INTEGRATED SCIENCE
FOR TTC

YEAR 2

OPTION: *ECLPE*

STUDENT BOOK

FOREWORD

Dear Student- teacher,

Rwanda Education Board is honoured to present to you this Integrated Science book for Year Two of TTC, ECLPE Option which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of Integrated Science subject. The Rwandan educational philosophy is to ensure that you achieve full potential at every level of education which will prepare you to be well integrated in society and exploit employment opportunities.

The government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate your learning process. Many factors influence what you learn, how well you learn and the competences you acquire. Those factors include the instructional materials available among others. Special attention was paid to the activities that facilitate the learning process in which you can develop your ideas and make new discoveries during concrete activities carried out individually or with peers.

In competence-based curriculum, learning is considered as a process of active building and developing knowledge and meanings by the learner where concepts are mainly introduced by an Activity, a situation or a scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values. For effective use of this textbook, your role is to:

- Work on given activities including laboratory experiments which lead to the development of skills;
- Share relevant information with other learners through presentations, discussions, group work and other active learning techniques such as role play, case studies, investigation and esearch in the library, from the internet or from your community;
- Participate and take responsibility for your own learning;
- Draw conclusions based on the findings from the learning activities.

I wish to sincerely extend my appreciation to the people who contributed towards the development of this book, particularly REB staff who organized the whole process from its inception. Special gratitude goes to teachers, illustrators and designers who diligently worked to successful completion of this book.

Dr. NDAYAMBAJE Irénée

Director General, REB

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I wish to express my appreciation to all the people who played a major role in development of this Integrated Science book for Year Two of TTC, ECLPE Option. It would not have been successful without active participation of different education stakeholders.

I owe gratitude to different Universities and schools in Rwanda that allowed their staff to work with REB in the in-house textbooks production project. I wish to extend my sincere gratitude to lecturers, teachers, tutors, illustrators, designers and all other individuals whose efforts in one way or the other contributed to the success of writing of this textbook.

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Joan MURUNGI

Head of CTLR Department

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UNIT 1

INTERDEPENDENCE BETWEEN ORGANISMS WITHIN THEIR ENVIRONMENT

Key Unit competence: Explain complex relationships between organisms within their environment.

Introductory Activity 1

The figure below shows the mode of life in a natural park. Organisms on this interact with each other.

a) Can you describe how these organisms interact?
b) Are their interactions beneficial or harmful?
c) How organisms on the figure above can be affected by one another in their physical environment?

1.1. Interrelationships among organisms and their effects

Activity 1.1

Read the following passage and answer related questions:

No organism exists in an absolute isolation. Organisms interact with each other. If the interaction involves individuals of the same species, it is called **intraspecific** interaction, and **interspecific** interaction, when the interactions involve individuals of different species.

Biological interactions can be **beneficial**, **harmful** or **neutral** for each of any two species. For example, the **competition** arises when two organisms strive for the same limited resource. Have you ever seen two bulls fighting for a female cow, or dog and cat fighting for meat?

The lion cannot compete with herbivorous antelopes. Instead, the lion, king of jungle, kills and feeds on antelopes. The two species live in **predation.**

A dog is the host **ectoparasite** such as fleas and **endoparasites** such as roundworms. The host suffers but the parasites get benefit. However, Heron birds also known as Inyange live in **mutualism** with the cows. Each species gets benefit from the interaction.

Nevertheless, in some cases, these interactions may result into long-term ecological and evolutionary changes among the individuals participating in these interactions. For example, the intraspecific competition enables the fittest organism to improve its fitness for acquisition of resources

a) Explain in your own words each of the following interaction: Intraspecific competition – Interspecific competition – Parasitism – Predation – mutualism.

b) Find examples of biological interaction which can be:

   i). Beneficial for one individual but harmful for another

   ii). Beneficial for both individuals

   iii). Harmful for both individuals

   iv). Neutral for both individuals.

c) Giving an example, support why biological interactions are very important in ecosystem.

Interactions among organisms within a community are termed **biological interactions** or **interrelationship among organisms**. These interactions may involve individuals of the same species or different species.

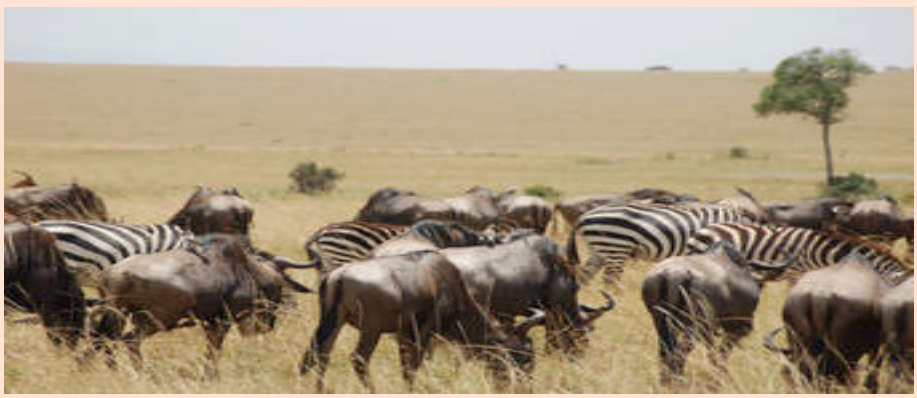
Thus based on these criteria, biological or population interactions may be divided into basic interactions and relationships. All the interactions are indicated by signs such as **+, +** or **–, –**, or **+, –,** even **0, 0**. The sign **(+)** indicates that a particular species is benefitting from the interactions. The sign **(–)** indicates that a particular species in the interactions is being harmed. And sign **(0)** simply indicates neutral position where it is neither benefited nor harmed in the interactions.

Table 1.1: Biological interaction

Types of Interaction	**Effect on species 1**	**Effect on species 2**	**General nature of interaction**
Competition, direct interference type	-	-	Direct inhibition of each species by the other or Indirect inhibition when common resource is in short supply
Commensalism	+	0	Population 1, the commensal, benefits, while 2, the host, is not affected
Parasitism	+	-	Population 1, the parasite, generally smaller than 2, the pray, and also harms the prey
Predation (including herbivory)	+	-	Population 1, the predator, generally larger than 2, the prey, and kills the prey
Mutualism	+	+	Interaction favorable to both and obligatory

Application Activity 1.1

Analyse the photograph or watch a documentary of the wildlife provided by your teacher. Then get ready to identify main species in the documentary and their relationship.



1. Are there intraspecific or interspecific relationships among observed organisms? Why?
2. Are there useful, neutral and harmful relationships among observed organisms?

1.2. Inter and Intra specific relationships between organisms

Activity 1.2

Observe the figure below showing interactions between organisms and answer questions below:

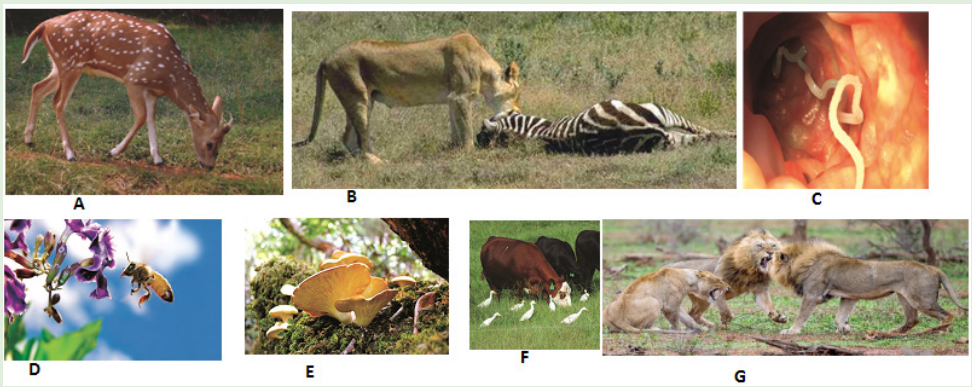


Figure 1.2: Inter and intraspecific relationships between organisms

a) Mention different biological interaction (inter and intraspecific relationships) labeled by letter A, B, C, D, E, F, and G
b) For each provided interaction, give its meaning and your own example in each case.
c) Explain the significance of each organism's interactions in nature.

Under natural conditions, plants and animals interact with other organisms of the same species as well as those of different species. The various organisms that surround and interact with a particular organism constitute its **biotic environment.** Such interactions have a great influence on the distribution and abundance of any one given species. Some of the most important interactions are: competition, parasitism, predation, saprophytism, mutualism and commensalism.

1.2.1. Competition (–,–)

In both types of competitions, the two or more species competing for the same resource inhibit one another directly or indirectly. That is why they are denoted as (–, –) signs.

a) Intraspecific Competition

Intraspecific competition is a competition where individuals of the same species compete for the same limited resources in an ecosystem. The resources could be food, water, space, light, mates or any other resource which is required for survival.

Significance of Intraspecific Competition

Intraspecific competition acts as an important regulator of population size, meaning successful individuals will survive while unsuccessful individuals will die. It can also be called population density dependent regulator. Moreover, since intraspecific competition results individuals with different reproductive success, it can be a selective factor in evolution.

b) Interspecific Competition

Interspecific competition is a type of competition in which individuals of different species compete for the same limited resources in an ecosystem. The resources could be food, space, light, water, etc. In this kind of interaction, populations of the two or more species are affected adversely.

Significance of Interspecific Competition

Gause's exclusive principle states that the species with identical ecological requirements cannot coexist over a long period of time. The less-fit species in the competition will be replaced by the better-fit species. Thus, in such situations, where interspecific competition is intense, the competition acts as one of the most important factors in structuring ecological communities and also as an agent of natural selection.

Competition can cause species to evolve differences in traits. The characteristics that enable an organism to reduce competition will function to improve fitness; therefore, influencing the evolution of characteristics related to the acquisition of resources.

Difference between Intraspecific and Interspecific Competition

Intraspecific competition	Interspecific Competition
– It is a competition among the individuals of the same species.	– The competition is among the members of different species.
– The competition is for all the requirements.	– The competition is for one or a few requirements.
– The competing individuals have similar type of adaptation.	– The competing individuals have different types of adaptations.
– It is more severe due to similar needs and adaptations.	– It is less severe as the similar needs are a few and the adaptations are different.
– Example includes finding mating partners.	– Example includes competition for food.

1.2.2. Parasitism (+, –)

Parasitism is an association between two different organisms, in which, one called the parasite obtains food and sometimes shelter from the other which is called the host. The host does not gain from the association and is usually harmed. Parasites are only found where there are suitable hosts. Parasites can be a number of things, including plants, animals, and even viruses and bacteria. For example, the malaria parasite, *Plasmodium vivax*, is only found in tropical and subtropical regions where its intermediate host, the female *Anopheles mosquito* inhabits.

Types of parasites

Parasites are classified by how they interact with their host. Overall, parasites are much smaller than their hosts and reproduce at a faster rate.

a) Ectoparasites

The term "ecto" in Greek means outside. Therefore, parasites that live on their host are termed ectoparasites. Examples of ectoparasites are fleas, ticks, and mites (See Figure 1.3). These parasites live on larger animals, like cats, dogs and deer.

Figure 1.3: Ectoparasitism (A flea on a dog's skin)

b) Endoparasites

Similarly, the term "endo" in Greek means inside. Parasites that live inside their host are termed endoparasites. These include the things like parasitic worms, bacteria, and viruses. Tapeworms are endoparasites. They live in human intestines where they feed on the partially-digested food in their host's intestines. It is a fully protected environment and they grow and thrive in these conditions.

The tapeworms have no digestive system of their own, but absorb nutrients through their skin from partially digested food as they pass through the host (See Figure 1.4).

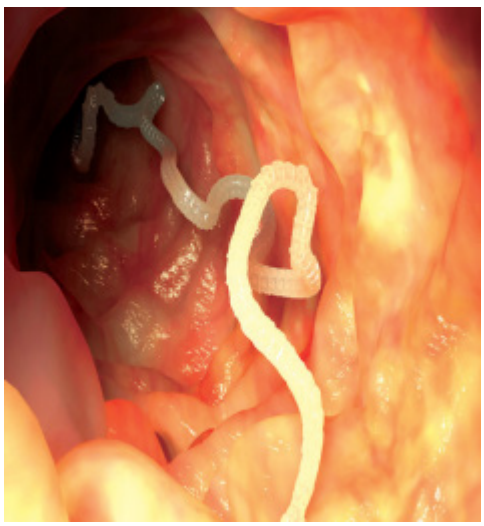


Figure 1.4: Tapeworm

Significance of Parasitism

1. Parasitism alters the behaviour and morphology of their hosts. This alteration increases the chance of being preyed by the predators thereby assisting the parasites to move from one host to another to complete their life cycle.
2. Parasitism promotes coexistence in biodiversity. Usually in an ecosystem, a competitively dominant species out-competes a competitively inferior species and doesn't allow coexistence with this species. However, parasites reduce the competitive ability of the dominant species in a biodiversity and, thereby, allow a competitively inferior species to exist together with a dominant species.
3. Parasitism affects the keystone species and modifies the structure of ecosystem. In an ecological community, the effect of parasitism is the strongest when the hosts are keystone or dominant species with crucial functions in an ecosystem.

4. Parasitism leaves parasite with no responsibility. A social parasite is a parasite that takes advantage of the interaction of other organisms. The best example of a social parasitism is brood parasitism. This is an interaction where the parasite, typically a bird, deposits its eggs in the nest of another species. The host (another species) then 'babysits' the egg in place of the parasite (bird), allowing the parasite to deposit eggs in other nests instead of spending time hatching their own young.

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.

1.2.3. Predation

Predation is an interaction between the two species, i.e., predator and prey, in which one species (predator) uses another species as food (prey). In other words, one organism kills and consumes another. Predation influences the distribution, abundance and diversity of species in ecological communities.

Types of Predation

Generally, predation can be divided into:

a) Carnivory

Carnivory takes place when a predator consumes meat, rather than plants, and consequently kills its prey. Organisms that prefer meat to plants are accordingly called carnivores. The example of the lion hunting the buffaloes is called carnivory (See Figure 1.5). In this type of predation, a predator kills its prey more or less immediately. Other examples are a shark eating a tuna or a Venus fly trap consuming a fly.

Figure 1.5: Lion attacking the prey

b) Herbivory

Herbivory is the act of animals eating plants. Or when an animal uses a plant as food, it is called herbivory.

Example, when a deer eats grass, the plant is the prey and the animal the predator (See Figure 1.6).

Figure 1.6: Herbivory: Deer eating grass

Predation and Adaptation

Adaptation in Predator Species

Based on their experience, predators also undergo certain adaptations to be an efficient hunter or killer. These adapted traits are passed down from generation to generation. Predators exhibit traits such as sharp teeth, claws, and venom that enhance their ability to catch food (See Figure 1.7). They also possess extremely acute sensory organs that help them to find potential prey.

Depending upon the requirement that arises, predators also adapt themselves to become much more efficient. Examples of some adapted animals are:

a) The ability of raptors to spot potential prey from over a kilometre away.
b) The acute sense of smell of moles.
c) The ability of owls to locate mice by sound.
d) The ability of pit vipers to sense body heat while tracking prey.
e) The ability of bats and dolphins to echolocate.

Predators catch their prey either by pursuing potential prey or by ambushing them. Organisms that give chase are capable of short bursts of speed like Cheetah (Figure 1.8). Those that lie in wait tend to be camouflaged to avoid detection.

Figure 1.7: Adapted sharp teeth (canine) of lion

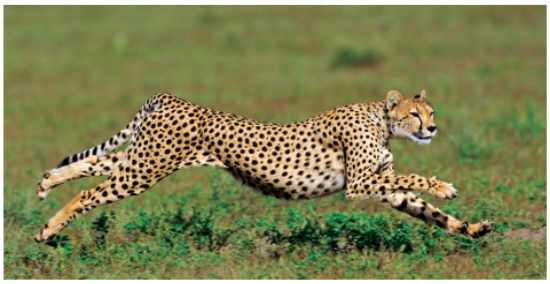


Figure 1.8: Cheetah adapted to run fast to capture prey

Adaptation in Prey Species

In the same way, as much as predator adapts itself to capture prey, preys also adapt as much as possible to escape from the predators. Many, such as leaf insects, moths, a variety of frogs and small lizards, and herbivorous mammals, are cryptically coloured to make them more difficult to see.

Other preys resemble inedible inanimate objects or unpalatable organisms. This is called **mimicry**. For example, walking stick insects resemble dry twigs and some moths resemble bees. This prevents birds from eating them.

Predator-Prey Relationships (Cycle)

Predator-prey relationships are characterized by oscillation of both predator and prey populations over a period of time. By oscillation, we mean there is a regular pattern of increase and decrease of populations of both predator and prey (See Figure 1.9). Generally, the predator is a carnivore, while the prey is a herbivore. However, this general truth may vary depending upon the kind of predator-prey interactions. For example, parasites become predator when they feed on their host (prey); herbivores become predator when they feed on plants (prey).

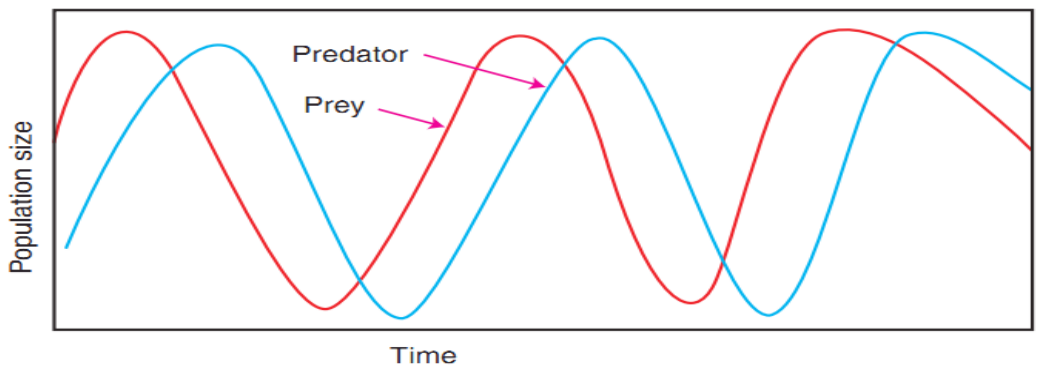


Figure 1.9: Predator-prey relationship (Cycle)

The main reason of oscillation is that as the predator population increases, it progressively consumes larger number of prey until the prey population starts to decline. Then the declining prey population no longer supports the large increasing predator population. As the prey population declines, the predator now faces a food shortage, and many of them starve or fail to reproduce. As a result, the predator population declines sharply to a point where the reproduction of prey more than balances its losses through predation. Eventually, the population of prey increases, which is followed by an increase in the population of predators. In this manner, there is a regular pattern of increase and decrease in the population of both prey and predator over a time period (Figure 1.9).

Significance of Predation

Predation Prevents a Single Species from Becoming Dominant

A keystone predator is a species that reduces the density of the strongest competitors in a community. These keystone predators may feed on the dominating prey species and prevent it from becoming dominant. Thus, they are tied up to the balance of organisms in a particular ecosystem. Addition or removal of these keystone predators can have drastic cascading effects on the equilibrium of many other populations in the ecosystem. For example, in grassland, herbivores (grazers) may prevent as single dominant species from taking over.

Predation can Either Increase or Decrease Species Richness

In an ecological community where predator and prey exist together, predator has the ability to either increase or decrease the number of prey species. The predator changes the number of prey depends on the favourability of the environment and also on whether prey is a competitively dominant species or competitively inferior species in a community. When keystone predator feeds on dominant prey, it generally promotes species richness by releasing the inferior prey species to coexist with the dominant species.

Predation as Source of Natural Selection

Predation is an important factor of moulding evolution of traits for both predators and prey species. Natural selection favours the fittest individuals in a community. Thus, the process of natural selection favours predators that are more efficient in capturing prey than the less efficient predators. In the same way, the process of natural selection favours prey species that are more efficient in escaping or deterring predators than the less efficient prey species.

On the one hand, predators impose strong selective force on their prey to evolve into the most efficient prey against the predators. On the other hand, prey species also counter-impose strong selective pressures on their predators

to evolve into the most efficient predator against the prey. Since these selection forces are working side-by-side on both predator and prey, these two parties evolve together. Thus, coevolution is evident. The process of evolution taking place side-by-side on two closely associated species is called **coevolution**

1.2. 4. Saprophytism

In Greek, sapro-("putrid matter") + phyte ("plant, growth"). The condition of certain living organisms feeding and living on dead organic matter is simply called saprophytism. It is generally exhibited by saprophytes. Saprophytes are living organisms which feed on dead organic matter such as dead plant or animal tissue. In this regard, they are detrivores. They break down organic matters in simpler forms that can be taken up and recycled by plants. Thus, they play a very important role in soil biology. Examples include most fungi (See Figure 1.10 (a) and (b), bacteria, and some orchids.

Figure 1.10: (a) *Mushroom (molds)* **(b)** *Bread mold, R. nigricans*

Most of the saprophytes lack chlorophyll, and therefore, cannot perform photosynthesis. Thus, they depend on the food energy they absorb from the decaying organic matters. This means that they are heterotrophs and are considered consumers in the food chain.

They are characterized by their use of a particular kind of digestion mechanism, called extracellular digestion. In this process, they secrete digestive substances into the surrounding environment through which they break down organic matter into simpler substances. The nutrient-rich broken organic substances are then directly absorbed through the membrane of the organism's cells and are metabolized.

The example of common saprophytic fungi belongs to Rhizopus family. These fungi have an extensive network of hyphae, similar to tiny roots, which grow

through the organic matter. They grow in a network called a mycelium. Mycelium helps the fungus to penetrate into the organic matter where the hyphae secrete digestive enzymes and absorb the resulting nutrients.

Significance of Saprophytism

Many micro saprotrophs and other decomposers, involving insects, snails and beetles help in recycling valuable nutrients from dead organic matter which is released back into the soil to be reabsorbed by plants. For example in a rainforest ecosystem, to promote healthy rainforest, nutrients such as iron, calcium, potassium and phosphorous are essentially required. The decomposers derive these essential nutrients from decaying organic matters and then release into the soil where the plants reabsorb it again.

1.2.5. Mutualism (+, +)

It is an interaction of two or more species where the interacting species mutually benefit from each other. And these interacting species mutually **benefit from each other so much that they become completely dependent on one another**. They cannot survive and thrive without each other. That is the reason why this interaction is termed as **mutualism or obligate symbiosis**. Mutualism seems to replace parasitism as **ecosystems evolve towards maturity**, and it seems to be especially important when some aspect of the environment is limiting (such as water or infertile soil).

Examples:

Bees and flowers: Bees depend on flowers for food in the form of nectar and pollen. And the flowering plants depend on bees or other pollinators to carry their male reproductive cells specifically to the female parts of other flowers of the same species. In this way, bees depend on flower for food, while flower depends on bees for pollination.

Significance of Mutualism

Mutualism is a type of symbiosis, which means living together. The most important impact of mutualism is that the species which cannot survive individually, can survive by partnering with other individual species. By living together and depending upon each other, they could overcome harsh and unfavourable conditions and thrive in the ecosystem. Mutualism thus helps in moulding or structuring community towards better species interactions.

1.2.6. Commensalism (+, 0)

It is an interaction of two or more species in which one species is benefited while the other species is neutral or is not benefited. The species which is benefitted is designated with "+" sign, while the species which is neutral is designated as

"0". In commensalism, the species which is unaffected is the **host**. The species that benefit from the association is called **commensal**. Commensal may obtain nutrients, shelter, support or locomotion from the host species. Normally, commensal relation is often between a larger host and a smaller commensal. Moreover, during the interaction, the host remains unchanged, whereas the commensal species may show great morphological adaptation.

Examples:

Oysters sometimes have a small, **delicate crab** (Figure 1.11) in the mantle cavity. These crabs are usually commensal, although sometimes they overdo their guest status by partaking of the host's tissues.

The **cattle egret follows cattle** (Figure 1.12), **water buffalo**, and other large herbivores as they graze. The herbivores flush insects from the vegetation as they move, and the egrets catch and eat the insects when they leave the safety of the vegetation.

Figure 1.11: *Crab inside oyster*

Figure 1.12: *Cattle egrets and cattle*

Significance and Criticism of the Concept of mutualism

The associations between two populations of species that result in positive effects are exceedingly widespread and are important in determining the function and structure of populations and communities.

Some biologists argue that the commensal in commensalism must be likely mutualistic or parasitic in a small scale which is undetected. And it is unlikely that the host is also completely not harmed or neutral. **Example:** Epiphytes

intercepting substantial amounts of nutrients from the host plant must be affecting the host in some other way which might be unnoticed.

Application Activity 1.2

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
Actual number of antelopes	15	15	20	35	35	100	45	15	15
Cheetah population	10	25	20	15	10	0	0	0	0

a) Plot a graph to represent the above data.

b) What conclusion can you make about the effect of the predator on the population of the prey?

c) In what way does the population of prey affect the population of the predator?

d) What would happen if all the predators died of a disease?

e) Is relationship between prey and predator beneficial or harmful? Justify.

f) How can a farmer apply the knowledge about the relationship between predators and preys, parasites and host?

Skills Lab 1

Visit your school garden/school farm/ nearby farmer's Activity; identify the biological interactions through observation. Evaluate the contribution of biological interaction in recycling matter and maintenance of equilibrium in environment. Do the report of your observation. What is your advice to the farmers who used to burns their farms in order to grow new plants in their garden?

END UNIT ASSESSMENT 1

I. Choose whether the given statements are True (T) or False (F)

1. Organisms' interaction does only harm.
2. Commensalism harms both species.
3. Competing for food is an example of interspecific competition.
4. Predation never promotes species richness.
5. There is a regular pattern of increase and decrease population in oscillation.
6. Parasitism doesn't promote coexistence of biodiversity.

II. Multiple Choice Questions

1. Both species are denoted by (+, +) in
   a) Mutualism
   b) Saprophytism
   c) Commensalism
   d) Predation
2. When two species compete for a shared resource, it is called
   a) Predation b) Exploitative competition
   c) Interference competition d) Apparent competition
3. Adaptations of a predator are
   a) Sharp teeth of lion
   b) Acute sense of smell of moles
   c) All the above
4. Mineral recycling in a rainforest is done by a
   a) Saprophyte b) Commensal c) Predator d) Ectoparasite
5. Brood parasitism is an interaction where
   a) A parasite kills the host
   b) A parasite lives in the host
   c) A parasite deposits its sperms to the other species' nest
   d) A parasite deposits its eggs to the other species' nest
6. In sexual cannibalism, normally
   a) Males eat females b) Males eat the younger males
   c) Females eat males d) Females eat the younger females

7. A flea on a dog is an example of
   a) Parasitism b) Commensalism c) Predation d) Coevolution
8. Saprophytes are
   a) Predators b) Plants c) Parasites d) Detrivores
9. A commensal is
   a) species that benefits association
   b) species that benefits from the association
   c) species that is negatively affected from the association
   d) species that negatively affects the association
10. The interaction of bees and flowers is an example of
    a) Protocooperation b) Commensalism c) Mutualism d) None of these

II. Long Answer Type Questions

1. Giving suitable examples, explain the various interactions of organisms in nature.
2. Giving examples, describe in your own words, the adaptations of predator species to catch and kill prey and the adaptions of prey species to avoid predators.
3. What are saprophytes? With one example, describe how saprophytes help in recycling minerals.
4. Briefly compare interspecific and intraspecific competitions with suitable examples.
5. Draw a predator-prey relationship graph and interpret it.
6. Give two examples of the following:
   a) Predation b) Parasitism c) Commensalism d) Mutualism
7. How does interrelationship among organisms commit for a sustainably developed environment? Cite examples to support your answer.
8. With examples, state in your own words, the significance of organisms' interactions in nature.

UNIT 2

PERIODICITY OF PROPERTIES OF ELEMENTS

Key Unit competence: Use atomic structure and electronic configuration to explain the trends in the physical properties of the elements

Introductory Activity 2

1. What features that make the chemical elements to exhibit different properties
2. The list of elements and their respective atomic numbers are given below. Group them as conductors or nonconductors of electricity and explain why some elements conduct electricity while others do not.

   Al(z=13), P(Z=15), Cu(z=29), B(Z= 5), N(z=7), Mg(Z=12), Fe(Z=26), Ag(Z=47), S(Z=16), Sr(Z=38)

2.1. Classification of the elements into blocks (s, p, d, f-block)

Activity 2.1

1. Using the s p d f notation write condensed electronic configuration for the following elements.

Al (Z = 13), K (Z = 19), Sr (Z = 38) and Fe (Z = 26). Br(Z = 35), Zr(Z = 40), Nd(Z = 60) ,Yb (Z= 70)

2. For each element, identify the last subshell that is occupied by electrons and draw adequate conclusions.

The long form of periodic table can be divided into *four main blocks*. These are: s- block, p- block, d- block, and f-block. Figure 2.1 illustrates the location in each of the blocks.

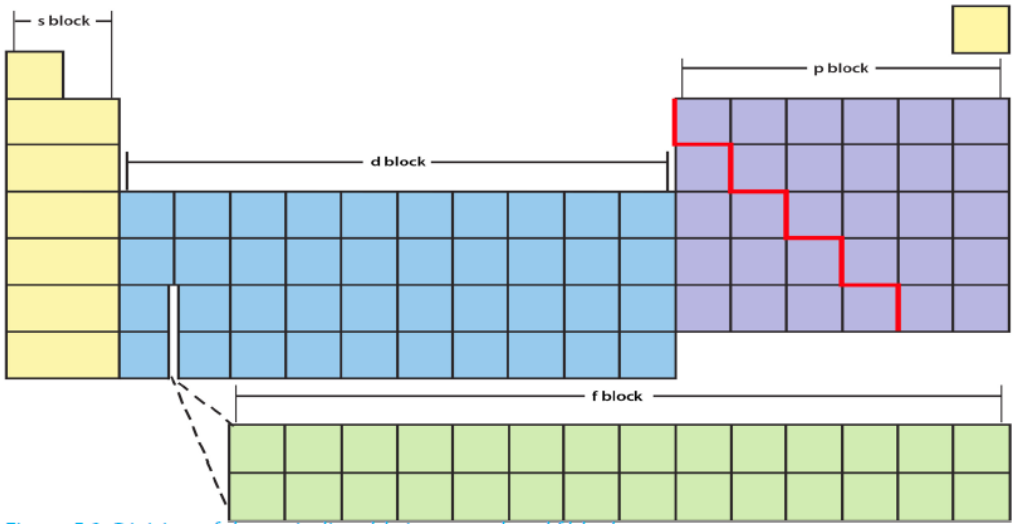


Figure 2.1: Division of the periodic table into s, p, d and f blocks.

2.1.1. s-Block Elements

The elements in which the last electron enters the s-subshell of their outermost energy level are called *s-block elements.*

This block is situated at extreme left of the periodic table. It contains elements of groups 1 and 2.

Their general configuration is $ns^{1 \rightarrow 2}$, where n represents the outermost shell.

The elements of group 1 are called alkali metals whereas the elements of group 2 are called alkaline earth metals.

2.1.2. p-Block Elements

The elements in which the last electron enters the p-sub-shell of their outermost energy level are called *p-block elements.*

The general configuration of their outermost shell is $\mathbf{ns^2\ np^{1 \rightarrow 4}}$. The only exception is helium (ls^2). Strictly, helium belongs to the s-block but its positioning in the p-block along with other group 18 elements is justified because it has completely filled valence shell ($1s^2$) and as a result, exhibits properties characteristic of other noble gases. This block is situated at the extreme right of the periodic table and contains elements of groups 13, 14, 15, 16, 17 and 18 of the periodic table.

Most of these elements are non-metals, some are metalloids and a few others are heavy elements which exhibit metallic character.

2.1.3. d-Block Elements

The elements in which the last electron enters the d-subshell of the penultimate energy level are called *d-block elements.*

Their general valence shell configuration is **(n-1) $d^{1\rightarrow10}$ $ns^{1\rightarrow2}$**, where n represents the outermost energy level. d-block contains three complete rows of ten elements in each. The fourth row is incomplete.

The three rows are called first, second and third transition series. They involve the filling of 3d, 4d and 5d orbitals respectively. The d-block contains elements of groups 3 to 12 of the periodic table.

2.1.4. f-Block Elements

The elements in which the last electron enters the f –sublevel of the anti-penultimate (third to the outermost shell) shell are called *f-block elements*.

Their general configuration is **$(n-2)f^{1\rightarrow14}(n-1)\,d^{0\rightarrow1}ns^2$**, where n represents the outermost shell.

They consist of two series of elements placed at the bottom of the periodic table.

The elements of first series follow lanthanum (^{57}La) and are called *lanthanides*. The elements of second series follow actinium (^{89}Ac) and are called *actinides.* Actinide elements are radioactive.

Briefly, in the periodic table, elements are divided into:

- The *s-block* contains reactive metals of Group 1A (1) and 2A (2),
- The *p-block* contains *metals* and *non metals* of Group 3A (13) through 8A (18),
- The *d-block* contains transition metals Group 3B (3) through Group 2B (12), and
- The *f-block* contains *lanthanide* and *actinide series* or *inner transition* metals.

Application Activity 2.1

1. a) How many blocks into which chemical elements are classified and how are they named?
   b) What is the criterion used for this classification?
2. Which block of elements will tend to form: positive ions? Negative ions?
3. Give any two examples of elements of s block, p block, d block and f block.
4. Why d-block elements are called transition elements?
5. Why f-block elements are called inner transition elements?

2.2. Factors that influence the change of each physical property of the elements across a period and down a group

Activity 2.2

The elements in the periodic table display many trends which can be used to predict their physical properties.

Use available resources and explain three of the factors that you think can influence the physical properties of elements in the periodic table.

In the Periodic Table, there are a number of physical properties that are trend-like. This means that as you move down a group or across a period, you will see a trend-like variation in the properties.

The actual trends that are observed with the physical properties are influenced by the following factors:

1. The number of protons in the nucleus (called the **nuclear charge**).
2. The number of electrons held between the nucleus and its outermost electrons (called the **shielding effect**).

Explanation:

Electrons in inner levels or *shells* tend to *shield* outer electrons from the full *nuclear charge*, which is reduced to *effective nuclear charge* (Z_{eff}).

Electrons are held in an atom or ion by the electrostatic attraction between the positively charged nucleus and the negatively charged electrons. In multi-electron species, the electrons do not experience the full positive charge of the

nucleus due to shielding by electrons which lie between the electron of interest and the nucleus. The amount of positive charge that actually acts on an electron is called the *effective nuclear charge*.

Electrons that have a greater *penetration* shield others more effectively. For example, electrons in level $n = 1$ shield those in level $n = 2$ very effectively, and those in $n = 1$ and $n = 2$ shield electrons in level $n = 3$. Electrons at the same level, but in different sublevels, also *shield* other electrons to some extent. The extent of *penetration* and *shielding effect* is in the order:

s>p>d>f.

The *effective nuclear charge* (Z_{eff}) greatly influences atomic properties. In general,

- Z_{eff} increases significantly across a period (left-to-right)
- Z_{eff} increases slightly down a group.

Application Activity 2.2

Periodic Table Trends are influenced by the following factors:

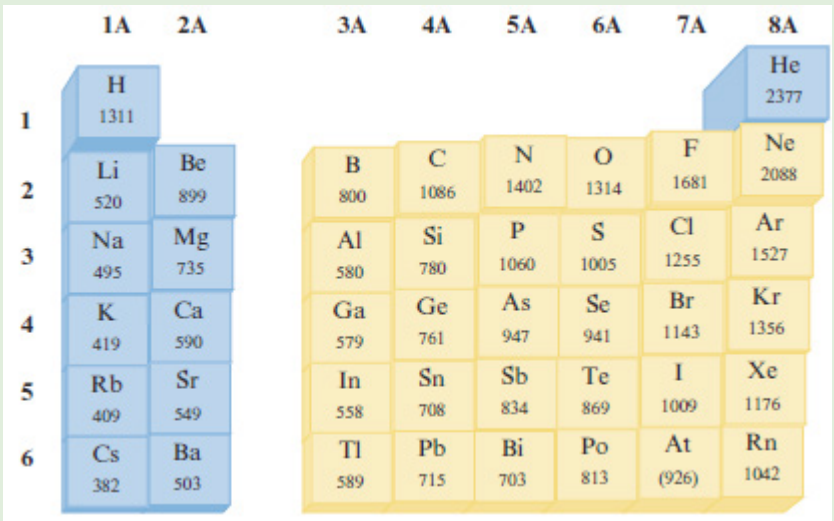
a) Size of the atom
b) Nuclear charge
c) Shielding effect

Which of them affect the variation of physical properties in a group, in a period?

2.3. Variation of the physical properties down the group and across the period

Activity 2.3

1. The table below shows the first ionization energy ($kJmol^{-1}$) of representative elements



	1A	2A	3A	4A	5A	6A	7A	8A
1	H 1311							He 2377
2	Li 520	Be 899	B 800	C 1086	N 1402	O 1314	F 1681	Ne 2088
3	Na 495	Mg 735	Al 580	Si 780	P 1060	S 1005	Cl 1255	Ar 1527
4	K 419	Ca 590	Ga 579	Ge 761	As 947	Se 941	Br 1143	Kr 1356
5	Rb 409	Sr 549	In 558	Sn 708	Sb 834	Te 869	I 1009	Xe 1176
6	Cs 382	Ba 503	Tl 589	Pb 715	Bi 703	Po 813	At (926)	Rn 1042

Analyze the table about the ionization energy values, and answers the questions that follow:

a) How is the variation trend of these values if you consider elements in the same

i). period? ii). group?

b) Using the available resources, attempt to give a plausible explanation of the observed trend

2. Analyze the trends of other physical properties and try to find each time appropriate reasons for those trends

Periodic trends are specific patterns that are present in the periodic table that illustrate different aspects of a certain element, including its *size* and its *electronic properties*.

Major periodic trends include: atomic radius, electronegativity, ionisation energy, electron affinity, melting point, density, metallic character. Periodic trends, arising from the arrangement of the periodic table, provide chemists with an invaluable tool to quickly predict an element's properties. These trends exist because of the similar atomic structure of the elements within their respective group families or periods, and because of the periodic nature of the elements.

The elements in the periodic table are arranged in order of increasing atomic number. All of these elements display several other trends and we can use the periodic table to predict their physical properties. There are many noticeable patterns in the physical and chemical properties of elements as we descend in a group or move across a period in the Periodic Table.

2.3.1. Atomic Radius

The atomic radius is the distance from the centre of the nucleus to the outermost shell of an atom.

The covalent radius is one-half the distance between the two nuclei of identical atoms that are joined together by a single covalent bond.

The *metallic radius* is one-half the distance between the nuclei of two atoms in contact in the crystalline solid metal.

A **cation** is an atom that has lost one of its outer electrons. Cations have a smaller radius than the atom that they were formed from.

An **anion** is an atom that has gained an outer electron. Anions have a greater radius than the atom that they were formed from.

Going **across a period**, the atomic radius ***decreases***. This is caused by the **increase** in the number of protons and electrons across a period. One proton has a greater effect than one electron; thus, electrons are pulled towards the nucleus, resulting in a smaller radius.

Atomic radius ***increases*** **down the group.** This is caused by electron shielding. The valence electrons occupy higher levels due to the increasing quantum number (n). As a result, the valence electrons are further away from the nucleus as '**n**' increases. Electron shielding prevents these outer electrons from being attracted to the nucleus; thus, they are loosely held, and the resulting atomic radius is large.

2.3.2. Electronegativity

Electronegativity is a measure of the relative ability of an atom to attract the pair of electrons in a covalent bond. Two factors help to explain determine the electronegativity value of an element:

- The size of the nuclear charge
- The size of the atom

Going across a period, the electronegativity value *increases*: as the nuclear charge increases, the size of the atom decreases and hence there is a greater attraction between the nucleus and the pair of electrons in a covalent bond.

Going down a group, the electronegativity value *decreases*. The effect of the increase in the nuclear charge is less than the increase in atomic radius and the shielding of the inner electrons.

Important exceptions of the above rules include the noble gases, lanthanides and actinides. The noble gases possess a complete valence shell and do not usually attract electrons. The lanthanides and actinides possess more complicated chemistry that does not generally follow any trends. Therefore, noble gases, lanthanides, and actinides do not have electronegativity values.

As for the transition metals, although they have electronegativity values, there is little variance among them across the period and up and down a group. This is because their metallic properties affect their ability to attract electrons as easily as the other elements.

According to these two general trends, the *most electronegative element is* **fluorine**, with 3.98 Pauling units.

2.3.3. Electropositivity or metallic character

Electropositivity or metallic character refers to the level of reActivity of a metal. Metals tend to lose electrons in chemical reactions, as indicated by their low ionization energies.

