein from point G towards the fingers (backwards) the veins remain flat where the finger has passed. Why is this so?

(d) What do you think would be the effect of pressing down on the vein at point G with another finger while keeping the first finger in position at H? Explain your answer.

8.7. Blood groups and transfusion

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?

Activity 8.11: Discussion Activity

1. With your partner, discuss the following:
   (a) You may have heard of a situation where someone was hospitalised and needed blood. Maybe that person was you, a close friend or a relative.
   (b) Have you ever donated blood during a blood donation week at school? Why was this necessary?
   (c) Explain some of the situations that cause a person to require blood from another person.
2. Suppose you had blood group A, study Table 8.4 and suggest the blood types that your body can accept or reject.
3. Assume your partner has blood group B. Suggest suitable blood types for your partner as well.
4. Now study Table 8.4 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.
5. Explain the precautions to be considered before a blood transfusion.
6. Share your findings with the rest of the class.

The facts

The red blood cells of humans have special types of protein 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. A person with only antigen A on their red blood cells is 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.

Table 8.4: Antigen and blood groups

Antigen present on red blood cell	Blood group
A	A
B	B
A and B	AB
None	O

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 8.5 for a summary of the blood groups.

Table 8.5: Antigens, antibodies and blood groups

Blood group	A	B	AB	O
Antigens	A	B	A and B	None
Antibodies	b	a	None	Both a and b

Blood transfusion

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, 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 a **blood transfusion**.

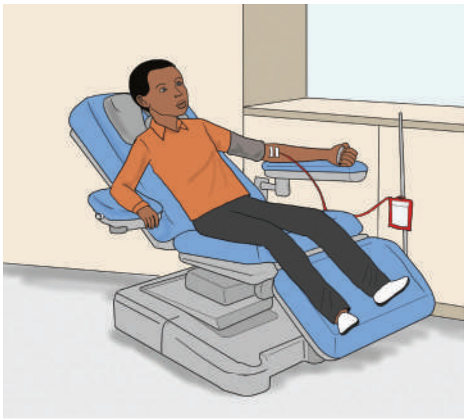


Fig 8.24: A person donating blood

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 necessitated by situations such as the following:

- When a person loses too much blood due to an injury that may result from a motor accident, a fall, a fight, among others.
- When a person becomes anaemic due to a disease such as malaria.
- When a woman loses too much blood due to childbirth.
- 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.

Table 8.6: showing if donor's blood is accepted by the recipient

Donor / recipient	O	A	B	AB
O	Yes	Yes	Yes	Yes
A	No	Yes	No	Yes
B	No	No	Yes	Yes
AB	No	No	No	Yes

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 has no antibodies to agglutinate the recipient's blood. People with **AB** blood are therefore described as **universal recipients**.

Precautions to be considered before a blood transfusion

Several considerations or precautions have to be taken, to ensure that the recipient does not suffer any harm as a result of the transfusion. The 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.
- The presence of any infective micro-organisms, for example, Human Immunodeficiency Virus (HIV); the organisms that cause diseases like **syphilis** and **Hepatitis B** and other diseases. Only blood from a healthy person is kept for future use. Any blood found having disease causing organisms in it is destroyed.

Did you know?

When you donate blood to a blood bank or a hospital, you receive a blood donor's card bearing your name and type of blood. It is important to carry this card with you, especially when you travel. It may be useful during a medical emergency.

The Rhesus factor

In some people, another type of antigen is found on their red blood cells. This antigen is called the **Rhesus antigen**, the **Rhesus factor** or **antigen**. 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– and so on. A+ blood has the Antigen A as well as the rhesus antigen. A– blood lacks the rhesus antigen but has antigen A.

Blood transfusion and the Rhesus factor

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.

- Suggest what will happen to a Rhesus negative pregnant mother if transfused with Rhesus positive blood in subsequent pregnancies.

Self-evaluation Test 8.6

1. If one of your parents is blood type A and the other is type B, which of the following blood types are you likely to be?
   A. A
   B. B
   C. O
   D. AB
2. Why is it important to determine the blood types of the donor and the recipient in transfusions?
3. What are universal donors and universal recipients in the ABO blood system?
4. Using your knowledge on blood transfusion, fill the table below, ticking where transfusion is permissible and crossing where it is not. Fill in all 16 squares.

Donor / recipient	O	A	B	AB
O				
A				
B				
AB				

8.8. Lymphatic system

Activity 8.12: Investigating the lymphatic system

Using computer simulations and charts, identify the location of lymph nodes, lymph vessels and glands.

Study questions

1. What is the function of the lymphatic system in the body?
2. How does the lymphatic system complement the blood circulatory system?

The facts

Blood entering the arteriole end of a capillary network has higher pressure compared to that leaving the venule end. This pressure forces water and small solutes in the blood to pass through the capillary wall and to form a fluid outside the capillaries.

This fluid surrounds the cells in the tissues and is called **tissue fluid**. Blood cells and large proteins do not pass through capillary walls. Tissue fluid is similar to plasma but with less protein in it. It is from this fluid that cells obtain their nutrients and oxygen by the process of diffusion. Waste materials and secretory products from the cells diffuse into it. Tissue fluid eventually drains back into the blood at the venule end of the capillary where the pressure is lower.

Most of the tissue fluid does not re-enter the capillaries but instead makes its way into another system of capillaries known as the **lymphatic capillaries**. Inside this system the fluid is now called **lymph**.

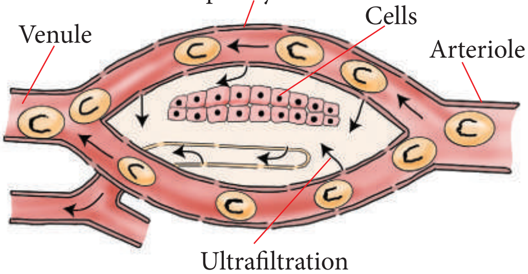


Fig 8.25: Formation of tissue fluid

The lymphatic capillaries link up to form another transport system made up of lymph vessels: lymph veins and lymph capillaries. These vessels are thinner than blood vessels and have many internal valves. They also have swellings along their length called **lymph nodes.** Lymph nodes contain **lymphocytes**. Lymphocytes are white blood cells which defend the body against infection by producing antibodies. The antibodies kill micro-organisms that cause the disease. Examples of such micro-organisms are bacterium, virus and fungi. An antibody is a protein produced in the blood that fights diseases.

Just like blood circulatory system which transports blood, the lymphatic system transports lymph.

The lymphatic system is a network of tubes throughout the body that drains fluid (called lymph) from tissues and empties it back into the bloodstream. Lymph is filtered through the spleen, thymus and lymph nodes before being emptied into the blood. Blood vessels tend to seep fluid into surrounding tissue. The lymphatic system drains off any extra fluid to stop the tissues from puffing up.

The lymphatic system consists of a fluid (lymph), vessels that transport the lymph and organs that contain lymphoid tissue.

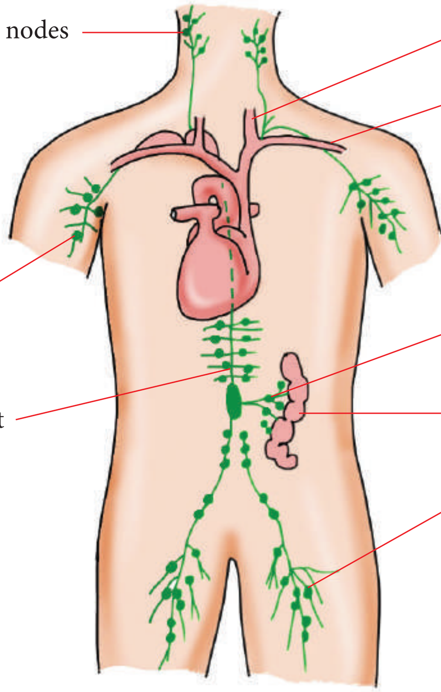


Fig 8.26: The lymphatic system

Lymph

Lymph is a fluid similar in composition to blood plasma. It is derived from blood plasma as fluids pass through capillary walls at the arterial end. As the interstitial fluid begins to accumulate, it is picked up and removed by tiny lymphatic vessels and returned to the blood.

Lymphatic vessels

Lymphatic vessels, unlike blood vessels, only carry fluid away from the tissues. The smallest lymphatic vessels are the lymph capillaries, which begin in the tissue spaces. Lymph capillaries are found in all regions of the body except the bone marrow, central nervous system and tissues, such as the epidermis, that lack blood vessels.

Lymphatic organs

Lymphatic organs are characterised by clusters of lymphocytes and other cells in branching connective tissue fibres. The lymphatic organs include:

- Lymph nodes
- Tonsils
- Spleen
- Thymus

Lymph nodes

Lymph nodes are small bean-shaped structures found in particular locations in the body. Such places include neck, armpits and between the lungs. Lymph nodes contain white blood cells which fight infections.

Tonsils

Tonsils are the two lymph nodes located on each side of the back of the throat.

They help to prevent the body from infection.

The spleen

The spleen is located in the upper left abdominal cavity, just beneath the diaphragm, and posterior to the stomach. It is similar to a lymph node in shape and structure but it is much larger. The spleen is the largest lymphatic organ in the body.

The thymus

The thymus is a soft organ with two lobes that is located inside the ribcage, just behind the breastbone. It is relatively large in infants and children but after puberty it begins to decrease in size so that in older adults it is quite small.

Functions of the lymphatic system

The lymphatic system has multiple interrelated functions:

i. It is responsible for the removal of interstitial fluid from tissues.

ii. It transports white blood cells to and from the lymph nodes into the bones.

iii. It absorbs and transports fatty acids and fats as chyle from the digestive system.

iv. It transports dendritic cells to the lymph nodes where an immune response is stimulated.

Self-evaluation Test 8.7

1. The spleen is a lymph organ that filters blood and also acts as a reservoir for__________.
   A. water
   B. fat
   C. fluid
   D. blood
2. Which of the following would not be classified as a lymphatic structure?
   A. Pancreas
   B. Spleen
   C. Tonsils
   D. Thymus
3. Both lymph and venous blood flow are heavily dependent on __
   A) the pumping action of the heart.
   B) skeletal muscle contractions and differences in thoracic pressures due to respiratory movement.
   C) contraction of the vessels themselves.
   D) two-way valves.

Unit summary

- A closed circulatory system is one in which blood is confined to blood vessels.
- In an open circulatory system blood leaves the blood vessels into spaces known as haemocoel where exchange of materials takes place before the blood goes back into the vessels.
- The components of blood are blood plasma, red blood cells, white blood cells and platelets.
- The number of red blood cells increases with increase in altitude.

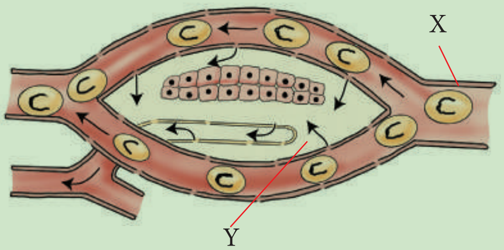
- There are about 5 million red blood cells per cm^3 of blood.
- There are about six thousand white blood cells per cm^3 of blood.
- Red blood cells contain haemoglobin which has a high affinity for oxygen. They are biconcave in shape to avail a large surface area for diffusion of oxygen into the cell. They lack a nucleus to enable more haemoglobin to be packed in them.
- White blood cells have an irregular shape. Some can engulf and digest bacteria, others produce antibodies that destroy bacteria and other pathogens.
- The heart is a muscular four chambered organ that pumps blood through the circulatory system. It is made up of two atria and two ventricles.
- The left ventricle has a thicker wall than the right ventricle because it pumps blood long distances, to the rest of the body, while the right ventricle pumps blood short distances, to the lungs.
- Arteries have thick muscular walls with small lumen. They take blood away from the heart.
- Veins have thin walls and are less muscular with large lumens. They direct blood to the heart.
- Capillaries have one cell thick walls and are very tiny. They allow exchange of materials between blood and the tissues.
- Oxygen is transported in the red blood cells as oxyhaemoglobin.
- Some common diseases and defects of the circulatory system are thrombosis, varicose veins and arteriosclerosis.
- Human blood is categorised into the blood groups A, B, O and AB.
- The knowledge of blood groups is important during transfusion. Only blood groups that are compatible can be transfused from donors to recipients. Individuals with blood group O are universal donors, and those with blood groups AB are universal recipients.
- The lymphatic system returns excess interstitial fluid to the blood, absorbs fats and fat-soluble vitamins, and provides defence against disease.
- Lymph is the fluid in the lymphatic vessels. It is picked up from the interstitial fluid and returned to the blood plasma.
- Pressure gradients that move fluid through the lymphatic vessels come from the skeletal muscle action, respiratory movements, and contraction of smooth muscle in vessel walls.

End Unit Assessment 8

1. The wall of the left ventricle is thicker because it ________.
   A. pumps blood to the lungs
   B. Pumps blood to the upper body
   C. pumps blood to all parts of the body
   D. pumps blood into the right atrium
2. Which of the following can best be compared to soldiers? Explain why.
   A. Lungs
   B. Capillaries
   C. Red blood cells

D. White blood cells

3. What effect does age have on the size of the thymus?
   A. The size of the thymus increases continuously from birth to death.
   B. The size of the thymus decreases continuously from birth to death.
   C. The thymus is not affected by age.
   D. The thymus initially increases in size and then decreases in size from adolescence through old age.
4. (a) How do the heart and lungs work together to pick up and deliver oxygen to the cells?
   (b) How does the structure of arteries and veins relate to their functions?
5. What are the risk factors for coronary heart disease?
6. Is ABO blood compatibility enough for the safety of blood transfusion? Why?
7. Lymph nodes are widely distributed throughout the body along the lymphatic pathways where they filter the__________ before it is returned to the _________.
8. What can one attribute the main causes of the circulatory system disorders in man to?
9. Discuss the good health habits and practices of a circulatory system.
10. The diagram below shows some capillaries in a tissue.

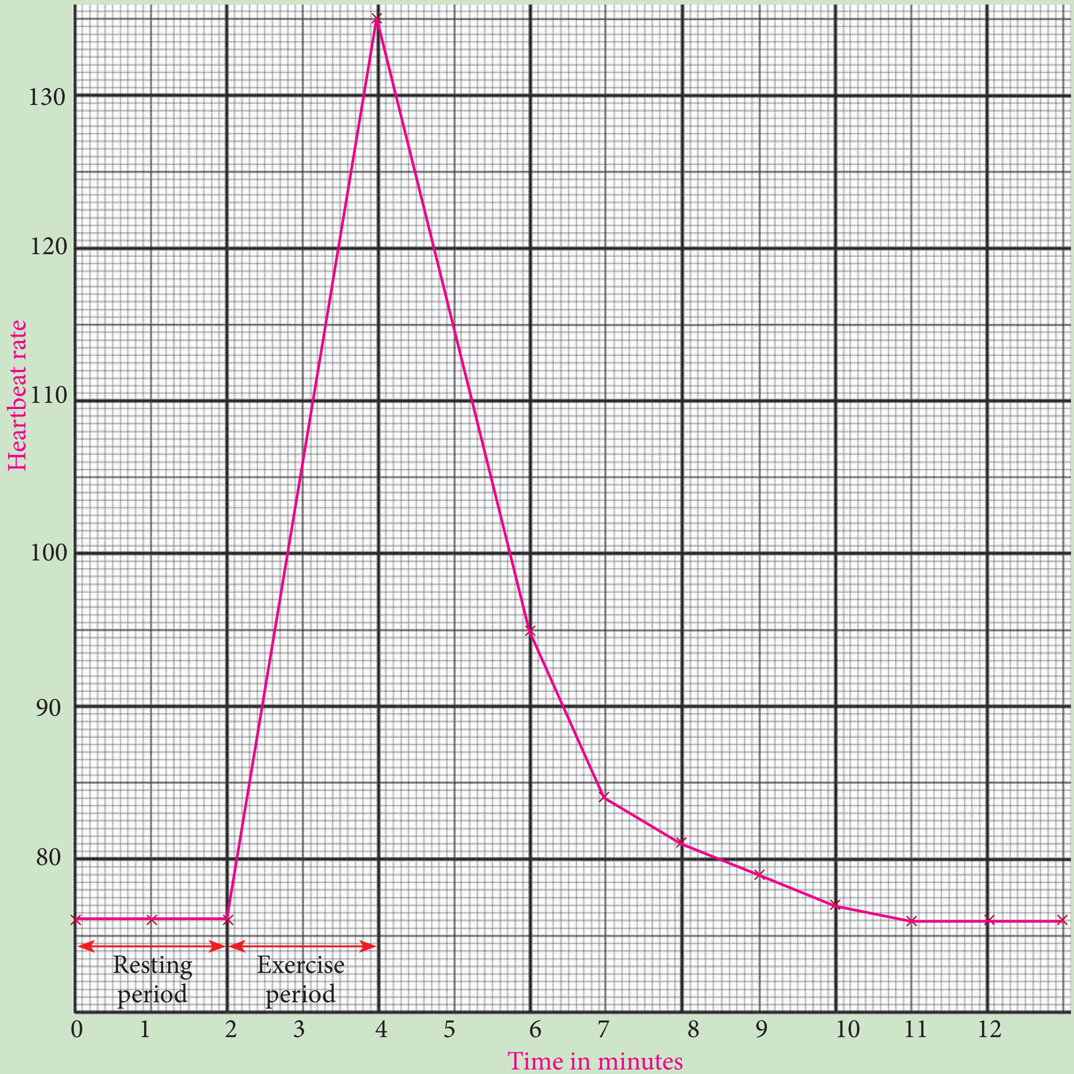


Answer the questions that follow.

(i) Is the blood vessel marked X a venule or an arteriole?
(ii) Name some substances that are found in blood and also in the fluid Y.
(iii) Name fluid Y.
(iv) How do useful substances in liquid Y get into the cells?
(v) Name one substance that leaves the cells into liquid Y.
(vi) How does liquid Y differ from blood plasma?
(vii) What causes substances to leave the blood and form part of the liquid Y?
(viii) Name two ways by which the excess fluid Y drains out of the intercellular space.

11. The pulse rate of a student was measured before and after a period of 2 minutes exercise. Immediately before and after the exercise, the student rested on a bed.

The results are as shown in the following graph



(a) Explain in detail why the pulse rate of the student rose during the period of exercise.

(b) By how many beats per minute did the pulse rate of the student increase during the exercise period?

(c) How long did it take, after the exercises had ended, for the student's heartbeat to return to its resting value?

(d) Explain why, after the exercise, the return to the resting rate was gradual.

(e) How does holding the breath affect the heart rate?

12. Blood samples were taken from groups of people living at different altitudes and the number of red blood cells in each mm^3 of blood determined. The results of this survey are shown in the following table.

Height above sea level (metres)	**Red blood cells (per mm^3 of blood)**
0	5,000, 000
400	5, 7500,000
1,500	6,5000,000
1,800	7,000,000
4,400	8,000,000

(i) Plot a graph of altitude against the number of red blood cells per mm^3 of blood.

(ii) Explain the significance of increase in number of red blood cells as altitude increases.

(iii) Explain what athletes going to compete in high altitude areas should do in order to increase O_2 absorption capacity during the competitions.

13. The following table shows what happens to the output of blood from the open side of the heart when the heartbeat per minute changes.

Heart beat per minute	55	70	80	90	120	140	150	175
Heart output in liters	4	4.8	5.2	5.6	6.0	6.0	5.8	4.6

(i) Plot a graph of the above data. Put heartbeat on the horizontal axis.

(ii) List the conditions that can lead to an increased heartbeat.

(iii) What is the effect of the heart beat on the output of blood from the heart?

(iv) What is the advantage of an increased heartbeat when an angry neighbour's dog is chasing you?

(v) What is the optimum output of the heart in this data?

(vi) Explain the reason for your answer in (v) above.

Unit 9

Cellular respiration

Key unit competence

After studying this unit, I should be able to compare energy yield in aerobic and anaerobic respiration.

Learning objectives

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

- Explain that the body needs energy in form of ATP to carry out metabolic reactions.
- Define cellular respiration as the process by which energy in food is converted into the energy for an organism to do biological work.
- Write simple chemical equations for aerobic and anaerobic reactions using glucose as substrate.
- Describe the effects of lactic acid in muscles during exercise and the role of anaerobic respiration in yeast during brewing and baking.
- Describe the role of anaerobic respiration in yeast during brewing and baking.
- Design simple experiments on respiration.
- Carry out controlled experiments on respiration.
- Compare anaerobic and aerobic respiration.
- Draw and interpret graphs of accumulation of lactic acid during anaerobic respiration.
- Recognise that the accumulation of lactic acid in active muscles during vigorous exercises leads to itching, muscle crumps and nausea.
- Appreciate the need and benefit of physical exercises.

Introductory Activity

Study the diagrams below carefully.

What happens on the left hand side is similar to what happens on the right hand side. In both cases, explain the role of oxygen (O_2). Of what importance is fuel to the car? How does this compare to the sugar or glucose to the cell?

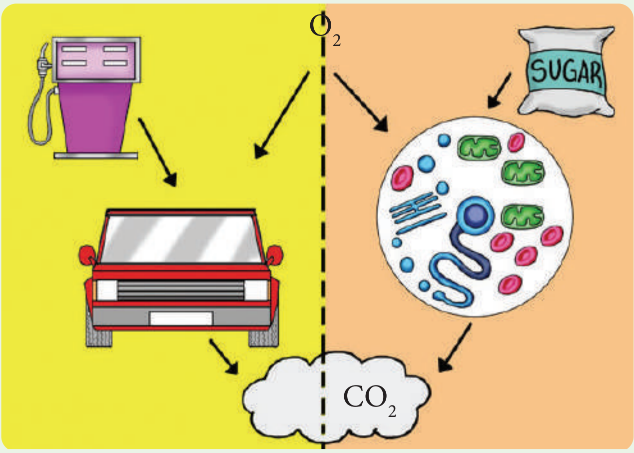


Fig 9.1: Cellular respiration

Based on the figure, predict what you will learn in this unit.

Introduction

Most of the activities we do everyday require the use of energy. Think about the activities you have done today. Which ones do you think required your body to spend a lot of energy? In which activity was the least energy used? Do you know where the body gets energy from?

All living organisms need energy in order to carry out various life processes. They need energy for growth, repair of worn out tissues and for reproduction. Energy is needed for both physical and mechanical work. Energy is also needed for other purposes which may not be so obvious such as building up of proteins from amino acids within cells and moving substances across the cell membrane. In this unit you are going to learn how organisms get energy for use in their bodies.

9.1. Role of ATP in metabolism

Discussion corner

1. Discuss the relationship between body activity and the amount and type of food eaten in different people.
2. Present your findings to the rest of the class

Living organisms obtain energy from breakdown of food substances which may be ingested in the case of animals or manufactured during photosynthesis in plants. The chemical process by which food is broken down in all living cells to release energy is called **respiration.** Sometimes it is referred to as **cell respiration, tissue respiration** or **internal respiration**. It is controlled by many enzymes so that energy is produced in small amounts but continuously.

Activity 9.1: The use of glucose in cellular respiration

Requirements

- Yeast suspension
- Three 50 ml beakers
- (100-ml) beaker
- Three test tubes for fermentation
- Thermometer
- Glucose
- Maltose
- Sucrose
- 10 graduated cylinder

Procedure

1. Prepare 78% glucose, maltose and sucrose solutions and place each in a beaker.
2. Add 1 ml of yeast solution to the beaker containing glucose solution. Then pour the glucose/yeast solution into the small test tube.
3. Flip the tube upside down into the beaker containing the remainder of the glucose/yeast solution.
4. Repeat procedures 1, 2 and 3 for sucrose and maltose solutions.
5. Measure the initial temperature of the glusoce/yeast solution and at the end of the experiment. Record the temperatures in your notebook.
6. Record all your observation during the experiment in your notebook.

Study questions

1. Explain the meaning of respiration.
2. What is the function of cellular respiration in organisms?
3. Is glucose required for cell respiration?
4. Was there a change in temperature at the beginning and end of the experiment? Why is this the case?
5. Can any type of sugar be used as a fuel for cellular respiration? Why?

The facts

Cellular respiration is the process by which animals produce energy for use in their bodies. In this activity, the glucose molecule is broken down by enzymes in the body into carbon dioxide and energy The main purpose of this process is to produce ATP molecules which are the main energy storage and transfer units in the cell. Cells need a constant flow of glucose in order to remain healthy and active. Yeast contains an enzyme that catalyses the breaking down of glucose to ethanol and carbon dioxide.

Cellular respiration is the process by which food molecules, like glucose, are broken down to carbon dioxide and water. The chemical equation for respiration is as below:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

The energy released is trapped in the form of **ATP** for use by all the energy-consuming activities of the cell.

The process occurs in two phases that is

glycolysis, the breakdown of glucose to pyruvic acid. The complete **oxidation of pyruvic acid** to carbon dioxide and water.

Respiration takes place in cell organelles known as **mitochondria.** In Senior One you learnt about parts of a cell which included mitochondria. Can you recall the structure and functions of the mitochondria?

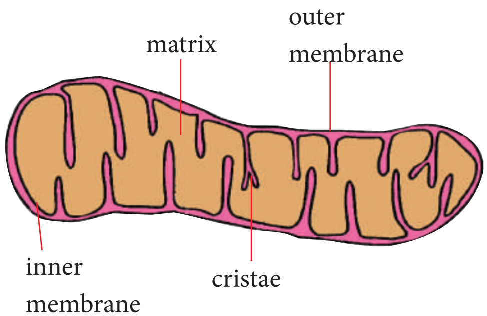


Fig. 9.2: Structure of mitochondrion

Mitochondria are found in nearly all cells. They are most abundant in cells that require a lot of energy, for example, sperm cells and muscle cells. Mitochondria contain enzymes and other special molecules required for respiration. These are located inside or on the surface of the inner membrane, which is deeply folded to create a large surface area.

Respiration involves the breakdown of organic substances to release energy. Substances that are broken down to release energy are called **respiratory substrates.** They are mostly carbohydrates, but sometimes fats or proteins are used. These are usually first converted to glucose before they are broken down. Starch in plants and glycogen in animals are examples of carbohydrates that would have to be converted to glucose first before they are used for respiration. Lipids may be used when all stored carbohydrates are used up. In animals like human beings, proteins are used to provide energy only in conditions of extreme starvation.

Cells are always carrying out an enormous amount of activities. For this reason, they need a constant supply of energy.

Animals and other organisms obtain the energy available in carbohydrates through the process of **cellular respiration.** Cells take the carbohydrates into their cytoplasm and through a complex series of metabolic processes, they break down the carbohydrates and release the energy.

Sixty per cent of the energy released in the process of respiration is in form of heat energy which is lost or is used to warm the body. Some energy is used immediately by the cell. The rest is converted into a storable form of energy molecule known as **adenosine triphosphate** or **ATP.**

ATP is a combination of a complex organic molecule called **Adenosine** and **three phosphate groups**. They are joined end to end as shown below.

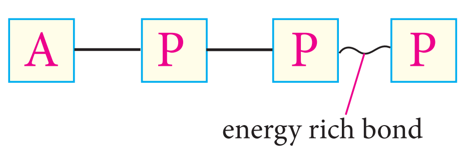


Fig. 9.3: Adenosine triphosphate (ATP)

A stands for **A**denosine and **P** for phosphate. The last link between the two phosphates is shown with a wavy line because it is an **energy-rich bond.** This is where a large amount of the energy is stored. When the third phosphate group is removed, the stored energy is released, leaving adenosine with two phosphate groups in a molecule called **Adenosine diphosphate (ADP).**

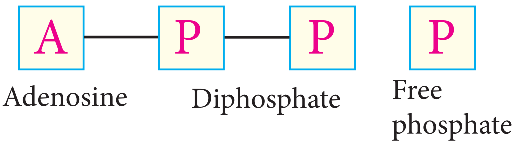


Fig. 9.4: Adenosine diphosphate (ADP) and free phosphate

Did you know?

In order to store energy, adenosine diphosphate is converted to adenosine triphosphate by using energy released from respiration to add the third phosphate group. Thus:

ADP + P + Energy $\longrightarrow$ ATP

In order to release the energy for use, ATP is split to ADP and a free phosphate.

ADP $\longrightarrow$ ADP + P + Energy

I. **The energy produced by respiration is used to attach a third phosphate group to ADP to form ATP.**

II. **When the third phosphate group is detached from ATP, the energy released is used for cell activities.**

III. **The ADP is returned for reuse. The energy from a single glucose molecule can form 36 molecules of ATP.**

The energy produced during respiration can be measured in units called joules (J) or kilojoules (kJ). For every molecule of ATP formed, 30.6 kJ of energy is used (stored). This means that for every molecule of ATP broken to ADP and P, 30.6 kJ of energy is released.

ATP is a crucial chemical in human metabolism because the cells use it as a direct source of energy. ATP is produced when sugars are burnt especially glucose and other nutrients. The cells consume ATP when they engage in activities like building larger molecules and producing movement. These activities that take place within a cell are called **metabolic activities**. Cells consume ATP through the following ways;

- Muscle movement.
- Growth and cell division.
- Building larger molecules from smaller ones i.e. proteins from amino acids.
- Allowing chemical reactions to take place.
- Absorbing molecules in active transport.
- Keeping your body temperature constant.
- Sending messages along nerves.

Activity 9.2: To show that heat is produced during respiration

Requirements

- Vacuum flasks
- Thermometers
- Beans
- Disinfectant
- Cotton wool
- Two clamp stands

Procedure

1. Soak some bean seeds for a day or two in order to allow them to germinate.

2. Take a second set of the bean seeds and boil or heat them to kill them. Wash both sets of beans with the diluted disinfectant.
3. Put each group of beans into sterilised vacuum flasks. (Do not fill the flasks to the brim).
4. Put a thermometer into each flask and hold it in place with cotton wool stuffed at the mouth of the flask.
5. Note the temperature of the flask.

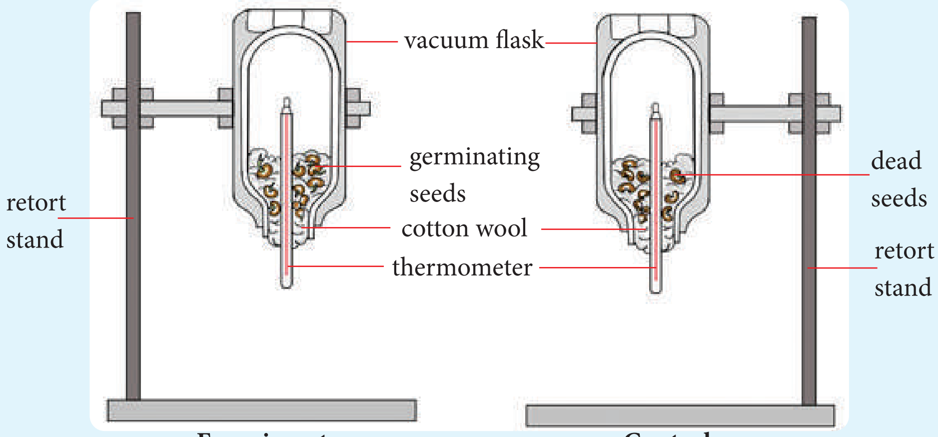


Fig. 9.5: Experiment to show that heat is produced during respiration

6. Using a clamp stand, support each flask upside down and leave them for five days.
7. After the five days, note the new temperature in each flask.

Study questions

1. In which flask was the temperature higher?
2. Why were the bean seeds disinfected before the experiment?
3. Why were the flasks:
   - put upside down?
   - half filled with beans?
4. Was all the energy released as heat energy?
5. Where did the heat energy come from?

The facts

Germinating seeds break down stored carbohydrates in the process of respiration in order to get the energy that they require for growth. Some of the energy is released as heat. You must have noticed temperature rise in the flask containing germinating seeds. You must have also noticed that the boiled seeds did not produce heat as indicated by the thermometer. Before the experiment, the seeds were disinfected in order to kill the bacteria that would cause the decay of the beans. The flasks were also inverted to prevent loss of heat. Warm air rises up and if the flasks are not upside down warm air in the flask would rise and lead to heat loss from the germinating seeds. This was also to allow carbon (IV) oxide diffuse out since it is heavier than oxygen and thus allows oxygen to diffuse in.

Self-evaluation Test 9.1

1. How do cells obtain energy they need to function?
2. What compound is phosphorylated for ATP formation?
3. What is the resulting compound when ATP releases energy?
4. Some of the carbohydrates produced in photosynthesis are used in respiration. What is respiration?

9.2. Types of respiration

Activity 9.3: Discussion

1. Discuss the following questions:
   - i. Why do you have to breathe in quickly during a physical exercise?
   - ii. What causes pain in the legs after an exercise?
   - iii. What makes milk go bad when not stored properly?
   - iv. Differentiate between aerobic and anaerobic respiration.

The facts

There are two kinds of respiration depending on whether oxygen is required or not. Respiration that requires oxygen in order to take place is known as **aerobic respiration. Anaerobic** respiration takes place in the absence of oxygen.

The first steps of both aerobic and anaerobic respiration are the same. They involve splitting glucose into **pyruvic acid.** This process is known as **glycolysis,** which means sugar-splitting (usually one molecule of glucose is split into two molecules of pyruvic acid). It takes place in the cytoplasm and does not require the presence of oxygen. Only 2 ATPs of energy is produced during this process.

9.3. Aerobic respiration

This type of respiration takes place in the presence of oxygen. Aerobic means 'with air'. The food substrate broken down to produce energy is glucose. This is a complex step by step process which is catalysed by several enzymes. The word equation for aerobic respiration is:

$$\text{Glucose} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

In the above equations we see that glucose is broken down by oxygen to release energy with carbon dioxide and water being produced as by-products of the reaction. Approximately 2900 kJ of energy is released when one mole of glucose is broken down. The released energy is used to make a special energy molecule ATP. ATP is where the energy is stored for use later on by the body.

Aerobic respiration occurs in living organisms.

Activity 9.4: To investigate aerobic respiration in mice

1. Put one mouse into a wire mesh box and another in a closed tin (tin with closed lid).
2. Leave the mice for a day or two. Observe them and make your observations.

Study questions

1. What do you think is the reason for the observations made in this experiment?
2. Which other experiments can you use to prove that organisms require oxygen for their survival?

Self-evaluation Test 9.2

1. In which part of the plant does respiration take place?
2. During exercise, what happens to the rate and depth of breathing?
3. Identify **X** and **Y** in the following equation which is a summary of aerobic respiration.

   $C_6H_{12}O_6 + \mathbf{X} \longrightarrow H_2O + \mathbf{Y}$
4. Which biological process is represented by the following word equation?

   Glucose + oxygen $\longrightarrow$ carbon dioxide + water + energy

9.4. Anaerobic respiration

Activity 9.5: To show the gas that is produced during fermentation of sugar by yeast

Requirements

- Sugar
- Yeast
- Water (boiled then cooled)
- Limewater (calcium hydroxide)
- Some oil e.g. corn oil
- Boiling tube (as in the diagram)
- Rubber band with hole in it to fit a delivery tube
- Delivery tube
- Test tube

Procedure

1. Take water and add some sugar to it to make a sugar solution.
2. Add some yeast to it and stir.
3. Set up the apparatus as shown in Fig. 9.7 then leave them aside in a warm place for one hour.

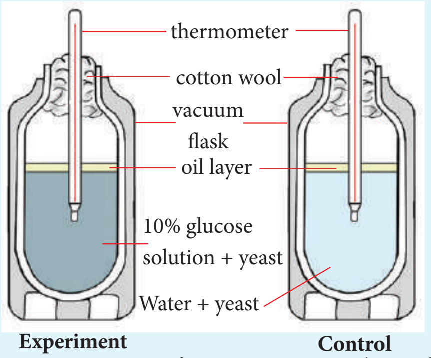


Fig. 9.6: Set up of experiment to show the gas produced during fermentation

- **Study questions**

1. Why is the water first boiled then cooled before the yeast is put in the sugar solution?
2. Why is a thin layer of oil poured over the yeast and sugar solution?
3. What do you observe in the boiling tube after one hour?
4. Explain your observation in (3).
5. Describe a control for this experiment.

Anaerobic respiration in plants

Anaerobic respiration takes place in both plants and animals. Sometimes there is not enough oxygen around for animals and plants to respire, but they still need energy to survive. Instead they carry out respiration in the absence of oxygen to produce the energy they require.

Organisms that respire anaerobically are called **anaerobes**. Examples include anaerobic bacteria and trichomonas. In these organisms, food substrates are broken down to release energy without the use of oxygen. Some anaerobes are so sensitive to oxygen that they get poisoned by its presence. An example clostridium. They are called **obligate anaerobes** because they can only respire anaerobically. Other anaerobes, however, can respire both aerobically and anaerobically. When oxygen is present in their immediate environment, they use it to respire but when it is absent, they can still respire without it. Such anaerobes are called **facultative anaerobes.** An example is streptococcus bacteria.

The facts

Oxygen supply to plants can also run out. When this happens, for example if the soil gets water logged, plants obtain their energy via anaerobic respiration. Anaerobic respiration in plants breaks down glucose to carbon dioxide and ethanol. This process is also known as **alcoholic fermentation**. The following equation is a summary of the process of anaerobic respiration in plants.

Glucose $\longrightarrow$ carbon dioxide + ethanol + energy

$$C_6H_{12}O_6 \longrightarrow 2CO_2 + 2C_2H_5OH + \text{Energy}$$

Alcoholic fermentation takes place only in the cytoplasm and does not take place in the mitochondria. It produces very little energy because the glucose is not completely broken down to release all the energy contained in it. The ethanol formed still stores some energy. This process is therefore not very efficient at energy production.

Did you know?

Higher plants respire aerobically. However, whole plants or their parts may respire anaerobically for a short time when necessary, for example, during temporary water logging when the plant is submerged in water.

Anaerobic respiration in animals

Activity 9.6: Demonstration of anaerobic respiration in animals

Requirements

- School athletic track
- Students themselves
- A video on racing

Procedure

1. Run around the athletic track twice.
2. Stop at designated area and rest.
3. Watch the video and compare the post-race ventilation behaviours of sprinters and marathon runners.

Study questions

1. State your experience after the exercise.

2. Compare the breathing rate before and after the exercise.
3. Explain what happened that enabled you to resume the previous state before the exercise.

The facts

Some animals also respire anaerobically. Tapeworms, for example, are able to survive in the small intestine where there is a very low concentration of oxygen because they are able to respire anaerobically. In mammals, the skeletal muscle cells can also respire anaerobically. However, they do so only when they fail to get enough oxygen for the work they are doing, for example, during heavy or strenuous exercise.

Oxygen debt

Anaerobic respiration is not as efficient as aerobic and only a small amount of energy is released. This is because glucose can only be partially broken down. Apart from this inefficiency, a poisonous chemical, **lactic acid,** is also produced. If the lactic acid builds up in the body it stops the muscles from working and causes a cramp. To rid the body of some lactic acid, oxygen is needed. The amount of oxygen required to break down the lactic acid is referred to as **oxygen debt.**

When glucose is broken down anaerobically in animal cells, **only lactic acid** and **energy** are produced. The equations for this reactions are as follows:

Glucose $\longrightarrow$ lactic acid + energy

$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3$ + energy

Lactic acid is toxic when it accumulates in animal cells. It causes **muscle fatigue**. Therefore, it is usually further broken down to less toxic substances like water and carbon dioxide. This happens when oxygen becomes available. We continue to breathe heavily or **pant** after a race or any strenuous exercise so as to supply this oxygen to the muscle cells. The following graph shows the level of lactic acid before and after exercise.

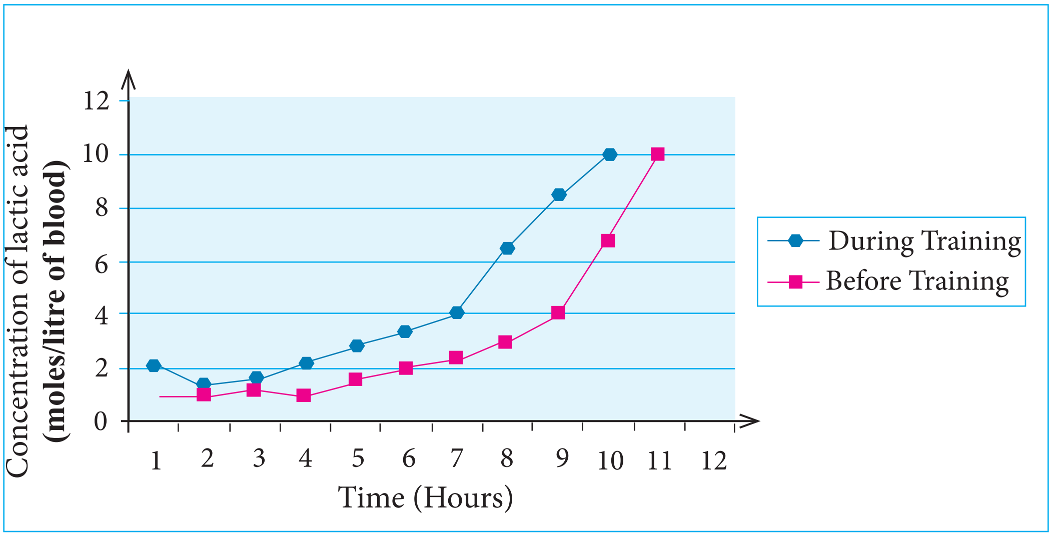


Fig. 9.7: Graph illustrating the level of lactic acid before and during training

Above is a classic lactic acid curve comparison depicting blood lactic acid levels during a test where exercise intensity is increased in fixed stages. Comparing repeated tests as fitness increases will show lower lactic acid levels for a given intensity. This is a result of both producing less lactate and clearing lactate faster at any given intensity due to adaptations primarily in the muscles, mitochondria, capillaries, lactate transporters and the liver. Heart rate will generally decrease for a given intensity as you become more fit, but using the same heart rate zones as your fitness increases will sell you short as heart rate will not account for the changes in metabolism that are indicated with lactate testing.

Those starting an exercise program will experience a greater degree of change in lactate levels at a given intensity than those who are well trained, requiring more frequent updates to heart rate zones.

Comparison of aerobic and anaerobic respiration

Aerobic and anaerobic respirations both take place in plants and animals.

Table 9.1: Differences between anaerobic and aerobic respiration

Aerobic respiration	Anaerobic respiration
Requires oxygen to take place.	Does not need oxygen in order to take place.
There is complete breakdown of glucose molecule.	There is incomplete breakdown of glucose; leading to the formation of intermediate compounds.
Large amount of energy released from each molecule of glucose.	Much less energy released from each molecule of glucose.

Aerobic respiration	Anaerobic respiration
The by-products formed are carbon dioxide and water.	The by-products formed are carbon dioxide and ethanol in plants and lactic acid in animals.
Occurs in the cytoplasm and in the mitochondrion.	Occurs only in the cell cytoplasm.

Self-evaluation Test 9.3

1. Which of the following is not a product of fermentation?
   A. Carbon dioxide
   B. Oxygen
   C. Lactic acid
   D. Ethanol
2. When lactic acid builds up in the blood, a person is said to be in oxygen debt. This debt must eventually be paid. Suggest how the debt is paid.
3. Give the difference between aerobic and anaerobic respiration.

9.5. Applications of anaerobic respiration

Activity 9.7: Discussion Activity

1. Discuss the role of yeast in baking and brewing.
   - What are the other applications of anaerobic respiration?
2. Present your findings to the rest of the class.

The facts

Although anaerobic respiration supplies only little energy to respiring cells, it has some large scale or industrial application useful to human beings.

Fermentation is the production of **ethanol**. It occurs when **yeast** breaks down sugars in the absence of oxygen. Fermentation is used in:

i) Bread making

During baking, yeast is mixed with water and sugar to activate it. The mixture is added to flour to make dough, and left in a warm place. The dough rises as the yeast respires and releases carbon dioxide, which gets trapped in the dough. When the dough is cooked, the high temperature kills the yeast and evaporates any alcohol formed. Air spaces are left where the carbon dioxide is trapped, which gives the bread a light texture.

ii) Brewing

To make beer, yeast is dissolved in a warm liquid containing the sugar maltose. The yeast respires anaerobically during fermentation producing an alcohol (ethanol) making the drink alcoholic. Carbon dioxide present makes the drink fizzy.

iii) In the dairy industry

A range of products can be made when milk is fermented. Milk contains lactic acid bacteria which anaerobically break down milk sugar called lactose to form lactic acid which makes the milk sour. Different products can be formed industrially by controlling the conditions under which the fermentation takes place. Some of the dairy products that can be formed this way are cheese, butter, yoghurt and cream.

iv) Sewage treatment plants

Most raw sewage that leaves households in towns and cities is directed to sewage treatment plants. Certain bacteria are introduced into the sewage to break it down by anaerobic respiration. This reduces the bulk of the sewage which on further treatment is purified and is safe for release into rivers or water bodies.

v) In agriculture

The making of silage is an anaerobic fermentation process which is carried out on farms. It preserves the food value of grass for animals. It also improves the flavour and taste of the grass. Bacteria in grass use the natural sugar found in grass and bring about fermentation. Farm manure and compost manure are to some extent due to activities of anaerobic bacteria. Think of why it is preferable to use the manure than the fertilisers.

vi) Production of biogas

Manure from cows or other wastes of plant material can be used as a substrate for fermentation. A mixture of microorganisms is used in the fermentation which can produce methane. Biogas contains 70% methane. The gas can be used for cooking and lighting.

Further Activity: Experiment

1. Design an experiment that will enable you to carry out alcoholic fermentation of banana juice or sugar.
2. Present your work for assessment.

Self-evaluation Test 9.4

1. Anaerobic respiration by micro-organisms is called fermentation.
   a. Name the micro-organism involved.
   b. Which industrial process involves fermentation?
2. Identify the source and use of biogas.
3. How are microorganisms important economically?

Unit summary

- Cellular respiration is the chemical breakdown of food substrates in the cells to release energy. It takes place in the cytoplasm and mitochondrion. Most of the energy, however, is produced in the mitochondrion.
- Respiration is important because it provides energy needed to carry out life processes.
- Respiration takes place in both plants and animals. It is a step by step reaction controlled by enzymes.
- There are two main types of cell respiration; aerobic and anaerobic.
- Aerobic respiration requires oxygen

and releases energy, carbon (IV) oxide and water.

- Anaerobic respiration can occur without oxygen. It releases energy. In plants it also produces alcohol and carbon (IV) oxide; in animals it produces lactic acid.
- Aerobic respiration yields more energy than anaerobic respiration.
- Organisms that respire anaerobically are called anaerobes.
- Organisms that respire aerobically are called aerobes.
- The knowledge of anaerobic respiration is used in the home and industry for economic gain e.g. in the baking industry where yeast respires anaerobically to release carbon (IV) oxide which raises the dough leaving small holes that make it swell into bread, cake, etc and in fermentation to form wine or alcohol (beer) which is extracted for sale.
- Production of yoghurt and cheese by the addition of curdle to form yoghurt or cheese; fermented porridge.
- Respiration rate in human beings depends on age, occupation, size and whether one is male or female.

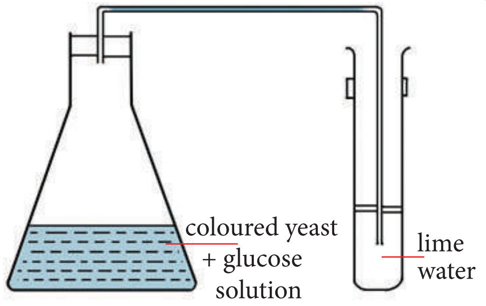
End Unit Assessment 9

1. Which of the following organisms carries out cellular respiration?
   A. A corn plant
   B. Dog
   C. Yeast
   D. A bacterium
2. What is the main cellular structure involved in respiration?
   A. Nucleus
   B. Golgi apparatus
   C. Mitochondrion
   D. Cytoplasm
3. Which of the following does not use energy for respiration?
   A. Muscle contraction
   B. Building larger molecules from smaller ones
   C. Maintaining a constant body temperature in fish and reptiles
   D. Maintaining a constant body temperature in mammals and birds
4. Oxygen is vital to the process of aerobic cellular respiration. Explain.
5. Suggest reasons why living organisms need to respire.
6. Fill the table below as whether aerobic or anaerobic respiration.

Characteristic	Process
Less energy produced	
Occurs in both plants and animals	
Complete breakdown of glucose molecule	
By-product formed is lactic acid	

7. For each of the statements write, true or false.
   (a) Aerobic respiration is the release of energy in the absence of oxygen. ________
   (b) All organisms require oxygen in order to respire. ________
   (c) Lactic acid is produced in animals only and not in plants during anaerobic respiration. ________
   (d) Both facultative and obligate anaerobes do not require oxygen in order to exist. ______

8. Study the diagram below.



   (a) Describe what happens to the lime water.
   (b) Why is the suspension of yeast made from water that is:
      (i) First boiled
      (ii) Then cooled
   (c) Why is the layer of oil poured over:
      (i) the yeast suspension?
      (ii) the lime water?
   (d) Name the type of respiration taking place in the flask.
   (e) What is the importance of this type of respiration in industry?

Unit 10

Skin and homeostatic mechanisms

Key unit competence

After studying this unit, I should be able to explain homeostatic mechanisms and the role of skin in temperature control.

Learning objectives

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

- Define homeostasis and explain the concept of control by negative feedback.
- Explain how the pancreas is both an exocrine and an endocrine gland.
- Describe the control of the glucose content of the body by the liver, and by insulin and glucagon from the pancreas.
- Describe the maintenance of a constant body temperature in humans and in terms of insulation and role of temparature receptors in the skin, sweating, shivering, vasodilation and vasoconstriction of urterioles skin capillaries and the coordinating role of the brain.
- Draw and label parts of the human skin.
- Interpret graphs for glucose tolerance in a person with normal glucose metabolism and diabetic.
- Develop good nutrition habits that reduce the risk of diabetes.
- Appreciate the importance of maintaining a constant internal environment.

Introductory Activity

Study the diagram below on temperature control. The illustration in **A** shows what happens in a home scenario. The illustration in **B** shows what happens in the body.

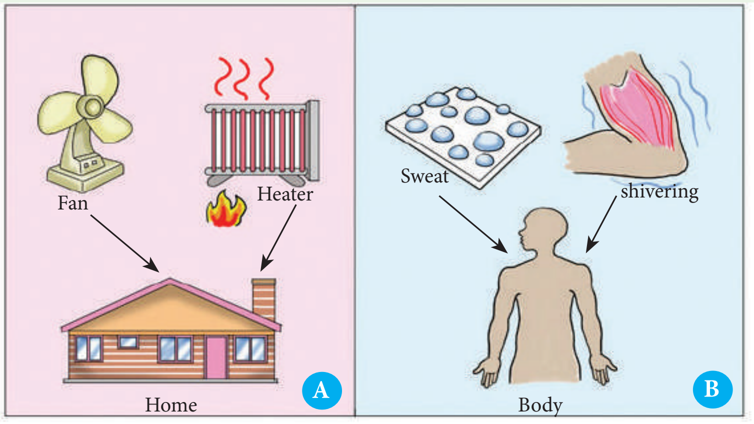


Fig. 10.1: Temperature control

With a friend, think about how temperature is regulated in a home. Compare that to what happens in the body. Which other things require regulation in our bodies?

Introduction

This unit deals with regulation of various body processes and functions. This is what **homeostasis** is about. You are going to learn about the skin and the mechanisms the body uses to maintain and regulate internal body environments in this unit.

10.1: Homeostasis

Organisms have different methods of regulating their body temperature. Some rely on **physiological mechanisms** to maintain the internal body temperature within narrow optimum ranges despite temperature changes in their external environments. These are the **homeothermic** animals. When the surrounding temperature is too low, they generate enough heat energy within the body through metabolic reactions like cell respiration to warm their bodies. For this reason, they are termed as **endothermic** animals. Examples are birds and mammals.

Animals that do not have physiological mechanisms to maintain constant body temperatures are **poikilothermic**. Their body temperatures vary with the temperature of the surrounding. Many of these animals are still able to maintain warm bodies mainly during the day. They use **behavioural methods** to keep fairly constant temperatures during the day, for example, the lizards bask in the sun to warm their bodies, and move into the shade to cool off. Such organisms that gain heat from the external surroundings to warm the body are called **ectotherms.**

Mammals are **homeotherms**: their internal body temperature has to be kept constant for normal functioning of the cells. They do not depend on the external temperature of the environment like the poikilotherms such as reptiles do.

In mammals cells are surrounded by tissue fluid. In Unit 9, you learnt that cells obtain their nutrients from tissue fluid and release waste products into it. Respiratory gases also diffuse through it to or from the cells. Tissue fluid therefore constitutes the internal environment of the body. It needs to be maintained under almost constant conditions of temperature and solute concentration for normal cell functions to occur.

The maintenance of the internal environment of cells under constant conditions is known as **homeostasis.** If the internal environment is not maintained at constant levels, illness or death of the organism may result. Aspects of the body's internal environment that need to be kept constant include:

- Temperature
- Osmotic pressure
- Chemical constituents
- Level of carbon dioxide

Did you know?

The internal environment is made of factors that fluctuate; therefore, they are maintained at an almost constant state.

Activity 10.1: To observe prepared slides, diagrams and models of a mammalian skin

Requirements

- Prepared slide of a vertical section of a mammalian skin
- Microscope
- Charts and diagrams
- Model of the skin

Procedure

1. Place the prepared slide under the microscope.
2. Examine the slide first under low power and then under high power.
3. Compare your observations with diagrams and the skin model provided.
4. Identify the two main parts of the skin: the epidermis and the dermis.

Did you know?

The cells of the malpighian layer are pigmented towards the outer surface and it has clear nuclei (it appears granular).

5. Locate other parts of the skin such as hair follicle, sebaceous glands, sweat gland and hair.
6. Draw and label what you observe.

The facts

The skin consists of two main layers. That is an outer **epidermis** and an inner **dermis.**

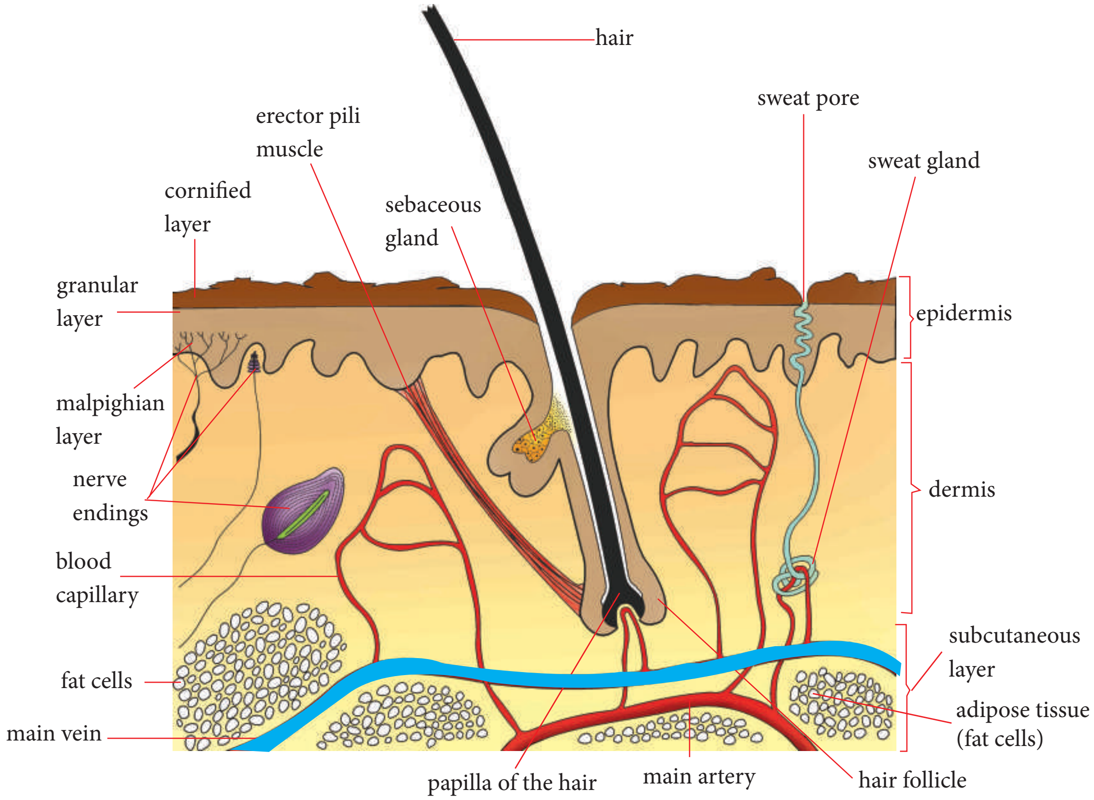


Fig 10.2: Cross-section of the mammalian skin

The epidermis

It is the upper layer of the skin. The epidermis is made up of three layers of cells. The three layers are **cornified** layer, **granular** layer and **Malpighian** layer.

(i) The cornified layer

The cornified layer is the outermost layer in the epidermis. It is made of dead cells which form a tough protective outer layer that acts as a barrier against entry of microorganisms. It reduces loss of water and protects the inner cells from mechanical damage.

The cells in this layer produce large amounts of tough waterproof protein called **keratin** which strengthens them. The thickness of this layer varies from one part of the body to another. For instance, it is thicker in the soles of the feet because of the high level of friction between the feet and the ground. As the layer wears away, it is replaced by new cells formed in the malpighian layer.

(ii) The granular layer

The granular layer is made of living cells which eventually form the cornified layer. It is the middle layer of cells in the epidermis.

(iii) The Malpighian layer

The Malpighian layer is the innermost layer of cells of the epidermis. It is made up of actively dividing cells which are responsible for the renewal of the epidermis. The cells in this layer contain **melanin** pigment which contributes to the colour of the skin. The more it is, the darker the skin colour. Melanin protects the skin against ultra violet light from the sun which would otherwise damage the skin cells beneath it.

Did you know?

Certain substances in skin creams destroy melanin and cause damage to the skin. Such creams should not be applied on the skin.

The dermis

This is thicker than the epidermis and is located below it. It contains hair follicles, sweat glands, blood capillaries, nerve endings, lymph vessels, sensory organs and sebaceous glands.

(i) Sweat glands

These are tiny coiled tubes which secrete and release sweat through pores on the surface of the skin. Sweat consists of water and mineral salts such as sodium chloride and traces of urea and lactic acid. The liquid that forms sweat is absorbed by the sweat glands from the blood capillaries supplied to each gland. It reaches the surface of the skin through the pore and the water in it evaporates into the air.

(ii) Blood capillaries

There are many blood capillaries in the skin. They supply the cells in the skin with oxygen and nutrients and take away carbon dioxide and waste substances.

(iii) Hair follicles

These are tiny pits in the dermis. Hair grows inside the follicle due to addition of cells to it at the bottom of the pit. Hair is made up of dead cells and protein called **keratin**.

(iv) Sebaceous glands

Sebaceous glands are small glands which open into the hair follicle. They produce an oily secretion called **sebum**, which keeps the skin soft and has antiseptic properties to kill bacteria on the skin.

(v) Erector pili muscle

The erector pili muscle is attached between the bottom part of the hair follicle and the epidermis. When it contracts, the hair fibres stand upright and very small pimples or swellings appear on the skin. When it relaxes, the hair lies flat on the skin.

Beneath the dermis is a layer of cells in which fat is stored. This layer is called the **subcutaneous fat layer.** It acts as a heat insulator.