Metals are located in the left and lower three-quarters of the periodic table, and tend to lose electrons to non-metals. Non-metals are located in the upper right quarter of the table, and tend to gain electrons from metal. Metalloids are located in the region between the other two classes and have properties intermediate between metals and non metals.

Metallic character is strongest for the elements in the leftmost part of the periodic table and tends to decrease as we move to the right of any period.

Within any group of the representative elements, the metallic character increases progressively going down.

2.3.4. Ionisation Energy

Ionisation energy is the minimum energy (in kJ/mol) required to remove one mole of electrons from one mole of gaseous atom in the ground state.

In general, going across a period from left to right, the ionisation energy *increases* because the nuclear charge increases and hence electrons are more strongly attracted to the nucleus. Ionisation energy decreases moving top to bottom down the group. This is because the size of the atom increases and hence the outermost electron becomes increasingly distance from the nucleus and electron is less attracted.

In general, the second ionisation energy of an element is always greater than the first ionization energy. This is explained as follows: every time you remove an electron from an atom, the remaining electrons are more strongly attracted by the nucleus and it requires more energy to remove other electrons from the atom.

Hence: 1^{st} IE < 2^{nd} IE < 3^{rd} IE

The first ionization energy is the minimum energy required to remove one mole of electrons from one mole of gaseous atoms to produce one mole of gaseous ions with a charge of +1.

The second, third….. ionization energy is the minimum energy required to remove one mole of electrons from one mole of gaseous ions with a charge of +1, +2, …. respectively, to produce one mole of gaseous ions with a charge of +2, +3, …. respectively.

Ionisation energy of rare gases or any species with an octet electronic structure show very high IE because the electron is being removed from a very stable electronic structure.

Down a group, the ionisation energy *decreases* because the electron which is removed is further from the nucleus. The nuclear charge also increases, but the extra inner electrons reduce the effect of the nuclear charge by shielding the outer electrons from the nucleus.

2.3.5. Electron Affinity

Electron affinity *is the ability of an atom to accept an electron*. Unlike electronegativity, electron affinity is a quantitative measurement of the energy change that occurs when an electron is added to a neutral gas atom. The more negative the electron affinity value, the higher an atom's affinity for electrons.

That is the electron affinity (E.A.) *is the energy change that occurs when an electron is added to a gaseous atom*.

It can be either positive or negative value. The greater the negative value, the more stable the anion is.

The electron affinity ***is positive***: $\mathbf{X(g)+e^{-}\rightarrow X^{-} + Energy}$ (Exothermic)

The electron affinity ***is negative:*** $\mathbf{X(g)+ e^{-} + Energy \rightarrow X^{-}}$ (Endothermic)

Electron affinity increases from left to right within a period. This is caused by the decrease in atomic radius. Moving from left to right across a period, atoms become smaller as the forces of attraction become stronger. This causes the electron to move closer to the nucleus, thus increasing the electron affinity from left to right across a period.

Electron affinity decreases from top to bottom within a group. This is caused by the increase in atomic radius. With a larger distance between the negatively-charged electron and the positively-charged nucleus, the force of attraction is relatively weaker. Therefore, electron affinity decreases.

2.3.6. Boiling and Melting Points

Trends can be a bit complicated due to significant structural change from one element to another in the same group.

For groups 1 and 2, the melting and boiling points decrease down the group. As the atomic radius increases, the strength of the metallic bonding decreases.

For groups 7 or17(halogens) and 18 or 0 (noble gases), the melting and boiling points increase down the group, as the molecule becomes bigger with more electrons, the Van der Waals forces increase.

Across a period, melting and boiling points depend upon the structure and the bonding in the elements.

Table 2.1: Melting and boiling point of the elements in the third period

Element	**Na**	**Mg**	**Al**	**Si**	**P_4**	**S_8**	**Cl_2**	**Ar**
Type of structure	Metallic	Metallic	Metallic	Giant covalent	Simple molecule	Simple molecules	Simple molecules	Monoatomic
Melting point/°C	98	650	660	1410	44	119	-101	-189
Boiling point/°C	890	1120	2450	2680	280	445	-34	-186

Sodium, magnesium and aluminium are metals. The strength of the metallic bonding depends upon the number of delocalised electrons in the metal structure. The melting point increases from sodium to aluminium.

Silicon exists as a giant covalent structure. Each silicon atom is covalently bonded to four other silicon atoms in a tetrahedral structure (similar to diamond). A great number of covalent bonds have to be broken to break up the giant structure.

Phosphorus, sulphur and chlorine are all simple molecular species. Phosphorus consists of P_4 molecules; sulphur consists of S_8 molecules; chlorine consists of Cl_2 molecules. The strength of the Van der Waals forces increases as the size of the molecule increases.

Argon exists as isolated atoms (it is monatomic) with weak Van der Waals forces between atoms.

2.3.7. Density

The density of a substance is its mass per unit volume, usually in g/cm^3. The density is a basic physical property of a homogeneous substance; it is an intensive property, which means it depends only on the substance's composition and does not vary with size or amount.

The trends in density of elements can be observed in groups and periods of the periodic table. In general in any period of the table, the density first increases from group 1 to a maximum in the centre of the period because the mass increases while the size decreases, and then the density decreases again towards group 18 because of the nature of bonds.

Going down a group gives an overall increase in density because even though the volume increases down the group, the mass increases more.

Electrical and Thermal Conductivity

The electrical conductivity is the ability of a substance to conduct an electric current. Across a period, the conductivity increases as the number of delocalised electrons increases and then decreases as the metallic character decreases because electrons within the covalent bonds are held much more tightly in these elements than in metals.

Down a group, the conductivity increases. The delocalised electrons become less attracted by the nuclei.

Application Activity 2.3

1. Explain the following observations
   a) The atomic radius decreases across a period.
   b) Electronegativity decreases down a group.
   c) Electron affinity increases across a period.
2. Describe and explain the trend in melting point and metallic character
   (i) Across a period (ii) down the group
3. Why is it always the case that the 2^{nd} ionisation energy is larger than the 1^{st} I.E, the 3^{rd} larger than the second I.E and so on?
4. In each of the following pairs, indicate (by giving reasons) which one of the two species is smaller: (a) Cl or Cl^-, (b) Na or Na^+, (c) O^{2-} or S^{2-}, (d) Mg^{2+} or Al^{3+}, (e) Au^+ or Au^{3+}.

END UNIT ASSESSMENT 2

1. Justify the following statements:
   a) The first ionization energy of nitrogen is higher than that of oxygen even though nuclear charge of nitrogen is less compared to oxygen.
   b) Noble gases are having high ionization energies.
2. Explain why:
   a) Alkali metals (group 1 elements) are not found free in nature.
   b) Atomic radius of gallium is smaller than that of aluminium.(Z of Al = 13, Z of Ga = 31)
3. Arrange these elements in order of decreasing atomic size; sulphur, chlorine, aluminium and sodium. Does your arrangement demonstrate a group or a periodic trend?
4. List these ions in order of increasing ionic radius: N^{3-}, Na^{+}, F^{-}, Mg^{2+}, O^{2-}
5. For each of the following pairs of elements
   (C and N) (Ar and Br), pick the atom with
   a) more favorable (exothermic) electron affinity.
   b) higher ionization energy.
   c) larger size.

UNIT 3

NERVOUS COORDINATION

Key Unit competence: Describe the structure of neurones and explain the mechanisms of impulse transmission.

Introductory Activity 3

The plants can't think, learn, memorize, run, fly or swim toward food or away from danger. They are usually rooted to the soil but animals think, learn, memorize, move and animals perform, in coordinated ways, many complex functions than plants.

What make animals to perform many complex functions such as locomotion, communication and reaction to environmental stimuli?

If you close your eyes and objects touch on your body, how do you know if the objects that touch on your body is hot or cold?

3.1. Human nervous system

Activity 3.1

Use search engine or textbook from the library or a video of extraction of a rat nervous system, answer the following questions:

1. Label from the above diagram the main parts of human nervous system.
2. Write down the relative functions of each identified part of the human nervous system.

The human nervous system is divided into two main divisions: The central nervous system (CNS) and the peripheral nervous system (PNS). The central nervous system (CNS) consist of the brain and spinal cord, which are located in the midline of the body. The peripheral nervous system (PNS), which is further divided into the somatic division and the autonomic division, includes all the cranial and spinal nerves.

The nervous system plays the main functions such as: **(i) Sensory input**: Sensory receptors present in skin and organs respond to external and internal stimuli by generating nerve impulses that travel to the brain and spinal cord, **(ii) Integration:** The brain and spinal cord sum up the data received from all over the body and send out nerve impulses **(iii) Motor output**: The nerve impulses from the brain and spinal cord go to the effectors, which are muscles and glands. Nervous system coordinates, ordinates and controls different activities.

Some key word definitions that will be used in nervous system are:

- **Irritability or sensitivity:** is the ability of living organisms to respond to a stimulus.
- **A stimulus**: is any change in the external or internal environment which provokes a response.
- **Receptors:** are specialized cells that detect a stimulus.
- **Neurones:** are cells which transmit nerve impulses.
- **Effectors:** are organs that respond to the stimuli and bring about a response.
- **A nervous system:** is a system which involved in the detection of stimuli (sensory inputs) integration and response (motor output).
- **Neurone or nerve cell:** is the basic functional unit of the nervous system. Neurones are cells specialized to generate and transmit nerve impulses (action potentials)

3.1.1 The division of nervous system

The nervous system of a mammal comprises of the central nervous system (CNS) consisting of the brain and the spinal cord, and the peripheral nervous system (PNS) consisting of the cranial nerves from the brain, the spinal nerves from the spinal cord and the sensory organs (Figure 3.1).

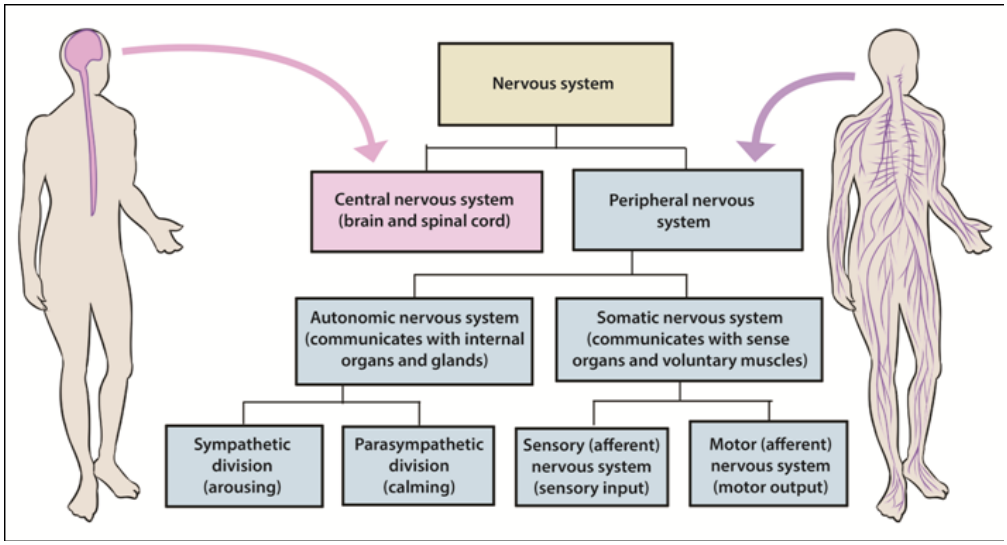


Figure 3.2: Organization of the human nervous system

1. The human brain

The brain is the enlarged end of the spinal cord. It is enclosed in the skull and is divided into three main parts namely: the fore brain, the mid brain, the hind brain.

a) The forebrain

This consist of: cerebrum, thalamus, hypothalamus and pituitary gland

The cerebrum: This is the largest part of the brain made up of two hemispheres called the right and the left cerebral hemispheres. The left cerebral hemisphere controls those activities of the right side of the body while the right cerebral hemisphere controls those of the left side of the body.

The functions of the cerebral hemisphere:

- It is the centre of the judgment, memory, reasoning and imagination.
- It receives the impulses from the sensory organs: sight, taste, sound and touch.
- It controls all the body's voluntary activities, e.g. walking, eating, singing,

The thalamus: This is a relay centre. It relays sensory information towards higher centre. It is the centre for the perception of pain and pleasure.

The hypothalamus: It performs many functions such as; regulates and monitors the temperature of blood, monitors and regulates the water content of blood, a coordinating centre for activities of the internal organs, e.g. rate of heart beat, blood pressure. It is a centre of for feelings such as; hunger, thirst,

sex drive, satisfaction, sleep, speech, etc. As an endocrine gland, it produces hormones i.e. anti-diuretic hormone (ADH) and oxytocin.

The pituitary gland: It produces hormones such as: Follicle-stimulating hormone (FSH), Thyroid stimulating hormone (TSH), Adreno-cortico trophic hormone (ACTH), Prolactin hormone and Luteinizing hormone (LH)

b) The mid brain

This acts as an association centre between the fore and the hind brain. It is a relay centre for audio and visual information. It is also responsible for movement of the head and the trunk.

c) The hind brain

This receives the impulse from the ear, the skin and the semi-circular canals. It consists of: The cerebellum and the medulla oblongata

The cerebellum: it lies behind the optic lobes. It receives impulses simultaneously from the eyes and the ears. It regulates and co-ordinate muscular movement, especially those concerned with maintaining body equilibrium and controls all the unconscious activities of the body.

The medulla oblongata: controls all the involuntary movements of the body especially those concerned with respiration, digestion, heartbeat, breathing rate and sneezing.

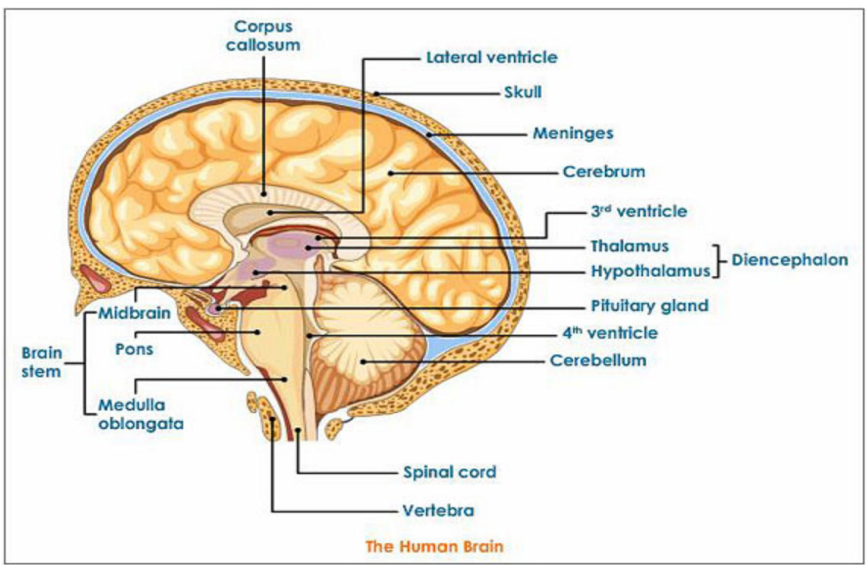


Figure 3.3: Main parts of the brain

2. The spinal cord

The spinal cord is a dorso -ventrally flattened cylinder of nervous tissue running from the base of the brain down the lumbar region. It is protected by the vertebrate of the backbone and the meninges.

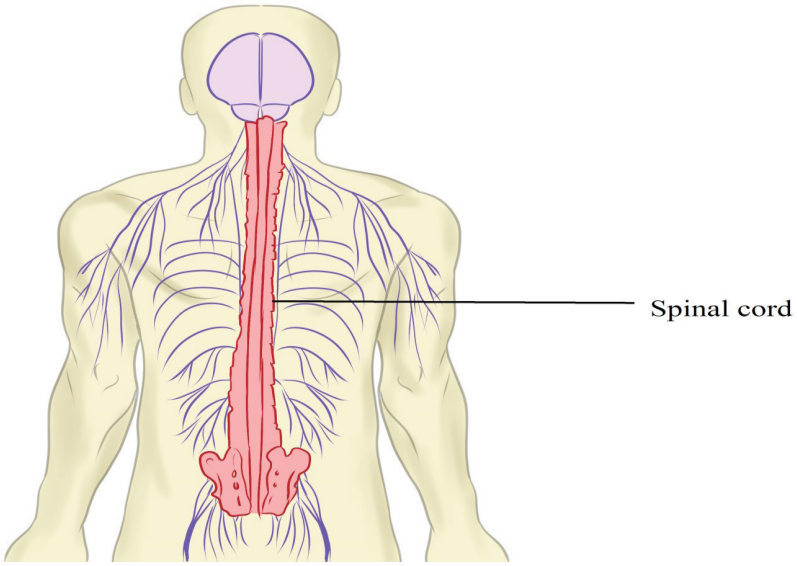


Figure 3.4: Position and external structure of spinal cord

A transverse section of the spiral cord shows an H-shaped central core of grey matter. Grey matter is composed of nerve cell bodies, dendrites and synapses surrounding a central canal which contains cerebrospinal fluid. White matter: around the grey matter, is an outer layer containing nerve fibres whose fatty myelin sheaths give it its characteristics colour.

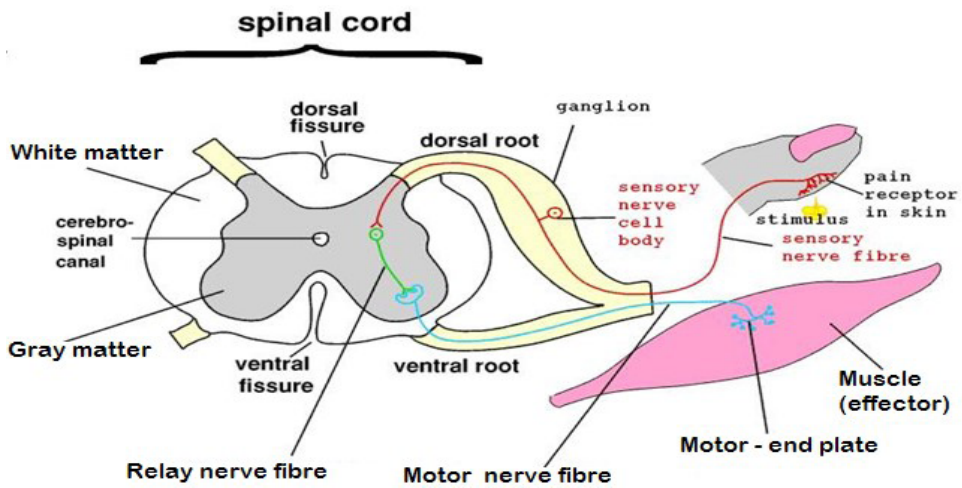
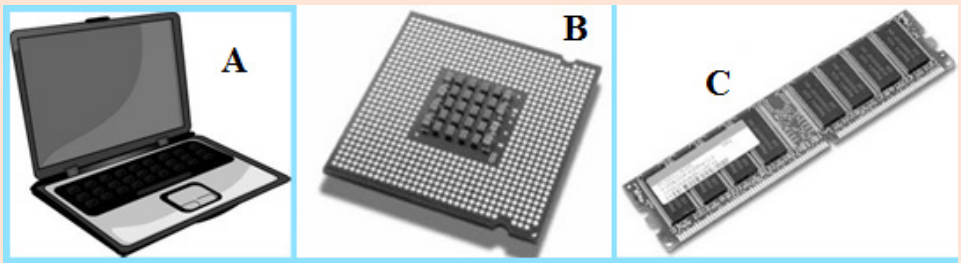


Figure 3.5: The transverse section of the spinal cord

The spinal cord acts as a coordinating centre for simple reflex such as knee jerk response and autonomic reflexes. The spinal cord acts as means of communication between spinal nerves and the brain. It sends impulses to the brain through sensory neurones from the body and returns the motor impulses to the effectors which are muscles and glands.

Application Activity 3.1

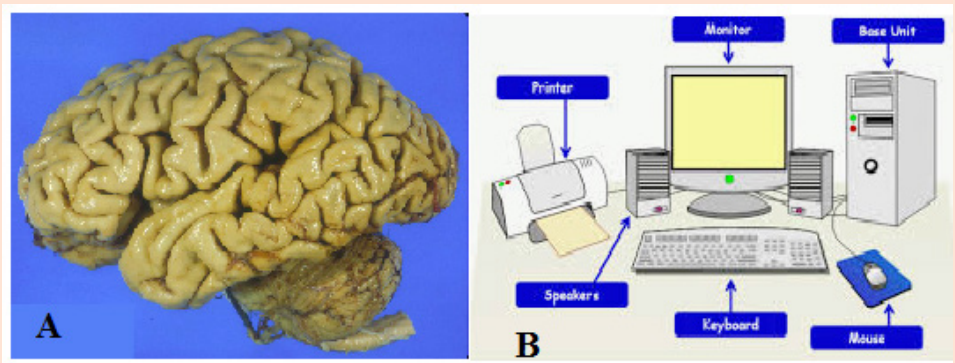
1. The diagrams A, B and C show a laptop, processor and RAM (Random Accessory Memory) respectively. Link what you learned to answer the following questions:



   i). Which organ of the nervous system that correspond to A,B and C

   ii). Identify the parts of the nervous system that plays the same role as C

2. Observe carefully the following diagram and answer the questions that follow:



Source : https://www.google.rw/search?q=parts+of+computer

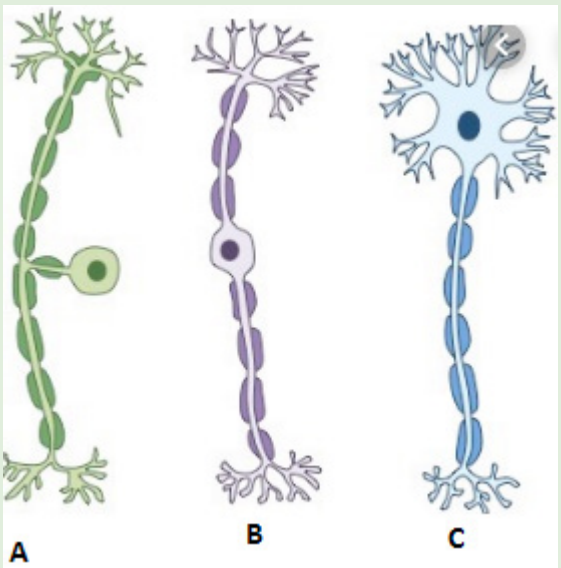
   a) Referring to this diagram, label the main parts of the organ named in 1 and give their functions.

   b) Explain how the parts of diagram A are similar to that of diagram B in functioning.

3.2. Structure, types and functions of neurones

Activity 3.2

Use the charts of neurones below to answer the questions that follow



1. How structure A, B and C are they different?
2. Make research on neurones from internet or school library to the following questions:
   a) Locate each type of neurones above mentioned
   b) State the function of each type
   c) Redraw the neurone C, label its main structure and state the function of each.

Neurone also called nerve cell is the basic functional unit of the nervous system. Neurones are cells specialized to generate and transmit nerve impulses (action potentials) are cells which transmit nerve impulses (action potentials).

3.2.1. Types of neurones

Nerve cells may be grouped according to the number of processes they possess so that their types include:

- **Unipolar neurones:** those with one process only, found mainly in invertebrates.
- **Bipolar neurones:** those with two separate processes such as neurones in the retina of the vertebrate eye.

- **Multipolar neurones:** those with more than two processes such as most of the vertebrate neurones.

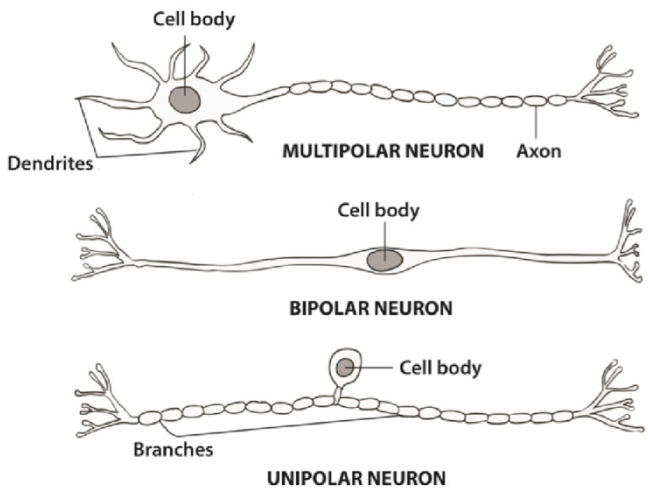


Figure 3.6: Multipolar, bipolar, unipolarneurones

3.2.2. Classification of neurones by their functions

In vertebrates, it is also common to group neurones according to their functions. They include:

- **Sensory or afferent neurones:** transmit impulses from the receptors to the central nervous system.
- **Motor or efferent neurones:** that transmits impulses from the central nervous system to effectors motor organs such as muscles or glands that carry out the response. Most motor neurones are stimulated by impulses conducted by interneurones. However, there are some others that are stimulated directly by sensory neurones.
- **Interneurones** also known as intermediate or association, or relay or interneurone connect the pathways of sensory and motor impulses, and are found mainly in the central nervous system.

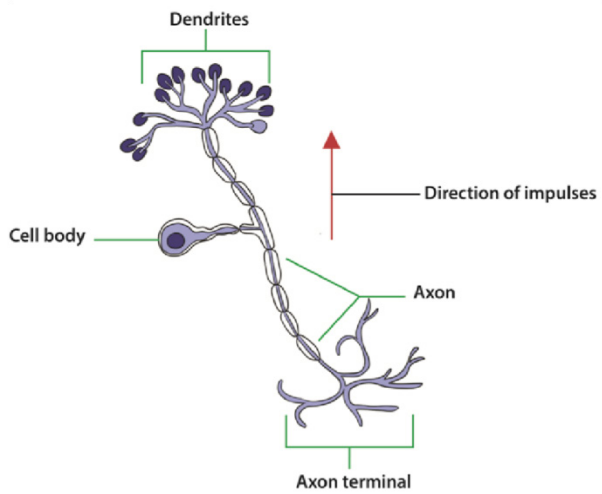


Figure 3.8: Sensory neurone

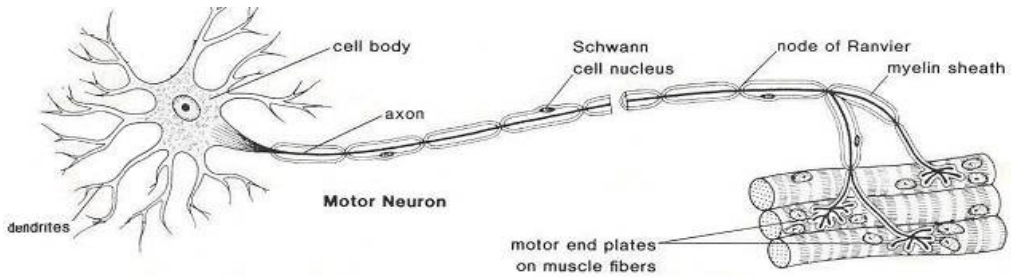


Figure 3.9: Motor neurone

Interneurones also known as intermediate or association, or relay or interneurone connect the pathways of sensory and motor impulses, and are found mainly in the central nervous system.

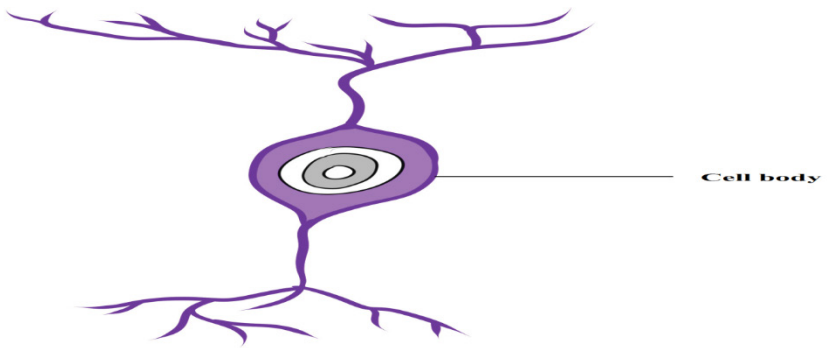


Figure 3.10: Intermediate neurone

3.2.3. Parts of a neurone and their functions

Each motor neurone possesses a cell body and cytoplasm with many mitochondria, endoplasmic reticulum, Golgi apparatus and ribosomes. The Nissl granules consist of endoplasmic reticulum and ribosomes function in protein synthesis. The table below (Table 3.1) shows all parts of neurone and their functions.

Table 3.1: The parts of a neurone and their functions

Structure	**Functions**
Cell body	The cell body has a number of processes called Dendron. The fine terminal branches are called dendrites. These dendrites receive and transmit nerve impulses. nerve impulses toward the cell It Coordinates the nerve cell activities and makes protein for the growth of the nerve cell,
Axon	Transmits impulses away from the cell body. It contains **axoplasm** surrounded by the axon membrane known as **axomembrane**
Synaptic knobs	These contain many mitochondria, endoplasmic reticulum and synaptic vesicles filled with neurotransmitters
Myelin sheath	In a myelinated fibre, the myelin sheath has three functions It acts as an electrical insulator and prevents movement of ions through it e.g. Na^+ /K^+ ions It speeds up the transmission of nerve impulse (action potential) along the axon. The action potential can leap from one node of Ranvier to the next by salutatory conduction. It guides regeneration of PNS axons
Schwann cells	Secrete the myelin sheath, The Schwann cells are located at regular intervals with their cell membranes wrapped around the axon
Node of Ranvier	Propagates nerve impulses and speeds up their transmission
Terminal dendrite	Transmits nerve impulses to effector organs.

3.2.4. Functions of sensory, relay and motor neurones in a reflex arc

A reflex action is a quick and involuntary response of the central nervous system to a stimulus. Example: The quick withdrawal of the hand from a hot object. When the spinal cord alone is involved, the reflex action is called spinal reflex and when the brain alone is involved, it is a cranial reflex e.g. blinking of eyes.

Reflex actions are described as involuntary actions and the same stimuli produce the same responses every time. Reflexes are useful because they make autonomic involuntary adjustments to changes in the external environment, such as the iris pupil reflex and the balance during locomotion. They also control the internal environment, such as breathing rate and blood pressure, and prevent damage to body as in cuts and burns. These help to maintain constant conditions, in other word they are involved in homeostasis.

The sequences of changes that occur during a spinal reflex are:

- A sensory receptor receives a stimulus and impulse is generated in it
- The impulse is transmitted along a sensory neurone towards the spinal cord via the dorsal root
- Once the impulse reaches the grey matter inside the spinal cord, it is passed on to the relay neurone across a synapse
- The relay neurone then transfers the impulse to a motor neurone across another synapse.
- The motor neurone conveys the impulse to an effector such as a muscle where a response takes place.

The pathway that is followed by an impulse along the sensory neurones relay and motor neurone, during a reflex action is called reflex arc.

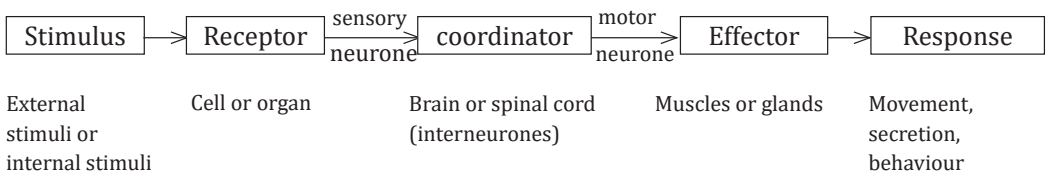


Figure 3.9: Sequence of change in a spinal reflex

The components of reflex arc are: stimulus, receptors, the sensory receptor that detects the stimulus, the sensory (or afferent) neurone along which the sensory impulse is transmitted, the relay neurone in the central nervous system to which the sensory impulse is passed on, the motor (or efferent) neurone along which the motor impulse is transmitted; and the effector (muscle or gland) which the motor impulse triggers to bring about an appropriate response and CNS (Brain or spinal cord).

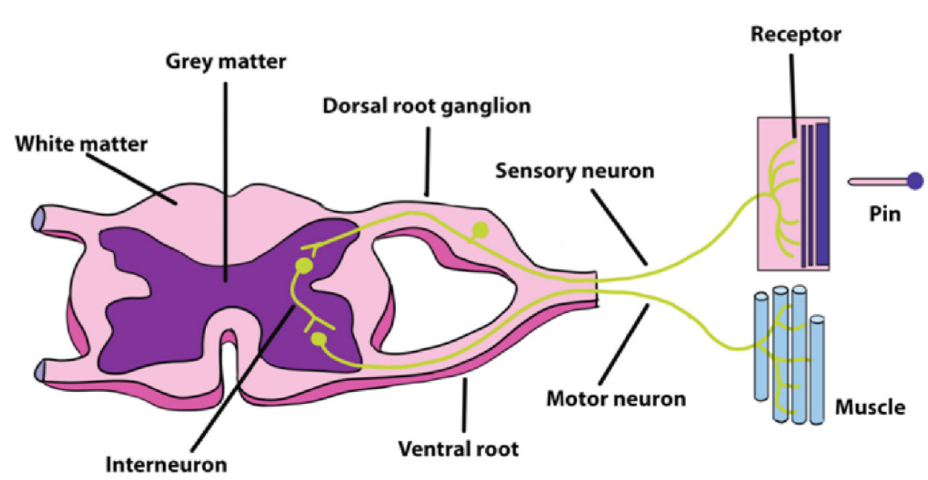


Figure 3.11: The diagram showing reflex arc

Application Activity 3.2

People get paralysis as the result of an accident or a medical condition that affects the way muscles and nerves function. The diagram below shows a paralyzed human hand and arm.

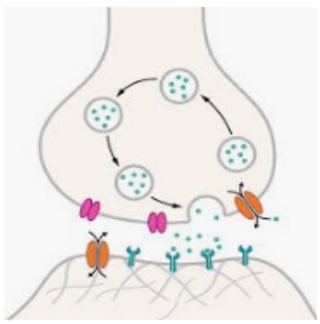
Figure 3.12. Paralyzed hand

Think about this hand paralysis, explain how to remedial the abnormality and make the hand working normal.

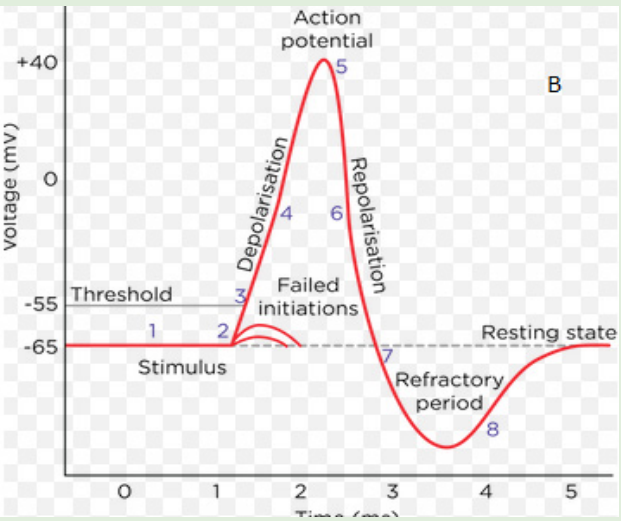
3.3. Nature, structure and function of synapse in the nervous system

Activity 3.3

Observe the figure A (representing synapse), figure B representing action potential



A



a) Explain how the structure of synapse in figure A is?

b) Through the observation of figure B, write short notes on how nerve impulse is generated.

c) Interpret the graph showing the action potential in B.

All cells in animal body tissues are electrically polarized; they maintain a voltage difference across the cell's **plasma membrane**, known as the **membrane potential**. This electrical polarization results from a complex interplay between protein structures embedded in the membrane called **ion pumps** and **ion channels**. Each excitable patch of membrane has two important levels of membrane potential: the resting potential, which is the value the membrane potential maintains as long as nothing passes along the cell, and a higher value called the threshold potential.

3.3.1. Resting potential in a neurone

A neurone is said to be in the resting state when it is not conducting an impulse. The membrane potential of an unstimulated excitable cell is called the resting potential. A resting potential is the difference in charge (electrical potential difference) which exists between the inside and the outside of the cell membrane. In excitable cells, the resting potential is about -70 millivolts (mV) and the threshold potential is around -55 mV. The negative sign indicates the

interior of the cell is negative with respect to the exterior environment.

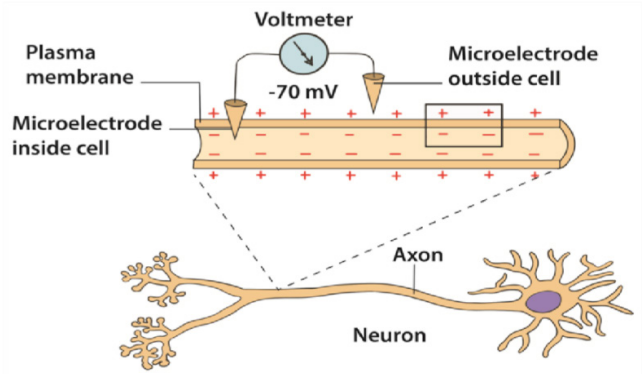


Figure 3.13: Resting potential in a neurone

The resting potential difference across the neurone membrane is maintained by:

- **The sodium –potassium pump (Na^+ /K^+)**. This is always working. Three sodium ions (Na^+) are actively transported out of the cell for every two potassium ions (K^+) pump into the cell. Energy supplied by ATP is used for the transport of ions against their electrochemical gradients.
- **The axon membrane:** It is more permeable to potassium ions than the sodium ions. This is due to the presence of more potassium ion non-gated, voltage independent channels and few sodium ion non-gated channels. More K^+ ions can diffuse out back again faster than Na^+ ions which can diffuse back in. The resting membrane potential is mainly determined by sodium-potassium pump, facilitated diffusion and electrochemical gradient of K^+ ions across the membrane.

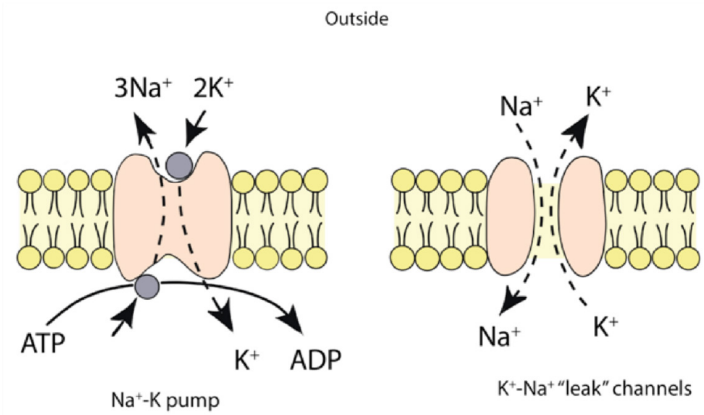


Figure 3.14: Sodium- potassium pump

3.3.2. Action potential

An action potential is rapid temporary reversal in the electrical potential difference of an excitable cell e.g. a neurone or a muscle cell. It is caused by changes in the permeability of the membrane following the application of a threshold stimulus. The action potential has a depolarization phase and a repolarization phase. There may be a short-hyperpolarized phase after the repolarization phase. The time taken for an action potential is 2 to 3 milliseconds.

3.3.3. Depolarization

When a stimulus such as electric current reaches a resting neurone, some sodium voltage gated channels in the stimulated region of the axon membrane open. Sodium ions (Na^+) move into the axon by facilitated diffusion down an electrochemical gradient. The initial influx of sodium ions is slow. The axon membrane becomes slightly depolarized and the sodium voltage gates are sensitive to voltage changes. More gates open allowing more Na^+ ions to diffuse into the cell leading to further depolarization.

When the potential difference across the membrane reaches a threshold value (-50mV), many more sodium voltage gated channels open. This is an example of positive feedback. The rapid diffusion of Na^+ ions leads to a sudden increase in the cell's potential difference which becomes positive (+ 40mV). This reversal in the potential difference is known as depolarization and lasts for about 1 millisecond

3.3.4. Repolarization

The reversal in polarity to + 40 mV causes the voltage gated sodium channel to close. At the same time the voltage gated potassium channels open. The potassium ions K^+ diffuse out of the cell down their electrochemical gradient to the tissue fluid outside. The axon membrane is repolarized. The action potential alters from + 40 mV to -70mV.

3.3.5. Hyperpolarization

The potassium voltage-gated channels are slow to close. An excess of K^+ ions leave the axon. The inside of the membrane becomes more negative. The voltage falls slightly below -70mV and causes hyperpolarization. However, within a few milliseconds, the potassium voltage-gated channels close. The resting potential of -70mV is reestablished by the Na^+/K^+ pump and different rates of facilitated diffusion of K^+ and Na^+ ions through the non-gated ion channels.

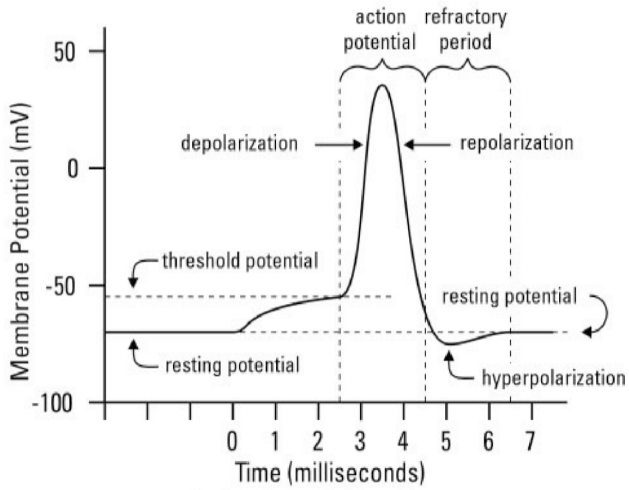


Figure 3.15: The action potential

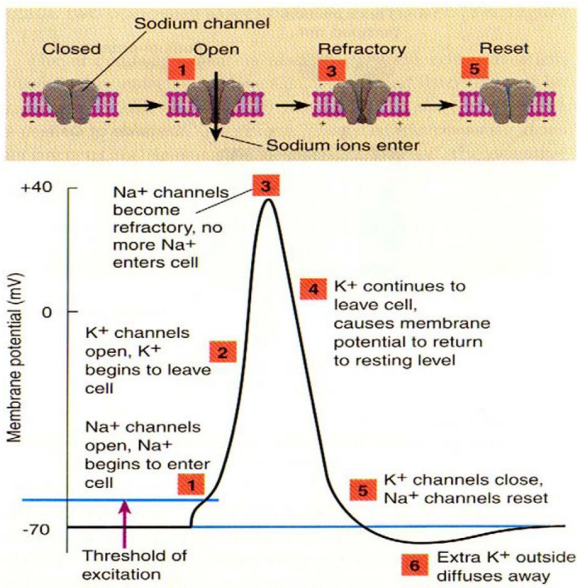


Figure 3.16: The sodium –potassium pump (Na+ /K+) and action potential

3.3.6. Frequency of action potentials

Information in axons is coded in the frequency of the action potentials. A weak stimulus above threshold produces fewer action potentials. A stronger stimulus produces a greater frequency of action potentials. As the intensity of stimulation increases, more action occurs.

3.3.7. Structure and function of a cholinergic synapse.

The cholinergic synapse is a synapse which uses acetylcholine (Ach) as neurotransmitter. Calcium and vesicles are involved in the release of neurotransmitter across the synaptic cleft in the mechanism of synaptic transmission to generate an excitatory post-synaptic potential.

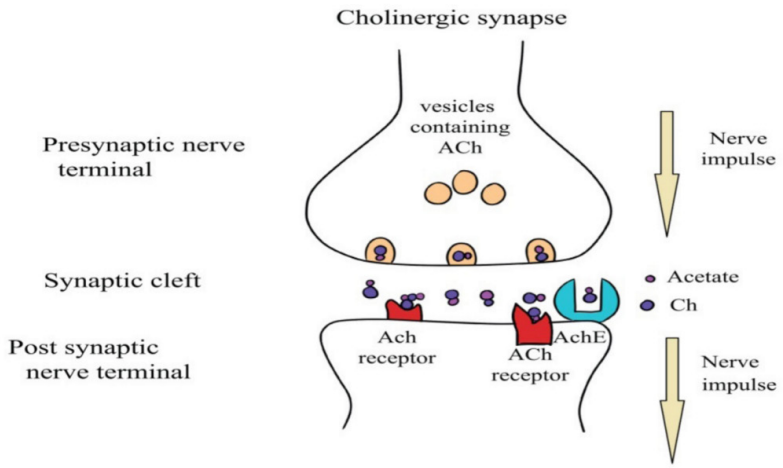
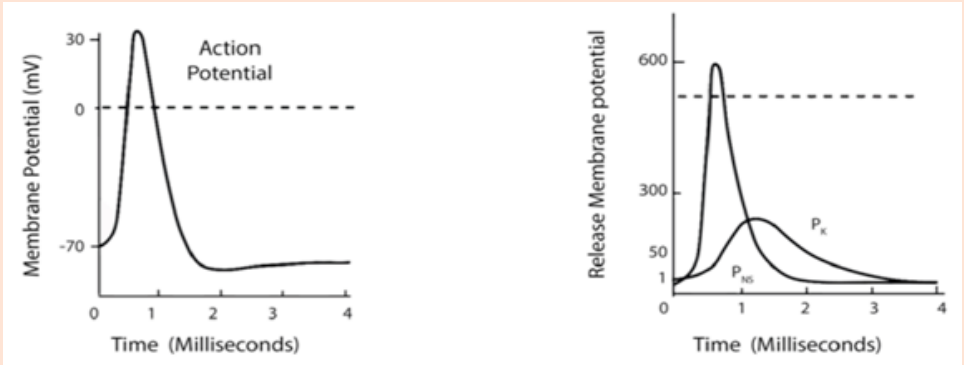


Figure 3.17: The cholinergic synapse

Application Activity 3.3

1. The graphs below show the changes that occurs during an action potential in a membrane potential and the relative permeability to sodium and potassium ions in a neurone. Observe them answer the related questions.



a) Describe the movement of ions during action potential.

b) Explain the effect of an action potential generation if there is a lowering of sodium ions in the extracellular fluid.

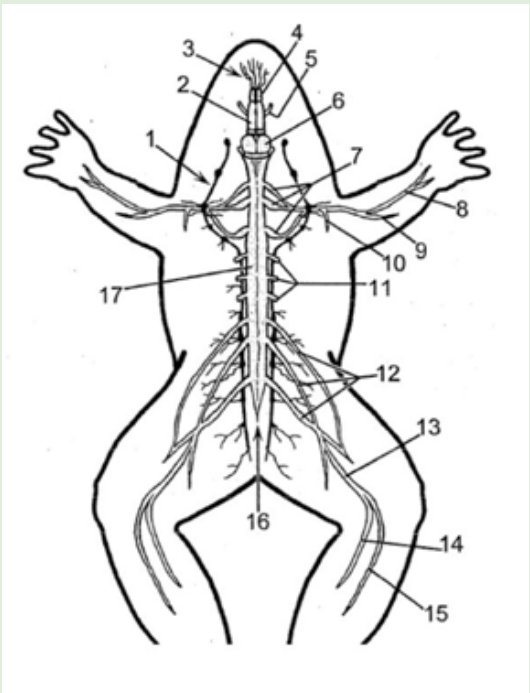
2. Use the synapse model in Figure below to explain why nerve impulses move from neurone A to neurone B, but not from neurone B back to neurone A.

3.4. Transmission of a nerve impulse

Activity 3.4

Understanding the frog sciatic nerve:

The diagram below shows different nerves of a frog after dissecting it. Use school library and search additional information on internet and watch the movies on YouTube related to frog dissection.



1. Redraw this diagram and label it from 1 to 17
2. Identify the main difference between the part numbered 13 from other parts
3. Identify the main function of 13
4. What would happen to a frog when 13 is damaged

3.4.1. Mechanism of transmission of nerve impulses along an axon

- The neurones, like other cells, are positively charged outside and negatively charged inside. The membrane of the axon is said to be polarized. The potential difference (voltage) across their membranes is of – 70mV and is called resting membrane potential (RMP).
- A stimulus (heat, pain, bite, sound ...) creates an action potential (AP) or an impulse that is transmitted along an axon by electro-chemical change.
- During an action potential, the membrane potential falls until the inside becomes positively charged with respect to the exterior. The membrane at this point is said to be depolarized. It takes few milliseconds to happen. In fact, the potential changes from – 75 mV to + 40 mV at the point of stimulation. That is an electrical change that runs along the axon.
- As the impulse is transmitted along the axon, the Na+/K+ pumps of the axolemma are re-established. Sodium channels open first, allowing a large number of Na+ ions to flow in.
- The axoplasm becomes progressively more positive with respect to the outside of the axolemma. Then, almost instantly, the permeability of the membrane to Na+ ions ceases, and the net flow of Na+ ions stop. At the same time K+ ion channels start to open and K+ ions flow out from axoplasm where they are in high concentration. The counter-flow is of 3Na+ ions against 2K+ ions.
- The axoplasm now starts to become less positive again. This begins the process of re-establishing the resting potential difference of the membrane. That is an electro-chemical change.

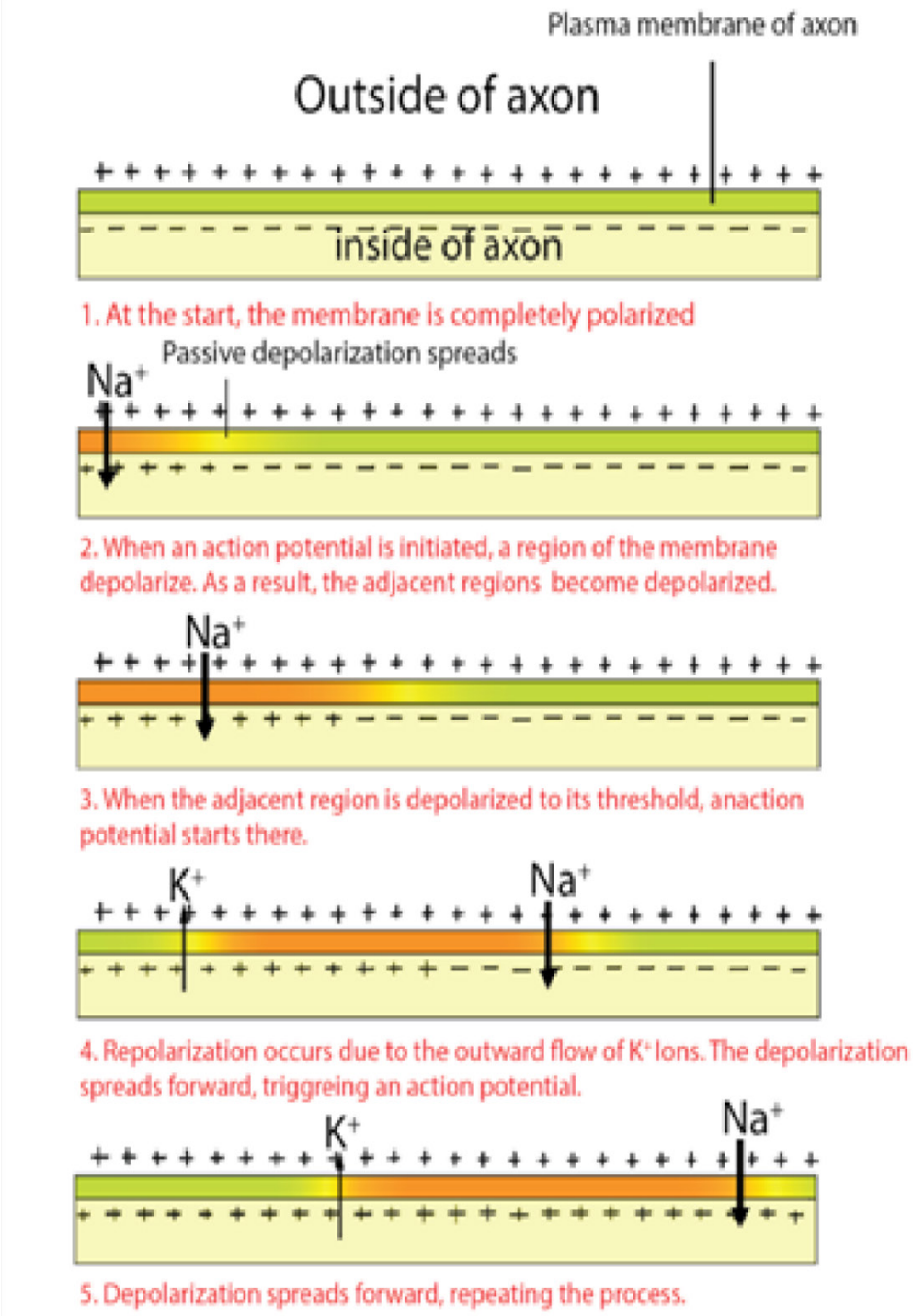


Figure 3.18: The nerve impulse transmission along axon

a) Factors that affect the transmission of nerve impulses along the axon membrane

Along the axon membrane, the transmissions of nerve impulses are affected as follows:

- The diameter of the axon: the greater the diameter the faster the speed of transmission of nerve impulses.
- The myelin sheath: myelinated neurones conduct impulses faster than non- myelinated neurones.
- The presence of nodes of Ranvier: speeds up the movement of impulses in myelinated neurones.

b) Structure of a synapse

Information from one neurone flows to another neurone across a synapse. The synapse is a small gap separating two adjacent neurones.

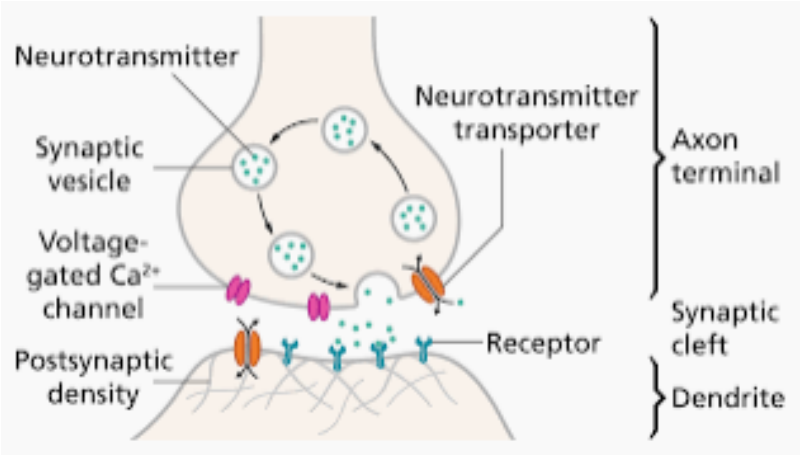


Figure 3.19.

Structure of synapse (Source: **https://www.google.rw/search?q=structure+of+synapse&***)*

The synapse consists of:

- A presynaptic ending that contains neurotransmitters, mitochondria and other cell organelles,
- A postsynaptic ending that contains receptor sites for neurotransmitters and,
- A synaptic cleft or space between the presynaptic and postsynaptic endings. It is about 20nm wide.
- The swollen tip of the axon of the presynaptic neurone, called synaptic knob or synaptic bulb contains many membrane-bounded synaptic vesicles, mitochondria and microfilaments.

- The synaptic vesicles contain neurotransmitter molecules such as acetylcholine or noradrenaline

c) Neurotransmitter

A neurotransmitter is a relatively small chemical found in the synaptic vesicle. It helps to transmit an impulse across a synapse or neuromuscular junction. There are about 50 different types of neurotransmitters in the human body. Examples are acetylcholine released by cholinergic neurones, noradrenaline (norepinephrine) released by adrenergic neurones, dopamine and serotonin including amino acids glutamate and glycine.

3.4.2. Mechanism of nerve impulse transmission across a synapse

- The arrival of an impulse on the synaptic knob causes the opening of Ca^{+2} ion channels on the presynaptic membrane, and Ca^{+2} ions flow in the presynaptic region from the synaptic cleft.
- The Ca^{+2} ions induce a few presynaptic vesicles to fuse with presynaptic membrane and to secrete their neurotransmitters (e.g. acetylcholine) by exocytosis into the synaptic cleft
- The neurotransmitter then binds with the receptor protein on the postsynaptic membrane. This causes the opening of Na^{+} channels on the postsynaptic neurone which in turn becomes depolarized.
- This causes a depolarization of the post-synaptic cell membrane, which may initiate an action potential, if the threshold is reached
- The action of the neurotransmitter does not persist because an enzyme cholinesterase catalyses the hydrolysis of acetylcholine into *choline* and *acetate*. The breakdown products (choline) are absorbed by the pre-synaptic neurone by endocytosis and used to re-synthesize more neurotransmitter, using energy from the mitochondria.

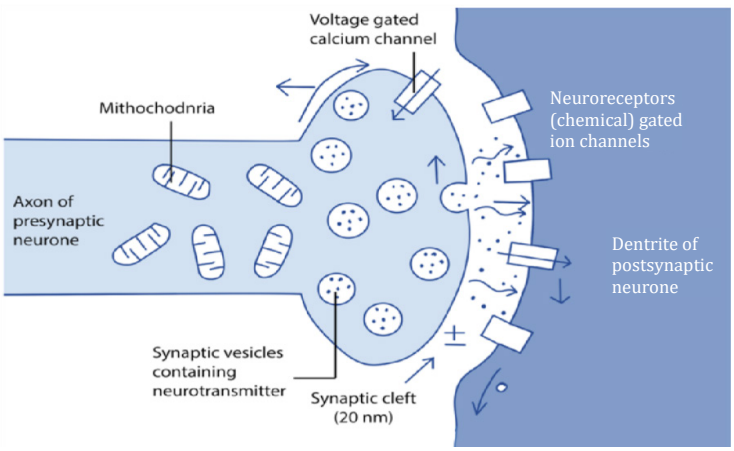


Figure 3.20: The nerve impulse transmission across synapse

3.4.3. Properties of a nerve impulse

a) All or none law

An action potential can only be generated after the threshold value is exceeded. After the threshold is reached, the size of the action potential produced remains constant and is independent of the intensity of the stimulus. This is the all or nothing response. All action potentials are of the same amplitude.

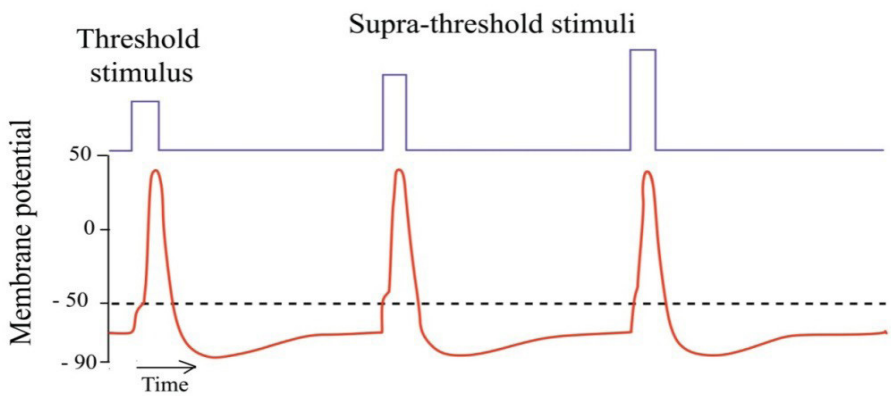


Figure 3.21: Illustration of all or nothing law

b) Refractory period

This is a brief period when an axon is unable to transmit an impulse following transmission of the same. It lasts about 5-10 milliseconds. It is divided into two; absolute and relative periods. During the absolute refractory period which lasts about 1ms, the axon membrane is unable to respond to another stimulus, no matter how strong it is. An action potential cannot be produced. This is because there is conformational change in voltage-gated sodium channels which are still in a closed, inactive state. This also prevents the action potential from moving backwards.

Following the absolute refractory period, there is a relative refractory period which lasts around 5ms. During this period, the resting potential is gradually restored by Na^+ /K^+ pump and the relative permeability of membrane to facilitated diffusion of ions is also restored. A new action potential can then be produced if the stimulus is greater than the usual one. The refractory period therefore allows impulses to move only in one direction and limits the frequency at which successive impulses can pass along axon.

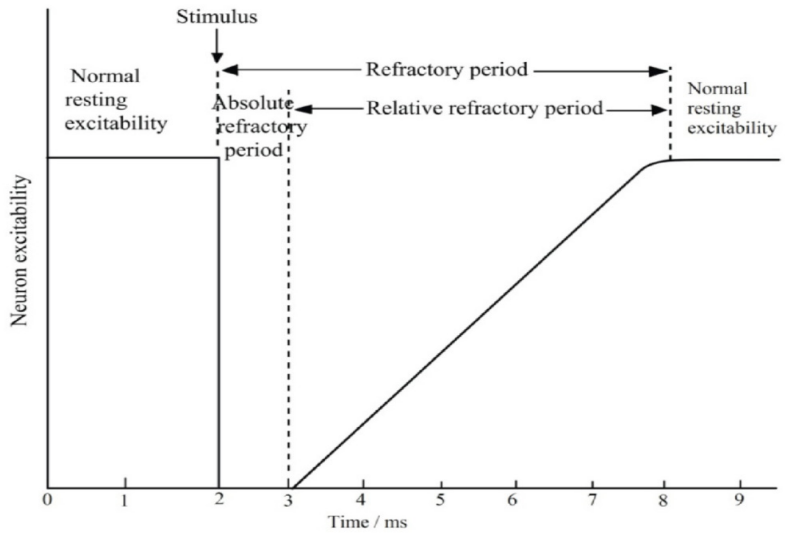


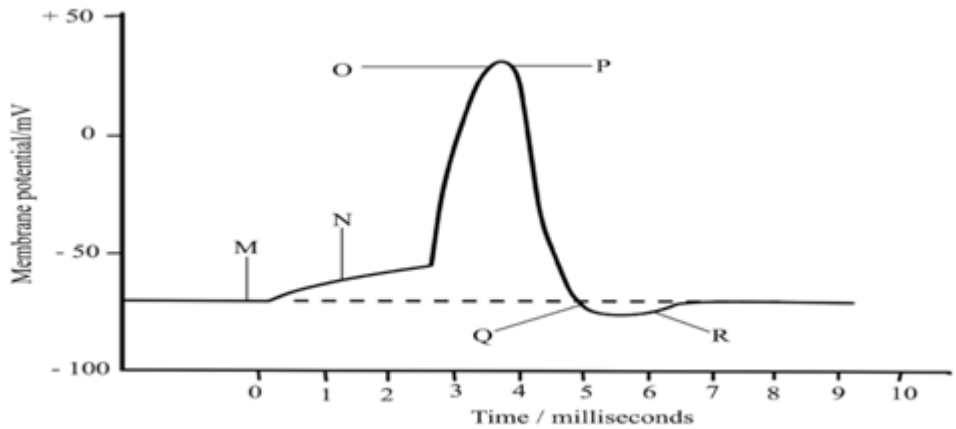
Figure 3.22: Neurone excitability before and after a nerve impulse

c) Salutatory conduction

It is movement or jump of nerve impulses from one node of Ranvier to another along the axon membrane of neurone.

Application Activity 3.4

The diagram below shows the changes in potential difference across an axon membrane as a nerve impulse passes. Observe and answer the related questions below



a) Determine the time for a single nervous impulse.

b) Describe what happens at M, N, O, P, Q and R as shown in the graph.

c) What factors can determine the speed of transmission of a nerve impulse and how each affects the speed.

d) Explain why initiation of an action potential is considered as positive feedback mechanism.

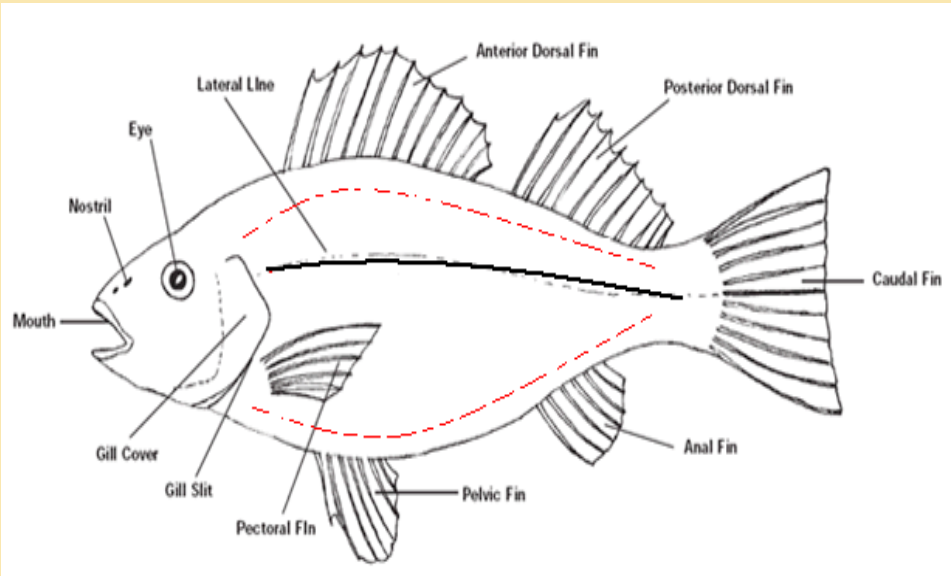
Skills Lab 3

1. Identifying of fish nervous system component

Materials needed: Dead fish, Dissecting kit, Dissecting board, Cotton wool, Pins

PROCEDURE

- Place the fish on the dissection board. Dissect along, as shown in dotted lines below



- Open the abdominal cavity

Questions:

i). Locate the organs (brain and spinal cord) associated with Nervous systems

ii). Draw and label the brain you are observing

2. Millipedes are free-living that have a distinct top and bottom, front and back, and head. Point small sticks on its body and observe the response of a millipede to a simple stimulus like other animals. Record the observation and interpret how the millipedes respond to the stimulus to adapt in environment.

END UNIT ASSESSMENT 3

I. Multiple choice questions: Choose the best answer

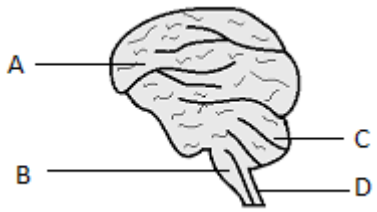
1. What happens when a neurone's membrane depolarizes?
   a) There is a net diffusion of Na^+ out of the cell.
   b) The equilibrium potential of K^+ becomes more positive.
   c) The neurone's membrane voltage becomes more positive.
   d) The neurone becomes less likely to generate an actionpotentia1.
   e) The inside of the cell becomes more negative relative to the outside.
2. Why action potentials are usually conducted in only one direction along an axon?
   a) The nodes of Ranvier can conduct potentials in only one direction.
   b) The brief refractory period prevents reopening of voltage gated Na^+ channels.
   c) The axon hillock has a higher membrane potential than the terminals of the axon.
   d) Ions can flow along the axon in only one direction.
   e) Voltage-gated channels for both Na^+ and K^+ open in only one direction.
3. During the repolarisation phase of an action potential, the permeability of the axon membrane to:
   a) Na^+ increases
   b) K^+ increases
   c) Ca^+ increases
   d) Organic anions increases
4. The list describes the main stages in the process by which information is transmitted across cholinergic synapses.
   - An action potential arrives at synaptic knob of presynaptic neurone. This causes…. the ions to enter the synaptic knob.

- Vesicles move to the…….. membrane.
- A neurotransmitter called……..is released into the synaptic cleft
- This moves across the cleft by a process known as…….. . The neurotransmitter combines with a…….. on the postsynaptic membrane.
- Influx of…….. ions cause local depolarisation and an action potential is set up in the postsynaptic neurone.

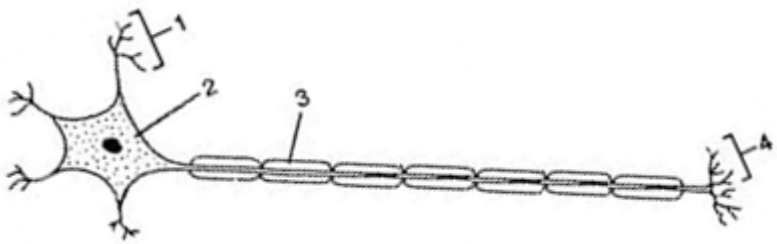
a) Copy the list. Using the correct scientific terms, add the words that have been omitted.

b) Explain what happens to the neurotransmitter after it has passed information across

5. The figure below shows the structure of the human brain. Identify the structures A – D and for each structure, give one function.



6. The diagram below shows a typical motor neurone.



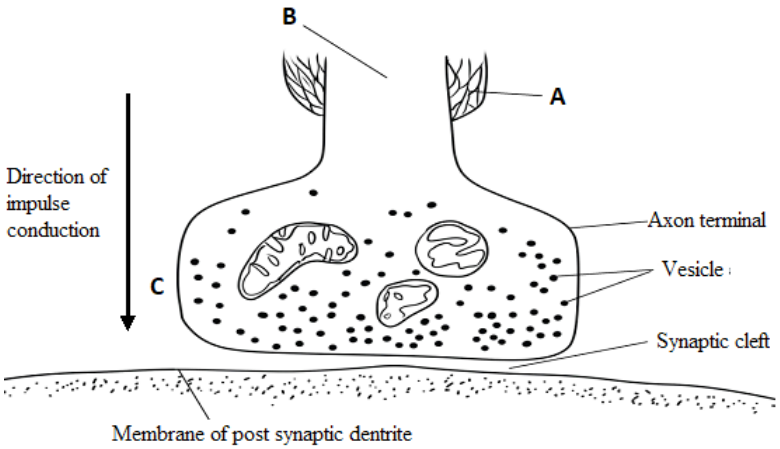
a) Name parts labelled 1 to 4

b) How does a nerve impulse propagate along the neurone?

c) Explain how drugs affect the transmission of impulses.

7. The diagram below represents the structures visible at a synapse with the aid of electron microscopy.

a) Identify the structures labelled A and B



b) Name the chemical found in the numerous vesicles that occur in the synaptic knob

c) Identify the structure labelled C and suggests a reason for its presence in the synaptic knob

d) A powerful hydrolytic enzyme is found in the synaptic cleft. What is its function in normal synaptic transmission?

8. Describe what happens when an action potential arrives at a synaptic knob of an excitatory synapse

UNIT 4

HORMONAL COORDINATION

Key unit competence: Identify the location and function of endocrine glands in the body.

Introductory Activity 4

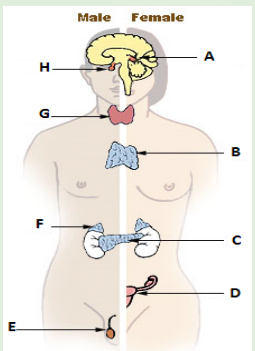
At a certain given age, there are certain changes which occur in the human body especially during puberty. As girls and boys enter the period of puberty, they start to develop remarkable differences in physical appearance and in their behaviour.

1. What do you think to be the causes of such changes?
2. What are some changes which can be observed in boys and not in girls?
3. Which the organs do you think are responsible for producing such changes?

4.1. Structure and function of the endocrine system in humans: location of endocrine glands and functions of their secretions

Activity 4.1

The following human diagram shows the location of the different endocrine glands in the human body. Observe and answer the following questions:



By search engine or library textbooks:

a) Identify on the diagram endocrine glands labelled A, B, C, D, E, F, G.
b) Write short notes on the structure and function of each gland labelled on the above diagram.

Endocrine glands secrete their products called hormones into the interstitial fluid surrounding the secretory cells rather than into ducts. From the interstitial fluid, hormones diffuse into blood capillaries and blood carries them to target cells throughout the body. Because most hormones are required in very small amounts, the circulating levels of hormones are typically low.

The word endocrine means internal secretion and endocrine glands are therefore glands of internal secretion. Since they shed their secretion into the bloodstream, they have no ducts and are hence known as ductless glands. Once in the bloodstream, the hormones are carried around the body, bringing about responses in various places. Structures that respond to them are called target organs.

A hormone is a chemical messenger having the following properties:

- It travels in the blood
- It has its effect at a site different from the site where it is produced. The site where it has effect is called the target, while itself is called messenger
- It fits precisely into receptor molecules in the target like a key in a lock. It is therefore specific for a particular target;
- It is a small soluble molecule;
- It is effective in low concentrations.

The ability of a target cell to respond to a hormone depends on the presence of receptors, within the cell or on its plasma membrane, to which the hormone can bind. Hormone receptors are dynamic structures. Changes in number and sensitivity of hormone receptors may occur in response to high or low levels of stimulating hormones.

The endocrine glands include the pituitary, thyroid, parathyroid, adrenal, and pineal glands (Figure 10.1). Taken together, all endocrine glands and hormone-secreting cells constitute the endocrine system. The science of the structure and function of the endocrine glands and the diagnosis and treatment of disorders of the endocrine system is endocrinology (endo: within; crino: to secrete; -logy: study of).

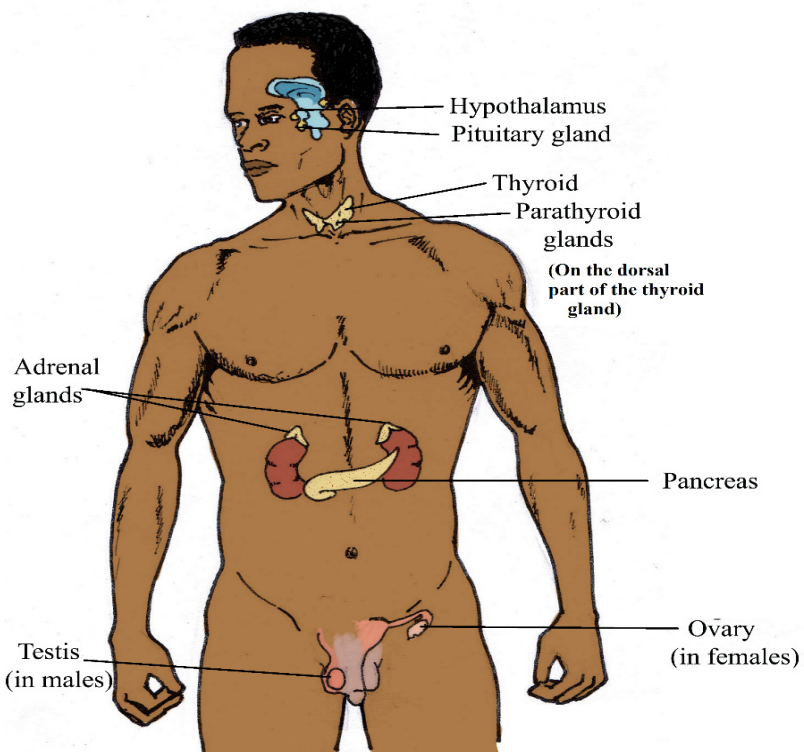


Figure 4.1: Major endocrine glands

a) The pituitary gland or Hypophysis or master gland

The pituitary gland also called hypophysis hangs from the base of the brain by a stalk and is enclosed by bone. It consists of a hormone-producing glandular portion called anterior pituitary and a neural portion called posterior pituitary, which is an extension of the hypothalamus. The hypothalamus regulates the hormonal output of the anterior pituitary and synthesizes two hormones that it exports to the posterior pituitary for storage and later release. Four of the six hormones produced by the pituitary gland are tropic hormones that regulate the function of other endocrine organs. Most anterior pituitary hormones exhibit a diurnal rhythm of release, which is subject to modification by stimuli influencing the hypothalamus.

- Growth hormone (GH) or Somatotropic hormone is a hormone that stimulates growth of all body tissues but especially skeletal muscle and bone. GH mobilizes the use of fats, stimulates protein synthesis, and inhibits glucose uptake and metabolism.
- Thyroid-stimulating hormone (TSH) stimulates the normal development and Activity of the thyroid gland. Thyrotropin-releasing hormone (TRH) stimulates its release; negative feedback of thyroid hormone inhibits it.
- Adrenocorticotropic hormone (ACTH) stimulates the adrenal cortex

to release its hormones. ACTH release is triggered by corticotropin-releasing hormone (CRH) and inhibited by rising glucocorticoid levels.

- The gonadotropins: follicle-stimulating hormone (FSH) and luteinizing hormone (LH) regulate the functions of the gonads in both sexes.
- Prolactin (PRL) promotes the production of milk in human's females. Its secretion is triggered by prolactin-releasing hormone (PRH) and inhibited by prolactin-inhibiting hormone (PIH).

The neurohypophysis stores and releases two hormones produced by the hypothalamus:

- Oxytocin stimulates powerful contractions of the uterus, which trigger labor and delivery of an infant, and milk ejection in nursing women. Its release is mediated reflexively by the hypothalamus and represents a positive feedback mechanism.
- Antidiuretic hormone (ADH) stimulates the kidney tubules to reabsorb and conserve water, resulting in small volumes of highly concentrated urine and decreased plasma osmolality.

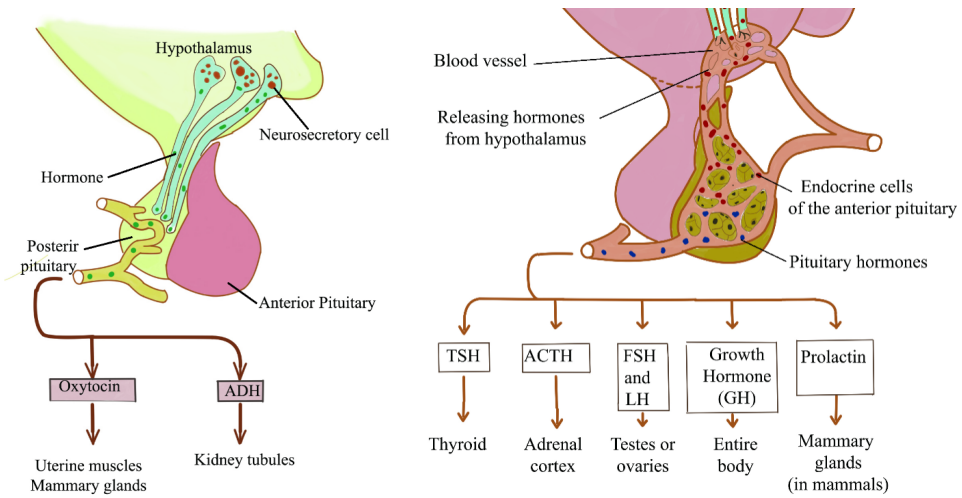


Figure 4.2: Pituitary and hypothalamic secretions

b) The hypothalamus

The hypothalamus plays an important role in integrating the vertebrate endocrine and nervous systems. The region of the lower brain receives information from nerves throughout the body and from other parts of the brain thus initiates endocrine signals appropriate to environmental conditions. A set of neurosecretory cells in the hypothalamus exerts control over the anterior pituitary by secreting two kinds of hormones into the blood: Releasing hormones which make the anterior pituitary to secrete its hormones and inhibiting hormones that make the anterior pituitary stop secreting hormones. Every

anterior pituitary hormone is controlled at least by one releasing hormone and some have both a releasing and an inhibiting hormone.

Unlike the anterior pituitary, the posterior pituitary or neurohypophysis is an extension of the brain. It develops from a bulge of the hypothalamus that grows downward the mouth fold that forms the anterior pituitary. The posterior pituitary remains attached to the hypothalamus. It stores and releases two hormones that are made by a set of neurosecretory cells in the hypothalamus.

c) Thyroid gland

The thyroid gland is located in the anterior throat. Thyroid follicles store colloid containing thyroglobulin, a glycoprotein from which thyroid hormone is derived. Thyroid hormone (TH) includes thyroxine (T_4) and triiodothyronine (T_3), which increase the rate of cellular metabolism. Consequently, oxygen use and heat production rise. Calcitonin, produced by the parafollicular cells of the thyroid gland in response to rising blood calcium levels, decreases blood calcium levels by inhibiting bone matrix resorption and enhancing calcium deposit in bone.

d) Parathyroid glands

The parathyroid glands are located on the dorsal aspect of the thyroid gland and secrete parathyroid hormone (PTH), which causes an increase in blood calcium levels by targeting bone, the intestine, and the kidneys. PTH is the antagonist of calcitonin. PTH release is triggered by decreasing blood calcium levels and is inhibited by increasing blood calcium levels.