Functions of the skin

a) Excretion

The skin eliminates waste substances like traces of urea, excess salts and water through the sweat.

These substances are transported to the sweat glands through the blood capillaries. They diffuse out of the blood into the sweat gland to form sweat which moves to the skin pore on the surface through a sweat duct. Sweat evaporates from the sweat pores into the environment, eliminating the waste products in the process.

b) It acts as a sensory organ

Due to the presence of the nerve endings and the sensory organs, the skin makes the body aware of the changes in the external environment through the senses of touch, heat, pressure and pain. This causes the body to respond appropriately to the changes.

c) Protection

- The skin prevents microorganisms and other foreign materials from entering the body. It acts as a barrier between the external and internal environments in the defense of the body against pathogens and mechanical injury.
- Since the outermost layer is waterproof, the skin also prevents the body from drying out.
- It produces melanin which protects the body from ultra-violet radiation. This kind of radiation can cause skin cancer.
- The skin also manufactures vitamin D through the action of sunlight on it. This vitamin is necessary for the formation and maintenance of bones.

(d) Receptors

The skin acts as a receptor site since it contains receptor cells sensitive to pressure, cold, touch and heat.

e) Temperature regulation (Thermoregulation)

The skin plays an important role in the regulation of temperature in organisms whose body temperature is kept constant.

Activity 10.2: Discussion Activity

Answer these questions:

1. One chilly day a student observed the following on a friend:
   (i) Pale skin
   ii) Swellings at the hair follicles
   (iii) Raised hair
   a) What should the student do to reverse this condition?
   b) What do you think will happen to the skin on a hot day?
   c) List the things you normally do to cool yourself when the day is too hot and you feel too uncomfortable.

2. Do you think the brain has a role to play during temperature regulation?
3. Explain the importance of this in thermoregulation.
4. Investigate how lizards control their body temperature under different conditions.
5. Write a report and present your findings to the rest of class.

The facts

Regulation of temperature in birds and mammals is made possible by the presence of a control centre near the base of the forebrain called the **hypothalamus.** It receives signals from the animal's body when the temperature fluctuates from the normal set point. In human beings this is at about 37˚C. The hypothalamus co-ordinates responses that initiate corrective measures to restore the temperatures to their normal levels.

Thermoregulation refers to this process of regulating the internal body temperature. The body temperature can change due to gaining heat from the environment or losing heat to the environment. The body can also generate heat by metabolic processes which cause changes in body temperature.

Human beings reduce or increase the amount of clothing depending on weather conditions. When it is hot, they reduce the amount of clothing. This increases the rate of heat loss from the surface of the skin. When it is cold, they wear more clothing or warmer clothing in order to reduce heat loss through the skin. These are termed as **behavioural** processes of regulating temperature.

The physiological processes involved in regulation of temperature in animals are:

- Metabolism
- Shivering
- Sweating
- Raising of hair or fur
- Vasodilation and vasoconstriction

The skin plays an important role in thermoregulation because it is in direct contact with the environment to which an organism loses heat or from which it gains heat. The skin has **sensory cells** and nerve endings that can detect temperature changes in the external environment which eventually affect body temperatures. It also has structures like **sweat glands, blood vessels, erector muscles** and **hair,** all of which are involved in regulation of the body temperature by physiological processes.

Sweat glands

We saw earlier that sweat glands are coiled tubular glands in the dermis. They are linked to the sweat pore on the surface of the skin by a sweat duct (Refer to Fig. 10.2).

Did you know?

Birds do not have sweat glands while dogs only have them on the pads of the feet. Can you explain why?

Human beings have sweat glands all over the skin. Sweat glands absorb fluid from the surrounding tissues which moves through the sweat duct and reaches the surface of the skin as sweat. Sweat absorbs heat from the skin to evaporate as water vapour. This causes cooling. That is why on a hot day there is increased sweating and evaporation of water taking place. This helps in lowering the body temperature. When there is a decrease in the body temperature below normal, sweating is suppressed. This prevents further cooling of the body.

Fig. 10.3: Sweating

Capillaries (and arterioles in the skin)

When the body temperatures rise above normal, blood vessels in the skin dilate (vasodilation). More blood flows nearer the surface of the skin and the heat in it is lost by radiation or conduction and convection. The body is able to cool down. The opposite happens when the body temperature is below normal. This helps the body to conserve its heat.

Blood vessels are in dilated state. More blood flows to the surface of the skin. More heat is lost.

Blood vessels are in constricted state. Less blood flows to the surface of the skin. Less heat is lost.

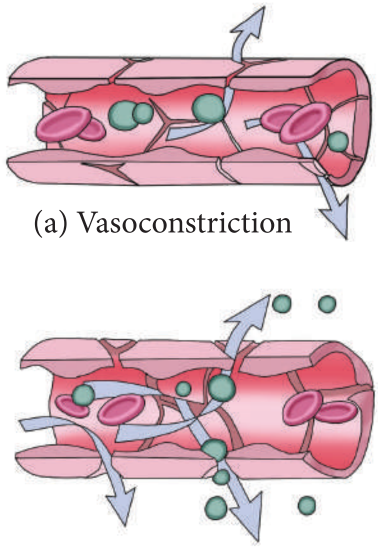


Fig 10.4: Vasoconstriction and vasodilation

The erector pili muscles and hair follicles

We saw earlier that hair follicles are tiny pits in the skin with hair in them. The base of the follicle has muscle called the **erector pili muscle.** When this muscle contracts, it changes the angle between the hair and the skin which in turn changes the amount of air trapped on the skin surface. The air trapped in the hair and fur of some mammals can act as a good insulator against heat loss and keeps the animal warm on cold days. On hot days, the insulation causes heat retention which makes it difficult for the animals to stay cool. The layer of air can be adjusted to reduce the amount of heat retained in the body or increased to increase insulation.

On a cold day when the body temperature drops below normal, the erector pili muscle contracts. This pulls at the end of the hair follicle and straightens it. The hairs trap more air on the skin and improves the insulation above the skin. This keeps the animal warm and more heat is retained in the body.

On a hot day, the temperature of the body may increase above normal. The erector pili muscles relax, pulling less at the base of the hair follicle. The angle of the hair and the skin surface is reduced and it flattens against the skin. Less air is trapped on the skin, therefore, less insulation of the body heat takes place as a result the temperature is lowered.

Loss of thermoregulatory mechanism

When the hypothalamus fails to register an increase in the body temperature above normal level, a further rise in temperature occurs. In human beings this causes fever, which is a sign of infection in the individual. Toxins produced by bacteria affect the hypothalamus. If the condition is not corrected, **hyperthermia** or abnormally high temperature occurs. This can lead to death if temperature goes above 43˚C.

Do you know any first aid to give to a person who has fever?

If a decrease in temperature below normal continues without correction due to failure of homeostatic mechanisms, **hypothermia** or abnormally low temperature occurs.

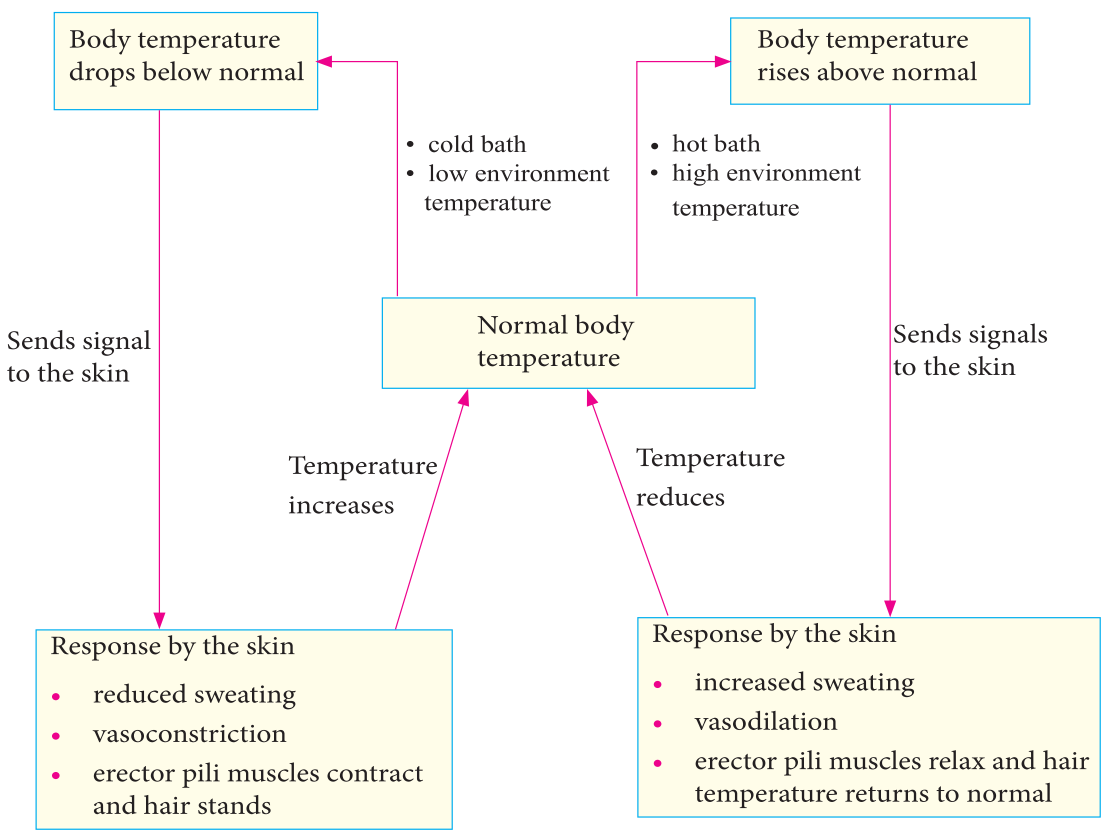


Fig 10.5: Role of the skin in regulation of body temperature

Self-evaluation Test 10.1

1. Define homeostasis.
2. Heat is lost from our skin on a hot day by the __________
   A. movement of the skin capillaries nearer to the surface.
   B. relaxation of arterioles so that the skin capillaries carry more blood.
   C. opening of the pores of all the sweat glands.
   D. evaporation of water from the sebaceous glands.
3. What is the function of the cornified layer of the epidermis of human skin?
   A. Temperature regulation through sweating
   B. Perception of sensation of temperature, pain and pressure
   C. Synthesis of Vitamin D
   D. Prevention of uncontrolled water loss by evaporation
4. What is the result of a rise in body temperature?
   A. A decrease in the production of sweat
   B. An increase in blood flow to the skin
   C. Narrowing of blood vessels in the skin
   D. Raising of hairs on the skin
5. Draw and label a section of mammalian skin.
6. Name three physiological processes involved in regulation of temperature in animals.

10.2. Controlling the internal environment

Maintaining a constant internal environment involves regulating the amounts of salts, water and glucose. Regulation of the internal environment is done either by the **endocrine glands** using hormones or the nervous system. The internal environment always has a normal level called a **set point**. Any change from the set point activates the control systems which return the conditions back to normal.

Activity 10.3: Discussion Activity

1. Have you ever used an electric iron box to remove creases from a piece of cloth? How does it get automatically switched off after reaching a certain temperature? Can you explain the mechanism involved?
2. How does the mechanism of controlling temperature in an electric iron box relate to the negative feedback mechanism?

The facts

A thermostat is involved in controlling temperature in some gadgets like electric iron boxes and air conditioners in buildings. The thermostat is a prime example of negative feedback. **Negative feedback** is the process by which the body mechanisms regulate the changing conditions from excesses back to normal or from low extremes back to normal.

A positive feedback on the other end enhances or amplifies an effect by its own influence on the process that gives rise to it.

All negative feedback loops occur in a series of steps. Using a thermostat in an air conditioner is an example of this.

There is a **stimulus** in which a change occurs. The temperature in the house increases.

There is a **sensor**, which detects change. The thermostat registers the increase in temperature.

There is a **control**, which is just a response to the change: The thermostat sends a signal to decrease the temperature.

There is an **effector**, or the effect of the response. This could be the air conditioner turning on to bring the temperature in the house back down to normal or the heater stopping for a period of time until the temperature is brought back to normal.

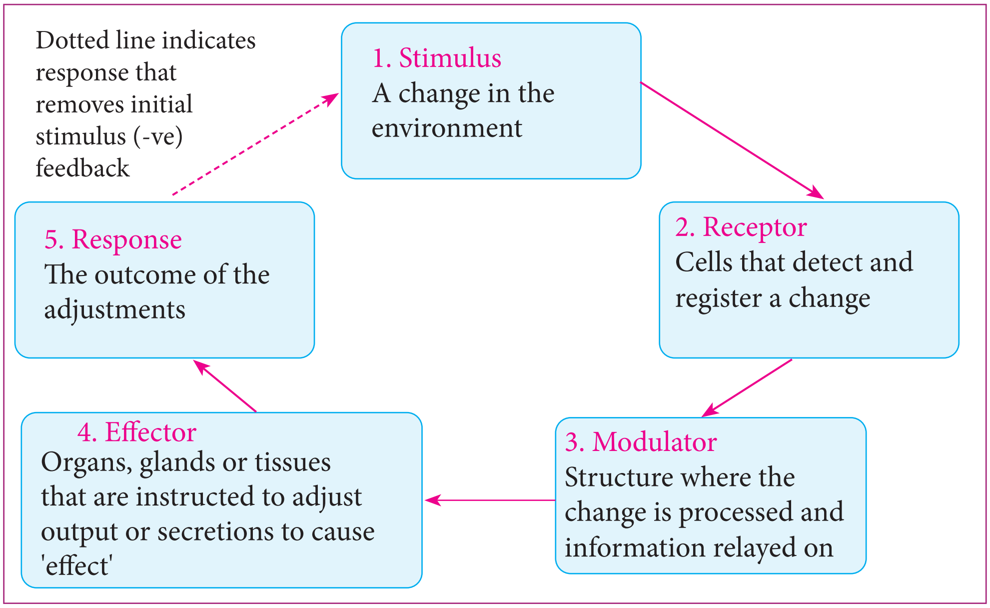


Fig 10.6: Negative feedback mechanism

A negative feedback loop serves to keep a certain variable in check, temperature in this case. The body has its own internal controller for maintaining its temperature, pH, hormone levels, blood sugar and other internal variable levels at homeostasis. This is the optimal internal state at which the body operates best. The controller of homeostasis in most animals is the **hypothalamus**. Without this structure in the brain, organisms would have great difficulty functioning normally.

Homeostasis is effective only if all the parts of the body that carry out this process work in a coordinated manner. This requires communication between the organs, tissue and cells of the body. Communication between the different parts of the body is made possible by the **neuro-endocrine system,** so called because it consists of the **nervous system** and the **endocrine system.**

The nervous system is composed of the **brain** and **nerve cells**. Nerve cells transmit messages from one part of the body to another, in the form of electrical nerve impulses. The endocrine system is made up of **glands** which produce **hormones.** Hormones are chemical substances which are released into the blood and are transported to various body tissues and organs. Hormones bring about change in the functioning of specific tissues and organs. Thus, the nervous system and the endocrine system interact and work together all the time to bring about homeostasis.

Some of the homeostatic processes in which the two systems work together include control of :

- the osmotic pressure of the blood
- the control of blood sugar level
- the regulation of body temperature.

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 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.

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.

It is therefore 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 **anti-diuretic 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 10.7.

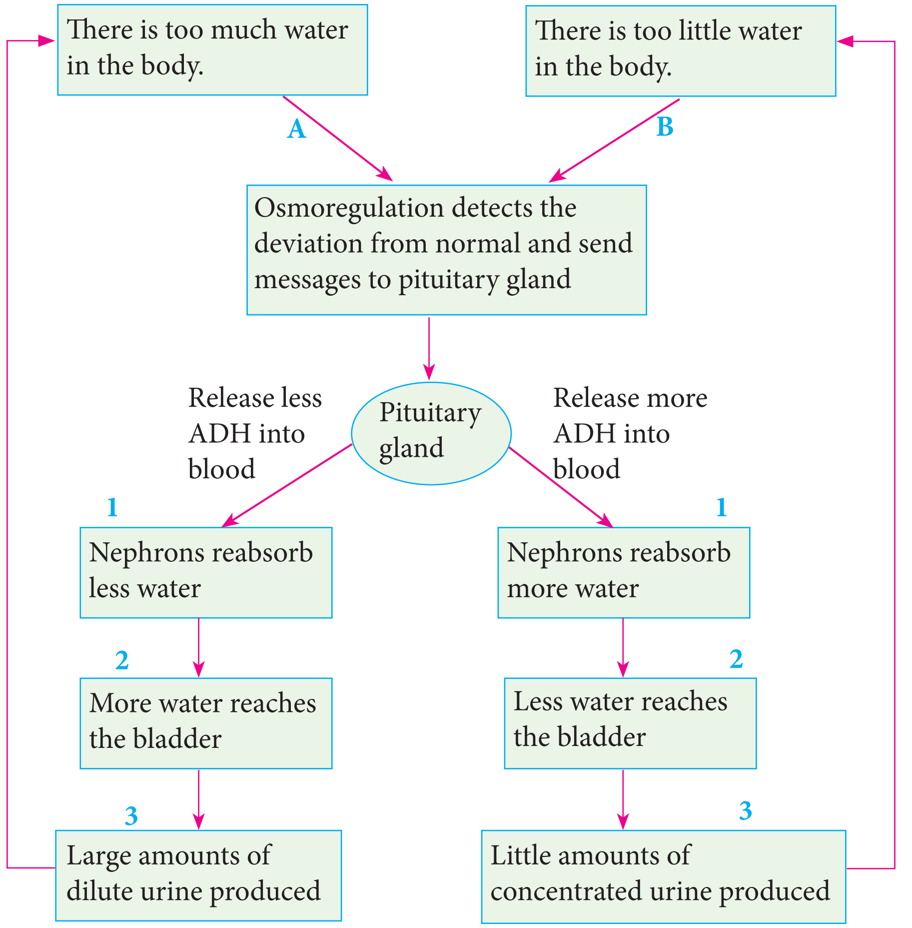


Fig 10.7: Homeostatic control of amount of water in the body

- What is happening to osmotic pressure of body fluids at A? What circumstances lead to there being too little water in the body?
- 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 nephron walls 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 molecules. 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.

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.

Self-evaluation Test 10.2

1. What is diuresis?
2. The body senses that there is too much substance X in the blood. The brain sends a message to organ Y to metabolise substance X. The brain keeps sending this signal until the level of substance X is within normal limits.
   A. This is a positive feedback loop.
   B. This is a negative feedback loop.
   C. This is not a feedback loop.
   D. This is a positive-negative feedback
3. Negative-feedback mechanisms ___
   A. are not homeostatic.
   B. respond by making deviations from normal even larger.
   C. may have a receptor, a control centre and an effector.
   D. are rare in healthy individuals.
4. The two body systems that regulate homeostasis are the ___
   A. cardiovascular and respiratory systems.
   B. cardiovascular and endocrine systems.
   C. nervous and cardiovascular systems.
   D. nervous and endocrine systems.
5. Name steps in which negative feedback occurs.

10.3. Control of blood glucose level

Activity 10.4: Investigating blood glucose control in the body

Requirements

- Glucose solution
- Glucometer
- Charts

Procedure

1. Using a glucometer measure blood glucose level of your partner and record in a table.
2. Let your partner take the glucose solution, measure the blood glucose and record your results.
3. Measure blood glucose levels in his/her blood in one hour intervals and record your results in a table like the one shown.

Table 10.1: Results of blood glucose level

Time (Hours) Volunteer	Before test	After Test	1	2	3	4	5
1							
2							
3							

4. Find out the mechanism by which blood glucose is controlled.
5. Write a report then present your findings to the rest of the class.

Study questions

1. What could be the normal blood sugar level?
2. What do you think happens when blood sugar level rises beyond normal?
3. What would happen if there was less blood sugar in the body?
4. Which organ in the body is responsible for blood sugar regulation?

The facts

Blood glucose is important in the body because it is the source of energy for cell respiration. The normal blood glucose level required in the body for normal cell function is kept within a narrow range of 90-100 mg per 100 ml of blood. The source of glucose in our bodies is our **diet**. Glucose is the end-product of digestion of carbohydrates. It is absorbed into the bloodstream from the ileum. This raises the blood glucose level. It also raises the glucose in tissue fluid. Glucose levels above the normal can make cells to lose water and become crenated due to increase in osmotic pressure outside of them. This creates the need for the sugar level to be reduced back to normal.

On the other hand, during exercise or during starvation, the glucose in the blood is used up by the cells for respiration. This can lead to a drop below normal of the glucose level in the body. Too little glucose in the blood can make the osmotic pressure lower than normal. This causes the cells to gain too much water, which affects their normal function.

The pancreas is a body organ which plays two roles: the secretion of pancreatic juice and the secretion of hormones insulin and glucagon.

The liver and pancreas play a role in regulating the amount of glucose in the blood.

Another part of the pancreas contains cells known as the **islets of Langerhans**. This part also contains two types of cells known as the **Alpha** and **Beta** cells. These cells release two types of hormones into blood. These hormones are insulin and glucagon respectively. Their role is to regulate the blood sugar level by negative feedback mechanisms. This makes the pancreas to be classified as an endocrine gland.

The liver has the immediate role of regulating the amount of blood glucose. Under the influence of insulin, the liver converts excess glucose to glycogen for storage when blood sugar levels are above normal. Under the influence of glucagon, it converts the stored glycogen to glucose when blood sugar levels are below normal.

- On reaching the liver, insulin stimulates the conversion of the excess glucose to glycogen which is stored in the liver tissue.
- In the muscle tissue, insulin causes some excess glucose to be converted to glycogen for storage.
- It also increases respiration in tissues to break down some excess glucose to carbon dioxide and water.
- Some excess glucose is also converted to fat and stored under the skin.

These processes lower the level of blood glucose back to normal.

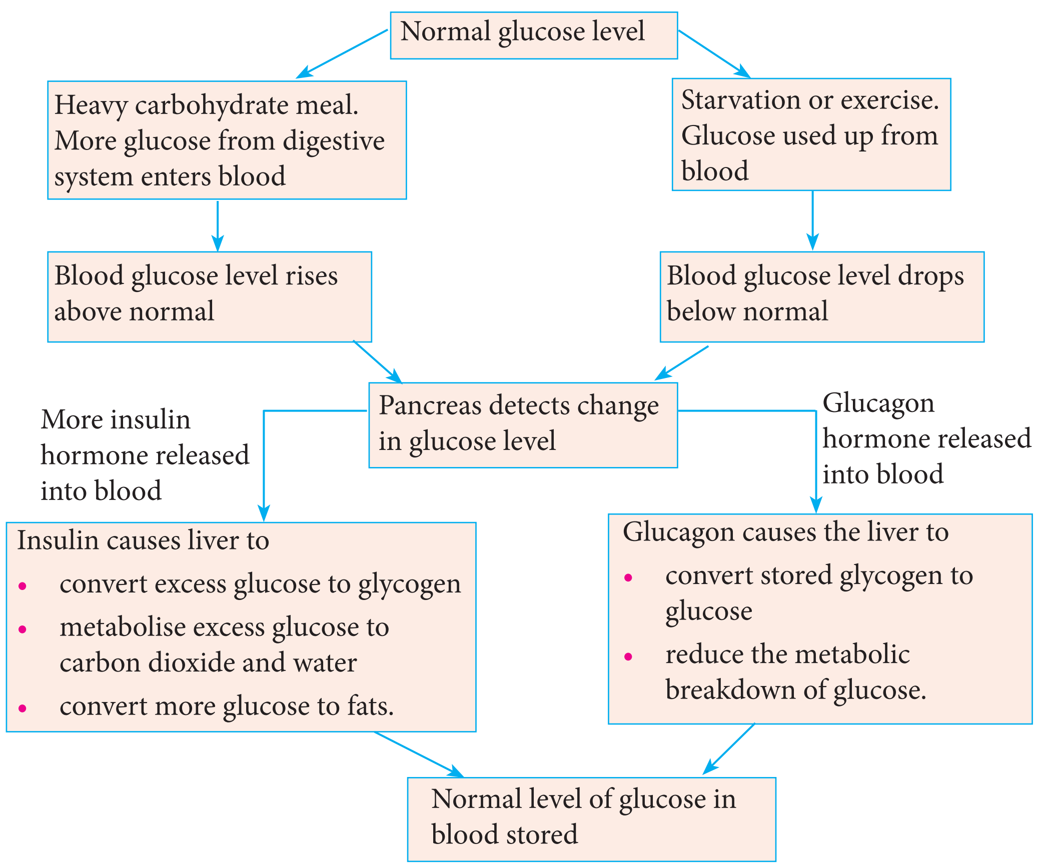


Fig. 10.8: Homeostatic control of blood glucose

When the level of blood glucose goes **below normal**, it stimulates the pancreas to secrete glucagon and stop secreting insulin. Glucagon has the following effects:

- In the liver, it stimulates the conversion of some of the stored glycogen to glucose which is released into the blood.
- Reduces respiration in the cells.

Thus the effect of glucagon on the liver is the opposite of that of insulin. Glucagon raises low levels of blood glucose to normal, while insulin lowers high levels of blood glucose to normal.

Diabetes mellitus

This is a condition in which the pancreas fails to produce adequate or no insulin. This may be due to hereditary reasons or disease affecting the islets of Langerhans. In this case it is refered to as type I diabetes. There is another type of diabetes known as type II where a person suffers diabetes due to lack of exercise or obesity. A person with diabetes mellitus has an abnormally high level of glucose in his or her blood (**hyperglycemia**). In some cases, the concentration of glucose is too low. This condition is referred to as **hypoglycemia**.

Symptoms of diabetes mellitus are:

- Passing urine frequently
- Constantly feeling thirsty
- Dehydration
- Loss of weight
- Poor resistance to infections

The kidney eliminates some glucose in the urine which is an unusual condition known as glycosuria (sweet urine). It can be treated by using insulin hormone, which decreases the glucose level to normal and reduces the symptoms of the disease. Insulin is administered through injection into a vein.

Good nutritional habits that reduce the risk of diabetes

- Exercise- It does not only help to lose weight, but keeps blood glucose, blood pressure, cholesterol and triglycerides at optimal levels. Even just moderate exercise of 30 minutes per day, five days a week can help.
- Eating foods that are low in animal/saturated fats. Use canola and olive oil in cooking since they both have unsaturated fats.
- Avoiding simple sugars.
- Eating protein sources low in saturated fat: turkey, fish, chicken (not fried).
- Get vegetable protein that is also high in fibre: beans, portabella and other varieties of mushrooms. Get dairy protein that is fat-free: egg substitutes and soy milk
- Visit the doctor regularly for medical check ups.

My health!

- A diabetic 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 with your diet and avoid alcohol and other drugs.

Self-evaluation Test 10.3

1. Insulin hormone is used to manage diabetic condition. Suggest reasons why insulin is not taken orally during its administration.
2. If a response enhances the original stimulus, the system is classified as a _______ feedback system.
   A. neutral B. polarised
   C. positive D. negative
3. Insulin and glucagon are antagonistic hormones because they increase and decrease _____
   A. calcium.
   B. potassium.
   C. glucose.
   D. cell metabolism.
4. Name the symptoms of *Diabetes mellitus.*

Unit summary

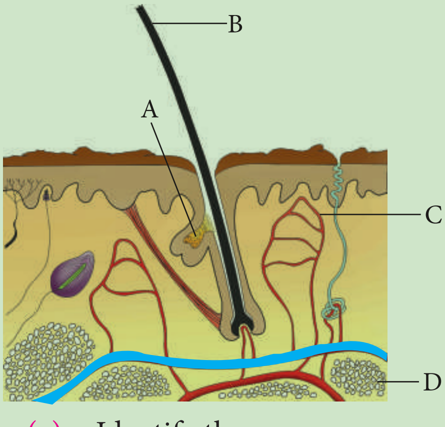
- The process of maintaining a constant internal environment in an organism is called homeostasis.
- The skin, lungs, liver and kidneys help maintain constant conditions of internal environment.
- Maintaining a constant internal environment involves regulating the amounts of salts, water and glucose. Temperature regulation is also a part of this process.
- Blood sugar in humans is regulated by the action of insulin and glucagon produced by the pancreas.
- Animals use behavioural and physiological methods to regulate the body temperature. They gain heat from metabolic processes and from the environment. They also lose heat to the environment.
- The hypothalamus plays a major role in the functioning of various organs involved in osmoregulation.
- The amount of water in humans is regulated by the action of antidiuretic hormone (ADH), which controls the reabsorption of water from the kidney tubules into the blood.

End Unit Assessment 10

1. By experiment, it was found that the heat loss per unit weight of a small mammal was greater than that of a large mammal, although their body temperatures remained constant. Which one of the following conclusions can be drawn from this result?
   A. Small mammals are more active than large mammals.
   B. Large mammals are better adapted than small mammals to their physical environment.
   C. Small mammals have a higher metabolic rate than large mammals.
   D. Large mammals have a greater surface area than small mammals.
2. Which one of the following is the reaction of the human skin when the body becomes very cold?
   A. The arterioles constrict, the hair stands on end and sweat production ceases.

B. The arterioles constrict, the hair lies flat on the skin and sweating occurs.
C. The arterioles dilate, the hair stands on end and sweat production almost ceases.
D. The arterioles dilate, the hair lies flat on the skin and sweating occurs.

3. Which of these conditions indicate positive feedback has occurred?
   A. Blood pressure decreases greatly; blood flow to the heart is inadequate, and blood pressure decreases.
   B. Hot temperatures increase your body temperature above normal; you sweat.
   C. Cold temperatures decrease your body temperature below normal; you shiver.
   D. Blood pressure decreases; as a result, your heart rate increases.
4. Human bodies are able to maintain their internal environment at a certain constant. This statement ____________
   A. refers only to the physiology of the vascular (circulatory) system.
   B. refers to homeostasis in the body.
   C. tells how positive feedback mechanisms work.
   D. refers to the direct control of cell activities by nucleic acids.
5. Destruction of the beta cells of the pancreas results in _________.
   A. type I diabetes (insulin-dependent)
   B. type II diabetes (insulin-non-dependent)
   C. diabetes insipidus
   D. hyperglycemia
6. In which circumstances may more blood sugar be found in the hepatic portal vein than in any other vessel?
7. When a person exercises for a short period, the heart responds to the increased level of activity. What is the heart's response to exercise and how does it enable greater physical activity?
8. Mammals are said to be homoeothermic. What is meant by this term?
9. Why is it important to maintain a constant internal environment?
10. How would you advice a person suffering from diabetes in your community?
11. (a) What is homeostasis?
    (b) Explain the following giving an example of each.
       i) Negative feedback
       ii) Positive feedback
12. The diagram below shows an organ of a mammal.



   (a) Identify the organ.

(b) Give the importance of the organ.

(c) Name the parts labelled A, B,C and D.

13. Using the data given below, plot a graph, showing the changes in uptake or output of sugar by the liver (Normal blood sugar level is in the range of 90 mg - 100 mg/100 cm^3).

	Glucose concentration	
Time (Min)	**Hepatic portal vein**	**Hepatic vein**
0	102	100
15	110	102
30	125	97
45	107	94
60	94	80
75	75	80
90	80	80

(a) Why is the glucose level in the hepatic portal vein _____
   (i) increasing in the first 30 minutes?
   (ii) decreasing after the 30^{th} minute?

(b) Why is the glucose level in the blood leaving the liver lower than that in blood entering it?

(c) (i) Name the other vessel that brings blood to the liver.
   (ii) What would be the expected level of glucose in this vessel?

Unit 11

Response and Co-ordination in plants

Key unit competence

After studying this unit, I should be able to explain response to light and gravity by plants and understand the importance of tropism in plants.

Learning objectives

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

- State and explain examples of plant responses.
- Define gravitropism or geotropism as a response in which parts of a plant grow towards or away from gravity.
- Explain the role played by responses in the life of the plant.
- Explain phototropism and geotropism of a shoot as example of chemical control of plant growth by auxins.
- Describe the role of auxins in controlling shoot growth.
- Identify other forms of plant responses by diffusion through plant and unequally distributed in response to light and gravity stimulating cell elongation.
- Apply knowledge of plant responses to light and gravity to explain the roles played by responses in life of the plant.
- Analyse the forms of responses shown by plant shoot and root systems.
- Research about other forms of plant responses and their importance to plants.
- Investigate responses of plant shoot towards light and gravity.
- Appreciate the importance of responses by plants to light and gravity to maintain life of a plant in places with limited light and other requirements.

Introductory Activity

When you see a fierce dog **charging** at you, what do you do? Why and how? Similarly when you touch a hot object, you quickly remove your hands from it. Why?

Plants also have such capabilities. For example, look at the plants below.

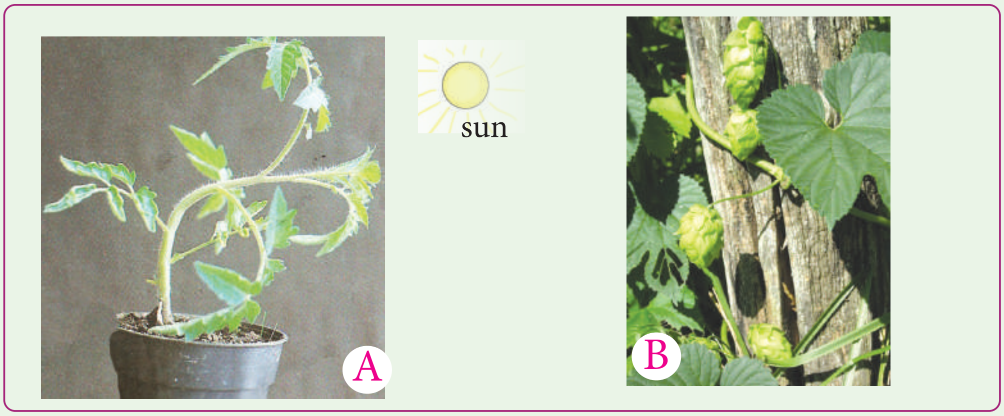


Fig 11.1: Plant responses

What caused the plant in picture **A** to bend? Why? How about the climbing plant in **B**? Why did it wind on the big plant? How do we call these kinds of responses? Do you now have an idea of what this unit is about?

Introduction

When a plant is put in a dark room with an open window, you find that the plant stem grows or bends towards the window where there is source of light.

Also, some plants with soft stems tend to wind round other stronger plants in the forests. These two are examples of plant responses. Which other plant responses do you know?

Have you ever wondered why all these responses happen? The reason behind this will be explained in this unit.

11.1. Plant responses

Activity 11.1: Investigating gravitropism and phototropism

Requirements:

- Potted plant seedlings
- Cotton wool
- Pea and bean seeds
- Containers
- Pins
- Clamps

Work to do

1. Design an experiment to investigate gravitropism and phototropism.

Study questions

1. What form of responses are shown by plant shoot and root systems?
2. Explain the roles played by the responses in the life of a plant.
3. What are the other forms of plant responses and their importance to plants?

Living organisms are able to respond to both internal and external stimuli. Co-ordination is the process whereby living organisms give the correct response at the correct time to a particular stimulus. This allows the organism to adapt, to change and increase their chance of survival.

Plants perceive stimuli that are important to their survival in the environment. The various external stimuli that plants respond to include light, water, gravity, chemicals, temperature and contact.

Plants respond to these stimuli by growing or moving towards or away from their direction. Plant responses that involve growth are called **tropisms**. Those responses that involve movement are called **taxis**. If the response is towards the stimulus, it is a positive response. If it is away from the stimulus, it is a negative response.

The specific responses of plants to a variety of stimuli are as given in Table 11.1.

Table 11.1: Plant responses and their stimuli

Tropisms	Stimuli
Phototropism	Light
Hydrotropism	Water
Geotropism (gravitotropism)	Gravity
Thigmotropism	Touch
Aerotropism	Air

The facts

Tropisms are directional movement responses that occur in response to a directional stimulus. Plants are not able to relocate if they happen to start growing where conditions are not optimal. However, plants can alter their growth so they can grow into more favourable conditions. To do so requires the ability to detect where the conditions are better and then alter their growth so they can "move" in the appropriate direction. Tropic responses result from differential growth.

Types of plant responses include:

a) Phototropism

Light is a stimulus that plants respond to. This is called phototropism (photo-light). Plants usually display a positive phototropic response to light, which means they grow towards a light source as shown in fig 11.2. The elongation on one side causes the plant to bend in the direction of the light. This bending allows more light to reach more cells on the plant that are responsible for conducting photosynthesis.

Fig 11.2: Phototropism

b) Geotropism (Gravitropism)

This is growth response towards gravity. The response of the radicle to gravity is positive geotropism and that of the plumule is negative geotropism.

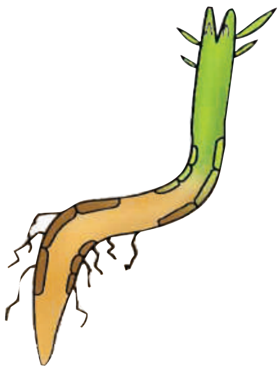


Fig 11.3: Geotropism

Geotropism enables:

- Plant roots to grow downwards in the soil. In this way, roots are able to absorb water and mineral salts for the synthesis of their food.
- Plants to anchor well into the soil hence ensuring that the plant remains firm against possible physical destruction by wind.
- The shoot to grow upwards and as such, leaves are in a position to get light which plants require to carry out photosynthesis.

c) Hydrotropism

This is the growth movement towards unidirectional stimuli of water. Roots show positive hydrotropism while shoots show negative hydrotropism.

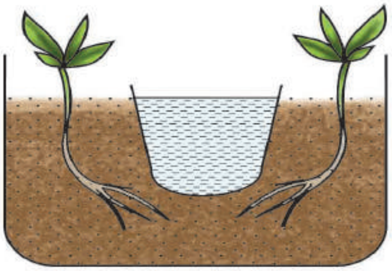


Fig 11.4: hydrotropism

d) Thigmotropism (haptotropism)

Thigmotropism is a movement or response that is generated when an organism is stimulated by touch. This type of stimulus is known as a **contact stimulus** and is important for the growth and development of many organisms. It is shown mostly by climbing plants e.g. pumpkins which have tendrils for support. Root tips grow away from stones and hard surfaces, therefore showing negative thigmotropism.

Chemotropism: Is the growth movement of part of a plant in response to a unidirectional source of chemicals for example pollen tubules grow towards the micropyle in the ovary of a flower where chemicals are produced, therefore the pollen tube is said to be positively chemotropic.

Photoperiodism: This is a situation whereby the plant is sensitive to light durations. Plants use this response during flowering.

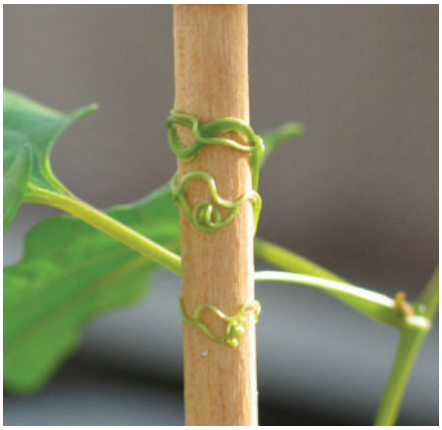
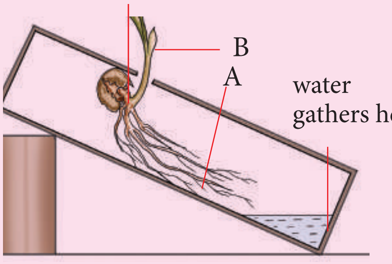


Fig 11.5: Thigmotropism

Self–evaluation Test 11.1

1. While animals can change their location as a response to a stimulus, plants change their growth pattern. True or false?
2. When an upright plant is placed on its side, the _____.
   A. plant dies.
   B. stems continue to develop horizontally.
   C. stem bends and grows upwards.
   D. stem bends and grows downwards.
3. (a) Curving away from light is called _____.
   A. positive phototropism
   B. positive phototropism
   C. negative gravitropism
   D. negative phototropism
4. The diagram shows a young plant growing in a tilted seed box.



   (a) Name the growth response shown by A.
   (b) Name the growth response shown by B.
   (c) Suggest the benefit to the plant of the growth response shown by B.
   (d) Give an example of a regulator in plants that inhibits growth.
   (e) Give **two** uses of plant growth regulators in horticulture.

11.2. Role of auxins in controlling shoot growth

Activity 11.2: Research Activity

1. Watch the video.
   Note down observations on role of auxins on plant growth.
2. Research on the role of auxins in controlling shoot growth. Use textbooks and the Internet.
3. Record and present your findings to the rest of the class.

The facts

Plant growth and development is influenced by growth regulating substances known as **plant growth hormones**. The hormones are produced in one part of the plant and transported to another part where they influence an aspect of growth. There are five major groups of plant hormones. These are **auxins**, **gibberelins**, **cytokinins**, **abscicic acid** and **ethylene**. In this subtopic, you will learn how auxins influence tropic growth responses.

Auxins

Auxins are produced at shoot tips and root tips. They then diffuse away from the shoot tips and root tips influencing cell division and elongation as they move. The amount of auxin present (concentration) affects how the shoot and root grows.

Auxins (**Indole Acetic Acid-IAA**) are plant hormones, which control growth. They influence growth by:

- Making the cells permeable to useful substances for growth.
- Increasing the metabolic rate of cells to produce more energy.
- Increasing the turgidity of cells.

Effects of auxin concentration on growth at shoots and roots

Activity 11.3: Research Activity

1. In an experiment, the shoot tip of a seedling was cut off. After some time; it was observed that growth had stopped. When the tip was replaced by an agar block which had been in contact with the cut off tip growth started again.

   When the shoot tip was chopped and the agar block placed halfway the cut off end, the shoot bent towards the side without the agar block. What does this tell you about the growth of shoots of plants? The above mentioned effects can be illustrated as shown below.

2. Study the graph below.

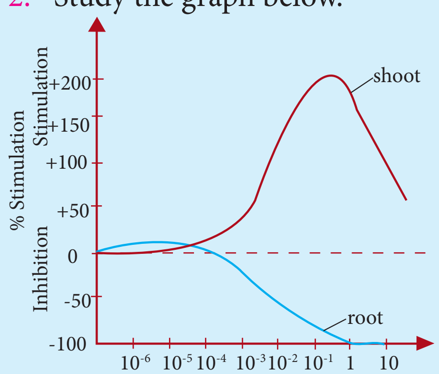


Fig 11.6: Effect of auxin concentration on growth of shoot and root

3. State the effects of concentration of auxins on the growth of shoots and roots.

The facts

The experiments show that bending of the shoot during growth is caused by an unequal distribution of auxins.

Auxins have strong effects on growth and are therefore required in very small amounts. The concentration that stimulates growth in shoots is higher than the concentration that stimulates growth in the roots. These concentrations occur in different ranges for the shoots and the roots.

The range for the shoot is higher than the range for the root. If the auxin concentration is above or below these ranges, growth is inhibited.

In the shoot tip, the higher the auxin concentration, the more the growth. The lower the auxin concentration, the less the growth. However, in roots the higher the auxin concentration the less the growth. The lower the auxin concentration within the range, the more the growth.

Auxins influence cell elongation by causing the cell wall to stretch. As the cells assimilate substances, the cell walls stretch. This increases the length and the thickness of the cell thus increasing the size of the tissue involved. Auxins are involved in plant response towards light, gravity and contact.

Auxins and phototropism

A plant shoot always grows upright 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. 11.7 below.

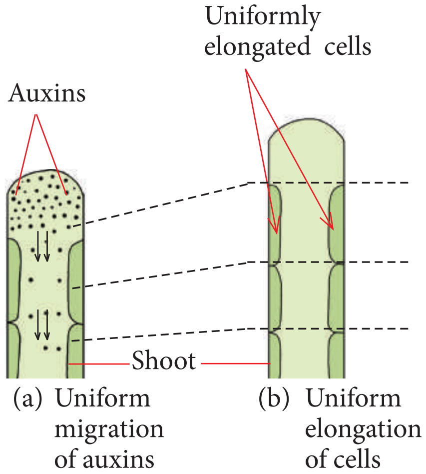


Fig 11.7: Growth of shoot under light coming from all directions or total darkness

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 exposed to the unidirectional light. This is as shown in Fig. 11.8.

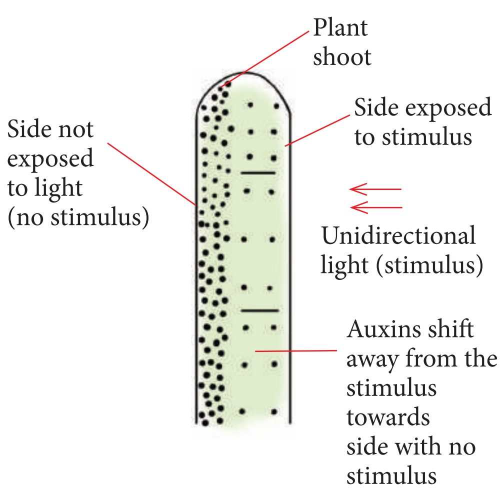


Fig 11.8: Auxins shift to the darker side of shoot away from side exposed to unidirectional light.

The high 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 11.9. This growth response is referred to as **phototropism**.

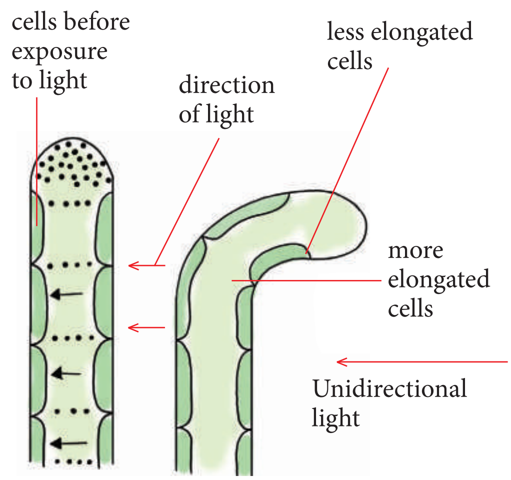


Fig 11.9: More growth of cells on darker side leads to bending of shoot towards the direction of light.

The following are types of tropisms named according to stimuli. They may be positive or negative depending on direction taken. If the growth is directly towards the stimuli then it is positive and if the growth is directly away from the stimuli then it is negative.

Auxins and geotropism

Geotropism is a response of plants to the stimulus of the pull of **gravity**. The roots show positive geotropism while the shoots show negative geotropism. Under normal circumstances, the shoot plumule grows upwards and the root radicle grows downward.

If a seedling was growing horizontally, the radicle grows bending downwards while the plumule grows bending upwards. This is because as auxins are produced, they diffuse away from the tip. The force of gravity pulls the auxins downwards. These cause auxins to concentrate along the lower part of the radicle and plumule as shown in Fig. 11.10 below while the upper side of the radicle and plumule ends up with a lower concentration of auxins.

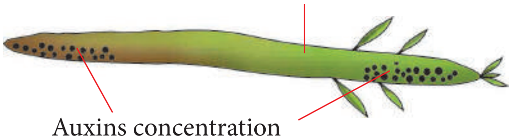


Fig 11.10: Seedling with auxin concentrated more on the lower side

In the **plumule** (young shoot), the lower part has a higher auxin concentration. The cells here elongate more. This results to more growth. The upper part has lower auxin concentration. The cells here undergo less elongation. This results in 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.

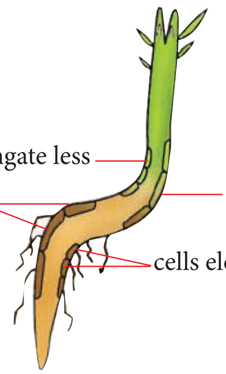


Fig 11.11: Geotropism as explained by distribution of auxins due to gravity

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 grow curving towards the point of contact. This way, the plant grows twining along the supporting structure.

Use of auxins as weed killers

Plant chemical hormones that work like plant hormones can be used to control unwanted plants. Auxin and chemicals that act like auxin are used in various types of weed killers. Some of the chemicals that have been used in the past or present include 2,4-D and 2, 4, 5-T.

These herbicides generally mimic auxin, a plant growth hormone. Auxin herbicides stimulate a variety of growth and developmental processes when present at low concentrations at the cellular sites of action. However, with increasing concentration and auxin activity in the tissue, growth is disturbed and the plant is lethally damaged.

The synthetic auxins are used primarily to control broadleaf weeds in grass crops and pastures.

Self–evaluation Test 11.2

1. Explain the behaviour of auxins when a shoot tip comes into contact with an object.
2. When you prune your plants you remove ______ that was produced by the apical meristem so your plant spreads out.
3. Auxins promote growth at a very low concentration in
   A. shoots
   B. roots
   C. flowers
   D. nodes
4. The table below shows the effects of auxin at different concentrations on the growth of shoots and roots of oat seedlings. The elongation of the test seedlings was compared to the elongation of a group of control seedlings which did not receive auxin treatment. A positive value indicates that the test seedlings grew more than the controls and a negative value indicates that the test seedlings grew less than the controls.

Auxin concentration / parts per million	Elongation relative to control/mm	
	Shoot	Root
10^{-6}	0	+3
10^{-5}	0	+5
10^{-4}	+2	+11
10^{-3}	+6	+10
10^{-2}	+9	-3
10^{-1}	+34	-23
1	60	-38
10	+33	-40
100	-22	-40

   a) Plot these results in a suitable graphical form.
   b) Compare the response of the shoots to auxin with the response of the roots.
   c) Synthetic auxins are used as weedkillers. Suggest how they operate selectively to kill broad-leaved weeds such as plantains in a lawn.

11.3. Other forms of plant responses

Activity 11.4: Research activity

1. Observe the video and note the different forms of plant responses.
2. Write a report of your findings.

The facts

Nastic response is a non-directional movement of part of a plant in response to an external stimulus. It mainly depends on the intensity of the stimulus.

Nastic movements are generally caused by changes in the osmotic pressure due to an influx or efflux of ions that cause water to move in or out of the cells. In many plants, shrinkage of the motor cells causes the overall movement of the plant.

Nastic movements in plants are reversible and repeatable movements in response to a stimulus whose direction is determined by the anatomy of the plant. They are generally slow movements. Examples include:

i. The leaves of many plants respond to the daily alternation between light and darkness by moving up and down. Leguminous plants exhibiting nastic movements include the sensitive plant *Mimosa pudica* shown in Fig 11.12 and the silk tree.

Fig 11.12: Mimosa plant before and after touch

ii. Mechanical disturbances that may trigger movements include touch or shaking the plant. The leaves of carnivorous plant such as Venus fly trap respond in a rapid, highly specialised way when an insect touches their leaves. The leaves have two lobes, within about a half-second, the two lobes of the leaf shut. Enzymes digest the insect in one to several days and the empty trap then reopens.

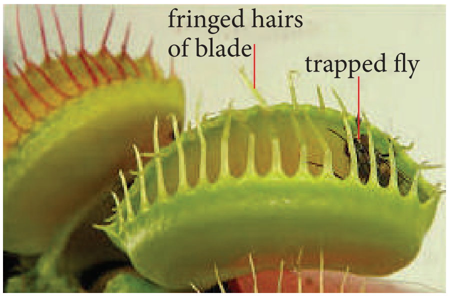


Fig 11.13: Venus fly trap showing leaf shut after trapping insect

iii. Movements of developing buds which swell, open up and eventually fall off.

iv. The opening and closing movements of many flowers.

v. The responses of leaves to changes in temperature and light.

Activity 11.5: Discussion Activity

1. Discuss the difference between tropism and nastic responses.
2. Share your findings with other class members.

Table 11.2: Differences between tropism and nastic response

Tropism	Nastic
The direction of movement is determined by the position of the origin of the stimulus.	The direction of movement is determined by the anatomy of the plant.
The movement is in a direction either toward or away from the origin of the stimulus.	The movement is determined by the position of the origin of the stimulus.
Changes that occur are generally irreversible.	Changes that occur are temporary; they are reversible and repeatable.

Self–evaluation Test 11.3

1. What is nastic?
2. A sleep movement is a ______. (tropism or nastic response)
3. Auxins ________________.
   A. promotes fruit growth
   B. stimulates positive phototropism
   C. causes roots to develop
   D. causes shoots to develop

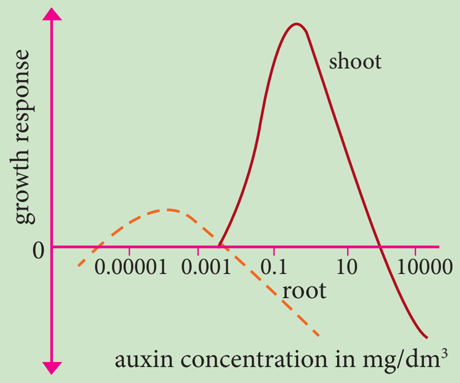
Unit summary

- Response is the change in activity in an organism due to the presence of a stimulus.
- Plants respond through growth curvature towards or away from stimulus.
- Tropism is growth movement towards or away from stimulus.
- Phototropism is growth curvature in response to light.
- Gravitropism is the growth curvature in response to gravity.
- Chemotropism is growth movement in response to chemical concentrations.
- Thigmotropism is growth curvature in response to touch or contact.
- Hydrotropism is growth curvature in response to moisture content.
- Auxins influence cell elongation.
- Auxins migrate away from unidirectional light causing growth in the dark side of the plant leading to phototropism.
- Auxins cause positive gravitropism in roots but negative gravitropism in the shoot.
- Auxins migrate away from the point of contact causing thigmotropism.
- Auxins are used in herbicides as a weed killer.
- Nastic response

End Unit Assessment 11

1. Which of the following is a long-term plant response?
   A. Opening and closing of stomata.
   B. The hypersensitive response
   C. Gravitropism
   D. All of the above

2. Explain the behaviour of auxins when exposed to
   (a) unidirectional light.
   (b) pull of gravity.
3. If the tip of a seedling is cut off or covered by a black cap, phototropism will not occur. True or false?
4. State the different responses in plant and their stimuli.
5. (a) What advantage is there for a plant when it responds to light positively?
   (b) Why is it important for plants to respond to gravity?
6. Stimulation by auxins causes cell elongation because turgor pressure increases in the cell which stretches the weakened cell wall. True or false?
7. When a plant is exposed to unidirectional light, auxins ______.
8. Mimosa (*Mimosa pudica*) is also called the 'sensitive plant' because its leaves fold inwards when touched. This is an example of a nastic movement. What is the possible significance of this nastic movement in mimosa?
9. Petal movement in Kalanchoe is a nastic response while bending of a seedling shoot tip towards light is tropism. Explain the difference between a nastic response and tropism using a table.
10. State ways through which thigmotropism enables a plant to survive in its environment.
11. The graph shows the effect of auxin concentration on the growth of a plant shoot and root.



   (a) Describe and explain the trends shown.
   (b) What use could be made of these results?
12. Read through the following passage about auxins and then complete it by filling in the spaces with the most appropriate word or words.

   Auxins, such ____________, are the most abundant plant growth substances. They are concerned with __________ growth due to cell __________ and differentiation. They also cause __________ to external stimuli, such as _____and ____________.

   They also promote the growth of _________roots from stems, suppress the development of______________ buds and initiate ____________ development, even if pollination has not occurred (a process known as _________). Auxin is produced in the ________ of stems and ___________ down to the target region.

Unit 12 Response and Co-ordination in animals

Key unit competence

After studying this unit, I should be able to relate structures of nervous and endocrine systems to their functions.

Learning objectives

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

- State the components of coordinated behaviour in an organism.
- Identify the components of the human nervous system.
- Identify neurons from diagrams.
- Describe a simple reflex arc in terms of receptor, sensory neurone, relay neurone and motor neurones.
- Explain how reflex actions are important to the body.
- Explain the difference between voluntary and involuntary actions.
- Recall the five human senses and outline the structure and function of the five mammalian sensation and their respective sense organs.
- Explain the importance of hormonal communication.
- Identify the location of the endocrine glands and state their functions.
- Analyse the structure of different neurons.
- Carry out an investigation to determine the time to react to a stimulus.
- Demonstrate the role of antagonistic muscles as effectors in rapid responses.

Introductory Activity

When you write in your book, your eyes help in locating the space to write in. The skin on your hand feels the page and brain interprets what you are writing. All these activities occur in a coordinated manner. Study the diagram on Fig 12.1.

It shows what happens when you touch hot objects or fire. Study it carefully. Try to understand the relationship between the spinal cord, the hand muscles and the skin on the finger. Trace the path of the stimulus from when the fire is detected at the finger until when it is removed. What does this tell you about how our bodies work?

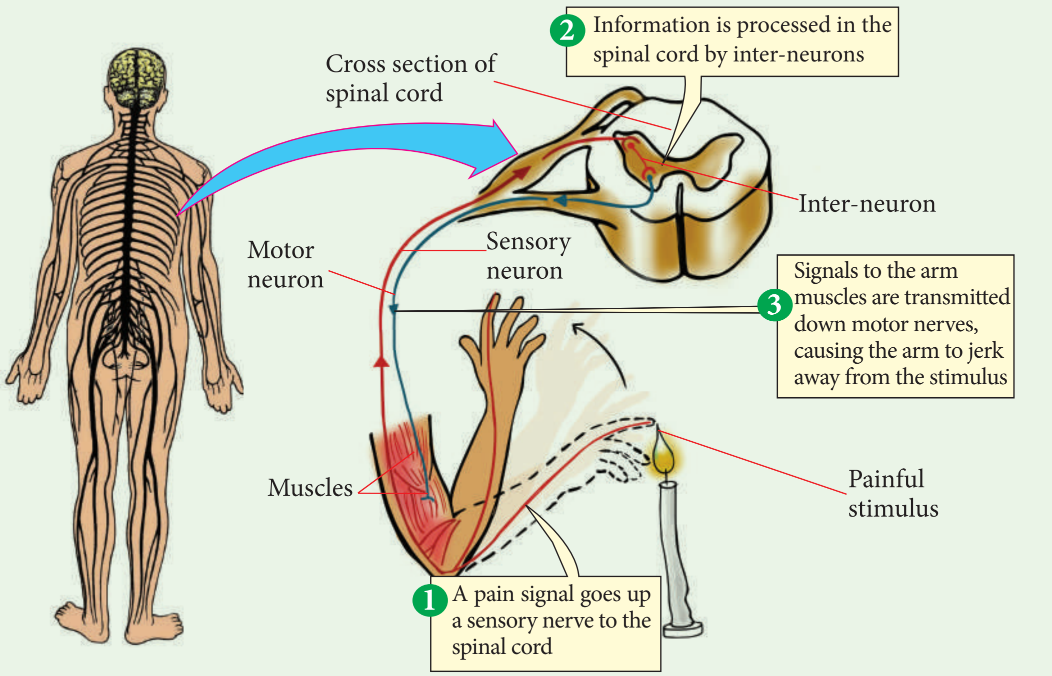


Fig 12.1: Signal transmission and response

12.1. Need for coordination and response in animals

Activity 12.1: Discussion Activity

1. Discuss why organisms require coordination and response.
2. Using textbooks in the library, look at the meaning of the following terms:
   (i) Coordination
   (ii) Irritability
   (iii) Stimulus
   - Response
   - Receptors
   - Effectors

   You can also use the Internet.
3. Share your findings with the rest of the class.

In Senior One, you 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. Living organisms have the ability to detect changes in their internal and external environments. They respond to these changes appropriately.