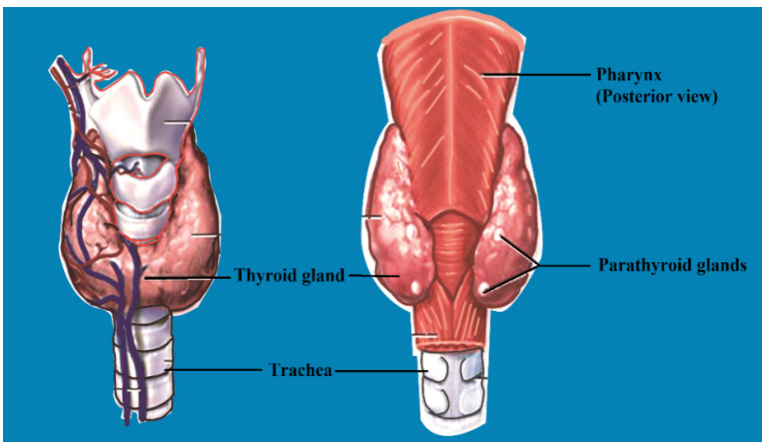


Figure 4.3: The location of the thyroid and the parathyroid glands

e) Pancreas

The pancreas is an organ located in the abdomen close to the stomach and is both an exocrine and an endocrine gland. The endocrine portion (islets of langerhans) releases insulin and glucagon and smaller amounts of other hormones such as somatostatine to the blood. Glucagon is released by alpha

(α) cells when glucose levels in blood are low. Glucagon stimulates the liver to release glucose to the blood. Insulin is released by beta (β) cells when blood levels of glucose (and amino acids) are rising. It increases the rate of glucose uptake and metabolism by most body cells.

f) Gonads

The ovaries of the female which are located in the pelvic cavity, release two main hormones. Secretion of estrogens by the ovarian follicles begins at puberty under the influence of FSH. Estrogens stimulate maturation of the female reproductive system and development of the secondary sex characteristics. Progesterone is released in response to high blood levels of LH. It works with estrogens in establishing the human menstrual cycle. The testes of the male begin to produce testosterone at puberty in response to LH. Testosterone stimulates the maturation of the male reproductive organs, development of secondary sex characteristics, and the production of sperm by the testes.

g) Adrenal Glands (Suprarenal Glands)

Each adrenal gland weighs about 5 g and sits on the superior pole of the respective kidney, like a cap. The glands are included in the fatty capsule of the kidney, and are noteworthy for their rich supply of nerves and vessels. A fresh adrenal gland section shows a bright yellow cortex, making up about 80% of the organ, and a more reddish-grey medulla. The endocrine activities of the adrenal cortex and the adrenal medulla differ both in development and function.

- **Adrenal cortex**

  Adrenal cortex makes mineralocorticoids (such as aldosterone and cortisol). Cortisol raises blood glucose level whereas aldosterone stimulates the reabsorption of Na^+ and excretion of K^+ in kidney.

- **Adrenal Medulla**

  The adrenal medulla makes two hormones *epinephrine* (*adrenaline*) (80 %) and *norepinephrine* (*noradrenaline*) (20 %). Epinephrine and norepinephrine are released into the bloodstream during stress and they act on the whole organism by preparing it for increased energy use. Both hormones, for instance, activate the liberation of fatty acids from fat depots and liberate glucose from glycogen storage in the liver (producing a rise in the blood sugar level). They raise the blood pressure and stroke volume of the heart and may lead to vasoconstriction in certain defined areas.

h) Other hormone-producing structures

Many body organs not normally considered endocrine organs contain isolated cell clusters that secrete different hormones. Examples include the gastrointestinal tract organs (gastrin, secretin, and others), the placenta (hormones of pregnancy such as estrogen, progesterone, and others) and the kidneys (erythropoietin and renin).

Table 4.1: Major human endocrine glands, their functions and the control of their secretions

Gland	Hormone	Functions
Hypothalamus	Releasing and inhibiting hormones, posterior pituitary hormones produced here	Control of anterior pituitary hormones
Posterior lobe of pituitary gland	Oxytocin	Contraction of uterus during childbirth and ejection of milk from mammary gland
	ADH	Promotes retention of water by the kidney
Anterior pituitary	Growth hormone	Stimulates growth especially of bones of limbs and metabolic functions
	Prolactin	stimulates milk production and secretion
	FSH	In male, stimulates spermatogenesis. In female, growth of ovarian follicles
	LH	In male, testosterone production In female, secretion of oestrogens and progesterone, ovulation and maintenance of corpus luteum.
	TSH	Synthesis and secretion of thyroid hormones, growth of thyroid glands
	ACTH	Stimulates the adrenal cortex to secrete its hormones
Thyroid gland	Triiodothyronine (T_3) and thyroxine (T_4) Calcitonin	Regulation of basal metabolic rate; Growth and development Decreases blood calcium level.
Parathyroid glands	Parathyroid hormone	Raises blood calcium level

Pancreas	Insulin	Lowers blood glucose level
	Glucagon	Raises blood glucose level
Adrenal cortex	Glucocorticoids and mineralocorticoids	Raises blood glucose level and promotes reabsorption of Na^+ and excretion of K^+ in kidney
Adrenal medulla	Epinephrine and norepinephrine	Raise blood glucose level, increase metabolic activities, constrict blood vessels
Testes	Androgens	Sperm formation; promote development and maintenance of male secondary sex characteristics.
Ovaries	Estrogens and progesterone	Stimulates uterine lining growth; promotes development and maintenance of female secondary characteristics.
Stomach	Gastrin	Secretion of gastric juices
Duodenum	Secretin	Secretion of pancreatic juice; inhibits gastric gastric secretion
	Cholecystokinin	Emptying of gallbladder and release of pancreatic juice into duodenum.
Corpus luteum	Progestrone and estrogen	Growth and development of uterus Fetal development
Placenta	Chorionic gonadotrophin	Maintenance of corpus luteum
Thymus	Thymosin	Stimulates T lymphocytes

Application Activity 4.1

A number of laboratory experiments were conducted on laboratory mice. The endocrine system of mice is similar to that of humans. Brief summaries of the procedures are provided in Table 2.3

a) In procedure 1, identify the gland that was removed and explain why the levels of ACTH increased.

b) In procedure 2, identify the hormone that was injected and explain why blood sugar levels decreased.

c) In procedure 3, identify the hormone that was affected and explain why urine production increased.

d) In procedure 4, identify the hormone that was injected and explain why blood glucose levels increased.

Table 2.3

	Procedure	**Observation**
1	gland removed	• urine output increased • NaCl ion concentration in urine increased • ACTH level increased in blood
2	hormone injected	• blood glucose levels decreased
3	blood flow from the posterior pituitary reduced	• urine production increased
4	hormone injected	• glycogen converted to glucose in the liver • blood glucose increased

4.2. Principles of the negative feedback mechanism of Hormonal action

Activity 4.2

The urine of non-diabetic patients should contain no glucose as it is selectively reabsorbed from the filtrate in the proximal convoluted tubule. Diabetics have higher levels of blood glucose due to either a lack of insulin secretion (type I) or insensitivity to insulin secretions (type II),

because of this, not all of the glucose in diabetics is reabsorbed into the blood (protein pumps in tubule wall become saturated). This results in the presence of glucose in the urine of untreated diabetics.

Make research from internet or library to describe the sequence of events involved in maintenance of constant blood glucose level in the human body.

Feedback mechanisms are necessary in the maintenance of homeostatic mechanisms. All homeostatic control mechanisms have at least three interdependent components for the variable being regulated that work together. The receptor is the sensing component that monitors and responds to changes in the environment. When the receptor senses a stimulus, it sends information to a control center, the component that sets the range at which a variable is maintained. The control center determines an appropriate response to the stimulus. In most homeostatic mechanisms, the control center is the brain. The control center then sends signals to an effector, which can be muscles, organs or other structures that receive signals from the control center. After receiving the signal, a change occurs to correct the deviation by either enhancing it with positive feedback or depressing it with negative feedback.

The homeostatic mechanisms in mammals require information to be transferred between different parts of the body. There are two coordination systems in mammals that control this: the nervous system and the endocrine system.

- In the nervous system, information in the form of electrical impulses is transmitted along nerve cells (neurones).
- The endocrine system uses chemical messengers called hormones that travel in the blood, in a form of long-distance cell signaling.

Positive feedback mechanisms are designed to accelerate or enhance the output created by a stimulus that has already been activated. Unlike negative feedback mechanisms that initiate to maintain or regulate physiological functions within a set and narrow range, the positive feedback mechanisms are designed to push levels out of normal levels. To achieve this purpose, a series of events initiates a cascading process that builds to increase the effect of the stimulus. This process can be beneficial but is rarely used by the body due to risks of the acceleration's becoming uncontrollable.

One positive feedback example event in the body is the accumulation blood platelets, which, in turn, causes blood clotting in response to a break or tear in the lining of blood vessels. Another example is the release of oxytocin to intensify the contractions of the uterus that take place during childbirth.

Another example of a positive feedback mechanism is the production of milk by a mother for her baby. As the baby suckles, nerve messages from the mammary

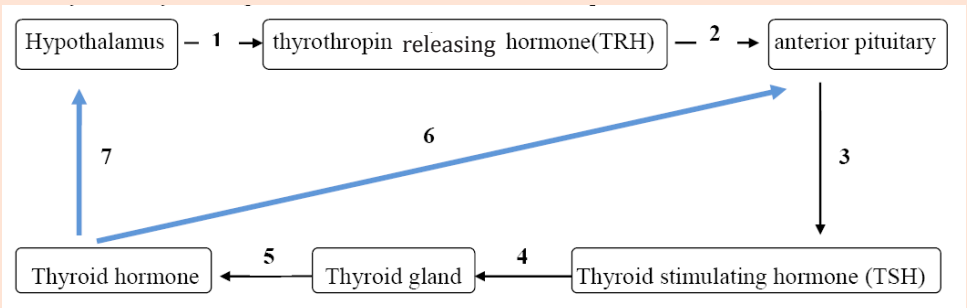
glands cause the mother's pituitary gland to secrete a hormone called prolactin. The more the baby suckles, the more prolactin is released, which stimulates further milk production by the mother's mammary glands. In this case, a negative feedback mechanism would not be helpful because the more the baby nursed, the less milk would be produced. Blood glucose levels are maintained at a constant level in the body by a negative feedback mechanism. When the blood glucose level is too high, the pancreas secretes insulin and when the level is too low, the pancreas then secretes glucagon.

Table 4.2: Negative and positive feedback compared

Negative feedback	**Positive feedback**
Shuts off the original stimulus, or reduces its intensity	Increases the original stimulus to push the variable farther.
In this feedback loop, the values remain within a range	Values go out of range
Common in the body	Very uncommon
This feedback loop is initiated by a stimulus that disturbs the homeostasis of a body system	Positive feedback is also initiated by a stimulus.
Examples: body temperature, sugar metabolism…	Examples: lactation, labor contractions, blood clotting

Application Activity 4.2

Study carefully the diagram below and answer the related questions



a) In the above diagram find arrow(s) that specify the following message:

"High concentration of hormone can inhibit the gland from releasing the same hormone in order to keep the concentration relatively stable".

b) What should happen if the event 6 and **7** were not there?

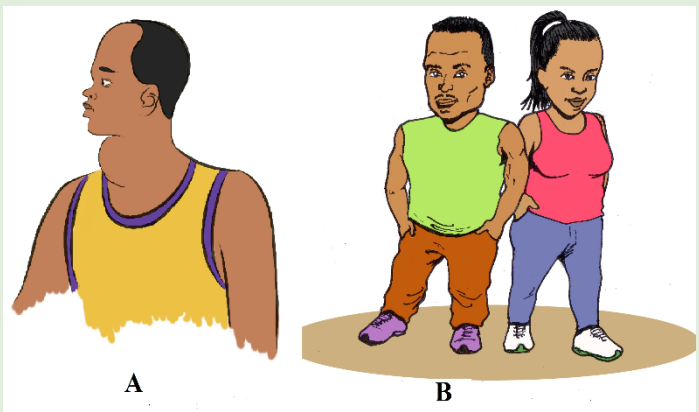
c) Explain what will happen when the quantity of thyroid hormone increases or decreases?

d) Suggest the name of the mechanism that intervenes in hormonal control?

4.3. Effects of hormonal imbalances

Activity 4.3

Observe carefully the photos below and answer questions that follow.



a) What concern do you have on these individuals?

b) Read the content from biology textbook provided to answer these questions:

i). What are the causes of abnormalities on individuals A and B?

ii). Discuss any other four hormonal disorders.

The disorders of the endocrine system often involve either the hyposecretion (*hypo* means too little or under), inadequate release of a hormone, or the hypersecretion (*hyper* means too much or above), excessive release of a hormone. In other cases, the problem is faulty hormone receptors, an inadequate number of receptors, or defects in second-messenger systems. Because hormones are distributed in the blood to target tissues throughout the body, problems associated with endocrine dysfunction may also be widespread.

4.3.1. Pituitary Gland Disorders

a) Pituitary dwarfism, gigantism, and acromegaly

Several disorders of the anterior pituitary involve human growth hormone. Hyposecretion of human growth hormone during the growth years slows bone growth, and the epiphyseal plates close before normal height is reached. This condition is called pituitary dwarfism. Other organs of the body also fail to grow, and the body proportions are childlike. Treatment requires administration of human growth hormone during childhood, before the epiphyseal plates close.

Hypersecretion of human growth hormone during childhood causes gigantism, an abnormal increase in the length of long bones. The person grows to be very tall, but body proportions are about normal. Hypersecretion of human growth hormone during adulthood is called acromegaly.

b) Diabetes insipidus

The most common abnormality associated with dysfunction of the posterior pituitary is diabetes insipidus. This disorder is due to defects in antidiuretic hormone (ADH) receptors or an inability of the pituitary gland to secrete ADH. A common symptom of diabetes insipidus is excretion of large volumes of urine resulting in dehydration and thirst. Bed-wetting is common in afflicted children. Because so much water is lost in the urine, a person with diabetes insipidus may die of dehydration if deprived of water for only one day. Treatment of diabetes insipidus involves the injection of ADH.

4.3.2. Thyroid gland disorders

Thyroid gland disorders affect all major body systems and are among the most common endocrine disorders. Congenital hypothyroidism or the hyposecretion of thyroid hormones that is present at birth has devastating consequences if not treated quickly. Previously termed cretinism, it causes severe mental retardation and stunted bone growth. At birth, the baby typically is normal because lipid-soluble maternal thyroid hormones crossed the placenta during pregnancy and allowed normal development.

Hypothyroidism during the adult years produces a disorder called myxoedema. An indication of this disorder is oedema (accumulation of interstitial fluid) that causes the facial tissues to swell and look puffy. A person with myxoedema has a slow heart rate, low body temperature, sensitivity to cold, dry hair and skin, muscular weakness, general lethargy, and a tendency to gain weight easily. Because the brain has already reached maturity, mental retardation does not occur, but the person may be less alert.

The most common form of hyperthyroidism is Graves' disease which is an autoimmune disorder in which the person produces antibodies that mimic the action of thyroid-stimulating hormone (TSH). The antibodies continually

stimulate the thyroid gland to grow and produce thyroid hormones. A primary sign is an enlarged thyroid, which may be two to three times its normal size. Graves' patients often have a peculiar oedema behind the eyes, called exophthalmos, which causes the eyes to protrude. Treatment may include surgical removal of part or all of the thyroid gland (thyroidectomy), the use of radioactive iodine to selectively destroy thyroid tissue, and the use of antithyroid drugs to block synthesis of thyroid hormones. A goitre is simply an enlarged thyroid gland. It may be associated with hyperthyroidism, hypothyroidism or by the lack of iodine.

4.3.3. Parathyroid gland disorders

Parathyroid gland disorders cause the hypoparathyroidism due to the too little parathyroid hormone leading to a deficiency of blood Ca^{2+}, causing neurones and muscle fibres to depolarize and produce action potentials spontaneously. This leads to twitches, spasms, and tetany (maintained contraction) of skeletal muscle. The main cause of hypoparathyroidism is accidental damage to the parathyroid glands or to their blood supply during thyroidectomy surgery.

Hyperparathyroidism or an elevated level of parathyroid hormone, most often is due to a tumour of one of the parathyroid glands. An elevated level of PTH causes excessive resorption of bone matrix, raising the blood levels of calcium and phosphate ions and causing bones to become soft and easily fractured. High blood calcium level promotes formation of kidney stones. Fatigue, personality changes, and lethargy are also seen in patients with high levels of parathyroid hormone.

4.3.4. Adrenal Gland Disorders

a) Cushing's syndrome

Hypersecretion of cortisol by the adrenal cortex causes an endocrine disorder known as Cushing's syndrome. The condition is characterized by breakdown of muscle proteins and redistribution of body fat, resulting in thin arms and legs accompanied by a rounded moon face and buffalo hump on the back. Facial skin is flushed, and the skin covering the abdomen develops stretch marks. The person also bruises easily, and wound healing is very slow. The elevated level of cortisol causes hyperglycaemia, osteoporosis, weakness, hypertension, increased susceptibility to infection, decreased resistance to stress, and mood swings.

b) Addison's disease

Hyposecretion of glucocorticoids and aldosterone causes Addison's disease (chronic adrenocortical insufficiency). The majority of cases are autoimmune disorders in which antibodies cause adrenal cortex destruction or block binding of ACTH to its receptors. Pathogens, such as the bacterium that causes tuberculosis, also may trigger adrenal cortex destruction. Symptoms,

which typically do not appear until 90% of the adrenal cortex has been destroyed, include mental lethargy, anorexia, nausea and vomiting, weight loss, hypoglycemia, and muscular weakness. Loss of aldosterone leads to the elevated potassium and decreased sodium in the blood, low blood pressure, dehydration, decreased cardiac output and even cardiac arrest.

4.3.5. Pancreas disorders

The most common endocrine disorder is diabetes mellitus caused by an inability to produce or use insulin. According to the diabetes atlas of 2018, the prevalence of **diabetes in Rwanda is about 3.16%** of the population with 1,918 diabetes related deaths per year. On the world health day in 2016, the world health organization (WHO) addressed a call for action on diabetes, drawing attention to the need to step up prevention and treatment of this disease. The first WHO Global report on diabetes demonstrates that the number of adults living with diabetes has almost quadrupled since 1980 to 422 million adults. This dramatic rise is largely due to the rise in type 2 diabetes and factors driving it include overweight and obesity. In 2012 alone diabetes caused 1.5 million deaths. Its complications can lead to heart attack, stroke, blindness, kidney failure and lower limb amputation.

Because insulin is unavailable to aid transport of glucose into body cells, blood glucose level is high and glucose is found in the urine, the process known as glucosuria. The cardinal signs of diabetes mellitus are polyuria (excessive urine production due to an inability of the kidneys to reabsorb water), polydipsia (excessive thirst) and polyphagia (excessive eating).

Application Activity 4.3

You meet someone and reported to you the following signs and symptoms he/she has: feeling very thirsty, extreme fatigue, weight loss, blurry vision, sweating, and sudden change in breathing rate, kidney failure and heart attack. The signs and symptoms reported characterize one of the endocrine disorders.

a) Identify the endocrine disorder he/she has.

b) Advice him/her on the precaution to take for the disorder.

4.4. Comparison between hormonal and nervous systems

Activity 4.4

Make a research using internet, using different books from the school library and charts showing nervous system and endocrine system; make table comparing nervous system and endocrine system.

The nervous and endocrine systems act together to coordinate functions of all our body systems. Remember that the nervous system acts through nerve impulses conducted along axons of neurones. At synapses, nerve impulses trigger the release of mediator molecules called neurotransmitters, while the endocrine system controls body activities by releasing mediators, called hormones. However, the means of control of the two systems are very different.

A basic similarity between the endocrine system and the nervous system is that both provide means of communication within the body of an organism. Both involve transmission of a message which is triggered by a stimulus and produces a response. Several chemicals function as both neurotransmitters and hormones including norepinephrine. Some hormones such as oxytocin are secreted by neuroendocrine cells; neurones that release their secretions into the blood. The target organs of a hormone are equivalent to nerve's effectors, both involve chemical transmission, both bring about survival response and both systems need a transporting medium.

The main differences between the two systems concern the nature of the message. In the endocrine system, the message takes the form of a chemical substance transmitted through the blood stream. In the nervous system it is a discrete-all or none action potential transmitted along a nerve fiber. All other differences arise from this fundamental one. They can be listed as follows:

- Because of the comparatively high speed at which impulses are transmitted along nerves, nerves responses are generally transmitted more rapidly than hormonal ones.
- Since it is conveyed by the bloodstream, there is nothing to stop a hormone being carried to every part of the body. Nervous impulses however are transmitted by particular neurones to specific destinations.
- As a result, hormones are often widespread, sometimes involving the participation of numerous target organs. In contrast, nervous responses may be much localized, involving perhaps the contractions of only one muscle.
- Hormonal responses frequently continue over a long period of time. Obvious examples of such long-term responses are growth and metabolism.

A comparison between nervous and endocrine system is summarized in the table 4.3

Table 4.3: Differences between nervous and endocrine system

Nervous system	**Endocrine system**
– Involves nervous impulses (electrical) and neurotransmitters (chemical)	– Involves hormones (chemical substance)
– Impulses transmitted by neurones	– Hormones transported by blood
– Quick response	– Usually a slow response
– Response short-lived	– Response may be short-lived or long term
– May be voluntary or involuntary	– Always involuntary
– Usually localized	– May affect more than one target organ
– Stops quickly when stimulus stops	– May continue responding long after stimulus stops
– Involves nervous impulses (electrical) and neurotransmitters (chemical)	– Involves hormones (chemical substance)
– Impulses transmitted by neurones	– Hormones transported by blood
– Quick response	– Usually a slow response
– Response short-lived	– Response may be short-lived or long term

Application Activity 4.4

1. With an example of everyday activities, show how the nervous system can be involved in voluntary and involuntary activities.
2. Describe with examples a short term effect of the endocrine system and a long term effect of the nervous system.

Skills Lab 4

Objective: Determine the blood glucose level: Test for glucose level in blood by using a glucometer

Requirements: Blood, sterile lancet, cotton wool, ethanol, glucometer.

Procedure:

1. Insert a disposable test strip into its place in the glucometer.
2. Wash your finger with alcohol using cotton wool.
3. Bite the sterile lancet on the tip of cleaned finger to get some drops of blood from your finger.
4. Place the drop of blood on a disposable test strip.
5. Read and calculate the blood glucose level.

Discuss what will happen when the amount of sugar in blood increases or decreases to the normal range of sugar level in blood.

Keeping a record of your glucometer results can help to get information on how your body is responding to certain foods, exercise and medicine. It also provides your doctor with an accurate picture of how your treatment is working.

i). Design procedures to follow while using glucometer.

ii). Follow the designed procedures and demonstrate the use of glucometer.

iii). Record glucometer data and explain the use experimental data to control the effects of blood sugar levels.

END UNIT ASSESSMENT 4

1. What are the chemical messengers of the endocrine system called?
   a) Neurones
   b) Hormones
   c) Blood cells
   d) Carbohydrates
2. Endocrine glands
   a) Function only after puberty
   b) Function only before puberty
   c) Release products through ducts
   d) Release products into bloodstream

3. X and Y are hormones. X stimulates the secretion of Y, which exerts negative feedback on the cells that secrete X. Suppose the level of Y decreases. What should happen immediately afterwards?
   a) Less X is secreted
   b) More X is secreted
   c) Secretion of Y stops
   d) Secretion of X stops
4. Which one of the following hormones is secreted by the neurosecretory cells in mammals?
   a) Adrenaline
   b) Antidiuretic hormone
   c) Insulin
   d) Thyroxin
5. Explain the role of insulin hormone in the body.
6. The pituitary gland is often described as the 'master gland'. Explain this statement.
7. Produce a table which compares the features of nervous control and chemical control.
8. Both the nervous system and endocrine system respond to stress. Explain the benefits of each system's response.
9. Complete the following table by stating which region of the brain controls each of the functions listed

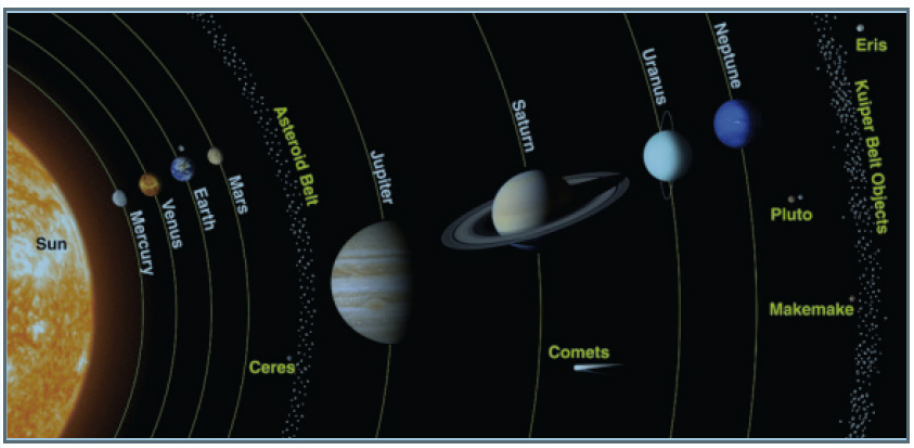
Function	Region of brain
Osmoregulation	
Control of posture	
Modification of heart rate	

UNIT 5

UNIVERSAL GRAVITATIONAL FIELD POTENTIAL

Key Unit competence: Explain the gravitational field potential and its applications in planet motion

Introductory Activity 5



People have always enjoyed viewing stars and planets on clear, dark nights. It is not only the beauty and variety of objects in the sky that is so fascinating, but also the search for answers to questions related to the patterns and motions of those objects. Until the late 1700s, Jupiter and Saturn were the only outer planets identified in our solar system because they were visible to the naked eye. Combined with the inner planets, the solar system was believed to consist of the Sun and six planets, as well as other smaller bodies such as moons. Some of the earliest investigations in physical science started with questions that people asked about the night sky.

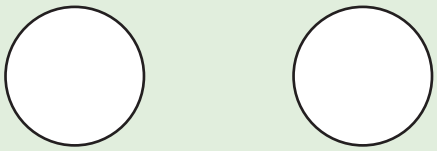
i). Why doesn't the moon fall on the earth?

ii). Why doesn't the Earth fly off into space rather than remaining in orbit around the sun?

5.1. Newton's law of universal gravitation

Activity 5.1

Two bodies are put together and are separated by a small distance as shown in the figure below:



a) Discuss the interactions between two bodies on figure above.

b) Can the two bodies attract one another? Explain your reasoning.

c) Imagine the two bodies were massive (too big) explain the difference in interactions of massive bodies and small bodies.

From the time of Aristotle, the circular motions of heavenly bodies were regarded as natural. The ancients believed that the stars, planets, and Moon moved in divine circles, free from any impressed forces. Newton, however, recognized that a force must be acting on the Planets; otherwise, their paths would be straight lines. And whereas others of his time, influenced by Aristotle, said that any such force would be directed along the planets' motion, Newton reasoned that it must be perpendicular to their motion, directed toward the center of their curved paths- toward the sun. This was the force of gravity, the same force that pulls apples off trees.

Newton's law of universal gravitation states that every point mass attracts every other point mass in the universe by a force pointing in a straight line between the centers-of-mass of both points, and this force is proportional to the masses of the objects and inversely proportional to their separation. This attractive force always points inward, from one point to the other. The Law applies to all objects with masses, big or small. Two big objects can be considered as point-like masses, if the distance between them is very large compared to their sizes or if they are spherically symmetric. For these cases the mass of each object can be represented as a point mass located at its center-of-mass.

Separately it was shown that large spherically-symmetrical masses attract and are attracted as if all their mass were concentrated at their centers.

The space surrounding the Earth where the mass of an object experiences a gravitational pull, or force due to gravity, is called **gravitational field** of the Earth. On the surface of the earth the value of gravitational field is $g = 9.8\ m/s^2$ on the surface on the moon's surface is only about $g = 1.6\ m/s^2$

Law of Universal Gravitation

While Newton was able to articulate his Law of Universal Gravitation and verify it experimentally, he could only calculate the relative gravitational force in comparison to another force. It wasn't until Henry Cavendish's verification of the gravitational constant that the Law of Universal Gravitation received its final algebraic form:

$$F_G = \frac{GMm}{r^2}$$

where F represents the force in Newtons, *M* and *m* represent the two masses in kilograms, and *r* represents the separation in meters.

The constant of proportionality *G* is known as the "universal gravitational constant" because it is thought to be the same at all places and all times, and thus universally characterizes the intrinsic strength of the gravitational force.

$$G = 6.67259 \times 10^{-11} m^3 .kg^{-1} s^{-2}$$

- M is the mass of the Earth, $M = 5.98 \times 10^{24} kg$
- We assume the Earth to be spherical and neglect the radius of the object relative to the radius of the Earth in this discussion. $r = 6380 km$
- The measured gravitational acceleration at the Earth's surface is found to be about $g = 9.80\ m/s^2$

$$\vec{F}_{12} = -\frac{Gm_1m_2}{r^3}\vec{r}_{12}$$

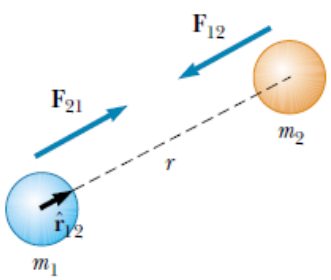


Figure5. 1: The gravitational force between two bodies

Example 5.1

1. Calculate the force of gravity between two bowling balls each having a mass of 8.0kg, when they are 0.50m apart.

Answer

$F = \frac{Gm_1m_2}{r^2}$ where m is mass

G is gravitational constant= $\frac{6.67\times10^{-11}\times8\times8}{0.5^5}$

$F = 1.7\times10^{-8}N$

2. What is the gravitational attraction between an object with a mass of 10 kg and another object with a mass of 20 kg if they are separated by 0.01 m? (Assume both objects are on some surface and not suspended in midair.)

Answer

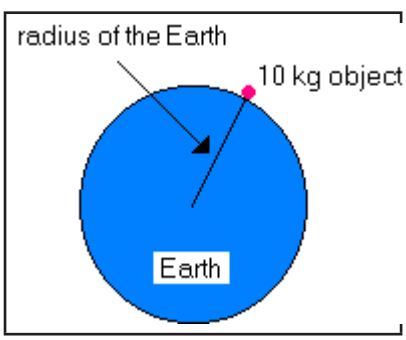
Solving this problem, all we have to do is to put the above values for mass and distance into the general gravity formula below:

$$F_G = G\frac{m_Am_B}{r^2}$$

$$F_G = \frac{6.67\times10^{-11}\times10\times20}{(0.1)^2}$$

$$F_G = 0.0001334N$$

Therefore, the two objects are attracted toward one another with a force of 0.0001334 N, just in opposite directions.



The gravitational attraction of object m_2 pulling on object m_1 designated $F21$ is in a direction opposite to the force exerted by particle 1 on particle 2 by Newton's third law, is equal in magnitude to F_{12} and in the opposite direction. That is, these forces form an action–reaction pair, and $F_{12} = -F_{21}$ and hence the

force F_{12} must be directed toward particle 1. In addition, the direction is along the line connecting the centers of the objects.

The gravitational force is a field force that always exists between two particles, regardless of the medium that separates them. Because the force varies as the inverse square of the distance between the particles, it decreases rapidly with increasing separation.

Note that the force of gravity between two objects depends on two factors: mass and distance.

5.1.1. Gravitational potential energy

Using this reference point:

- All objects at infinity have the same amount of potential energy; zero.
- Any object closer than infinity has a negative amount of potential energy, since it would need to acquire energy in order to reach infinity and have zero energy.

The gravitational potential at a point in a gravitational field is the potential energy per unit mass placed at that point, measured relative to infinity.

Calculating potential and potential energy

When an object is within the gravitational field of a planet, it has a negative amount of potential energy measured relative to infinity. The amount of potential energy depends on:

- The mass of the object.
- The mass of the planet.
- The distance between the centres of mass of the object and the planet.
- The Centre of mass of a planet is normally taken to be at its centre.
- The gravitational potential energy measured relative to infinity of a mass, m, placed within the gravitational field of a spherical mass M can be calculated

- Using: $Pe = \frac{GMm}{r}$

- Gravitational potential, V, is given by the relationship: $V = -\frac{GM}{r}$
- Gravitational potential is measured in Jkg $^{-1}$

Example 5.2

1. Determine gravitational potential at a point 5000 km above the surface of the moon (mass of moon $M = 7.32 \times 10^{22} kg$; $Radius\ of\ moon = 1740\ km$)

Answer:

Gravitational potential $V = -\frac{GM}{r}$

$$V = -\frac{(6.7 \times 10^{-11})(7.32 \times 10^{22})}{(5.00 + 1.74) \times 10^{6}}$$

$$V = -7.2 \times 10^{5}\ Jkg^{-1}$$

5.1.2 Gravitational field

A field is a region of space where forces are exerted on objects with certain properties. The diagram represents the Earth's gravitational field. The lines show the direction of the force that acts on a mass that is within the field.

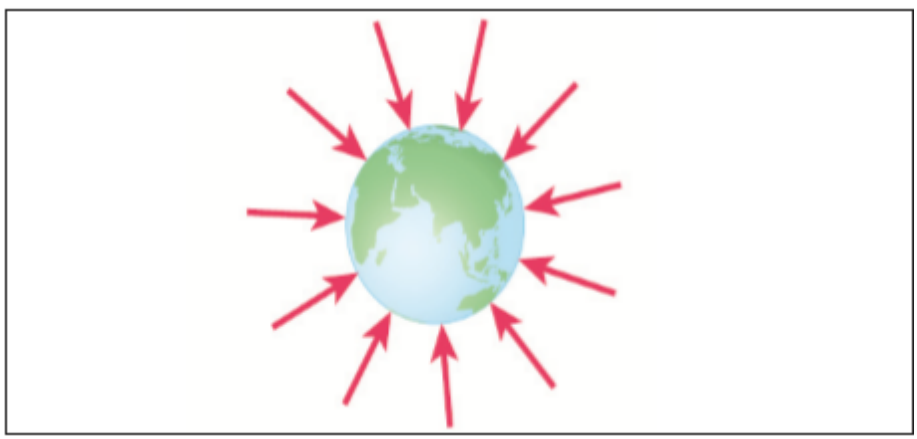


Figure 5. 2: Gravitation field

This diagram shows that:

- Gravitational forces are always attractive -the Earth cannot repel any objects.
- The Earth's gravitational pull acts towards the centre of the Earth.
- The Earth's gravitational field is radial; the field lines become less concentrated with increasing distance from the Earth.

The force exerted on an object in a gravitational field depends on its position. The less concentrated the field lines, the smaller the force. If the gravitational field strength at any point is known, then the size of the force can be calculated.

The gravitational field strength "g" at any point in a gravitational field is the force per unit mass at that point: $g = \frac{F_g}{m}$

Close to the Earth's surface, g has the value of $9.81\ N \cdot kg^{-1}$, though the value of 10 Nkg^{-1} is often used in calculations. Gravitational field strength is a vector quantity: its direction is towards the object that causes the field.

That is, the gravitational field at a point in space equals the gravitational force experienced by a *test particle* placed at that point divided by the mass of the test particle.

Notice that the presence of the test particle is not necessary for the field to exist—the Earth creates the gravitational field. We call the object creating the field the *source particle*. We can detect the presence of the field and measure its strength by placing a test particle in the field and noting the force exerted on it.

As an example of how the field concept works, consider an object of mass *m* near the Earth's surface. Because the gravitational force acting on the object has a magnitude, $F_g = \frac{M_E m}{r^2}$ the field g at a distance *r* from the center of the Earth is

$$g = -\frac{M_E}{r^2}\vec{i}$$ toward the Centre of the earth

where $\vec{i}$ is a unit vector pointing radially outward from the Earth and the negative sign indicates that the field points toward the center of the Earth . Note that the field vectors at different points surrounding the Earth vary in both direction and magnitude. In a small region near the Earth's surface, the downward field g is approximately constant and uniform, as indicated in Figure below

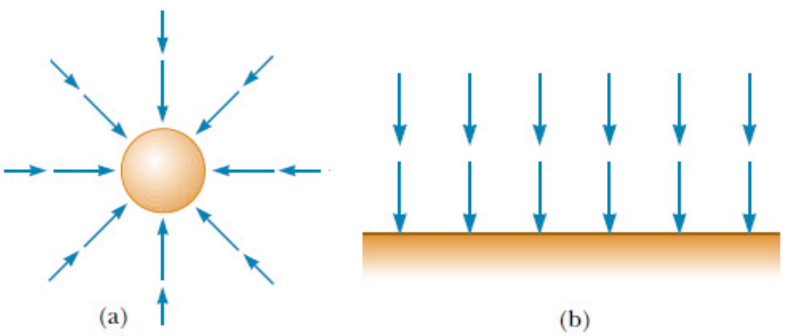


Figure 5. 3 Gravitational field

Application Activity 5.1

1. a) Calculate the magnitude of the gravitational field strength on the surface of Mars.

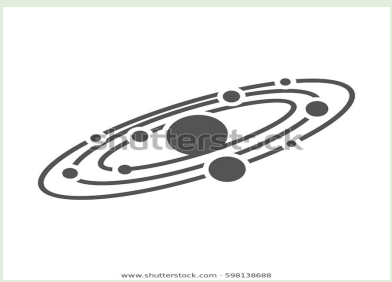
   b) What is the ratio of the magnitude of the gravitational field strength on the surface of Mars to that on the surface of Earth?

2. Determine the mass of Earth using the magnitude of the gravitational field strength at the surface of the Earth, the distance r between Earth's surface and its centre $6.38\times10^{6}\ m$, and the universal gravitation constant

3. The magnitude of the total gravitational field strength at a point in interstellar space is $8.91\times10^{5}kg$ What is the magnitude of the gravitational force at this point on an object (a) of mass 1.00 kg and (b) of mass $8.91\times10^{5}kg$?

5.2. Planetary Motion

Activity 5.2



Critically observe the picture above and answer the questions that follow.

a) Describe the motion of bodies (planet) as indicated in the picture.

b) Do the different planets pass through the same path?

c) With clear observations, which body is the largest?

d) Basing on the knowledge from Newton's law of gravitation, is there any force of attraction between the body stated in (c) above and other bodies? Explain your reasoning.

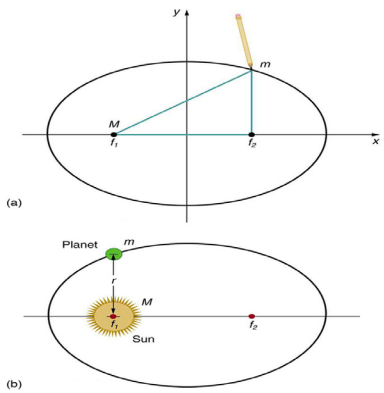
e) If yes, how does the force affect the motion of the bodies as they are in their paths

5.2.1. Kepler's Laws

Kepler's First Law

"The orbits of the planets are ellipses, with the Sun at one focus of the ellipse"

An ellipse is a closed plane curve that resembles a stretched out circle. The Sun is not at the center of the ellipse, but instead at one of its foci. The other focal point, f_2, has no physical significance for the orbit. The center of an ellipse is the midpoint of the line segment joining its focal points. A circle is a special case of an ellipse where both focal points coincide.



The planet then follows the ellipse in its orbit, which means that the Earth-Sun distance is constantly changing as the planet goes around its orbit.

For purpose of illustration we have shown the orbit as rather eccentric; remember that the actual orbits are much less eccentric than this.

Kepler's Second Law

"The line joining the planet to the Sun sweeps out equal areas in equal times as the planet travels around the ellipse."

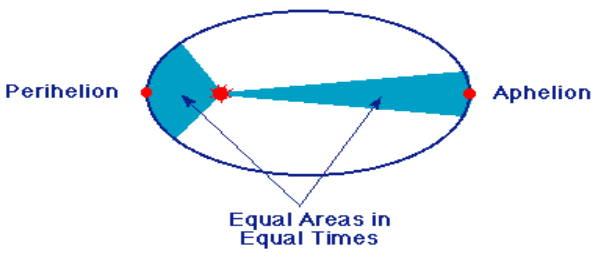


Figure 5. 4: Kepler's Second Law

Kepler's second law is illustrated in the above figure. The line joining the Sun and planet sweeps out equal areas in equal times, so the planet moves faster when it is nearer the Sun. Thus, a planet executes elliptical motion with constantly changing angular speed as it moves about its orbit.

What happen is best understood in terms of **energy.** As the planet moves away from the Sun (or the satellite from Earth), it loses energy by overcoming the pull of gravity, and it slows down, like a stone thrown upwards. And like the stone, it **regains** its energy (completely--no air resistance in space) as it comes back

The point of nearest approach of the planet to the Sun is termed **perihelion**; the point of greatest separation is termed **aphelion**. Hence, by Kepler's second law, the planet moves fastest when it is near perihelion and slowest when it is near aphelion.

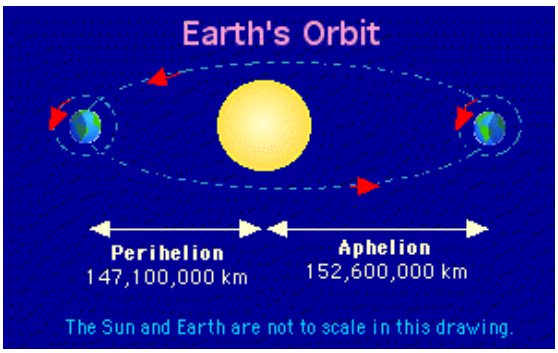


Figure 5. 5: Earth's Orbit

The eccentricity of the orbit of Comet Halley is 0.97, describing an orbit whose major axis is much longer than its minor axis. As a result, Comet Halley spends much of its 76-year period far from the Sun and invisible from the Earth. It is only visible to the naked eye during a small part of its orbit when it is near the Sun.

Kepler's Third Law

Kepler's third law states that *the square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.*

In other words, *"The ratio of the squares of the revolutionary periods for two planets is equal to the ratio of the cubes of their semi-major axes":*

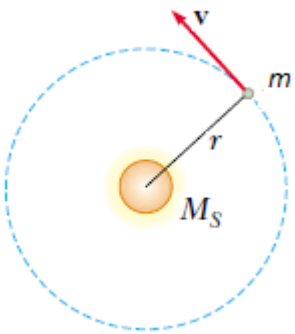
Symbolically, the law can be expressed as $\mathbf{T^2 \propto R^3}$, where **T** is the orbital period of the planet and **R** is the semi-major axis of the orbit.

$$\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3}$$

In this equation T represents the period of revolution for a planet and R represents the length of its semi-major axis. The subscripts "1" and "2" distinguish quantities for planet 1 and 2 respectively. The periods for the two planets are assumed to be in the same time units and the lengths of the semi-major axes for the two planets are assumed to be in the same distance units.

Kepler's Third Law implies that the period for a planet to orbit the Sun increases rapidly with the radius of its orbit. Thus, we find that Mercury, the innermost planet, takes only 88 days to orbit the Sun but the outermost planet (Pluto) requires 248 years to do the same.

Kepler's 3rd law applies only to objects orbiting the same attracting center. Do not use to compare, say the Moon's orbit around the Earth to the orbit of Mars around the Sun because they depend on different attracting centers.



Derivation of Kepler's third law

There is only one speed that a satellite can have if the satellite is to remain in an orbit with a fixed radius.

All of the planet orbits, except those of Mars, mercury and Pluto, Are almost circular. Since the gravitational force acting on the satellite of mass m in the radial direction, it alone provides the centripetal force. Therefore, using Newton's law of gravitation, we have:

$$F_G = F_C \Leftrightarrow \frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM}{r}}$$

The mass **m** of satellite does not appear in equation consequently, for a given orbit, a satellite with a large mass has exactly the same orbital speed as a satellite with a small mass.

The radius r of the orbit (distance from the center of satellite to the center of the planet) is in the denominator in the above equation. This means that the closer the satellite is to Planet, the smaller is the value for r and the greater the orbital speed must be.

The period T of a satellite is the time required for one orbital revolution. The period is related to the speed of the motion by:

$$v = \frac{2\pi r}{T},$$

Thus

$$\sqrt{\frac{GM}{r}} = \frac{2\pi r}{T} \Leftrightarrow T = 2\pi\sqrt{\frac{r^3}{GM}}$$

Therefore, the preceding expression becomes $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

5.2.2. Relation between the universal gravitational constant and force of gravity (g and G)

A small object of mass m, placed within the gravitational field of the Earth, mass M, experiences a force, F, given by

$$F = G\frac{Mm}{r^2}$$

Where r is the separation of the centres of mass of the object and the Earth. It follows from the definition of gravitational field strength as the force per unit mass that the field strength at that point, **g** , is related to the mass of the Earth by the expression:

$$g = \frac{F}{m} = \frac{GM}{r^2}$$

The same symbol, **g**, is used to represent:

- Gravitational field strength.
- Free-fall acceleration.

Example 5.3

1. Determine the magnitude of the gravitational field strength at a point
   a) 1000km above the surface of the Earth
   b) On the surface of the Earth

   ($G = 6.7\times10^{-11}\,Nkg^{-2}m^{-2}$, $M_E = 6.0\times10^{24}\,kg$, $Radius\ of\ Earth = 6.7\times10^{6}\,m$)

Answer:

a) The gravitational field strength at the given point is

$$g = \frac{GM_E}{r^2}$$

$$= \frac{(6.7\times10^{-11})(6\times10^{24})}{\left[(1.0+6.4)\times10^{6}\right]^2}$$

$$g = 7.3N\ kg^{-1}$$

b) On the surface of the Earth $g = \frac{GM}{R^2}$

$$g = \frac{(6.7\times10^{-11})(6\times10^{24})}{(6.4\times10^{6})^2}$$

$$g = 9.8\ Nkg^{-1}$$

Application Activity 5.2

1. State three Kepler's laws
2. Calculate the mass of the sun using the fact that the period of the Earth's orbit around the sun is $3.156\times10^{7}\ s$ and its distance from the sun is $1.496\times10^{11}\ m$

Skills Lab 5

Make a comprehensive research about planetary motion. In your research focus on the following

a) Nature of motion of the planets about the sun

b) Time taken by a given planet to make a complete revolution (one cycle)

c) What makes the planets remain in their paths

d) Make a comprehensive report about your findings from the research.

END UNIT ASSESSMENT 5

1. If the gravitational force on an object is directly proportional to its mass, why don't objects with large masses fall with greater acceleration than small ones?
2. What is the gravitational attraction between an object with a mass of 10 kg and another object with a mass of 20 kg if they are separated by 0.01 m? (Assume both objects are on some surface and not suspended in midair.)
3. What is the gravitational attraction between an object with a mass of 10 kg and the earth if the object is on the earth's surface? (Assume the 10 kg object is a very tiny but dense ball. In other words, assume it is a point.)
4. A 50kg person and a 75kg person are sitting on a bench. Estimate the magnitude of the gravitational force each exerts on the other
5. During a solar eclipse, the Moon, Earth, and Sun all lie on the same line, with the Moon between the Earth and the Sun (The Sun-Earth distance is $1.496\times10^{11}kg$ and the Earth-Moon distance is $3.84\times10^{8}\ m^{3}$, The mass of the Sun, Earth, and Moon are

   $M_S = 1.99\times10^{30}kg; M_E = 5.98\times10^{24}kg\ and\ M_M = 7.36\times10^{22}kg$

   a) What force is exerted by the Sun on the Moon?

   b) What force is exerted by the Earth on the Moon? (c) What force is exerted by the Sun on the Earth?
6. Calculate the force of attraction between two 90kg spheres of metal spaced so that their centers are 40cm apart
7. computer the mass of the earth assuming it to be a sphere of radius 6370km
8. A mass $m_1 = 1\,kg$ weighs one-sixth as much on the surface of the moon as on the earth. Calculate the mass m_2 of the moon. The radius of the moon's $1.738\times10^{6}\ m$

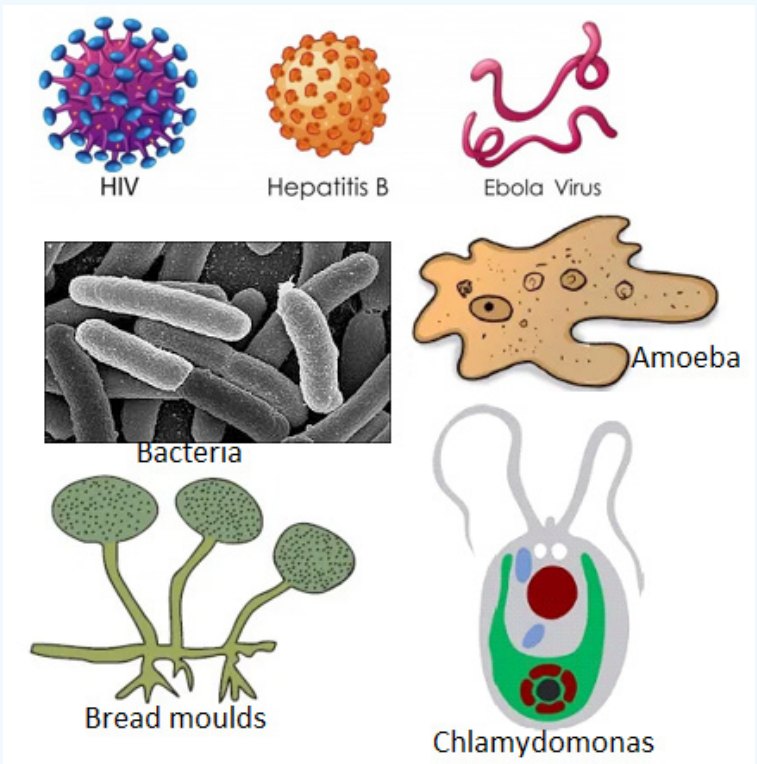
UNIT 6

CHARACTERISTICS OF DIFFERENT GROUPS OF MICROORGANISMS AND ITS APPLICATIONS

Key unit competence: Describe the structure and characteristics of microorganisms and its applications.

Introductory Activity 6

Observe carefully the following living things on the figure and answer the questions that follow:



a) Suggest a common name given to the living things on the figure.

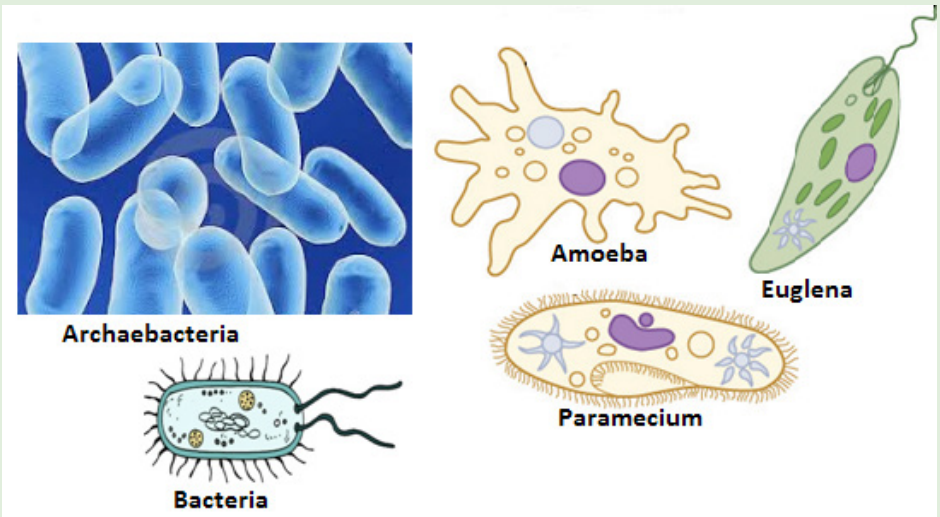
b) Are the living things mentioned on the figure useful or harmful? Justify your answer.

c) Can you predict what you are going to learn in this unit?

6.1. Classification of Micro organisms

Activity 6.1

The following figures represent the examples of microorganisms; observe them and answer the questions that follows:



Using books or internet, search for the characteristics of:

(i) Archaebacteria, (ii) Bacteria (iii) Amoeba, Paramecium and Euglena in common.

The term "**microbiology**" comes Greek words: '**micros**' which means small, 'bios' which means life and 'logos' which means science. Microbiology is the study of microorganisms which are too small organisms to be seen with the unaided eye and require a microscope to be seen. They are also referred to as microbes. They include bacteria, fungi, algae, protozoa and viruses, they are useful to humans and they play a vital role in decay and recycling of nutrients in the environment. Some of them cause diseases.

Micro-organisms are everywhere: in the air, water soil, on plants, on rock surfaces in very hot and cold places (ice). Before the invention of the microscope, microbes were unknown and thousands of people died in devastating epidemics because, vaccines and antibiotics were not available to fight against infectious diseases. Nowadays, microorganisms can be grown in the laboratory and studied.

There are three domains used by biologists to divide organisms into three large groups based on their cell structure. The domain is the highest taxon in the hierarchy. The prokaryotes are divided into the Domains Eubacteria and Archaebacteria, while all the eukaryotes are placed into the domain Eukarya.

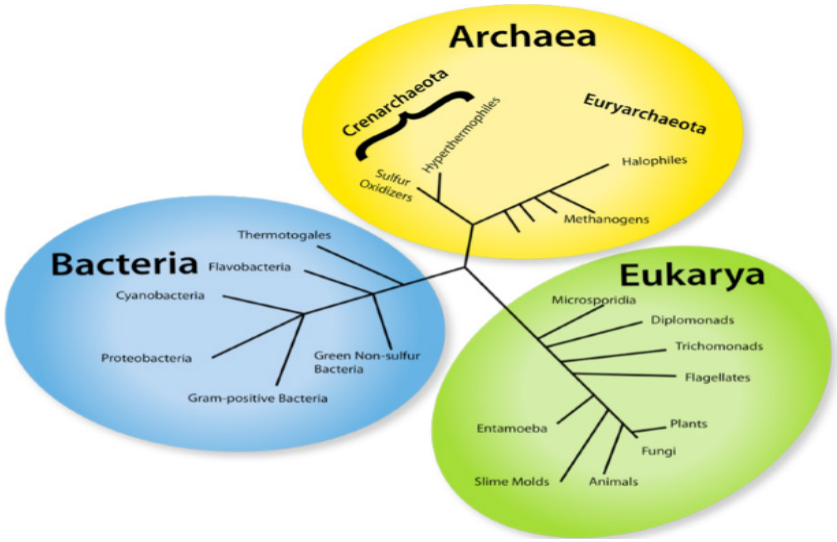


Figure 6.1. The three domains of organisms

a) Domain Eubacteria

Domain Bacteria include prokaryotic organisms as their cells have no true nucleus. They are all microscopic that vary in size between 0.2 to 10 micrometers. The characteristic features of bacteria are:

- Cells with no true nucleus
- DNA exists in circular chromosome and does not have histone proteins associated with it.
- No membrane-bound organelles (mitochondria, endoplasmic reticulum, Golgi body, chloroplasts)
- Contain mesosomes as infolding of membrane and acts as sites for respiration as they lack mitochondria.
- Ribosomes are smaller than in eukaryotic cells
- Cell wall is always present and contains peptidoglycans in place of cellulose
- Cells divide by binary fission
- Usually exist as single cells or colonies.

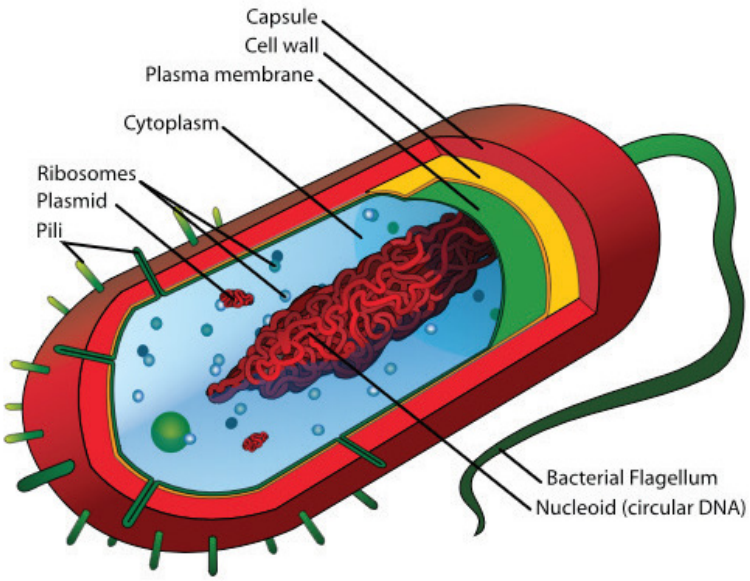


Figure 6.2 : Structure of a typical bacterial

Eubacteria occur in many shapes and sizes and have distinct biochemical and genetic characteristics. Eubacteria that are rod-shaped are called **bacilli**, sphere-shaped are called **cocci** (sing. Coccus) and spiral-shaped are called **spirilla** (sing. Spirillum).

1. **The bacilli**: bacteria with rod-shape. Ex: Clostridium tetani, Bacillus subtilis
2. **Vibrios**: comma-shaped with a single flagellum. eg: Vibrio cholera
3. **The cocci**: group of bacteria with spherical shape such as Streptococci. Cocci that occur in chains are Staphylococci which are grapelike clusters of cocci and Diplococci which is sphere shaped that are grouped two by two.
4. **The spirilla**: bacteria with spiral shape. e.g.: *Spirillum volutans*.

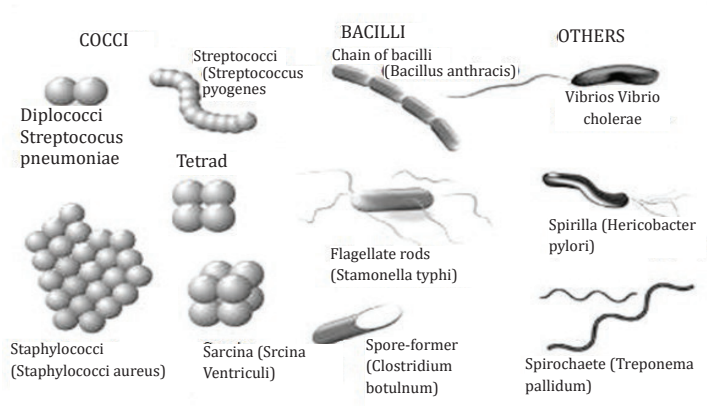


Figure 6.3: Shapes of bacteria cells

b) Domain Archaea (Archaebacteria)

This includes bacteria that live in extreme environments where few other organisms can survive, like in volcanic hot springs and black organic mud totally devoid of oxygen.

They are classified according to the environments they live in:

- **Methanogenic:** bacteria that live in habitats deprived of oxygen and give off methane as a product of metabolism, for example those that live in the guts of ruminant animals.
- **Halophilic:** bacteria live only in salty conditions
- **Thermoacidophilic:** bacteria tolerate extreme acid and temperature that exceed boiling point of water and a pH below 2.

c) Domain Eukarya

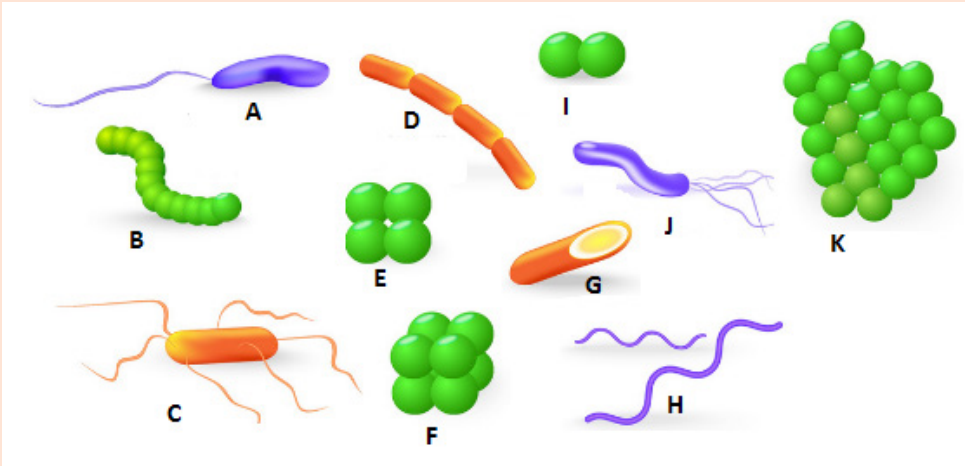
All the organisms classified into this domain have cells with true nuclei and membrane-bound organelles. It includes the four remaining kingdoms: protists, fungi, plantae and Animalia. Their characteristic features are:

- Cells with a nucleus and membrane-bounded organelles
- linear DNA associated with histones arranged within a chromosome in the nucleus
- Ribosomes in the cytosol are larger than in prokaryotes, while chloroplasts and mitochondria have small ribosomes, like those in prokaryotes.
- Chloroplast and mitochondrial DNA is circular as in prokaryotes suggesting an evolutionary relationship between prokaryotes and eukaryotes

- A great diversity of forms: unicellular, colonial and multicellular organisms
- Cell division is by mitosis.
- Many different ways of reproduction including asexually and sexually.

Application Activity 6.1

The following figures represent different types of bacteria; observe them and attempt the related questions:



a) Relate each figure to the appropriate group of bacteria (cocci, bacilli and spirilla).

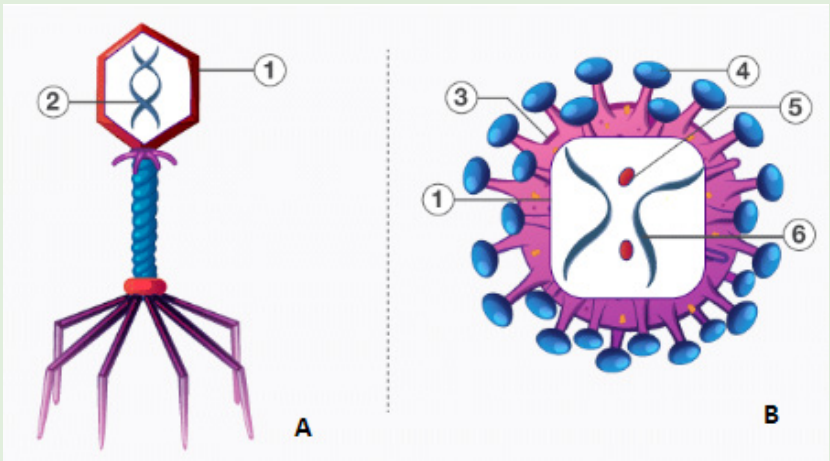
b) Describe how you have grouped the above bacteria.

6.2. Structure and life cycle of viruses

Activity 6.2

The figures below show the structure of viruses.

Visit the school library to conduct a research and then answer the questions that follow:



a) Are structures A and B similar? Justify your answer.
b) Name the parts labeled from 1 to 6 on the figure A and B.
c) Make research to find out common characteristics of viruses

i). Structure of virus

The term "**virus**" was first used in the 1890s to describe agents smaller than bacteria that cause diseases. The existence of viruses was established in 1892, when, Russian scientist, **Dmitry Ivanovsky** discovered later microscopic particles known as the **tobacco mosaic virus.**

There are at least 3,600 types of virus. Hundreds of which are known to cause diseases in animals, bacteria, and plants. Viruses consist of an inner core of either **ribonucleic acid (RNA) or deoxyribonucleic acid (DNA)** plus a protein protective coat called capsid made of protein or of protein combined with lipid or carbohydrate components. An entire virus particle is called vibrios.

The core confers infectivity, and the capsid provides specificity to the virus. In some virions, the capsid is further enveloped by a fatty membrane. The later may cause virion inactivation by exposure to fat solvents such as ether and chloroform.

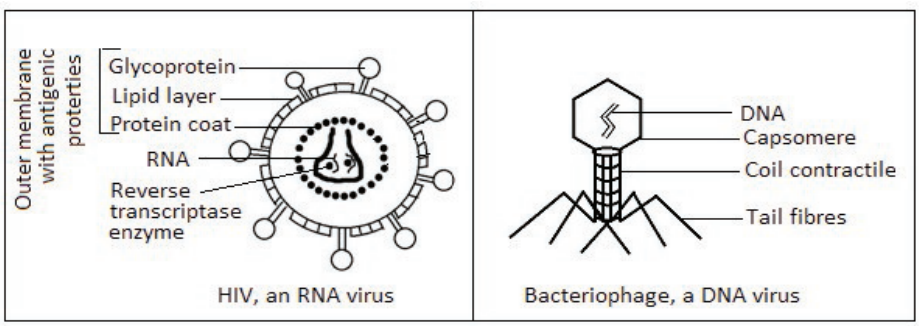


Figure 6.4 : Structure of Virus

Classification of viruses

Viruses can be classified according to:

- Type of nucleic acid molecules they have. Most animal viruses contain RNA while plant viruses contain DNA.
- Type of host cell: plant or animal viruses are specific to their hosts.
- Presence or absence of the envelope: Plant viruses' bacteriophage are no enveloped while animal viruses like HIV and influenza virus are enveloped.

ii). Characteristics of viruses

Viruses are complex biochemical molecules having the following characteristics:

- Viruses are not visible under light microscope because they are very small than bacteria.
- They possess a single type of nucleic acid either DNA or RNA enclosed in a protein coat.
- They can reproduce and grow inside the host cell.
- They have no cell and no cell organelles.
- They are obligate parasite i.e. cannot survive outside a host cell.
- They do not feed, respire and excrete.

Viruses infect and live inside the cells of living organisms. They are also regarded as parasites since they depend entirely on living cells for their survival. Although viruses are not classified as living things, they share two important traits with living things: They have genetic material, and they can reproduce.

iii). Life cycle of Bacteriophage

Bacteriophage is a virus that infects bacteria. Bacteriophage is composed of an icosahedral head that contains a nucleic acid. Beneath the head is a contractile tail that includes a collar and a sheath.

The contractile tail helps to inject the nucleic acid into the host cell. The tail rests on a base plate from which tail fibers emerge. These fibers assist the virus to attach to a host cell.

Viruses replicate by using either the **lytic cycle** or the **lysogenic cycle**:

a) The lytic cycle

During the lytic cycle, a virus invades a host cell, produces new viruses, destroys the host cell, and releases newly formed viruses. Viruses that undergo the lytic cycle are called **virulent** because they cause disease. The lytic cycle consists of five phases:

- The Bacteriophage first attaches to susceptible bacterium by attaching

its tail fibers to a receptor site. Receptor sites are specific sites that viruses recognize and attach to on the host cell's surface. If the Bacteriophage does not find a receptor site, it cannot infect the cell.

- Next the Bacteriophage releases an enzyme that weakens a spot in the cell wall of the host. Then the phage presses its sheath against the cell and injects its DNA into the host cell through the weak spot in the cell wall. The Bacteriophage leaves its capsid outside.
- The virus then takes control of the host's protein synthesizing mechanisms, transcribing mRNA from the viral DNA. The resulting Bacteriophage mRNA is translated on ribosomes and proteins that are synthesized form B a capsid. So the viral DNA is also replicated during this phase.
- Every replicated viral DNA is enclosed in the newly created viral capsid. The assembly of new virus particles usually occurs in the cytoplasm.
- During the last phase of the lytic cycle, one of the enzymes that are produced by the Bacteriophage genome causes the host cell to disintegrate, releasing new Bacteriophage. The cell disintegration is called lysis. In case of the enveloped viruses, the newly formed viruses move to the cell surface and force their way through the cell membrane.

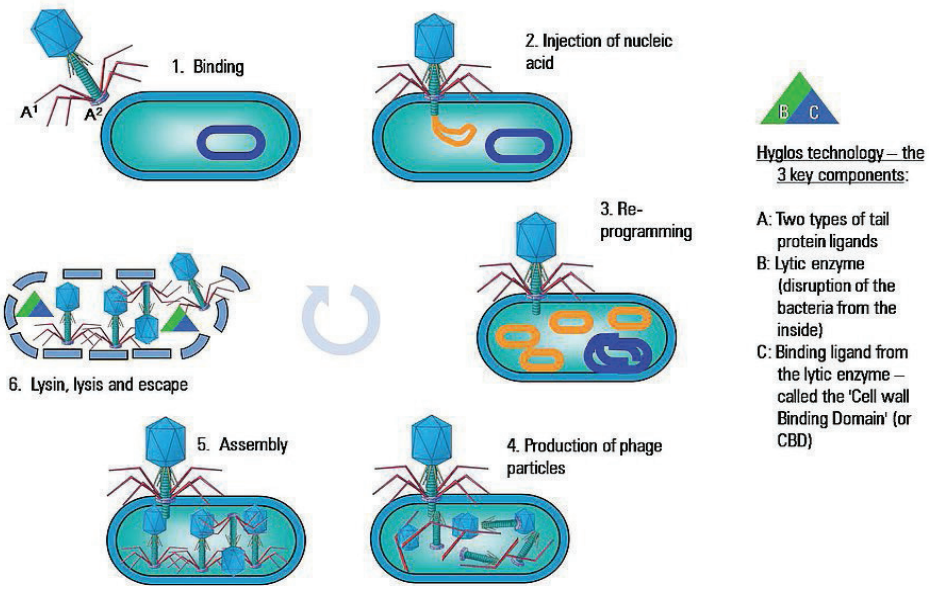


Figure 6.5: Lytic Cycle of a Bacteriophage

The **first step** in the replication of the phage in its host cell is called **adsorption** or binding. The bacteriophage adheres to the receptor site by means of its tail fibres. Following adsorption, the **phage injects its DNA** into the bacterial cell.

The tail sheath contracts and the nucleic acid or the core is driven through the wall to the membrane. This process is called **penetration** and it may be both mechanical and enzymatic.

Immediately after **injection** of the viral DNA there is **transcription** and translation of a section of the phage DNA to make a set of proteins that are needed to replicate the phage DNA and proteins that make up the capsid and the various components of the tail.

After making all viral parts, the **assembly** process follows. While the viruses are assembling, produced lysozymes are used to break down the cell wall peptidoglycans of the host bacteria. This is known as **lysis** and then mature viruses are released and spread to nearby cells for new infection.

b) The lysogenic cycle

Some viruses can infect a cell without causing its immediate destruction. Such viruses stay in their host cell for an extended period of time: days, months or years in a lysogenic cycle. A virus that replicates through lysogenic cycle and does not kill the host cell immediately is called a temperate virus.

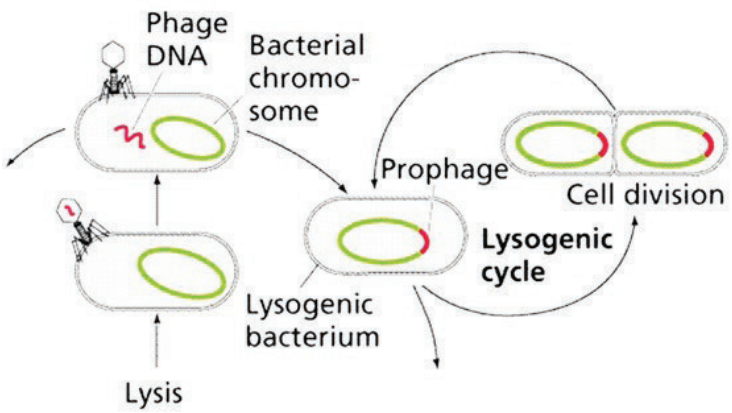


Figure 6.6. The lysogenic cycle

Retroviruses, such as **HIV, have RNA that is transcribed into DNA** by the viral **enzyme *Reverse transcriptase*** upon entry into the cell. (The ability of retroviruses to copy RNA into DNA earned them their name because this process is the reverse of the usual transfer of genetic information, from DNA to RNA). The DNA form of the retrovirus genome is then integrated into the cellular DNA and is referred to as the ***provirus***. The viral genome is replicated every time the host cell replicates its DNA and is thus passed on to daughter cells.

iv). Virus as living or non-living

Viruses do not belong to any of the five kingdoms into which life is classified. It is difficult to say whether they are living or non-living.

a) Features that make viruses to look like living things:

- They have the genetic material composed of either DNA or RNA They cause diseases to other living things: All viruses are infectious.
- They evolve as a result of mutation and natural selection.
- They reproduce /multiply only in other living things: they are obligate intracellular parasites

b) Features that make viruses non-living things:

- They cannot metabolize
- They crystallize in isolation.
- They cannot reproduce outside of host.
- They are not made of cells. This means that they have a relatively simple noncellular organisation.
- They cannot respond to stimuli
- They have one type of nucleic acid, either DNA or RNA. But living cells contain both DNA and RNA.

v). Some common viral diseases

Table 6.1: Some common viral diseases

Name of disease	Cause	Signs and symptoms
Influenza	Myxovirus (DNA virus)	Sudden fever with headache, sore throat and muscular aches.
Common cold	Large variety of viruses, most common are rhinovirus (RNA virus)	Nasal and bronchial irritation, resulting in sneezing and coughing. Usually affects upper respiratory passages.
Measles	A paramyxovirus (RNA virus)	Occurs mainly in children. Sore throat, runny nose, watery eyes, cough and fever.
Mumps	A paramyxovirus (RNA virus)	Occurs mainly in children. Fever, followed by swelling of the parotid (salivary) glands on one or both sides lasting about 10 days. Testes, ovaries and pancreas may be affected.

Mumps	A paramyxovirus (RNA virus)	Occurs mainly in children. Fever, followed by swelling of the parotid (salivary) glands on one or both sides lasting about 10 days. Testes, ovaries and pancreas may be affected.
Poliomyelitis (Polio)	Poliovirus (a picornavirus) (RNA virus)	Fever, headache and feeling of stiffness in neck and other muscles. Nerve cells and muscles are destroyed causing paralysis and muscle wasting. Most cases of paralysis occur in children aged 4 – 12 years, but adults may also be affected.
Yellow fever	An arbovirus, that is arthropod-borne virus (RNA virus)	Fever, headache, backache, nausea, tenderness in pit of stomach. Affects lining of blood vessels and liver.
AIDS	HIV virus; a retrovirus (RNA virus)	Loss of appetite, loss of weight, fevers, persistent dry cough, …

Application Activity 6.2

Read the scenario and answer the questions.

You are informed by a national surveillance officer about the detection of an infectious disease outbreak of unknown origin in a forested area that has caused the death of three people and left 14 seriously ill. Initial symptoms include sudden high fever, headache, backache, nausea, tenderness in pit of stomach. Most of those who died did so within 1-2 weeks of onset of symptoms. One patient who died tested positive for malaria. A team of infectious disease epidemiologists is currently in the field for investigation. Blood samples have been sent to the National Laboratory for confirmation but results are still pending. The country has experienced repeated outbreaks of viral hemorrhagic fevers.

a) Is the public health impact of the event serious?

b) Referring to signs and symptoms, suggest the infectious disease that is most likely affecting people.

c) Suggest preventive measures to avoid the spread of diseases in whole area.

6.3. Moulds and life cycle

Activity 6.3

Observe the figure showing the structure of bread mould to answer related questions:

a) Name the structure shown on the figure labelled a, b, c, d and e.
b) Outline the characteristics of mould.
c) Describe the life cycle of mould referring to the above figure.

Moulds pervade our world, living wherever moisture is present. Some are of great benefit to humans, providing antibiotics, acting as decomposers so that nutrients can be recycled, or taking part industrial processes. Other moulds cause diseases which lead to serious damage.

Moulds have cells arranged in long thread-like filaments, the hyphae, that form a mass called **Mycelium**. Moulds are usually considered as fungi, but mould may also be formed by filamentous bacteria, slime moulds, and water moulds. Therefore, there are two main types of moulds: fungal moulds and non-fungal moulds

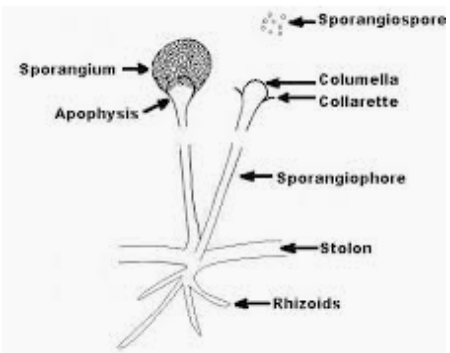


Figure 6.7: Bread mould

1. Fungal moulds

All fungi that produce mycelia can be called moulds, but the term is usually used for an organism in which the mycelium forms the main body of the fungus. In the black bread mould *Rhizopus* and the pin mould Mucor, the mycelium consists of a tangled mass of hyphae with many nuclei. These hyphae are called coenocytic because the fungal tissue is not separated by cell walls.

Fungal hyphae have an outer cell wall made of chitin and inner lumen which contains the cytoplasm and organelles. A cell surface membrane surrounds the cytoplasm and sticks tightly to the cell wall.

Rhizopus and *Mucor* are **Saprotrophic**, obtaining their nutrients from dead organic material. *Rhizopus nigricans* and *Mucor mucedo* can live on bread but some species of *Rhizopus* feed on living plants, and *Mucor* commonly grows on rotting fruits and vegetables, in the soil or on dung.

Rhizopus and Mucor secrete hydrolytic enzymes onto their food source and digest the food outside the organism and then absorb the soluble digestion products and assimilate them.

a) Life cycle of Rhizopus and Mucor.

Rhizopus and *Mucor* belong to the fungal phylum **Zygomycota**. The phylum got its name because its members produce two kinds of spores: Sexual **zygospores** as well asexual **sporangiospores.**

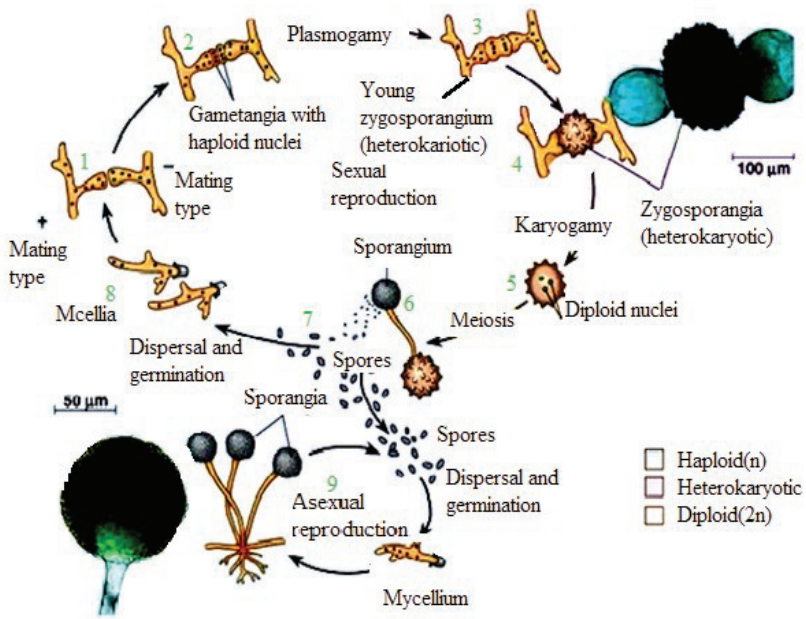


Figure 6.8. Life cycle of Rhizopus and Mucor

The asexual sporangiospores formed by mitosis, develop in **sporangium** at the tip of hyphae. When sporangium busts, the spores are released.

In most species of *Mucor*, the sporangium dissolves then water enters the spore mass, and the spores are dispersed by the raindrop or are transported by the insects. In most *Rhizopus* species, the sporangium wall fractures and dry spores are released by the wind.

The sexual reproduction involves **conjugation.** Usually the hyphae from mycelia of different mating types meet and interconnect via outgrowths. The interconnecting walls break down and their cytoplasm containing haploid nuclei mix, then the diploid zygote formed by the fusion of two nuclei develops a thick, rough, black coat and becomes a dormant zygospores. Meiosis probably occurs at the time of germination; the **zygospore** cracks open to liberate several haploids spores which can give rise to asexual sporangia and mycelia of either mating strain.

b) Use of moulds

Even if species of *Rhizopus* and *Mucor* are responsible for the spoilage of food, they are also useful as follow:

- They are used to make the human foods. For example, *Mucor* is used with soya beans to make a cheese called sufu.
- The fungal moulds belonging to the Zygomycota are used to make anaesthetics, birth control pills, meat tenderisers, and the yellow colouring agents used in margarines and butter substitutes.

2. Non-fungal moulds

The following are different groups of non-fungal moulds:

a) Bacterial moulds: including those of *Streptomyces griseous*, which secretes the antibiotic **streptomycin.**

Antibiotics are used to treat bacterial infections. Some are highly specialized and are only effective against certain bacteria. Others, known as broad-spectrum antibiotics, attack a wide range of bacteria, including ones that are beneficial to us. There are two main ways in which antibiotics target bacteria. They either **prevent the reproduction** of bacteria, or **they kill the bacteria,** for example by stopping the mechanism responsible for building their cell walls.

b) Slime moulds: These are a peculiar group of organisms that resemble fungi in appearance and lifestyle, but are more closely to protoctists such as Amoeba in their cellular organization, reproduction, and life cycles.

Application Activity 6.3

A culture of yeast, *Saccharomyces cervicea*, is present in the banana juice for 7 days at 30°C.The table below shows the change in number of yeasts within that time:

Time/days	1	2	3	4	5	6	7
N° of yeast	2	2	6	16	20	20	8

a) Draw a curve showing the growth of the yeast population.

b) What is the use of banana juice in that experiment?

c) State any two conditions that should be constantly maintained during the above experiment and why?

d) With reference to the curve, explain what happened between:

i). 1 and 2 days

ii). 3 and 4 days

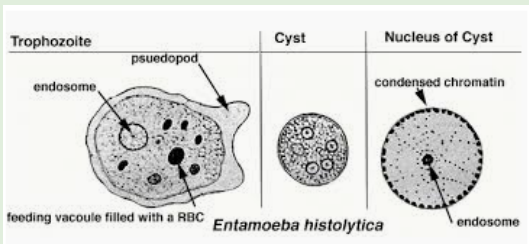
iii). 5 and 6 days

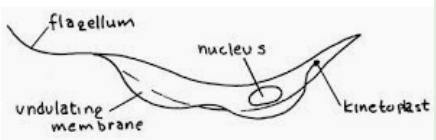
iv). 6 and 7 days

6.4. Protozoans and life cycle

Activity 6.4

Observe the following diagram of Entamoeba histolytica, Plasmodium and Trypanosoma, conduct a research on internet or library to answer the following questions.





plasmodium

Suggest the disease which is caused by each of the above protozoa.

a) Outline the common characteristics of protozoan.

b) Describe the life cycle of Entamoeba histolytica, Plasmodium and Trypanosoma.

c) Suggest preventive measures of diseases caused by the above parasite.