This characteristic is of great survival value to the organisms. The structures involved in detecting the changes may be located far away from the ones that respond. Therefore, there is need for communication pathways within the body to link the structures involved in detecting changes with the structures that respond to the changes.

Co-ordination is the process whereby a living organism gives the correct response at the correct time to a particular stimulus. This allows the organism to adapt, to change and increase their chance of survival.

In animals, coordination is performed by the nervous system and the endocrine system as you will learn in this unit.

Animals, like plants, are able to perceive changes in their external and internal environment. They detect these changes through special cells and organs called **receptors**. The process of detection or perceiving the changes is known as **reception**.

They then respond appropriately to enhance their survival. Muscles and glands that bring about responses are referred to as **effectors**. The receptors and effectors are linked together by a coordinating system composed of the **nervous system** and the **endocrine system**. The endocrine system is made up of ductless glands which release hormones.

12.2. Components of the human nervous system

Carry out Activity 12.2 to investigate the components of the human nervous system.

Activity 12.2: Investigating the components of the human nervous system

Requirements

- Charts
- Models of different parts of the human nervous system

Procedure

1. Observe the charts and models.
   - What are the components of the human nervous system?
   - Can you name and label the different parts of the nervous system?
   - Suggest functions of the different parts of the nervous system.
   - How do the parts above work together?
2. Draw the parts observed in your notebook.
3. Present your findings to the class.

The nervous system is a system of specialised cells known as **nerve cells** which are linked to each other and to different sensory cells and effectors in the body. The nervous system is composed of the following:

- The central nervous system (CNS) which is made up of the brain and the spinal cord.
- The peripheral nervous system - which is made up of the peripheral nerves.

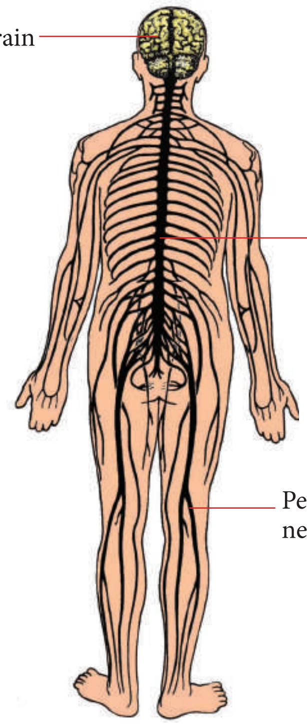


Fig 12.2: Parts of the human nervous system

The Central nervous system

The central nervous system is made up of the **brain** and the **spinal cord**. The spinal cord is an extension of the brain.

The brain

The brain is protected by three main structures.

(i) The skull (cranium) - which protects it externally.
(ii) The meninges – these are membranes which protect it internally.
(iii) Cerebral–spinal fluid - this is a shock absorber and it also provides nourishment to the brain.

The brain is composed of three regions, namely:

1. The fore brain (Cerebrum and olfactory lobes)
2. The mid brain (Hypothalamus, optic lobes, thalamus and pituitary gland
3. The hind brain (Cerebellum and Medulla oblongata)

The brain functions to:

- Receive impulses from sensory organs and send them to the respective organs for proper functioning of the body (relay centre).
- Make decisions based on inherited characteristics or past experiences so as to modify behaviour.
- Help the muscular body balance.
- Coordinate the vital body processes like regulation of body temperature, breathing and heartbeat.

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 hemispheres are organised into a number of parts. These include cerebrum, cerebellum, medulla oblongata, hypothalamus, thalamus, pons and pituitary bodies. 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 three 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.
- **Arachnoid matter** is the middle layer of the meninges. It is filled with cerebral-spinal fluid. All blood vessels entering the brain pass through this space. 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 contains lymphocytes which also protect the brain against disease infections.

The brain is divided into two hemispheres, the left and the right hemispheres. Fig. 12.3 below shows the structure of the brain.

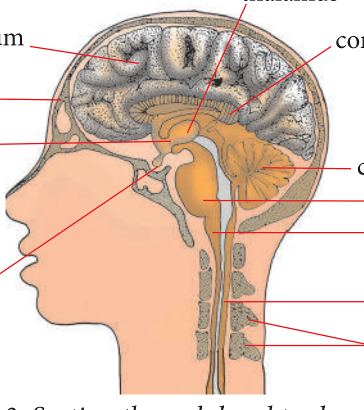


Fig 12.3: Section through head to show the brain

Cerebrum

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.

When you are practising for your music and drama festivals, you probably recite poems and act in plays.

- *What do 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 presentations, 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.

Cerebrum is the largest part of the human brain. It makes up about two-thirds of the brain mass.

Did you know?

Cerebrum is divided into the right cerebral hemisphere and the left cerebral hemisphere.

The cerebrum therefore has the following functions:

- It is the thinking centre.
- 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 receptors in the skin and other organs. This means that the cerebrum is responsible for sight, hearing, taste, smell and speech.

Health check!

A Plasmodium parasite sometimes can enter the brain and specifically in the cerebrum. This causes cerebral malaria. Cerebral malaria may lead to mental disorder if not treated early. It is therefore important to take malaria patients to hospital as early as symptoms appear to avoid this condition.

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.

Assume you are watching the final football match between your school and a neighbouring school. The striker of the opposing team dodges the defense of your team and remains with the goalkeeper. Everyone waits for the goal to be scored. Surprisingly, the goalkeeper saves it.

- What do you think the goalkeeper had to do to save the ball?

The goalkeeper probably had to keep his or her eyes on the ball to judge the speed and its direction. This way he or she managed to coordinate his or 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.

Health check!

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 where 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 died 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.

Other parts of the brain include:

- **Pons** - Works together with medulla oblongata to bring about involuntary activities.
- **Thalamus** – Relays sensory information to other parts of the brain.
- **Hypothalamus** – Controls secretion of hormones by pituitary glands and so it is involved in homeostatic processes. It also control hunger, thirst and sleep.
- **Corpus callosum** –Composed of axons that connect the left and right hemispheres.
- **Corpora quadrigemia** -Controls movement of head and trunk and have relay neurones for sight and hearing.
- **Pituitary gland** -This is an endocrine gland responsible for the production of many hormones that control other endocrine glands. It is also known as the **master gland**.

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 Fig 12.4 below.

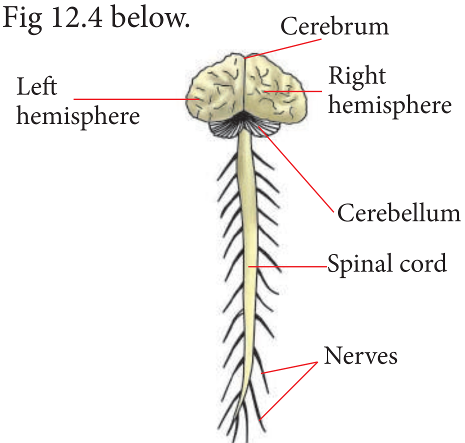


Fig 12.4: The central nervous system

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 cerebral-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) Coordinating certain automatic responses.

(iii) Coordinating spinal reflexes.

The peripheral nervous system

This is a system of nerves that connects the spinal cord and the brain to all other parts of the body.

The nerves that connect the brain to surrounding parts in the head such as the ear and the eyes are known as **cranial nerves.** The nerves that connect the spinal cord to surrounding parts of the body such as hands, legs, ribs and abdomen are known as the **spinal nerves.**

The peripheral nervous system connects the receptors to the central nervous system. It also connects the central nervous system to the effectors. The peripheral nervous system is divided into:

- Voluntary which is responsible for the movement of the skeletal muscles
- Autonomic (involuntary) nervous system. This is responsible for the involuntary movements in the body like breathing, heartbeat and movement of food along the gut.

The nervous system carries out the following functions:

- It perceives the changes around us through our senses.
- It controls and coordinates all the activities of the muscles in response to the changes outside.
- It also maintains the internal environment of the body by coordinating the functions of the various internal organs and the involuntary muscles.
- It stores the previous experiences as memory that helps us to think and analyse our reactions.
- It conducts messages between different parts of the body.

Self-evaluation Test 12.1

1. What does CNS refers to?
   A. The central nervous system consisting of the brain and spinal cord
   B. The cerebral nervous system consisting of the brain, spinal cord and retinas
   C. The central nervous system consisting of the brain and motor neurons
   D. The cerebral nervous system consisting solely of the brain
2. The _________ contains centres for heartbeat, breathing and blood pressure.
   A. cerebellum
   B. cerebrum
   C. spinal cord
   D. medulla oblongata
3. What is the function of the nervous system?
   A. To make us think
   B. To send messages to and from the brain and spinal cord to and from the body
   C. To break down food to be used by the body
   D. To remove wastes from the body

12.3. Structure and functions of neurones

Suppose your finger is pricked by a needle and, you have felt the sensation. Then your brain senses the prick and generates a response and you withdraw your hand. This flow of message through the nerve is called **impulse**.

Nerve impulse upon generation passes along a neuron in only one direction. The neuron is connected to a sensory receptor that receives the message or stimulus and converts it into electrochemical waves. These electrochemical waves are carried by the neuron. The stimulus from the receptor organ is received by the dendrites, conducted to cell body of the neuron and finally to the effector organ.

Activity 12.3: Observing the structures of neurones

1. Using charts from internet, observe the structures of the types of neurons.

   Are they all similar?
2. Draw and label the structure of the neurons in your notebooks.
   - Suggest the functions of the neurons based on their structure.
   - Share your findings with the rest of the class.

The facts

The nervous system is made of specialised cells known as **nerve cells**. The nerve cells are also referred to as **neurones.** The neurons relay an electrical signal called a **nerve impulse**.

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 extensions 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.**

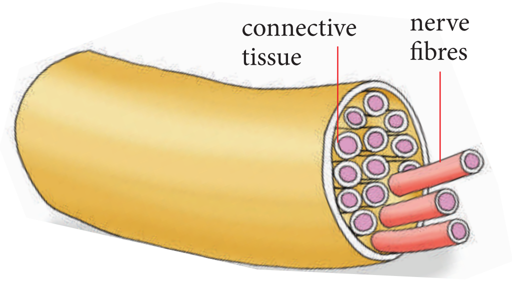


Fig 12.5: Nerve fibres grouped together form a nerve.

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 increase 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).

There are three main types of neurones. These are:

- **Sensory neurones**, which transmit impulse from receptor (sense organ) to the central nervous system (brain or spinal cord).
- **Motor neurones**, which transmit impulse from central nervous system to effectors (muscle or glands).
- **Intermediate neurones**, which connect sensory and motor neurons found in the grey matter.

The three types of neurons vary in structure but they share a number of structural features including;

1. Cell body

This consists of dense cytoplasm surrounding a prominent nucleus. It is where energy required to transmit the impulse is produced and the nucleus controls all the other activities within the neurone. In motor neurons, the cell body is found at the end of axon and it branches into dendrones which also branch into dendrites.

2. Myelin sheath

This is a fatty material that surrounds the axon. It is produced by Schwann cells. The myelin sheath insulates and protects the axon and also aids the transmission of impulses. It is broken at various points called **Node of Ranvier** and this increases the rate at which the impulse is transmitted.

3. Dendrites

These provide connection in form of a synapse with other neurones to effect communication. They are delicate hair like outgrowths, which are in close contact with other neurones or with stimulus receptor cells.

4. The axon

This is a long cytoplasmic extension running from the cell body. Inside the axon is exoplasm which contains ions that facilitate transmission of impulses. In motor and sensory nerves, it is usually covered with myelin sheath.

Sensory neurones

These are also called **receptor neurone.** These are neurones that carry messages (impulses) from the sensory cells and organs to the central nervous system. Their cell body 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.

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.

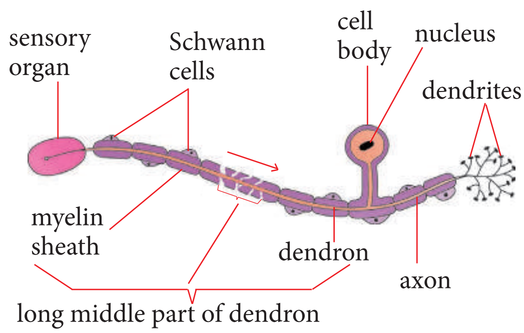


Fig 12.6 Sensory neurone

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 dendrites. See Fig. 12.7 below.

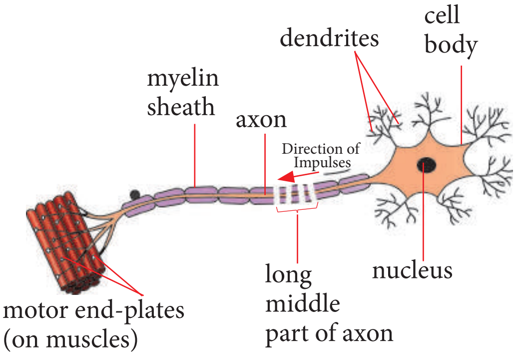


Fig 12.7: Motor neurone

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.

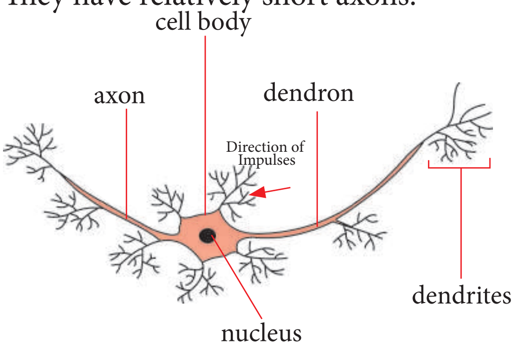


Fig 12.8: Intermediate (relay) neurone

Synapses

A synapse is a specific functional point that links one neuron to another or it is a means by which a nervous impulse is passed from one neuron to another.

Impulse transmission across a Synapse

When a stimulus reaches the receptors it generates an impulse which passes to the cell body of the sensory neuron. The impulse then goes through the axon to the dendrite and then to the dendrite of another neuron across the synapse.

An impulse in one axon triggers release of a transmitter substance (acetylcholine) into the synaptic gap. The transmitter substance stimulates the adjacent neurone to form an impulse and so the stimulus is passed on.

The transmitter substance is then destroyed and is resynthesised to carry more impulses. This ensures that an impulse travels only in one direction.

Self–evaluation Test 12.2

1. A neurone generally has all of the following principle areas, except ___________.
   A. microvilli
   B. a cell body
   C. dendrites
   D. an axon
2. _____ send signals away from neurons whereas _____ receive signals from other neurons.
   A. dendrites; axons
   B. axons; dendrites
   C. axons; synapses
   D. synapses; dendrites
3. Which item should not be grouped with the rest?
   A. Spinal nerve
   B. Cranial nerve
   C. Spinal cord
   D. PNS

12.4. Reflex arcs and reflex actions

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.

- What would you call such a response?

Activity 12.4: The knee jerk experiment

1. Ask your partner to sit on a chair with their legs crossed so that one leg hangs freely.
2. Strike gently the part just below the knee of the hanging leg using a ruler or edge of your hand.
3. Make your observations.
4. Change places with your partner and repeat the activity.

Study questions

1. What did you observe when you struck your partner's knee?
2. What type of response is this?

The facts

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.

A **reflex action** can be defined as a rapid and automatic response to a stimulus. It usually has a survival value. They are involuntary, 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.

Reflex arc is described as the path taken by a nerve impulse in a reflex action. The route that is followed by impulses during a reflex action is called **reflex arc**. A reflex action moves in the following direction:

1. A receptor is stimulated and an impulse travels along a sensory nerve fiber to the spinal cord.
2. The impulse is picked up by an intermediate neuron within the CNS.
3. The intermediate nerve fiber transmits the impulse to a motor nerve fiber which is connected to an effector.
4. The effectors which could be muscles or glands respond to the stimuli appropriately.

Spinal reflex, this is a reflex action which involves the spinal cord. It usually occurs in actions which occur below the head such as knee jerk and peristalsis.

Cranial reflex; this is a reflex action which occurs in the region of a head and it involves the brain, for example salivation and blinking.

Characteristics of reflex actions

- They occur rapidly.
- They occur spontaneously and take a short time.

- They are coordinated either by brain or spinal cord.
- They are not learned but inborn.

There are two types of reflex actions:

- Simple reflex action
- Conditioned reflex action.

(a) Simple reflex action

Have you experienced any of the following?

(i) Touching a hot object, you quickly withdraw your hand. This prevents burning of the hand.

(ii) Sudden blinking when someone throws an object towards your eyes. This prevents the eye from possible physical injury.

(iii) Salivation at the sight of food. This prepares the individual for softening and lubrication of food to make it easy to swallow.

(iv) Sneezing when dust gets into your nose. This helps in releasing and expelling the dust that may contain infectious bacteria.

(v) 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.

(vi) Secretion of tears when an onion is peeled near you. The tears wash away the irritating chemicals that can damage the eye.

All the above are examples of simple reflex action: a given stimulus always produces the natural or expected reflex response.

During a simple reflex action, an impulse passes through a certain pathway from the receptor to the effector. This pathway usually involves the three neurons; 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. 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** as illustrated below.

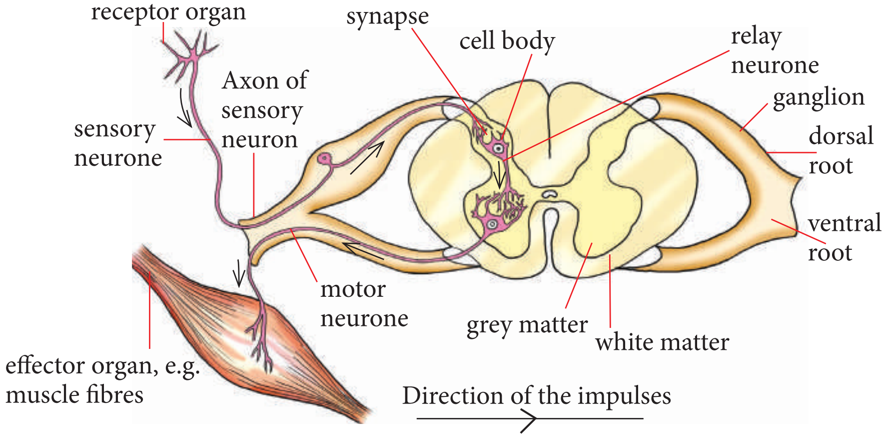


Fig 12.9: The reflex arc

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 is called a **synapse.** It is through this synapse that impulses are transmitted from one neurone to another.

A synapse is a junction formed when two neurones meet end to end.

(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 not able to respond to the name 'Captain' alone?

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 **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.

Other examples of conditioned reflex action include:

- Cycling
- Walking
- Swimming
- Driving
- Training of animals in various skills.

Can you suggest some other examples of conditioned reflex action apart from the ones given above?

Pavlov's experiments on dogs

Ivan Petrovich Pavlov was a Russian physiologist known primarily for his work in classical conditioning. He 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.

Sequence of events during reflex action is shown:

- When the original stimulus (taste of food) caused salivation in the dog. This is simple reflex pathway.
- When the new stimulus (sound of a bell) caused the same response of salivation. This is the conditioned reflex pathway.

Antagonistic muscles

- Antagonistic pairs of muscles create movement when are (prime mover) contracts and the other (the antagonistic) relatives after being stimulated.
- The examples of antagonistic pairs are:

(i) The Quadriceps and the hamstrings in the leg.

(ii) The Biceps and triceps in the arm

Activity 12.5: To demonstrate role of antagonistic muscles in movement

Requirements

- Cardboards.
- 50cm meter rule.
- 30 cm ruler.
- Elastic bands.
- Paper fastener

Procedure

1. Measure and cut (2) 40 cm by 10 cm cardboards.
2. Measure 15 cm from one end of the cardboard and cut a slot about 2 cm wide and in depth.
3. On the second cardboard, cut another slot with same dimensions as in step (2); 5 cm from the edge.
4. Connect the cardboards using a paper fastener and place an elastic band through the two slots as indicated in figure below.

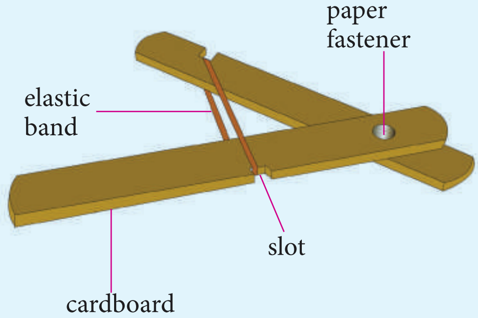


Fig 12.10: Apparatus showing role of antagonistic muscles in movement

5. Stretch the elastic band by separating the cardboards. Draw an illustration to represent the position of the cardboards.
6. Release the tension on the elastic band by allowing it to shorten. Draw an illustration to represent the position of the two cardboards.

Study questions

1. Which position of the elastic band represents biceps muscle contraction and relaxation;
   i) Stretched elastic band?
   ii) Shortened elastic band?
2. Which bones are represented by the cardboards oriented;
   i) Horizontally?
   ii) Vertically?
3. How do the following affect the bones you have mentioned in 2 (i) above to do?
   i) Stretching of elastic band
   ii) Shortening of elastic band

Voluntary actions

These are actions done consciously by an animal i.e one is aware of them. They are initiated by the cerebral cortex of the brain. The actions include: singing, writing, running and eating.

Table 12.1 Differences between voluntary actions and involuntary actions

Voluntary actions	Involuntary actions
They do not occur spontaneously	Occur spontaneously after receiving a stimulus
They do not occur very rapidly	Occur very rapidly
Many neurons are involved	Only three types of neurons are involved
They are mediated by pathways in the cerebral cortex of the brain	Are mediated by pathways either in the brain or spinal cord
Responses to stimulus are always varying according to conditions	Responses to stimulus are normally the same

Autonomic nervous system

This is part of the nervous system that controls involuntary activities such as blinking. It is made up of two parts:

- Parasympathetic system
- Sympathetic system.

The **sympathetic** system is important especially during emergency situations. It brings about responses associated with fight or flight. The parasympathetic nervous system controls internal responses associated with a relaxed state. These often cause antagonistic effects in the organs, for example the heartbeat may be accelerated by the sympathetic system while the parasympathetic system slows it down.

Self–evaluation Test 12.3

1. Which of these is an example of conditioned reflex?
   A. Sneezing
   B. Yawning
   C. Withdrawal of hand on touching a hot plate
   D. Watering of mouth at the smell of food
2. Reflex action is controlled by ___.
   A. autonomic nervous system
   B. peripheral nervous system
   C. central nervous system
   D. none of these
3. Which one illustrates a reflex arch?
   A. Brain – spinal cord – muscles
   B. Muscle – receptor – brain
   C. Muscles – spinal cord– brain
   D. Receptor – spinal cord – muscles

12.5. Sense organs

What do you think an organism uses to detect changes in its external and internal environment?

Can you name the five sense organs and their functions?

Activity 12.6: Investigating the sense organs

Requirements

- Source of sound
- Sugar
- Lemon
- Salt
- Different coloured papers
- Different sprays or perfumes
- Different surfaces

Procedure

Design an experiment to investigate the sense organs and their functions.

Study questions

1. How does frequency range and source of sound affect hearing?
2. Map out the regions of the tongue concerned with sweet, sour, salty and bitterness.
3. How do your eyes behave when exposed to too much light or in pitch darkness?
4. Do you use your hands to touch or the skin?
5. What happens when you smell several sprays at a go?

The facts

Sense organs are organs of the body that responds to external stimuli by conveying impulses to the sensory nervous system. The sense organs are the eyes, ears, tongue, skin and nose.

(a) The eye

Activity 12.7: Investigating how a camera works

1. Observe the camera carefully.
2. Using the Internet and textbooks, draw a cross-section of a camera, and the human eye.
   - How do they form images?
3. Try to take photographs at any angle with the camera.
   - How do the images appear?
5. Share your findings with the class.

Study questions

1. How does a camera operate?
2. How does the working mechanism of a camera compare to the human being eye?

The facts

The **eye** is a sense organ. It detects and responds to light. It has sensory receptor cells that are stimulated by light. A pair of eyes is found in most animals. They are located on the head. The human eye is spherical in shape.

The human eye forms images of the objects it sees just the way a camera does. These images of the object are formed inside the eye. The images are then transferred to the brain in the form of nerve impulses. These nerve impulses are transmitted to the brain via the **optic nerve** where they can be interpreted. The brain then makes sense of them and this is how you see.

External features

The external eye consists of a spherical eyeball which is located in a spherical space called the **orbit** or **socket** found on the front part of the skull as shown in Fig. 12.11 below.

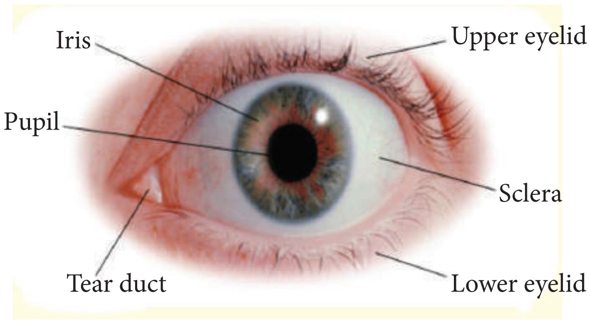


Fig 12.11 External parts of the eye

The eye ball is held in place by muscles. These muscles also control the movement of the eyeball in the orbit. On the outside of the eye, there are eyelids that cover and protect it from physical damage. The edges of eyelids have hairs known as eye lashes.

They trap dust particles preventing them from entering into the eyes. **Tear glands** are located just above the eyeball. They secrete tears that keep the eye moist. The tears also wash away dust particles. The excess tears drain away into the nasal cavity through a duct called **tear duct.** The tears also contain antiseptics to kill pathogens.

Internal features of the eye

The internal structure of the eye is mainly composed of three layers:

- the sclera – outermost layer
- the choroid – middle layer
- the retina – inner layer.

It is also composed of other parts as shown in Fig 12.12 below.

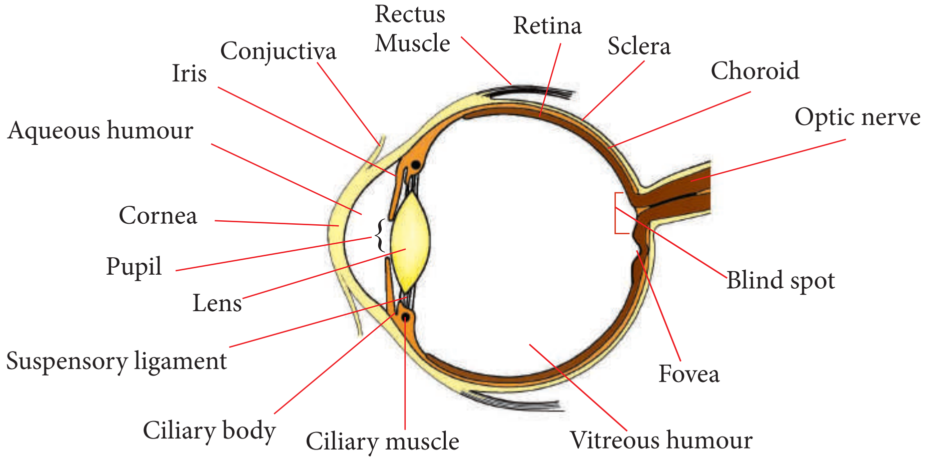


Fig 12.12: Internal parts of the eye

Parts of the eye and how they are adapted to their functions

The sclera

The sclera is the outermost layer of the eye. It is very tough and fibrous. It is white in colour. It protects the eyeball and maintains a spherical shape towards the front of the eye. It forms the transparent part known as the **cornea**.

Cornea

The cornea is the transparent front part of the sclera. It curves outwards. It allows light into the eye. It also bends or refracts the light towards the retina.

Conjunctiva

The conjunctiva is a thin transparent layer of tissue which covers and protects part of the cornea.

The choroid layer

The choroid layer is a thin lining of tissue on the inner side of the sclera. It contains numerous blood vessels which supply the retina and the rest of the eye with oxygen and food nutrients. These blood vessels also remove carbon dioxide and other metabolic wastes. The choroid layer has pigmented cells that contain melanin. Melanin gives the layer a dark colour that enables it to absorb stray light rays and prevents reflection of light in the eye.

Ciliary body

The ciliary body is found at the junction of the sclera and cornea. It contains blood vessels and ciliary muscles. It produces aqueous humour.

Ciliary muscles

These are a ring of muscles which on contraction and relaxation change the thickness of the lens. This enables the eye to focus light onto the **fovea**.

We will learn more about their functions in a process known as accommodation.

Suspensory Ligaments

These attach the ciliary body to the lens and hold the lens in place. They also have a role in altering the thickness of the lens during focusing.

Lens

The lens is circular in shape, transparent, elastic and biconvex. It refracts (bends) light onto the retina. Its thickness is usually adjusted during focusing. It also separates the eye into two chambers: the anterior and posterior chambers. It therefore separates the fluids in this chamber into an aqueous and the vitreous humour.

The vitreous humour

The vitreous humour is a clear semi-solid substance which fills the posterior chamber of the eye. It exerts pressure outwards which helps support and maintain the shape of the eyeball. It also bends or refracts light onto the retina.

Aqueous humour

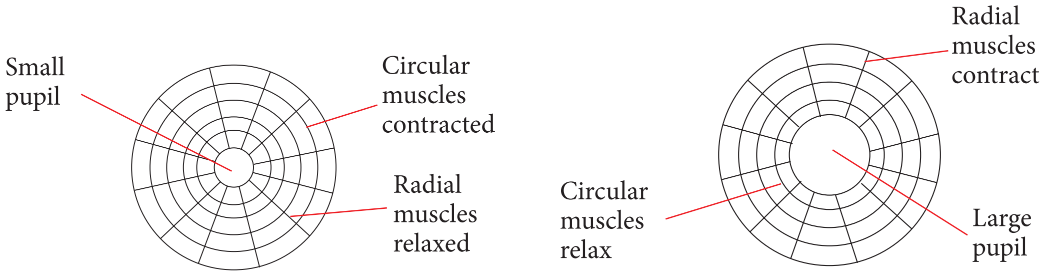
The aqueous humour is a clear watery solution found in the interior chamber. It is secreted by the ciliary body. It contains blood vessels that supply the cornea and the lens with oxygen and nutrients. The blood vessels also remove wastes.

The outward pressure exerted by this aqueous humour keeps the eye round in shape. It also bends the light slightly towards the lens.

Iris

The iris is circular in shape. It is a sheet of circular and radial muscles. It contains the pigment which gives the eye its colour.

Its function is to control the amount of light which enters the eye. It does this by allowing the pupil to open wide in dim light and to reduce in size in bright light. The radial and circular muscles are antagonistic muscles. This means that they do not contract at the same time. When the circular muscles are contracted, the radial muscles are relaxed and vice versa.



(a) Small pupil (b) Large pupil

Fig 12.13: Diagrams showing the contraction and relaxation of radial muscles to determine the size of the pupil due to amount of light

In bright light, the circular muscles in the iris contract. The radial muscles relax and the pupil becomes smaller. This controls excess light from entering the eye and damaging the retina.

In dim light, the circular muscles in the iris relax and the radial muscles contract. The pupil becomes bigger and more light rays enter the eye.

Pupil

The pupil is an opening or hole in the iris. It allows light to enter into the eye. The size of the pupil is controlled by the iris.

Retina

The retina is the innermost layer of the eye. It is made up of light sensitive cells and sensory neurones. The sensory neurones join to form the optic nerve. The light sensitive cells are called **photoreceptor cells.** They are of two types, the rods and cones.

Differences between cone and rod cells in terms of function and distribution

CONES	RODS
Outer segment is cone shaped.	Outer segment is rod shaped
Much more concentrated in and around fovea	Occur in greater number is the retina
Contain the visual pigment iodopsin which occurs in 3 forms	Contain the visual pigmentrhodopsin which has single form
Sensitive to high intensity of light used for day vision.	Sensitive to low intensity of light, used for night vision
Cones are sensitive to colours.	Rods are not sensitive to colours.

Gives good visual acuity because each cone has its own neurone connected to the brain	Gives poor visual acuity because many rods share a single neurone connected to the brain.

The rods have a pigment called **rhodopsin** which is sensitive to light of low intensity. The cones have a pigment called **iodopsin** which is sensitive to light of high intensity. The sensory neurones transmit impulses formed in the photoreceptors to the brain via the optic nerve. The impulses are interpreted on reaching the brain.

Health check!

Eating foods rich in vitamin A is important especially in the formation of rhodopsin which assists in proper vision. Deficiency of vitamin A causes inability to see clearly in the dark (night blindness).

The fovea

It is also called the **yellow spot.** This part of the retina contains cones only. Most light rays refracted in the eye fall on the fovea. It is also the only part of the retina sensitive to colour. An image falling here is interpreted as very clear in the brain. We shift our eyes when observing objects so that their images can fall on the fovea for them to be clear.

The optic nerve

The optic nerve is made up of numerous nerve fibres carrying impulses from the retina to the brain.

The blind spot

It is the point where the optic nerve leaves the eye. It is not sensitive to light. This is because there are no photoreceptor cells, rods or cones located here. Any image falling here is not seen. This is because it does not cause formation of an impulse.

Activity 12.8: To determine the distance of the blind spot

Procedure

1. With your eyes on Fig 12.14 with a cross and a dot below, hold this book at arms length.

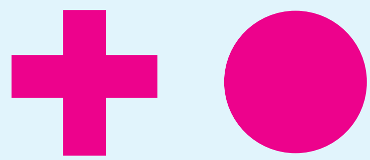


Fig 12.14: Cross and dot for investigating distance of blind spot

You may also trace this figure on a sheet of paper. Make sure you retain the distance between the cross and the dot at approximately 10 cm apart.

2. Close your left eye.
3. Stare (keep looking) at the cross with your right eye.
   - You will still see the black circle.
   - 4. Bring the book slowly towards you.
   - You will notice that there is a point where the circle becomes invisible or disappears.

5. Stop the movement of the book and ask your partner to measure and record the distance of the book to the eyes at this point. Ask your partner to perform the same activity.

Study questions

1. At what distance from your eyes does the circle disappear?
2. Why do you think the circle disappears?

Defects of the mammalian eye and their corrections

Defects of the mammalian eye are structural deviations of the eye which alter the focusing mechanism of the eye.

The common main eye defects are short-sightedness and long-sightedness.

1. Short-sightedness (Myopia)

A short-sighted person cannot focus distant objects properly. This individual can only focus near objects properly. This is because the light rays of a distant object converge at a point in front of the retina. This may be due to the eyeball being too long. As a result, distant objects appear blurred meaning not clear. This defect is corrected by using spectacles with *concave lens*. Concave lenses *diverge* the light rays before they reach the eye. (Fig 12.14)

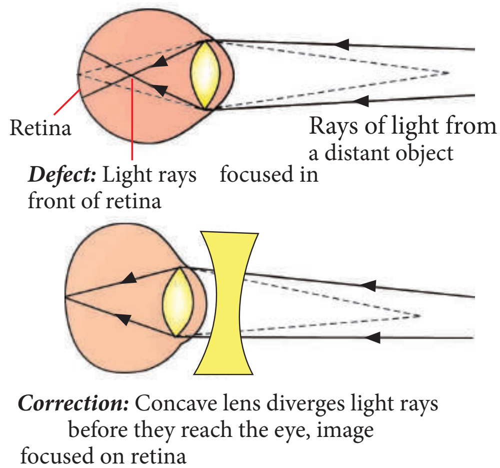


Fig 12.15: (a) Defect of short-sightedness and its correction

2. Long-sightedness (Hypermetropia)

A long-sighted person cannot focus near objects properly. This individual can only focus on objects at a distance properly. This is because the light rays of a near object converge at a point behind the retina. This may be due to the eye ball being too short. As a result, near objects appear blurred meaning not clear. This defect is corrected by using spectacles with *convex lenses*. Convex lenses *converge* the light rays before they reach the eye. (Fig. 12.15)

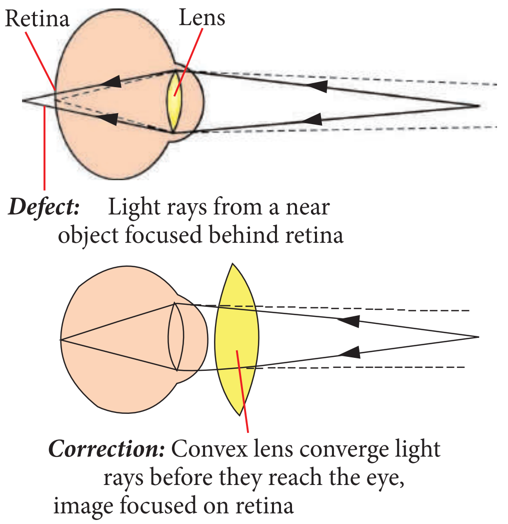


Fig 12.15: (b) Defect of long-sightedness and its correction

3. Astigmatism

This is the condition in which the cornea or the lens is uneven such that the images are not focused properly on the retina. This is caused by unequal curvature of the cornea or lens which produces unequal refraction of light rays entering the eye. This defect can be corrected by using spectacles with special cylindrical lens.

4. Squintedness

This is the condition in which the extrinsic muscles of the eyeballs that control the turning of the eye, do not co-ordinate well upon stimulation. The defect affects the paired rectus muscles which turn the eye up and down and the oblique muscles which move the eye ball left and right. In this condition, the eyeballs faces different directions. Squintedness is corrected through surgery at an early age.

5. Presbyopia

This is the condition in which the image from a near object is focused behind retina. This defect is caused by loss of flexibility or elasticity of the lens and also when the ciliary muscles weaken. This defect can be corrected using spectacles with bifocal lens.

6. Colour blindness

This is a genetic disorder in which certain colours cannot be distinguished by an individual. A common example is red-green colour blindness in which the individual is not in a position to distinguish between red and green colours. This can be corrected by wearing contact lenses for colour and also through surgery.

7. Glaucoma

This defect is common in old people. Glaucoma is caused by pressure in the eye. The individual suffers from blockage in the eye where aqueous humour builds up and distorts the shape leading to blurred images. Glaucoma can be treated with eye drops, pills, laser surgery, traditional surgery or a combination of these methods.

(b) The ear

The ear is a sense organ involved in hearing. It is found in almost all vertebrates. They are usually found in a pair, one on each side of the head. It is involved in hearing and maintaining of body balance and posture.

This is possible because they have sensory receptor cells. Some of these cells are sensitive to sound vibrations and other cells are sensitive to movement and position of the head.

The ear is usually divided into three chambers surrounded by a bone. These are the **outer ear**, **middle ear** and **inner ear**. These chambers are composed of different parts, each suited to a specific function.

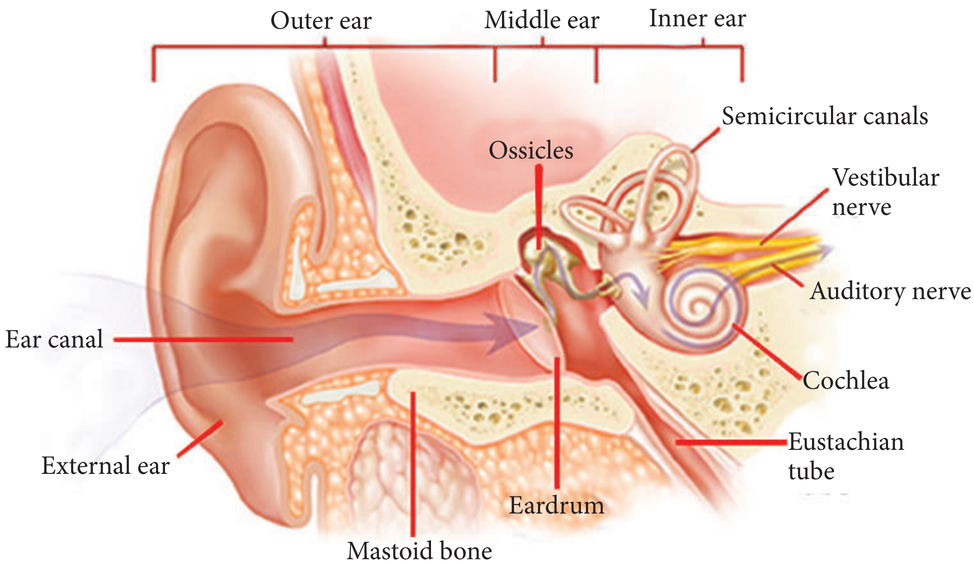


Fig 12.16: The human ear

Structure and functions of parts of the mammalian ear (human)

- Outer ear - is composed of the pinna, the external auditory meatus and the eardrum.
- The middle ear - is composed of the Eustachian tube, hammer, anvil and stirrup, oval window and round window.
- The inner ear - is composed of the cochlea, semi-circular canal and auditory nerve.

The outer ear

The outer ear is made up of the earlobe which is also known as the **pinna,** an ear tube called the external **auditory meatus** and the eardrum also called the **tympanic membrane**.

The pinna is made up of skin and cartilage. It is usually funnel shaped. This allows it to receive or collect sound waves and direct them into the ear tube.

The ear tube is a passage between the pinna and the eardrum. It is lined by cells that secrete wax. This wax keeps the eardrum soft. The wax also traps dust. The eardrum is a thin flexible sheet-like membrane. It passes sound vibrations from the outer ear to the **ossicles** in the middle ear.

The middle ear

The middle ear is separated from the outer ear by the eardrum and from the inner ear by the oval window (*Fenestra ovalis*) and round window (Fenestra *rotunda).* It is an air filled chamber. Three tiny bones, the ossicles, are suspended by muscles into this chamber. The chamber also opens into the throat or pharynx through the eustachian tube. The ear ossicles are in contact with the eardrum at one end and the oval window at the other end. They are also in contact with each other. They are named according to their shapes. They are arranged in the following order from the eardrum to the oval window: **hammer** (malleus), **anvil** (incus) and **stirrup** (stapes).

The function of these bones is to receive vibrations from the eardrum. They then amplify (strengthen) the vibrations and pass them to the oval window.

The Eustachian tube that connects the middle ear to the pharynx ensures equal air pressure on both sides of the tympanic membrane i.e. in the middle ear and the external air pressure.

Infections in the throat such as sore throat can pass through the Eustachian tube and cause infections in the middle ear. The oval window and the round window are both thin flexible membranes. They are involved in transmission of vibrations to the cochlea in the inner ear.

The inner ear

The inner ear is made up of the vestibular apparatus and the cochlea. The **vestibular apparatus** consists **of semi-circular** canals, the **utricule** (**utriculus**) and the **saccule (sacculus).**

The semi-circular canals, the utricule and saccule have spaces filled with fluid. There are three semi-circular canals placed at right angles to each other as shown in Fig 12.16.

The semi-circular canals open into the utricle which in turn opens into the saccule. The saccule in turn opens into the cochlea. The semi-circular canals are enlarged at one end to form the **ampulla.**

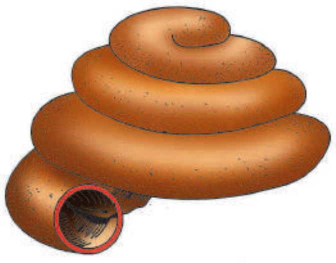


Fig 12.17: Cochlea

The cochlea is a coiled tube, spiral in shape. It is filled with a fluid which is continuous with that found in the vestibular apparatus. The fluid is known as **endolymph**. The cochlea is involved in hearing. The vestibular apparatus are involved in maintaining balance and posture.

Transmission of sound wave

Activity 12.9: To determine production, sources and effects of sound

Requirements

- Metallic string / rod
- Metre rule
- Whistle/ flute
- Glass beaker
- Drum

Procedure

A

(i) Pluck a stretched metallic string or rubber band.

(ii) Fix a half-metre rule on the side of a table and press the free end downwards slightly and release.

(iii) Blow a whistle.

(iv) Hit a metallic rod against another.

(v) Gently hit a drum.

B.

(i) Stand about 100 m away from a wall.

(ii) Clap your hands.

(iii) Note the sound produced through reflection.

Study questions

What is the state of motion of the sources of sound in these experiments?

The facts

We have learnt that the part of the ear involved in hearing is the cochlea.

- How does the sound that you hear reach the cochlea?
- How are you able to tell the sound of a dog from the sound of a cat?

Vibrations of sound cause the sensation of hearing. These vibrations pass through air in the form of sound waves. On reaching the ear, the sound waves are directed by the pinna into the ear tube and then the eardrum. On reaching the eardrum, eardrum causes sound waves to vibrate. The vibration of the eardrum causes the ear ossicles, malleus in contact with it to vibrate. The malleus in turn causes the incus to vibrate which in turn causes the stapes to vibrate. As these vibrations pass through the ossicles, they are amplified. The last ossicle (the stape) causes the oval window to vibrate. These vibrations are then transmitted to the round window. The vibrating oval window causes the fluid inside the cochlea to vibrate accordingly.

The sensory cells in the cochlea are stimulated by the vibrations reaching them. They start nerve impulses which are transmitted to the brain via the auditory nerve. On reaching the brain, the impulses are interpreted into sound. We are then able to learn the sound as it came from the source.

- Why does a tape recording of your voice sound so different from your voice as you hear it when you speak?

The tape recording only picks up sound vibrations from your mouth to the tape. When you talk, sound vibrations reach your inner ear through the air as well as through your bones and tissue from the inside. This makes the two voices sound different. Your voice as you know it does not sound the same as other people hear it.

Fig 12.18: How we hear our voice is different from the way others perceive it.

Maintenance of balance and posture

As we learnt earlier, balance and posture of the body is the function of the vestibular apparatus. When walking, you may suddenly trip and fall. You fall because you lose your balance. Sometimes, you respond to prevent yourself from falling by quickly holding onto something or someone for support.

Balance refers to a condition whereby your body is in a physical stability in relation to gravity. The part of the body that helps your body to maintain balance is the **semi-circular canal.** The utricle and the saccule may also be involved.

Posture is the position of the body in space. There are different body postures that your body can take, for example, bending, standing and lying. The part of the ear that is sensitive to the position of your body in space are the **utriculus** and **sacculus**.

(c) The tongue

The tongue is a muscular organ in the mouth. The tongue is covered with moist, pink tissue called **mucosa**. Tiny bumps called **papillae** give the tongue its rough texture. Thousands of taste buds cover the surfaces of the papillae. Taste buds are collections of nerve-like cells that connect to nerves running into the brain.

The tongue is anchored to the mouth by webs of tough tissue and mucosa. The tether holding down the front of the tongue is called the **frenum**. In the back of the mouth, the tongue is anchored into the hyoid bone. The tongue is vital for chewing and swallowing food, as well as for speech.

Activity 12.10: To determine the taste map of the tongue

Requirements

- Sugar
- Salt
- Lemon
- Oranges
- Glucose
- Coffee
- Sour milk
- Icing sugar
- Clean drinking water

Procedure

1. Clean your hands thoroughly.
2. Taste each of the substances provided. Rinse your mouth after each tasting.
3. Note the part of the tongue involved in tasting each substance.
4. Record your findings in a table like the one shown below.

Table 12.2: Results of taste map of the tongue

Sweet	Sour	Bitter	Salty

The four common tastes are sweet, sour, bitter and salty. The tongue has many nerves that help detect and transmit taste signals to the brain. Because of this, all parts of the tongue can detect these four common tastes as illustrated in Fig. 12.17.

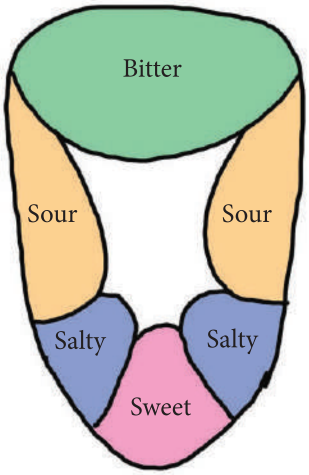


Fig 12.19: The different taste buds of the tongue

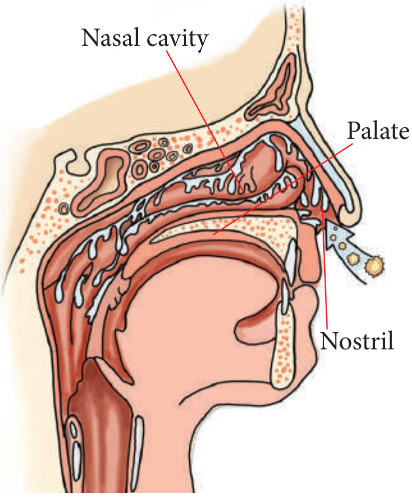


Fig 12.20: Diagram showing the nasal passageways

(d) The nose

The nose is mainly concerned with filtering and providing a passage for air on its way to the lungs. The walls of the nasal cavity enable both these functions. In particular, the nasal passageways are filled with mucosal respiratory membranes coated in cilia-tiny hair-like cells that act to move waves of mucus toward the throat. These trap inhaled bacteria, dirt, viruses and chemical particles in the mucus. The cilia and swallowing action then serve to sweep the allergens and infectious agents into the back of and down the throat for destruction (digestion) in the stomach.

A limited portion of the nose and nasal cavity is for the sense of smell, through its olfactory organs. These olfactory sense organs are located beneath the bridge of the nose atop the nasal cavity. These organs (olfactory membranes), are to be found in two clefts there and can be identified as a small grey or yellow patch of tissue.

We smell something when airflow passes through the nose during normal breathing. This allows a limited fraction of the inhaled air to reach the olfactory clefts. This is sufficient to trigger an olfactory response. When a person sniffs at an odour, it quickly draws air into the nose. The increased speed alters the direction of airflow, drawing more of the scent towards the sensors of the olfactory clefts.

(e) The skin

Our sense of touch allows us to receive information about our internal and external environments, making it important for sensory perception. The skin is the largest organ in the human body and has receptors that sense touch.

Touch receptors in the skin are nerve cells that inform the brain about touch sensations. There are 2 main types:

- ***Thermoreceptors***: These tell you about temperature.

- ***Mechanoreceptors***: These tell your body about pushing or pulling forces and body movement and are responsible for translating these physical forces into nerve impulses.

Self–evaluation Test 12.4

1. It is a muscle in the mouth covered with pink mucosa and tiny buds. It helps in chewing food and sending it down the throat. What is it?
   A. Papillae
   B. Tongue
   C. Mucosa
   D. Sinuses
2. The cells in the sense organ that receive sensory information are called __________.
   A. receptor cells
   B. stimulus
   C. acceptor cells
   D. olfactory
3. Which of the following is the most correct order of sound transmission?
   A. tympanum > ossicles > basilar membrane > scala vestibuli
   B. ossicles > tympanum > basilar membrane > scala vestibuli
   C. tympanum > ossicles > scala vestibuli > basilar membrane
   D. scala vestibuli > ossicles > tympanum > basilar membrane
4. The __________ is a membrane covering the anterior portion of the eyeball except for the cornea.
5. If you are walking slowly and then speed up, the acceleration will be sensed by the ________________ of the inner ear.
6. (a) Bright light can damage the eyes. Explain.
   (b) Mention conditions that affect the eyes.

12.6. Hormonal control in coordination

Activity 12.11: Research Activity

Using textbooks and computers with Internet connection, research on the hormonal control during coordination. Write a report then present your findings to the class.

Comparison between endocrine and exocrine glands

There are other type of glands in the body. These glands are called exocrine glands or duct glands because they have special tube or duct that transport the secretions from the gland where they are made to where they are needed or rejected outside by an organism. The following are examples of exocrine glands and their secretions:

EXOCRINE GLANDS	SECRETION PRODUCTS
Sweat glands	sweat
Sebaceous glands	Sebum
Salivary glands	saliva
Lacrimal glands	tears
Gastric glands	Gastric juice
Intestinal glands	Intestinal juice
Mammary glands	Breast milk

Many exocrine glans produce enzymes which are the biological catalyst that controls the rate of chemical reaction in the body.

Similarities:

- Both are glands.
- Both produce useful substances
- Both are found in human body
- Both are mad up by group of cells

The following are main differences between endocrine and exocrine glands:

ENDOCRINE GLANDS	EXOCRINE GLANDS
They are ductless	They have ducts
They secrets hormones	They secrete other useful substances like enzymes
The pituitary gland is a master glands means it controls the activities of other ductless glands	There is no exocrine gland that controls other exocrine glands
They secrete hormones directly into blood	They secrete other useful substances like enzymes into ducts which leads to lumen or on the surface

The endocrine system produces 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 12.21 below shows various endocrine glands.

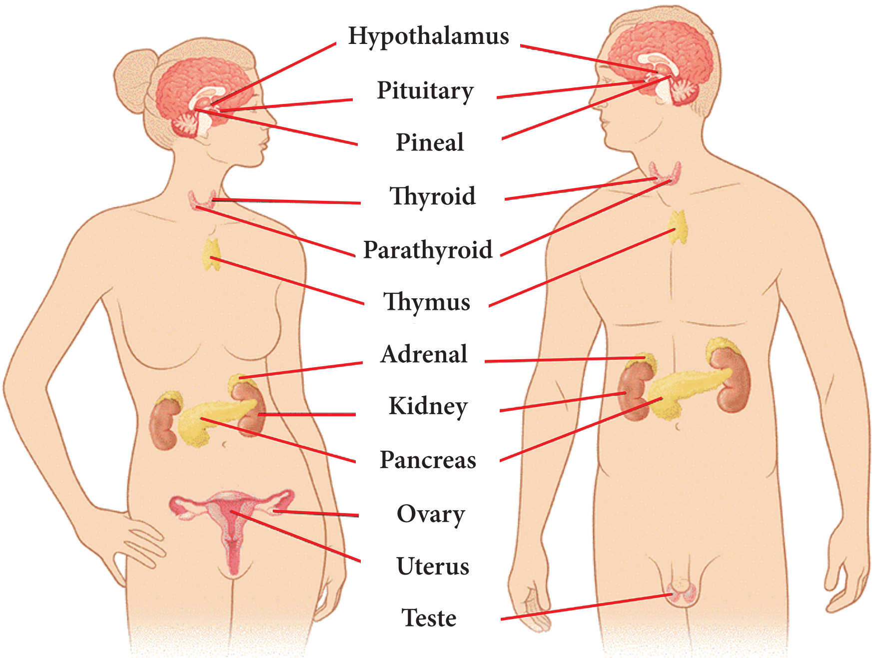


Fig 12.21: Position of endocrine glands in the human body

The endocrine glands produce hormones which are released into the blood circulatory system. As the blood circulates in the body, the hormones stimulate 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. In this section, we will discuss two hormones involved in coordination. These are **thyroxine** and **adrenaline**.

Thyroxine

Thyroxine hormone is produced by the thyroid glands found at 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 i.e. 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 occurs when the thyroid gland produces less thyroxine than the amounts required for normal metabolism, growth and development. Under-secretion of thyroxine leads to the following conditions:

- 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.
- 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. Hair is also lost from the head. The thyroid gland swells to form the colloid goitre. This condition can be rectified by swallowing thyroxine tablets.

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 **exophthalmic goitre.** Over-secretion of thyroxine leads to increased metabolic rate in the body which results to the following:

- High body temperatures.
- Increased breathing rate and heartbeat.
- 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.

Health check!

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 under-activity 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.**

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 increasing blood supply to them.
- Increased rate of breathing to supply oxygen required for more energy production.
- Increased rate of muscle contraction to enable rapid movements.

These responses make the body ready to respond to emergency or threatening situations.

Underproduction of adrenaline causes

- Reduced activity
- Fatigue
- Stress and slow response to danger

Table 12.3: Table showing the hormones produced by the endocrine system and their effects

Glands	Hormone produced	Effects or functions
Anterior pituitary gland	Thyroid stimulating hormone (TSH)	It stimulates the thyroid gland to produce the thyroxine hormones.
	Follicle stimulating hormone (FSH)	It stimulates egg development in the female and sperm development in the male. Stimulates the ovaries to produce oestrogen. Stimulates release of progesterone by the ovary. Stimulates testosterone secretion in testes.
	Luteinizing hormone (LH)	It causes ovulation in the females. It causes conversion of the Graafian follicle into corpus luteum in ovaries. It stimulates testosterone secretion in the testes.

	Growth hormone (GH)	It stimulates growth especially in bones. Excess in children results into gigantism and under-secretion in children results into stunted growth (dwarfism).
	Adrenocorticotropic hormone (ACTH)	It causes the adrenal cortex to secrete its hormones. Stimulates lipid breakdown to release fatty acids from fat cells.
Posterior pituitary gland Note: Pituitary gland is the master gland	Anti-diuretic hormone(A.D.H) vasopressin	It causes reabsorption of water in the kidney nephrons i.e. osmoregulation. Under-secretion results in diabetes insipidus.
	Oxytocin	It brings about parturition (contraction of the uterus during birth). Stimulates milk flow from the mammary glands.

Thyroid gland (neck region)	Thyroid hormones: Triiodothyronine (T3) and Thyroxine (T4)	Controls metabolic activity, raises body metabolic rate (BMR) Excess results into an increased metabolic rate which leads to protrusion of eye balls. Under-secretion leads to goitre.
Parathyroid glands	Parathyroid hormone	It increases iron & calcium absorption.
Stomach	Gastrin	Stimulates secretion of gastric juice
Duodenum	Secretin	Controls secretion of bile and pancreatic juices
Pancreas (Islets of Langerhans)	Insulin	It controls the balance of sugar in blood by converting glucose to glycogen in case there is an excess. Under-secretion results into diabetes mellitus.
	Glucagon	It converts glycogen into glucose.
Adrenal gland	Adrenaline	For flight and fight actions, by increasing heart rate and metabolic rate.

Ovary (lower abdomen)	Oestrogen hormone	It brings about healing and repair of the uterus wall after menstruation. It brings about development of female reproductive organs. It brings about development of secondary sexual characteristics. Deficiency causes delay in the development of secondary sexual characteristics.
	Progesterone	It promotes proliferation of uterus wall. Controls the menstrual cycle. It maintains pregnancy.
Testis (produced in scrotum)	Testosterone (male sex hormone)	Development of male sexual characteristics. Deficiency causes delay in the development of secondary characters.

Functional differences and similarities between the endocrine and nervous systems

Activity 12.12: Discussion Activity

1. Discuss the differences and similarities between the endocrine and nervous systems.
2. Compare your findings.

As we had said earlier, both the nervous and the endocrine systems are involved in linking coordination. Since the two systems are involved in coordination, 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.

However, the two systems have several differences related to how they function.

These differences are summarised in the Table 12.4 below.

Table 12.4: Functional differences between the endocrine and the nervous systems

Glands 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 short periods of 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.

Application of hormones in food production

Activity 12.13: Research activity

Use textbooks and journals to.

1. Carry out a research on the use of hormones in food production.
2. Discuss the use of bovine somatotropin (BST or bST) to increase milk production.
3. Present your findings in class.

The facts

Hormones are naturally present in human beings and animals for growth, development and reproduction. But many animals raised for meat and dairy production are being given additional hormones, natural and synthetic, to speed up the growth process and increase milk production.

A number of **steroid hormones** are used in beef cattle and sheep, including natural oestrogen, progesterone, testosterone and their synthetic versions. These drugs increase the animals' growth rate and the efficiency by which they convert the feed they eat into meat. These hormones are used based on studies that the food from the treated animals is safe for people to eat and that the drugs do not harm the treated animal or the environment. The drugs also have to be effective, meaning that they work as intended.

Some hormones are considered safe, such as recombinant bovine growth hormone (rBGH) which is used in meat and dairy production. However, there are significant concerns that residues of hormones found in meat and dairy products may interfere with human hormone balance and have a negative effect on human health, causing cancer, developmental and reproductive issues at the early onset of puberty in girls.

Dairy cows are often injected with recombinant bovine growth hormone (rBGH), also known as recombinant bovine somatotropin (rBST), to increase milk production. The hormone is believed to be present in milk in small quantity and it is broken down by the digestive tract. However, this hormone also raises levels of Insulin Growth Factor-1 in cows, which is linked to tumour growth in human beings. Cows that have been treated with rBGH are more susceptible to mastitis, an udder infection, due to increased milk production. The infection must be treated with antibiotics, contributing to the real and growing problem of antibiotic resistance.

Hormones present in cow manure also lead to environmental issues as they easily enter water sources, negatively affecting aquatic ecosystems.

Self–evaluation Test 12.5

1. How is the circulatory system involved in the functions of the endocrine system?
2. Why is the ingestion of dietary iodine so important for thyroid function?
3. What is the importance of blood glucose levels for human health?

Unit summary

- The nervous system of a mammal has two components: CNS (brain and spinal cord) and peripheral nervous system (nerves that connect the whole body to the CNS.)
- The brain is covered by meninges: the outer dura, the inner pia with a space between them known as arachnoid filled with cerebrospinal fluid.
- Spinal cord is involved in simple reflex actions or automatic responses.
- A neuron is a nerve cell that has the following parts: axons, dendrons, cell body and myelin sheath.
- There are three types of neurons: sensory, motor and intermediate.
- Parts of the brain include cerebrum, cerebellum, medulla oblongata, hypothalamus, thalamus, pons and pituitary gland.

- Reflex action is the path of impulse from receptors to effectors through the CNS. It is a rapid and automatic response to a stimulus.
- Simple reflex action uses a stimulus to produce the expected response.
- Conditioned reflex action involves use of another stimulus to produce a response that was being produced by the original stimulus.
- The sense organs are for sight, hearing, touch, smell and taste.
- Hormones are chemical substances produced in one part of the body and bring responses in another part. They are produced by endocrine glands.
- Both endocrine and nervous systems are involved in coordination.
- Hormones are also used to increase food production in animals and plants.

End Unit Assessment 12

1. The body's largest organ is the ________.
   A. brain
   B. skin
   C. large intestines
   D. heart
2. Which of the following glands are present in the eyes?
   A. Pituitary glands
   B. Lacrimal glands
   C. Thyroid glands
   D. Mucus glands
3. Which of the following is a function of the myelin sheath?
   A. Increases the speed at which nerve impulses travel along an axon
   B. Receives information from other neurons or from sense organs
   C. Releases neurotransmitters that can cross over to neighboring neurons
   D. All of the above
4. The nervous system is divided into the _______ and the _______; the former consists of _______; the latter_______.
   A. ANS; PNS; the nerves around the body; the ventricles
   B. CNS; PNS; the nerves around the body; the ventricles
   C. ANS; CNS; the nerves around the body; the brain and spinal cord
   D. CNS; PNS; the brain and spinal cord; the nerves around the body
5. Which of these is not a reflex action?
   A. Salivation
   B. Secretion of sweat
   C. Flexion due to needle prick
   D. Blinking of eye due to strong light
6. A change in the environmental that generates a response is called __________.
   A. touch
   B. olfactory
   C. stimulus

D. receptor

7. Both eyes seeing the same object is called __________.
   A. long sightedness
   B. short sightedness
   C. binocular vision
   D. colour vision

8. Middle ear infection may follow a throat infection because ________
   A. auditory (Eustachian) tube opens into the base of the inner ear.
   B. the pharyngeal (throat) mucosa is continuous with the mucosa of the middle ear.
   C. the sphenoid sinus opens into the tympanic cavity of the middle ear.
   D. the vestibule cochlea nerve passes through the tympanic cavity.

9. The function of the lens is to bend or refract light rays and focus them on the optic disc. True or false?

10. Give the main differences between response in green plants and response in multicellular animals.

11. (a) Why do diabetic patients often undergo dietary sugar restriction?
    (b) Differenciate between type I and type II diabetes.
    (c) What evidence is there to prove that environmental contaminants are causing endocrine disruption in human beings and/or wildlife?
    (d) What are the dangers associated with the usage of hormones in animal breeding?

12. Alongside is a diagram of the human body.
    On it indicate the location of the following.
    (a) The master gland
    (b) Gland that produces sex hormones in females
    (c) Mixed gland
    (d) Gland associated with goitre
    (e) Gland that produces hormones
    for fight and flight

13. The pituitary gland is sometimes called the master gland. Why?

14. A girl is sreaching for a book on a bookshelf. She pricks her finger on the sharp point of a nail. She pulls her hand away very quickly.
    (i) State the type of response which has occurred.
    (ii) What is the effector in this response?

(iii) Name the type of nerve cell which links the central nervous system to the effector.

15. Complete the following table:

Endocrine gland	Hormone Secreted	Target Organ	Function
___________	Human growth hormone	All cells	
	Antidiuretic hormone	Kidney	
Thyroid	___________	All cells	
Parathyroid	parathyroid hormone	___________, ___________	
___________	Adrenaline ('fight or flight' hormone)	Most cells	
Pancreas	Insulin	All cells	
	___________	All cells	
___________	Oestrogen	Sex organs	
	Progesterone	Sex organs	
	Testosterone	Sex organs, muscles	

Unit 13

Asexual and Sexual reproduction

Key unit competence

After studying this unit, I should be able to distinguish between sexual and asexual reproduction giving the advantages and disadvantages of each.

Learning objectives

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

- Define sexual and asexual reproduction as a process resulting in the production of genetically identical offspring from one parent.
- Describe fertilisation as the fusion of gamete nuclei.
- Describe the advantages and disadvantages of sexual and asexual reproduction to a population of species in the wild and to crop production.
- Define sexual reproduction as a process involving the fusion of the nuclei of two gametes (sex cells) to form a zygote and the production of offspring that are genetically different from each other.
- State that the nuclei of gametes are haploid and the nucleus of a zygote is diploid.

Introductory Activity

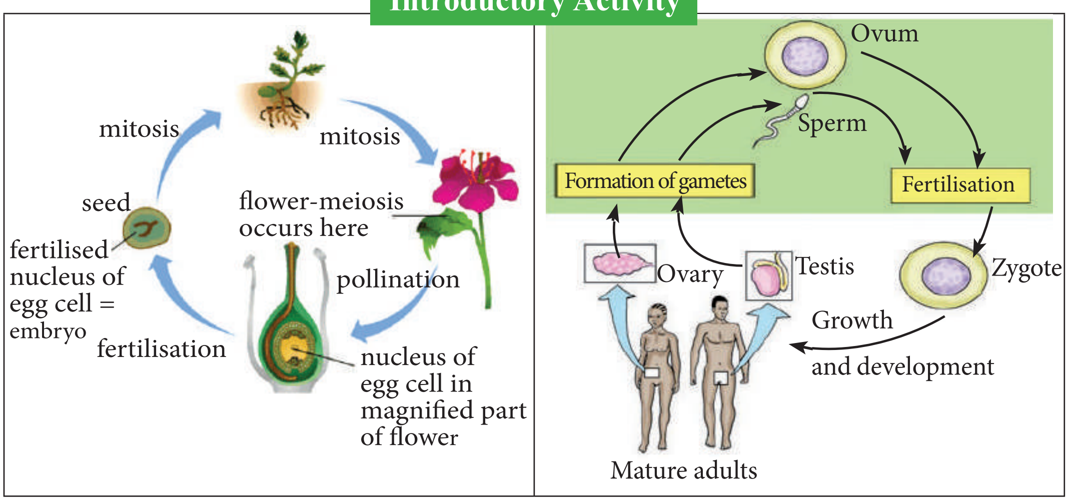


Fig 13.1: Types of reproduction

List some differences in the two diagrams. Of the two diagrams, which one do you think depicts sexual reproduction? How about asexual reproduction? Based on your responses above, what do you think this unit is about?

Introduction

Every organism on the planet seeks to continue its existence through reproduction. This is one of the characteristics of living things. Each organism has its own unique way of propagating itself to survive extinction.

The process of reproduction involves the passage of genetic materials to a new generation.

In this unit, you will learn about the different ways organisms reproduce. The two main modes of reproduction are: **sexual** and **asexual** reproduction. Asexual reproduction involves one individual parent and takes place when offspring are formed from a single organism. Sexual reproduction on the other hand involves interaction of gametes produced by two sexually mature male and female organisms.

13.1. Asexual reproduction

Asexual reproduction in microorganisms

Activity 13.1: To observe forms of asexual reproduction in microorganisms

Requirements

- Charts and diagrams
- Computer animations

Procedure

1. By observing the computer animations, charts or diagrams,
   - Identify the type of reproduction shown.
   - Are organisms reproducing alone or in pairs?
   - Are the offspring produced similar to the parent(s)?

The facts

Asexual reproduction is the mode of reproduction that results in formation of genetically identical offspring from the same parent. It takes place when offspring are formed from a single organism or parent without the formation of gametes.

In this type of reproduction, the offspring are duplicates of the parent. This means that they are completely identical in appearance and structural make-up to their parents.

In asexual reproduction, parts of the mature organism may develop into a new individual. One or more cells from the parent may also separate and develop into a new individual. The type of cell division that occurs in asexual reproduction is called **mitosis.** It is responsible for the formation of new cells. Asexual reproduction is important because it is responsible for reproduction in organisms like *Mucor, Amoeba*, yeast, *Rhizopus* among others. Asexual reproduction results in rapid production of genetically identical offspring.

Types of asexual reproduction

(a) Binary fission

Binary fission is a form of asexual reproduction. It occurs in single-celled organisms like *Amoeba*, bacteria and *Paramecium*. The word **'binary'** means two and **'fission'** means splitting.

(i) Binary fission in bacteria

Most bacteria rely on binary fission for propagation at a favourable time. The nucleus of the parent cell first divides followed by the cytoplasm resulting to formation of two daughter cells that are identical to the parent cell. The daughter cells increase in size and mature. They will also undergo binary fission. All these processes are controlled by the nucleus.

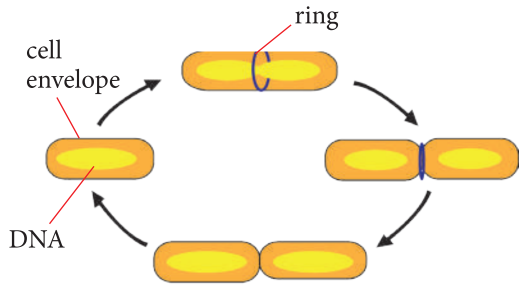


Fig 13.2: Binary fission in bacteria

One difference between fission and budding in bacteria is that, in the latter, the mother cell often has different properties from the offspring.

(ii) Binary fission in amoeba

When *Amoeba* reproduces, it divides to form two cells. Each cell becomes a separate organism capable of existing on its own. First, the nucleus inside the cell divides followed by division of the cytoplasm and the entire cellular components of the organism.

Did you know?

Two new cells are therefore formed from the original parent cell. These cells are described as daughter cells because they are produced by the mother cell.

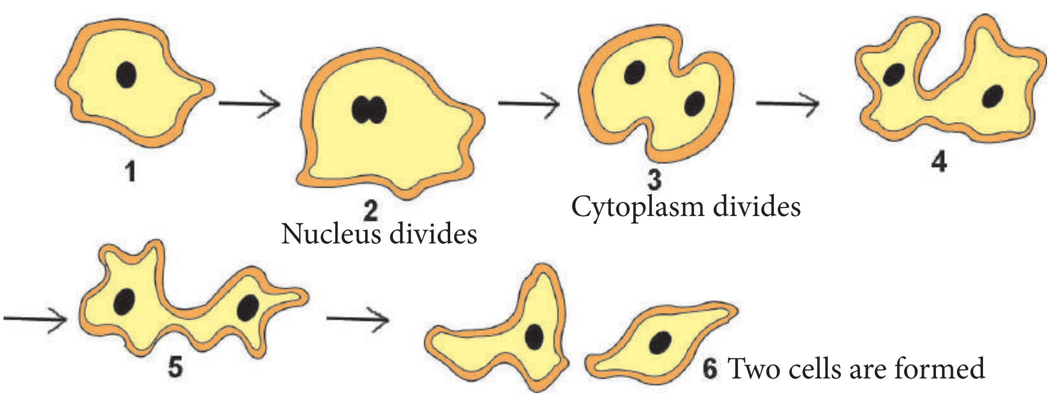


Fig 13.3: Binary fission in amoeba

(b) Budding

This mode of asexual reproduction occurs in fungi like yeast. The parent organism forms an outgrowth or protuberance called a **bud.** This bud enlarges and takes on the shape and appearance of the parent. The nucleus of the parent cell divides into a daughter nucleus and moves into the daughter cell. The daughter cell continues to grow until it eventually breaks away from the parent cell and survives as an independent cell. Once it grows and matures, it produces another organism by budding.

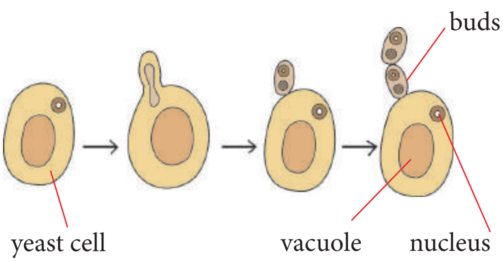


Fig 13.4: Budding in yeast

Under favourable conditions that are warm and with enough nutrients, yeast cells bud rapidly.

(c) Spore formation

Activity 13.2: To grow bread mould and examine it using a hand lens

Requirements

- 2 or 3 slices of bread
- Hand lens
- Small beakers or flat plastic lids or open petri dishes
- Water
- Small box, bell jar or beaker

Procedure

1. Dust or pat 4 to 5 slices of bread thoroughly on a dusty surface. This exposes the bread to spores in the dust.
2. Sprinkle some water onto the bread using your hands to moisten it.
3. Place the bread into a container.
   Note: If you are using open containers with no lids, use a bell jar, large beaker or a small box to cover the bread.
4. Leave it undisturbed in a warm place like a cupboard for 3 to 4 days. Remove the container from the cupboard and examine the bread using a hand lens.
5. Draw and label what you observe.
6. Put the bread back in the cupboard for another 3 days and repeat the procedure. Write down your observations.

Study questions

1. Why should the pieces of bread be dusted or patted over a dusty surface?
2. Why should they also be kept moist and put in a warm place?
3. What do you notice on the bread after some days?
4. Describe the appearance of what is seen growing on the bread.
5. How did the growth on the bread come about?
6. If you leave it to grow for a longer time, what new changes do you notice?

The facts

Spores are responsible for the process of asexual reproduction in organisms such as *Mucor, Rhizopus,* ferns and mosses. A **spore** is a unit of asexual reproduction that may be adapted for dispersal and for survival.

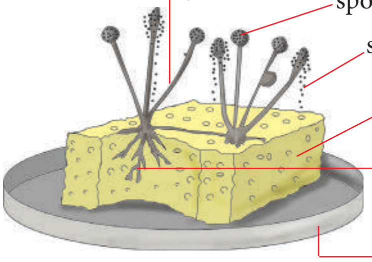


Fig 13.5: Mucor growing on a piece of bread

The aerial hyphae produce swollen reproductive structures called **sporangium** which contain unicellular cells called **spores**. The sporangium mature, burst and release spores which are carried by air currents. Fungal spores are usually small and light hence easily spread by air currents or by insects. Given favourable conditions of warmth and moisture, they can grow into new organisms.

When the spores land on a suitable substrate such as bread containing moisture and sugars, they germinate and produce new **mycelia**.

Different fungi may produce different coloured sporangium. *Penicillium* for instance produces blue-green coloured sporangium, *Mucor* produces white to cream and *Rhizopus* black or grey.

Spore formation is also called *sporulation*. Spores are able to survive even under adverse environmental conditions such as high temperatures and very dry conditions. In ferns, spores are located in structures known as **sori**.

Asexual reproduction in plants

Activity 13.3: To observe forms of asexual reproduction in plants

Requirements

Vegetative materials such as:

- Sugarcane cuttings
- Potato tubers
- Yams
- Grass rhizomes
- Banana suckers

Procedure

1. Examine each specimen provided carefully.
   - Note the parts where food substances are stored.
   - Note the parts in the structure that are involved in reproduction.
2. Draw and label each of the specimens provided.

The facts

Vegetative propagation is a form of asexual reproduction in plants, in which multicellular structures become detached from the parent plant and develop into new individuals that are genetically identical to the parent plant. It can occur naturally or be induced by man (artificially). Plants survive from one germinating season to another under unfavourable conditions such as drought or winter. They develop **perennating organs**, which stores enough nutrients to sustain them during such periods.

Common forms of perennating organs are, for example, tubers, rhizomes and buds. Perennation is closely related to vegetative reproduction as the organisms commonly use the same organs for both survival and reproduction.

Natural methods of asexual reproduction include strategies that plants have developed to self-propagate. Plants use vegetative materials which are parts of the plants other than seeds that can be used to produce new individual plants. The vegetative parts or structures have the ability to develop new shoots and roots.

Many plants, such as ginger, onion and dahlia, continue to grow from buds that are present on the surface of the stem. In some plants, such as sweet potato, adventitious roots or runners (stolons) can give rise to new plants. When these parts are detached from the plant, they grow into independent plants. Some plants may also start growing into independent plants if the leaf touches the soil. Other plants can be propagated through cuttings alone.

Examples of vegetative plant parts are:

(i) cuttings e.g. tea
(ii) suckers e.g. banana
(iii) crown e.g. pineapple.

Plant parts used for vegetative propagation

Vegetative propagation is used in the growing of many crop plants. Some of these plant parts are storage organs such as **bulbs**, **rhizomes**, **corms**, **tubers** and **suckers**.

(a) Bulb

This is a short modified underground stem with nodes bearing fleshy scale leaves surrounded by some dry scale leaves. The internodes of the stem are close to each other so that leaves overlap tightly over each other. Buds arise in the axils of the fleshy scale leaves. The food is stored in the fleshy scale leaves and not in the stem. Adventitious roots are found at the base of the stem. Examples of bulb crops are onion, garlic and tulip.

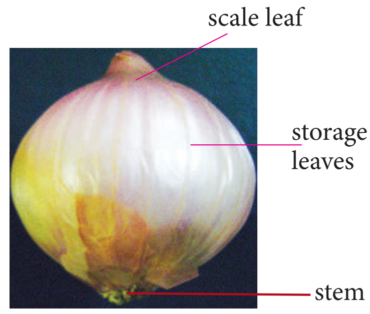


Fig 13.6: Onion bulb

(b) Stem tuber

This is a swollen tip of underground stem bearing a number of reduced scale leaves. Each scale leaf surrounds the 'eye' of the tuber. The eye is actually the bud. The buds produce aerial shoots and adventitious roots grow at the base. Examples include the Irish potato and yams.

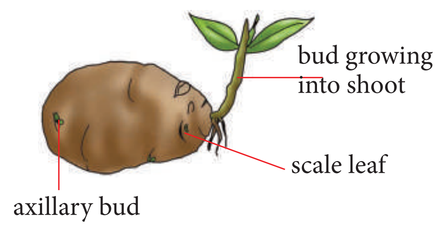


Fig 13.7: Irish potato tuber

Some tubers have swollen roots, which are called **root tubers**. Examples of root tubers are sweet potato, cassava and dahlia.

(c) Suckers

These are lateral branches of a stem with terminal buds at the tips. They grow from the base of the underground stem just beneath the soil surface. New shoots grow along the sucker with adventitious roots developing below the stem. Examples of plants produced by suckers are banana, sisal and pineapple.

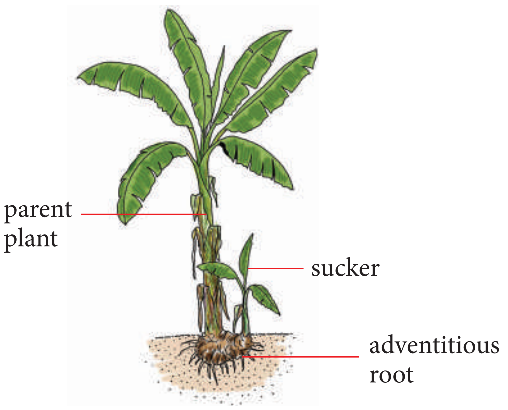


Fig 13.8: Suckers

(d) Rhizomes

These are horizontal underground stems which possess thin scale leaves and buds. In some plants, adventitious roots are present. Examples of plants with rhizomes are edible canna lily, ginger and turmeric.

Rhizomes are used to store starches and proteins and enable a plant to survive an annual unfavourable season underground. In plants such as water lily and many ferns, the rhizome is the only stem of the plant. In such cases, only the leaves and flowers are readily visible. Notably, the rhizomes of some species including ginger, turmeric and lotus are edible.

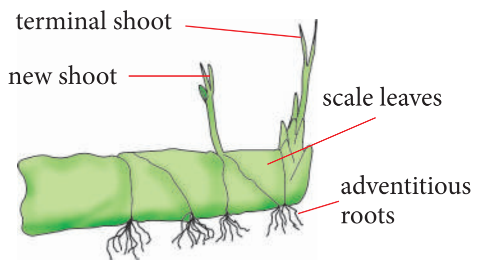


Fig 13.9: Rhizome

Artificial propagation

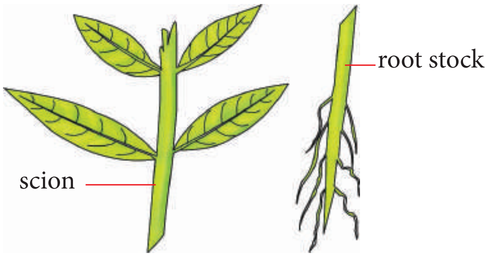
Artificial vegetative propagation does not occur naturally. These are ways in which human beings influence the production of a new plant from another so as to get a desired offspring. This type of propagation may be carried out in order to get healthier plants, desired traits and/or more rapid efficient production rate of offspring or for general experimentation. Methods of artificial propagation include: **grafting**, **cutting** and **budding**.

(a) Grafting

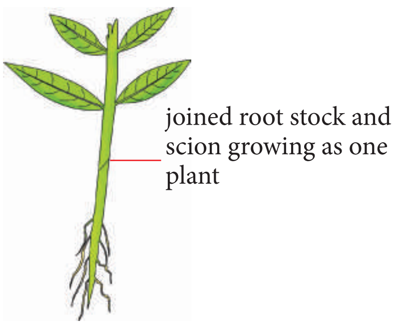
Grafting is the art of joining two parts of plants together in such a manner that they will unite and continue their growth as one plant. The part of the grafting combination, which is to become the upper portion of the new plant, is termed as **scion** and the lower portion that forms the root is called **rootstock**.

Scion is the short piece of detached shoot containing several dormant buds which forms the upper portion of the graft that grows into shoots or branches of the grafted plant. The stock (root stock) develops into root system of the grafted plant.

Grafting is commonly used in propagation of citrus fruit varieties such as: sweet orange, rough lemon, sour orange, grape fruit, trifoliate orange, citranges, among others. In grafting, good rootstocks must be carefully selected.



(a) Before grafting



(b) After uniting scion and root stock

Fig 13.10: Grafting

(b) Cuttings

Cuttings can be developed from stems or roots. Stem cuttings or sections of the stalks called setts or seed pieces propagate, for example in sugarcane cuttings. Each sett contains one or more buds. Stem cuttings can be either raised in the nursery e.g. in tea, or planted directly in the field e.g. in sugarcane. Most cuttings for perennial crops are obtained from the hard section of the plant part e.g. tea cuttings. For sugarcane setts, cuttings are usually taken from the soft upper parts of the shoot.

Stem cuttings are obtained from healthy parent plants which are high yielding, healthy and have rooting ability.

(i) *Single-leaf stem cuttings for tea propagation:* These are obtained from the middle part of stems of selected mature trees, then planted in polythene sleeves filled with rooting medium. They are then placed in a nursery. High relative humidity must be maintained for their rapid growth and development.

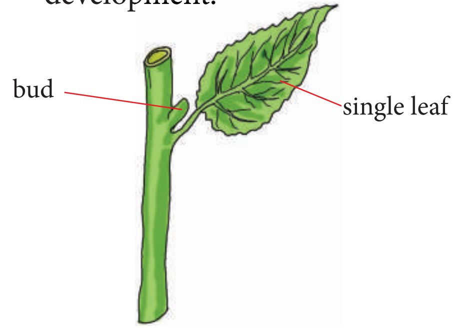


Fig 13.11: Single leaf stem cutting of tea

(ii) *Setts for sugarcane propagation:* Sizeable cuttings are planted directly in the seedbed. Setts with three nodes are prepared and subjected to heat treatment or treated with an organo-mercurial fungicide against ratoon stunting disease. Each sett usually measures 30 - 45 cm long.

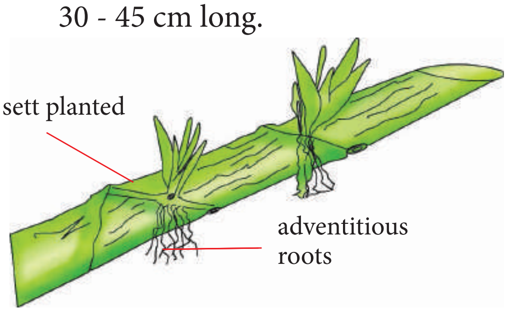


Fig 13.12: Stem cutting of sugar cane

Self–evaluation Test 13.1

1. Distinguish between sexual and asexual reproduction.
2. Name the vegetative part used for the propagation of the following crops:
   (i) Sweet potatoes
   (ii) Sisal
   (iii) Pineapples
   (iv) Banana
   (v) Cocoyam
   (vi) Cassava
3. In binary fission how does the DNA of the daughter cells compare to the DNA of the parent cell?
   A) It has some similarities and some differences.
   B) It is only half of the amount of DNA found in the parent.
   C) It is identical.
   D) It is a mix of the parents' DNA.
4. How can asexually reproducing organisms gain some genetic diversity?
   A) Meiosis
   B) Mitosis
   C) Crossing over
   D) Mutations
5. What are the benefits of artificial propagation to man?

13.2. Advantages and disadvantages of asexual reproduction in plants

Activity 13.4: Research Activity

1. Use the Internet and text books in the library to do a research on the advantages and disadvantages of asexual reproduction.
2. Present your findings to the rest of the class.

Advantages of asexual reproduction

1. **Less energy is required:** It is a simple procedure that requires less energy as compared to sexual reproduction. Organisms that reproduce asexually do not have to carry their offspring (gestate) and produce more than one at a time. This makes it a quick and inexpensive process for them in the terms of time.
2. **Can take place in various environments:** It allows for different organisms to have the ability to take different forms. This allows them to successfully produce offspring in various environments.
3. **Large quantities of offsprings are produced:** It enables organisms to produce large quantities of offspring. This fast reproduction checks intruders and competition from invading species. There are also better chances of survival when conditions change and the number of predators increases.

4. **One parent is required:** Finding a mate can be very difficult for organisms that are in isolated environments, for example, the deep ocean. Asexual reproduction takes the need to find a mate away, allowing these organisms to multiply. This is important especially when colonising new areas.
5. **It does not need mobility:** Organisms that often stay in one place do not need to move to other places just to produce offspring.

Disadvantages of asexual reproduction

1. Organisms are identical: In this type of reproduction the offspring produced are genetically identical to each other and to the parent. This causes no or very little genetic variation within a population therefore, lack of diversity among the population of these organisms. They become less adapted to certain environmental changes, and might not survive the changes.
2. **Organisms are prone to extinction:** Having the same traits also means having the same weaknesses. Parasites and other predators that have evolved to kill just one of the organisms can take out the entire population. It requires a single asexual parent, from which the chromosomes and genes are copied. This means the genetic mutations or defects which are bred out would be present in the offspring. Any mutation in the parent cell can cause harmful effects on the survival ability of the offspring.
3. This form of reproduction has no control over the rapid increase of the population of the organisms. There might be the risk of food and space competition. This usually leads to the struggle for existence and overcrowding within the community.
4. **Easy spread of diseases:** Due to the large quantities of offsprings that result from each reproduction on phase, diseases can be spread easily from one plant to another in case of a break out.

Activity 13.5: Investigating asexual reproduction in Irish potato tubers

Requirements

- Plastic cups
- Toothpicks
- Water
- Potatoes

Procedure

1. Pour water in the plastics cups.
2. Place potatoes in the plastic cups with water using toothpicks to hold them.
3. Change water often and after sometime observe the changes on potatoes.

Study questions

1. What observations did you make on the potatoes after some time?
2. Which kind of reproduction is this?

The facts

After sometime roots and shoots will sprout out from the potatoes. Potatoes, when exposed to favourable conditions, will reproduce asexually.

Self-evaluation Test 13.2

1. The ability of many offspring to be produced through asexual reproduction is also disadvantageous. Explain.
2. Why is population control an issue in any species?
3. How is asexual reproduction important?

13.3. Sexual reproduction

Activity 13.6: To examine sexual reproduction in *Mucor*

Requirements

- Microscopes
- Dropper or pipette
- Slides
- A mould culture
- Forceps

Procedure

1. Using forceps pick some hyphae of the *Mucor* from a mould culture.
2. Add water to prevent them from drying.
3. Mount them on a microscope.
4. Observe and identify hyphae that are undergoing conjugation and zygospores in the specimen.

Sexual reproduction involves fusion of gametes from two individual organisms; **male** and **female** referred to as **parents**. Each individual organism produces a reproductive cell known as **gamete**. The nucleus from the male gamete fuses with the nucleus from the female gamete to form a **zygote** in a process called **fertilisation**.

Organisms that exhibit sexual reproduction have organs (gonads) that are specialised for the formation of gametes. Inside these gonads are specialised cells that can divide to form new gametes. They can do this by undergoing a kind of cell division called **meiosis**. This takes place in higher organisms.

The process of meiosis produces unique reproductive cells called **gametes**, which have half the number of chromosomes as the parent cell. During fertilisation, the fusion of haploid gametes from two individuals restores the diploid condition. Gametes are haploid (containing only one set of chromosomes) while the zygote is diploid (containing two sets of chromosomes).

Thus, sexually-reproducing organisms alternate between haploid and diploid stages.
In sexual reproduction, two individuals produce offspring that have genetic characteristics from both parents.
Sexual reproduction introduces new gene combinations in a population through genetic recombination.

The facts

As mentioned earlier in this unit, *Mucor* can reproduce asexually by the process of spore formation. However, it can also reproduce sexually through the process of **conjugation**. In this process two separate hyphae growing alongside each other and they produce short branches. When the branches of the two hyphae come into contact with each other, their tips swell.

The walls at the point of contact dissolve and the cytoplasm and nucleus in the swollen part is mixed. This results in fertilisation. The two swollen parts fuse to form one part called a **zygospore**. The zygospore develops a tough outer wall; it then breaks off from the two hyphae. It then germinates to produce a new hyphae that continues to grow into a new *Mucor*.

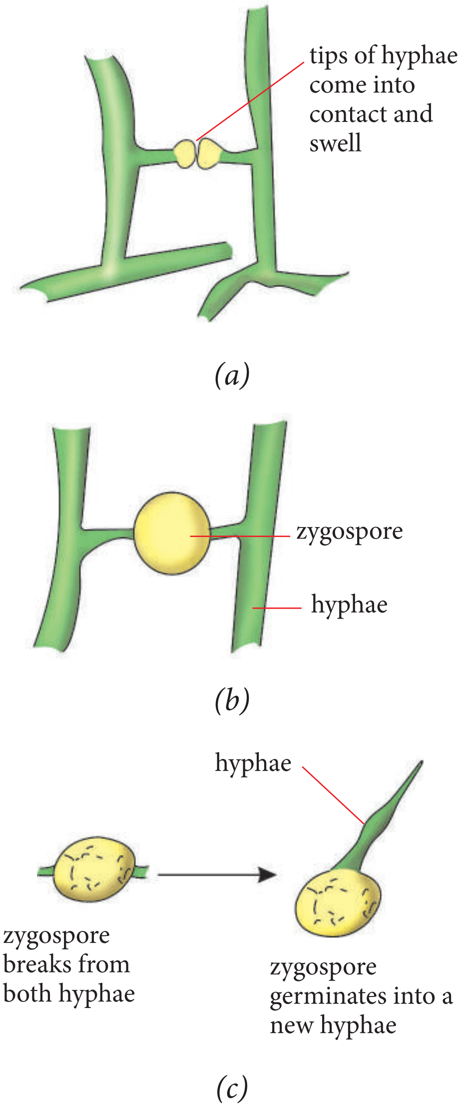


Fig 13.13: Process of sexual reproduction in Mucor

Did you know?

In some organisms, one individual can produce both male and female gametes, for example, some snails and worms.

Activity 13.7: Discussion Activity

1. Discuss the advantages and disadvantages of sexual reproduction
2. Present your work to the rest of the class.

Advantages of sexual reproduction

1. Offspring produced exhibit variation and improved vigour. The offspring therefore have improved qualities such as higher yields, resistance to diseases and can withstand environmental changes.
2. There is diversity of offspring from their parents. The offspring bear traits from each parent.
3. The only way that a species can evolve is through sexual reproduction.
4. With each passing generation the genes become better suited to handle environmental and biological issues that would wipe out creatures that produce in other ways.

Disadvantages of sexual reproduction

1. Reproduction rate is slower than in asexual. This is because it requires two parents. The parents must use energy in order to find, court or identify and copulate with their mate.
2. Genetic recombination may be counter-reproductive. This is because sexual reproduction is less

efficient at passing on genes. The favourable genes combination may be broken.

3. Sexual reproduction also requires more time to produce offspring. Animals may take months before they can produce offspring. In plants, it may take years before they bear fruits.
4. Animal offspring require a large amount of parental effort from the day that they are conceived. The mother must carry the baby and give birth. Then the child has to be taken care of until they are grown and independent enough to survive on their own.

Table 13.1: Comparison between sexual and asexual reproduction

Sexual	Asexual
Two parents are involved.	Single parent is involved.
Male and female gametes are produced during gametogenesis.	No gamete is produced.
Diploid zygote is formed after fertilisation.	No zygote formation
Meiosis is essential for gamete formation.	Mitosis is essential for spore formation.
There is variation in offspring.	Offspring are identical to parents.
It is slow in propagation.	It is rapid in favourable conditions.
Population numbers increase slowly.	Population numbers increase rapidly.

Self–evaluation Test 13.3

1. Compare asexual reproduction and sexual reproduction.
2. Which statement about sexual reproduction is correct?
   A. Sexual reproduction needs just one parent.
   B. The offspring are always genetically identical in sexual reproduction.
   C. The offspring are not identical to the parents in sexual reproduction.
   D. None of the above
3. From the list below, select the ones that reproduce through fusion of gametes.

   Grass, mushroom, lion, yeast, sugar cane, mould, fern
4. Give examples of plants which reproduce through the following processes.
   i) Sexual reproduction
   ii) Asexual reproduction
5. What are the disadvantages of sexual reproduction?

Unit summary

- Reproduction is a characteristic of all living organisms that ensures that new individuals are produced by mature ones. It involves the giving rise of new individuals of the same species that ensures continuity and increase in population.
- Asexual reproduction involves one parent without fusion of gametes.

- The modes of asexual reproduction are; binary fission, budding, spore formation and vegetative propagation in plants.
- Asexual reproduction brings forth many new individuals that are genetically identical.
- Vegetative reproduction is asexual and does not involve fusion of gametes nor spores but uses plant parts.
- Natural propagation is a method in which plants self-propagate naturally without man's intervention.
- Artificial propagation is a method that man uses to produce desired plants.
- Sexual reproduction involves fusion of male and female gametes.
- Fertilisation is the fusion of gamete nuclei.
- Sexual reproduction results in variation and the offspring produced have more vigour.

End Unit Assessment 13

1. What type of traits do organisms need to have in order to survive and reproduce?
   A) Traits that make them most attractive
   B) Traits that make them the smartest
   C) Traits favourable for survival
   D) Traits like the parents

2. Asexual reproduction involves_______.
   A. single gamete
   B. two gametes
   C. single parent
   D. two parents

3. The following statements describe certain features of reproduction.
   (i) Gametic fusion takes place.
   (ii) Transfer of genetic material takes place.
   (iii) Offspring have resemblance to the parents.

   Which statement is true for both asexual and sexual reproduction?

4. What type of reproduction is more conducive to evolution due to the increased genetic diversity it offers?
   A) Binary fission
   B) Budding
   C) Asexual
   D) Sexual

5. When is being genetically identical to the parent an advantage for organisms?
   A) When the environment is changing and fast production is needed
   B) When many offspring are needed in a short amount of time
   C) When the environment is just like the one the parent lived in successfully
   D) When mates cannot be found

6. If organisms cannot adapt to changing environmental conditions, what is likely to happen to the species?
   A) They will have to learn to attract mates from other areas.
   B) They may become extinct.
   C) They will have to find new ways to care for the offspring.
   D) They will have to learn to eat different foods.
7. Which of the following structures is not involved in vegetative reproduction?
   A. Fruits
   B. Stolon
   C. Bulb
   D. Corm
8. What type of asexual reproduction is found in an amoeba?
   A. Binary fission
   B. Budding
   C. Fragmentation
   D. Vegetative propagation.
9. Which of the following is true about grafting?
   A. A bud is fixed onto a slit on the stem
   B. Two separate stems are joined together to form one stem
   C. A stem is induced to produce roots and form a cutting.
   D. A swollen stem is used for planting.
10. The part of the Irish potato plant responsible for vegetative reproduction is the_________.
    A. root
    B. stem
    C. foliage leaf
    D. fruit
11. The production of new plants by underground stems is an example of _______reproduction.
12. What is the difference between cutting and grafting in artificial propagation?
13. With illustrations, give four parts of the plants used in propagation.
14. Using a table, give the differences between asexual and sexual reproduction.
15. Fill in the blank spaces in the paragraph below.

    The process of meiosis produces unique reproductive cells called _________which have half the number of chromosomes as the parent cell. During _________the fusion of ________ gametes from two individuals, restores the _________ condition. Gametes are ________ (containing only one set of chromosomes) while the zygote is _________ (containing two sets of chromosomes).

    Thus, sexually-reproducing organisms alternate between haploid and diploid stages. In sexual reproduction, two individuals produce offspring that have _________characteristics from both parents. Sexual reproduction introduces new _________ combinations in a population through _________.

Unit 14

Sexual reproduction in flowering plants

Key unit competence

After studying this unit, I should be able to explain how sexual reproduction occurs in flowering plants.

Learning objectives

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

- Identify and draw the parts of an insect pollinated flower using hand lens.
- Describe the anthers and stigmas of a flower.
- State the functions of the sepals, petals, anthers, stigmas and ovaries.
- Define pollination, self-pollination and cross-pollination.
- State the agents of dispersal of fruits and seeds.
- Discuss the implications to a species of self-pollination and cross-pollination.
- Explain the process of fertilisation.
- Describe the mechanisms of dispersion of seeds and fruits.
- Explain the importance of fruit and seed dispersal.
- Analyse the structural adaptations and compare insect pollinated and wind pollinated flowers.
- Investigate the environmental conditions that affect germination of seeds.
- Classify fruits and seeds according to mechanism by which they are dispersed.

Introductory activity

Study the following diagram carefully. It shows the life cycle of a flowering plant.

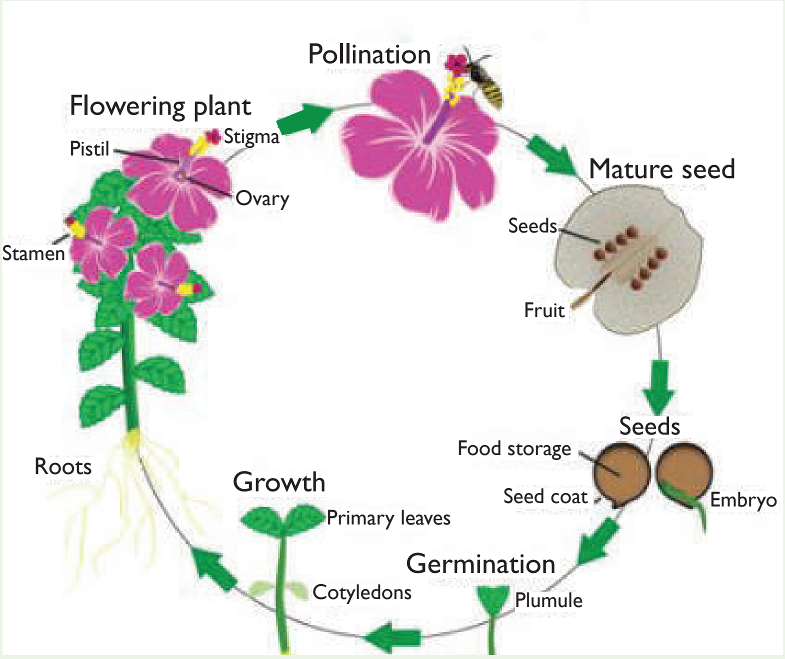


Fig 14.1: Life cycle of a flowering plant

How do we call this type of reproduction? What special name is given to this kind of life cycle in organisms?

Introduction

Flowering plants are the most abundant and widespread group of plants on earth. They are found in most habitats, from deserts to polar-regions. They include species of trees, shrubs and herbs. The flowers are the reproductive structures that produce new plants. Reproduction in flowering plants, as in animals, involve the fusion of male and female gametes in a process known as **fertilisation**. After fertilisation, **seeds** are formed which germinate into new plants.

A flower may have both male and female structures hence the term **bisexual** flower or it may have structures of one sex only, thus **unisexual** flower. A complete flower will have all parts while an incomplete flower will lack some parts. Flowers which are **insect** pollinated are brightly coloured while **wind** pollinated flowers are usually dull. Flowers need to be protected to ensure continuity of a species and to protect biodiversity.

14.1. Structure of a flower

Flowers are structures for sexual reproduction. There are many different types of flowers with great variation in size, colour and floral parts. Some plants have flowers whose structures are suited for pollination by insects. These are insect pollinated flowers for example *Hibiscus*. Other plants have flowers that are suited for wind pollination. These are wind pollinated flowers. Examples are grass and maize flowers.

Activity 14.1: Examining various types of flowers

Requirements

- Hand lens
- Notebook
- Pencil
- Various flowers

Procedure

1. Collect a variety of flowers from the school compound.

   Caution: Do not destroy any plants.
2. Examine each flower carefully using a hand lens.
3. Draw and label it as fully as you can.
4. For each flower, note the following points in your notebook.
   - Name of the flower (ask your teacher for assistance).
   - Number and colour of the sepals. Are they fused or separate?
   - Number, colour and size of petals. Are they fused or separate?
   - Number and arrangement of stamens.
   - Position and shape of the stigma.
   - Presence or absence of scent.

Caution: If you are asthmatic or allergic to pollen do not smell the flowers.

Study questions

1. How can you describe the appearance of each of the flowers you have observed?
2. What is the general arrangement of the floral parts (flower parts)?
3. Did you notice insects visiting some of these flowers? Why do you think some flowers were visited by insects while others were not?
4. Discuss with your friends the functions of parts of a flower.

The facts

Flowers are made of four main parts: the sepals, petals, stamens and carpels. The arrangement of the basic parts also varies from flower to flower. Fig 14.2 below shows generalised parts of a flower.

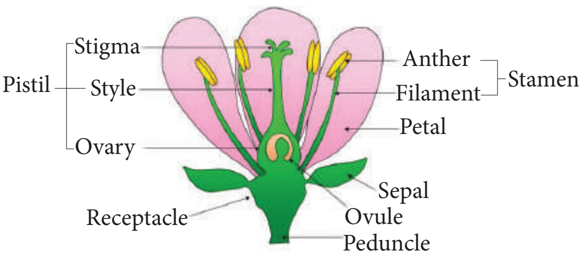


Fig. 14.2: Longitudinal section of a flower

Structure and function of parts of an insect pollinated flower

A **Hibiscus** flower is attached to the stem or branch of the plant by a **flower stalk** or **pedicel**. The top part of the flower stalk is sometimes known as the **receptacle**. It is the point from which the *Hibiscus* flower parts arise. There are four flower parts each arranged in a circle around a point.

The outermost part is made up of an **epicalyx**, followed by **calyx**, then **corolla**. Finally at the centre is the **gynoecium** (female parts)which is made up of carpels and **androecium**(male parts).

In the *Hibiscus,* the stamens are fused to make a hollow tube with free anthers towards its end while the styles are fused with free sticky stigmas towards its tip. The structure and function of the above-named parts of a *Hibiscus* flower are the same for most insect pollinated flowers. We will now study each part of the flower in order to see how it relates to its function.

Calyx

The calyx is made up of **sepals** which are leaf-like structures. They may be free and separate or fused to form a tube like structure as in the *Hibiscus* flower. They protect the inner parts of the flower before it opens when it is still in bud form from desiccation or drying up. It also protects the inner parts from being attacked by aphids. They are usually green in colour but are brightly coloured in some flowers.

Corolla

The corolla is made up of **petals**. They are found next to the sepals. They are large and colourful in insect pollinated flowers. They are either fused to form a tube or are free and separate. They are important because they attract insects for pollination in insect pollinated flowers. They also protect the inner parts of the flower from mechanical damage.

Stamens

The stamens form the male part of the flower known as the **androecium**. One stamen consists of four pollen-containing sacs which are fused together to form an anther.

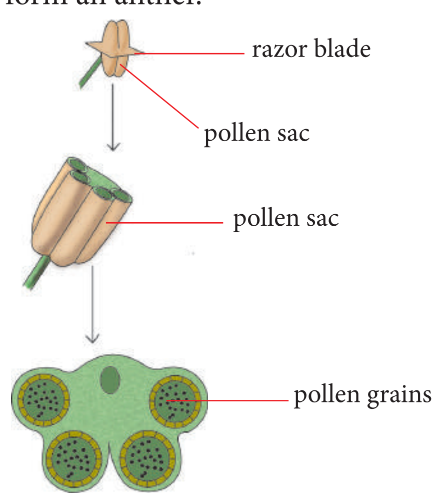


Fig. 14.3: Cross section through anthers to show pollen sacs

The anther is attached onto a stalk known as a **filament**. The anther and the filaments form the **stamen**. Pollen grains are formed inside the anthers. The number and arrangement, shape and attachment of stamens to the flowers vary from one plant to another.

Some flowers are called **staminate** flowers because they have only stamens and no carpels along with the other parts of the flower. The main function of the stamens is to produce pollen grains, which contain male gametes.

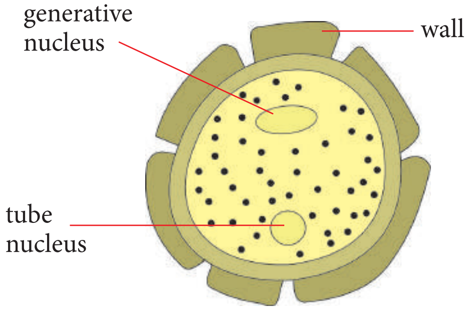


Fig 14.4: Internal structure of a pollen grain

Once the pollen grains in the anthers are fully formed, the anther is described as being mature. The cells of the outer layer of the wall of the pollen sac dry out. This creates tension which causes the anther to split at the line of weakness present on each side of the anther as shown in the diagram below.

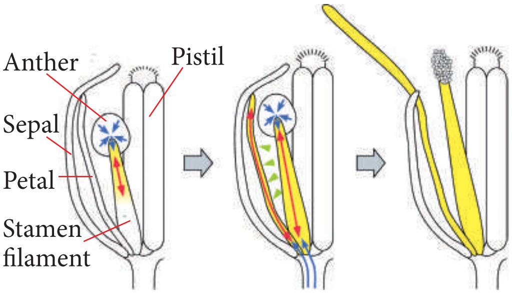


Fig 14.5: Dehiscing anther releasing pollen

(d) Carpels (Pistil)

A flower can have one or more carpels also referred to as the **gynoecium** which is the female part of the flower. Each carpel consists of a stigma, a style and an ovary. It is also referred to as the ***pistil.***

The ovary has a hollow space or cavity which contains one or several ovules. The reproductive cell is an egg cell and it develops inside the ovule. The ovule contains a structure called an **embryo sac** which contains the egg cell.

Did you know?

The joined styles shown in the following diagram are located inside the tube of fused filaments seen earlier.

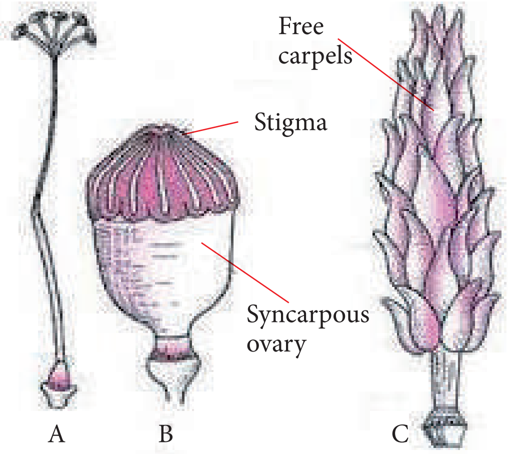


Fig. 14.6: Fused styles (without filaments and anthers)

Self–evaluation Test 14.1

1. The female and male reproductive structures of a flower are the________.
   A. petals and sepals
   B. receptacle and epicalyx
   C. pistil and stamen
   D. calyx and corolla
2. Identify the odd one out.
   Ovary, anther, ovule, pistil
3. The following describes the structure of a flower. Which one does not apply to a wind pollinated flower?
   A. Anthers dangle of the flower
   B. Brightly coloured
   C. Large quantities of pollen produced
   D. Stigma are large and feathery
4. Draw a flower and on it label the following:
   (a) Part of the stamen that supports the anther
   (b) Part of the pistil that is adapted to receive pollen grains
   (c) The part that protects the inner parts of the flower
5. Name the male parts of the plant.
6. Give three parts of a flower and their functions.
7. What are synergids?

14.2. Pollination

Activity 14.2: Investigating flower structures of wind and insect pollinated flowers

Requirements

- Flowers collected in activity 14.1
- Hand lens

Procedure

1. Collect wind pollinated flowers such as grass flowers and insect pollinated flowers such as *Hibiscus*.
2. Using a hand lens, observe the anthers and stigma of the two flowers.
3. Study the flowers that you have collected.
   - Note how the anthers and stigma of the two flowers are held by the filaments and style respectively.
4. Study the petals of the two flowers.
5. Group the flowers into those that were visited by insects and those that were not.
   - Do you notice any similarities in colour or scent among the two groups of flowers (those visited by insects and those not visited by insects)?
6. Make a list of the characteristics of flowers visited by insects and do the same for those not visited by insects.
7. Fill out the following table to show the differences between the two flowers.

Table 14.1: Features of flowers

Part of the flower	Feature	
	Insect pollinated	Wind pollinated
Anther		
Stigma		
Petals		

8. Compare your results with those of other groups.
9. Present your work to the rest of the class.

Caution: Some flowers are visited by insects that sting such as bees. Be careful as some insects can be dangerous when disturbed.

Study questions

1. Why do insects visit some flowers and leave other flowers?
2. Name two things that insects may collect from a flower.
3. What role do insects play in sexual reproduction in flowering plants?
4. List some of the characteristics of flowers most commonly visited by insects. Make a second list of characteristics of those flowers not commonly visited by insects.

The facts

The structure of some flowers is modified to encourage insects to visit the flowers and lead to pollination. Other flowers have features that enable wind pollination.

Wind pollinated flowers

- Flowers that are wind pollinated usually occur in groups called **inflorescences** on the plant. They produce pollen grains that are very small with smooth surfaces so that they do not clump together.
- They have light weight to be lifted easily by air currents from the anthers of one flower to the stigma of another easily.
- They have features that ensure pollination takes place. For their pollen grains to be readily dislodged from the anthers and be airborne, the flowers have well exposed stamens with anthers dangling out of the flower.
- The stigmas of such flowers are large and feathery creating a net to ensure that the pollen in air is trapped and lands on the stigma.
- Large quantities of pollen are produced. This is to ensure that there are increased chances of some of it landing on the stigmas because the wind also blows most of it away and it is lost.
- They have groups of two or three flowers which form spikelet. The spikelets are borne on a common stalk forming an *inflorescence* as shown in Fig. 14.7.

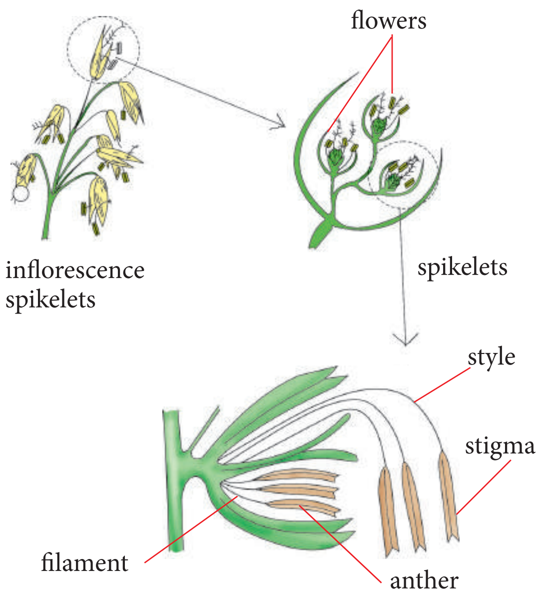


Fig 14.7: Wind pollinated flower

Activity 14.3: Discussion Activity

1. Using textbooks and the Internet, research on the following:
   (a) Meaning of the term pollination.
   (b) Differences between self-pollination and cross pollination.
   (c) Compare the features of insect and wind pollinated flowers.
2. Compare your findings with the rest of the class.

The facts

Male gametes are formed inside the anthers in pollen grains while female gametes are formed in the ovary inside ovules. Therefore, reproduction cannot occur unless the gametes meet. Pollen is transferred from the anthers to the sticky stigma in a process called **pollination.**

Pollination is important because the male gametes are found inside the pollen grains and require to be exposed or brought closer to the female gametes. There are two types of pollination.

- Self-pollination
- Cross pollination

Self-pollination is when pollen from anther of the same plant arrives at the stigma of a flower. There are two types of self-pollination: that is autogamy and geitonogamy. In **autogamy,** pollen is transferred to the stigma of the same flower. Some plants have mechanisms that ensure autogamy, such as flowers that do not open or stamens that move to come into contact with the stigma. In geitonogamy pollen is transferred from the anther of one flower to the stigma of another flower on the same flowering plant. Few plants self-pollinate without the aid of pollen vectors (such as wind or insects). The mechanism is seen most often in some legumes such as peanuts**.** Most of the self-pollinating plants have small, relatively inconspicuous flowers that shed pollen directly onto the stigma, sometimes even before the bud opens. Self-pollinated plants spend less energy in the production of pollinator attractants and can grow in areas where the kinds of insects or other animals that might visit them are absent or very scarce—as in the Arctic or at high elevations.

Advantages of self-pollination

- Self-pollination can be an advantage when the number of flowers is small or widely spaced. During self-pollination the pollen grains are not transmitted from one flower to another. As a result the wastage of pollen is less.

- Also it does not depend on any external career. The plant that develops in that way of pollination cannot make changes in their characters and so the features of a species can be maintained. This way a species can maintain purity in it.

Disadvantages of self-pollination

The disadvantages of self-pollination come from lack of variation that allows no adaptation to the changing environment or potential pathogen attack.

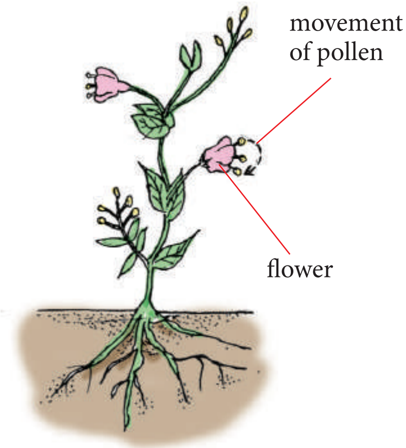


Fig 14.8: Self –pollination

When the pollen is transferred from the anthers of a flower from one plant to the stigma of a flower on another plant this is called **cross pollination.** The two plants should be of the same species.

Characteristics of cross pollinated plants

- Flowers are small and inconspicuous.
- Non-essential parts are either absent or reduced.
- The flowers are colourless, odourless and nectarless.
- In case of unisexual flowers, the male flowers are more abundant. In bisexual flowers, the stamens are generally numerous.
- Flowers are produced above the foliage, before the appearance of new foliage or placed in hanging position.
- Pollen grains are light, small and winged or dusty. They can be blown by wind to distances of up to 1300 km.
- Pollen grains are dry smooth, nonstick and unwettable.
- Stigma is hairy, large, feathery or branched to catch the wind-borne pollen grains.
- Pollen grains are produced in very large number. Consequently, the pollen grains spread over large tracts so that even isolated plants get pollinated.

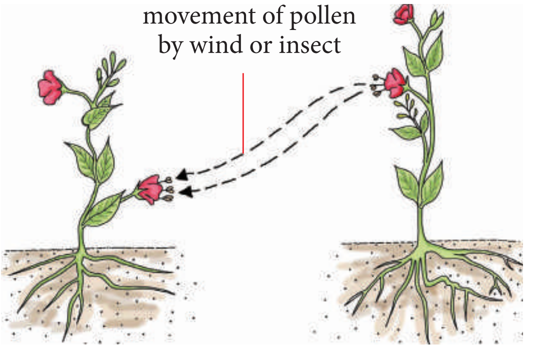


Fig 14.9: Cross - pollination

Advantages of cross pollination

- A number of plants are self-sterile, that is, the pollen grains cannot complete growth on the stigma of the same flower. Cross pollination therefore allows complete growth on stigma.

- Cross pollination introduces genetic re-combinations and hence variations in the progeny. New and more useful varieties can be produced through cross pollination.
- Cross pollination increases the adaptability of the offspring towards changes in the environment.
- It makes the organisms better fitted in the struggle for existence. The plants produced through cross pollination are more resistant to diseases.
- The seeds produced are usually larger and the offspring have characters better than the parents due to the phenomenon of hybrid vigor.
- The defective characters of the race are eliminated and replaced by better characters.
- Yield never falls below an average minimum.

Disadvantages of cross pollination

- It is highly wasteful because plants have to produce a larger number of pollen grains and other accessory structures in order to suit the various pollinating agencies. Therefore, less economical.
- A factor of chance is always involved in cross pollination.
- Some undesirable characters may be produced during cross pollination.
- The very good characters of the parent plant are likely to be spoiled.

Agents of pollination

Pollen does not have structures that enable it to move. How do you suppose that the pollen found on the anthers finds its way to the stigma of the same flower or that of a different flower?

Activity 14.4: To investigate insects and wind pollinated flowers.

Requirements

Flower of plants such as rose, maize, grass and hibiscus.

Procedure

1. Study each of the flowers listed above.
2. Design a table where you are going to record the features that you have observed in each of the flowers.
3. Use the following guidelines.
   a) Flowers scented and have nectar.
   b) Flowers large, conspicuous with brightly coloured petals.
   c) Stigma small and sticky.
   d) Stigma large and feathery.
   e) Pollen grains small, light and smooth.
   f) Flowers not scented and lack nectar.
   g) Flowers small and inconspicuous.

Pollen requires an agent to carry it to ensure its transfer from anther to stigma. An **agent of pollination** can therefore be defined as the means by which the pollen grains can be transferred from anthers to stigma. Examples of these means are animals, for example, insects, spiders, human beings, humming birds, wind and water.