1. Entamoeba histolytica

a) Characteristics of Entamoeba histolytica

Entamoeba histolytica is a protozoan parasite responsible for a disease called **amoebiasis**. It occurs usually in the large intestine and causes internal inflammation as its name suggests (**histo** which means tissue, **lytic** which means destroying). 50 million people are infected worldwide, mostly in tropical countries in areas of poor sanitation. Inside humans Entamoeba histolytica lives and multiplies as Trophozoites. Trophozoites are oblong and about 15–20 µm in length. In order to infect other humans, they encyst and exit the body.

b) Life cycle *Entamoeba histolytica*

Entamoeba histolytica **life cycle** does not require any intermediate host. Mature cysts (spherical, 12–15 µm in diameter) are passed in the feces of an infected human. Another human can get infected by ingesting them in fecally contaminated water and food. If the cysts survive on the acidic stomach, they transform back into Trophozoites in the small intestine. Trophozoites migrate to the large intestine where they live and multiply by binary fission. Both cysts and Trophozoites are sometimes present in the feces. Cysts are usually found in firm stool, whereas Trophozoites are found in loose stool. Only cysts can survive longer periods (up too many weeks outside the host) and infect other humans. If trophozoites are ingested, they are killed by the gastric acid of the stomach. Occasionally Trophozoites might be transmitted during sexual intercourse.

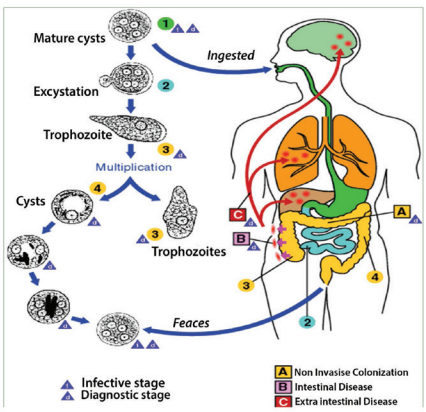


Figure 6.9. Life cycle Entamoeba histolytica

c) Symptoms

Many Entamoeba histolytica infections are asymptomatic and Trophozoites remain in the intestinal lumen feeding on surrounding nutrients. About 10–20 % of the infections develop into amoebiasis which causes 70 000 deaths each year. **Minor infections** (luminal amoebiasis) can cause **symptoms** that include:

- Gas (flatulence) intermittent
- constipation loose stools
- stomach ache
- Stomach cramping.

Severe infections inflame the mucosa of the large intestine causing amoebic dysentery. The parasites can also penetrate the intestinal wall and travel to organs such as the liver via bloodstream causing extra-intestinal amoebiasis. **Symptoms** of these more **severe infections** include: Anemia, Appendicitis (inflammation of the appendix), bloody diarrhea, fatigue, fever, gas (flatulence), genital and skin lesions, intermittent constipation, liver abscesses (can lead to death, if not treated), malnutrition, painful defecation (passage of the stool), peritonitis (inflammation of the peritoneum which is the thin membrane that lines the abdominal wall), pleurapulmonary abscesses, stomach ache, stomach cramping, toxic mega-colon (dilated colon), Weight loss.

d) Prevention

To prevent spreading the infection to others, one should take care of personal hygiene. Always wash your hands with soap and water after using the toilet and before eating or preparing food. Amoebiasis is common in developing countries. Some good practices, when visiting areas of poor sanitation:

- Wash your hands often.
- Avoid eating raw food.
- Avoid eating raw vegetables or fruit that you did not wash and peel.
- Avoid consuming milk or other dairy products that have not been pasteurized.
- Drink only bottled or boiled water or carbonated (bubbly) drinks in cans or bottles.

Natural water can be made safe by filtering it through an “absolute 1 micron or less” filter and dissolving iodine tablets in the filtered water.

e) Methods of diagnosis

Amoebiasis is **diagnosed** by your health care provider under a microscope by finding cysts and (rarely Trophozoites) from a stool sample. The results are usually said to be negative, if *Entamoeba histolytica* is not found in three different stool samples. But it still does not necessarily mean that you are not

infected because the microscopic parasite is hard to find and it might not be present the particular samples. A blood test might also be available but is only recommended, if your health care provider believes that the infection could have spread to other parts of the body. Trophozoites can be identified under a microscope from biopsy samples taken during colonoscopy or surgery.

2. Plasmodium species

a) Characteristics:

- *Plasmodium* is the genus of the class of Sporozoa that includes the parasite that causes malaria. *Plasmodium* is a type of protozoa, a single-celled organism that is able to divide only within a host cell.
- The main types of *Plasmodium spp* are *P.falciparum*, the species that causes falciparum malaria, the most dangerous type of malaria; *P. malariae,* the species that causes quartan malaria; *P. ovale*, a species found primarily in east and central Africa that causes ovale malaria; and *P. vivax*, the species that causes vivax malaria, which tends to be milder than falciparum malaria.

b) Life cycle of *Plasmodium*

Plasmodium species exhibit three life-cycle stages **gametocytes, sporozoites**, and **merozoites**.

Gametocytes within a mosquito develop into sporozoites. The sporozoites are transmitted via the saliva of a feeding mosquito to the human blood stream. From there, they enter liver parenchyma cells, where they divide and form merozoites. Inside the host's liver cell, the *Plasmodium* cell undergoes asexual replication. The products of this replication, called merozoites, are released into the circulatory system. The merozoites invade erythrocytes and become enlarged ring-shaped Trophozoites.

More erythrocytes are invaded, and the cycle is reinitiated. The merozoites are released into the bloodstream and infect red blood cells. Rapid division of the merozoites results in the destruction of the red blood cells, and the newly multiplied merozoites then infect new red blood cells. Some merozoites may develop into gametocytes, which can be ingested by a feeding mosquito, starting the life cycle over again.

The red blood cells destroyed by the merozoites liberate toxins that cause the periodic chill-and-fever cycles that are the typical symptoms of malaria. *P. vivax*, *P. ovale*, and *P. falciparum* repeat this chill-fever cycle every 48 hours (tertian malaria), and P. malariae repeats it every 72 hours (quartan malaria). P. *knowlesi* has a 24-hour life cycle and thus can cause daily spikes in fever.

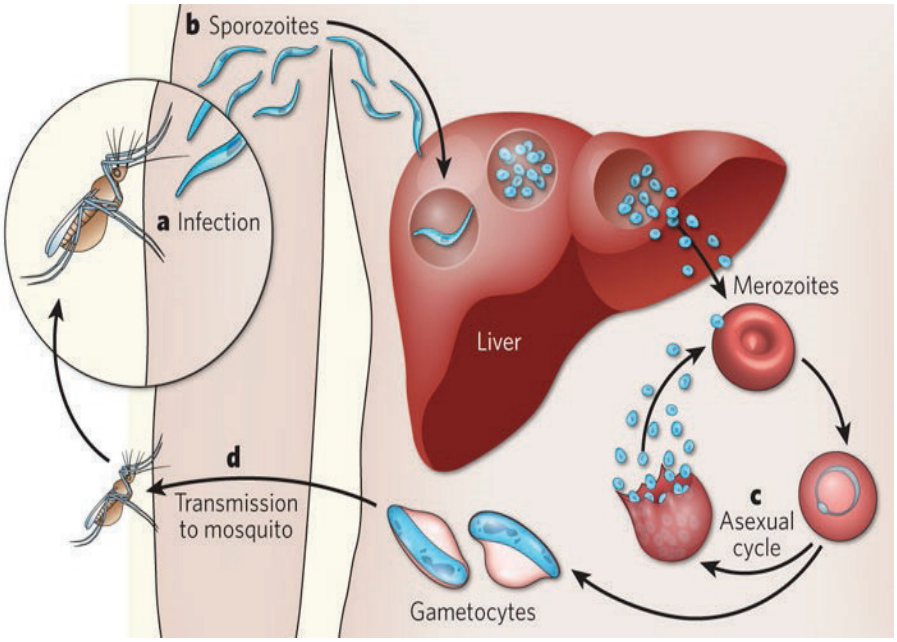


Figure 6.10: Cycle of Plasmodium.

c) Occurrence of malaria

The disease now occurs in tropical and subtropical regions of the world, and its distribution is limited by conditions that are inimical to the development of the mosquito vector, such as temperature and altitude.

Malaria is **endemic** in tropics because:

- Tropical climate provides the best breeding and living conditions for the Anopheles mosquito which transmits malaria
- The Anopheles cycle requires areas of stagnant water and these are common within tropics
- In the tropical areas there is presence of bushes or abundant vegetation which makes suitable habitat for mosquitoes
- Plasmodium needs temperature in excess of 20°C for it to complete its cycle within the mosquito.

d) Treatment and prevention of malaria

To prevent the infection, people should:

- use insecticides that kill the vectors(mosquito)
- clean bushes nearest their homes where mosquitoes lay eggs
- avoid stagnant water where mosquitoes lay eggs
- sleep under net to avoid the bite of mosquitoes during the night

- Control birth that leads to population growth and this contributes to disease spread.

e) Failure to eradicate malaria

- There is no effective vaccine against malaria
- The pathogens are transmitted by mosquitoes which are not eradicated.
- The Plasmodia have become resistant to different anti-malarial drugs
- Ignorance of some people toward the disease and how it is spread.

3. Trypanosoma species(spp)

a) Characteristics

- *Trypanosoma* is the genus containing a large number of parasitic species which infect wild and domesticated animals and humans in Africa.
- Commonly known as African sleeping sickness, human trypanosomiasis is caused by the species *Trypanosoma brucei* and is transmitted to humans through either a vector or the blood of ingested animals.
- The most common vector of *Trypanosoma brucei* is the tsetse fly, which may spread the parasite to humans and animals through bites.
- Through a process called antigenic variation, some trypanosomes are able to evade the host's immune system by modifying their surface membrane, essentially multiplying with every surface change. *Trypanosoma brucei* gradually infiltrates the host's central nervous system.

b) Symptoms

Symptoms include: Headache, weakness, and joint pain in the initial stages; anaemia, cardiovascular problems, and kidney disorders as the disease progresses; in its final stages, the disease may lead to extreme exhaustion and fatigue during the day, insomnia at night, coma, and ultimately death.

c) Occurrence

Human trypanosomiasis affects as many as 66 million people in sub-Saharan Africa. Trypanosomes are also found in the Americas in the form of *Trypanosoma cruzi,* which causes American human trypanosomiasis, or Chagas' disease. This disease is found in humans in two forms: as an amastigote in the cells, and as a **trymastigote** in the blood.

d) Mode of transmission

- The vectors for *Trypanosoma* cruzi include members of the order Hemiptera, such as assassin flies, which ingest the amastigote or trymastigote and carry them to animals or humans.

- The parasites enter the human host through mucus membranes in the nose, eye, or mouth upon release from the insect vectors. Left untreated, Chagas' disease may cause dementia, megacolon, and megaesophagus, and damage to the heart muscle, and may result in death.

e) Life cycle of Trypanosoma

Trypanosoma's cell structure plays a vital role in allowing the cell to morph into three forms (trypomastigote, epimastigote, and amastigote) during its life cycle, depending on where the cell is located in the host's anatomy. The location of the kinetoplast in relation to the nucleus and the flagellum emergence dictate in which stage the trypanosome cell is found.

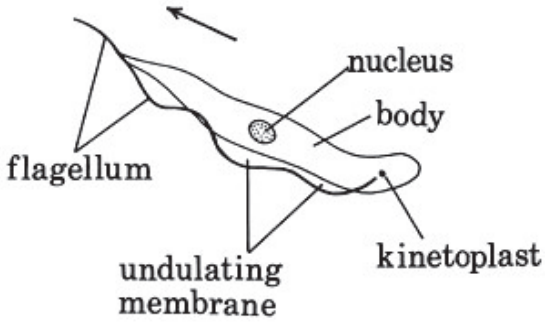


Figure 6.11: Cell Structure of Trypanosoma

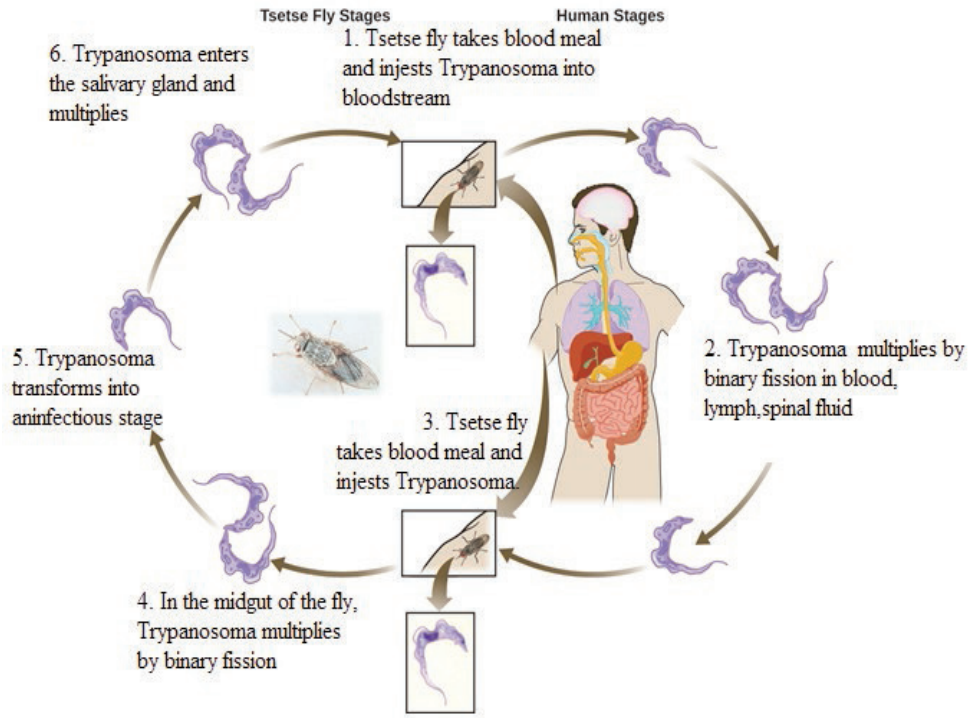


Figure 6.12: Life cycle of Trypanosoma

Application Activity 6.4

Read the scenario and answer related questions.

Mr. Kabo lives in one of the sector around Kigali city. He prepares and sells chapattis on street. He is usually very clean, but one morning, he was late for the work and he did not wash his hands after visiting the toilet. That day he prepared 400 chapattis all of which are sold. Few hours later, his customer Sandra suffered from a disease with the following signs and symptoms: constipation loose stools, stomach ache, Stomach cramping. Gas (flatulence) intermittent, later Anemia, Appendicitis (inflammation of the appendix), bloody diarrhea, fatigue, fever, gas (flatulence), genital and skin lesions, intermittent constipation, liver abscesses (can lead to death, if not treated), malnutrition, painful defecation (passage of the stool). Later, all his customers were rushed and admitted in hospital due to the same problem.

a) Suggest the disease that Mr. Kabo's customers were suffering from and what caused the disease?

b) Name three other ways this disease might be spread around city.

c) c. After reading this scenario, what message do you have for people who are like Mr. Kabo?

d) Suppose you were the health officer for the area in sector with such a problem. What steps would you take to prevent the disease from spreading further?

e) House flies are described as vectors. Describe how houseflies transmit diseases to humans.

6.5. Eubacteria and life cycle

Bacteria have a peptidoglycan or **murein** cell wall that maintains cell shape, provides protection and prevents the cell from lysis. Based on the composition of the cell wall, bacteria can be classified as **Gram-positive** and **Gram-negative**. During the process of Gram staining t, some bacteria without a lipid layer along with their peptidoglycan cell wall take the gram stain and appear **violet** (purple) and are therefore called **gram positive.** Example: streptococcus and staphylococcus. Bacteria having a lipid layer along with their peptidoglycan cell wall do not take up the gram stain and are therefore called **gram negative**.

Example: *Escherichia coli*, Azotobacter, Salmonella.

Activity 6.5

A student left fresh milk in a cup exposed to the air. After 6 hours, he/she found that milk changed its state from fresh milk to stale milk. Why do you think this happened?

Martin prepared food for dinner. Some of the food was immediately put in tightly covered flask while the remaining food was left in the saucepan covered with banana leaves. In the evening, food in the flask was warm and safe while food in the saucepan has deteriorated.

1. What is the cause of the food spoilage in the saucepan?
2. What practice do you frequently observe at your home kitchen which cause the food spoilage?
3. What advice can you provide?

i). The structure and life cycle of Escherichia coli

E. coli reproduce asexually by undergoing binary fission. This type of reproduction begins with the replication of DNA molecule. Then, the copies of the genetic material attach themselves to the cell membrane. When the bacterium's size has doubled from its original size, the cell membrane starts pinching inward and a cell wall is produced between the two DNA molecules. Finally, the cell wall divides the cell into two daughter cells.

E. coli can also go through another process of reproduction known as conjugation. Conjugation is a reproduction process which involves the transfer of genetic material by the sex pili between two bacteria. This is not a sexual reproduction because there is no combination of gametes. The process of conjugation starts once the *E. coli, called a donor*, has finished replicating its genetic material in form of a plasmid. The enzyme of the donor can now send signals to show that it is ready to mate. Once a mate is found, the donor attaches itself to the sex pilus of its mate. By doing so, the donor transfers the plasmid.

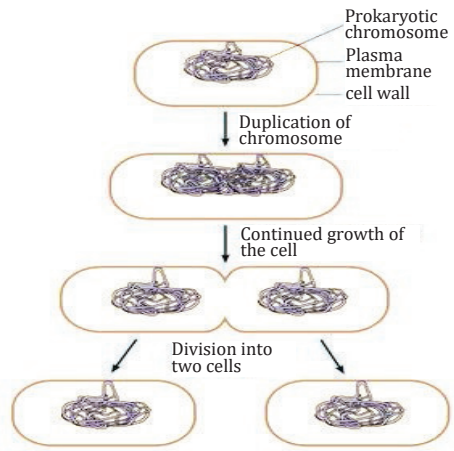


Figure 6.13:Binary fission in E. coli

ii). E. coli and food poisoning

E. coli is a rod-shaped bacterium measuring about 2.5µm by 0.5µm. It is mainly found in guts of vertebrates. It is chemoheterotrophic, capable of thriving on a variety of the organic molecules. Its presence in water indicates contamination by faeces. *E. coli* reproduces asexually by binary fission. It can also take part in a primitive form of sexual Activity called conjugation where genetic material is passed in one direction from bacterium to another through a pilus. Although conjugation does not in itself produce new offspring, after the process has finished, the bacteria reproduce asexually, passing on their new genetic make-up to their offspring.

iii). Evolution of harmful strain of bacteria

E. coli was thought to be a relatively harmless resident of the human gut which might link to the occasional upset stomach and mild diarrhoea. When massive colonies of mutualistic bacteria are present in the gut, including most strains of *E. coli,* they help to keep harmful bacteria away from starving them of food. They also help make vitamin K. But in 1982, it became clear that a new strain of E. coli had evolved into a much more troublesome organism. The strain had acquired a gene that enabled it to produce a powerful toxin which damages the intestinal wall, causing severe diarrhoea and internal bleeding.

This may lead to internal serious dehydration in young children and elderly people, and may result into death. In majority of the cases, infections of pathogenic strain of *E. coli* are not fatal and the disease clears without treatment.

iv). Sources of infection

Touching a source of contamination and not washing hands before handling food may be sufficient to cause the infection.

In 1996, there was an outbreak which led to 20 deaths in Scotland due to contaminated meat. In the same period, another one was traced due to apple juice poisoning. Contaminated person can pass the bacteria on vegetables, and other foods. We must practice good habits of dealing and handling food to minimise cases of contamination. It is therefore, important to practice good hygiene. It is also essential to store and package food. It might be vital to pasteurise all fresh fruit juices just as milk is required to be pasteurised.

v) Food storage and packaging

The optimum storage conditions differ; raw meat and poultry are kept at around 0^0c, meat products at 1^oc - 40^oc. Canned foods and many vegetables in dry conditions at 10^oc - 150^oc, and dried foods such as flour are stored, in air tight containers at10^oc – 150^oc. For long term storage, meat and fish are vacuum-sealed or can be vacuum packed in laminated plastic containers. For pasteurisation, food and drinks such as milk are heated to a temperature that kills disease causing microorganisms. Example: *Mycobacterium tuberculosis*.

Application Activity 6.5

The ministry of health reports that 16 cases, including 4 deaths, of suspected food poisoning had been detected during the last week. The clinical picture compatible with food poisoning was characterized by abdominal pain, nausea, vomiting, headache and blurred vision, with a history of eating in a poorly hygienic locally restaurant. The food of locally restaurant in question had been sampled and sent for testing to the toxicological and microbiology centre. While the toxicological and microbiology forensic analysis is pending and the investigation is still ongoing, public health authorities have started to stop the suspicious restaurant, strengthen surveillance of the event and to run public awareness campaigns on the risk.

a) Does the event have a serious impact on the public health? Justify your answer.
b) What do you think is the main cause of the situation?
c) Provide the advice to the people who are at risk?

6.6. Algae

Activity 6.6

Rural people fetch water using plastic materials (Jerricans) and store it in. Sometimes they look green inside if used for longtime.

a) What cause plastic to look green inside?
b) What advice can you give people to prevent this to be developed in swimming pool?

Algae are eukaryotic organisms that have no roots, stems, or leaves but do have chlorophyll and other pigments for carrying out photosynthesis. Algae can be multicellular or unicellular.

Unicellular algae occur most frequently in water, especially in plankton. **Phytoplankton** is the population of free-floating microorganisms composed primarily of unicellular algae. In addition, algae may occur in moist soil or on the surface of moist rocks and wood. Algae live with fungi in **lichens.**

According to the Whittaker scheme, algae are classified in seven divisions, of which five are considered to be in the Protista kingdom and two in the Plantae kingdom. The cell of an alga has eukaryotic properties, and some species have flagella with the "9-plus-2" pattern of microtubules. A nucleus is present, and multiple chromosomes are observed in mitosis. The chlorophyll

and other pigments occur in **chloroplasts**, which contain membranes known as **thylakoids.**

Most algae are **photoautotrophic** and carry on photosynthesis. Some forms, however, are **chemoheterotrophic** and obtain energy from chemical reactions and nutrients from preformed organic matter. Most species are saprobes, and some are parasites.

Reproduction in algae occurs in both asexual and sexual forms. Asexual reproduction occurs through the fragmentation of colonial and filamentous algae or by spore formation (as in fungi). Spore formation takes place by mitosis. Binary fission also takes place (as in bacteria).

During sexual reproduction, algae form differentiated sex cells that fuse to produce a diploid **zygote** with two sets of chromosomes. The zygote develops into a sexual spore, which germinates when conditions are favorable to reproduce and reform the haploid organism having a single set of chromosomes. This pattern of reproduction is called **alternation of generations**

Application Activity 6.6

"Algae production is strongly connected to regional weather conditions, but also to the infrastructure for resource supply and to the processing of biomass" Explain how algae is indicator of water pollution.

6.7. Application of microorganisms

Activity 6.7

Government of Rwanda sensitizes farmers to fertilizers such as natural fertilizers and industrial fertilizers. Natural fertilizer is frequently prepared using composting method.

a) What are the components of compost in decomposing?

b) Describe the role of each component mentioned in (a) in preparing quality organic manure**.**

Although the role of microorganisms in the transformation of organic matter was only discovered in the middle of the 19th century, their processes have been used by man since pre-historic times for the production of foods and drinks.

6.7.1. Food conservation

A variety of methods can be used to preserve food during storage thus preventing spoilage. The various methods are based on four biological principles: (i) inhibiting the multiplication of microorganisms already in the food, (ii) killing of the microorganisms already in the food, (iii) preventing microbial contamination of food during storage (iv) inhibiting the action of enzymes naturally present in the food which cause autolysis (self-digestion). The methods used for the preservation of foods are as follows:

a) Drying

Drying has been used for preserving food for many centuries and is still the most widely used method today. It is used for the preservation of grains, beans, peas, meat, vegetables, milk and fruits. Since microorganisms require moisture for their growth, drying makes food unsuitable medium for their growth. In addition, drying prevents the activities of enzymes that are naturally present in foods and those produced by microorganisms.

b) Salting and addition of sugar

Salting kills or inhibits the growth of microorganisms by drawing water from them osmotically (i.e plasmolysis). Salting is used for the preservation of a wide variety of foods especially meat and fish. In practice, the food is immersed in a strong salt (sodium chloride) solution or the salt is injected into it. Alternatively, the salt is sprinkled over the surface of the food. Salting is often together with drying or freezing.

The same principle is used for the preservation of sugary foods such as jam, fruits in syrup and sweetened condensed milk. The high sugar content kills or inhibits the growth of microorganisms by plasmolysing them.

c) Preservatives

A number of chemical preservatives are applied to foods to prevent microbial spoilage. In high concentrations, such chemicals will kill microorganisms but may also harm the consumers. For this reason, they are applied in low concentrations which will only inhibit microbial growth. The most commonly used chemical preservatives are sulphur dioxide, benzoic acid, scorbic acid, acetic acid as well as nitrates and nitrites.

6.7.2. Fermentation

Fermentation is anaerobic breakdown of organic compounds by living cells (microorganisms) that produces ethanol and carbon dioxide or lactate (lactic acid). It occurs in yeast and bacteria, but also in oxygen-starved muscle cells, as in the case of lactic acid. Fermentation is also used more broadly to refer to the bulk growth of microorganisms on a growth medium, often with the goal of producing a specific chemical product. French microbiologist Louis Pasteur

is often remembered for his insights into fermentation and its microbial causes. The science of fermentation is known as zymology. To many people, fermentation simply means the production of alcohol: grains and fruits are fermented to produce beer and wine. If a food soured, one might say it was 'off' or fermented. Fermentation react NADH with an endogenous, organic electron acceptor. Usually this is pyruvate formed from the sugar during the glycolysis step. During fermentation, pyruvate is metabolized to various compounds through several processes:

1. Ethanol fermentation, alcoholic fermentation, is the production of ethanol and carbon dioxide.
2. Lactic acid fermentation refers to two means of producing lactic acid: **Homolactic fermentation** is the production of lactic acid exclusively. **Heterolactic fermentation** is the production of lactic acid as well as other acids and alcohols.

Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, Carbon dioxide, and hydrogen gas (H_2). However, more exotic compounds can be produced by fermentation, such as butyric acid and acetone. Yeast carries out fermentation in the production of ethanol in beers, wines, and other alcoholic drinks, along with the production of large quantities of Carbon dioxide. Fermentation occurs in mammalian muscle during periods of intense exercise where oxygen supply becomes limited, resulting in the creation of lactic acid.

Although anaerobic respiration supplies only little energy to respiring cells, it has some large scale or industrial application useful to human beings.

Fermentation is used in:

a) 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.

b) Biogas production

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter (methanogens or archaebacterial) in the absence of oxygen. Biogas is produced by anaerobic fermentation of organic wastes such as agricultural waste, manure, municipal waste, plant material, sewage, green waste, or food waste. It is a renewable energy source and in many cases exerts a very small carbon footprint.

Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy released allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking.

It can also be used in a gas engine to convert the energy in the gas into electricity and heat. Biogas can be compressed, the same way the natural gas is compressed to compressed natural gas (CNG), and used to power motor vehicles. In the UK, for example, biogas is estimated to have the potential to replace around 17% of vehicle fuel. It qualifies for renewable energy subsidies in some parts of the world. Biogas can be cleaned and upgraded to natural gas standards, when it becomes biomethane.

The production of biogas involves three stages and three communities of microorganisms namely

i). **Anaerobic fermentation** by eubacteria including lactobacillus, which converts the organic waste into a mixture of organic acids and alcohol, with some Hydrogen, Carbon dioxide, and acetate.

ii). **Acetogenic (acetate-producing) reaction** by bacteria such as acetobacterium which, in addition to acetate, produce hydrogen and Carbon dioxide from the organic acid and alcohol.

iii). **Methanogenic (methane-producing) reactions** by archaebacteria, including Methanobacterium, Metanococcus, and Methanospirillum. The archaebacteria generate methane either:

By reducing the carbon dioxide: $CO_2 + 4H_2 \rightarrow CH_4 + H_2O$, or – By converting acetate: $CH_3COOH \rightarrow CH_4 + CO_2$.

c) 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.

6.7.3. Water purification

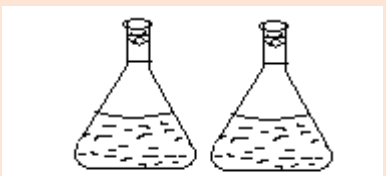
Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids, and gases from **water**. The goal is to produce **water** fit for specific purposes.

Before being discharged into the rivers and lakes, waste waters must be purified. One of the systems used for this purpose is activated-sludge purification. This process utilizes the water self-purification principle, in which the micro-organisms (bacteria, protozoa and metazoa) use the organic substances

contained in the water, transform them and remove them from the water. The aerobic process is the most commonly used one, i.e. oxygen is supplied to trigger the biological processes in which the organic substances are oxidized. When this reaction is over, water is purified and flakes of biological material known as "activated sludge" are produced. This activated sludge consists of organic and inorganic components and different species of microorganisms (especially bacteria). Ciliated protozoa play a very important role in the purification process. There is competition for food in the oxidization tanks, i.e. the place in which purification takes place: bacteria are eaten by small predators (ciliated protozoa), which in their turn are eaten by larger organisms (carnivore protozoa or metazoan). So, bacteria need nutrients which consist of organic matter contained in the waste water. The presence of ciliated protozoa in the activated sludge proves therefore that there are bacteria.

Application Activity 6.7

1. Yeast releases digestive enzymes which allow the transformation of glucose into ethanol as result of anaerobic fermentation. The presence of bubbles is the evidence that CO_2 is released as waste product of the alcoholic fermentation.
   - Boil a mixture of 200 mg of table sugar and 1 L of water in a conical flask
   - Cool the mixture and on it add 1 g of baker's yeast or 10 ml of local banana beer. Then filter the mixture and cover the flask with cotton wool.
   - Leave the filtrate for five days and then taste it.



Alcoholic fermentation

   a) Suggest the way of controlling fermentation process.
   b) Write down your observation and a chemical equation for the reaction which takes place.

3. Visit local area site of biogas production and local industrial businesses that apply biotechnology to produce medicine or genetically-modified crops.
   i). Explain how anaerobic respiration produces alcohol during the fermentation process.

ii). Describe how biotechnology is applied in the production of ethanol, cheese, yogurt, antibiotics, breads and biogas.

iii). Is it possible to apply biotechnology in Rwanda? State the reasons for your answer clearly.

Skills Lab 6

Your parent plans to run a micro plant industry producing beer from bananas. Draw the machinery installation of the process and show where the fermentation will take place and why. Advise him for the cost effectiveness of his production.

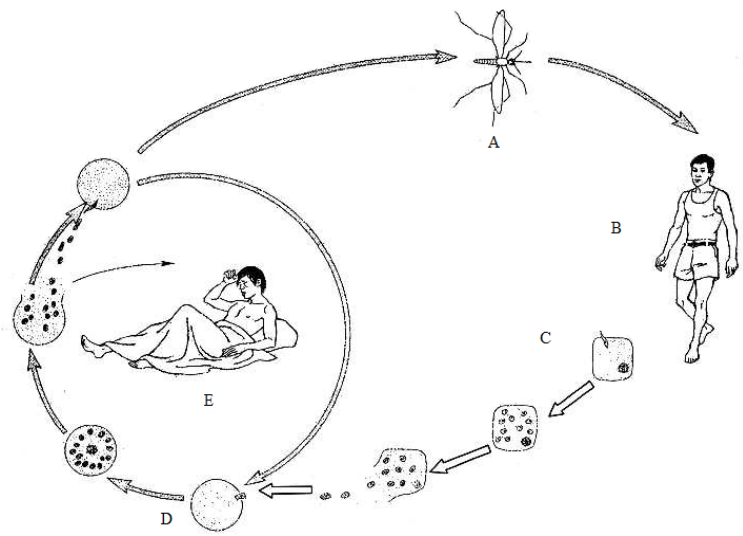
END UNIT ASSESSMENT 6

1. Match the elements of column A and B in each case.

A	B
Gram-positive bacteria	Stain red or pink
Gram-negative bacteria	Stain blue or purple

2. State any TWO diseases caused by:
   a) Bacteria
   b) Protozoa
   c) Microscopic fungi
3. What is the main feature of moulds?
4. Why viruses are not generally considered to be living things?
5. Discuss why viruses are thought to be very dangerous to our lives than bacteria

6. The diagram below show the life cycle of plasmodium. Analyse it and then answer the questions that follow.



a) What is the vector of malaria?

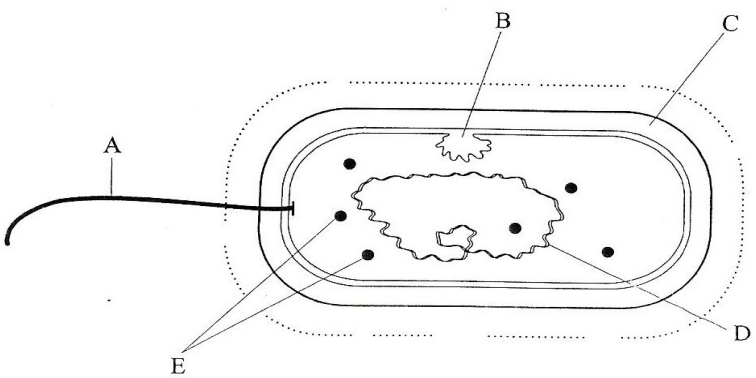
b) Between stages C and D, which one takes place in the red blood cells and which one takes place in the hepatic cell (liver)?

c) State any two symptoms of malaria displayed in individual in stage E.

7. a). What does the germ theory of disease mean?

b). State any four causes of diseases in our life.

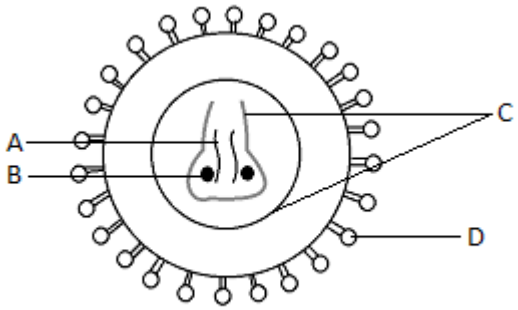
8. The figure below shows the structure of a bacterial cell seen using an electron microscope.



a) Name the parts labelled A, B, C and D

b) Describe the roles of parts labelled B, C and E

9. The diagram below represents the structure of the human immunodeficiency virus (HIV/AIDS).



HIV / AIDS

a) Name the parts A, B, C, and D.

b) HIV/AIDS is under *retroviruses*. What is meant by retroviruses?

c) What type of leucocytes (white blood cells) are destroyed by HIV/AIDS?

10. Discuss the methods of reducing the risk of food poisoning by pathogenic bacteria.

UNIT 7

INTRODUCTION TO ORGANIC COMPOUNDS

Key Unit competence: Apply IUPAC rules to name organic compounds and explain the types of isomers for organic compounds.

Introductory Activity 7

1. The human being uses energy in different forms and from different sources. Give the names of the compounds which are used as fuel.
2. Have you ever observed petroleum, alcohol, and vinegar mixed with water? If yes, how each of them behaves when mixed with water? If no, now take a small quantity of petroleum, alcohol, and vinegar and pour each of it differently in a half-filled flask of water. Explain your observations and why those substances behave differently in water.

7.1. Classification of organic compounds as aliphatic

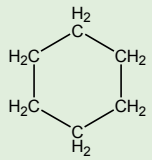
Activity 7.1

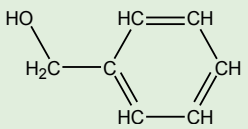
Observe the following compounds and based on the structure of the chain of each compound, attempt to classify them.

1. CH_3-CH_2-CH_2-CH_2-CH_2-CH_3

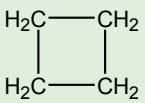
2. CH_3-CH_2-C≡C-CH_2CH_3

3. $CH_3CH_2CH_2OH$

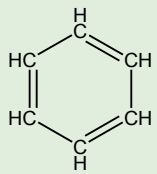
4. 

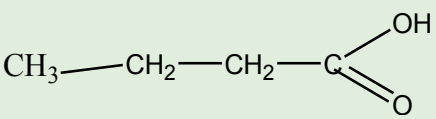
5. 

6. CH_3-CH_2-CH=CH_2

7. 

8. $CH_3CH_2CHCH_2CH_2CHCH_3$ (with CH_3 branches)

9. 

10. 

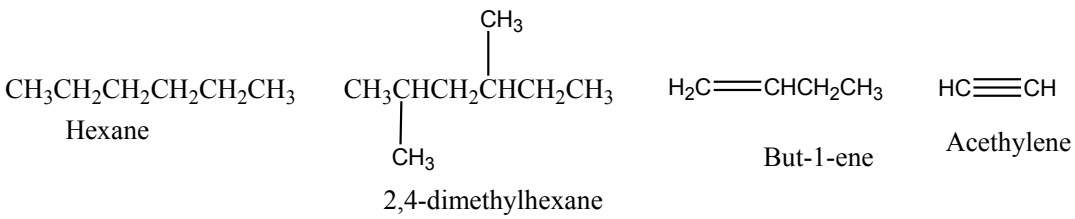
Organic chemistry is the chemistry of carbon compounds except carbonates $CaCO_3$, Na_2CO_3..., oxides CO_2 and CO and cyanides as HCN, KCN.... Carbon forms a vast number of compounds because it can form strong covalent bonds with itself. This enables it to form long chains (up to 5000 in length) of carbon atoms, and hence an almost infinite variety of carbon compounds are known.

All organic compounds contain carbon. Most contain hydrogen. Carbon always forms four covalent bonds and hydrogen one.

Aliphatic compounds

Aliphatic Compounds are the large class of organic molecules consisting essentially of straight or branched chains of carbon atoms. Aliphatic compounds include the alkanes, alkenes, and alkynes and their derivatives, alcohols, ketones, carboxylic acids, ...

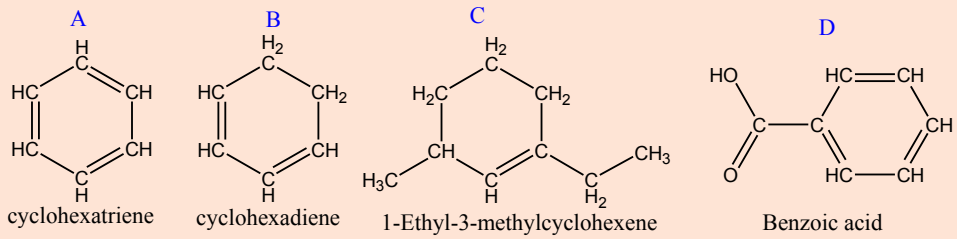
Examples of aliphatic compounds



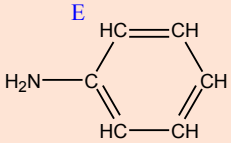
CH_3-CHOH-CO- CH_2-COOH

Application Activity 7.1

Which of the following organic compounds are aliphatic, alicyclic or aromatic?

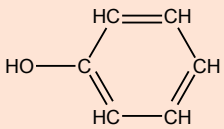


E



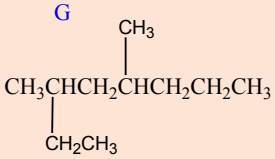
Aniline

F



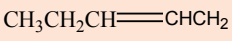
Phenol

G



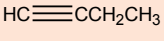
2-Ethyl-4-methylheptane

H



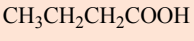
Pent-2-ene

J



But-1-yne

K



Butanoic acid

7.2. Types of formulae for organic compounds

Activity 7.2

Match the compound in column A with its corresponding compound in column B in terms of similarities and ratio of atoms

Column A	Column B
1. C_2H_5	A. $C_6H_{12}O_6$
2. CH_2O	B. C_6H_6
3. CH	C. C_6H_{12}
4. C_3H_6	D. C_4H_{10}
	E. C_3H_8

7.2.1. Empirical formula

An **empirical formula** is the simplest whole number ratio of the atoms in a compound as found by experiment i.e. chemical analysis. It gives no structural information and may or may not be the same as the molecular formula e.g. CH_4 is both the empirical formula and the molecular formula of methane. However, the molecular formula of the butane molecule is C_4H_{10} but its empirical formula is C_2H_5. The molecular formula of a glucose sugar molecule is $C_6H_{12}O_6$ but its empirical formula is only CH_2O

Empirical formula is calculated from the percentage composition.

The steps are :

i). The percentage of each element is divided by its atomic weight.

ii). The result in i. above is now then divided by the smallest one among them to give the atomic ratio.

iii). If the atomic ratios obtained in ii. are not the whole number, they should be multiplied by a suitable common factor to convert each of them to the whole numbers (or approximatively equal to the whole numbers). Minor fractions are ignored by rounding up or down (ex: 7.95 = 8).

Example

A certain organic compound has 39.13% by mass carbon, 52.23% oxygen and the rest of hydrogen. Calculate the empirical formula of the compound.

Answer:

Elements	C	H	O
% composition	39.13	8.64	52.23
Relative Ratio of atoms,molecules	$\frac{39.13}{12} = 3.26$	$\frac{8.64}{1} = 8.64$	$\frac{52.23}{16} = 3.26$
Smallest ratio	$\frac{3.26}{3.26} = 1$	$\frac{8.64}{3.26} = 2.65$	$\frac{3.26}{3.26} = 1$
Whole number ratio and Empirical formula $C_3H_8O_3$	3	7.95=8	3

Note: 2.65 can not be corrected to 3 so we multiply those atomic ratios with 3 equals to 7.95 which is rounded to 8.

7.2.2. Molecular formula

The **molecular formula** is a chemical formula that gives total number of atoms of each element in each molecule of a substance.

e.g. if **n = 5** for the number of carbon atoms in the molecular formula you get

- alkanes of molecular formula $\mathbf{C_5H_{12}}$
- alkenes/cycloalkanes of formula $\mathbf{C_5H_{10}}$
- alcohols/ethers of formula $\mathbf{C_5H_{12}O}$ and amines of formula $\mathbf{C_5H_{13}N}$

This is a formula expressing the true number of atoms of various elements present in a molecule .

Molecular formula = Empirical formula × n ,where $n = \frac{\text{Molecular weight}}{\text{Empirical weight}}$

when n=1, then the molecular formula is the same as the empirical formulae

Examples

1. An organic compound that contains 31.9% by mass carbon, 6.8% hydrogen and 18.51% nitrogen the rest being oxygen has a vapour density of 37.5. Calculate the molecular formula of the compound.

Answer

Elements	C	H	O	N
% composition	31.9	6.8	42.79	18.51
Relative Ratio of atoms,molecules	$\frac{31.9}{12}=2.568$	$\frac{6.8}{1}=6.8$	$\frac{42.79}{16}=2.674$	$\frac{18.51}{14}$=1.322
Atomic ratio	$\frac{2.658}{1.322}=2.01=2$	$\frac{6.8}{1.322}=5.14=5$	$\frac{6.674}{1.322}$=2.02=2	$\frac{1.322}{1.322}=1$

Empirical formula , $C_2H_5NO_2$

Vapour density =½ molecular weight

Therefore, molecular weight = 2× vapour density= 2×37.5= 75gr/mol

$$n=\frac{molecularweight}{empiricalweight}\Rightarrow n=\frac{75}{75}\Rightarrow n=1$$

Hence molecular formula=empirical formula= $C_2H_5NO_2$

2. 0.45g of organic acid on combustion gave 0.44g of carbon dioxide and 0.09g of water.If the molecular weight of the acid is 90, deduce the molecular formula.

Answer:

Percentage of carbon in CO_2 : $\frac{12}{44}\times\frac{0.44}{0.45}\times100=26.66\%$

Percentage of hydrogen in H_2O: $\frac{2}{18}\times\frac{0.09}{0.45}\times100=2.22\%$

Percentage of oxygen = 100-26.66-2.22=71.12%

Elements	C	H	O
% composition	26.66	2.22	71.12
Atomic Ratio	$\frac{26.66}{12}=2.22$	$\frac{2.22}{1}=2.22$	$\frac{71.12}{16}=4.44$
Smallest ratio	$\frac{2.22}{2.22}=1$	$\frac{2.22}{2.22}=1$	$\frac{4.44}{2.22}=2$
Empirical formula	CHO_2		
Molecular formula	n= 90/45=2	$C_2H_2O_4$	Oxalic acid

Note: From the above calculation, we can extend our generalized expression:

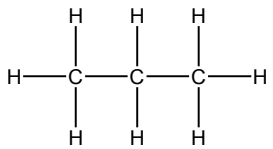
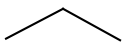
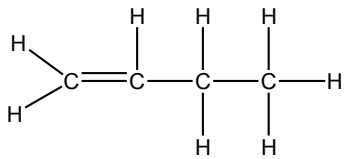
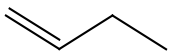
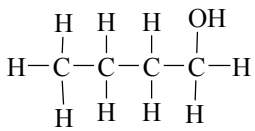
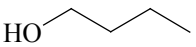
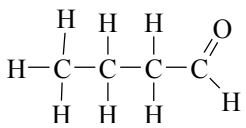
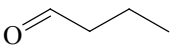
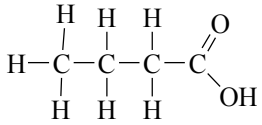
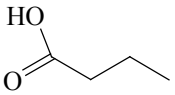
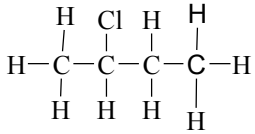
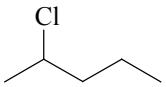
$$\%\text{ of carbon in } CO_2 = \frac{12}{44} \times \frac{m_{co_2}}{m_{sample}} \times 100$$

$$\%\text{ of hydrogen in } H_2O = \frac{2}{18} \times \frac{m_{H_2O}}{m_{sample}} \times 100$$

$$\%\text{ of oxygen } = 100 - (\%\text{ of } H_2 + \%\text{ of carbone})$$

7.2.3. Structural formula

There are three types of structural formulas: displayed, condensed and skeletal (stick)/line formulas. Structural formula shows how the different atoms in a molecule are bonded (i.e. linked or connected)

Molecular formula	Condensed structural formula	Displayed structural formula	Stick / skeletal/line formula
C_3H_8	$CH_3CH_2CH_3$		
C_4H_8	$CH_2{=}CH\text{-}CH_2CH_3$		
$C_4H_{10}O$	$CH_3CH_2CH_2CH_2OH$		
C_4H_8O	$CH_3CH_2CH_2CHO$		
$C_4H_8O_2$	$CH_3CH_2CH_2COOH$		
C_4H_8Cl	$CH_3\overset{Cl}{C}HCH_2CH_3$		

Note: Stick formula is also considered as structural formula.

Application Activity 7.2

1. An organic compound M contains, C (80%), H (6.7%) and the remaining being oxygen.
   a) Determine the empirical formula of M.
   b) Deduce its molecular formula if the molecular mass of M is 120 g
2. A complete combustion of 7.5 g of an organic compound M containing carbon, hydrogen and oxygen gave 17.8 g of CO_2 and 9.27 g of water.
   a) Determine the empirical formula of M and deduce its molecular formula if the molecular mass of M is 74 g.
   b) Suggest a possible structural (displayed, condensed and skeletal) formula for the compound M.

7.3. Functional groups and homologous series

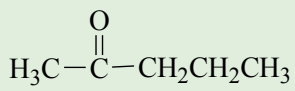
7.3.1. Functional groups

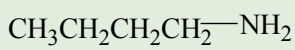
Activity 7.3.1

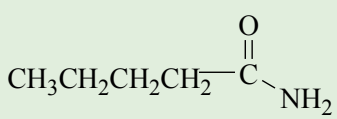
Observe the structure of the following compounds and point out the features that distinguish one each other.

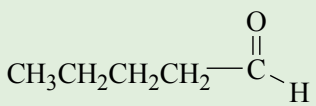
1 $H_2C=CHCH_2CH_2CH_3$

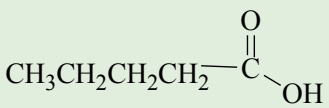
2 $HC\equiv CCH_2CH_2CH_3$

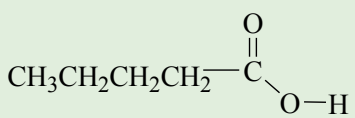
3 

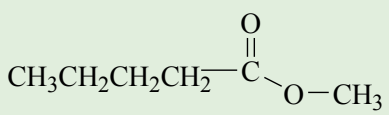
4 

5 

6 

7 

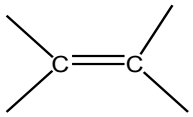
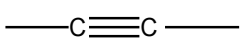
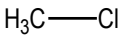
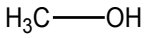
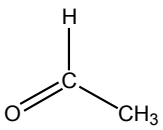
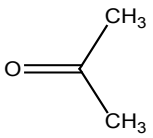
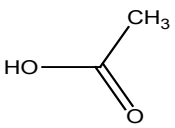
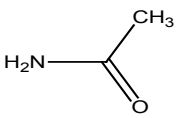
8 

9 

Give the name assigned to the features that distinguish the above compounds?

A **functional group** is an atom or group of atoms in a molecule which determines the characteristic properties of that molecule. Examples of some common functional groups are indicated in the Table 7.1

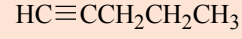
Table 7.1: The common functional groups

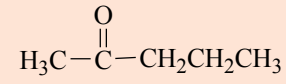
Functional group	**Family/ homologous series**	**Prefix/ suffix**	**Example**	**Systematic name**
C = C	Alkenes	-ene		Ethene
C ≡ C	Alkynes	-yne		Ethyne
R-X	Haloalkanes	Halo-		Chloromethane
R-OH	Alcohols/ Alkanols	-ol		Methanol
R-O-R	Ether	-ether	CH_3-O-CH_3	Dimethylether
R-CO-H	Aldehydes/ Alkanals	-al		Ethanal
R-CO-R	Ketones/ Alkanones	-one		Propanone
R-COOH	Carboxylic acids	-oic acid		Ethanoic acid
R-C ≡ N	Nitriles	-nitrile	CH_3-CH_2-C ≡ N	Ethylnitrile
R-NH_2	Amines	-amine	CH_3-CH_2-NH_2	Ethylamine
R-CO-NH_2	Amide	-amide		Ethanamide
R-COO-R	Ester	-oate	$CH_3COOCH_2CH_3$	Ethyl ethanoate

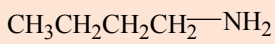
Application Activity 7.3.1

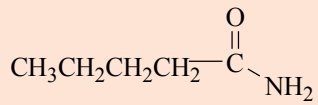
1. Give a precise definition of functional group.
2. Indicate the name of functional group in the following compounds:

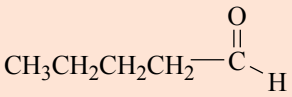
a 

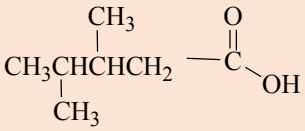
b 

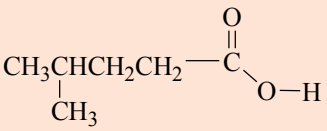
c 

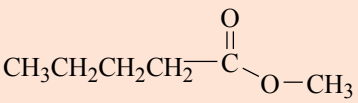
d 

e 

f 

g 

h 

j 

What name assigned to the concerned features?

7.3.2. Homologous series

Activity 7.3.2

Observe the structure of the following compounds and point out their similarities and differences

1 $HCOOH$ methanoic acic

2 CH_3COOH ethanoic acid

3 CH_3CH_2COOH propanoic acid

4 $CH_3CH_2CH_2COOH$ butanoic acid

5 $CH_3CH_2CH_2CH_2COOH$ pentanoic acid

6 $CH_3CH_2CH_2CH_2CH_2COOH$ hexanoic acid

7 $CH_3CH_2CH_2CH_2CH_2CH_2COOH$ heptanoic acid

8 $CH_3CH_2CH_2COOCH_2CH_3$ ethyl butanoate

When members of a class of compounds having similar structures are arranged in order of increasing molecular mass, they are said to constitute a **homologous series**. Each member of such a series is referred to as a "homologous" of its immediate neighbors.

For example, the following sequence of straight chain of alcohols forms a homologous series.

CH_3-OH: Methyl alcohol/methanol

CH_3-CH_2-OH: Ethyl alcohol/ethanol

CH_3-CH_2- CH_2-OH: Propyl alcohol/propan-1-ol

CH_3-CH_2-CH_2-CH_2-OH: Butyl alcohol/butan-1-ol

Characteristics of a homologous series

1. Any member of the series differs from the next by the unit – CH_2 – (methylene group)
2. The series may be represented by a general formula of alcohols which is $C_nH_{2n+1}OH$
3. where n =1,2,3, etc.
4. The chemical properties of the members of a homologous series are similar, though in some series the first members show different behaviour.
5. The physical properties such as density, melting point and boiling point generally increase with the molecular mass.

Application Activity 7.3.2

1. How are butane and isobutane related? How do they differ?
2. Give **one word or phrase** for each of the following descriptions:
   a) The name of the homologous series to which 2-methylpropene belongs.
   b) The name of the functional group that gives alcohols their properties.
   c) The group of organic compounds that have acidic properties.
3. The following table gives the boiling point of ten organic compounds.

	Compound	Molecular formula	Boiling point (°C)
1	Methane	CH_4	-162
2	Ethane	C_2H_6	- 89
3	Propane	C_3H_8	- 42
4	Butane	C_4H_{10}	0
5	Pentane	C_5H_{12}	36
6	Methanol	CH_4O	64.7
7	Ethanol	C_2H_6O	78.4
8	Propan-1-ol	C_3H_8O	97
9	Propane-1,2-diol	$C_3H_8O_2$	188
10	Propane-1,2,3-triol	$C_3H_8O_3$	290

The following questions refer to the compounds shown in the above table.

a) Show compounds which belong to the same homologous series.

b) Which of the above compounds are gases at room temperature?

c) What is the reason for the trend of increasing boiling points seen in compounds 1 to 5?

d) Despite the fact that the length of the carbon chain in compounds 8, 9 and 10 is the same, the boiling point of propan-1, 2, 3-triol is much higher than the boiling point of propan-1-ol. What is responsible for this large difference in boiling point?

7.4. Isomerism in organic compounds (structural isomers)

Activity 7.4

Consider the following compounds:

a) $CH_3CH_2CH_2CH_2CH_2CH_3$

b) $CH_3CH(OH)CH_2CH_2CH_3$

c) $CH_3CH_2CH_2CHO$

d) $CH_3CH{=}CHCH_2CH_3$

e) $CH_3CH{=}CHCH_3$

f) $CH_3CH_2CH_2CH_2CH_2COOH$

g) $CH_3CH_2CH_2CH_2CH_2OH$

h) $CH_3COCH_2CH_3$

i) $CH_3CH_2CH_2COOCH_2CH_3$

j) $CH_3CH_2CH_2OCH_2CH_3$

k) $CH_2{=}CHCH_2CH_2OH$

l) $CH_3CH_2CH_2CH(OH)CH_3$

m) $CH_3CH(CH_3)CH_2CH_2CH_3$

n) $CH_3CH(CH_3)CH(CH_3)CH_3$

Analyse the structure of the compounds listed above and point out:

1. Compounds with the same structural formula
2. Compounds with the same molecular formula
3. Are there any compounds having the same molecular formula but different by their structures? 4. Explain the main differences displayed by them? Name the relationship between them?

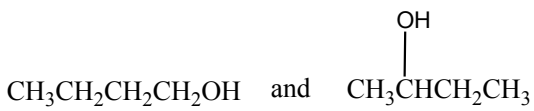
Isomerism is the existence of compounds that have the same molecular formula but different arrangements of atoms; these compounds are called "**isomers**".

Structural isomers are compounds with the same molecular formula but with different structural formula. They are subdivided into position isomers, chain isomers and functional isomers

a) Position isomerism

Position isomers are compounds with the same molecular formula but different positions of the functional group or substituent(s).

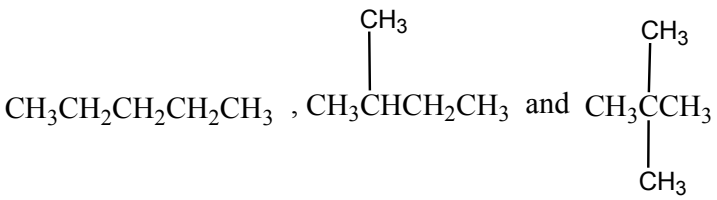
Examples:



b) Chain isomerism

Chain isomers are compounds with the same molecular formula, belonging to the same homologous series, with chain of carbon atoms of different length.

Examples:



c) Functional isomerism

Functional isomers are compounds which have the same molecular formula but different functional groups.

Examples:

C_2H_6O: CH_3OCH_3 and CH_3CH_2OH

$C_4H_8O_2$: $CH_3CH_2CH_2COOH$ and $CH_3CH_2COOCH_3$

Application Activity 7.4

For each of the given molecular formula, write out their corresponding possible position isomers and functional isomers

a) $C_4H_{10}O$
b) $C_5H_{10}O_2$
c) $C_5H_{10}O$

7.5. General rules of nomenclature of organic compounds according to IUPAC

Activity 7.5

Analyse the names of compounds given below.

Acethylene, ethanol, aniline, formic acid, paracetamol, 2-methylpentane, formol, acetaldehyde, ethanol, ethyne, methanoic acid, acetone, propanone, 2,4-dimethylhexane, but-2-ene.

Select from the list

1. the systematic names
2. the common names

The organic compounds are named by applying the rules set by the International Union of Pure and Applied Chemistry (IUPAC). The purpose of the IUPAC system of nomenclature is to establish an international standard of naming compounds to facilitate the common understanding.

In general, an IUPAC name has three essential parts:

i). A **prefix** that indicates the type and the position of the substituents on the main chain.

ii). The **base** or **root** that indicates a major chain or ring of carbon atoms found in the molecule's structure. e.g. **Meth-** for one carbon atom, **eth-** for 2 carbon atoms, **prop-** for 3 carbon atoms, **pent-** for five carbon atoms, **hex-** for six carbon atoms, **hept-, oct-, non-, dec-**, etc.

iii). The suffix designates the functional group.

Example: **-ane** for alkanes, **-ene** for alkenes, -**yne** for alkynes, **-ol** for alcohols, **-oic acid** for carboxylic acids, -**al** for aldehydes, -**one** for ketones and so on.

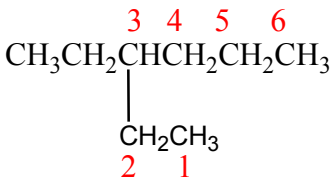
Steps followed in naming organic compounds:

Step 1: Identify the parent hydrocarbon:

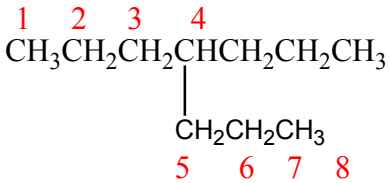
It should have the maximum length, or the longest carbon chain

Example

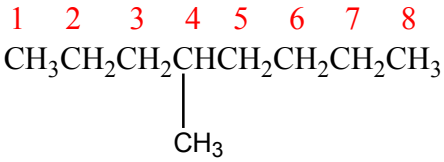
It should have the maximum number of multiple bonds



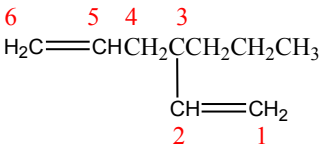
3-Ethylhexane



4-Propyloctane

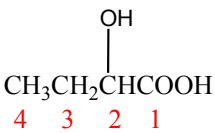


4-methyloctane



3-propylhexa-1,5-diene

Step 2: Identify the parent functional group, if any, with the highest order of priority

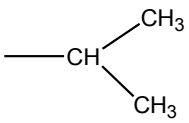
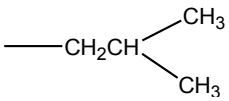
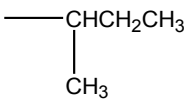
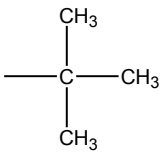


2-Hydroxybutanoic acid

Step 3: Identification of the side chains.

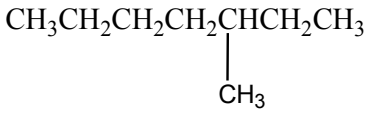
Side chains are usually alkyl groups. An **alkyl group** is a group obtained by a removal of one hydrogen atom from an alkane. The name of alkyl group is obtained by replacing **-ane** of the corresponding alkane by **–yl (see Table 7.3)**.

Table 7.3: Nomenclature of useful alkyl groups

Formula of alkyl group	Name of alkyl group	Corresponding alkane
—R	Alkyl	Alkane
—CH_3	Methyl (Me)	Methane
—CH_2CH_3	Ethyl (Et)	Ethane
—$CH_2CH_2CH_3$	Propyl (Pr)	Propane
	isopropyl(^{i}Pr)	propane
—$CH_2CH_2CH_2CH_3$	Butyl (Bu)	Butane
	isobutyl(^{i}Bu)	Butane
	*sec*-butyl(^{s}Bu)	Butane
	*tert*-butyl(^{t}Bu)	Butane

A side chain must be identified by the smallest possible numbers.

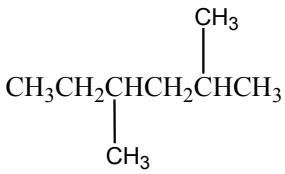
Example



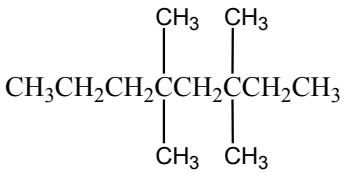
3-Methylheptane not 5-Methylheptane

Step 4: If the same substituent occurs two or more times, the prefix di-, tri-, tetra- , ... is attached to substituent's name.

Examples



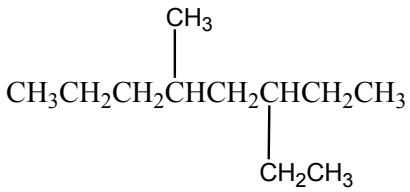
2,4-dimethylhexane



3,3,5,5-tetramethyloctane

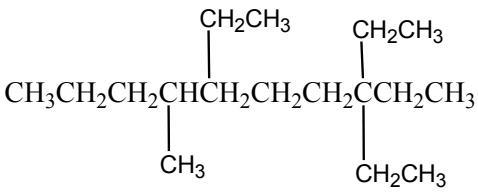
Step 5: Identify the remaining functional groups, if any, and name them. Different side chains and functional groups will be listed in alphabetical order.

Examples

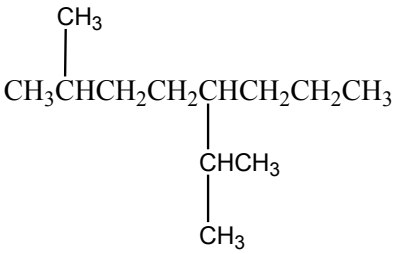


3-Ethyl-5-methyloctane not 5-Methyl-3-ethyloctane

The prefixes ***di, tri, tetra***,...are not taken into consideration when grouping alphabetically. But prefixes such **iso-, tert-** are taken into account



3,3,6-triethyl-7-methyldecane



2-methyl-5-isopropyloctane

Identify the position of the double/triple bond.

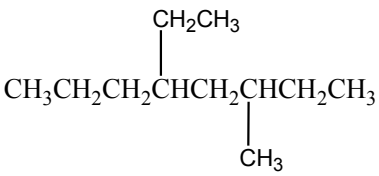
Example:

$CH_3CH_2CH{=}CHCH_2CH_2CH_3$: hept-3-ene (3-heptene)

Number the chain (left to right) or right to left).

The sum of the numbers which show the location of the substituents is the possible smallest

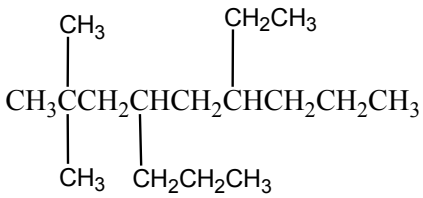
Example



5-Ethyl-3-methyloctane not 4-Ethyl-6-methyloctane

The correct name will be the one which shows the substituents attached to the third and fifth carbon, respectively and not to the fourth and the fifth carbon atom.

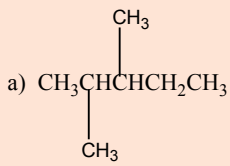
Numbers are separated by commas Hyphens are added between numbers and words. Successive words are merged in one word.



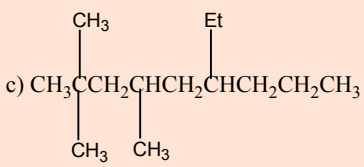
6-Ethyl-2,2-dimethyl-4-propylnonane

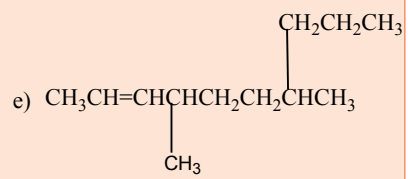
Application Activity 7.5

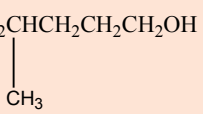
1. Complete the sentence; the systematic nomenclature of organic compounds follows rules established by the …… …. ……
2. What are the main parts which made up the name of an organic compound?
3. Name each of the following compounds using the IUPAC system.



b) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$







g) $CH_3CH_2CH_2CH_2CH_2COOH$

Skills Lab 7

Homemaking the Shoe Polish

You are provided for the following

Materials

- 100 g banana peelings
- 2 g black dye coloring powder
- 1teaspoon rock salt

Tools

- Mortar and pestle,
- stirring rod,
- plastic spoon,
- plastic cup,
- steel fork

Operational Procedure

1. Scrape the white part of the banana peel with the use of steel fork.
2. Mash the peeling with mortar and pestle.
3. Pour in the salt and mix it with the peelings.
4. Pour in the black dye powder and mix it with the peeling-salt mixture.
5. Put the finished product in its packaging.

Note: Before applying the shoe polish made with this method, clean your shoes with a damp cloth to remove any loose dirt.

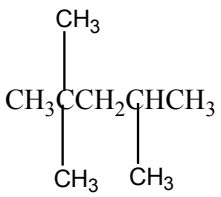
Question: What improvements would you apply to make this shoe polish more effective?

END UNIT ASSESSMENT 7

1. a) An atom or group of atoms which dictates the characteristic properties of an organic compound is……
……

   b) A set of compounds that have the same functional group is referred as ……

2. Chain isomers belong to the same class. True/False
3. Organic compounds belonging to the same class have similar physical properties. Tue/False
4. What is the name of the following compound?

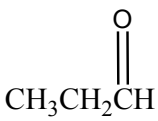


   a) 1,1-butyl-2- methylpropane
   b) 2,2,4-trimethylpentane
   c) 2,2,4-methylpentane
   d) 2,4,4-trimethylpentane
   e) none of the above

6. The compounds that follow belong to which class of organic compounds?

   i). 

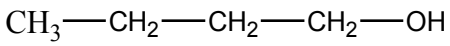
   a) alcohols
   b) alkenes
   c) alkynes
   d) aromatic

   ii). 

   a) ethers
   b) aldehydes
   c) ketones
   d) alcohols

7. Write the structural formula of:
   a) 4-ethyl-3-methylheptane
   b) 3-ethyl hexane
   c) 3,3,5-trimethyloctane
   d) 4-ethyl-2,2-dimethylnonane

8. Consider the following compound.



a) Determine the percentage composition of each element present in the compound.

b) Determine the empirical formula of the above molecule

c) From the results from a) calculate the molecular formula of the compound

d) Write all possible structural formulae of isomers of the compound.

e) Name the isomers in d) according to the IUPAC system.

f) From the results in d) Classify the isomers as chain, position, and functional isomers.

UNIT 8

MOMENTS AND EQUILIBRIUM OF BODIES

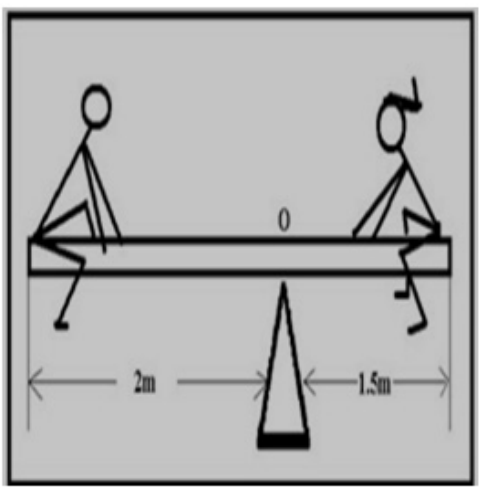
Key Unit competence: Explain the principle of moments and apply it to the equilibrium of a body.

Introductory Activity 8

Study the diagrams (a), (b) and (c) below:

(a)

(b)

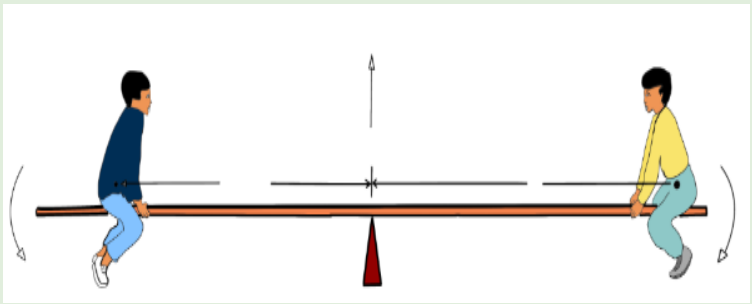


(c)

1. Referring to (a) and (b), name the tools used.
2. What happens when force is applied:
   i). At the end of the tool used?
   ii). In the middle of the tool used?
3. Referring to (c) that shows two children balancing on a seesaw.
   i). If they have different weights can they balance? Explain
   ii). If they have the same weight do they balance? Explain

8.1. Moment of a force about point

Activity 8.1



The above photo shows two pupils Nziza (in black) and Mutoni (in yellow) playing on a sea saw of a bar that is 3m. Nziza is 41 kg and Mutoni is 38 kg.

a) Imagine Nziza near the fulcrum about 80 cm and Mutoni is also about 50 cm from the fulcrum. Where will the bar bend to?

   Explain your reasoning?

b) If in the next phase they all sat at the same distance from the turning point, would the bar balance?

c) Discuss about the distance where Nziza and Mutoni would sit from the turning point to make the bar balance.

8.1.1. Force as vector and moment of a force

Most quantities measured in science and particularly in Physics are classified as either scalar or vector.

A scalar quantity is a physical quantity that is defined by only its magnitude (size).

Examples of scalar quantities are volume, mass, speed, and time intervals. The rules of ordinary arithmetic are used to manipulate scalar quantities.

A vector quantity is a quantity with both magnitude and direction.

Example of vector quantity: velocity, acceleration, force, weight, electric field, displacement and pressure.

The force is vector quantity. We can think of force as that which causes an object to accelerate. What happens when several forces act simultaneously on an object? In this case, the object accelerates only if the net force acting on it is not equal to zero.

The net force acting on an object is defined as the vector sum of all forces acting on the object.

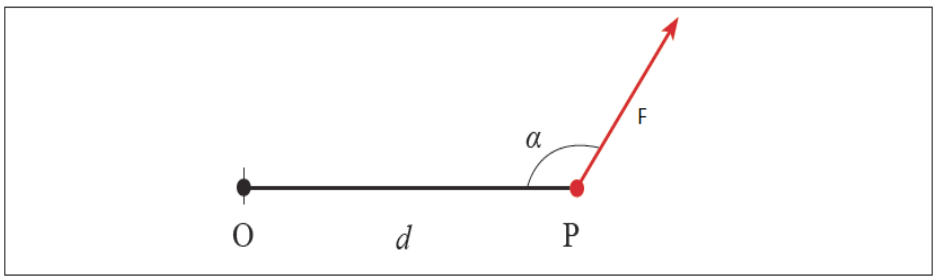


Figure 8. 1: Moment of a force about a point

This figure shows a force $\vec{F}$ acting on a body that is free to rotate about an axis. The force is applied at the point P whose position is defined by the vector .

The direction of $\vec{F}$ and make an angle α with each other.

We define the torque τ or moment of a force acting on the body from

$$\tau = F \times d \sin \alpha$$

The perpendicular distance of the line of action of the force from the axis of rotation is called the moment arm of the force.

The S.I unit of torque is Newton-metre [N m] or metre-newton [m N]

A **lever arm** is the perpendicular distance from the axis of rotation to a line drawn along the direction of the force.

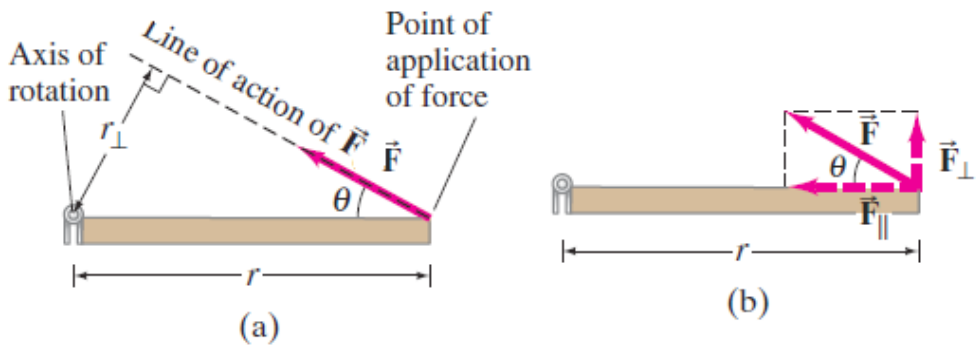


Figure 8. 2: Lever arm

8.1.2. Principles of moments

The principle of moments states that" when in equilibrium the total sum of the anticlockwise moment is equal to the total sum of the clockwise moment." When a system is stable or balance it is said to be in equilibrium as all the forces acting on the system cancel each other out.

In equilibrium

Total anticlockwise moment = total clockwise moment

$$\sum_{i=1}^{n} \tau_i^{+} = \sum_{i=1}^{n} \tau_i^{-}$$

The principle can be explained by considering two people on a seesaw.

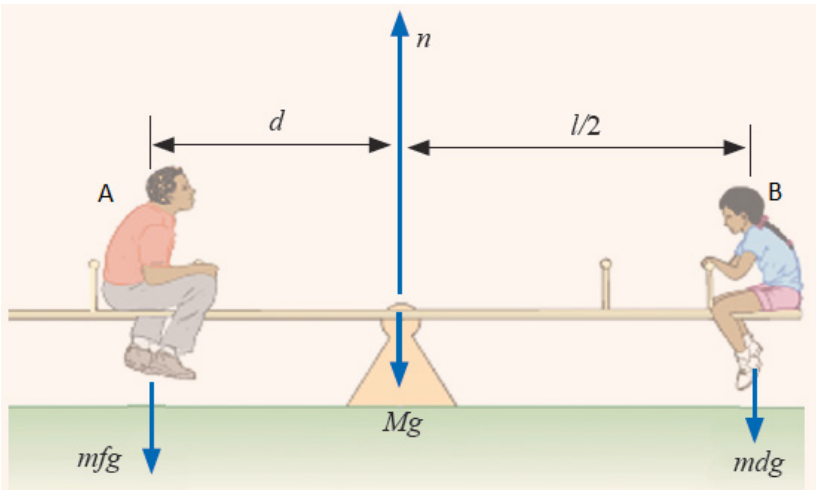


Figure 8. 3: Boy and girl in equilibrium

Moments acting on a seesaw

Both people exert a downward force on the seesaw due to their weights.

Person A's weight is trying to turn the seesaw anticlockwise with person B's weight is trying to turn the seesaw clockwise.

Person A's moment = force × perpendicular distance from fulcrum

$$mfg \times d$$

Person B's moment=force × perpendicular distance from fulcrum

$$mdg \times \frac{l}{2}$$

Person A's moment=Person B's moment

Anticlockwise moment = clockwise moment

$$mfg \times d = mdg \times \frac{l}{2}$$

Therefore, the seesaw is in equilibrium

8.1.3. Condition for equilibrium of a body about an axis

Objects in daily life have at least one force acting on them (gravity). If they are at rest, then there must be other forces acting on them as well so that the net force is zero. A book at rest on a table, for example, has two forces acting on it, the downward force of gravity and the normal force the table exerts upward on it.

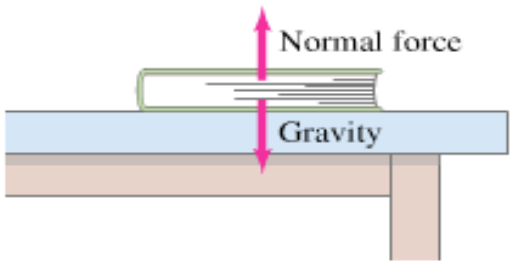


Figure 8. 4: Equilibrium of a body about an axis

The book is in equilibrium: the net force on it is equal to zero.

Since the net force on the book is zero, the upward force exerted by the table on the book must be equal in magnitude to the force of gravity acting downward on the book. Such an object is said to be in equilibrium (Latin for "equal forces" or "balance") under the action of these two forces. The two conditions for equilibrium of a rigid object under the action of coplanar forces are:

1. **The first or force condition**: The vector sum of all forces acting on the body must be zero:

   $$\sum F_x = 0, \sum F_y = 0$$

   Where the plane of the coplanar forces is taken to be the xy-plane. We must remember that if a particular force component points along the negative x or y axis, it must have a negative sign.

2. **The second or torque condition**: Take an axis perpendicular to the plane of the coplanar forces. Call the torques that tend to cause clockwise rotation about the axis negative, and counterclockwise torques positive;

then the sum of all the torques acting on the object must be zero:

$$\sum \tau = 0$$

8.1.4. Free –Body Diagrams (FBD)

In physics and engineering, a free body diagram (force diagram, or FBD) is a graphical illustration used to visualize the applied forces, movements, and resulting reactions on a body in a given condition. They depict a body or connected bodies with all the applied forces and moments, and reactions, which act on the body(ies).

In educational environment, learning to draw a free body diagram is an important step in understanding certain topics in physics, such as statics, dynamics and other forms of classical mechanics.

Free body diagrams consist of:

- A simplified version of body (often a dot or a box)
- Forces shown as a straight arrows pointing in the direction they act on the body
- Moments shown as curved arrows pointing in the direction they act on the body
- Coordinate system
- Frequently reactions to applied forces are shown with hash marks through the stem of the arrow.

A number of forces and moments shown in a free body diagram depend on the specific problem and the assumptions made; common assumptions are neglecting air resistance, friction and assuming rigid bodies. In statics all forces and moments must balance to zero; the physical interpretation of this is that if the forces and moments do not sum to zero the body is accelerating and the principle of statics do not apply. In dynamics the resultant forces and moments can be non-zero.

Example: Motion on a horizontal plane with frictional force

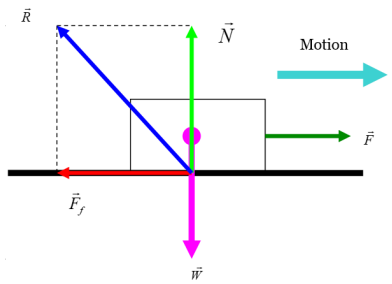


Figure 8. 5: Free-body diagram of an object on horizontal plane

Example 2.3

1. A uniform 1500 kg beam, 20.0 m long, supports a 15,000-kg printing press 5.0 m from the right support column (Figure below). Calculate the force on each of the vertical support columns.

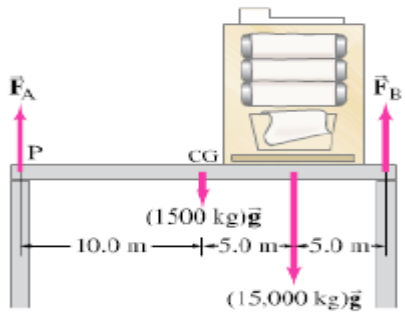


Figure: A 1500-kg beam supports a 15,000-kg machine.

Answer

The torque equation, with the counterclockwise direction as positive gives

$$\sum\tau = -(10.0m)(1500kg)g - (15.0m)(15,000kg)g + (20.0m)F_B = 0$$

Solving for F_B, we find $F_B = (12,000kg)g = 118,000N$

To find F_A, we use $\sum F_y = 0$, with + y upward:

$$\sum F_y = F_A - (1500kg)g - (15,000kg)g + F_B = 0$$

Putting in $F_B = (12,000kg)g$, we find that

$$F_A = (4500kg)g = 44,100N$$

8.1.5. Equilibrium of a system of objects

Forces in equilibrium

When all the forces that act upon an object are balanced, then the object is said to be in a state of equilibrium. The forces are considered to be balanced if the rightward forces are balanced by leftward forces and the upward forces are balanced by the downward forces. This however does not necessarily mean that all the forces are equal to each other.