Insects like ants, bees, wasps, termites, moths, butterflies are the most common animals that pollinate flowers. Insects are attracted to flowers that are scented and brightly coloured. Insects also visit flowers to look for pollen and nectar which is food to them.

As the insects move in and out of the flower, some of the pollen previously stuck on their bodies from other flowers stick onto the sticky stigma in the flowers. This way the insect acts as an agent of pollination. Insect pollinated flowers are said to be **entophilous.**

Wind is moving air. When the wind blows it readily dislodges pollen which is loosely held on the anther. Such pollen is carried by the wind to stigmas that have feathery net-like structures. They readily trap the pollen. Wind pollinated flowers are said to be **anemophilous.**

Table 14.2: Characteristics of wind pollinated and insect pollinated flowers

Insect pollinated	Wind pollinated
Flowers have petals that are large and brightly coloured. Very conspicuous.	Flowers are small with green bracts. Not very conspicuous.
Have nectaries with nectar guides to direct the insects to the nectaries	No nectar and nectaries
Are scented	Not scented
Small rigid sticky stigmas located inside the flower	Stigma often feathery and large. Mostly hanging outside the flower
Pollen grains have rough crispy surface	Pollen grains are small, light-weight, have smooth surfaces and are produced in large amounts
Anthers are small attached firmly to the filaments and located inside the flowers and positioned where the insects can brush against them	Anthers are large and loosely attached to the filaments. They are on filaments that dangle out of the flower, they shake readily when the wind blows

Activity 14.5: Research Activity

1. Carry out a research on the features and mechanisms that hinder self pollination and self-fertilisation.
2. Write a report on your findings and present your work to the teacher.

Self–evaluation Test 14.2

1. What is pollination? State two types of pollination.
2. Why do you think farmers who grow cereals such as wheat, barley and rice ensure that the plants grow close to each other?
3. What will be the effect on flower pollination on the yield of some crop plants if pollinating insects are accidentally killed by insecticides?
4. What feature of the stigma of an insect pollinated flower enables the pollen grain to adhere?
5. Which statement describes the sepals?
   A. Part of the flower that attracts insects
   B. Part that protects the flower while it is a bud
   C. Part that produces pollen grains
   D. Part to which all other parts of the flower are attached
6. What are the advantages of self pollination?
7. Give an illustration of cross pollination.
8. What are the two main agents of pollination?

14.3. Fertilisation and seed formation

Activity 14.6: To familiarise with the process of fertilisation and seed formation

Requirements

- Computer animation
- Charts and diagrams

Procedure

1. Observe the computer animations or charts and diagrams
   - Can you trace the path of the gametes during fertilisation?
2. Make a drawing of the path taken by the gametes.
3. Compare your work with others

Study questions

(i) How does fertilisation occur in a flower?

(ii) What structures are involved during fertilisation?

(iii) How does a seed develop after fertilisation?

The facts

When the pollen grain lands onto the sticky stigma it germinates. A pollen tube emerges from the grain and quickly grows down the style to the ovary.

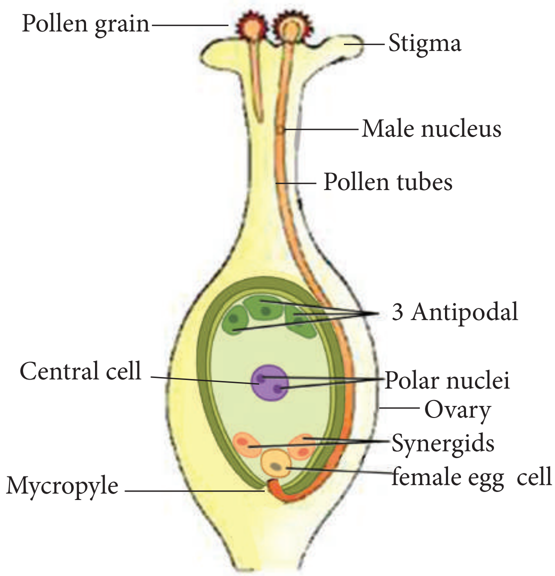


Fig 14.10: Vertical section through a pistil just before fertilisation

The pollen grain has two nuclei in it: the generative nucleus and the pollen tube nucleus. The generative nucleus is immediately behind the pollen tube nucleus. The generative nucleus divides to form the male gametes (or nuclei). The tube nucleus is located at the tip of the tube and it directs and controls the growth of the tube to the ovary. As the tube continues growing downwards, the generative nucleus divides by mitosis. It forms two male nuclei which represent the male gametes.

The pollen tube then grows through the ovary wall and reaches the ovule and enters it through the **micropyle**. At this point, the role of the tube nucleus is over and it degenerates (breaks up). The tip of the pollen tube then bursts open to release the two male nuclei.

The two male nuclei enter the part of the ovule known as the embryo sac. One male nucleus fuses with the nucleus in the egg to form a fertilised egg cell or zygote.The other male nucleus fuses with the two polar nuclei to form a triploid nucleus (i.e. a nucleus with three sets of chromosomes) known as the primary endosperm nucleus. This is known as **double fertilisation**.

In some ovaries, there are several ovules, for example, the ovary of a bean flower. In such a case, several pollen grains are responsible for the fertilisation of the ovules in that ovary.

In some plants, fruit formation takes place without fertilisation. This process is called **parthenocarpy.** Example is in bananas and potato fruits.

Seed formation

After fertilisation of the flower, several changes take place in it. The zygote formed undergoes mitotic division to form an embryo which comprises of three parts, the plumule, radicle and cotyledon(s).

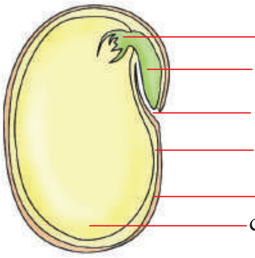


Fig 14.11: Parts of a seed

A seed that has one cotyledon is known as a **monocotyledonous** seed. Examples include maize and wheat. A seed that has two cotyledons is known as a **dicotyledonous** seed, for example, beans and peas. The cotyledon or endosperm stores food substances for the growth and development of the embryo during germination.

The parts of the ovule that were the integuments develop into **seed coats**. The inner integument becomes the **tegmen** and the outer integument forms the **testa**. These form protective layers to the seed.

What was originally the micropyle remains as a tiny pore or hole through which oxygen and water enter the seed when it germinates. The seed also loses most of its water. This reduction is from 90% of the total seed mass to about 10%. This reduces the chemical or metabolic activities that occur in the cell. The seed can then enter a period of reduced growth and development called **seed dormancy**. In this condition, the seed can withstand adverse conditions.

Self–evaluation Test 14.3

1. Which of the following is necessary for seed formation in angiosperms?
   - A. Ovule
   - B. Pollination
   - C. Double fertilisation
   - D. All the above
2. Seed dormancy may be due to________.
   - A. immature embryo
   - B. hard seed coat
   - C. presence of germination inhibitors
   - D. all of the above
3. You are provided with the following: mango, castor, rice and pea. Which ones are monocots?
4. Outline the stages in seed formation.
5. Draw and label parts of a seed.

14.4. Fruits, seed dispersal and germination

The fertilised ovary develops into a fruit. A fruit can also be described as a mature ovary. Its main function is to protect the inner seed or seeds and to assist in their dispersal. In the process, the ovary develops into a fruit. The ovary wall becomes the fruit wall or pericarp. The pericarp varies in structure from one fruit to another. It may be thick or it may be thin. It has three main functions.

- Its main role is to protect the seed and therefore the embryo.
- It also acts as a storage for food.
- It is important in the dispersal of seeds.

In ovaries that have matured into fleshy fruits, three distinct regions in the pericarp can be noted. The outer part or skin is called the **epicarp**. The middle part is the **mesocarp** and the inner part which surrounds the seeds is the **endocarp**.

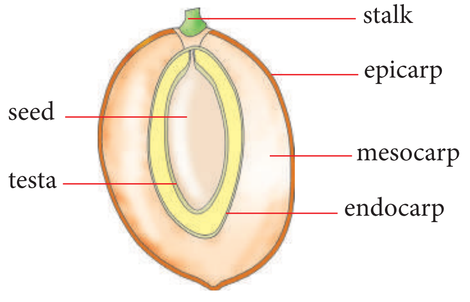


Fig 14.12: A section through a fruit showing various parts of a fruit

There is a great diversity of fruits. This is because of the great variation of flowers that exist. The type of flower influences the type of fruit that will be formed. For example, if the flower was an *inflorescence* i.e. had several flowers in a cluster, then multiple fruits form. Fruits can be classified into two main groups; **dry fruits** and **succulent fruits**.

Dry fruits are fruits whose pericarp dries up enclosing the seeds. Examples include legumes, maize grains and nuts. Succulent fruits include mango, berries, apples and oranges.

Dispersal involves the scattering of seeds and fruits away from the parent plant. Many different adaptations have arisen to enable efficient dispersal. This ensures that plants do not grow very close together to avoid competition for water, minerals and sunlight. The mode of dispersal of the seed or fruit depends on the agents of dispersal which are: animal, wind and water.

Fruit and seed dispersal

Suppose that most of the fruits dropped immediately beneath the parent plant. This would mean that the seeds in the plant would eventually get exposed and eventually germinate around the parent plant.

This would lead to overcrowding. All the plants would compete for light, space, soil nutrients and water. This means that they would not grow to become healthy and strong enough to survive and carry out the cycle of reproduction once more. This can endanger the survival of the plant species.

Activity 14.7: To describe mechanism of dispersion of seeds and fruits

Requirements

- Hand lens
- Scalpel
- Variety of fruits

Procedure

1. Identify and collect a variety of fruits from different types of plants.
2. Study the structure of these fruits externally and internally by cutting cross sections through them. Your teacher will assist you.
3. Put them into categories or groups according to the observations made. For example
   - Fleshy or succulent fruits.
   - Dry fruits that do not split (indehiscent).

- Dry fruits that split (dehiscent)

4. In each of these groups or categories, the fruits have further variations in characteristics. Number of seeds present. Number of fleshy layers, whether outer layer is thick and fleshy, dry, hard, etc.
5. Try to identify each fruit you have collected either by name or the category that you have grouped it into and state the mode of dispersion.
6. Repeat procedure 1, 2, 3, 4 and 5 with seeds.

The facts

After fertilisation, the ovule develops into a seed and the ovary into a fruit. The process of reproduction would not be complete if the seed did not reach favourable ground in order for it to germinate and grow into a new plant.

Seeds should be able to reach new and suitable ground where the parent plant is not growing and where few such seeds are also growing. This means that the seeds should leave the parent plant either on their own or in the fruits. The process by which seeds and fruits are spread from the parent plant is known as **dispersal.**

Seed dispersal is important because it ensures that too many plants do not grow and overcrowd around the parent plant. It also ensures that seeds reach new and suitable habitats where there is no competition for resources.

There are several methods of fruit and seed dispersal. They range from physical means, for example, when they are dispersed by wind or water. By biological means, for example, when dispersed by animals like birds, monkeys, humans among others.

There are some plants that have mechanisms that can forcefully eject their seeds from the fruit to some distance away from the plants i.e. self dispersal.

Dispersal by wind

Seeds or fruits that are dispersed by wind are usually small or light in weight. They may or not also have wing-like or hair-like structures that keep them airborne.

1. Seeds and fruits with wing-like structures

Some seeds have part of their structure extended to form wing-like structures which are flat, broad and papery. These structures create a large surface area against which the wind can blow, pushing them far away from its parents. Common examples are the *Jacaranda* seeds, *Tecoma* and *Spathodea* seeds.

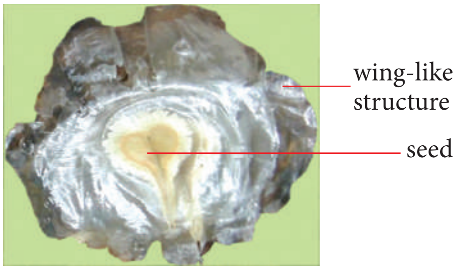


Fig 14.13: Jacaranda seed

2. Fruits and seeds with hair-like structures

Some fruits and seeds have many hair-like structures that project from their surfaces. These increase the surface area of the fruit or seed. Because of this they can be blown by wind over large distances and as they fall to the ground slowly, they look like parachutes. Examples are *Sonchus,* which have a pappus of hairs on their fruit and cotton seeds, which have hairs that grow out of the seed coat.

Fig 14.14: Seeds with hair-like structures

3. Fruits that disperse seeds by the censor mechanism

Some ovaries form dry capsules which open partially at the top to expose the seeds. The capsules are at the end of long stalks. Some seeds are shaken out and dispersed. The wind aids the dispersal of the seeds which are usually very tiny and easily carried.

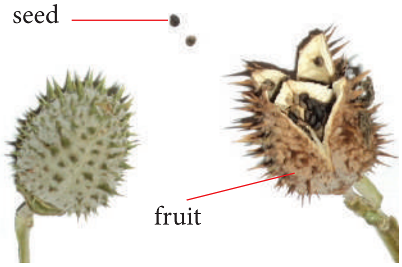


Fig 14.15: Seeds dispersed by censor mechanism

Animal dispersal

1. Some fruits have hooks on their surfaces

These hooks attach on the fur of mammals or peoples clothes, as they pass. They are moved away from the parent plant by the animal and they later fall off onto the ground or are removed by the animal as it cleans itself. Such seeds eventually germinate and grow into new plants away from the parent plant for example a black jack fruit.

2. Other fruits have pericarps that are succulent and edible.

This makes them attractive to animals as a source of food. Birds and mammals like monkeys eat the fruits.

Some seeds are swallowed, but because they have seed coats that are resistant to digestion by enzymes, they pass out of the digestive tract with the faeces later.

Once they reach the ground away from the parent, they germinate into new plants if conditions are favourable. Examples are passion and guava seeds. Some of the seeds are in fruits which are edible. They are picked by humans as food. Once the fruit is eaten the seeds are disposed off to areas away from the parent plant. They later germinate and grow into new plants. In this way, human beings are agents of seed dispersal.

Water dispersal

Water dispersal is the method in which some fruits and seeds are carried from where the parent plant is growing to new ground by water. This happens when the parent plant is growing near a river, lake or ocean. The seeds or fruits drop off from the plant into water and water currents sweep it away to another place. Some examples of fruits like the coconuts have structures that suit them to water dispersal. The coconut, being a drupe, has a fibrous mesocarp which contains many air spaces.

The air spaces make the fruit light enabling it to float in water. The pericarp is waterproof to enable it float without soaking in water.

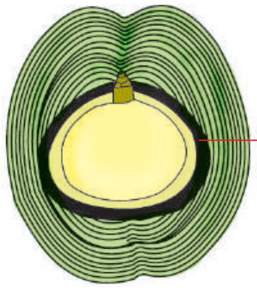


Fig 14.16: Coconut fruit

Self dispersal

Self dispersal is the method by which mechanisms in the fruit eject the seeds. Flowers like those of the bean plant form pods, which dry up and shrivel, the pericarp shrinks and some tension is set up in the fruit wall. Along two sides of the pod are two lines or seams of weakness, the pod splits along these lines. Each half twists suddenly and projects the seeds with some force away from the parent plant. This method is sometimes referred to as the explosive method. It occurs in plants such as legumes, for example, squirting cucumber and wall flower plant.

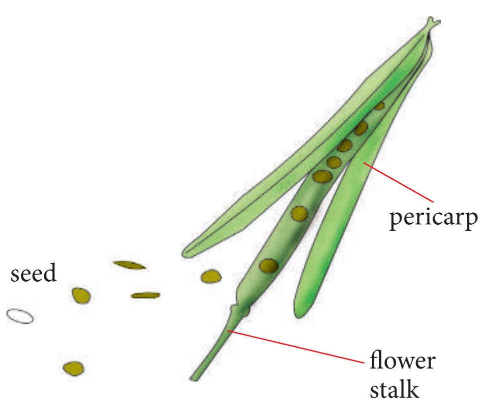


Fig 14.17: Wall flower fruit

Importance of seed and fruit dispersal

Dispersal of fruits and seeds is important for the survival of any plant species since:

- Reduced overcrowding of seedlings which would grow around the parent plant resulting in competition for resources.
- Seeds may be dispersed to new areas with more suitable conditions than where the parent plants are growing.

Germination

Activity 14.8: To investigate conditions necessary for germination

Requirements

- Conical flasks
- Cotton wool
- Pyrogallic acid
- Water
- Kidney beans
- Refrigerator, cool box or cupboard
- Ignition tube

Procedure

1. Put some dry cotton wool at the bottom of four conical conical flask.
2. In each flask, place five healthy bean seeds on top of the cotton wool.
3. Label the flasks **A**, **B**, **C** and **D**.
4. To flask **A**, moisten the cotton wool by adding water. Then place pyrogallic acid mixed with sodium hydroxide) in an ignition tube in the conical flask. Cork the conical flask to make sure it is airtight.

5. Put flask **B** in a corner of the classroom.
6. To flask **C**, moisten the cotton wool and keep the flask in a refrigerator or in a cool place.
7. To flask **D**, moisten the cotton wool and also place it in a warm place in the classroom.
8. Record your observations after few days filling in your observations in a table below.

Table 14.3: Results of the experiment

	Setting	Observations
A		
B		
C		
D		

Study questions

1. What is the role of pyrogallic acid and sodium hydroxide?
2. What conditions were being investigated in each of the flasks?
3. Account for the observations made in each of the flasks.

The facts

Germination is the development of a seed into a seedling. After seed formation, the seed undergoes a period of dormancy. Once this dormancy is broken and necessary factors for germination are provided, the physiological activities in the seed are activated, leading to germination, only a viable seed that can germinate. This is a seed in which the cells remained alive during dormancy.

For the seed to germinate, it needs water, oxygen and suitable temperature. Before germination, many seeds go through a period of dormancy that is accompanied by very low metabolic activities such that growth does not occur. There are two types of germination, that is, **hypogeal** and **epigea**l.

Conditions necessary for germination

1. Water

For germination to take place, water enters the seed through the micropyle in a process known as **imbibition.** This causes the seed to swell, and the testa to soften and eventually break. Enzymes in the seed become activated. They break down food stored in the cotyledon and endosperm into simple soluble substance in a process known as **hydrolysis.** Stored starch is broken down to glucose, stored proteins into amino acids and stored lipids into fatty acids and glycerol.

These soluble food substances are transported by the water from the storage parts of the seed to the regions of growth in the plumule and radicle. As a result of the assimilation of these food substances, the plumule and radicle increase in size and they grow out of the seed. The cotyledons and endosperm shrink due to the depletion of the stored food.

2. Oxygen

Oxygen is necessary in germination for the aerobic respiration which provides energy for the growth and development of the seed into a seedling.

3. Warmth

Warmth provides optimum temperature for maximum enzyme activity.

Fact of life: Germination enzymes are also involved in hydrolysis.

Epigeal germination

This is a type of seed germination in which the cotyledon emerges above the ground. It is caused by the elongation of the hypocotyls. The hypocotyl elongates as an arch or a hook which pushes upward through the soil. It pulls the cotyledon that encloses the plumule in between them. The hypocotyl straightens then cotyledons open and turn green. They start to photosynthesis providing food for the developing seedlings for 1-2 days.

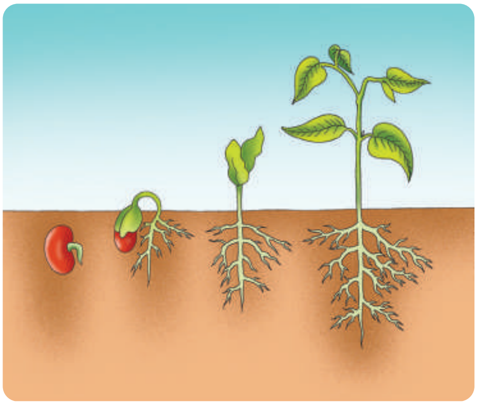


Fig 14.18: Epigeal germination

Hypogeal germination

This is a type of germination in which the cotyledon is left under the ground as the seed germinates. It is caused by the elongation of the epicotyls. The epicotyls elongates straight up with the plumule protected by the sheath known as coleoptiles. The coleoptiles protects the delicate plumule as it penetrates up the soil.

Fig 14.19: Hypogeal germination

Self–evaluation Test 14.4

1. What is germination?
2. State the role played by water during germination.
3. State two types of germination.
4. Which of the following statements best describes dispersal?
   - A. A seed growing into a new plant
   - B. A seed starting to sprout
   - C. The scattering of seeds to other places away from the parent plant
   - D. A seed starting to grow roots
5. What types of seeds are carried by wind?
   - A. Seeds in pods
   - B. Seeds with hairy parachute-like structures
   - C. Seeds with holes
   - D. Seeds with lines of weakness

6. Not all seeds fall under the parent plant. Others are dispersed far away. What is the importance of this?
7. Seed dormancy is important. Explain.
8. What is the role of each of the following in germination?
   (a) Cotyledons and endosperm
   (b) Enzymes

Unit summary

- Sexual reproduction in plants involves the fusion of gametes.
- Flowers are the structures for sexual reproduction in plants.
- The stamen is the male part while the pistil is the female part.
- The pistil and stamen are the essential parts while the calyx and corolla are the accessory parts of a flower.
- Pollination is the act of transferring pollen grains from the male anther of a flower to the female stigma.
- Wind pollinated flowers are small and inconspicuous. They have no nectar and nectaries. They have no scent, small pollen grains light in weight produced in large numbers with smooth surfaces. Anthers are large and loosely attached to filaments.
- Insect pollinated flowers have large brightly coloured conspicuous petals, have nectar and small sticky stigmas, pollen with rough surfaces and small anthers firmly attached to filaments.
- The fusion of male gametes with the egg cell and with the polar nuclei is called double fertilization.
- A seed develops from a fertilised ovule while a fruit develops from the ovary after fertilization.
- Seeds are dispersed away from the parent plants to prevent overcrowding that would lead to competition for resources like water and minerals.
- Seed dormancy refers to a condition where a viable seed remains in an inactive state with reduced physiological activities in its cells. During dormancy period, the seed cannot germinate.
- For seeds to germinate, water, oxygen and warmth are necessary.
- Water dissolves food substances allowing them to be broken down into simpler substances and then transports them to the plumule and radicle.
- Oxygen is involved in respiration to provide energy.
- Warmth stimulates action of enzymes.

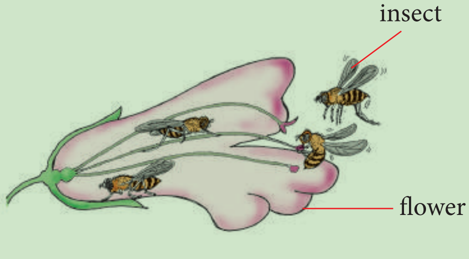
End Unit Assessment 14

1. Which one of the following statements is FALSE?
   A. A zygote is formed during the process of fertilisation.
   B. Reproduction in a plant results in the formation of a new plant.
   C. All plants reproduce by either sexual or asexual reproduction.
   D. In sexual reproduction, the offspring of a plant is identical to one of the parents only.
2. Which statement describes petals of flower?
   A. Part of the flower that produces nectar
   B. Ring of leaf- like structures around the flower
   C. Brightly coloured part of a flower that attracts insects
   D. Part that attaches the flower to the stem
3. The two nuclei of the pollen grain are the____________.
   A. endospermic nuclei.
   B. egg nucleus and polar nucleus.
   C. generative and tube nucleus.
   D. synergids and tube nucleus.
4. Which statement about wind-pollinated plants is correct?
   A. Their stamens and stigmas are inside the flower and compared to insect-pollinated plants, they have larger petals.
   B. Their stamens and stigmas are outside the flower and, compared to insect-pollinated plants, they have smaller petals.
   C. Their stamens and stigmas are outside the flower and compared to insect-pollinated plants, they have larger petals.
   D. None of the above
5. Fill the table by writing the adaptation associated with the following features of the seeds or fruits to adapt them to their modes of dispersal.

Feature	Adaptations
Hard testa	
Hollow seeds	
Lines of weakness on the fruit body	
Long flexible stalk onto which the fruit body is attached	

6. Describe the method of dispersal in the following fruits or seeds. For each method, indicate the structural adaptation suited to the method of dispersal and give an example of such a seed or fruit.

   Coconut, bean pods, black jack, jacaranda.
7. Study carefully the following flower.

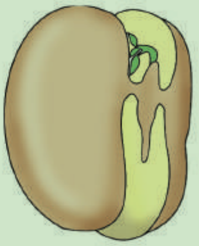


(a) Name the agent of pollination.

(b) Give two reasons for your answer in (a) above.

(c) What other factors make it possible for the flowers to be pollinated by the agent named in (a)?

8. The diagram below shows a structure of a bean seed. On it label the part that____________.



(a) grows up during germination.

(b) stores food required during germination

(c) grows down during germination.

9. What happens to the female parts of the flower after fertilisation?

10. How are the pollen grains of insect-pollinated plants adapted for transfer?

11. Using a table, give the difference between epigeal and hypogeal germination.

12. Describe factors that cause seed dormancy, how seed dormancy can be broken in seeds and advantages of seed dormancy.

13. With aid of diagrams, describe the characteristics of seeds dispersed by animals.

14. Describe a simple experiment you would use to investigate conditions necessary for germination.

Unit 15

Reproduction in human beings

Key unit competence

After studying this unit, I should be able to describe the process of sexual reproduction in humans.

Learning objectives

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

- Identify and label on a diagram the male and female reproductive system.
- State the adaptive features of the male and female gametes.
- Define fertilisation as the fusion of the nuclei from a male gamete and female gamete.
- State the adaptive features of the umbilical cord, placenta, amniotic sac and amniotic fluid.
- Outline the growth and development of the foetus in terms of increasing complexity in early stages and increasing size towards the end of pregnancy.
- Describe the ante-natal care of pregnant women.

Introductory Activity

Study the cycle below carefully. What is it about?

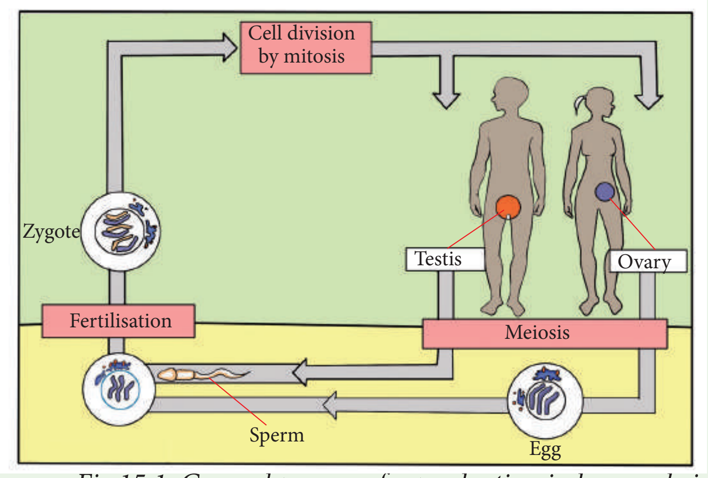


Fig 15.1: General process of reproduction in human beings

Find out what happens, during fertilisation, during cell division by mitosis and during meiosis.

What does this tell you about how reproduction occurs in human beings?

Introduction

Living organisms do not live forever. There comes a time when living organisms die. In spite of the numerous deaths, life has never ceased from the earth. It is not likely for it to disappear either. One would then ask "What makes it possible for life to continue when organisms are continuously dying?" The answer to this question is that living things have the ability to form new ones. This is known as **reproduction**.

Reproduction is one of the characteristics of living things. In human beings, reproduction involves two different mature individuals: **male** and **female**. The individuals possess reproductive organs **(gonads)** that produce sex cells or **gametes**. The male gamete **(sperm)** and female gamete (**egg** or **ovum**) meet and fuse during **fertilisation** to form a zygote which later develops into a baby.

15.1. Male and female reproductive systems

Activity 15.1: Identifying parts of the male and female reproductive system

1. Using charts and computer animations provided:
    - Study the parts of the male and female reproductive systems.
    - Observe photomicrographs of the male and female gametes.
    - Identify the internal structures of the male and female reproductive systems.
2. Discuss the functions of these parts.
    - Compare the adaptive features of the male and female gametes.
3. Present your work in class.

The male reproductive system

The male reproductive system consists of the following main structures. The testes (singular testis), scrotum or scrotal sac, seminiferous tubules, vas deferens (singular vas deferentia), epididymis, urethra, penis, Cowper's gland, prostate gland and seminal vesicles.

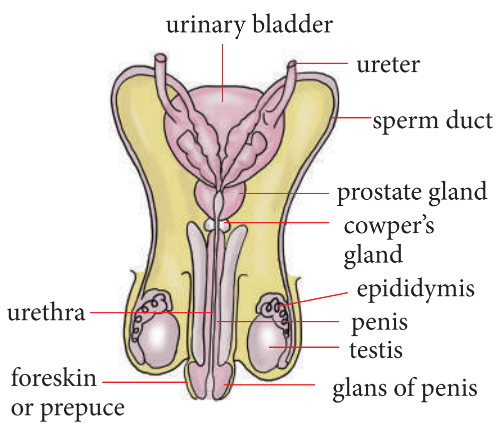


Fig 15.2: The male reproductive system

The male gonads are called **testes** (*singular- testis*). They are two in number. The testes produce sperm cells as well as the male androgen, testosterone. Testosterone is responsible for secondary sexual characteristics in males.

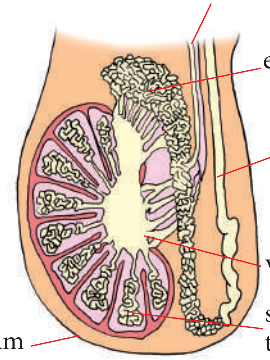


Fig 15.3: Internal structure of the testes

The two testes are located in a sac of skin called the **scrotum** which hangs outside the body wall. The scrotum is suspended immediately beneath the base of the penis. The function of the scrotum is to support and protect the testes. It also ensures that the testes are located at a lower temperature than that of the body. This is because sperms require temperatures slightly lower than that of the body for their production.

Each testis is made up of numerous fine coiled tubes called **seminiferous tubules** where sperm cells are formed. The walls of these tubules have specialised cells that produce sperms or spermatozoa. Other specialised cells located in between the seminiferous tubules, known as interstitial cells produce and secrete the hormone testosterone. In the seminiferous tubules, cells known as sertoli cells provide nourishment to the developing sperms.

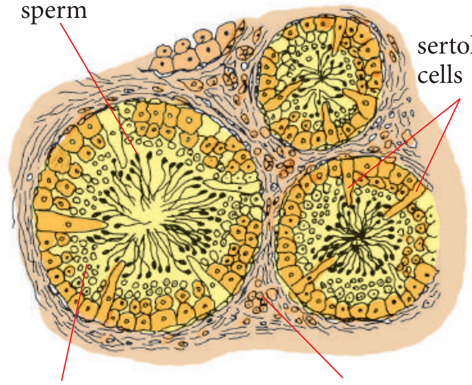


Fig 15.4: Cross-section of seminiferous tubules with sperms

The testes is linked to the epididymis by **vas efferentia**, which are tiny tubes that direct the sperm from the seminiferous tubules to the epididymis. In the **epididymis,** sperm are stored temporarily as they mature. The epididymis join up to the **vas deferens (sperm duct)** which conducts sperms out of the testes.

Near the distal end of the sperm duct are the seminal vesicles, a pair of Cowper's glands and prostate gland which are sometimes referred to as **accessory glands**.

- **The prostate gland** secretes mucus and a slightly alkaline fluid that is released during ejaculation. It makes sperms more active. It also neutralises the acidity of the vagina.
- **The Cowper's glands** secrete a clear, sticky slightly alkaline fluid, which cleans the urethra prior to ejaculation by neutralising any urine present.

- **The seminal vesicles** produce a mucus secretion which aids sperm movement. The resultant combination of secretions and sperm is called semen.

Semen is made up of sperms, sugars that nourish the sperms making them more active, mucus that forms a semi-fluid liquid that the sperms can swim in, alkaline substances to neutralise the acidic conditions in the urethra and vagina and hormones which help sperms reach the ovum by causing muscular contractions of uterus and oviducts.

The two sperm ducts join at the **urethra** which passes through the penis to the outside of the body. The urethra directs urine from the bladder as well as sperm from the vas deferentia out of the male body via the penis at different times.

Did you know?

The reproductive structure in human beings, just like in other mammals, is closely associated with part of the urinary system. These systems together are sometimes referred to as the **urogenital** system.

The **penis** is made up of capillaries, muscle and spongy erectile tissues. As part of the reproductive system, its role is to deposit sperm into the vagina of the female. This is possible due to the presence of specialised tissue known as erectile tissue. This tissue has spaces that fill up with blood during sexual excitement causing the penis to become rigid and erect, a process known as erection.

The tip of the penis is called the glans. It has sensory neuron endings that are stimulated by friction to cause the expulsion of sperm with fluid known as semen through a process of **ejaculation**. There is a foreskin which covers the glans. This skin may be removed during circumcision.

Health check!

Circumcision should be done by qualified person preferably medical doctors to prevent injury that can cause excessive bleeding which may lead to death.

The instruments used should be sterile and they should not be used on more than one person before sterilising due to the possibility of infection with HIV and AIDS.

The sperm

A sperm cell comprises of:

- A head which has an acrosome containing lytic enzymes and a nucleus.
- The middle piece which contains mitochondria and a single centriole.
- A tail.
- Nucleus

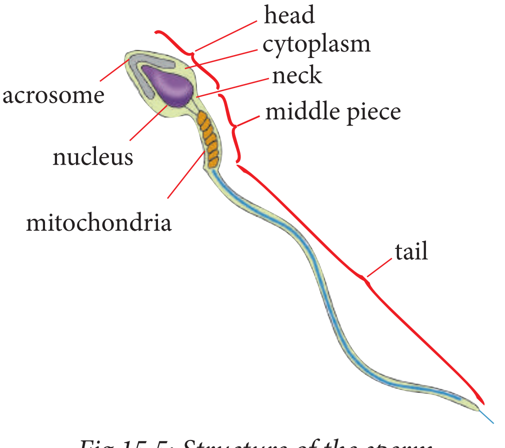


Fig 15.5: Structure of the sperm

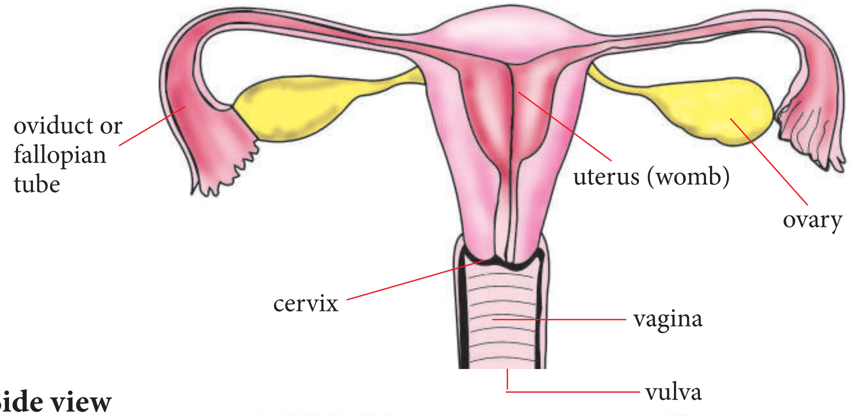
Adaptation of sperms

1. Long whip-like tail used for propulsion (swimming).
2. They are produced in large numbers to increase the chances of survival.
3. Large number of mitochondria helps to provide enough energy needed for propulsion.
4. The large nucleus helps the sperm cell to carry a lot of genetic information.
5. The lytic enzymes in the acrosome help to digest the egg membrane to facilitate fertilization.

The female reproductive system

The main structures that make up this system are the ovaries, oviducts or fallopian tubes, uterus, cervix and the vagina.

(a) Front view



(b) Side view

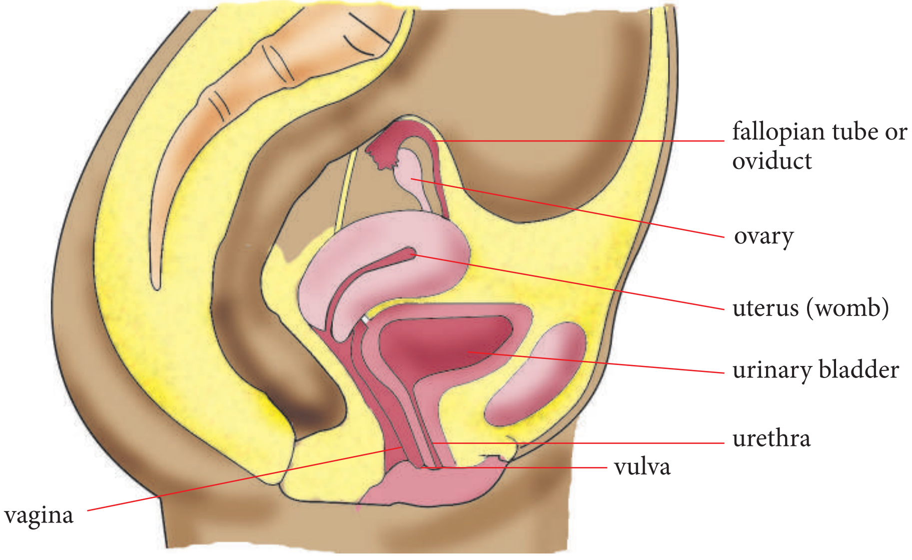


Fig 15.6: The female reproductive (a) front view (b) side view

The female gonads are the **ovaries** which produce the egg cells. They also secrete the female sex hormone called **oestrogen** which is responsible for the female secondary sexual characteristics. The ovaries are located one on the left side of the uterus and the other on the right of the uterus. They are suspended in the abdominal cavity by ligaments. Inside the ovaries are immature eggs at different stages of development.

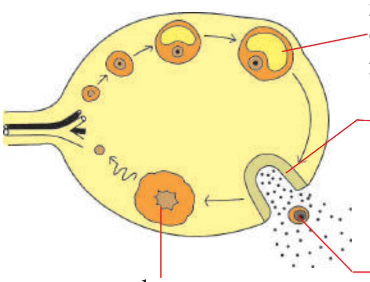


Fig 15.7: Section through ovary with ova at various stages of development

A baby girl is born with egg cells that are just starting to develop. Each month after puberty, one of these cells completes its development into an ovum. During development, each egg cell is in the form of a **Graafian follicle**. The Graafian follicle is a fluid filled structure containing one egg cell surrounded by a few cells known as follicle cells. In human beings, one egg is usually released once every month from alternating ovaries in a process known as **ovulation**.

The **oviducts or fallopian tubes** are tubes which lead from the ovaries to the uterus. It is through these tubes that the ova moves from the ovaries to the uterus. Each tube has an open ended funnel shaped part which lies next to the ovary.

Did you know?

The lining of the oviducts has ciliated cells. The movements of the cilia transports an egg cell towards the uterus. Fertilisation takes place in the oviducts.

Health check!

Sexually transmitted infection of the oviducts may result in their becoming scarred and blocked. This may cause sterility.

If a fertilised egg implants itself in the oviducts, a tubal or ectopic pregnancy occurs. If the situation is not diagnosed and treated early the tube ruptures and severe internal bleeding occurs which can cause death.

The oviducts join the uterus on the lower end. The **uterus** or **womb** is a hollow thick walled muscular organ with the size and shape of an inverted pear. It has a space inside it known as the uterine cavity. The outer layer of the uterus wall has thick muscles that contract strongly during birth. The inside layer of the uterus wall is made up of many blood vessels. It is called the **endometrium.** The uterine cavity leads to the cervical canal which extends to form a ring of muscle in the cervix. The cervix opens into the space of the vagina.

A fertilised egg implants itself in the thickened endometrium. The uterus contains a developing embryo during pregnancy until birth. It also enlarges during this time to occupy a large space in the abdomen. It shrinks rapidly immediately after childbirth.

The narrow neck of the uterus is called the **cervix** that connects the uterus to the vagina. It is also sometimes referred to as the mouth of the uterus. It has a ring of muscle to close it and also a mucus plug. During pregnancy, the mucus plug seals the cervix and prevents entry of harmful microorganisms into the uterus. The ring of muscles remains contracted to keep the baby in the uterus. During birth, the ring of muscles relaxes to allow the baby to pass through to the world.

The **vagina** is a muscular tube, leading from the cervix. It stretches during childbirth to allow the passage of the baby. The vagina opens to the outside through the vulva a (general name for the external genital organs.) copulatory organ as well as a passage for the baby during parturition.

The ovum

It is relatively large and round. It is made up of cytoplasm and nucleus surrounded by a membrane. The ovum is also surrounded by follicle cells.

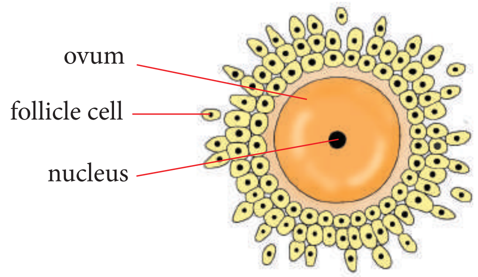


Fig 15.8: The structure of an ovum

The ovum is adapted to its function of being fertilised by the sperm and development of the zygote through:

- The egg cell is much bigger than the sperm.
- It has a chemical layer around the outside to stop more sperm getting in.
- It also contains one set of cytoplasm to survive on for the couple of hours it takes the egg cell to reach the womb and form the embryo

Self–evaluation Test 15.1

1. State the scientific terms that fit the following definitions.
   a) The sac of skin located outside the body wall in which the testes are located
   b) The tube with a funnel-like end in which the released ovum from the ovary enters
   c) The birth canal
2. Trace the pathway of sperm leaving the male reproductive system.
3. Using a table, compare the adaptive features of the sperm and ova.
4. With illustrations, give the structure of an ovum.

15.2. The menstrual cycle

Activity 15.2: Investigating the menstrual cycle

1. Using charts and computer animations:
   - Study the menstrual cycle.
   - Identify the stages involved.
2. Discuss the events involved in the stages and the interaction of hormones that control the menstrual cycle.
3. Present your work in class.

The facts

In the human female, a mature egg develops and is released from one of the ovaries every month. The average length of the **menstrual cycle** is 28 days. It can however be as short as 24 days or as long as 35 days. This cyclic event is known as the menstrual cycle. Before the release of the egg, the uterine lining becomes thick and is supplied with dense network of capillaries in preparation for implantation.

If fertilisation does not occur, the new uterus lining and the egg are discharged from the uterus. This is called **menstruation** or **period** and usually lasts for about five days. The first day of the menstrual period can be regarded as day 1 of the menstrual cycle. During this time, the endometrium is shed from the uterus through the cervix and vagina together with some blood. After this event, four other main events occur:

- The healing and repair of the uterine lining (endometrium) after menstruation.
- Ovulation - the release of ovum from Graafian follicle.
- Thickening of the uterine lining in preparation for implantation.
- Menstruation occurs again if fertilisation does not occur.

Role of hormones in the menstrual cycle

After the endometrium has been shed from the uterus, the pituitary gland releases the **Follicle-Stimulating Hormone (FSH)**. This hormone stimulates the development of follicles in the ovary. One of these follicles develops into a *Graafian follicle.* Each egg in the ovary becomes surrounded by a layer of cells called **follicle cells**. When the FSH is released, it causes one of these follicles to undergo some change. It forms a space, accumulates some liquid, increases in size to develop into a structure called a **Graafian follicle**.

The ovary secretes **oestrogen**. When the oestrogen level rises in the blood to a certain point, it causes two events.

(i) One is the growth and replacement of the uterine lining shed during the previous menstruation with new tissue. This helps repair the lining of the uterus.

(ii) The second effect of oestrogen is that at its highest level in the blood, it triggers the anterior pituitary gland to release **Luteinising Hormone (LH)**. The LH stimulates ovulation and the formation of the *corpus luteum*.

Ovulation is the release of the ovum from the ovary. The level of LH rapidly rises in the blood. It triggers the process of ovulation at about the 14th day of the cycle.

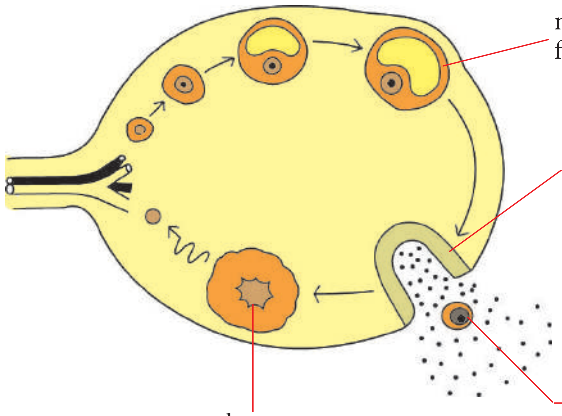


Fig 15.9: Growth of follicle and Ovulation

For ovulation to take place, a mature Graafian follicle moves to the surface of the ovary. It forms a bulge on the ovary surface.

The remaining part of graafian follicle after the release of ovum changes into a yellow body or a corpus luteum. The corpus luteum secretes relatively moderate levels of **oestrogen** and high levels of **progesterone**. The progesterone causes further thickening of the endometrium during which it is enriched with blood capillaries. This is in preparation for an embryo to be implanted. By this time the level of progesterone is quite high. This high level of progesterone inhibits further production of the FSH and also LH, from the pituitary gland. Less FSH means less oestrogen from the ovary, a low level of oestrogen will cause the pituitary gland to stop releasing LH.

The high levels of progestrone ensure that the thick endometrium layer in the uterus is maintained and no new follicle develops.

If the egg is not fertilised, the corpus luteum lasts for about 10 to 12 days and then it degenerates because the level of LH decreases in blood. The secretion of progesterone also stops.

The endometrium lining can no longer be maintained or protected so the capillaries break up and the endometrium is lost from the uterus with some blood.

The pituitary gland starts to secrete FSH again because the levels of progesterone go down. The pituitary gland is no longer inhibited to secrete FSH and the cycle repeats itself.

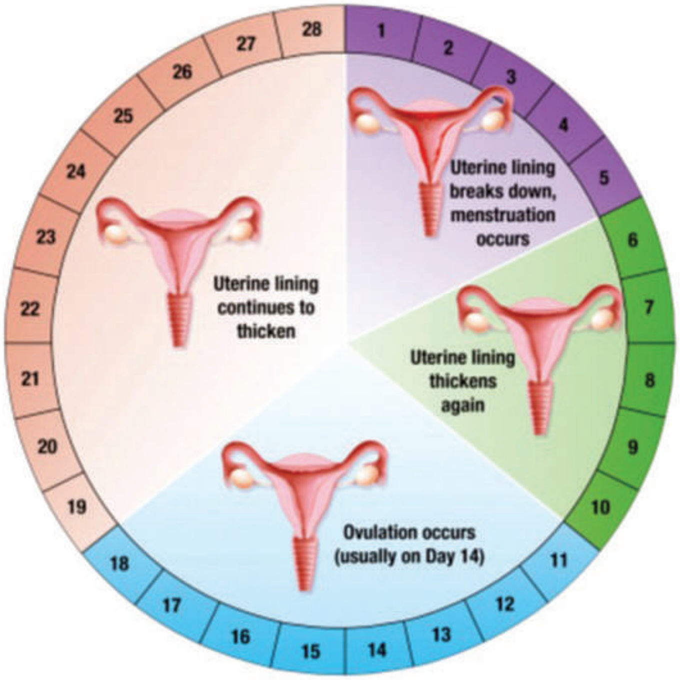


Fig 15.10: Menstruation cycle for 28 days

Self–evaluation Test 15.2

1. Explain why the uterine wall thickens and becomes spongy before ovulation.
2. On ovulation ___________.
   A. the egg is fertilised
   B. an egg is released from a mature follicle sac
   C. the egg enters the uterus
   D. menstruation begins
3. What is the importance of progesterone hormone inhibiting the secretion of FSH and LH?

15.3. Sex hormones

Activity 15.3: Discussion Activity

1. Using textbooks and the Internet, research about the roles of oestrogen and testosterone in the development of secondary sexual characteristic in females and males respectively.
2. Present your work to the rest of the class.

The facts

Hormones are chemicals secreted by special glands in the body called endocrine glands. These hormones are transported via the bloodstream to specific organs called target organs. The hormones cause specific effects in the target organs which coordinate various body activities. Hormones that influence sexually related changes in the body are called **sex hormones.** These hormones control:

- The entire process of reproduction from the development of the reproductive features at puberty to pregnancy and birth.
- The shedding of the (lining of the uterus) endometrium every month i.e. menstruation.

As a child develops to puberty (its onset on average is between 13 to 15 years in males and 12 to 13 years in females), other features develop that further distinguish adult females and males. These are known as the **secondary sexual characteristics**. Development of secondary sexual characteristics is controlled by sex hormones. There are three different organs that release these hormones. These are the **hypothalamus**, the **pituitary gland** and the **gonads**.

The hypothalamus secretes a hormone which is taken to the anterior pituitary gland. Here, it stimulates the release of **Follicle Stimulating Hormone (FSH)** in females and **Interstitial Cell Stimulating Hormone (ICSH)** in males.

These two hormones are chemically identical but have different names because they have different effects in males and females.

In females, FSH stimulates the ovaries to produce oestrogen and progesterone. Oestrogen is responsible for the development of the female secondary sexual characteristics. The ovaries start producing eggs and this leads to the first menstruation also known as **menarche**. At first, it is irregular and unpredictable. Within a year the hormone levels increase and monthly menstruation periods become more regular. In some people, pains may be experienced due to the progesterone hormone, which causes the uterine muscles to contract (muscle cramps).

In boys, the interstitial cell-stimulating hormone (ICSH) is taken to the interstitial cells in the testes.

It stimulates these cells to secrete testosterone which is responsible for the development of the male secondary sexual characteristics.

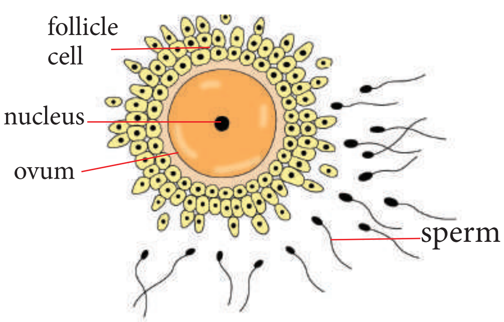
Self–evaluation Test 15.3

1. Give two functions of sex hormones.
2. What are secondary sexual characteristics?
3. Describe five secondary sexual characteristics in __________.
   - females
   - males

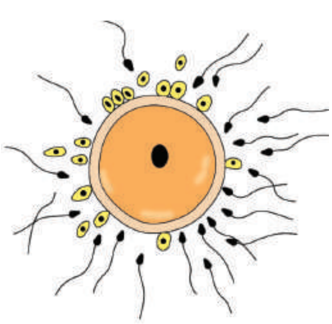
15.4. Fertilisation and implantation

Activity 15.4: Observing the process of fertilisation and implantation

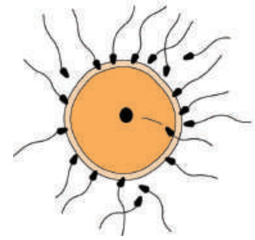
1. Using charts and computer animations,
   - Observe the process of fertilisation and implantation.
2. Discuss the functions of the umbilical cord, placenta, amniotic sac and amniotic fluid.



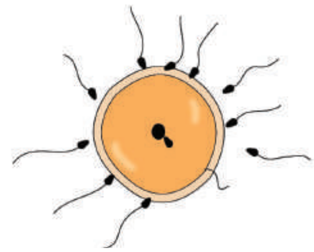
(i) Sperms meet ovum



(ii) Follicle cells dispersed



(iii) Sperm head penetrates egg membrane



(iv) Sperm and ovum nuclei fuse

Fig 15.11: The process of fertilisation

C**opulation** is the act of having sexual intercourse. It's mostly done when an erect penis is inserted into the vagina. Ejaculation is the time when semen (sperms and fluids) is delivered into the vagina at the end near the opening of the cervix. The sperms move towards the **fallopian tubes (oviduct).** Both tubes receive the sperms. Most of fertilisation takes place in the **oviduct.**

When sperms reach the egg, they are attracted toward it. Only one sperm enters the egg leaving the tail behind. The process of **fertilisation** starts as shown in Figure 15.11. Usually a sperm from a different species cannot enter the egg that's why usually two different species cannot produce younger ones.

After fertilization the egg becomes a zygote in the oviduct. Since gametes are **haploid (n)**, the zygote is **diploid(2n).** The cells of the zygote divide mitotically to form a ball of cells called **blastocyst** which is pushed forward towards the uterus. When it reaches the uterus, **implantation** occurs. Implantation is a very important stage of pregnancy.

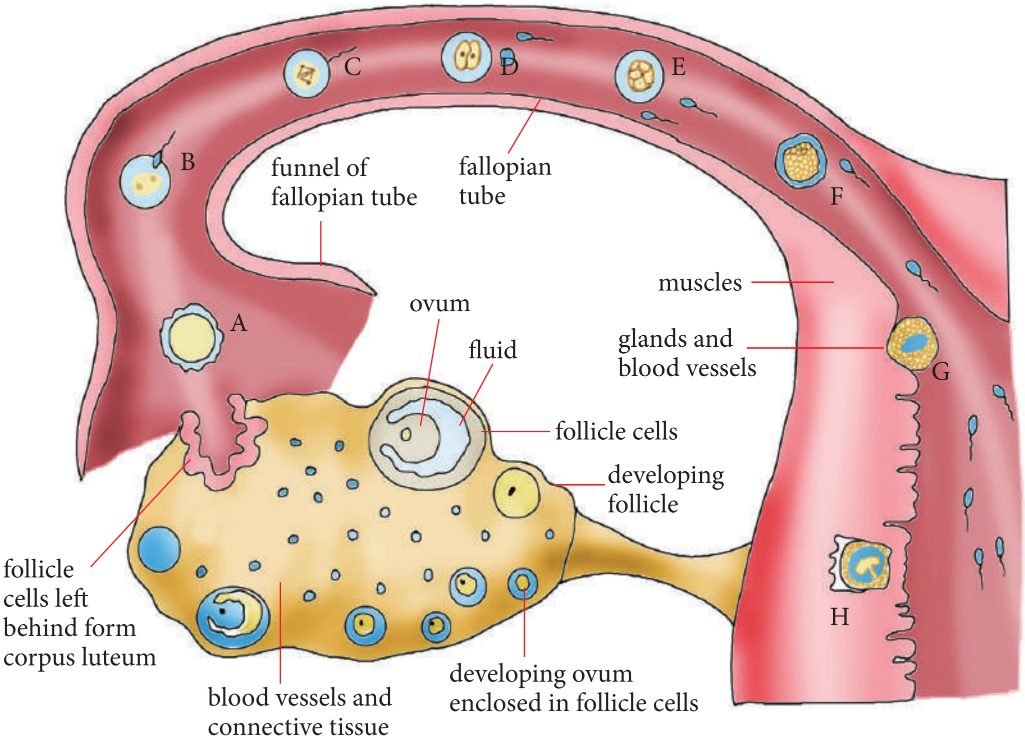


Fig 15.12: The process of fertilisation and implantation

KEY

A *— Ovum/secondary oocyte*

B *— Sperm penetrates ovum*

C *— Sperm nucleus fuses with ovum nucleus (fertilisation).*

D, E, F *— Cell division of zygote which produces a ball of cells (embryo).*

G, H *— The embryo digests its way into the uterus wall and becomes completely embedded.*

Following implantation, one part of the blastocyst develops into the embryo while the outer layer of cells of the blastocyst develops into three membranes; chorion, allantois and amnion. **Chorion** lines the endometrium and provides a surface for the exchange of substances between mother and foetus.

Amnion is a sac that develops from the embryo and envelops it. It becomes filled with the **amniotic fluid** which plays the following roles:

- Gives the foetus physical support allowing it to float and move around.
- Acts as a shock absorber protecting the foetus from mechanical injury.
- Lubricates the foetus and prevents it from dehydrating.

The **allantois** contributes to the formation of umbilical blood vessels which transport substances to and from the placenta. These membranes surround and protect the growing embryo until birth.

The villi on the outer surface of the chorion extend into the lining of the uterus and form an organ called the *placenta*. A rope-like structure called the **umbilical cord** forms and connects the developing foetus to the placenta. The amnion, being the innermost of the membranes completely surrounds the foetus like a balloon within a balloon.

A fluid called amniotic fluid fills up the amnion. It surrounds the foetus and keeps it moist, gives it a stable environment and cushions it from physical damage and shock.

The villi that develops from the blastocyst represent the beginning of the **placenta.** The placenta is made up of tissues and a large number of blood vessels. It has a disc like shape. The capillaries in the placenta unite to form a vein and two arteries which run in the umbilical cord from the placenta to the abdomen of the foetus.

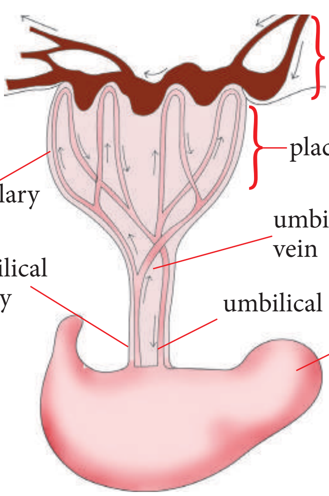


Fig 15.13: Placenta

The placenta forms the link between the circulatory systems of the foetus and the mother. It is made up of both foetal and maternal tissues and has a rich network of blood capillaries. The foetus is linked to the placenta by the umbilical cord which contains the umbilical artery and vein.

The placenta has **membranes** which separate the blood vessels of the mother and the foetus. These membranes are thin and hence allow dissolved oxygen, glucose and amino acids and salts in the mother's blood to diffuse into the blood vessel of the placenta. They also allow waste products such as carbon dioxide and nitrogenous wastes to pass from the placental blood vessels into the blood vessel of the mother.

Blood from the embryo is directed to the placenta capillaries through umbilical arteries. It has a high level of carbon dioxide and wastes like urea. Blood rich in nutrients and oxygen which have diffused into the placenta from the mothers' circulatory system are directed to the foetus through the umbilical vein.

- The membranes are selective in that they allow only certain materials to pass into the foetal circulation. In this way, they prevent some harmful materials from reaching the foetus.

Health check!

Substances such as drugs, alcohol and nicotine can pass through the placenta. Therefore, pregnant women are always advised not to take such harmful substances.

- Another role of the placenta is to produce hormones such as progesterone and oestrogen which assist in maintaining the pregnancy and preparing the body for birth.

Self –evaluation Test 15.4

1. What happens when fertilisation does not take place?
2. Only one sperm cell fertilises an ovum.
   (a) Why is this important?
   (b) How is it possible?
3. Suggest possible reasons that can hinder fertilisation.
4. Give three roles of placenta.

15.5. Pregnancy, ante-natal care and birth

Activity 15.5: Investigating the stages in the development of pregnancy

1. Using charts and computer animations, sequence the stages in the development of pregnancy.
2. Discuss the ante-natal care of a pregnant woman.
   - Is it okay for a pregnant woman to drink alcohol or smoke?
   - What takes place during birth?
3. Present your findings to the rest of the class.

The facts

Pregnancy is also known as **gestation period.** This is the period within which the embryo grows and develops into a human being. In human beings, pregnancy lasts 38–40 weeks. During this period, the foetus develops as it is nourished by the mother through the placenta.

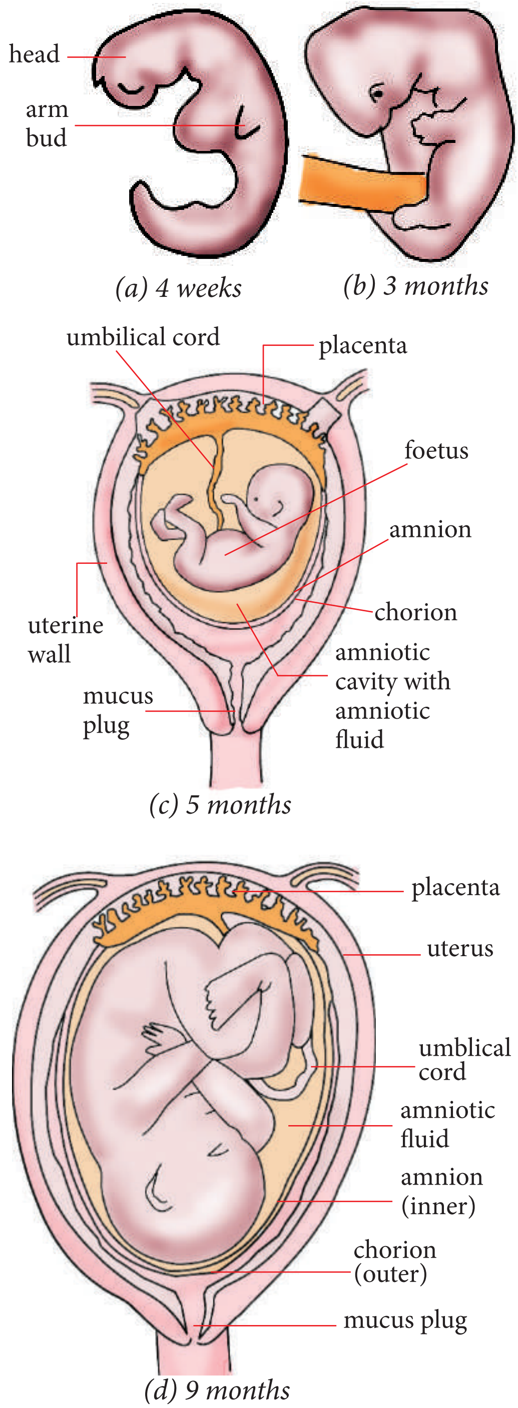


Fig 15.14: Stages of foetal development during pregnancy

During foetal development the following structural changes occur. The nervous system: the brain and spinal cord start to develop at the third week. The rhythmic contractions of the heart begin by end of week four as well as the circulation of blood. By around the seventh week, the brain starts to function.

Other vital organs like the kidneys, stomach and the liver become functional at eight weeks and the embryo is now referred to as a **foetus**. The genitals start to develop by the fourth month. From the sixth month, the foetus increases rapidly in size and by the 40th week the baby is fully formed and can be born.

Ante-natal care

Antenatal care is the care received from healthcare professionals during pregnancy. A pregnant woman should take extra care of her health for her benefit and that of the baby.

Her diet should have plenty of iron which is needed for the formation of haemoglobin. This is necessary to supply oxygen and nutrients to the placenta. She should also take plenty of calcium to be used in the formation of bones by the foetus.

- Name foods that contain iron and calcium that a pregnant mother should take.

Pregnant mothers should seek immediate medical attention in case of sickness. They should avoid getting some diseases like *Rubella* which could lead to disabilities and deafness of the foetus. Malaria is also a threat to pregnant women. They should sleep under treated mosquito nets always. Pregnant mothers are advised to attend ante-natal clinics without fail.

Pregnant women should also avoid certain types of clothes, for example, wearing high heeled shoes which could cause her to fall and tight clothes. They should do light exercises like walking.

Pregnant women should avoid taking alcohol and smoking cigarettes since they harm the foetus and can result to giving birth to underweight babies or a miscarriage.

Birth

Before a baby is born, it normally turns upside down with its head just above the cervix. The process of birth begins with labour. The amnion ruptures and the amniotic fluid passes out through the vagina. The uterine contractions become stronger and more frequent and the cervix dilates to let the baby's head pass through. The uterine contractions and the contractions of the abdomen together expel the baby out through the cervix and vagina.

The umbilical cord is then tied in two places and cut. After some time the placenta, which is also called the "after-birth", is also expelled from the uterus.

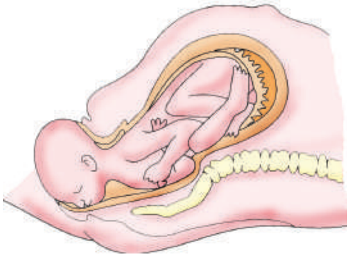


Fig 15.15: The process of birth

Advantages of breastfeeding to a baby

- Nutrition: Breast milk is the ideal food for a baby. It is nutritionally balanced, with the perfect amount of proteins, carbohydrates, fats, vitamins and iron to help the baby to grow.

- Boosting immunity: The baby receives the mother's antibodies to help it fight infection.
- Less likelihood that the baby suffers constipation and diarrhoea.
- More protection against gastroenteritis, childhood diabetes, allergies like eczema and chest and ear infections.

Advantages of breast feeding to the mother

- Convenience: There is no need to get up in the night to sterilize bottles. Breast milk is always at the right temperature, is available immediately, is easy for the baby to digest, contains all the nutrients the baby needs and is free.
- Reduction in the risk of the mother contracting early breast or ovarian cancer.
- A speedier return to the pre-pregnancy figure for the mother as breastfeeding helps the womb to contract and also burns up calories.

Self–evaluation Test 15.5

1. Give one general term for the following:
   a) The length of pregnancy
   b) The lining of the uterus with smooth muscles
2. Select substances that pass from the mother's blood to the foetus.
   Oxygen, carbon dioxide, drugs and nutrients
3. The umbilical vein carries ______ blood. (Deoxygenated or oxygenated)
4. State the function of amniotic fluid.
5. Name some of the things that pregnant mothers should avoid.
6. With illustrations, give stages of foetal development during pregnancy.

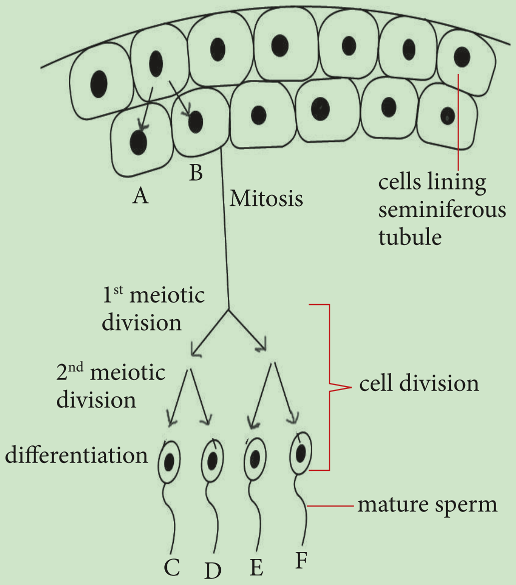
Unit summary

- Humans, like other animals exhibit sexual reproduction. Fertilisation is internal and the young one is carried to term and born at the end of gestation.
- The male and female reproductive systems are suited to their functions.
- The male reproductive system is made up of testis, scrotum, sperm ducts, prostate gland, urethra and penis.
- The female reproductive system is made up of the ovaries, oviducts, uterus, cervix and vagina.
- The process of gamete formation takes place in the gonads; i .e. male and female gametes fuse to form a zygote which is diploid through a process called fertilisation.
- An ovum released periodically in a female in what is termed as the menstrual cycle which is accompanied with shedding of blood from the vagina; a process called menstruation.

- The zygote undergoes mitosis resulting in formation of a blastocyst that embeds into the uterine wall.
- A placenta which is derived from both the mother and fetal tissue forms at the site of implantation and persists till the end of gestation period.
- By the end of gestation, that is after about 40 weeks, the fetus is fully formed and is born.

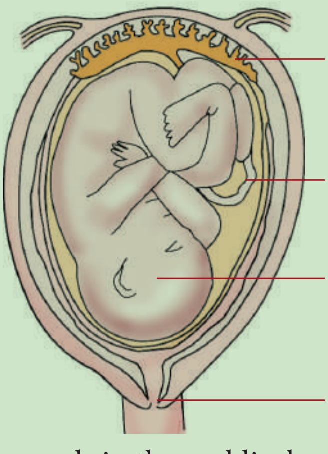
End Unit Assessment 15

1. Which one of the following is the correct order of the events?
   A. Fertilisation-implantation-ovulation
   B. Ovulation-fertilisation-implantation
   C. Implantation-ovulation-fertilisation
   D. Fertilisation-ovulation-implantation
2. In human beings, fertilisation takes place in the___________.
   A. vagina
   B. oviduct
   C. uterus
   D. cervix
3. If the menstruation cycle occurs on days 4 to 9 of the month, what would be the date of ovulation in a menstrual cycle of 28 days?
   A. 17th
   B. 12st
   C. 14th
   D. 28th
4. Shortly after an egg is fertilised the product is known as__________.
5. Contraction of the uterus before and after birth is brought about by the means of hormone produced by the posterior lobe of the pituitary gland called________.
6. Differentiate between spermatogenesis and oogenesis.
7. State the functions of the following structures______________.
   a) placenta
   b) vas deferens
   c) epididymis
   d) prostate gland
8. What is the role of Cowper's gland in the male reproductive system?
9. State three adaptations of the fallopian tube to its function.
10. State what happens to each of the following during the birth of a baby.
    (a) Muscles in the uterus
    (b) The cervix
    (c) Placenta
11. The following are events that occur in the reproductive cycle of a human female. Arrange them in their correct order of occurrence.
    (i) Growth of follicle
    (ii) Menstruation
    (iii) Ovulation
12. The following diagram illustrates the process of sperm formation in mammalian testes.



(a) Explain why cells A and B are genetically identical.
(b) Describe one way in which cell division leads to cells C and D being genetically different.
(c) Give structural differences between sperms and ova.
(d) In what way does the zygote differ from the cells A, B, C and D?
(e) (i) Why are the mammalian testes located outside the body?
(ii) Name the structure in which they are located.

13. Study the following illustration and answer the questions that follow.



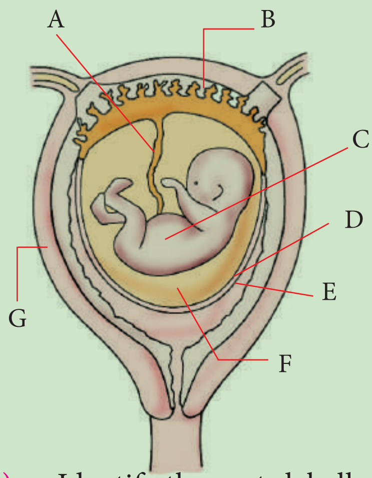
(a) Name the blood vessels in the umblical cord.
(b) How does the composition of blood vary or differ in these two blood vessels?
(c) Name the fluid that surrounds the embryo.
(d) If the embryo's lungs are also filled with this fluid, why does it not suffocate?

(e) Describe how substances are exchanged across the placenta between the mother's blood and the foetus' blood.
(f) One of the first signs of pregnancy is that the menstrual period stops. Explain why you would expect this.
(g) Which hormone maintains the thickened lining of the uterus during pregnancy?

14. Fill the table below

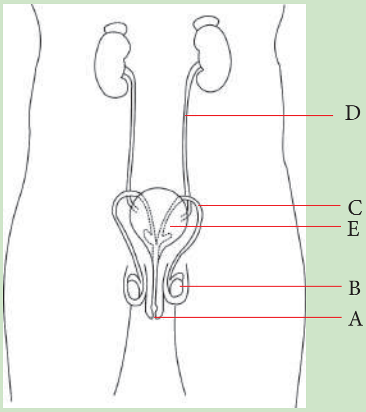
Hormone	Site of production	Effect
FSH	Anterior lobe of pituitary gland	
	Ovary	Repair of uterine lining
	Anterior lobe of pituitary gland	Ovulation
Progesterone		Ovulation and maintenance of uterine lining

15. The diagram below shows a foetus in the uterus.



a) Identify the parts labelled A, B,C,D,E,F and G.
b) Briefly explain the functions of the amniotic fluid during the development of the foetus.
c) Which hormone is produced by part B?
d) What is the role of the hormone you mentioned in (c) above?

16. The diagram below shows the urogenital system.



a) Name the parts label A, B,C,D and E.
b) Where are sperms produced?
c) Name the hormone produced in part B.
d) In which part is urine formed?
e) Which parts are not associated with the reproductive system?

Unit 16 Social factors that affect good health

Key unit competence

After studying this unit, I should be able to:

- Describe social factors that affect good health.
- Apply the information gained in familiar and unfamiliar contexts.

Learning objectives

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

- Describe factors that affect good health.
- Define a drug and carry out research on common drugs.
- Describe the uses of antibiotics for the treatment of bacterial infections.
- Describe the effect of excessive alcohol and marijuana consumption.
- Demonstrate factors that affect good health.
- Appreciate the organisation and function of public health service.
- Campaign against drug and substance abuse.

Introductory Activity

Have you ever asked yourself why it is important to practise healthy habits? Look at the pictures below.


A


B


C

Fig 16.1: Different practices

Which situation provides an environment that can promote good health? Why? Based on your answers, what do you think this unit is about?

Introduction

Social factors are things and experiences that influence our personality, attitudes and lifestyle. Social factors include things like religion, family, physical status, economic status, education, location, life partners, children and political systems.

16.1: Study the photograph below

Fig 16.2: A sick child in hospital

Use the diagram above to answer the following questions.

1. State the health status of the person in the diagram.
2. Outline factors that might have led the person to be in such state.
3. What could be done to correct the condition identified in 1 above?

Good health on the other hand is a state in which a person's body is able to function normally both mentally and physically. Good health is therefore important in living a full and satisfying life.

16.1. Factors that affect good health

Activity 16.2: Research Activity

1. Carry out a research on factors that affect good health.
   - How is good health related to good housing, food inspection, clean water and hygiene?
2. Present your findings to the class.

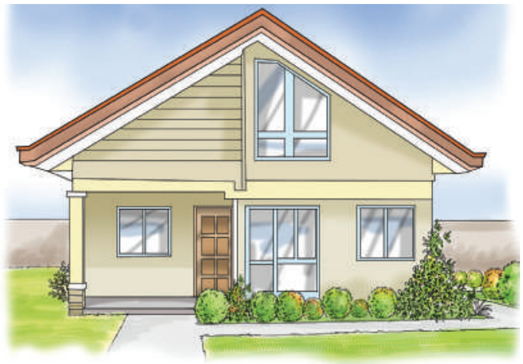
The facts

Good health is not lack of sickness. When you are healthy, you enjoy many benefits. Good health enables one to express full potential within the environment in which one is living. Good health is influenced by several factors such as good housing, safe food, clean water and hygiene. All these factors together contribute to a healthy individual.

Good housing

Good housing is a house with proper ventilation; has enough room, has no health hazards and is warm. Therefore it improves life quality by reducing stress, mental problems and diseases. The community benefits by having a healthy population that is progressing.

Housing is an important social determinant of health. Poor housing is associated with health conditions such as respiratory diseases, injuries and poor mental health. Poor housing has an ineffective waste disposal system and is a fertile breeding ground for vectors such as rats, mites and insects. All



(a)

(b)

Fig 16.3: (a) Good housing vs. (b) poor housing

these contribute to spread of infectious diseases. Damp, cold and mouldy housing is linked to chronic respiratory infections such as asthma.

Poor housing is also associated with depression, anxiety, injuries and deaths from accidents and fires. Lack of good space causes congestion, accumulation of dirt, dust and smoke which may cause skin and eye irritation.

Food inspection

Food meant for human consumption must be safe to prevent contraction of diseases. All food must be inspected to ensure that it is clean, fresh and free from microorganisms that cause diseases.

Meat sold in butcheries must be inspected and stamped to verify to the public that the meat is safe for human consumption.

Fig 16.4: Veterinary doctor inspecting meat

Fact of life: Dead animals should never be consumed.

Everyone should ensure that the food they consume is healthy and germ free. When buying food, check for expiry date. Also food should be properly stored to prevent attracting harmful microorganisms.

Clean water

Water is a necessity to all organisms. Human beings need clean and safe water daily. Water is used for drinking, cooking and cleaning. Apart from personal hygiene, water is very useful in food production.

Clean water is water that is free from contamination and is safe enough for drinking and cooking.

Fig 16.5: Boiling drinking water to kill germs

Contamination of water could lead to transmission of waterborne diseases such as cholera and typhoid. Lack of access to clean and safe water contributes to increase in levels of poverty in a society. Many people walk long distances to search for water, wasting time for other economic activities.

To ensure that the quality of drinking water is maintained, contamination of water at the source should be prevented; both on the surface and the ground.

Hygiene

Hygiene involves all practices that bring about safe and healthy environment that prevents diseases through cleanliness. Hygiene is involved with the preservation of health. Whatever is considered hygienic however may vary between different cultures, gender and other groups.

Keeping the environment and our body clean is an effective form of hygiene that keeps away disease causing microorganisms. Another form of hygiene is washing one's hands that helps to prevent the spread of infectious diseases.

Fig 16.6: Washing hands is hygienic

Self–evaluation Test 16.1

1. Why is personal hygiene important?
2. What is the reason for drying your hands after washing them?
3. Which of the following is true about bacteria?
   - A. Bacteria multiply and grow faster in warm environments.
   - B. Bacteria need air to survive.
   - C. Every type of bacteria can give people food poisoning.
   - D. By freezing food you can kill bacteria.

16.2. Public health services

Activity 16.3: Interactive talk

1. Design a questionnaire involving the following questions.
   - How is the public health services system organised in Rwanda?
   - What are the functions of public health system in Rwanda?
2. Write a report and present it to the teacher for assessment.

The facts

Public health services are measures that help to: prevent disease, prolong life and promote health of a community. It aims to protect and improve the health and well-being of all populations.

Public health service officers are involved in:

- Assessing health of communities and populations at risk.
- Designing policies.
- Ensuring that people have access to appropriate and affordable care for health and disease prevention services.

To improve public health services, campaigns are done on: provision of safe drinking water, safe healthy foods, safer working place and vaccination and control of infectious diseases.

Fig 16.7: Vaccination during a disease outbreak

Organisation of public health services

Public health services have broad functions, they are therefore organised into levels. This allows for efficient provision of health care services. These levels of organisation may include:

- Public health agencies
- Public safety bodies
- Healthcare providers
- Environment agencies
- Humanitarian agencies and charity organisations

Function of public health services

Public health services work to protect citizens from:

(i) Public and environmental health hazards.

(ii) Prevent and reduce chronic diseases and injuries.

(iii) Respond to health emergencies or disease out-breaks like cholera and flu pandemics.

(iv) Promote good health habits within the community.

Self –evaluation Test 16.2

1. Public health services are given free of charge. Is this statement true or false?
2. Public health is involved in ________________ (providing home care to sick people who are not confined in the hospital or preventive not curative service)

16.3. Drugs

Drugs are substances that influence the physiological processes and affect normal body functions when taken. Human beings have always used drugs to cure diseases or heal wounds. Drugs are administered by medical practitioners to treat diseases. An example of the medicinal drug is an antibiotic that is used to treat bacterial infections. Others include painkillers, antiseptics, antifungal and many others.

Individuals at times use drugs that have not been prescribed by a medical practitioner. Drugs have a devastating impact on people's health and social life especially the youth. Most commonly abused drugs include antibiotics, alcohol, tobacco and marijuana.

Antibiotics

Activity 16.4: Visit to a health centre

Visit a local health facility. Engage the medical officer in charge on use and misuse of drugs.

1. Design a questionnaire involving the following questions.
   - What is antibiotics resistance? What causes it and how can it be prevented?
   - Which drugs are commonly abused in our society?
   - What are the effects of drug and substance abuse?
2. Take notes during the presentation.
3. Make a summary from your notes.

The facts

Antibiotics are medicines used to treat or prevent infections or diseases caused by bacteria, for example, respiratory tract infections such as pneumonia. Antibiotics are used for a range of other infections caused by bacteria, including urinary tract infections, skin infections and infected wounds.

Fig 16.8: Examples of antibiotic drugs

Antibiotics work by blocking vital processes in bacteria, killing the bacteria or stopping them from multiplying. This helps the body's natural immune system to fight the bacterial infection.

Antibiotics differ in the types of bacteria they work against. Antibiotics that affect a wide range of bacteria are called **broad spectrum antibiotics**, for example, amoxycillin and gentamycin.

Antibiotics that affect only a few types of bacteria are called **narrow spectrum antibiotics** such as penicilin.

Penicillin which is an antibiotic made by fungus *Penicillium* was the first antibiotic to be discovered by Alexander Fleming et al.

Different types of antibiotics work in different ways, for example, penicillin destroys bacterial cell walls while other antibiotics can affect the way the bacterial cell works.

The discovery of antibiotics brought about tremendous effect in the ability to treat bacterial infections. However, because they have been overused, many antibiotics are no longer effective against the bacteria they once killed.

Resistance of bacteria to antibiotics

Antibiotic resistance happens when bacteria change to protect themselves from an antibiotic. They are then no longer sensitive to that antibiotic. Antibiotics that previously killed bacteria or stopped them from multiplying no longer work. The more antibiotics are used, the more chances bacteria have to become resistant to them. Major causes of antibiotic resistance include:

- Using antibiotics when they are not needed.
- Not taking antibiotics at the doses and times that a doctor prescribes. This allows time for the bacteria in your system to become resistant.

  Antibiotics are also often overused in animals. An antibiotic-resistant bacterial infection could lead to:

  - Having complications of the infection.
  - Remaining infectious for longer and pass the infection to other people.

This is dangerous for tuberculosis (TB) cases.

Health check!

Antibiotics will neither cure a cold or flu nor help shorten the illness. Most respiratory tract infections are caused by viruses; therefore antibiotics will not have any effect.

Fact of life: Viruses have no cell walls hence antibiotics cannot harm them.

Mutant bacteria are advantaged over the other bacteria and go on reproducing more bacteria of the same kind. Eventually a large population of antibiotic-resistant bacteria is produced. Use of the same type of antibiotic would therefore not treat the bacterial infection. An example is *Staphylococcus aureus* (also known as staph) a common type of bacteria. It is often carried on the skin and inside the nostrils and throat. It can cause mild infections of the skin, such as boils.

These bacteria have become resistant to many different antibiotics. It is therefore known as Methicillin-Resistant Staphylococcus Aureusis (MRSA). MRSA bacteria are usually spread through skin-to-skin contact with someone who has an MRSA infection or has the bacteria living on their skin. MRSA infections can be more difficult to treat than other bacterial infections. It is sometimes known as the **super bug**.

To reduce the risk of becoming infected with MRSA, do the following:

- Wash hands frequently, especially after using the toilet and before and after eating.
- Maintain good hygiene and sanitation.
- When infected, complete the dosage prescribed by the doctor.

Effect of excessive use of alcohol, tobacco and marijuana.

Activity 16.5: Research Activity

Using pamphlets, textbooks and the internet:

1. Carry out research on drugs such as alcohol, marijuana and tobacco.
    - How do these drugs affect the health of a person?
    - Describe the effects of addiction to these drugs
2. Present your findings for assessment.

The facts

Drug abuse or **misuse** refers to the usage of drugs in a way that is harmful to the body. Drug misuse or abuse is commonly associated with use of prescription medication to cause stimulation, mood alteration or intoxication. Some drugs can change a person's body or brain in ways that can last for long or permanently even after stopping the use of the drug.

When a drug user cannot stop taking a drug even if he wants to stop, it is called **addiction**. People with an addiction do not have control over what they are doing, taking or using. Their addiction may reach a point at which it is harmful. Some of the drugs that are mostly abused include prescription drugs (for example antibiotics), alcohol, marijuana and tobacco.

Alcohol

Alcohol is a liquid that forms the intoxicating constituent of wine, beer, spirits and other drinks. It is also used as an industrial solvent and as fuel. Alcohol abuse is defined as a pattern of drinking that can lead to alcoholism.

When a person drinks beer, wine, or other alcoholic drink, the alcohol quickly enters the bloodstream and is then carried throughout the body. affecting the brain and other tissues, until it is completely metabolised. The alcohol gets broken down in the liver through metabolism.

Fig 16.9: Effects of alcoholism

Drinking too much alcohol affects many parts of the body. It can be harmful especially to the liver, the organ that metabolises (breaks down) alcohol and other harmful substances. People who drink heavily for a long time can develop diseases such as liver inflammation (alcoholic hepatitis) or severe liver scarring (cirrhosis). Alcohol-related liver disease can cause death.

Alcohol not broken down by the liver goes to the rest of the body, including the brain. Alcohol can affect parts of the brain that control movement, speech, judgement and memory. These effects lead to the familiar signs of drunkardness: difficulty walking, slurred speech, memory lapses and impulsive behaviour. Long-term heavy drinking can shrink the frontal lobes of the brain, which impairs thinking skills. Excessive consumption of alcohol is linked to cancer of the mouth, throat and breasts.

Fig 16.10: Stop alcohol and drug abuse

Tobacco

Cigarette smoking is the most popular method of using tobacco; however, many people also use smokeless tobacco products, such as snuffing and chewing. These smokeless products also contain nicotine, as well as many toxic chemicals.

Cigarette smoking poses danger for both smokers and non-smokers; this is a public health concern. A non-smoker inhales smoke exhaled by a smoker and is even at higher risk from the harmful effects.

Health check!

In most countries, cigarette smoking in public places is now banned.

Parents should also not smoke in the house or near their children.

Fig 16.11: No Smoking sign

Cigarettes contain nicotine, tar and carbon monoxide. Each of these components has a different effect on the body. It also contains other chemical substances that are carcinogenic that may result to throat, lung cancer among others.

Effects of Tobacco

(i) Carbon monoxide is a poisonous gas that binds with haemoglobin in the red blood cells preventing transportation of oxygen. In pregnant women it may pass through the placenta and find its way to the foetus hindering its normal growth.

(ii) Carbon particles in cigarette smoke enter the lungs and trigger the action of white blood cells to try and eliminate them. In the process, white blood cells produce some chemicals which end up damaging the lungs resulting to **chronic obstructive pulmonary disease (COPD).** The walls of the alveoli become thin and break down thereby decreasing the surface area over which gaseous exchange takes place. This result in a condition called **emphysema**. A person would therefore not get enough oxygen into their blood.

(iii) Nicotine is a stimulant which affects the brain causing a person to be more alert. It is addictive and for this reason, smokers find it difficult to give up smoking.

(iv) Smoking also greatly increases the chances of one developing coronary heart disease where coronary arteries are blocked.

Marijuana

Marijuana *(Cannabis sativa)* it is also known as pot, Indian hemp, grass, among many other names. It contains chemical compounds including cannabinoids that produce a variety of effects in the body. Its leaves and flowers can be smoked or eaten in food such as baked cookies. When smoked, the short term effects are manifested within seconds.

The feelings produced in individuals vary from anxiety, euphoria, feeling of well-being, increased sexuality, relaxation and paranoia.

Fig 16.12: Marijuana (Cannabis sativa)

Excessive use of marijuana may lead to:

(i) Decreased concentration associated with difficulty in thinking and learning.

(ii) Irritation of the lungs with increased risk of developing chronic bronchitis and cancer of the respiratory tract.

(iii) Decreased sex- drive in some individuals, low sperm count in males and irregular periods in females.

(iv) Intake of **Cannabis** in large amounts induces hallucinations.

Did you know?

Some individuals can mix drinks with drugs or even bake **Cannabis** in cookies and cakes. Therefore, do not buy or accept food from individuals unknown by your parents or the school authorities.

Self–evaluation Test 16.3

1. Why is cigarette smoking a public health concern?
2. What are the effects of drinking alcohol in the body?

Activity 16.6: Discussion Activity

1. Find out the answers for the following questions:
   - Identify the socio-economic problems associated with drug abuse?
   - How can you avoid drug abuse?
2. Make a report on your findings.

Unit summary

- Good health is the relative state in which the body is able to function well physically, mentally, emotionally and spiritually such that an individual is able to reach their full potential in the environment they are in.
- Good health is affected by: good housing, food inspection, clean water and hygiene.
- Drugs are substances that alter the chemical reactions in the body when taken.
- Medicinal drugs such as antibiotics are used to treat diseases. Antibiotics do not kill viruses because viruses lack cell walls.
- Antibiotics should not be taken too often to avoid developing resistance by bacteria.
- Drug abuse may result in damage of the body and produce changes that could last for a very long time or permanently.

End Unit Assessment 16

1. What is the single most effective way to prevent the transmission of disease?
   A. Antibiotics
   B. Hand washing with water only
   C. Hand washing with soap and water
   D. No way
2. How can you tell if food has enough bacteria to cause food poisoning?
   A. It will smell.
   B. You cannot, it will appear normal.
   C. It will have a different colour.
   D. It will taste different.
3. Which one of the following is a waterborne disease?
   A. Influenza
   B. Small pox
   C. Malaria
   D. Cholera
4. The major illness caused due to lack of sanitation facilities is __________.
5. i) In your opinion, is moderate consumption of alcohol okay?
   ii) Which organ does heavy drinking affect? Give a reason for your answer.
   iii) How can alcoholics be rehabilitated and integrated back into the society?
6. Give reasons as to why access to safe drinking water is important.
7. a) What do you understand by the term hygiene?
   b) How does poor hygiene affect your work?
8. John was diagnosed with tuberculosis (TB). He was given medication, which he never completed as prescribed by the doctor. Once he felt better he abandoned the medication altogether. After several months he was critically ill, upon examination it was found out that he had to be given several drugs to help him combat the disease.
   i) Why is it important to complete your medication?

ii) What form of TB was John suffering from?
iii) What are the signs and symptoms of TB?
iv) Why are viruses not affected by antibiotics?

9. Discuss factors that can hinder someone from having good health.
10. What are the roles of a public health worker in the community?

Unit 17 Decision-making regarding sexual relationships

Key unit competence

After studying this unit, I should be able to identify potential legal, social and health consequences of sexual decision-making.

Learning objectives

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

- Identify a range of risk reduction strategies for effectiveness and personal preference.
- Analyse factors that affect sexual decision making.
- Demonstrate communication and decision making skills in relation to safe sex.
- Show resilience against engaging in unsafe sexual practices.

Introductory activity

What factors will affect your decision regarding a sexual relationship? Is it your friends, peers or what you watch or listen to? When faced with a sexual decision of a kind, what would your answer be?

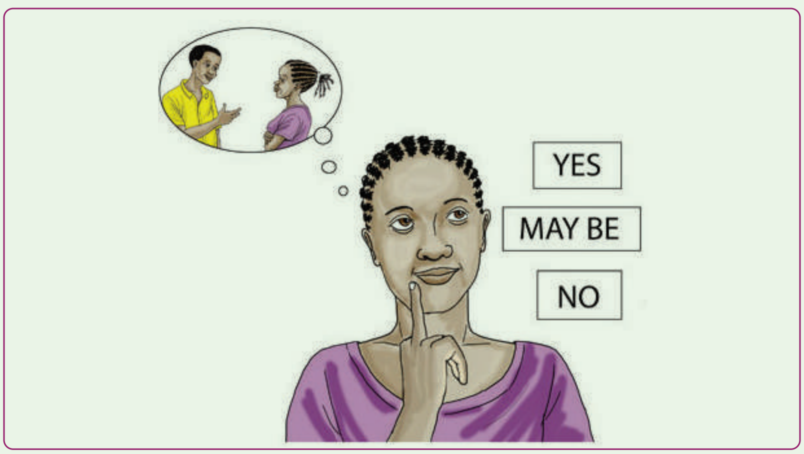


Fig 17.1: Possible options when making a decision regarding sexual relationship

What would influence that decision? How would you know it is the right or wrong decision you made? Answer the questions above then think about what this unit is likely to cover.

Introduction

We learn about sex and sexuality in many different ways. For instance, we can learn about it from peers, family members, teachers and friends. We also get information about sex and sexuality through several outlets such as media, by listening to radio and watching TV programmes or through social media.

Some of these messages may be empowering but others may be offending and destructive. We should therefore be able to make the right sexual decisions at all times. This topic is about what you should do in order to make proper decisions which will be of help in the rest of your life.

17.1. Factors hindering practice of safe sex

Activity 17.1: Discussion Activity

1. Share difficult situations relating to sexual relationships.
2. Use the following questions as guidelines during the discussion.
   - What is safe sex?
   - Which factors hinder practice of safer sex?
   - How do you make the right sexual decisions when faced with many conflicting information about sex?
   - Identify risk reduction strategies for safer sex and personal preference.
3. Present your work to the rest of the class.

The facts

Safe sex is defined as a sexual activity by people who have taken precautions to protect themselves against sexually transmitted infections (STIs) such as HIV and AIDS. Sexual contact that does not involve the exchange of semen, vaginal fluids or blood between partners is considered to be safe sex.

Safe sex practices reduce the risk of transmitting STIs but do not completely eliminate the risk of contracting the diseases. Safe sex is effective in reducing sexually transmitted infections only if both partners agree to it. Unsafe sex may put you or your partner at risk of STIs such as chlamydia, gonorrhoea, syphilis, HIV and AIDS, hepatitis B or may result in an unplanned pregnancy.

There are however several challenges that hinder the practice of safe sex including peer pressure, alcohol and drug abuse, misleading information, sex for financial gain and ignorance.

(a) Peer pressure

This is the influence of a group (usually an age group or social group) on an individual. A person might feel pressured to do something just because others are doing it (or say they are). Peer pressure can influence a person to do something that is relatively harmless or something that has more serious consequences.

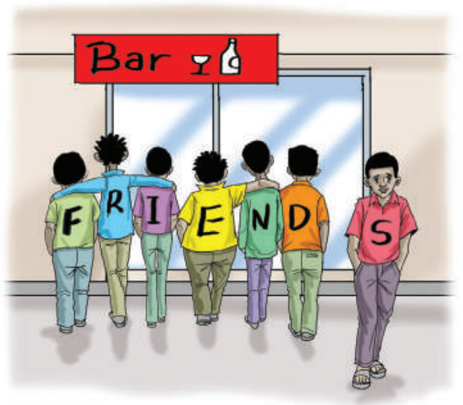


Fig 17.2: Saying no to peer pressure

Teenagers are at higher risk of peer pressure influence than adults especially during adolescence. Peer influence is mostly associated with conformity especially to style, appearance, ideologies and values. Association with a group of friends who engage in risky sexual behaviour possess a great challenge to the practice of safe sex. In addition, the need to feel accepted by the group may compromise the use of protection if the partner demanded otherwise.

(b) Alcohol and drug abuse

The use of alcohol or drugs affects an individual's perception, thinking and ability to make the right choice. When faced with the need to make a decision regarding safe sex by using protection during intercourse, a person under the influence of alcohol or other substance may make irrational decisions and engage in unprotected sex.

(c) Misleading information

The information spreading amongst the youth about safe sex is misleading. The notion that having sex without protection is more pleasurable also hinders the practice of safe sex. Other people are misinformed by individuals who pass the information that use of contraceptives to prevent pregnancies may also protect against contracting of STIs and HIV and AIDS. This information is very wrong and misleading and increases transmission of STIs including HIV and AIDS.

In addition some people believe that oral sex is safe. This is a misconception since either of the parties involved may come in contact with infected body fluids if they have open wounds in the mouth.

(d) Practice of sex for financial gain

Individuals who engage in prostitution are always faced with the challenge of unprotected sex if the partner in question demanded so. Since money is more important to them, then the person might decide to give in and have unprotected sex.

(e) Ignorance

Most people especially teenagers lack the knowledge on ways to practise safe sex. Others who are not learned may not understand information on posters, radio or television promoting the practice of safe sex.

Activity 17.2: Constructing word webs

1. Suggest words or phrases regarding decision making in sexual relationships.
2. Use the suggested words to make a word web like the one shown below.

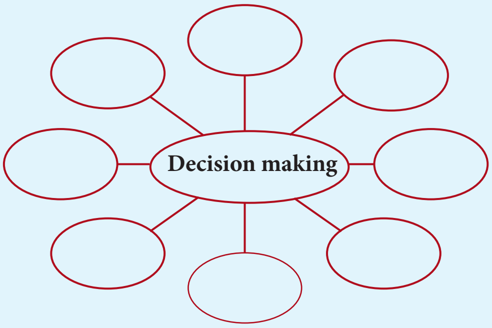


Fig 17.3: An example of a word web diagram

Self–evaluation Test 17.1

1. Write true or false for the following statements.
   a) You cannot get pregnant during menses.
   b) Oral sex is safe sex.
   c) Pulling out (withdrawing) before ejaculating is safe.
2. What social factors influence sexual decision making?

17.2. Strategies for dual protection against both unplanned pregnancies and STIs, including HIV

Activity 17.3: Role play

1. With your friends, practise a short play on effective communication in difficult situations to minimise transmission of STIs and HIV and unwanted pregnancies.

Activity 17.4: Discussion Activity

1. Discuss the following questions:
   - Meaning of dual protection against STIs and HIV.
   - Means of protection against unwanted pregnancies that does not protect one against STIs and HIV.
2. Present your work for assessment.

The facts

Dual protection refers to the use of methods which will prevent both unwanted pregnancy and STIs including HIV and AIDS during sexual intercourse.

Contraceptives are effectively used to prevent unwanted pregnancies. The contraceptive methods include, abstinence, sterilisation, norplant, injection, oral contraceptive pill, IUD, male condom with spermicide, female condom, diaphragm or cervical cap, vaginal spermicide alone and natural family planning.

However, to protect against the transmission of HIV and STIs the following methods are effective: abstinence, non-penetrative sex, long-term mutual monogamy with HIV testing, male condom with spermicide, male condom, female condom, diaphragm and cervical cap and vaginal spermicide alone.

Dual protection may be achieved through either the use of a barrier method such as a male or female condom together with another contraceptive method or through the use of the male or female condom alone.

The male condom is the most common device that is used for dual protection. The female condoms are effective as well. The male condom covers the penis during sexual activity, hence if used correctly, this barrier method protects against transmission of STIs and HIV and AIDS as well as reducing the risk of unwanted pregnancies. The female condom can also offer dual protection against unwanted pregnancies and transmission of STIs and HIV if used properly.

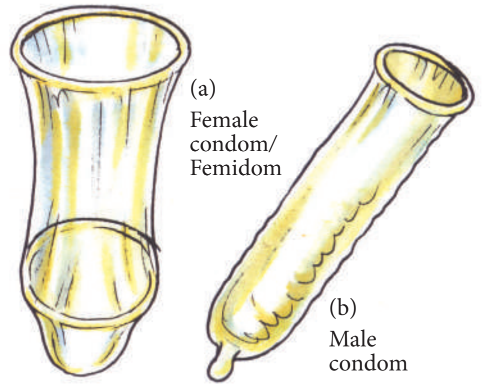


Fig 17.4: Types of condoms

Contraceptives alone cannot be used for dual protection since they do not offer protection against STIs including HIV and AIDS and unwanted pregnancies. Contraceptive may however be used as a means of dual protection if partners enter a monogamous union, get tested to ensure that none of them is infected with STIs or HIV.

The use of condoms may be effective in preventing transmission of STIs and unwanted pregnancies but they are not 100% effective. This is due to:

- Sex using a condom may still spread an infection if the condom does not fully cover the infected area. Some infections such as pubic lice, scabies, the genital wart virus and the herpes virus are spread by close skin-to-skin contact.
- A condom may break, particularly if it is not used or stored properly.

Safer sex is about having sex when you are ready. This practice is respectful and protected.

Practices for safer sex include:

- Having sex with only one partner, when neither of you has any STIs.
- Going for Voluntary Counselling and Testing (VCT) regularly to get tested for common infections and having treatment if necessary.
- Be aware that drugs and alcohol may affect your ability to make good decisions. Protect yourself from having sex that you might regret or were pressured into because you were not thinking properly.

Male and female condoms can be used with contraceptives to provide more effective dual protection against STIs including HIV and AIDS and unwanted pregnancies.

Another means of dual protection is **abstaining** from sexual intercourse. This is a better method because it offers complete protection against STIs including HIV and AIDS and unwanted pregnancies.

Self–evaluation Test 17.2

1. In your opinion, is it correct for the youth to use contraceptives?
2. Explain why sterilisation methods cannot be used to prevent against unwanted pregnancies and STIs.

Unit summary

- Safe sex is sexual activity engaged by two people who have taken precaution to protect themselves against sexually transmitted infections including HIV.
- The practice of safe sex is hindered by peer pressure, alcohol and drug abuse, misleading information, practice of sex for financial gain and ignorance.
- Dual protection prevents both unintended pregnancies and STIs including HIV.
- Having regular STI screening and reducing the number of sexual partners also reduces the transmission risk of STIs.
- Condoms are more effective since they provide dual protection.
- Abstinence is the most effective way to prevent both STI and unwanted pregnancy.

End Unit Assessment 17

1. A male condom cannot be used for sexual protection if__________.
   A. expired
   B. torn or ripped
   C. used previously
   D. all of the above
2. What are the four fluids that can transmit HIV and AIDS?
   A. Blood, semen, urine, saliva
   B. Blood, semen, vaginal fluid, breast milk
   C. Blood, semen, vaginal fluid, saliva
   D. Blood, semen, vaginal fluid, urine
3. Which two STIs can be cured with antibiotics?
   A. Chlamydia and Gonorrhea
   B. Chlamydia and HPV

C. HPV and Herpes

D. Syphilis and HIV

4. Which two hormones are contained in female birth control pills?

    A. Adrenaline and oestrogen

    B. Oestrogen and progesterone

    C. Testosterone and progesterone

    D. Prolactin and testosterone

5. Explain how peer pressure hinders practice of safe sex.

6. How true are these statements?

    (a) Women can only get pregnant during a certain part of the menstrual cycle. Therefore having unprotected sex during the safe days will prevent pregnancy.

    (b) Condoms are coated with HIV and AIDS.

    (c) Using a condom during part of the time offers protection from STIs, including HIV.

7. What are the options available for unwanted pregnancies?

8. (a) Who is more at risk of becoming infected with an STI? Men or women? Explain why.

    (b) What are the risk factors for STIs?

    (c) How can STIs affect pregnancy?

10. (a) Identify the following contraceptives.

        (i) Oral contraceptive pill

        (ii) IUD

        (iii) Female condom

        (iv) Diaphragm

    (b) How effective are the above contraceptives in offering dual protection?

Unit 18

HIV and AIDS (stigma, treatment, care and support)

Key unit competence

After studying this unit, I should be able to explain the importance and key elements of living positively with HIV.

Learning objectives

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

- State the rights of people living with HIV (PLHIV).
- Explain the importance and key elements of living positively with HIV.
- Conduct research to identify human rights of PLHIV.
- Organise drama and clubs aiming at supporting PLHIV.
- Recognise the importance and responsibility of non-discrimination against PLHIV.

Introductory Activity

Study the two scenarios in the diagram below. What do you make out?

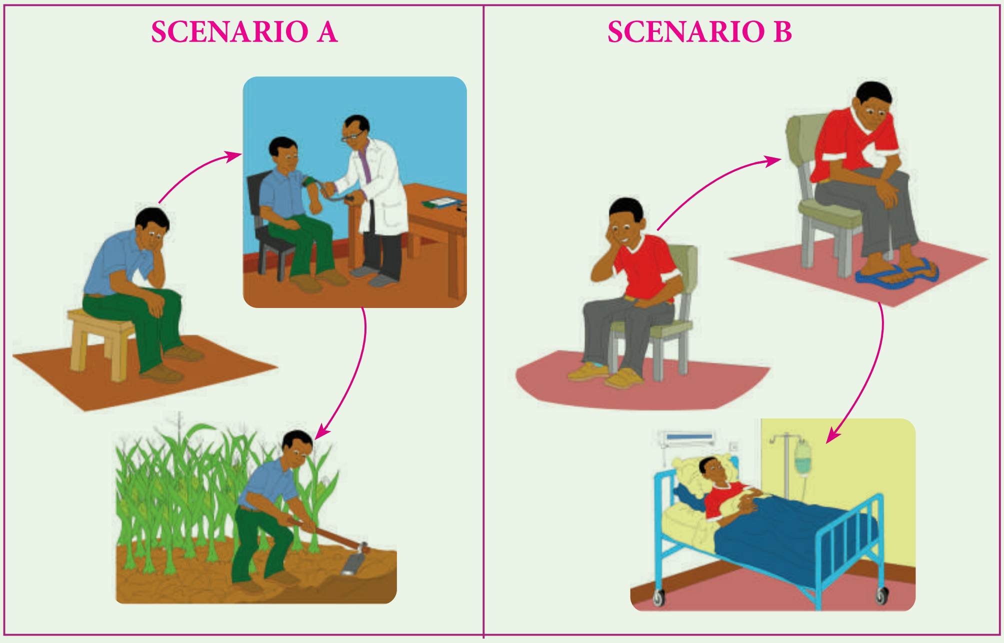


Fig 18.1: Effects of stigma on HIV and AIDS patients

Based on the two cases, what do you think this unit is about?

Introduction

You have already learnt about HIV and AIDS in Senior 1 and Senior 2. What does it mean? HIV is a sexually transmitted infection just like other STIs. It can also be transmitted by sharing needles, through blood transfusion and from mother to child at birth or during breastfeeding. There are however several myths on how HIV is transmitted. These myths have greatly contributed to stigmatisation of people living with HIV and AIDS. Concerted efforts have been put in place by the Rwandan government to control the spread of HIV. The government has come up with elaborate strategies and policies to combat this scourge. This is contained in the vision 2020 document.

18.1. Rights of people living with HIV (PLHIV)

Activity 18.1: Research Activity

Organize for a meeting with PLHIV, support groups and government agencies.

1. Prepare a questionnaire you will use to engage the various groups.
2. Carry out further research using the Internet.
3. The following questions should be your guidelines as you conduct the research.
   - What are the laws, social and health policies that relate to PLHIV in Rwanda?
   - How does the government and the community support PLHIV?
   - What are the myths associated with transmission of HIV?
4. Write a report on your findings and share it with the class.

Fill table 18.1 by indicating (T) for true or (F) for false in the respective column.

Table 18.1: Myths and misconceptions about HIV and AIDS

Statement about HIV and AIDS	True/ False
If you live in the rural areas, you really do not have to worry about contracting HIV and AIDS.	
HIV is the virus that causes AIDS.	
A cure for HIV/AIDS has been found.	
An infected mother can pass HIV and AIDS to the unborn baby.	
You will be infected with HIV and AIDS if you go swimming in a pool where a person with HIV and AIDS has swam.	
Doctors and nurses who treat patients with HIV and AIDS get infected with the virus.	
A person with HIV and AIDS is bewitched.	
You could get HIV and AIDS if you hug a person with HIV or AIDS.	
HIV and AIDS is transmitted through mosquito bites.	
HIV and AIDS is transmitted through sharing of public toilets.	
A person with HIV has AIDS.	

Statement about HIV and AIDS	True/ False
You might get infected with HIV and AIDS if you sit next to a person with HIV and AIDS.	

The facts

HIV- related discrimination and stigma refers to negative attitude, prejudice and abuse against PLHIV. They may be shunned by family, peers or the community while some may receive poor treatment in healthcare facilities and in public. The main cause associated with this stigma and discrimination being the myths about transmission of HIV. These myths, misinformation or ignorance and fear coupled with other reasons have caused many people to falsely believe that:

- HIV and AIDS is always associated with death.
- HIV and AIDS is a result of irresponsible behavior and deserves to be punished.
- HIV and AIDS is only transmitted through sexual intercourse, which is a taboo subject in many cultures.
- One may get infected if they associated with persons with HIV and AIDS.

PLHIV face various challenges associated with stigma and discrimination. They include loss of: income and livelihood, reputation, marriage and hope.

Rights of PLHIV

(i) No person living with HIV and AIDS should be discriminated against.

(ii) PLHIV have the right to medical treatment and care from the health facilities.

(iii) No one can be dismissed from work because they are HIV-positive.

(iv) No one should be forced to take a HIV test in any situation, for example, before getting a job.

(v) Children living with HIV and AIDS should be allowed to attend any school.

(vi) Pregnant women living with HIV and AIDS have the right to make a choice about their pregnancy.

(vii) Test results cannot be shown to any other person without the permission of the person who took the test.

Self–evaluation Test 18.1

1. Which of the following can protect a person from contracting HIV?
   A. Morning after pills
   B. Spermicides
   C. Condoms
   D. Coil
2. HIV causes illness because ________.
   A. it reduces the number of red blood cells.
   B. it attacks the immune system
   C. it increases the body's core temperature.
   D. it causes loss of weight.
3. Can a HIV-positive woman give birth to a HIV-negative baby?
4. How does HIV-related stigma and discrimination affect the fight against the disease?

18.2. Sexuality education and programs promoting positive living with HIV and AIDS

Activity 18.2: Research Activity

1. Identify organisations in Rwanda that run education and campaign programs to curb the spread of HIV and promote positive living.
2. Check the activities of the organisations, using pamphlets or the Internet. Use the following questions as your guidelines.
   (a) How should public education campaign programs be run to be more effective?
   (b) Identify some slogans that may be used in HIV prevention and education campaigns.

The facts

Education programs and campaigns are important in order to reduce HIV and AIDS infection rates. Many organisations run prevention and education programmes. These organisations use methods such as: television adverts, billboards, pamphlets and radio. The message passed in these campaigns is directed to the general public.

All members of the community should be informed about HIV and AIDS, although vulnerable groups should be targeted first. These vulnerable groups are more likely to contract HIV and AIDS they include:

(a) Sexually active youths.
(b) Sex workers.
(c) Men and women who are already HIV-positive and are spreading it to other people by engaging in indiscriminate sexual behaviour.
(d) Women who are in relationship with partners who are HIV-positive and have do not have the power to decide on the use of condoms.

Public education programs on sexuality aim at encouraging people to:

- Get tested by visiting voluntary counselling and testing (VCT) centres.
- Protect themselves against the spread of the virus.
- Access treatment and care when infected.
- Treat PLHIV with the dignity they deserve.

Most people who are HIV-positive are not aware of their status and therefore unknowingly spread the virus during the early stages of infection. Education programmes emphasise on everyone to be tested to prevent the spread of the virus and encourage positive living.

People who are influential in the society such as politicians, religious leaders, traditional leaders and teachers should be involved in the promotion of campaigns on living positively with HIV and AIDs.

Positive living is a lifestyle adopted by an HIV-infected person in order to live life as fully as possible while slowing progression to AIDS. Adopting positive living practices improves the quality of life of PLHIV remarkably. Important aspects of positive living for PLHIV include making positive choices to care for one's mental and physical health, having a positive outlook on life and avoiding risky behaviours. Positive living involves:

(i) Preventing the spread of HIV. Patients who are on antiretroviral therapy (ART) can transmit HIV even if treatment has been effective. There is also a possibility of re-infection with a different strain which can accelerate infection.

(ii) Taking medications as prescribed by the healthcare worker to prevent further infections.

(iii) Working as their energy allows and avoiding stress.

(iv) Maintaining a good nutritional status is essential for improving the quality of health. They should eat a well-balanced diet consisting of regular meals (even when they do not feel hungry). Meals should include protein, fat, carbohydrates and vitamins.

(v) Getting regular exercise and medical care.

Activity 18.3: Drama and clubs

1. Form a club in your school that champions the rights of PLHIV and educate the community.
2. Organise skits on issues related to HIV.
3. Perform the skits in school and in the community.

Self–evaluation Test 18.2

1. What issues need to be promoted in any HIV prevention campaign?
2. Other than preventing spread of HIV, explain why it is important for people with HIV to practise safe sex by using condoms.

18.3. Support groups and mechanisms for PLHIV

Activity 18.4: Interactive talk

Listen to the PLHIV visiting your school or listen to the video of people living with HIV and AIDS.

1. Take notes during the presentation.
2. Ask questions during the presentation.

The facts

The stigma surrounding HIV and AIDS makes life more difficult for PLHIV and their families. Loneliness, anxiety, stress, confusion, bitterness and depression can make people more vulnerable to illness if they do not get any kind of support. PLHIV need a lot of emotional, spiritual, psychological, social, physical and clinical support.

Different people and different institutions can provide some support, but it is important for PLHIV to come together and support one another. They would know better what their hopes, joys, anxieties, fears and needs are and they are the ones who should define how best they want to be understood and treated.

Some of the common needs of PLHIV are:

- Health and medical supplies and skilled medical services.
- Counselling to reduce isolation and promote acceptance.
- Community support groups to provide a safe place where feelings and advice can be shared.
- Spiritual support such as prayer groups and home visits by religious leaders.
- Social acceptance to help them feel welcome by visiting them and treating them like friends.
- Physical care such as bathing, cleaning their homes when they are sick and any other thing they are not able to do on their own.
- Nutritional help so that families improve their diets using cheap and available foods.
- Safe clean water that has been boiled or treated with chlorine.
- Accurate information about HIV and AIDS.

Support groups can be set up for many different reasons. Here are a few:

- To provide emotional support and coping mechanisms to those people who are undergoing a difficult time in their lives, and are willing to be part of a support group.
- To provide information for its members so that they can understand the disease and be able to educate their family members, friends, colleagues, neighbours about the disease.
- To draw strength and share information from other members, experiences.
- To educate people about antiretroviral (ARV) medication and to encourage people to keep taking their medication.
- To ensure they live a positive and productive life.
- To demystify the disease and promote de-stigmatisation and community acceptance of PLHIV and their families.

In Rwanda several organisations offer support for PLHIV, for example**:**

(i) AIDS Healthcare Foundation (AHF) Rwanda has been operating in the country since 2006. It commenced services in Shyira, Kibagabaga and Kanombe District Hospitals. Currently, AHF Rwanda works in 8 Districts (Kicukiro, Nyarugenge, Gasabo, Nyabihu, Musanze, Rubavu, Huye and Nyanza) and supports 20 Health Facilities.
AHF activities include:
    - Providing medicine and advocacy regardless of the ability to pay.
    - Increasing access to HIV and AIDS care and treatment services through a targeted model. This ensures greater population coverage in terms of HIV Counselling and Testing (HCT).
    - Access to antiretroviral therapy (ART)

(ii) INACOS (INitiative des Amis COmbattant le SIDA) is the Friends Church HIV and AIDS programme in Rwanda. Quakers Fidele Nsengiyumva and his wife Antoinette Runiga, both HIV-positive themselves, founded it in 2002. She died in 2004, but he continues the work they began together. INACOS tries to be a community change agent by:

- Preventing new infection.
- Reducing the impact on PLWHAs (People Living with HIV and AIDS) or affected by it.

INACOS has targeted three groups in particular:

- Vulnerable people living with or affected by HIV and AIDS, especially children.
- Vulnerable families exposed to HIV infection, e.g. orphans and widows.
- Men and religious leaders living with or affected by HIV and AIDS.

Key activities have been sensitisation and awareness-raising, workshops, counselling, care and support, and the development of income-generating activities.

Self –evaluation Test 18.3

1. Name support groups in your locality and explain what they do.
2. Are support groups necessary in dealing with the HIV and AIDS scourge?

18.4. Non-discrimination against PLHIV

Activity 18.5: Discussion Activity

1. Discuss ways of promoting non-discriminatory behaviours and inclusion of PLHIV in the community.

The facts

Stigma and discrimination related to HIV and AIDS has been a prevalent problem. PLHIV experience many faces of stigma and discrimination in a variety of ways in households, communities, work place, health care settings, media and government places. Stigma seems to be particularly more common in poor neighbourhoods.

Stigma and discrimination creates a culture of secrecy, silence, ignorance, blame, shame and victimisation leading to societal rejection, job loss, school expulsion, ostracism and violence, lack of care and support and loss of property.

This prevents implementation of strategies for effective management of PLHIV, voluntary counselling and testing (VCT), accessing HIV care including effective use of Antiretroviral (ARV) drugs and the behaviour and perception of the health care they receive.

There is also a perception of what PLHIV feel that the society believes or thinks about them could directly relate to the various forms of stigma they encounter from the public with which they have contact with.

Self-evaluation Test 18.4

1. Why do you think PLHIV are concerned about stigmatisation?
2. How can you help reduce stigmatisation of PLHIV in your community?

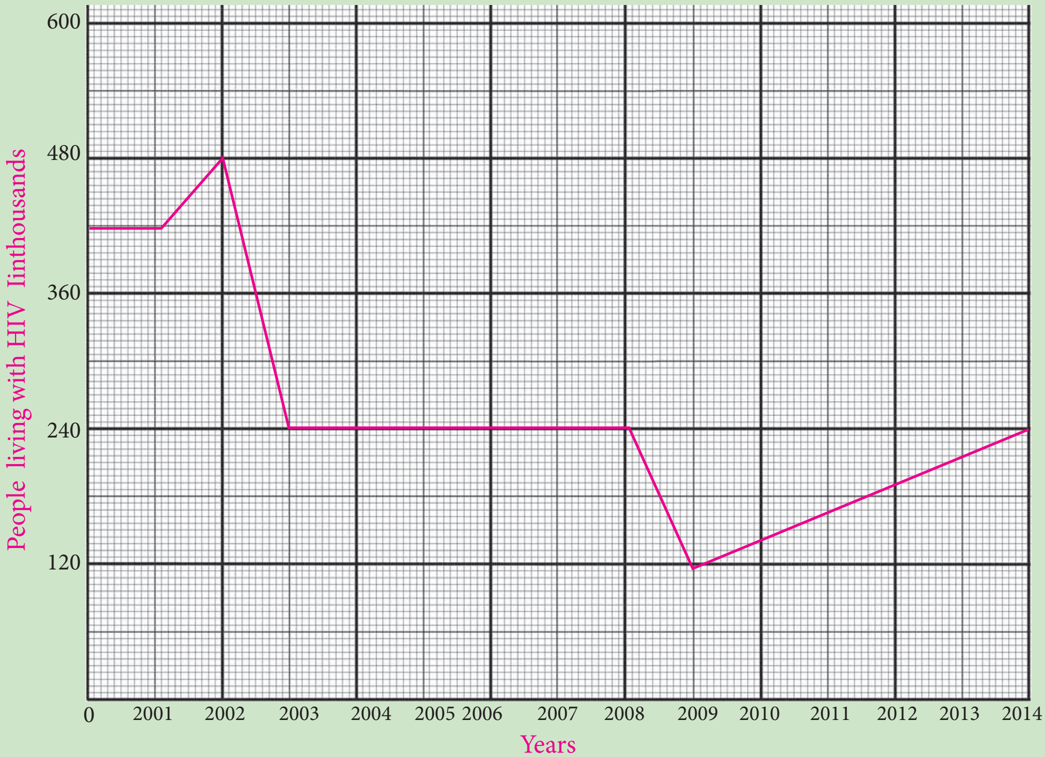
Unit summary

- HIV is a sexually transmitted infection that may also be transmitted through other means such as breastfeeding, transfusion of infected blood, among others.
- People living with HIV suffer from stigma and discrimination i.e negative attitude, prejudice and abuse.
- PLHIV have rights that should be respected, having HIV does not mean loss of self worth.
- Education programs and campaigns are important in order to reduce HIV infection rates.
- All members of the community need to be informed about HIV although vulnerable groups should be targeted first.
- Public education programs should encourage people to get tested and emphasise positive living for those who are positive.

End Unit Assessment 18

1. Which of the following increases your risk of HIV exposure?
   A. Unprotected anal, oral or vaginal sex
   B. Sharing needles
   C. Drug use
   D. Infection with another sexually transmitted disease
2. If I think that I have been exposed, the best thing to do is ____________.
   A. not to worry - one exposure is not enough to get infected.
   B. do nothing and hope for the best.
   C. get tested at VCT centre.
   D. it does not matter - if I am infected there is no hope for me anyway.

3. The graph below shows the number of PLHIV in Rwanda between 2001 and 2014.



   a) Describe the trend shown the graph.
   b) What do you think caused the trend?
   c) What measures is the government taking to curb the spread of HIV and AIDS?

4. a) What is the difference between HIV and AIDS?
   b) What is the impact of HIV and AIDS in the society?

5. __________ are the most effective in protecting against transmission of HIV.

6. a) Suggest a diet plan for PLHIV.
   b) Why is information important when dealing with PLHIV?
   c) Explain the precautions you will take when caring for PLHIV.

7. a) In what ways can PLHIV live longer?
   b) The rights of PLHIV are the rights of everyone. Explain.
   c) What do you think of marriage relationship in PLHIV?

8. Suggest ways in which sexuality education needs to be conducted in order to reach the majority.

9. Explain the truthfulness of the following statements.
   a) Children should not be allowed to go to school if they are HIV- positive.
   b) I can get HIV from touching an infected person or being in the same room with them.
10. Fill the following table with missing information.

Rights of PLHIV	How the issue should be addressed
Confidentiality and privacy	
Health and support services, public benefits, medical schemes and insurance	
Education on HIV and AIDS	
The responsibilities of the media	
The right to safer sex	
The rights of prisoners	
Liberty, autonomy, security of the person and freedom of movement	

Unit 19 Sexual behaviour and sexual response

Key unit competence

After studying this unit, I should be able to describe common sexual behaviours and how to make responsible decisions.

Learning objectives

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

- Identify common sexual behaviours.
- Describe abstinence.
- Explain transactional sexual activity.
- Demonstrate effective communication of personal needs and sexual limits.
- Recognise possible consequences of engaging in sexual activity and my personal responsibility.
- Be aware of own sexual limits.
- Develop assertiveness and negotiation skills to help one to resist sexual pressure or reinforce the intention to practise safer sex.

Introductory Activity

Study Figure 19.1 below carefully. What is happening in the pictures?

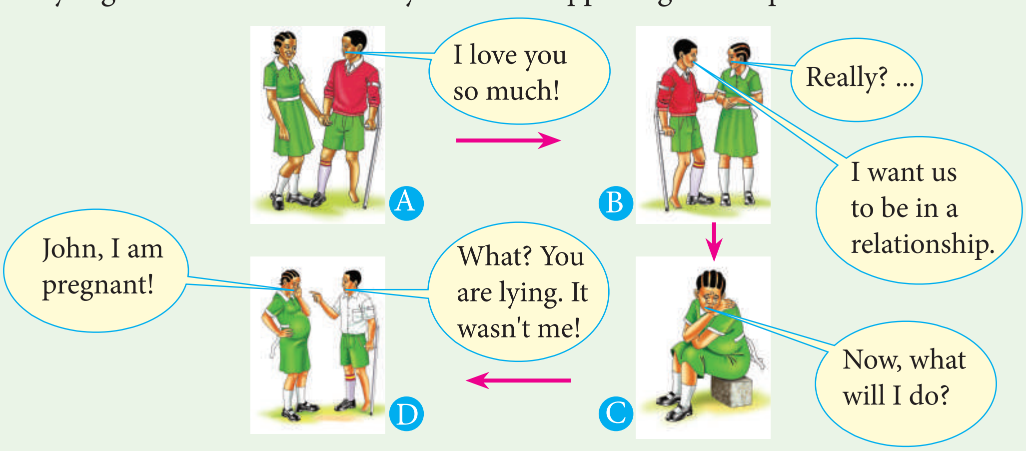


Fig 19.1: Aspects of sexual behaviour

From the chat in Fig. 19.1, what can you learn? Based on what is going on in the pictures, what do you think this unit is about?

Introduction

Any activity that induces sexual arousal is referred to as **sexual behaviour**. This activity can either be solitary, between two persons or a group of people. Human sexual behaviour is determined by two main things: genetic pre-disposition that determines inherited sexual response patterns and the degree of influence exerted by the society on an individual in expressing their sexuality. Information concerning sexual behaviour in most communities especially in Africa is restricted since much about sex and sexuality is regarded as **taboo**. There is increasing need to overcome these beliefs in order to create proper awareness about how to behave in light of the various cases that you will come across which require appropriate sexual response.

In Senior Two, you learnt about sexual response, can you recall what is involved during a response? Whose responsibility is it in preventing unintended pregnancies and HIV and AIDS? In this unit, you are going to learn about how to make responsible sexual decisions.

19.1. Common sexual behaviours

Activity 19.1: Game

Requirements

- Marker pens
- Card boards or blank hard papers

Procedure

1. Write on the cardboards different sexual behaviours. This will form your flash cards.
2. Play a game of flash cards with your classmates. Each flash card has different forms of sexual behaviour written on it.
3. Lift a flash card at a time. Let your partner identify the form of sexual behaviour and discuss whether they think it is high, low or no risk behaviour.
4. Fill the table below.

Sexual behaviour	High risk	Low risk	No risk

The facts

Human sexual behaviour is classified according to the number of participants in the sexual activity and the sex of the individuals. Sexual behaviour may be: solitary involving sexual stimulation, between a male and a female, between two males or between two females. Common sexual behaviours include:

(i) **Self-masturbation** is a solitary behaviour of self-stimulation with the intention of arousal and orgasm. This kind of sexual behaviour has no risk at all with regard to the transmission of STIs including HIV and unwanted pregnancies. The side effects of masturbation are loss of memory and concentration, testicular pain, fatique, lower back pain, thinning of hair, weak erection and subsequent ejaculations.

(ii) Sexual activity between a male and a female is mainly vaginal but in rare cases, anal sex involved. Oral sex may also be incorporated in this form of sexual behaviour. One of the negative impacts of playing sex is unwanted pregnancy and the risk of sexually transmitted infections. Protection using male or female condoms may be used to prevent unwanted pregnancies and minimise the risk of transmission of STIs including HIV.

(iii) Sexual activity may also occur between persons of the same sex, thus between males or females. Sex between males involves anal sex; in females, sex toys may be used. Penetrative anal sex has a higher risk of spreading sexually transmitted infections than many other types of sexual activities. This is because the lining of the anus is thin and can easily be damaged. Homosexuality is morally bad and should be discouraged.

(iv) **Group sex** is another form of sexual activity although rarely common. This is a high risk sexual activity since more than two people are involved and there is very high chance of transmission of STIs including HIV.

(v) **Non-penetrative sexual** activity is a low risk sexual activity that involves kissing and touching. It does not need use of protection. HIV may only be transmitted if partners have large open sores in the mouth.

(vi) **Transactional sex** activity involves exchanging money, goods or protection for sexual favours. Unlike prostitution, the benefit or favours is not predetermined but there is motivation to benefit if sexual favours are given. Transactional sex is more in regions that have higher levels of poverty. Men and women in transactional sex may have multiple sex partners and this contributes more to the spread of HIV/AIDS and other STIs.

The risk involved in the different sexual behaviours is different. Teenagers and young adults are at higher risk than adults.

Activity 19.2: Role play

1. With friends, role-play how to avoid transactional sexual activity and other sexually abusive relationships.
2. Perform your skit in class.

Self-evaluation Test 19.1

1. Why is it important to know the sexual behaviours of your partner?
2. Young people like experimenting new experiences in life. Do you think this is possible when it comes to sexuality?

19.2. Prevention of unintended pregnancies and HIV and AIDS

Activity 19.3: Discussion Activity

1. Discuss the methods of preventing pregnancies. Use the following guide questions.
   (i) How effective is the method in preventing pregnancies?
   (ii) Is it affordable and easily available?
   (iii) Does it protect against unwanted pregnancies?
   (iv) Can one partner use it or both?
   (v) Does the method fit with religious and moral beliefs?
2. Whose responsibility is it between the partners to prevent unintended pregnancies and HIV?

The facts

It is the responsibility of both sexual partners in preventing unintended pregnancies and HIV. The use of contraception should not only be the responsibility of the female. Contraceptives can be used by both to prevent unwanted pregnancies and HIV. Sexual partners involved ought to discuss on the best method possible and be able to deal with the consequences thereafter. Some of the birth control measures include:

(a) Abstinence

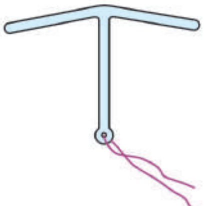
Abstinence is the self-restraint from sexual activity. Being consistently abstinent is the only sure way of preventing unintended pregnancy and STIs, including HIV. It is a safe way to prevent pregnancies with no side effects. Therefore abstinence prevents these risks until when one is older, more informed and better placed to handle the risks.

(b) Use of contraceptives

Contraceptives are methods or devices used to prevent pregnancy. Barrier methods such as condoms are a form of contraception that help to protect against sexually transmitted infections (STIs) and pregnancy.

Other contraceptives such as diaphragm, IUD, pills, implants and injections can only prevent pregnancy.

(a) Female condom



(b) Copper "T" coil/ Intrauterine device (IUD)

Fig 19.2. Examples of contraceptives

Activity 19.4: Writing Activity

1. Write stories about possible consequences of sexual decisions.

Self–evaluation Test 19.2

1. Basically, oral contraceptives work by ________________.
   A. blocking passage of the ovum into the uterus.
   B. interfering with normal patterns of ovulation and implantation.
   C. keeping sperm away from the unfertilized ovum.
   D. preventing uterine implantation of the zygote.
2. What are the advantages of abstinence?
3. Is there any other method of preventing unintended pregnancies other than abstinence, condoms and contraceptives?

19.3. Communication skills in consensual and safe sex

Activity 19.5: Discussion Activity

1. Discuss the importance of communication.
2. Relate your experiences to negotiation skills for safer sex and how important it is.
   - How would you deal with sexual harassment?
   - How can one communicate the intention to practise safer sex?

The facts

Communication is the process of sharing information, thoughts and feelings between people through speaking, writing or body language. Effective communication on the other hand extends the concept to require that transmitted content is received and understood by someone in the way it was intended. The inability of people to communicate effectively, especially teenagers, makes it difficult to maintain positive relationships. This decreases the ability to engage in safer sex practices.

Most people are aware of the need to get tested and stay safe, but ignore the aspect of consent. It is safer to first discuss sexual activity before engaging in it. As teenagers, there is need to know that just because your partner responds to your touch and kisses does not mean you go ahead and have sex with them. There is need to seek consent by verbal yes to know that both of you are in agreement of what is to happen next and agree on what to use to stay safe, that is, prevent unintended pregnancies and transmission of STIs including HIV.

Consent of sex is one of the most important strategies in preventing transmission of STIs including HIV and unintended pregnancies. Teenagers mostly receive misleading information about sex such as:

- Girls are supposed to be submissive and accepting in their relationships.
- Boys are entitled to sex whenever they want it irrespective of their partner's decision.

This leads to unhealthy and hostile relationships between teenagers and increase the likelihood of transmission of STIs including HIV and unintended pregnancies. It is very important for teenagers to express their own views and decisions concerning sex very clearly and at the same time pay close attention to their partner's needs.

Being able to express one's opinion freely and seeking consent will not only improve communication in the relationship but also ensure that neither of the partners engages in sexual activity they are not comfortable with. It is the responsibility of both sexual partners to prevent unintended pregnancies and transmission of STIs including HIV.

Self –evaluation Test 19.3

1. What are your thoughts on sex education?
   A. Abstinence is the only way.
   B. A broad knowledge base will best help young people to make informed decisions.
   C. Society teaches kids about sex so we do not really need formal education on it.
   D. It is good to teach kids how to use protection because they are going to be having sex whether we teach them or not.
2. Why is it important to seek the verbal consent from a sexual partner before engaging in sexual activity?
3. What is the other aspect of good communication apart from expressing oneself freely and clearly?

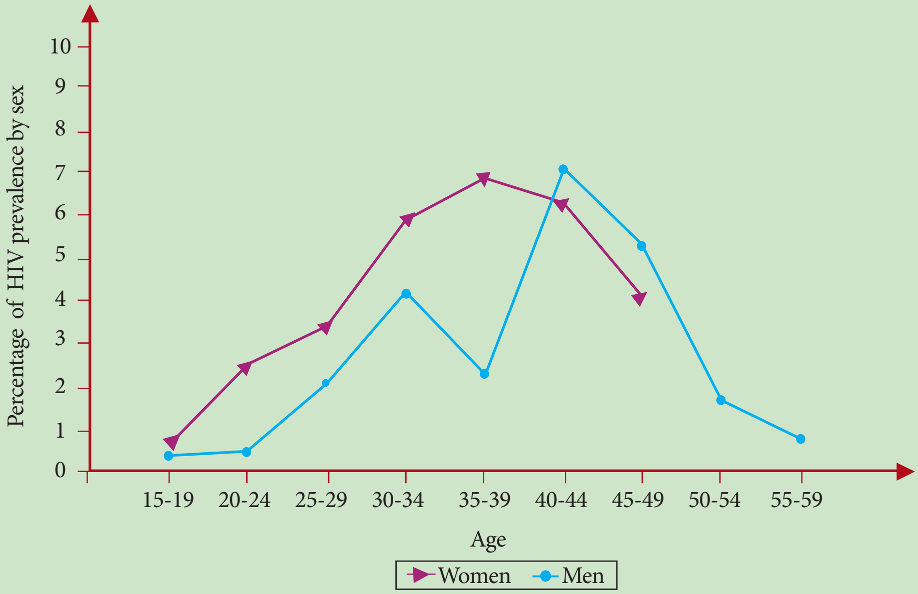
Unit summary

- Human sexual behaviour is categorised according the sex of persons involved and the number of participants involved.
- Sexual activity could be solitary, involving a male and female or two people of same sex.
- Abstinence is the safest way to avoid unintended pregnancies and prevent transmission of STIs including HIV.
- Condoms provide protection from unintended pregnancies and STIs including HIV.

- Contraceptives provide protection from unintended pregnancies but not STIs and HIV.
- Effective communication between partners is important in maintaining positive relationships and ensuring that people do not engage in sexual activity they might be uncomfortable.

End Unit Assessment 19

1. One of the major obstacles in making contraceptive decisions is the belief that____________
   A. contraception is the woman's responsibility.
   B. contraceptives do not prevent pregnancy.
   C. sex must be spontaneous.
   D. unmarried men and women are more likely to be infertile.
2. Which of the following is the most accurate predictor of who is likely to contract an STI?
   A. General health habits
   B. Level of formal education
   C. Number of sex partners
   D. Sexual orientation
3. One of the best approaches to ending sexual harassment is to___________
   A. counter the harassing behaviour with aggressive acts.
   B. immediately report the harassing behaviour to the police.
   C. share specific information about the offender's behaviour with friends and neighbour.
   D. write a clear, specific letter to the offender about his or her behaviour.
4. How do feelings such as guilt, fear or shame about sex influence contraceptive behaviour?
   A. These feelings influence sexual behaviour but have not been shown to influence the use of contraceptives.
   B. These feelings may interfere with gathering information and planning for intercourse.
   C. The feelings may lead to overuse of birth control techniques, resulting in later infertility.
   D. These feelings typically lead to promiscuity among women and inhibition among women.
5. (a) What do you understand by the term sexual orientation?
   (b) Which sexual behaviours are considered taboo in your community?
   (c) Is transactional sexual activity a form of economic activity?
6. (a) How safe are non-penetrative sexual behaviours?
   (b) Explain why the condom is most effective in ensuring safer sex.
7. The following graph shows HIV prevalence by sex and age in Rwanda in the year 2009. Use it to answer the questions that follow.



HIV prevalence by sex and age

(a) Discuss the trend in the graph.

(b) What does the Age/sex distribution of HIV prevalence suggest?

(c) What should be done to curb the spread of HIV?

Unit 20

Genetics

Key unit competence

After studying this unit, I should be able to explain how genes determine structure and function of individuals.

Learning objectives

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

- Define inheritance as the transmission of genetic information from generation to generation.
- Define key genetic terms limited to the content.
- Describe the inheritance of sex in humans with reference to XX and XY chromosomes.
- Explain co-dominance in ABO blood groups.
- Interpret pedigree diagrams for the inheritance of a given characteristic.
- Use Punnett square and genetic diagrams to determine genetic make up.
- Defend the fact that inheritance of sex in humans is determined by males.

Introductory Activity

Study the pictures in Fig. 20.1 below. Count the number of blue, red and yellow marbles in each bottle. How many are they per generation?

Assuming that each colour represents a characteristic of an individual, can you note any trend in the characteristics as you move from one generation to another? Where do you think the red characteristic disappeared to in the 4th generation? Why did the number of blue characteristic in the 4th generation increase? Assuming this is how inheritance occurs, what do you think genetics is all about?

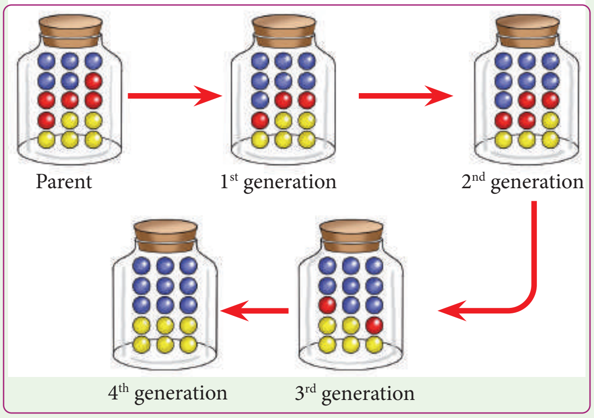


Fig 20.1: Generation representation

Introduction

Genetics is a branch of science that deals with the study of inheritance and variation of characteristics in individuals. Heredity is the principle behind inheritance of characteristics. **Gregory Mendel** - an Australian monk carried out the first ever investigations on inheritance of characteristics. For this reason he is referred to as the 'father of genetics'.

Fig 20.2: Gregory Mendel (1822-1884)

20.1. Inheritance and key terms used in genetics

Activity 20.1: Investigating inheritance and variation

1. Discuss the following:
   (i) Features of either of your parents that you have and those you have but are not seen in either of your parents.
   (ii) Reasons for the variation observed in characteristics in members of the same family.

2. Do a survey in class and fill the following table.

Table 20.1: Characteristic traits

Characteristic	Description
Ear lobes	
Height	
Skin colour	
Have allergies	
Use left hand	

3. Present your work to the rest of the class.

Activity 20.2: To investigate variation in tongue rolling ability among members of class

Procedure

1. Let the members of your class try and roll their tongues to form a U-shape.
2. Count the number of students in the class that:
   a) are able to roll their tongue.
   b) are unable to roll their tongue.
3. Fill your results in a table as shown below.

Table 20.2: Result of rollers and non-rollers

Rollers		
Non-rollers		
Total		

4. Calculate the percentage of students i.e. those who are able to roll their tongue and those who are not able to roll their tongue.

Study questions

(i) How many students had the ability to role their tongue?

(ii) How many students were unable to role their tongue?

(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 distinctions.

The facts

From Activity 20.2, you may have found out that the students in the class can be put into two groups according to their ability to roll their tongue. One group was able to roll their tongue while the other group was unable to roll their tongue. Also you may have noticed that there are no students in between the two groups i.e. students who could roll their tongue halfway. In this case each student was either a roller or a non-roller.

The characteristic of 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. Discontinuous variation 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.

The transmission of genetic information from generation to generation is known as **inheritance**. Genes are the "vehicles" of inheritance and are responsible for the appearance of an organism. Genes are arranged in a specific sequence along each chromosome. Mendel used the garden pea, *Pisum sativum* in his experiments to determine how characteristics were transmitted from parents to offspring through what he called *factors*. These were later called **genes**.

Common terms used in genetics

To understand Mendel's findings, it is first important to know some genetical terms.

Gene refers to a portion of DNA that is responsible for synthesis of a polypeptide (protein). It is the unit of heredity that is transferred from a parent to offspring and is held to determine some characteristic of the offspring.

Trait is the characteristic shown by an organism i.e. the characteristic of an individual e.g. red, tall, blood group, etc.

Chromosomes: are threadlike structures of nucleic acids and protein found in the nucleus of living cells carrying genetic information in the form of genes.

Some characteristics show variations in species. For example, in dogs, the skin fur could be white, black or brown. A different gene determines each colour. These genes determine variation in the same characteristic and are therefore found on the same locus 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 "allele 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 that always occur in pairs. These pairs of alleles in the homologous chromosomes can be the same or different.

A **dominant allele** is the allele that influences a characteristic to develop in an individual over another allele.

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***.**

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.

Genotype is the genetic constitution or genetic make up of an organism. The genotype influences the development of physical characteristics in an individual. The genotype is always denoted by use of letters. The letters used are in 'twos' or in 'pairs'. For example, BB, Bb or bb are three different genotypes. 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**.

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

Phenotype is the outward or physical appearance of an organism. It is determined by the inheritance of the genes and the environment e.g. tall, short, brown, round, etc. The phenotype of an individual is expressed in words. Black fur and white fur are examples of phenotypes. Table 20.3 gives the difference between genotype and phenotype.

Table 20.3: Genotype and phenotype

Genotype	Phenotype
BB	Black
Bb	Black
bb	White

Locus is the exact position or location of a gene on a chromosome. The plural of the word locus is loci.

Haploid refers to half the number of chromosomes in the body cell. Haploid cells are produced in the gonads i.e. ovaries and testes. The haploid cells include the sperms and eggs (ova).

Diploid refers to the nucleus of a cell that has its chromosomes in the homologous pair. Diploid cells include all the somatic (body) cells. They are formed by the process of fertilisation and denoted as 2n. Mitosis maintains the diploid state of an organism.

First generation refers to the offsprings that are produced after crossing the parental genotypes. It is abbreviated as F1 generation.

Second generation refers to the offspring produced by the crossing of the F1 generation. It is abbreviated as F2 generation.

Hybrid refers to the offspring produced by crossing two individuals with contrasting characteristics.

Parents are individuals that form the starting point of a breed. A cross between parents produces an offspring.

Pedigree is a historical or ancestral record of individuals shown in a chart, table or diagram.

Self–evaluation Test 20.1

1. The passing of genes from parents to offspring is ________________.
2. What is the physical structure in a cell that contains genetic information?
3. A diagram that shows the different possible ways in which gene from parents combine is ________________.
4. How many homologous pairs of chromosomes are present in a human body cell?
5. Differentiate between first generation and second generation.
6. Which one of the following statements is FALSE?
   A. Phenotype is the outward or physical appearance of an organism.
   B. Locus is the exact position or location of a gene on a chromosome. The plural of the word locus is loci.
   C. Diploid refers to half the number of chromosomes in a body cell.
   D. Each characteristic of an individual is represented in the cell by alleles that always occur in pairs.

20.2. Monohybrid inheritance

Activity 20.3: Modelling genetic crosses

Requirements

- Beads of two colours e.g. 20 red and 20 black
- Five jars
- Plasticine

Procedure

1. Take the two jars and in each place 20 red beads. In the other place 20 black beads. The 20 beads represent 10 pairs of alleles in a pure parent.

   Note: All pure parents are homozygous; alleles in a pair are similar.
2. Put the two jars one to the right and one to the left.
3. Pick a bead at a time from each jar. Put them together to form a pair. You can also stick them together using plasticine. Place them in one empty jar. Count the pairs formed and the combination.

Note: In the pair formed, all will be 10 pairs each made of one black bead and one red bead. This represents the F1 generation. It is composed of offspring with one dominant gene and one recessive gene hence heterozygous.

4. Divide the mixed beads into two halves and put them in two separate jars. Make sure each jar has 10 red beads and 10 black beads. These two jars represent two parents in F1 generation.
5. Place one to the right and one to the left.
6. Pick one bead at random without looking from each jar at a time. Observe the beads picked. Place them together on a table. If both are black, place them on one jar labelled **X**. If one is black and one is red place them on a second jar labelled **Y**. If both are red, place them on a third jar labelled **Z**. Repeat the picking until all the beads from the two jars are picked.
7. Count the number of pairs in X, Y and Z.
8. Record them in a table as shown below.

Table 20.4: Genetic crosses

Set	Number of pairs
X-black pairs	
Y-black and red pairs	
Z-red pair	

Study questions

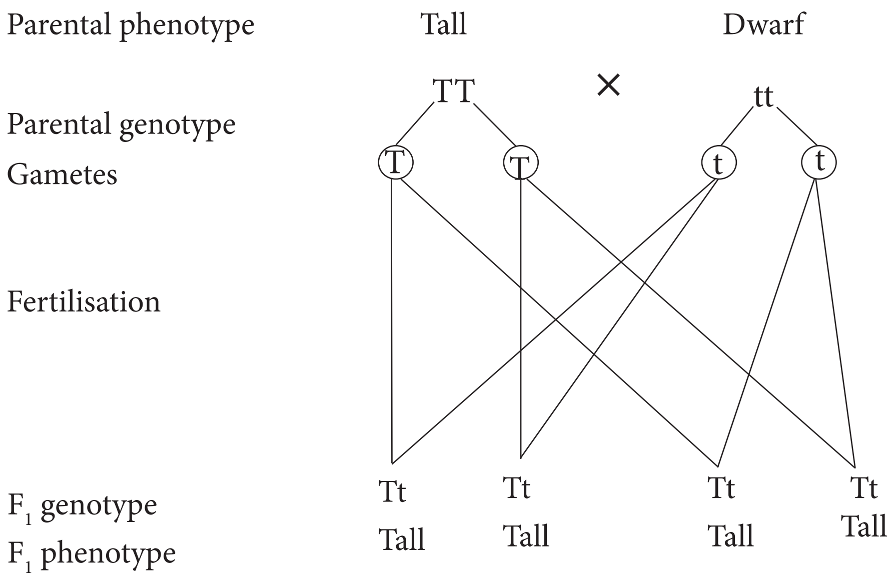
1. Calculate the ratio of X, Y and Z.
2. Calculate the ratio of X added to Y to that of Z i.e. (X, Y)

The facts

Mendel's first experiments involved monohybrid crosses only. In this case, he studied the inheritance of only **one pair of contrasting characteristics**.

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 hence true breeding. For instance, if the parent plant was tall and was allowed to self-pollinate, all the offspring produced were tall. All pure lines are homozygous to a given characteristic. For example, pure tall plants have genotype **TT** meaning it is homozygous dominant.

Pure line dwarf plant has a genotype **tt** meaning it is homozygous recessive. He cross pollinated the two plants. 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.



Interpretation: Genotype 100% Tall

Phenotype 100% Tt

Fig 20.3: Crossing of genotypes

Fact of life: 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 **F1 generation plants.** F1 stands for the first filial generation. The word "Filial"means offspring and so F1 means the first offspring. He noted that all the plants in the F1 generation were tall. He concluded that on crossing a pure tall plant with a pure dwarf pea plant, an F1 generation that was composed of only tall pea plants was 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 that were phenotypically tall.

Mendel then allowed the flowers of F1 generation plants to undergo self-pollination and fertilisation. He took the seeds produced and planted them to get the second Filial (F2) generation.

The fertilisation that resulted in the F2 generation is illustrated in the following cross diagram.

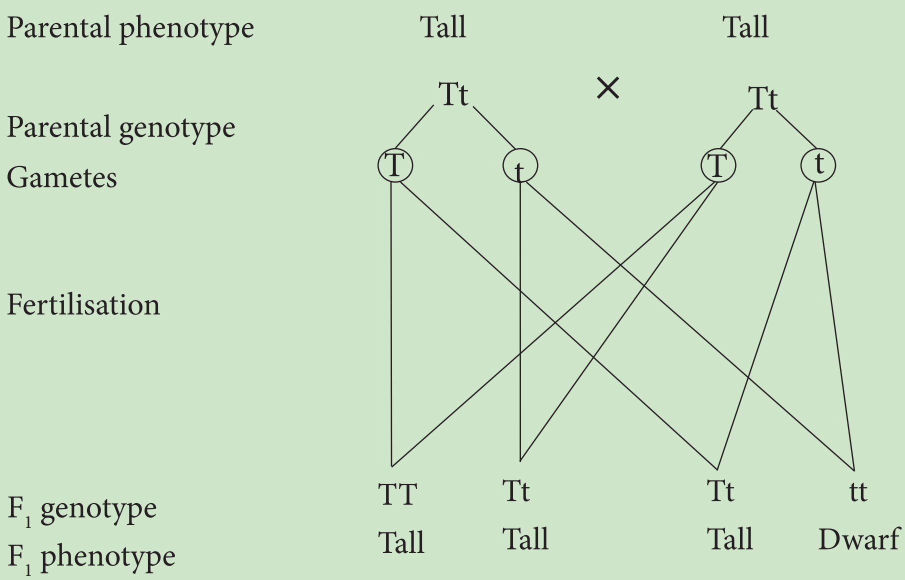


Fig 20.4: F2 generation crossing of genotypes

The interpretation for crossing F1 generation:

1. Phenotype: 3/4Tall and ¼ dwarf
2. Genotype: 1/4 TT, 2/4 Tt, 1/4tt
3. Phenotypic ratio: 3:1
4. Genotypic ratio: 1:2:1

He noted that the F2 generation pea plants were composed of tall pea plants and dwarf plants. On counting, he noted that the number of tall plants was 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. The example given above is typical of all Mendel's experiments involving the inheritance of a single characteristic. This inheritance is referred to as **monohybrid inheritance.**

The genotypic ratio is the ration of all the different genotypes of the four possible offspring produced. These are in our case TT,Tt, Tt, tt. The ratio is written as 1TT : 2Tt : 1 tt.

The phenotypic ratio is the ratio of the different phenotypes in the four possible offspring produced. These in our case above are Tall, tall, tall and dwarf.

The phenotypic ratio is written as 3 Tall : 1 Dwarf.

The crosses above can also be illustrated by use of a table known as the **Punnett 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.

Table 20:5: Punnett square for tall and dwarf plants

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

For example, if we consider the cross between the tall and dwarf plant discussed earlier from *Fig. 20.3*, the results would be like in the following Punnett square.

	Female	Male
Parental phenotype	Tall	Dwarf
Parental genotype	TT	tt

Female genes/alleles / Male genes/ alleles	T	T
t	Tt	Tt
t	Tt	tt

F1 generation genotype – Tt for All
F1 generation phenotype – All Tall

Did you know?

The genotype and phenotype of the parents are indicated above the Punnett square and those of the offspring below the Punnett square.

Self–evaluation Test 20.2

1. State Mendel's first law of hereditary.
2. State the correct science vocabulary term that fits each of the following definitions.
   (i) The offspring of a cross between pure breeding parents.
   (ii) A cross in which only one pair of contrasting characteristics are studied.
   (iii) A type of inheritance in which neither of the pair of alleles is dominant to the other both phenotypes appear in the offspring.
3. In a certain species of mice, black coat colour is dominant over white coat colour. If two heterozygous black mice are mated, the phenotypic ratio would probably be______.
   A. 3:1 B. 1:2:1
   C. 1:3 D. 3:3:1
4. In short-horned cattle, the allele for white coat and the allele for red coat are both dominant. A cross between a red bull and a white cow produces roan calves. If two roan cattle are mated, which percentage of their offspring will probably have white coat?
   A. 50%
   B. 25%
   C. 75%
   D. 100%

5. In pea plants, the allele for tallness (T) is dominant over the allele for shortness (t). Using a Punnett square:
   a) Determine the genotype of offspring of a cross between a hybrid and short plant.
   b) State the genotypic and phenotypic ratios.

20.3. Co-dominance

Discussion corner

1. Discuss the following questions:
   a) What is the difference between complete dominance, incomplete dominance and co-dominance?
   b) What is the ABO blood group?
   c) Can blood group type be used in a paternal dispute?
2. Share your findings with the rest of the class.

The facts

We have learnt that when two alleles are present in a heterozygous state, the dominant allele is the one that expresses itself in the phenotype. Such an allele determines the outcome of the phenotype of the individual whereas the recessive allele will not express itself. The recessive allele will have no effect on the outcome of the phenotype of the individual. This is what is called **complete dominance.**

For example in Mendel's experiments, we found out that when a pure tall pea plant is crossed with a pure dwarf plant, an F1 generation of tall pea plants is produced. In this generation, we find that only the allele for tallness influences the phenotype. The allele for dwarfness does not influence the phenotype. Therefore, the allele for tallness is completely dominant over the allele for dwarfness. However, in certain cases, two alleles present in a heterozygous state may both express themselves in the phenotype. Such alleles determine the outcome of the phenotype of the individual. This is known as **incomplete dominance.**

For instance, flower colour of the snap dragon plant. The plant has two alleles: one for production of red flower pigmentation and the other for production of white flower pigmentation. When the two alleles are found together in a heterozygous state, both red and white pigments are produced. The flower colour is neither red nor white, but a mixture or intermediate of the two colours, which is pink.

This shows that the two alleles show incomplete dominance. Such alleles are denoted by using different capital letters.

Co-dominance on the other hand is a condition in which both alleles of a gene pair in a heterozygote are fully expressed, with neither one being dominant or recessive to the other. Example of co-dominance is seen in the 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
- 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. 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.

Table 20.6:The relationships between genotypes in blood groups

Possible genotype	Antigen formed on red blood cell	Blood group
AA	A	A
AO	A	A
BB	B	B
BO	B	B
AB	A and B	AB
OO	None	O

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

The ABO blood group system exhibits four phenotypic blood groups that are controlled by three alleles, which are represented as IA, IB and IO. There are six possible genotypes for the ABO blood group system.

Table 20.7: Genotypes for ABO blood groups

Genotypes	Phenotypes (Blood group)
IA IA	A
IA IO	A
IB IB	B
IB IO	B
IA IB	AB
IO IO	O

The inheritance of the ABO blood group alleles follows the normal Mendelian fashion. For instance, if a man who is homozygous for blood group B, genotype IB IB, marries a woman who is blood group O, genotype IO IO, all their children will have blood group B.

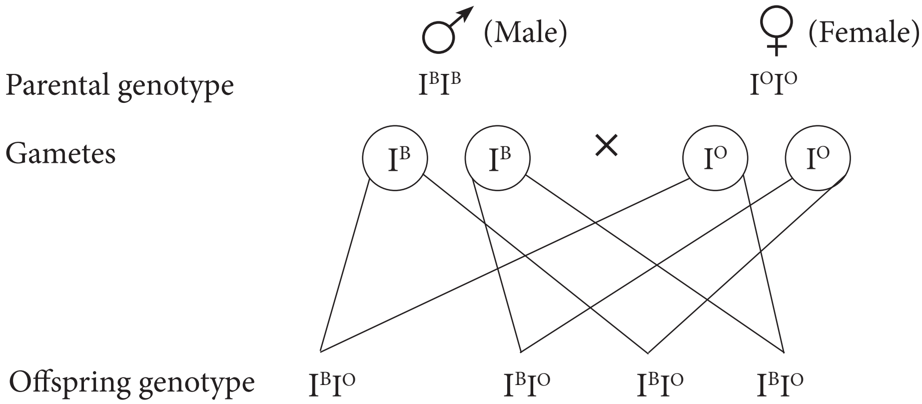


Fig 20.5: Cross diagram for blood groups

Self–evaluation Test 20.3

1. A woman gave birth in a hospital but there was a problem identifying their child. Both the woman and the husband think their child has been switched for another. If the woman is blood group B and the man blood group A. Use genetic crosses to support or disagree with their allegations given that their child is blood group O. (Use the symbols IA,IB,IO.)
2. A man who is blood group A marries a woman who is blood group B. If one of their children is blood group O, use a Punnett square to determine the genotype of the other children.
3. Incomplete dominance is also known as ______________.
   A. co-dominance
   B. dominance
   C. segregation
   D. blending inheritance
4. Name two antigens that determine blood groups in human beings.
5. What type of dominance is portrayed in the inheritance of blood group ___________?
   a) AB
   b) A
6. Use a Punnett square to get the probable blood group of the offspring born to the following parents, a father of blood group AB and a mother of blood group O.

20.4. Inheritance of sex in humans

Activity 20.4: Research

1. Using the Internet and textbooks, research on the inheritance of sex in humans and sex linkage in haemophilia and colour blindness.
2. Present your findings to the class.

The facts

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.

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. In karyotype of human males chromosomes, the sex chromosomes are separate as **X** and **Y**. The rest are autosomes.

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

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.**

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

Parental genotype	Male		Female
Parental genotype	XY	X	XX

Male / Female	X	Y
X	XX	XY
X	X X	XY

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.**

Did you know that a female passes the X-chromosome to her son while the daughter receives an X-chromosome from the father?

Self–evaluation Test 20.4

1. Define linkage in relation to hereditary.
2. A certain man always complains that his wife can only bear female children. Explain to this man using a cross diagram, that he is the one responsible for determining the sex of the children.
3. Between a pair of alleles and a pair of chromosomes, what determines the sex of an individual?

20.5. Sex linkage

Study the homologuous pair of chromosomes below. What does it show?

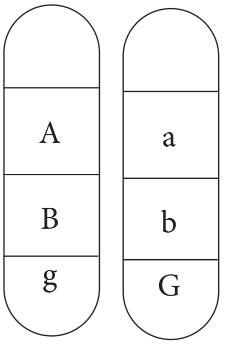


Fig 20.6: A pair of homologous chromosomes

The genes represented by **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, that is, A and a, or A and G are **not linked** because they are found on different chromosomes.

In humans, some traits are controlled by genes located on the sex chromosomes. 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 trait is more likely to appear in one sex than the other.

The sex of a given individual is determined by genes found on the sex chromosomes. The sex-chromosomes also 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.**

The **Y** chromosome is shorter 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 in Fig. 20.7.

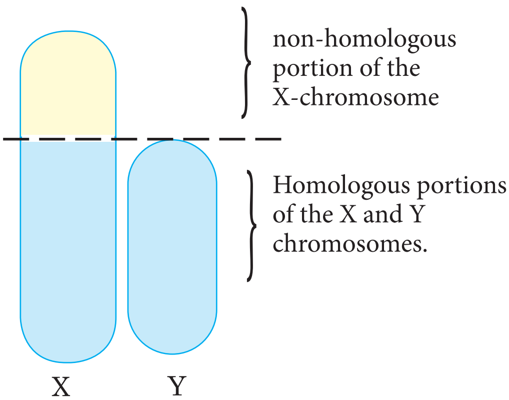


Fig 20.7: Homologous and non homologous portions of the sex chromosomes.

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

Note: The genotype of the individual is written as XX or XY. Since the genes that determine the **sex-linked trait** 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 **X**H. If it is a small letter, it denotes a recessive gene e.g. **X**h.

Haemophilia

Haemophilia, also known as the bleeder's disease, is a sex-linked trait where the normal allele for blood clotting is replaced by a defective recessive allele. The allele is located on the X chromosome. Therefore the condition occurs more in males than in females.

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^hX^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^hX^h, 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 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.

Table 20.8: Relationship between genotypes and inheritance of haemophilia

Possible phenotype	Clotting factor	Phenotype
$X^H X^H$	Normal	Normal female
X^H X^h	Normal	Normal female but carrier
$X^h X^h$	Defective	Haemophilic female
X^H Y	Normal	Normal male
X^h Y	Defective	Haemophilic male

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.

In a case where a haemophilic male marries a normal female; all girls will be carriers while the boys will be normal.

Male / Female	X^h	Y
X^H	$X^H X^h$	$X^H Y$
X^H	$X^H X^h$	$X^H Y$

Did you know, from the table it can be noted that the male requires only one recessive allele to be haemophiliac, while the female requires two recessive alleles to be haemophiliac. In a population therefore, the chances of males being haemophiliac is higher than that of females.

Colour blindness

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. If the mother has the defective allele, there is over 50% chance that the son will receive the defective allele. The daughter on the other hand receives an X from the mother and Y from the father. Hence she would only be a carrier.

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 $X^C X^C$, X^cX^c and $X^C X^c$.
- In males, the possible genotypes are X^CY and X^cY.

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

Table 20.9: Relationship between genotype and inheritance of haemophilia

Genotype	Phenotype
$X^C X^C$	Normal female
$X^C X^c$	Normal female but carrier
X^cX^c	Colour blind female
$X^C Y$	Normal male
$X^c Y$	Colour blind male

If a man with normal colour vision marries colour blind woman and they have children, then the possible genotypes would be:

Male / Female	X^C	Y
X^c	$X^C X^c$	X^cY
X^c	X^cX^c	X^cY

From this cross, all boys will be colour blind but half of the girls will be colour blind while the other half carriers.

Self–evaluation Test 20.5

1. What is haemophilia?
2. On which chromosomes is the gene that cause haemophilia linked to?
3. Sex-linked genes ____________.
   a) are located on the X chromosome
   b) control the production of sex chromosomes
   c) are located on sex chromosomes
   d) expressed more in females
4. What is the probability that the sons of a colour blind man and a normal homozygous woman will be colour blind?
5. A haemophiliac man has two sons, one normal and the other haemophiliac. What is the probability of the couple getting a haemophiliac daughter?
6. State the possible genotypes of a normal person in relation to haemophilia.

Unit summary

- Genetics is the study of heredity.
- Inheritance is the transmission of genetic information from one generation to another.
- Chromosomes are threadlike structures that carry hereditary

materials. They are made up of DNA molecules and a protein.

- A gene is a unit of a chromosome that influences a particular characteristic. They are located on specific positions known as loci on the chromosomes.
- Two genes located on the same loci on homologous chromosomes form an allele pair. A pair of alleles influences the same characteristic.
- The allele that does not influence a characteristic in the presence of the dominant allele is said to be recessive while the allele that influences developing of a characteristic is dominant allele.
- A homozygous individual has two similar alleles while a heterozygous individual has two alleles that are not similar.
- Monohybrid inheritance involves study of transmission of one pair of contrasting characteristics.
- Test cross is used to determine the genotype of an individual with an unknown phenotype.
- The Punnett square is a diagram that is used to predict an outcome of a particular cross or breeding experiment.
- In complete dominance, one allele is completely dominant over the other allele which is masked and is only expressed in homozygous state.
- In co-dominance, both alleles responsible for transmission of a pair of contrasting traits are dominant and are represented in the phenotype of the offspring.
- Co-dominance is exhibited in the ABO blood groups where allele IA and IB are dominant.
- Sex in humans is determined by a pair of chromosomes, the female has two X-chromosomes while the male has an X-chromosome and a Y-chromosome.
- Linkage occurs where genes are located on the same chromosome. Gene on the sex chromosomes are said to be sex-linked.
- Sex-linked genes cause sex-linked characteristics. Examples of sex linked characteristics are haemophilia and colour blindness.
- Colour blindness and haemophilia are linked to the X chromosome and is more common in males than females.

End Unit Assessment 20

1. State two types of variation.
2. Give two sex-linked traits.
3. Which one of the following is not correct?
   A. Inheritance of blood groups involves both complete and incomplete dominance.
   B. Variation refers to difference within a characteristic.
   C. The gene for normal colour vision is dominant.
   D. Genes located on the homologous part of the chromosome determine certain characteristics which are referred to as sex-linked traits.

4. When a red flowered plant of a certain species was crossed with a white flowered plant, all the plants produced had red flowers.

   State the appropriate term that can be used to describe the allele for:

   a) red colour of flowers.

   b) white colour of flowers.

5. The allele for tallness in pea plants (*Pisum sativum*) is dominant over the allele for dwarfness. Using letter T to represent the allele for tallness and t to represent allele for dwarfness, write down the genotypes of:

   (a) homozygous dominant.

   (b) heterozygous.

   (c) homozygous recessive.

6. In a certain breeding experiment, tall plants were crossed with dwarf plants. They produced 106 tall plants and 104 dwarf plants.

   a) Using appropriate letter symbols, state the parental genotypes.

   b) State the expected genotypic and phenotypic ratio if the offspring were selfed.

7. A pure breeding black male mouse was mated with a pure breeding brown female mouse. All offsprings produced were black.

   (a) Using letter B to represent the dominant allele and letter b to represent the recessive allele, work out the genotype of the offspring from a cross between a heterozygous male mouse and a brown female mouse.

   (b) Determine the genotypic and phenotypic ratios from the cross above.

8. Red green colour blindness is a sex linked trait. A colour-blind woman marries a man who has normal colour vision. If they have eight children; six boys and two girls, how many are normal, how many are colourblind? (Use appropriate symbols to show your working.)

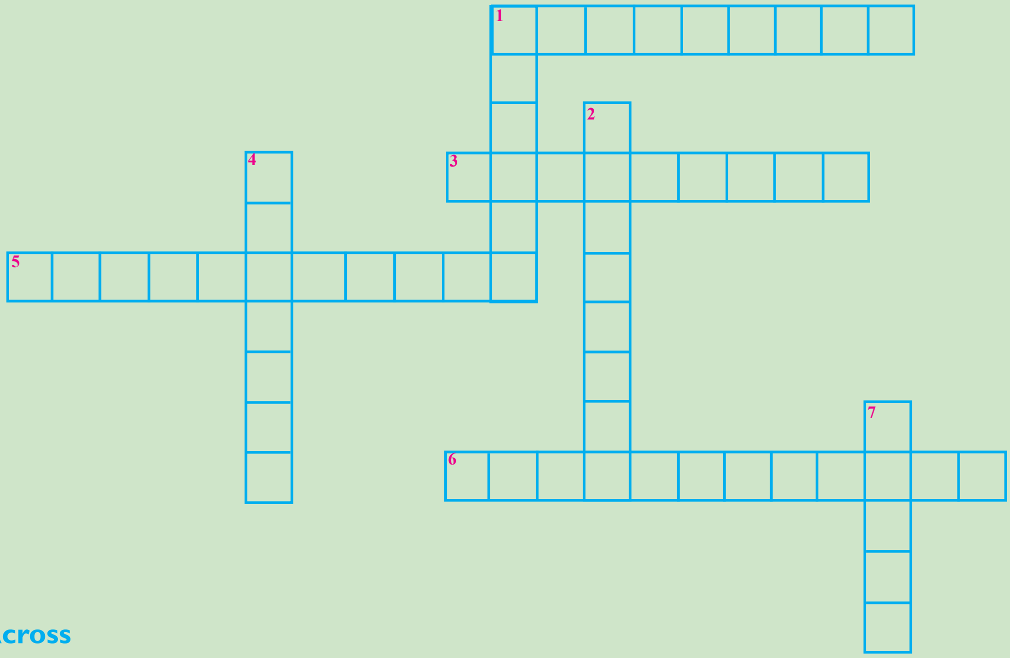
9. A cross between a red flowered plant of a certain species with a white flowered plant produced all pink flowered plants.

   (a) Work out the genotype and phenotypes of the offspring from a cross between two pink flowered plants.

   (b) Name the type of inheritance exhibited above.

   (c) If 7324 plants were produced from the above cross, work out the number of white flowered plants.

10. A woman who is a carrier for haemophilia marries a man with haemophilia. Could any of their children have haemophilia? If so, would the child be male or female?
11. Mukamutara observed the size of abdomen of a fruit fly. He found out that some had broad abdomen while others had narrow abdomen. He wished to know the dominant characteristic among the two. Explain to the student how he would identify the dominant trait.
12. Fill in the crossword below using questions given.



Across

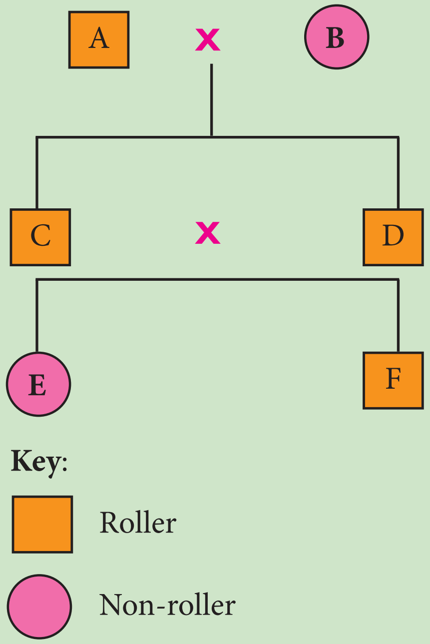
1. Chromosomes that determine body characteristics and are 22 pairs in human beings.
3. A gene that cannot influence development of a characteristic in the presence of a dominant gene.
5. __________ refers to the situation when the contribution of both alleles are visible in the phenotypes.
6. A term used to describe a situation where the two genes in an allele are different.

Down

1. Different forms of the same gene.
2. Genetic composition of an individual.
4. Part where two adjacent chromosomes cross over.
7. Position occupied by a gene on a chromosome.

13. A child's blood is found to be blood group O, the father of the child is found to have genotype AO. Two mothers both with blood group A claim to be the real mother of the child. Explain why their claim may be true or false.

14. The family tree shows the inheritance of the traits of the tongue rolling and the inability to roll the tongue.



a) Which is the dominant trait?
b) Give the word used to describe the genotype of C.
c) For which individual(s) is it not possible to state the genotypes?
d) Is the tongue rolling an example of continuous or discontinuous variation?

15. Femaleness in a human being depends on ___________.
   a) presence of Y
   b) presence of X
   c) absence of Y
   d) absence of X

16. The hereditary factors are transferred in the form of ______.
   a) nucleus
   b) chromosomes
   c) genes
   d) nucleolus

17. A carrier woman for haemophilia who marries a normal man is not likely to get _________________.
   a) normal boy
   b) haemophilic boy
   c) nNormal girl
   d) haemophilic girl

18. The observable characteristics by which an organism is recognized are called _____________.
   a) phenotype b) genotype
   c) anatomy d) genome

19. A sheep has 54 chromosomes in its cells. How many of these are sex chromosomes?
   a) 46 b) 27
   c) 2 d) 1

Unit 21

Gene therapy

Key unit competence

After studying this unit, I should be able to explain the role of genetic engineering in industrial production of insulin and genetically modified crops.

Learning objectives

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

- Define genetic engineering.
- Explain industrial production of insulin.
- Explain the advantages and disadvantages of genetically modifying crops.
- State examples of genetic engineering limited.
- Compare the advantages of the natural crops and genetically modified crops.
- Appreciate that modified crops increase worlds food production to increasing human population.
- Appreciate that animal insulin is available and safe for use to people with diabetes mellitus.

Introductory Activity

Read this story then answer the study questions that follow.

A farmer and his wife are now in their sixties. They have lived in a maize growing village in Rutsiro district for the entire period of their lives. In the past they used to sustain their families by growing local maize in the farm.

In those days, rainfall was reliable and they were sure to get enough harvest to last them for a whole year. However in the last three years, the varieties of local maize they used to plant have been disappointing them. He found himself going to the shops to buy maize since his granaries were empty. He could not understand why the crop that had all along sustained his family was now producing only 2 bags per hectare, a harvest that is hardly enough to sustain him and his seven children and 10 grand children.

Fig 21.1: Harvesting maize

His story remained a mystery, until last year when agricultural officers visited his home and introduced to him a new variety of maize that had recently been produced at ***Karama Research Station****. Throughout his life, The farmer thought that all maize were the same. At first he thought that the officers were not genuine in their mission. He reluctantly accepted to plant the new variety popularly known as ISAR MO81. To save his old tradition, he decided to plant one hectare of local maize and one hectare of the new maize variety that he called 'maize from Karama'.*

To his amazement, the new variety matured far much earlier than his local maize. It produced large kennels and most of the stems produced two cobs. He ended up harvesting 40 bags of the ISAR MO81, while the local variety could hardly reach maturity before the rains stopped. He only managed to get 2 bags of harvest from them. The farmer had also discovered something else, the new variety according to him produced better flour that made his children like the ***'ubugali'*** *prepared from it.*

Fig 21.2: New variety of maize

From that day onwards, the farmer has vowed never to go back to the local variety of maize. He now has enough maize to feed his large family and surplus to sell.

Study questions

1. What two observations can you make about family farming?
2. What type of work is done in research stations?
3. Identify three good qualities of *ISAR MO81* over local varieties of maize.

Introduction

Gene technology is the direct modification of the chromosomes of an organism. It is used to produce new breeds of animals with better production output and new varieties of crops with higher output and which are more resistant to drought and diseases. It is a part of a wider branch of Biology known as **biotechnology**.

Biotechnology refers to productive application of Biology in research and industry to maximize output. Biotechnology is involved in cultivation of food plants that produce high-yielding crops, production of antibiotics, enzymes and hundreds of other products.

In biotechnology, the organisms are not always modified to be different, but their natural processes are enhanced to get the optimum product.

Fig 21.3: GMO maize plantation

The main streams that biotechnology touches are cell and tissue culture, genetic engineering, microbiology, embryology and molecular biology. In this unit you are going to learn about **gene technology** which is also referred to as **genetic engineering**.

Activity 21.1: Field study

1. Visit a research centre.
2. During the visit, study the following:
   - Type of research carried out in the research centre.
   - How biotechnology is applied in that research centre
   - The impact the research centre makes to the community and the country as a whole
3. Write a report of the study.

21.1. Genetic engineering

Activity 21.2: Research Activity

1. Using textbooks and the Internet, research on the need for genetically modified crops.
   - Why are they important?
   - How does that improve world's food supply?
2. Suggest plants that require less fertilizer, resist drought, diseases, pests and cold weather to produce more nutritious or abundant fruit.
   - How do you suppose these plants are produced?
3. Write a report of your findings.
4. Present your findings to the rest of the class.

The facts

Genetic engineering is a biotechnological application where useful DNA or genes of organisms are manipulated according to the requirement. Genetic engineering is used mainly to benefit the needs of human beings. In genetic engineering, an identified gene of an organism that is responsible for a certain function is isolated and introduced into another organism. The introduction of foreign genes into an organism's gene make up (genome) is performed through the techniques of Recombinant DNA Technology (RDT).

Fact of life: The first use of RDT was demonstrated in 1972.

The organism to which the gene has been introduced is called the **genetically modified organism** (GMO). When a certain food is produced through a genetically modified organism, it will be a genetically modified food. Production of food and medicine has been the main practice performed through genetic engineering. In addition, the use of genetic engineering has been starting to benefit the agricultural crops so that there may be an increased immunity against insects or herbicides.

Genetic engineering is different from traditional cross breeding, where genes can only be exchanged between closely related species. With genetic engineering, genes from completely different species can be inserted into one another.

Genetically modified organisms do not have a great chance of surviving in nature. They need special conditions or management of their population sizes. This is because; natural selection did not take place and may be disastrous for the genetically modified organisms.

Steps involved in genetic engineering.

There are many different ways in which a GMO may be produced, but these steps are essential.

- The gene that is required is identified. It may be cut from a chromosome, made from mRNA by reverse transcription or synthesized from nucleotides.
- Multiple copies of the gene are made using the technique known as the polymerase chain reaction (PCR).
- The gene is inserted into a vector which delivers the gene to the cells of the organism. Examples of vectors are plasmids, viruses and liposomes.
- The vector takes the gene into the cells.
- The cells that have the new gene are identified and cloned.

Tools used in Genetic engineering

- Enzymes,
- Vectors,
- Genes

Genetic engineering in vitamin production

Vitamins are essential as nutritional components and are indispensable for the maintenance of many metabolic processes. They cannot be synthesised in the human body and have to be therefore taken up in sufficient amounts from food. An insufficient vitamin supply can lead to deficiency diseases.

There are various methods for production of vitamins: chemical synthesis, biotechnological methods with the help of microorganisms, extraction from plants or herbal material.

- For some vitamins production methods have now been developed that use genetically modified microorganism.
- Vitamin E can be produced both biotechnologically or from soya beans. For extractions from soya beans, it is probable that a certain percentage derives from genetically modified plants.
- Many vitamins, especially the fat-soluble vitamins A, D, E and K, are attached to carrier molecules for better handling. Gene technological methods can be utilised for producing some of these carriers, e.g. starch, glucose and maltodextrin.

Genetic engineering in pest resistance crops

Genes can also be inserted or removed from crop plants to improve their characteristics or traits. Such plants that are as a result of genetic engineering are called **transgenic plants**. Genes for insect resistance now can be moved into plants more quickly and deliberately. *Bacillus thuringiensis,* commonly known as Bt, is a bacterium that occurs naturally in the soil. Some strains of Bt produce proteins that kill certain insects with alkaline digestive tracts. When these insects ingest the protein produced by Bt, the function of their digestive systems is disrupted, producing slow growth and ultimately death.

Bt is very selective, that is, different strains of the bacterium kill different insects and only those insects. Strains of Bt are effective against corn borers, cotton bollworms, certain flies and mosquitoes. Bt is not harmful to humans, other mammals, birds, fish or beneficial insects.

The table below shows examples of traits that can be genetically modified and the plants it can be done.

Table 20.1: Other examples of genetic engineering

Example	Gene donor	Gene receiver	Benefit
Golden rice	Carotene gene from carrots	Rice	People lacking vitamin A in their traditional diet can make the vitamin if they eat genetically modified 'golden' rice.
Insect resistance	Resistant gene from bacteria	Maize and cotton	Confer resistance to insect pests.
Weedkiller resistance	Resistant gene from plant	Soya beans	Genetically modified soya beans can be sprayed with weedkiller and remain unaffected, so only weeds are killed. This increases yields of soya.

Genetic engineering and Herbicide Resistance

Herbicide tolerance is a plant's ability to endure the effects of a herbicide at the rate normally used in agricultural production. Herbicide resistance is the ability of a plant to be unaffected at any feasible rate of herbicide application. Most crops are resistant to one or more herbicides. Genetic engineering has provided plant scientists with additional tools to determine the chemical and genetic modes of action of many of these herbicides and also the mechanisms that account for a plant's natural tolerance or resistance to herbicides.

Scientists use this knowledge to incorporate herbicide tolerance into crop plant species. This is done by:

- Finding a closely related species that has herbicide tolerance or resistance and then incorporate that tolerance into the desired plant.
- Use of cell or tissue culture to test many different lines of plants for tolerance to a specific herbicide.
- Determining the specific gene or genes within a plant or microbe that allows tolerance or resistance to a specific herbicide.

Genetic engineering in industrial manufacture of insulin

Activity 21.3: Observing the process of insulin production

1. Using diagrams, charts, micrographs or simulations on insulin production.
2. Observe the process of insulin production.
3. List the steps involved in production of insulin.

The facts

The human body is capable of producing insulin from the pancreas. The pancreas however might not function properly because of disease and age. The body therefore will face a shortage of insulin which results into an increase in blood sugar level. When this increase is not checked, it will develop into a condition known as *diabetes mellitus*. Scientists through history have always tried to find methods of obtaining insulin.

For many years, insulin was obtained by purifying it from the pancreas of cows and pigs slaughtered for food. The insulin obtained was introduced to the patient inform of injection. This proved to be expensive and difficult. Although cow and pig insulin are similar to human insulin, their composition is slightly different. In 1955, the structure of human insulin was found, and insulin from cows and pigs were chemically modified to be the same as human insulin.

The insulin produced could cause allergic reactions to the recipient and also lead to long term complications ensuing from the regular injection of a foreign substance. Projected decline in the production of animal derived insulin led researchers to consider synthesizing human insulin. This was achieved by inserting the insulin gene into a suitable vector, the *E. coli* bacterial cell. The insulin produced is chemically identical to the natural one. This method is more reliable, sustainable and produces human insulin in a pure form that is less likely to cause body reactions.

The industrial manufacture of insulin involves several steps:

(i) Isolation of the DNA of insulin from a human cell.

(ii) A plasmid made of DNA is removed from the bacterial cell.

(iii) A restriction enzyme cuts the plasmid from the bacterial cell open, leaving sticky ends.

(iv) The insulin gene from the human cell is added to the plasmid.

(v) The plasmid which is now genetically modified is inserted back into the bacterium.

(vi) The bacterium host cell divides and produces copies of the plasmid. The bacterium manufactures human insulin using the genes in the plasmid.

(vii) The insulin is extracted from the bacterial culture and purified.

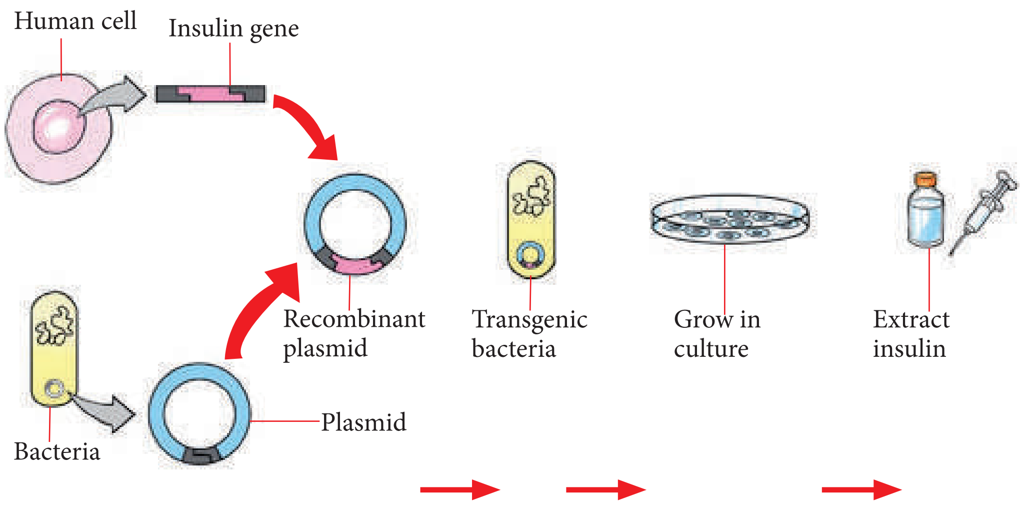


Fig 21.4: Steps of manufacturing insu

Self-evaluation Test 21.1

1. What sort of organisms can be genetically modified?
   A. Plants only
   B. Plants and animals
   C. Animals only
   D. All of the above
2. What is genetic engineering?
   A. Cutting the DNA code
   B. Copying the DNA code
   C. Changing the DNA code
   D. Moulding the DNA code
3. True or false? The artificial crossing of two different varieties to produce a new one that has the best traits of both organisms is considered a type of genetic engineering.
4. Genetic engineering has been used to do all of the following except ________________.
   A. make plants more resistant to frost
   B. make plants more resistant to disease
   C. make plants more resistant to herbicides
   D. improve the nutritional balance of plants

21.2. Advantages and disadvantages of genetically modified organisms (GMOs)

Discussion corner

1. Discuss the advantages and disadvantages of genetically modified crops.

Advantages of genetically modified crops

1. Genetically modified crops are more productive and have a higher yield. Due to higher yield, food prices would go down.
2. Genetically modified crops offer more nutrition and flavour. Some food products have been engineered to become more nutritious in terms of vitamin or mineral content. This plays a significant role in fighting against malnutrition.
3. Genetically modified crops eliminate allergy-causing properties in some foods.
4. Genetically modified crops inbuilt resistance to pests, weeds and disease. The amount of chemicals used on the plants is reduced, so their exposure to dangerous chemicals is also reduced.
5. Genetically modified crops can withstand extreme and fluctuating weather conditions. This means that there will be good quality and sufficient yields even under a poor or severe weather.
6. Genetically modified crops are environment friendly as they require less herbicides and pesticides.They also require less time, tools and chemicals.
7. Genetically modified crop foods are more resistant and stay ripe for longer so they can be shipped long distances or kept on shop shelves for longer periods.
8. More crops can be grown on relatively small pieces of land.

Disadvantages of genetically modified crops

1. Gene pollution cannot be cleaned up. Once released into the environment, genetically engineered organisms cannot be cleaned up or recalled.
2. Genetically engineered crops can cross-pollinate related weed species, passing on their ability to survive the application of weed killers. This leads to the evolution of super weeds that are very difficult to control.
3. Some genetically modified seeds are engineered so that plants cannot reproduce their seeds. Most farmers save seeds from season to season. Therefore, with genetic engineering technology, seeds can be sterile, forcing farmers to rely on seed companies for their livelihood. This is expensive as they may not be able to bear.
4. They can pose significant allergic risks to people. Genetic modification often adds or mixes proteins that were not indigenous to the original animal or plant, which might cause new allergic reactions in the body.

5. Some organisms in the ecosystem could be harmed, which in turn could lead to a lower level of biodiversity. When we remove a certain pest that is harmful to crops, we could also be removing a food source for a certain species.
6. Genetically modified foods are observed to have unnatural tastes compared with the ordinary foods that are sold in the market. This could be the result of the substances that were added to their composition. The substances may cause new diseases and even death to other organisms.

Self–evaluation Test 21.2

1. In your opinion, do you think genetic engineering is good or bad?
2. Are genetically modified crops the answer to perennial food shortages in Africa?

Unit summary

- Genetic engineering is the deliberate modification of the characteristics of an organism by manipulating its genetic material.
- Recombinant DNA technology is the process of artificially combining two or more gene sequences. This new combination may or may not occur naturally, but is engineered specifically for a purpose.
- Insulin is a hormone that regulates the amount of glucose (sugar) in the blood and is required for the body to function normally.
- People who do not produce the necessary amount of insulin can be attacked by diabetes.
- Production of insulin is done industrially by inserting genes coding for insulin production in human beings to a bacterium that acts as a vector.
- Use of biotechnology raises ethical issues on morality and safety

End Unit Assessment 21

1. Genetic engineering ___________.
   A. is a natural process
   B. only takes place in micro-organisms
   C. happens when cells divide
   D. involves combining DNA from different species
2. Why is genetic engineering considered a scientific breakthrough?
3. Cross breeding is a type of genetic engineering. True or false?
4. Which of the following is not an example of a GMO?
   A. Sheep that has wool
   B. Modifying a plant to grow in the winter
   C. Modifying an animal to glow in the dark
   D. Rice having vitamin A
5. Which one of the following is not a principle of genetic engineering?
   A. Create less thirsty crops to lower costs in irrigation
   B. Produce insect resistant plants
   C. Be able to transfer desired genes from one organism to another

D. Find new ways to create aliens

6. Insulin is a ________ produced by the ________, which reduces the concentration of glucose in the blood. People who cannot produce insulin, or do not produce enough of it, are called ________. Many diabetics need daily ________ of insulin. For many years this insulin has been extracted from the pancreas of ________, sheep. Human insulin can now be produced using a technique known as ________.

7. Suppose it was possible to use genetic engineering to make people more intelligent. Do you think this should be allowed?

8. Unscramble the following words associated with genetic engineering.
   a) NAD
   b) PIADLSM
   c) BEACIART
   d) NEZYSME
   e) EGNE

9. What are the potential health risks associated with genetically modified foods?
   A. Allergies and toxins
   B. New diseases
   C. Nutritional problems
   D. All of the above

10. What do you think is the concern of anti-GMO activists in the world?
   A. Unforeseen long-term effects of genetic manipulation
   B. Genetic manipulation in humans as a result of consuming GMO food
   C. Control of food supply by a small number of seed producers
   D. All the above

11. Identify at least four advantages and disadvantages of genetically modified organisms.

12. Insulin is a chemical substance released in the body to reduce the levels of blood sugar.
   a) Which part of the body produces insulin?
   b) What would happen to a person if insulin is not produced in the body?
   c) Identify the type of bacterium used to manufacture insulin on a large scale.

13. Global warming is a current problem worldwide. It has caused more harm than good. As a Biology student, do you think GMOs can help solve this problem? Explain your answer.

14. Some crops have become so much resistant to weed. How can this be related to genetic engineering? Explain.

15. You wish to select a variety of maize to plant in the next planting season. Outline the features you would consider to arrive at the variety of choice.

Unit 22 Variation and adaptive features

Key unit competence

After studying this unit, I should be able to explain that variation is caused by both genetic and environmental factors and adaptive features as shown in different organisms.

Learning objectives

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

- Define variation.
- Distinguish between phenotypic variation and genetic variation, continuous and discontinuous variations.
- Define mutation and adaptive features.
- Record and present the results of investigations into continuous and discontinuous variation.
- Define adaptive feature as an inherited feature that helps an organism to survive and reproduce in its environment.
- Appreciate variation in human beings.

Introductory Activity

Look at the tree diagram below. What is it about?

Assuming children **C** and **E** are daughter and son respectively of parents **A** and **B**, where do you think the difference in the colour of hairs came from? Why did the bald head of parent **A** disappear?

From which parent is grandchild **I** likely to have obtained the characteristics of her hair; **E** or **F**? Why? Why would you say great grandchild **L** is far from reality? Based on your analysis of the chart, what do you think this unit is about?

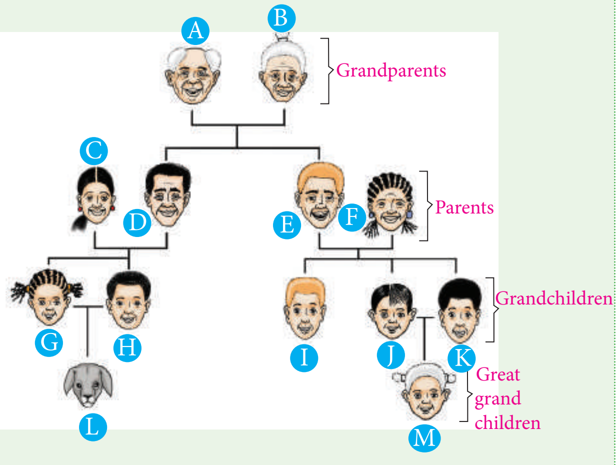


Fig. 22.1: Family tree

Introduction

You may have realised that though organisms may be from same parents, they show differences in their characteristics. This is an example of **variation**.

In this unit, you will learn about variation and how the variations adapt the organisms to their habitats.

22.1. Variation

Activity 22.1

1. Observe charts, pictures of plants and animals of the same type.

   Note down the characteristics of the animals in the pictures.
2. Look at your classmates.
   - Are they of the same skin colour and hair, height or weight?
   - Is the colour of the eyes similar?
   - How about the shape of the nose and ears?
3. What do you think causes these differences in characteristics?

The facts

Your friends and classmates may have different eye colour and skin colour. Some will be boys and some will be girls. Some will be tall and some will be shorter.

The word variation comes from the word 'vary' which means 'to differ'. **Variation** therefore refers to the differences within the observable and non observable characteristics in a given species of organisms. 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. Variation between different species is usually greater than the variation within a 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 fur constitute variation within the characteristic of fur colour.

Variation among organisms of the same species can be caused by one or some of the following factors.

- Separation of chromosomes during gamete formation and crossing over during meiosis.
- Mutations which is the sudden changes in the structure and amount of genetic material in the cells of an organism. They can be caused by mutagens such as UV rays, cosmic rays and other chemicals.
- Sexual reproduction where a zygote is formed by gametes of two parents with varied features.
- Environmental characteristics determine how an organism will grow and how characteristics in it will be developed.

- 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.
- Heredity is the passing on of physical or mental characteristics genetically from one generation to another.

There are two main types of variation, namely; genetic variation and phenotypic variation.

Genetic variation

You probably look similar to your parents and siblings and they look similar to their parents and siblings. However, you do not look exactly the same and this is due to **genetic variation** that causes differences in external characteristics.

You get your genes from your parents that is why you and your siblings look similar to them and each other. Your genes have *alleles*, which are different forms of the same gene. Alleles are like a code for your body that determines hair colour and eye colour, height and other genetic features.

Genetic variation refers to differences amongest organisms of the same species caused by the differences in the genes they inherit from their parents. Some individuals are tall and others are short. This is because they inherited different genes from their parents. Such variations can be inherited because they are genetically determined. Genetic variation can be caused by:

- Mutation
- Random mating
- Random fertilization
- Recombination between homologous chromosomes during meiosis

Did you know?

Genetic variation is the variation in alleles and genes, both within and among populations.

Phenotypic variation

Phenotypes are traits or characteristics of an organism that we can observe such as size, colour, shape, capabilities, and behaviours. Not all phenotypes can actually be seen. For example, blood types are phenotypes that we can only observe using laboratory techniques. Phenotypes can be caused by genes, environmental factors, or a combination of both.

Phenotypic variation is the variability in phenotypes that exists in a population. This type of variation can be due to inheritance of genes and also to environmental factors such as climate and diet. The external environments that can bring about phenotypic variation include:

- climate
- diet
- physical accidents
- culture
- lifestyle

Organisms of the same species may be exposed to different environmental factors such as temperatures, light, humidity and nutrients. Man-made factors such as loss of body parts through accidents, dehorning of cattle and lightening of the skin using cosmetics contribute to the variation. Such variations are not genetically acquired but environmentally acquired. These characteristics cannot be passed from parents to their offspring.

Many kinds of variation are influenced by both environmental and genetic factors. Although our genes decide what characteristics we inherit, our environment affects how these inherited characteristics develop. For example:

- A person might inherit a tendency to be tall, but a poor diet during childhood will cause poor growth.
- Plants may have the potential for strong growth, but if they do not receive sufficient mineral resources from the soil, they may hardly grow at all.
- Identical twins are a good example of the interaction between inheritance and environment; as such twins are genetically the same. Any differences you may see between them, for example in personality, tastes and particular aptitudes are due to differences in their experiences or environment.

Table 22.1: Comparison between genetic variation and phenotypic variation

Genetic variations	Phenotypic variations
Are due to genes	Are due to environmental factors e.g. food, climate and diseases
Reappear in offsprings	Cannot reappear in offsprings
Mainly unchangeable	Sometimes changeable in a lifetime e.g. one may lose weight

Self-evaluation Test 22.1

1. Joan has bright blue hair. What kind of variation has caused this?
   A. Inherited
   B. Environmental
   C. Intended
   D. Dyed
2 What does the term variation mean?
   A. Differences in an organism
   B. Difference in the population
   C. Difference within a characteristic
   D. Difference in body structure
3. State the differences between genetic variation and phenotypic variation.
4. Identify some of the sources of environmental variation.

22.2. Continuous and discontinuous variation

Continuous and discontinuous variations are influenced by genes hence a type of genetic 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.

Activity 22.2: To measure and record height of class members

Requirements

- Metre rule
- Notebook

Procedure

1. Ask your friend to stand straight against a vertical wall.
2. Measure the height of your friend or a student from the heel to the top of the head using the metre rule.

Fig. 22.2: Measuring height

3. Record the height of your friends and others in your notebook.

Study 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)?
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). Fill the following table.

Range	Frequency
100-109	
310-119	
320-129	
330-139	
340-149	
350-159	
360-169	

4. Draw a histogram or a graph from the data above.
5. Determine the mean, median and mode.
6. Identify the range with the least number of students.
7. Identify the range with the largest number of students.

The facts

Measurement of heights of class members differed slightly from one extreme end to the other. In each case, there was a measurement to the lower extreme end and a measurement to the higher extreme end. In between the two extremes, there were intermediate measurements that differed slightly from each other. In this case, the variations in the measurements could not put the individuals studied into distinct groups. The variations demonstrate continuous variation.

Continuous variations are controlled and influenced by environment, for example; you may have genes that can influence you to grow tall. However, if you do not eat enough food, you may become malnourished and have stunted growth.

Some examples of characteristics that show continuous variation are listed below:

- Height
- Weight
- Stem diameter in plants
- Length of leaves
- Length of internodes in plant stems
- Skin colour in humans
- Size of seeds and fruits
- Length of fingers in humans

This is the type of variation of a given character or trait where differences among organisms of the same species are slight and grade into each other. These characters can be measured and mean, mode and median can be obtained.

This is a type of variation where there is a range of values; a line graph is always used to express continuous variation. If you plot frequency as a histogram or as a frequency polygon, you will find that most of the values are close to the average (mean), and extreme values are actually rather rare.

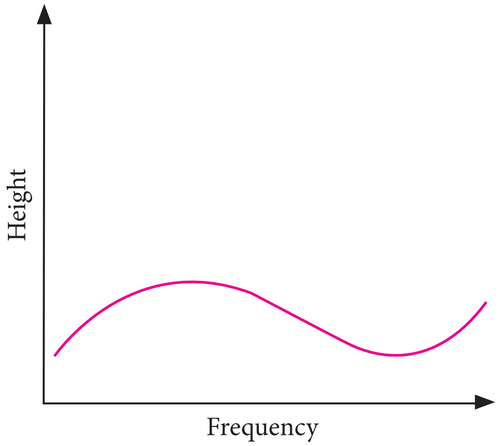


Fig. 22.3: Plot of range in height against frequency

Discontinuous variation

Some characteristics in a given species show definite or distinct differences; there are no intermediates.

Activity 22.3: To investigate the number of male and female students

Procedure

1. Count the number of male and female in your class or school and fill your results in a table like the one shown below.

male	
female	
Total	

3. Plot a histogram showing those who are males and those who are females.

Study questions

(i) How many students are male?

(ii) How many students are female?

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

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

The facts

Students were either male or female. The characteristic for sex therefore has two variations that are distinct from each other. This type of variation which shows clear-cut and sharp differences amongst organisms over a given trait is called **discontinuous** variation.

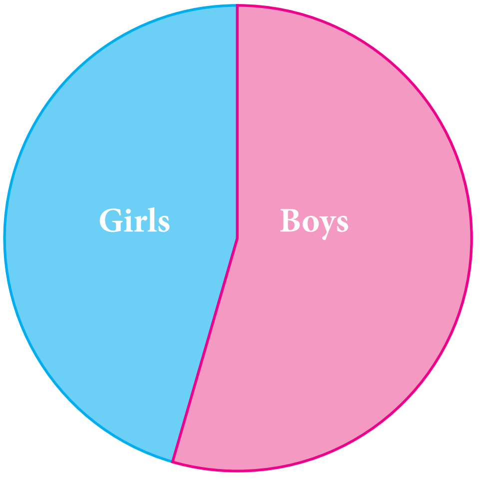


Fig. 22.4: Pie-chart on distribution of students in school by sex

In discontinuous variation differences do not merge into each other and therefore there are no intermediate grades. The features cannot be measured but can be observed. A normal distribution curve cannot be obtained. For example in a class of 49 students, it was found that 10 students were able to roll their tongues, while the rest were not capable. The information above can be represented in a bar graph as shown in Fig. 22.5.

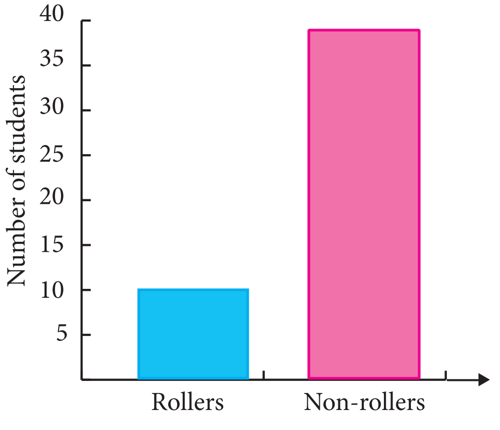


Fig 22.5: Graph of rollers and non-rollers

The features persist throughout the lifetime of an organism. They show distinct differences. The table below summarises examples of discontinuous variation.

Table 22.2: Examples of discontinuous variation

Characteristic trait	Variation
Leaf venation	Parallel or network
Sex	Male or female
Rhesus factor	Positive or negative
Blood groups	A, B, AB or O
Fingerprint patterns	Tentrach, mixed or double looped, or pocked
Skin coat in dogs	Rough or smooth
Flower colour in garden pea	Red or pink

Did you know?

All these characteristics are not affected by environmental conditions.

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

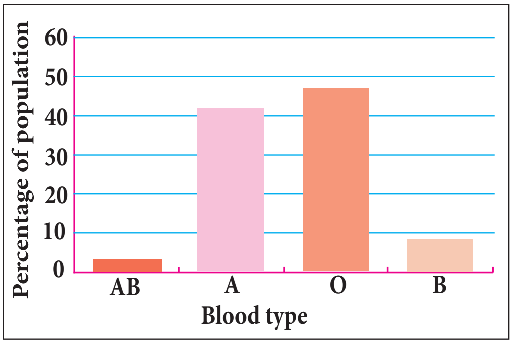


Fig. 22.6 Blood groups

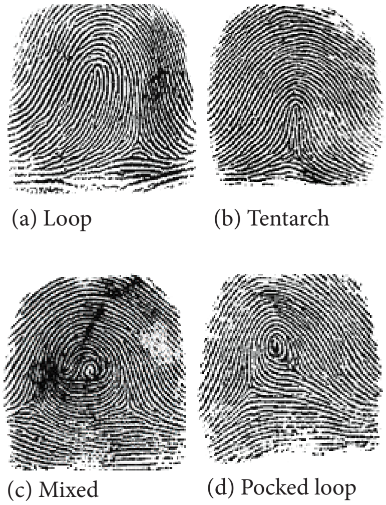


Fig. 22.7 : Fingerprint patterns

Activity 22.4: Investigating the difference between continuous and discontinuous variation

1. Discuss the difference between continuous and discontinuous variation.
   - Note the differences in the table shown below.

Continuous variation	Discontinuous variation

2. Present your findings to the rest of the class.

   Did your table look like this?

Table 22.3: Summary of the differences between continuous and discontinuous variation

Continuous variation	Discontinuous variation
Show no clear-cut distinction	Show clear-cut distinction
Show intermediate between two extremes	No intermediate form
Character influenced by environment	Character not influenced by environment

Self-evaluation Test 22.2

1. Group the following characteristics as either continuous or discontinuous variation.

   Gender, blood group, weight, height, length of fore arm,
2. Which of these factors can be changed by both environmental and inherited variation?

   A. Tattoos B. Scars
   C. Weight D. Dye
3. Where is most variation found?

   A. Between different species
   B. Within one species
   C. Lions and tigers
   D. Among human beings
4. Using a table, give the difference between continuous variation and discontinuous variation.

22.3. Mutations

Activity 22.5: Discussion

1. You want to send a text message to a friend using your mobile phone and this is what happens.

   (a) Original message:
   HE CAME WITH HIS THER**MO**

Conveyed message:
HE CAME WITH HIS **MO**THER

(b) Original message: HE IS EATING
Conveyed message: HE IS **HE**ATING

(c) Original message: THE CO**W** SHADE IS DIRTY
Conveyed message: THE CO**B** SHADE IS DIRTY

2. What do you think will happen to your intended message and the recipient?
3. What do you suppose will happen to a gene sequence in a chromosome if the above takes place in DNA structure?

The facts

If one thinks of the information in DNA as a series of sentences, mutations are therefore errors in spelling the words that make up those sentences. Sometimes mutations are inconsequential, like a misspelled word whose meaning is still quite clear. At other times mutations have stronger consequences, like a sentence whose meaning is completely changed.

Mutations are alterations to a DNA sequence resulting into the formation of new alleles. These new alleles also bring about new characteristics in a population. Mutations can also function as tools of evolution, aiding in the development of new traits, characteristics, or species. There are two types of mutations:

1. **Gene mutation** which occurs as a result of altering the chemical structure of genes. There is a change in sequence of nucleotides in the segments of DNA corresponding to one gene. This in turn alters the sequence of amino acids required in the synthesis of a particular protein. The protein formed will be different from the normal one and will produce profound effects on both the structure and the development of the organism. Gene mutation is associated with certain genetic disorders such as albinism, haemophilia, colour blindness and dwarfism.
2. **Chromosomal mutations** which involve changes in structure of a chromosome or a change in the number of chromosomes in a given individual. This may lead to failure of development of some body parts or over emphasis of a particular trait.

Mutations can be caused by:

a) The DNA failing to copy accurately. Such mutations lead to evolution because they are naturally-occurring. For example, when a cell divides, it makes a copy of its DNA. Sometimes the copy is not quite perfect. This small difference from the original DNA sequence is a mutation.

b) External influences such as exposure to specific chemicals or radiation. These agents cause the DNA to break down. These agents are known as Mutagens.

Health check!

Ionizing radiations from particles, X-rays or gamma rays or chemicals in nuclear plants increases the rate of mutation.

The whole human family is one species with the same genes. Mutation creates slightly different versions of the same genes, called alleles. These small differences in DNA sequence make every individual unique. They account for the variation seen in human hair colour, skin colour, height, shape, behaviour and susceptibility to disease. Individuals in other species vary too, in both physical appearance and behaviour.

Genetic variation is useful because it helps populations change over time. Variations that help an organism survive and reproduce are passed on to the next generation. Variations that hinder survival and reproduction are eliminated from the population. This process of natural selection can lead to significant changes in the appearance, behaviour, or physiology of individuals in a population, in just a few generations.

Once new alleles arise, meiosis and sexual reproduction combine different alleles in new ways to increase genetic variation.

Self-evaluation Test 22.3

1. Which of the following would be responsible for an increased rate of mutation?
   A. Ultra sound
   B. Ultra violet light
   C. Infra- red light
   D. All of the above
2. What is the most likely cause of the unexpected appearance of a new characteristic within a species?
   A. Mutation
   B. Crossing over
   C. Reproduction
   D. evolution
3. Mutation always causes a mutant phenotype. True or False.

22.4. Adaptive features

Have you ever wondered how plants survive in areas with very little or excess water?

Activity 22.6: Investigating adaptive features for hydrophytes and xerophytes

Requirements

- Collected hydrophytes and xerophytes
- Charts and micrographs
- Microscope or hand lens

Procedure

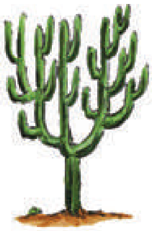
1. Observe carefully the charts and specimens of plants. Use a hand lens if necessary.
2. Use a microscope to observe the micrographs.
   - Which adaptive features are you able to identify?
   - How do the features help the plant to survive?
   - Give examples of xerophytes and hydrophytes.
3. Write a report of your observations.
4. Compare your findings with the rest of the class.

The facts

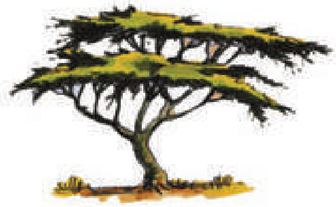
Adaptive features are inherited characteristics that allow an organism to both survive and reproduce in its environment. Adaptive characteristics arise over time within populations of a species, but do not arise within an individual organism.

Xerophytes are plants that survive in very dry regions. They can live in these environments because they contain specialised features that help them prevent water loss. Examples of xerophytes include cactus, euphorbia , acacia and aloe vera.

(a) Cactus



(b) Euphorbia



(c) Acacia

Fig. 22.8: Examples of xerophytes

Xerophytes have the following adaptations to prevent water loss.

- Smaller leaves, almost needle-shaped that create a smaller surface area to reduce the rate of transpiration.

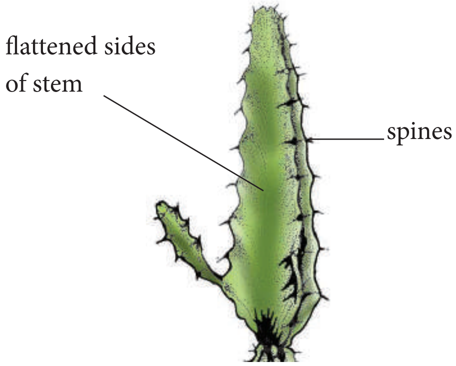


Fig. 22.9: Succulent stem of euphorbia showing spines

- A densely-packed spongy mesophyll layer to provide less surface area that is exposed to the air spaces inside the leaf. Therefore less water evaporates into these air spaces.
- Controlled opening and closing of stomata so that fewer gases can escape. Some plants, such as the tea plant, only open their stomata at night so as to further inhibit their water loss.
- A thicker waxy cuticle on the outer surface of the leaf. This controls evaporation from the leaf.
- Hairs on the surface of the leaf, and especially around the stomata, which trap humid air, and prevent air from being moved away by currents so as to keep the water vapour potential low.
- Sunken stomata in pits of the epidermis; moist air trapped here lengthens the diffusion pathway and reduces evaporation rate.

- Rolled leaves in some plants, which also maintain the humid air around the stomata.

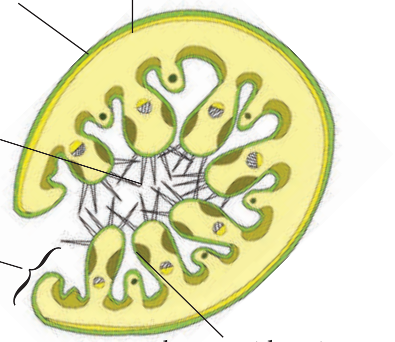


Fig. 22.10: Rolled leaf of murram grass (Ammophila)

- Extensive shallow root systems which tend to be circular in shape, allowing quick absorption of large quantities of water when it rains.

Hydrophytes are plants that are well adapted to survive in or on water logged areas. Examples include lotus, seaweeds and water lily. Common adaptations are to increase the rate of gaseous exchange.

Fig. 22.11: The water hyacinth is an example of hydrophyte

Hydrophytes have the following features to increase water loss:

- The epidermal layer has little cuticle, as water loss is not a problem. All the surface cells appear to be able to absorb water, nutrients and dissolved gases directly from the surrounding water.
- The vascular bundles are often greatly reduced.
- The root system is very much reduced in some floating plants and in submerged plants the roots are absent.
- In some aquatic plants the stems are long, slender, soft and spongy which can bend easily in each and every direction.
- The submerged leaves are often highly dissected or divided to create a very large surface area for absorption and photosynthesis. The emergent leaves are much less divided.

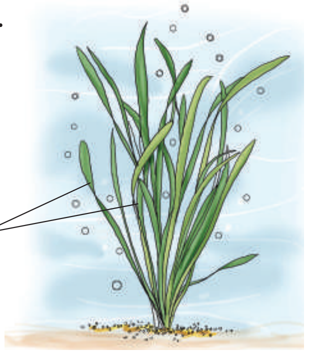


Fig. 22.12: Submerged leaves of Vallisneria gigantea

- Stomata are mostly found only on the upper surface of the leaf. This upper surface often has a thick waxy cuticle to repel water and help to keep the stomata open and clear.

- Presence of aerenchyma tissues that allow diffusion of oxygen from the aerial portions of the plant into the roots.

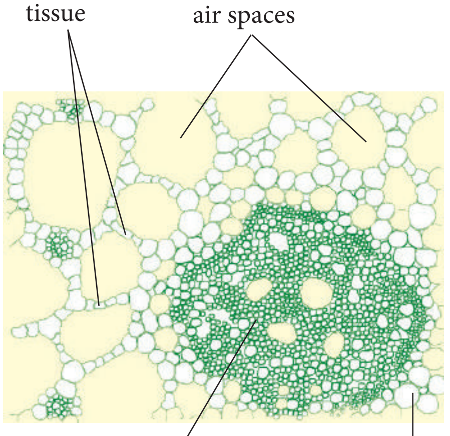


Fig. 22.13: Cross-section through hydrophyte leaf showing aerenchyma tissue

Self-evaluation Test 22.4

1. Plants that have adaptations to reduce transpiration rates are common in ___________.
2. In order to reduce water loss, plants may ____________.
   A. shed leaves
   B. depend on peripheral layer of root
   C. show cell division in shoot apex
   D. get rid of stomata
3. Sunken stomata are found in ___________.
4. What are adaptive features?

Unit summary

- Variation is the difference between individuals of the same species.
- Phenotypic variation is the variability in phenotypes that exists in a population. This type of variation can be due to inheritance and also to environmental factors.
- Genetic variation gives rise to differences between individuals that are inherited.
- Continuous variation has no limit on the value that can occur within a population.
- Discontinuous variation results in a limited number of phenotype with no intermediates.
- Mutation is a genetic change that results into formation of new alleles.
- Adaptive features help organisms to survive in the environment.
- Xerophytes are plants that are adapted to survive in dry environments.

End Unit Assessment 22

1. How much of the genetic information does an individual sperm cell contain?
   A. All the genetic information
   B. Half of the genetic information
   C. None of the genetic information
   D. Some genetic information
2. What type of factor is involved in

determining body mass?
   A. Environmental factors only
   B. Inherited factors only
   C. Both environmental factors and inherited factors
   D. No factors involved
3. Suggest a type of graph that can be used to depict discontinuous variation.
4. Mutations cannot be caused by copying errors in the genetic material during cell division. True or false?
5. Genetic variations are _________.
   A. temporary
   B. influenced by the environment
   C. stable
   D. not heritable
6. A mutagen is defined as ________.
   A. an enzyme that repairs mutations
   B. a chemical or physical agent that induces mutations
   C. an inhibitor of gene modification
   D. a molecule which stabilises DNA thus prevents mutations from occurring
7. Among the following characters, which one does not characterize a hydrophyte?
   A. Abundant air spaces and air chambers
   B. Plentiful xylem
   C. Leaves having stomata on the upper side
   D. Poor development of roots.
8. Which of the following is not a cause of variation?
   A. Mutagens
   B. Meiosis
   C. Fertilisation
   D. A sexual reproduction
9. The major adaptation of xerophytes is to _________.
10. Distinguish between the following and in each case give an example.
   a) Continuous and discontinuous variation
   b) Genetic and phenotypic generation
11. Give examples of disorders brought about by mutations.

Unit 23

Natural and artificial selection

Key unit competence

After studying this unit, I should be able to explain natural and artificial selection in relation to evolution and breeding.

Learning objectives

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

- Describe natural selection, selective breeding, role of artificial selection and evolution.
- Interpret images of extinct animals and relate to present species to determine the course of evolution.
- Appreciate the role of artificial selection in producing varieties of breeds with increased economic importance.

Introductory Activity

Look at the figures below of how human beings evolved. Can you list down the very contrasting characteristics between figure **A** and **F**? How about figures **B** to **E**, can you note some differences? Write them down.

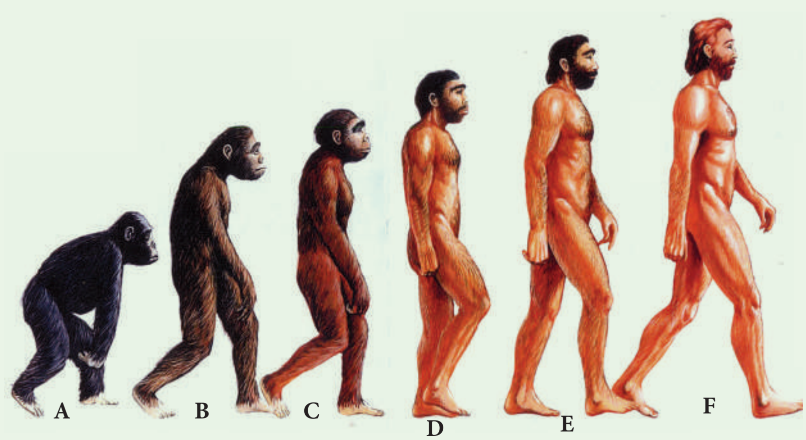


Fig. 23.1: Evolution in human being

What do you think necessitated the change in characteristics between the early human being (Figure **A**) and modern day human being (Figure **F**)? How is this significant? Based on this, how do you think human beings will look like 1 million years from now considering the fact that we are living in the computer age? What does this tell you about this unit?

Introduction

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 on the other hand compete for food, space, mates and shelter. In the process, some of these organisms survive, while others die.

This process is known as the **selection** process. When it happens naturally, it is **natural selection**. Some times human beings influence such a selection process by manipulating the environment. This is known as **artificial selection**.

Fig. 23.2: Climber plants and tall trees in a forest

23.1. Natural selection

The term evolution is derived 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 minor changes that accumulated over millions of years thus selection. This led to the great variations of complex plants and animals we have today. Therefore selection is evolution's engine. Selection acting on random variation makes adaptive evolution possible.

Activity 23.1: Observing natural and artificial selection

Observe and watch documentaries, CD's, pictures and computer simulations about artificial and natural selection.

1. Relate extinct animals and present species to determine course of evolution.
   - Differentiate between natural and artificial selection.

Natural selection is a process whereby organisms with favourable characteristics survive and produce more offsprings than organisms with less favourable characteristics.

In any population of organisms, many new individuals are always produced. However, it is observed that the population of these organisms remains 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, diseases, etc. These can be caused by overcrowding and competition between the organisms. As a result, this creates a **struggle for existence**.

These cause some organisms to die and others to survive. The reason why not all organisms survive this competition is because of their characteristics which 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** or **favourable variations**. The variations that do not enable an organism to compete effectively are referred to as **non-beneficial variations.**

The beneficial variations are referred to as **adaptations.**

An adaptation is an inheritable characteristic that improves the organism's chances of survival in an environment. So there is survival for the fittest.

In nature, environmental conditions keep changing. Organisms that have adaptations to the changes in the environment will always survive. Those organisms that do not have adaptations to the changes in the environment will always 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 offspring. 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 offspring. 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 which says that *members of a species compete with each other for resources and that individuals that are better adapted to their lifestyle have a better chance of surviving to reproduce.*

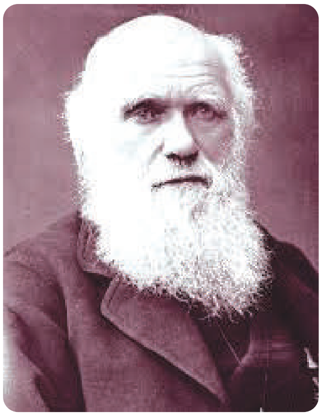


Fig 23.3: A portrait of Charles Darwin

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 offspring with the original one. This means that the gradual changes have led to the formation of a new species. This is called **speciation.**

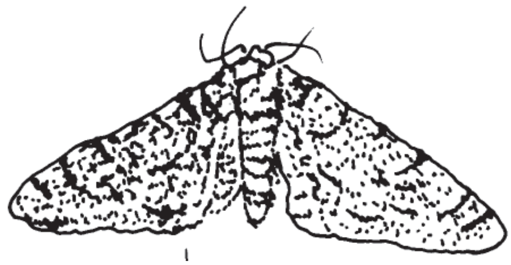
Evolution occurs slowly and continuously over millions of years by natural selection. Other sources of variations that contribute to natural selection in a species include:

- Mutations.
- Recombination of genes as a result of sexual reproduction.
- Migration of individuals between populations which leads to introduction of new genes in the population.

An example of natural selection is exhibited by:

I. 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 industries.

This phenomenon is illustrated in the table below.



(a) Light coloured moth

(b) Dark coloured moth (melanic form)

Fig. 23.4: Different forms of Peperred moth

II. Resistance to drugs, pesticides and antibiotics by disease causing microorganisms.

Methods of artificial selection

1) Outbreeding

This method of artificial selection involves crossing unrelated individuals showing two different characteristics in order to obtain an individual which combine both characteristics for example by crossing a crop plant that gives an excellent yield with the one which resist to disease in the expectation of a plant with a high yield and disease resistance.

2) Inbreeding

In breeding methods, is a method of artificial selection in which there is a breeding of closely relative's individuals with a desired trait, in this case the chances to obtain offspring showing the desired characteristics are greater.

Self-evaluation Test 23.1

1. Through careful observation, Charles Darwin came to understand that ________.
   A. populations of plants and animals in nature most often consist of individuals that are clones of each other
   B. those individuals whose variation gives them an advantage in staying alive long enough to reproduce are more likely to pass their traits on to the next generation.
   C. populations of a species that become isolated from others by adapting to different environmental niches quickly become extinct.
   D. all of the above
2. What causes the following in the theory of natural selection?
   a) Struggle for existence.
   b) Survival for the fittest.
3. Distinguish between beneficial variations and non-beneficial variations.

23.2. Artificial selection

Activity 23.2: Farm visit

Take a visit to a farm near the school.

1. Observe selective breeding of domestic animals and crops.
2. Record your findings in a Exercise book .
3. Compare your findings with others in class.

Study questions

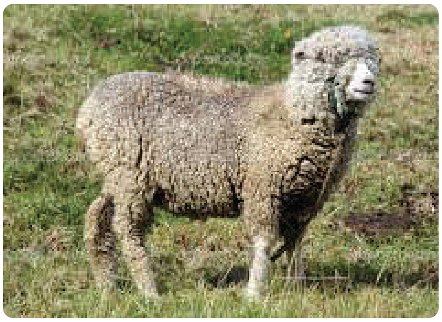
i) What types of animals or plants are selected?
ii) How are the selected plants and animals bred?
iii) Which desirable features are required?

The facts

Artificial breeding, also known as selective breeding, is a process in the breeding of animals and in the cultivation of plants by which the breeder chooses to perpetuate only those individuals having certain desirable inheritable characteristics.

Human beings have been taking the advantage of genetic variations for improving the qualities of domesticated plants and animals. This is done through selecting individuals with desired characteristics and separating them from those which do not have such characteristics. The selected individuals are interbred.

(a) Grade cow



(b) Merino sheep

Fig. 23.5: (a) Grade cow and (b) Merino sheep

This process of selection is repeated for many generations to produce new breeds with desired characters. If cows with high milk yield are desired, the animal breeders select those cows which produce a large quantity of milk. The calves of high milk-yielding cows are interbred to get the new generation of calves. After repeating this process for a number of generations, a breed of high milk-yielding cows is produced.

Through artificial selection, animal breeders are able to produce improved varieties of different kinds of domestic animals such as dogs, horses, pigeons, poultry, cows, goats, sheep and pigs from their wild ancestors.

Similarly, plant breeders have obtained improved varieties of useful plants such as wheat, rice, sugarcane, cotton, pulses, vegetables, fruits among others.

Artificial selection is similar to natural selection except that the role of nature is taken over by man and the characters selected are of human use.

Advantages of artificial selection

i) It creates new desirable traits for plants and animals.

ii) Animals can produce a lot of products.

iii) Farmers and breeders can attract a lot of consumers by selling their plants and the products produced by animals in their new desirable trait.

iv) Artificial selection rules out weakness and disability.

Disadvantages of artificial selection

i) If there is an environmental factor occurring on plants and animals that were domesticated through artificial selection, there will be a higher possibility of extinction.

ii) With artificial selection, the society will be highly competitive.

iii) This is very expensive so only wealthy farmers and breeders can afford it.

iv) It is inhumane so it can cause mutations or produce new problems.

Self-evaluation Test 23.2

1. Which of the following is an example of artificial breeding?
   A. Letting dogs choose their mate
   B. Crossing different species of a pig

C. Creating larger cobs of maize
D. Both B and C

2. Which is not an advantage of selective breeding?
   A. Can create stronger animals
   B. Creates new genes for plants and animals
   C. Breeding is expensive
   D. Farmers and breeder will get better business

3. What caused the light form of the peppered moth to become less common in the nineteenth century?

Unit summary

- Natural selection refers to a situation whereby an organism with beneficial variations in a population of other organisms survives in a competition for resources while organisms with non-beneficial variations die.
- Natural selection causes evolution because with time and over many generations, favourable adaptations accumulate in a species while the unfavourable ones disappear. This leads to development of new organisms.
- The theory of natural selection was studied by Charles Darwin and Alfred Wallace.
- Artificial selection is the intentional reproduction of individuals in a population that have desirable traits.
- Artificial selection has made it possible to develop superior breeds of plants and animals. Superior quality of wheat, corn, soya beans have been grown through careful breeding in agriculture.
- Artificial selection essentially lessens the variation in a certain species and as a result the organisms produced selectively are susceptible to any change in the environment and easily succumb to diseases.

End Unit Assessment 23

1. Organisms that are least likely to experience extinction over the long term are most likely to be found in ________________.
   A. areas inhabited by humans
   B. very stable habitats
   C. desert
   D. savanna

2. Kayitesi is a farmer. She only breeds the largest pigs, fastest horses and cows that produce more milk. This is an example of ________.
   A. natural selection
   B. directional selection
   C. artificial selection
   D. stabilising selection

3. According to Darwin ____________ was the key to developing new species based on what he observed.
   A. reproduction
   B. transcription
   C. artificial selection
   D. isolation

4. When antibiotics were first introduced they killed almost all

bacteria, but varieties have now evolved which are resistant to antibiotics. What caused this?

A. Resistant organisms survived while others were killed
B. Resistant organisms reproduced
C. Resistant organisms occurred by mutation
D. None of the above

5. A certain town was intensively sprayed with a pesticide in an effort to control the houseflies. The number of houseflies immediately and greatly reduced. Each year, the town council would again spray the pesticide but the flies started to gradually increase in numbers until 10 years later they were as many as they were when the control program began. Explain the reason for this.

6. Organism A can interbreed with B, and B can interbreed with C, yet A and C cannot interbreed. How many species are present?

7. Mutation is a relatively unimportant source of variation and is not the foundation for evolution. True/false.

8. Show the differences between natural and artificial selection by filling the following table.

Natural selection	Artificial selection

9. In your words, what do you understand by the term evolution?

10. Explain the role of natural and artificial selection in producing plant and animal varieties.

Glossary

Abstain: restrain oneself from doing or enjoying something.

Acid Rain: polluted rain that contains acids formed from gases such as carbon dioxide, sulphur dioxide and oxides of nitrogen

Acreage: An area of land under cultivation

Aerobes: organisms which use oxygen in respiration

Aerobic respiration: the type of respiration that takes place in the presence of oxygen

AIDS: Acquired Immunodeficiency Syndrome

An impulse: an electrical message transmitted a long nerve fiber

Anaerobes: organisms that do not use oxygen to respire

Anaerobic respiration: the type of respiration that takes place without oxygen

Androecium: male part of a flower formed of anthers and filament

Anemophilus: flowers that are pollinated by wind

Anti-retroviral: drugs that are use to suppress HIV virus and prevent progression into AIDS

Arousal: state of sexual excitement in anticipation of sexual activity

Artificial breeding: also known as selective breeding is a process in the breeding of animals and in the cultivation of plants by which the breeder chooses to perpetuate only those individuals having certain desirable inheritable characteristics

Assimilation: a combination of two process which are; absorption of digested food from intestines to blood stream and a second process is the alteration of absorbed food by the liver and cells into other compounds

ATP: Adenosine Tri Phosphate

Autotrophism: the type of nutrition where organisms make their own food from simple substances such as carbon dioxide and water

Auxins: a family of plant hormones produced at the growing regions of the plant

Axon: a long cytoplasmic extension running from the cell body

Beneficial or favourable variations: variations that enable the organisms to compete effectively

Biodegradable: these are substances that can be broken down by living things

Biodiversity: the variation in life forms, diversity in ecosystems species or genetic make-up

Biotechnology: the exploitation of biological processes for industrial and other purposes, especially the genetic manipulation of microorganisms for the production of antibiotics, hormones

Bisexual: a flower having both male and female structure i.e. stamen and carpels. Sometimes such flowers are referred to as **Perfect**

Blastocyst: hollow ball of cells formed from the zygote after a series of mitotic divisions

Bolus: chewed food mixed with saliva ready for swallowing

Buccal cavity: the area behind the teeth that stops at the opening of the gullet

Cardiac sphincter: a ring of muscle or valve that closes the upper side of the stomach

Carrying capacity: Maximum population size of a species that the environment can sustain indefinitely

Centromere: constricted region where sister chromatids are attached

Chiasmata: a point of crossing over for non-sister chromatids of different homologous chromosomes

Chromatid: one copy of a newly copied chromosome which is still joined to the other copy by a single centromere

Chromatin: substance found in cell nuclei that forms chromosomes during cell division

Chyme: the semi solid food mixed with gastric juice ready to leave the stomach to the duodenum

Cloning: a form of asexual reproduction in which an organism can be reproduced from a single cell

Coagulation: the solidifying of a liquid such as milk or blood

Communication: means of passing information to an intended audience

Competition: the interaction between organisms of the same or different species in which both are harmed

Conditioned reflex: a reflex action triggered by a certain stimulus which the animals learn to associate with a different stimulus

Condom: a rubber sheath worn on an erect penis and is used to prevent unintended pregnancies and transmission of STIs including HIV

Conjugation: form of asexual reproduction that involves direct cell-to-cell transfer of genetic material

Conservation: the use of natural resources without wasting them for social and economic development

Constipation: a digestive disorder in which evacuation of the bowels is difficult and does not occur regularly

Contraceptive: **birth control** sometimes called **fertility control** used to prevent pregnancy

Cooperation: the kind of interaction in which organisms of the same species live together and share work between themselves

Crossing over: the exchange of genetic material between non-sister chromatids of homologous chromosomes

Cusps: are ridges found on top of premolar and molar teeth

Deciduous or milk teeth: the first set of teeth that grow in the mouth

Defeacation: the act of releasing feaces from the rectum through the anus to the outside

Dental caries: sometimes called dental cavities are the holes formed on teeth due to acids from bacteria in the mouth

Dental floss: sometimes called **tooth floss** is a strong thread used to remove food and dental plaque from between teeth

Dental plaque: a mass of bacteria which is sticky and grows on surfaces such as teeth surfaces making them yellow or brown

Dentition: characteristic arrangement of teeth in the mouth

Depression: a disorder that results to low mood, persistent loss of interest and feeling of sadness

Diarrhoea: a condition when feaces are watery

Diploid: cell containing a double set of chromosomes arranged in homologous pairs within its nucleus. All cells in the body are diploids except gametes

Dispersal: the movement of seeds and fruits away from the parent plant

Dissection: the cutting up of body parts of an animal or plant for the purpose of careful examination so that analysis can be done

DNA (Deoxyribonucleic acid): a molecule that carries most of the genetic instructions used in the development, functioning and reproduction of cells of all living organisms

Drug abuse: the habitual excessive use of drugs resulting into addiction

Ecosystem: a community of organisms interacting with each other and with their environment

Ecotourism: tourism industry that focuses on ecology and conservation of the environment (by conducting trips to the rainforest, African savannas, etc)

Effectors: structures that aid animals to react to stimuli i.e. they carry out a response; they can be glands or cells

Effluent: something which flows out e.g. out flowing branch of a stream

Egest: the expelling of undigested material through the anus

Egg: female gamete

Emulsification: physical breaking down of fats into small droplets for easy digestion

Enamel: the hardest part of the teeth that covers the surface

Endangered species: species of plants and animals that are at risk of going extinct because their numbers are too few to have successful breeding

Entomophilus: flowers that are pollinated by insects

Epiglottis: a tissue that closes the trachea or wind pipe during swallowing so that food particles do not enter the lungs

External environment: the immediate surroundings of an organism

Feaces: formed in the large intestine from material which is not absorbed or digested

Fertilisation: the fusion of male and female gamete to form a zygote

First generation: refers to the first offspring produced after crossing the parental genotypes

Flatus: a mixture of gases formed by bacteria in the colon which is normally let out through the anus during farting

Fossil fuel: fuels formed from the remains of plants and animals that lived in an earlier era such as coal, petroleum, natural gas

Fruit: seed bearing structure formed from a flower after fertilisation

Gamete: a reproductive cell containing a haploid or half number of chromosomes

Gastric gland: gland located in the stomach that produces gastric juice

Gastric pits: the openings of the gastric glands

Gastrin Hormone: a hormone produced by the stomach walls responsible for the stimulation of gastric gland to produce gastric juice

Gene: It's the unit of inheritance located on DNA

Genetic engineering: a set of technologies used in manipulating DNA (genes) of an organism to produce desired characteristics in that particular organism

Genetic predisposition: increased probability of developing a disorder due to genetic constitution of an organism

Genetics: the study of heredity and the variation of inherited characteristics

Genome: the total genetic constitution of any cell in an organism

Genotype: the genetic constitution or genetic makeup of an organisms

Geothermal: heat energy generated and stored in the Earth

Germination: is the process by which an organism grows from a seed or spore

Gibberellins: are plant hormones that regulate growth and influence various developmental processes, including stem elongation, germination, dormancy, flowering, sex expression, enzyme induction, and leaf and fruit senescence

GMO: a genetically modified organism, or GMO, is an organism that has had its DNA altered or modified in some way through genetic engineering

Greenhouse effect: a process in which carbon dioxide and other green house gases radiate heat back to earth causing temperature to rise up

Gynoecium: female part of a flower made of stigma, style and ovary

Habitat: an area where an organism is usually found

Haploid: half number of chromosomes in a cell

Health: a state of well-being resulting from complete physical, mental and social well-being

Herbicides: chemicals used to kill weeds

Heterotrophism: the type of nutrition where organisms get ready-made food from the environment

HIV: Human Immunodeficiency Virus

Homologous chromosomes: a set of one maternal and one paternal chromosomes that pair up with each other inside a cell during meiosis

Hormone: an organic chemical substance, which is produced in small quantities and transported by blood to target organs where it exerts its effects

Host: an organism which provides food and sometimes shelter to the parasite

Hydroelectricity: Is electricity produced from hydropower which is the power derived from falling or fast running water

Hydroponics: the growing of plants in nutrients solution without soil

Hygiene: practices that bring about safe and healthy environment that prevents diseases through cleanliness

Ileo-colonic sphincter muscle: the muscle that controls the movement of food from the ileum to the colon

Immune system: a protection mechanism comprising of biological structures and processes that defend the body against pathogenic microorganisms

Implantation: attachment of the blastocyst into the uterus

Infection: invasion into the body and multiplication of pathogenic microorganisms

Inflorescence: clusters of flowers formed on a modified shoot

Ingest: is the putting of food into the mouth

Inspection: careful examination of something

Insulin: a hormone produced by the pancreas and responsible for lowering blood sugar

Intensive farming: farming on a small piece of land using modern techniques

Interdependence: depending on each other for either food or shelter

Internal environment. the immediate surroundings of the cells, which is mainly tissue fluid

Lactation: production of milk by mammary glands

Macronutrients: nutrients which provide energy needed in large quantities for metabolism of an organism such as carbohydrates, proteins, fats, calcium, etc

Mastication: the breaking of food into smaller pieces by the teeth in the mouth while mixing it with saliva

Menstruation: periodic shedding of the endometrium in the form of blood and tissue debris which are let to the outside through the vagina

Meristem: is the tissue in most plants containing undifferentiated cells (**meristematic cells**), found in zones of the plant where growth can take place for example, apex and near root tips

Micronutrients: nutrients required by an organism in small quantities for physiological functions such as vitamins, iron, zinc, copper, e.t.c

Miscarriage: loss of pregnancy before the foetus is able to survive independently, i.e. before the end of 23 weeks or six months

Monoculture: cultivation of one type of crop usually on a large scale

Monogamy: the state of having only one sexual partner or one wife

Myometrium: middle uterine layer comprising of smooth muscles

Nastic responses: responses towards stimulus but which are non-directional

Natural selection: a process where organisms with favourable variations survive and produce more offspring than organisms with less favourable variations

Non-beneficial variations: are variations that do not enable an organism to compete effectively

Oesophagus: the tube sometimes called gullet that carries food from the mouth to the stomach

Ovulation: release of mature egg from the ovary

Oxygen debt: oxygen deficit that develops when an aerobic organism or tissue cannot increase its oxygen uptake sufficiently to match the increased demand for energy

Parotid gland: a salivary gland located in the upper region of the buccal cavity

Parthenocarpy: formation of fruits without fertilisation

Parturition: the process of giving birth.

Pathogen: disease-causing microorganism including bacteria, fungi and viruses

Peer pressure: a feeling that one must do the same things as other people of one's age and social group in order to be liked or respected by them

Perennating organ: part of a plant that is adapted to sustaining an organism through adverse or unfavourable conditions and is capable of developing into one or more new plants

Pericarp: fruit walls comprising of epicarp/ exocarp, mesocarp and endocarp

Periodontal disease: general term for diseases and bacterial infections of the gums and teeth that cause much damage and can result in loss of teeth

Periodontal membrane: the membrane which separates the jaw bone from the cement part of tooth

Peristalsis: the automatic movement that pushes the food along the alimentary canal from the oesophagus to the rectum

Pharynx: the area at the back of the mouth or at the opening of the gullet or oesophagus

Phenotype: the outward or physical appearance of an organism

Phototropism: the growth or movement response of a cell or an organism due to the light stimulus

Placenta: an organ found in mammals through which substances exchange between the mother and foetus take place. It's made up of embryo and maternal tissues

Plumule: part of the seed that grows into the shoot system

Pollination: transfer of pollen grains from anther to stigma of a flower

Pollution: the introduction of harmful substances into the environment at a higher rate than the rate at which they are removed

Population density: the number of organisms in a given place per unit area

Preservation: the protecting of the environment by the act of saving it from damage

Progesterone: a pregnancy hormone that maintains the uterus and is secreted by the ovary and placenta

Propagation: type of reproduction where part of an organism is used to develop new organisms

Pyloric sphincter: a ring of muscle or valve that closes the lower side of the stomach

Radicle: part of the seed that grows into the root

Receptors: structures or organs that receive stimuli e.g. skin, eye, ears, tongue, and nose. They are also known as sense organs

Reflex action: a sudden, automatic and uncontrolled response of parts of the body to a stimulus e.g. knee jerk

Reflex arch: described as the path taken by a nerve impulse in a reflex action

Renewable resources: able to be replaced by nature e.g. forests are renewable natural resources

Reproduction: a process by which living organisms give rise to new individuals of the same kind

Scalpel: a small sharp knife used in dissection

Second generation: the offspring produced by crossing the first generation

Semen: fluid containing mature sperm cells and seminal fluid

Sewage: waste water and excrement

(feaces) conveyed in sewers

Sexual harassment: sex discrimination that involves bullying and coercion

Sexuality: how a person expresses themselves as a sexual being

Speciation: the gradual process of formation of new species due to evolution

Spermicide: a substance that is used as a contraceptive to kill spermatozoa; it is normally applied before intercourse

Spindles fibers: microtubules which are a components of the cytoskeleton, found throughout the cytoplasm used to move chromosomes from one place to another

Spore: an enclosed single or many-celled reproductive structure that is adapted to withstand harsh conditions and can give rise to new organisms

Stigma: a mark of shame or disgrace associated with a certain condition, circumstance or person

Stimulus: any change in the environmental conditions which can bring about a change in the activity of an organism e.g. chemical change, light

Sub maxillary gland: a salivary gland located under the tongue

Sublingual gland: a salivary gland located at the lower jaw on the sides of the tongue

Submissive: an individual that allows himself to other peoples' demand

Succus entericus: the intestinal juice that contains digestive enzymes and mucus in the ileum

Sustainable development: the development which does not damage the environment either by using all the resources or polluting the environment

Sustainable resources: the resources which can be renewed as in the case of agricultural products

Synapse: a specific functional point that links one neuron to another

Tetrad: a haploid cell formed from meiotic division of a pollen mother cell

Thermoelectricity: electricity produced by the direct action of heat

Trait: the characteristics shown by an organism

Transgenic plants: are plants that have been genetically engineered through a breeding approach that uses recombinant DNA techniques to create plants with new characteristics

Umbilical cord: part of the foetus containing two arteries and one vein that transports material between mother and foetus

Unisexual: a state of having one of the two distinct sexes in an individual organism

Uvula: a soft tissue that closes the opening of the nose so that food does not enter the nose

Villi (singular: Villus): finger like projections on the inner surface of the ileum which are used in food absorption

Wildlife: wild animals and plants which are not domesticated

Wisdom tooth: the last molar tooth to grow

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