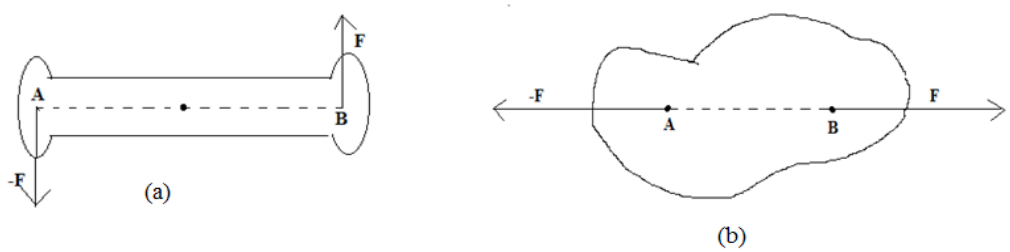


Figure 8. 6(a): The object is not in equilibrium since two forces do not have the same line of action; (b) the object is in equilibrium since two forces act along the same line.

Case I: If an object is subjected to two forces, the object is in equilibrium if and only if the two forces are equal in magnitude, opposite in direction and have the same line of action.

Figure (a) shows a situation in which the object is not in equilibrium because the two forces are not along the same line. Note that the torque about any axis such as one through A is not zero. Which violate the second condition of equilibrium.

Figure (b), the object is in equilibrium because the forces have the same line of action. In this situation, it is easy to see that the net torque about any axis is zero.

Case II: If an object subjected to three forces is in equilibrium, the line of action of the three forces must intersect at a common point; that is the force must be concurrent. One exception to this rule is the situation in which none of the lines of action intersect. In this situation, the forces must be parallel.

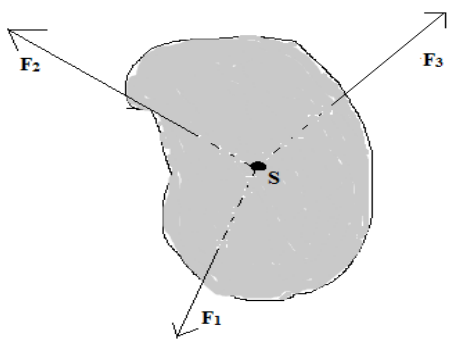


Figure 8. 7: Concurrent forces

Equilibrium of moments of force

We consider the equilibrium of an object like a horizontal bar. In the lab it will be a meter stick. Equilibrium means that it does not have translation (motion in which all points on the body move with the same vector velocity) or rotation. We can define the rotation by choosing any point on the body, calling that point the "axis", and considering rotation about that axis.

There may be several forces acting on the body, and each force acts at certain point. In the diagram, F_1 acts at point P_1 and F_2 acts at point P_2 ; A is the axis.

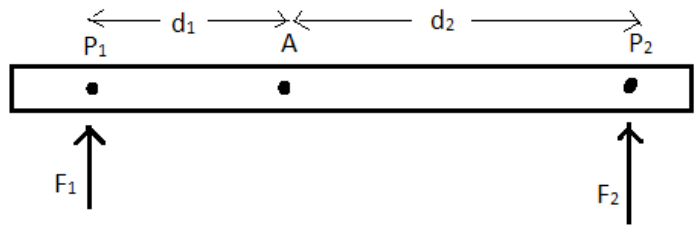


Figure 8. 8: Equilibrium of moments of force

We consider only forces that act up or down. The distance from point where the force acts to the axis is called the moment arm, d_1 and d_2 in the diagram. The product of the force and the moment arm (or force times moment) is called the torque (also called the moment), and is represented by a Greek letter tau τ

$$\tau = F \times d$$

Torque also has a sign: it is positive (by convention) if it tends to rotate the object in counterclockwise direction around the axis. It is negative if it tends to rotate the object in a clockwise direction around the axis. In the diagram the torque due to F_2 is positive and the torque to F_1 is negative. The forces themselves have signs. We may take forces positive if directed upward, and negative downward.

The conditions for equilibrium are then stated simply: the sum of all forces must be zero, and the sum of all torques must be zero. One particular force requires further consideration: the weight of the bar. The weight (force of earth's gravity) does not act at a point, but acts at all points along the object. However, for the purposes of determining equilibrium, the weight can be considered to be concentrated at a single point, called the center of mass. Thus a bar supported by two upward forces, and held in equilibrium, looks like the figure below.

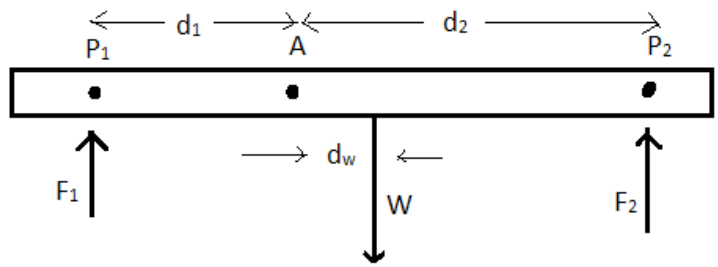
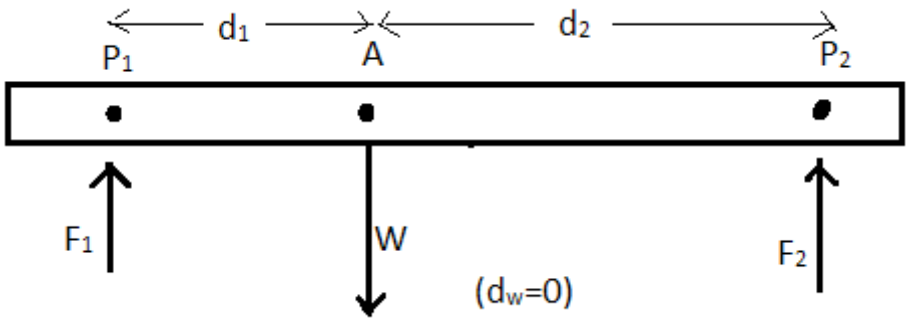


Figure 8. 9: Equilibrium of a rigid bar supported by two upward forces

Since the axis, for problem-solving purposes, can be chosen anywhere along the bar, it is convenient to choose it at the point where one of the forces acts. Then the moment arm of that force will be equal to zero, and so that force will not come into torque equation. For example, we may choose the axis to be at the center of mass.

Example 2.4

1.



In this diagram, suppose $F_1 = 20N, d_1 = 0.14m, d_2 = 0.5m$ and F_2 is unknown. W is also not known, but $d_w = 0$ and so the torque due to the weight $t_w = 0$. The torque equation thus becomes,

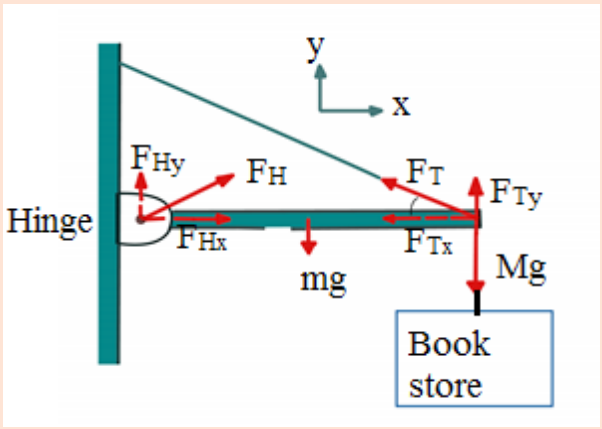
$$\tau_1 + \tau_2 = 0$$
$$\tau_1 = -F_1 d_1 = -2.0\ N \times 0.4\ m = -0.8\ N.m$$
$$\tau_2 = +F_2 d_2 = +F_2 \times 0.5\ m$$
$$+F_2 \times 0.5\ m - 0.8N\ m = 0 \Leftrightarrow F_2 = 1.6\ N$$

Note that the weight is not given, or determined, in the discussion above. To find the weight we have to use the second equilibrium condition, that the sum of all forces is zero. Since and are up, and W is down, we have

$$2.0N + 1.6N - W = 0 \rightarrow W = 3.6N$$

Application Activity 8.1

1. A uniform beam, 2.20 m long with mass m=25.0 kg , is mounted by a hinge on a wall as shown in figure below. The beam is held in horizontal position by a cable that makes an angle $\Theta=30^0$ as shown. The beam supports a sign of mass M=28.0kg suspended from its end.



Determine the components of the force **FH** that the hinge exerts on the beam, and the tension **FT** in supporting cable.

2. A 5.0-m-long ladder leans against a wall at a point 4.0 m above a cement floor as shown in figure below. The ladder is uniform and has mass m=12.0kg . Assuming the wall is frictionless (but the floor is not), determine the forces exerted on the ladder by the floor and by the wall.

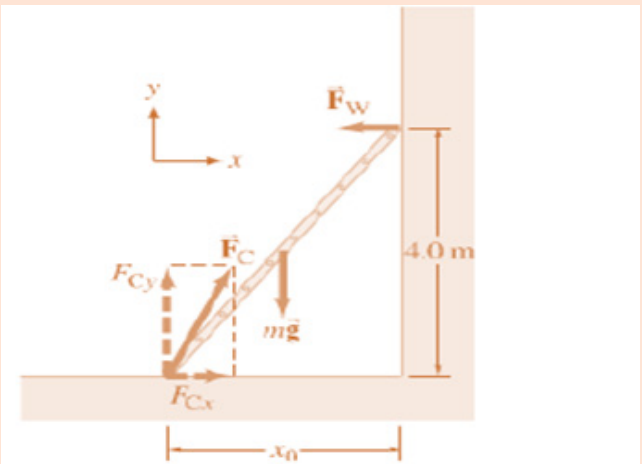


Figure: A ladder leaning against a wall

8.2. Types of equilibrium: stable, unstable and neutral

Activity 8.2

1. Displace the desk. What happens when you withdraw the force you applied?
2. Place a bottle on a table so that it rests on its horizontal surface. Displace or roll it. What happens?
3. Place a knife edge on a table resting on its tip. Give it a small displacement. What happens to it?
4. From the observations made, how do you conclude?

Equilibrium has many different meanings, depending on what subject (chemistry or physics) or what topic (energy or forces). Dealing with energy, there are three types of equilibrium.

A body is in either Stable, Unstable or in neutral equilibrium depending how it behaves when subjected to a small displacement.

Stable is when any sort of movement will raise the object's centre of gravity. When objects in stable equilibrium are moved, they have a tendency to fall back to their original position. For instance, a skateboarder at the bottom, in the middle, of a ramp. Either way the skateboarder moves, his/her potential energy will increase because he/she will be rising in height. The boarder will also roll back to the bottom of the ramp if he/she doesn't exert any sort of energy to maintain the new position.

When a body returns to its original position after being slightly disturbed, it is said to be in stable equilibrium.

Unstable is when any sort of movement will lower the object's centre of gravity. When such objects are moved, they cannot return to their original position without some exertion of energy. For instance, when a coin is placed on its side, it exhibits unstable equilibrium. Any sort of push will cause the coin to fall flat, lowering its centre of mass. The coin will not return to its side unless someone picks it up and resets it.

If the position of a body is disturbed and the body does not return to its original position, it is in unstable equilibrium.

Neutral is when any sort of movement does not affect the object's centre of gravity. For instance, a ball on a table exhibits neutral equilibrium. If the ball rolls, the centre of mass stays at the same height and thus it maintains the same equilibrium.

A body is said to be in neutral equilibrium if it moves to a new position when it is disturbed.

Let us consider a cone to understand these states.

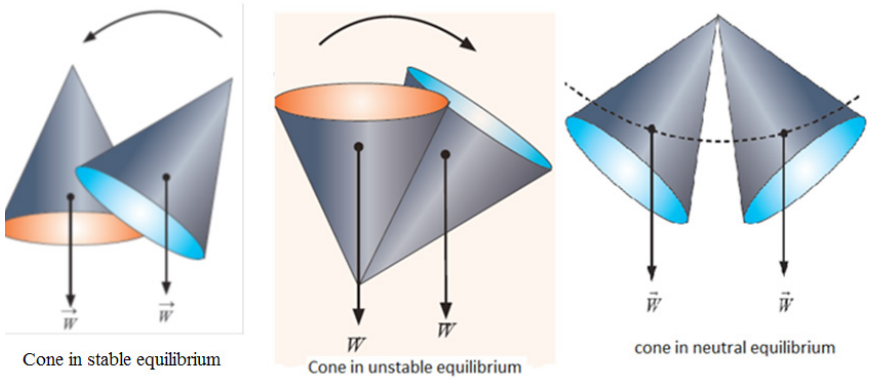


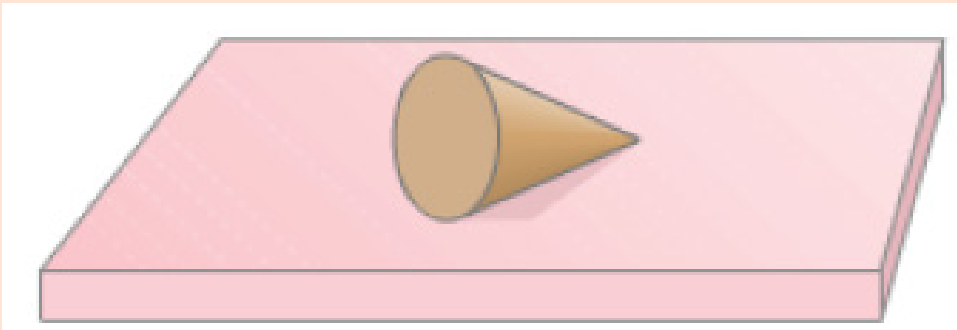
Figure 8.10: A cone in stable, unstable and neutral equilibrium.

From whatever we have done, we can conclude and say that a body is stable when:

1. The object's base is broad.
2. The centre of gravity is as low as possible.
3. The vertical line drawn from the centre of gravity should fall within the base. Lowering the centre of gravity of an object is important for stability.

Application Activity 8.2

Figure below shows a cone. Explain how to lay it on a flat table so that it is in (a) stable equilibrium, (b) unstable equilibrium, (c) neutral equilibrium.



8.3. Centre of gravity of objects and its determination

Activity 8.3

Given a pencil, a ruler, a notebook or other regular shaped material

Try to balance the material using your finger. Is it balanced? If yes, what causes it to be balanced? How do you call the point of balance? How can you locate this point?

8.3.1. Concept of Centre of gravity and center of mass

The **center of gravity** is the average location of the weight of an object. The Centre of gravity is defined as the point of application of the resultant force due to the earth's attraction on it. The center of gravity is a geometric property of any object.

The centre of gravity of a body also coincides with its centre of mass. The **center of mass** of an object may be defined as the point at which an applied force produces acceleration but no rotation

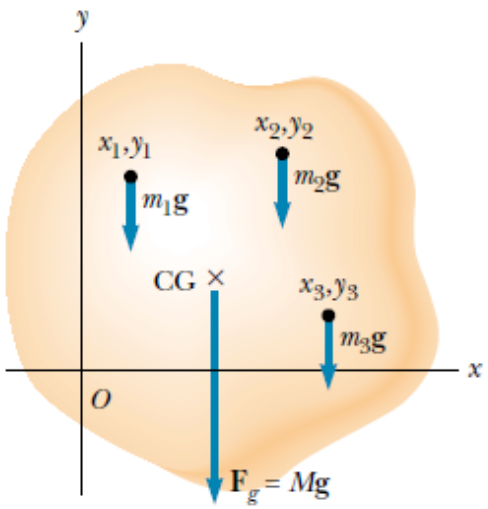


Figure 8.11: The center of gravity of an object is located at the center of mass if g is constant over the object.

Centre of gravity and base of support of a body

1. For balance to exist, the line of gravity must intersect the base of support.
2. If the area of the base of support of an object is increased, this tends to increase the stability of the object.

3. The lower the center of gravity is above the base of support the more stable the object tends to be. (This is true even though the size of the base of support is unchanged.)
4. Objects that are more massive tend to be more stable.
5. For an object, the farther the line of gravity's intersection is from the edge of its base of support the more stable the object tends to be in that direction.

8.3.2. Determining the center of gravity

Determining the center of gravity is very important for any flying object. In general, determining the center of gravity (cg) is a complicated procedure because the mass (and weight) may not be uniformly distributed throughout the object.

If the mass is uniformly distributed, the problem is greatly simplified. If the object has a line (or plane) of symmetry, the center of gravity lies on the line of symmetry.

For a solid block of uniform material, the center of gravity is simply at the average location of the physical dimensions.

Example: For a triangle of height h, the Center of Gravity is at h/3, and for a semi-circle of radius r, the cg is at ($\frac{4r}{3\pi}$), for a rectangular block, 50 × 20 × 10, the center of gravity is at the point(25, 10, 5),

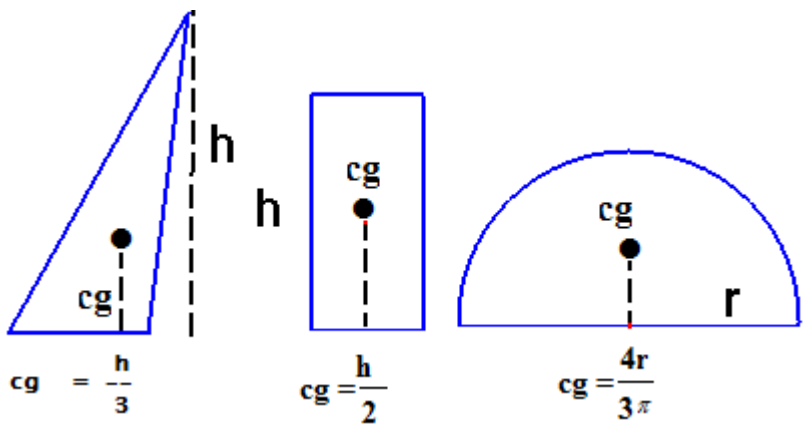


Figure 8.12: Centre of gravity

For a general shaped object, there is a simple mechanical way to determine the center of gravity:

In Step 1, you hang the object from any point and you drop a weighted string (plumb line) from the same point. Draw a line on the object along the string.

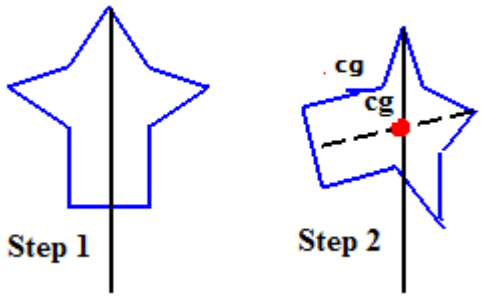


Figure 8.13: General shape

For Step 2, repeat the procedure from another point on the object you now have two lines drawn on the object which intersect. The center of gravity is the point where the lines intersect. This procedure works well for irregularly shaped objects that are hard to balance.

8.3.3. Determination of the center of mass

Consider several point masses m_1, m_2, $m_{3...}m_n$

If the position vectors relative to a fixed origin O are r_1, $r_{2,}...,r_n$

The centre of mass is define by $(m_1 + m_2 + ... + m_n)r_G = m_1r_1 + m_2r_2 + ... + m_nr_n$

Total mass $M = m_1 + m_2 + m_3 + ... + m_n = \sum_{i-1}^{n} m_i$

$$m_1r_1 + m_2r_2 + m_3r_3 + ... + m_nr_n = \sum_{i-1}^{n} m_ir_i$$

The position vector of G: $r_G = \dfrac{\sum_{i-1}^{n} m_ir_i}{\sum_{i-1}^{n} m_i}$

In the *x-y* plane:, ,..., $m_1(x_2, y_2)$, $m_2(x_2, y_2)$,,,, $m_n(x_n, y_n)$

Then $r_G(x, y)$ where $x = \dfrac{\sum_{i}^{n} m_ix_i}{\sum_{i}^{n} m_i}$

and $y = \dfrac{\sum_{i}^{n} m_i y_i}{\sum_{i}^{n} m_i}$

Application Activity 8.3

1. Does mass affect centre of gravity?
2. What is the difference between centre of gravity and centre of mass?
3. Find the distance from the centre of the earth to the center of mass of the earth-moon system if the earth-moon separation is $3.8\times10^{5}\ km$ and the mass of the earth is 81.3 times the mass of the moon. To what fraction of the earth's radius of 6370 km does this distance correspond?

Skills Lab 8

Title: Determination of the mass of the meter rule

Apparatus: 2 meter rules, knife edge, 6 masses of 10 g,

Procedure

Balance the meter rule provided on a knife edge with the graduated side facing upwards.

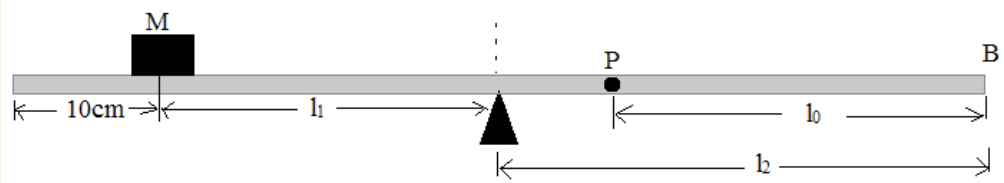
Note the balance point P and record its distance from B.

Place a mass M of 10 g on the top of mater rule at the 10 cm mark and balance the arrangement as shown in figure below.

Read and record distance l_1 and l_2

Repeat the procedures (3) and (4) from the values of M = 20,30,40,50, and 60g.

Record your results in a suitable table including the values of $l_2 - l_0$ and $\dfrac{l_2 - l_o}{l_1}$



Plot a graph of M against $\frac{l_2 - l_o}{l_1}$

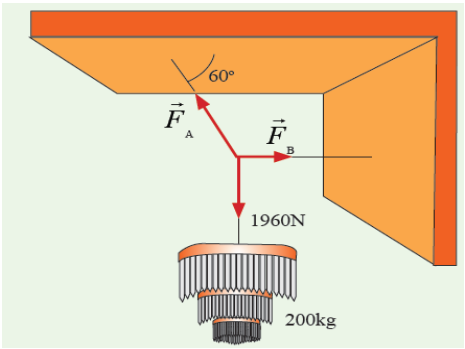
Find the slope of your graph.

END UNIT ASSESSMENT 8

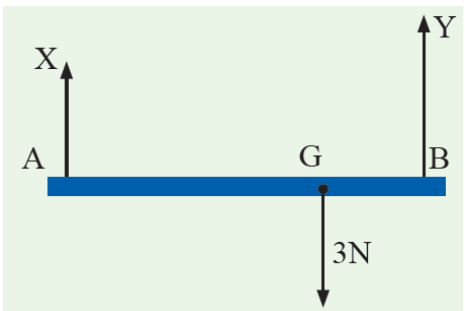
1. a) State the principle of moment

   b) What are the conditions for equilibrium?

2. Calculate the magnitudes FA and FB of the tensions in the two cords that are connected to the vertical cord supporting the 200kg chandelier in the figure.



3. A horizontal rod AB is suspended at its ends by two strings. (See the figure below). The rod is 0.6m long and its weight of 3N acts at G where AG is 0.4m and BG is 0.2m. Find the tensions X and Y



UNIT 9

MONOHYBRID INHERITANCE

Key unit competence: Explain the role of genes in inheritance

Introductory Activity 9

Read the passage below and answer the questions that follow

Imagine that you are planning to meet at the airport somebody you never met before.

a) How would you describe yourself? Would you say that you are tall or short, have curly hairs or straight hair; have brown eyes or green eyes? Make a list.
b) Put a check mark next to traits you think you inherited/ get from your parents.
c) Explain why you look like one or both of your parents?
d) Why do the people of the same family resemble in traits like skin colors, hair colors, eye colors, etc.

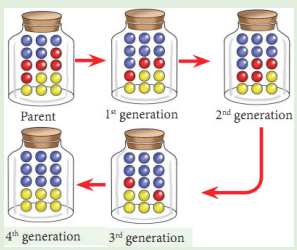
For thousands of years, humans have understood that characteristics such as eye color or flower color are passed from one generation to the next. The passing of characteristics from parent to offspring is called **heredity**. Humans have long been interested in understanding heredity. Many hereditary mechanisms were developed by scholars but were not properly tested or quantified. The scientific study of genetics did not begin until the late 19th century. In experiments with garden peas, Austrian monk **Gregor Mendel** described the patterns of inheritance.

9.1. Definition of key words in genetics

Activity 9.1

Count the number of blue, red and yellow marbles in each bottle.

a) How many are they per generation?



b) What do the marbles represent? Why are they colored differently?

c) Why do the people sometimes cultivate white seeds of maize and harvest mixed colours of maize seeds?

Gene: Gene is the entity/unit which has the information for particular trait. For example: in garden pea, gene for stem height has information for height whether it would be long or small.

Locus: The position of gene on chromosome constitutes its locus/loci.

Allele: The alternate forms of genes are known as Alleles. A pair of alleles for each trait is present in the zygote of an organism. For example: in garden pea, true breeding tall parent plants have two similar alleles (TT).

Dominant Allele: In individual, out of two alleles for the particular trait, only one allele is expressed. The expressed allele is known as dominant. For example, allele (T) for tallness is expressed in F1 individuals (Tt), dominant allele. Dominant allele is generally referred by capital alphabet.

Recessive Allele: In individual, out of two alleles for the particular trait one allele is under expressed. The under-expressed allele is known as recessive. For example, allele (t) for shortness is not expressed in F1 individuals (Tt), recessive allele. Recessive allele is generally referred by small alphabet.

Co-dominant: It's a phenomenon when both alleles present in an individual, are equally expressed. For example, in humans, Blood cells express both the alleles M and N (alternate form of gene encoding Red blood cell membrane protein) when present together.

Linkage: The genes are said to be linked when present on the same chromosome and inherited together as unit.

F1: F symbolized filial, which means "progeny" in Latin. F1 is the filial generation first, produced by cross between parent individuals.

F2: F2 is the filial generation second, produced by cross between F1 individuals.

Phenotype: The morphological appearance for particular trait constitutes its phenotype. For example: In the cross between tall and dwarf parent plants, F1 plants are tall. Tallness is their phenotype. In F2 plants, tall and dwarf plants are obtained in ration of 3 : 1, it is phenotypic ratio.

Genotype: The combination of allele for a particular trait in an individual constitutes its genotype. For example: In the cross between tall and dwarf parent plants, F1 plants are Tt. "Tt" constitute their genotype for the trait

stem height. Similarly, F2 plants are tall and dwarf. But genotype of all tall F2 plants is not same, one third are pure (TT) while two third are hybrid (Tt). So genotypically F2 ratio is 1 : 2 : 1.

Homozygous: When in an individual, two alleles for a particular trait are alike, and then individual is considered homozygous for the particular trait. For example, parent plants tall and dwarf plants are homozygous for stem height.

Heterozygous: When in an individual, two alleles for a particular trait are different then individual is considered heterozygous for the particular trait. For example, F1 plants are genotypically "Tt". They are heterozygous for stem height.

Monohybrid Cross: '*It is a cross between two individuals of a species which is made to study the inheritance of a single pair of factors or genes of a trait.*' A ratio among the offspring of F2 generation of a monohybrid cross is called a **'monohybrid ratio**.' It is usually 3 : 1 (phenotypic ratio) or 1 : 2 : 1 (genotypic ratio), in which 1/4 individuals carry the recessive trait, 1/4 pure dominant and 1/2 have impure dominant trait.

Application Activity 9.1

Observe the herd above and answer the following questions:

d) What is the apparent common characteristic of the elements of that herd?

e) Why do the cows and calves have that common characteristic?

f) How is that common characteristic transmitted from cows to calves?

g) By which means is that common characteristic transmitted? In your opinion, what science studies the transmission of physical characteristics?

9.2. Mendel's Laws of Inheritance

Activity 9.2

1. Analyze the photo below and answer the questions that follow:

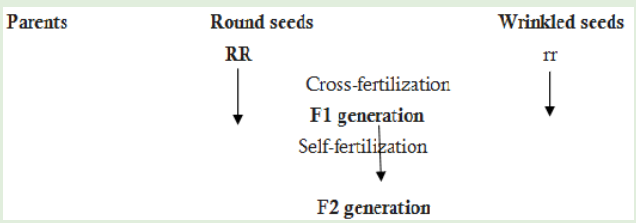
The young cat looks similar to her mother.

a) What characteristics does the young cat receive from its mother?

b) How are information transmitted from the mother cat to its offspring?

c) The diploid number of chromosome for the cat is 38 (2n = 38). How many chromosomes does the young cat receive from its mother? Why?

2. A plant with round seeds along with wrinkled seeds is crossed. What will be the genotype and phenotype of F1 generation and F2 generation if trait follows Mendelian pattern of Inheritance?



- Observe the given diagram carefully.
- Draw the punnett square showing the gametes from both the parents on each side.
- Note down the genotype and phenotype of F1 generation.
- Again draw the punnett square showing the gametes of F1 parents.
- Note down the genotype and phenotype of F2 generation.
- What will be the phenotype and genotype of a cross between offspring of F1 generation and recessive parent?

An organism produced by sexual reproduction tends to have two parents and inherits certain traits from father and certain traits from mother. It leads to variation in organism. So, heredity and variation are characteristics of sexually reproducing organism. The study of heredity and variations in biology is referred to as **Genetics**.

1. Mendel's Experiments

In 1856, Gregor Mendel conducted experiments in garden pea (*Pisum sativum*) in the limited space of a monastery garden. Garden pea plant has both male (pollen-producing part) and female parts (pollen-receiving part). Since both the male and female parts are on the same plant, it has tendency to undergo self-fertilization. Because of self-fertilization, the tall plants always give rise to tall plants and dwarf plants always produce dwarf plants. Such true breeding varieties are known as pure lines. Furthermore, he was lucky to get pure lines in garden pea.

He then carefully conducted hybridization experiments between two parent plants expressing contrasting form of single trait. He also made sure that self-fertilization didn't happen by removing male parts from one parent (say tall plants) before female part got matured. In his initial experiments (Figure 9.1), he carefully transferred pollen from male parent (say dwarf plant) to tall parent's female part and analyzed transmission of one particular trait (stem height) in all progenies of the first generation (also known as F_1 generation where F symbolizes the Latin word "filial" meaning progeny and 1 represents first). Furthermore, he followed the transmission of same trait (stem height) in second (F_2) and third generation (F_3) progenies as well which were naturally produced by self-fertilizing power among first generation plants and second-generation plants. He maintained the quantitative records of all his experiments.

Since Mendel focused on one trait at a particular time, a cross between parents which differs in contrasting form of single trait is known as **Monohybrid cross** or **inheritance**.

Gregor Mendel: *Father of Genetics*

(Source: http://www.biography.com/people/gregor-mendel-39282)

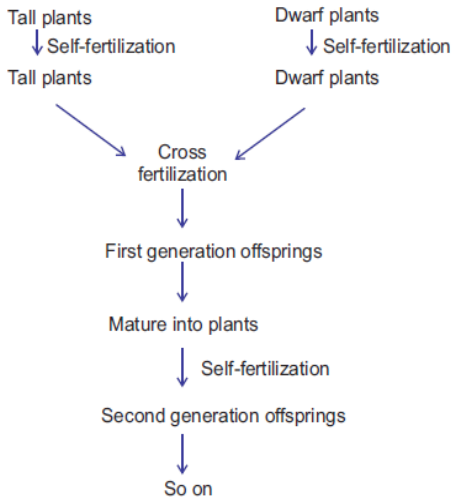


Figure 9.1: A hypothetical experimental plan by Mendel to follow the inheritance of particular trait or monohybrid inheritance

2. Monohybrid inheritance

Mendel first worked with plants that differed in a single characteristic, such as flower color.

Hybridization is a cross between two individuals that have different traits. A hybridization in which only one characteristic is examined is called a **monohybrid cross**. The offspring of such a cross are called **monohybrids**. Mendel noted that hybridizing true-breeding (P-generation) plants gave rise to an F1 generation that showed only one trait of a characteristic. For example, a true-breeding purple-flowering plant crossed with a true-breeding white-flowering plant always gave rise to purple-flowered hybrid plants. There were no white-flowered hybrids!

Mendel wanted to know what happened to the white-flowered plants' "heritable factors." If indeed the white flower "heritable factor" had disappeared, all future offspring of the hybrids would be purple-flowered. To test this idea, Mendel let the F1 generation plants self-pollinate and then planted the resulting seeds.

a) Mendel's Results

The F2 generation plants that grew included white-flowered plants! Mendel noted the ratio of white flowered plants to purple-flowered plants was about 3:1. That is, for every three purple-flowered plants, there was one white flowered plant.

Mendel carried out identical studies over three generations, (P, F1, and F2), for

the other six characteristics and found in each case that one trait "disappeared" in the F1 generation, only to reappear in the F2 generation. Mendel studied a large number of plants so he was confident that the ratios of different traits in the F2 generation were representative.

b) Mendel's Observation

Mendel carried out experiments to follow the pattern of inheritance of particular trait in several generations. On crossing **tall plants** (which provided the female part) verse **dwarf plants** (which provided pollen), he observed that (Figure 13.3).

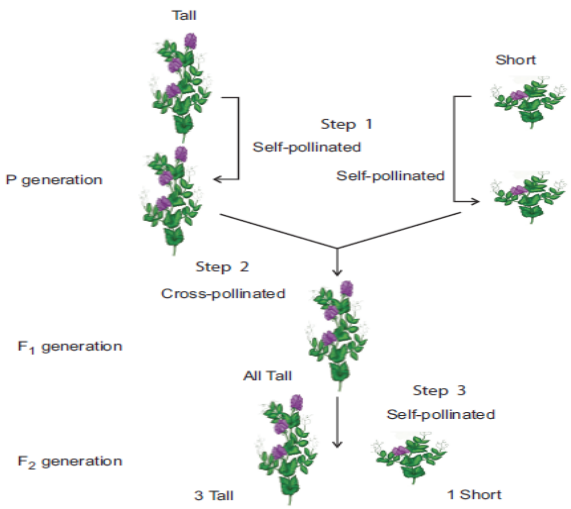


Figure 9.2: The experimental observation from a cross between tall and dwarf plants

- First generation progenies were always tall.
- Second generation progenies (also known as F2 generation) include tall plants as well as dwarf plants almost in ratio of 3 (tall plants): 1 (dwarf plants).

Mendel then performed the **reciprocal cross** (A similar cross where tall plants provided male parts whereas dwarf plants represented female plants). Mendel observed similar results.

On performing similar cross-fertilizing experiments with parent plants showing other contrasting set of traits such as seed colour, seed shape, seed coat colour, pod colour, pod shape and flower position/arrangement (figure 9.3), he observed similar observation and concluded that:

- First generation progenies were always showing one form of trait expressed in one of the parent plants.
- Second-generation progenies include the plants showing both contrasting forms of traits, almost in ratio of 3:1.

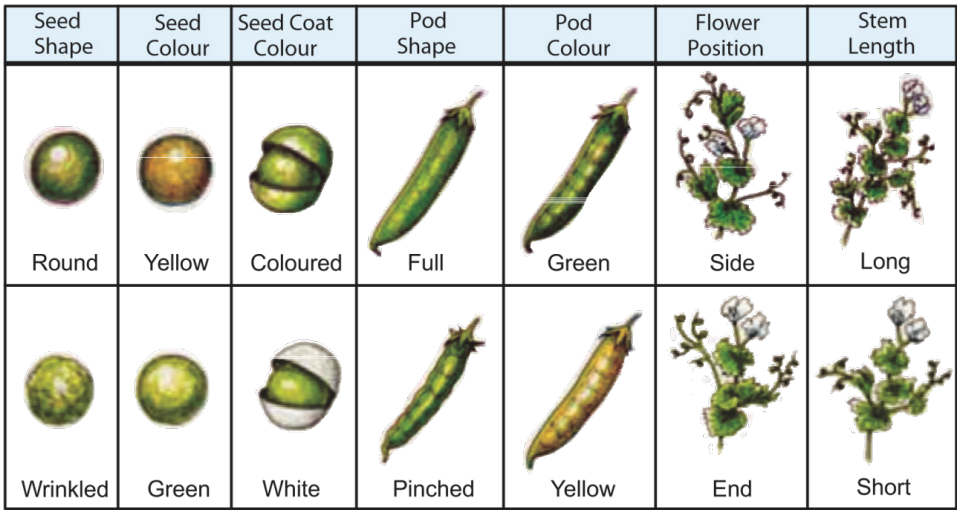


Figure 9.3: *A seven pairs of contrasting traits in garden pea, the inheritance pattern was followed*

On self-fertilization of F2 plants for various contrasting traits (for example: for stem height), Mendel observed the following points:

- Dwarf F2 plants always yielded dwarf plants only.
- All F2 tall plants were not genetically same. The one-third tall plants produced tall plants only but two-third tall plants yielded both tall plants and dwarf plants in the ratio of 3: 1. It means phenotypic ratio is 3: 1 but genetically the ratio is 1 : 2 : 1.

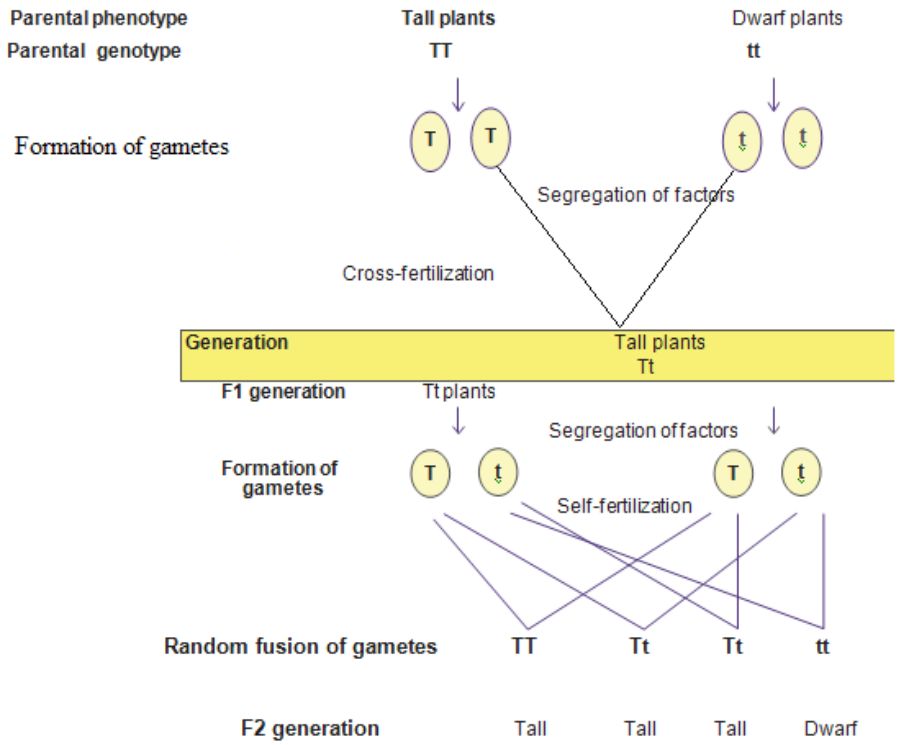
The results of Mendel´s experiment were published in the monograph "***Experiments in Plant Hybridization***" *in 1866*.

3. Mendel's Postulates: Principles of Inheritance

Based on consistency of his results in transmission of seven contrasting traits, he derived postulates which later became principles of inheritance.

- There are two alleles (**Unit allele in pairs**) for each trait. In pure lines of plants, both the alleles for particular trait (stem height) are alike. For example, if allele "T" donates height, there are two alleles for each trait. The tall plants have TT and dwarf plants have tt.
- At the time of gamete formation, the alleles for particular trait **randomly segregate** with equal likelihood. Each gamete contain single allele, therefore the gamete is always pure for the trait. Later on, it becomes popular as "**Mendel's principle of segregation**". For example: all the gametes from tall plants have single factor "T" and dwarf plants have "t" (Figure 17.4).

- After fertilization, when gametes from parents randomly fuse, allele for a particular trait also unites together. For example, in a cross between tall and dwarf plants, gamete from tall plant with allele "T" fuses with gamete from dwarf plant with allele "t" to form "Tt" organism.



F2 generation
Genotypic ratio : 1:2:1 (1TT: 2Tt: 1tt)
Phenotypic ratio : 3 tall (1 TT and 2 Tt) :1 Dwarf (1tt)

Figure 9.4: *Mendel's conclusion from hybridization experiments*

- In F1 generation, only one of the parental traits is expressed, it indicates that out of two forms of allele for the single trait, one allele is dominant. For example: Tt organisms are tall, so the allele for tallness "T" is dominant over the allele "t" for dwarfness. The allele which remains under-expressed in presence of dominant allele is known as recessive allele.
- In the F1 populations, the alleles again randomly segregate in the gametes. So a 'Tt' organism will produce two type of gametes either having 'T' or't' form for particular trait. During self-fertilization, there is random fusion of gamete and formation of TT, Tt, Tt or tt. Hence, three out of four F2 progeny becomes tall whereas one out of four progeny are small (figure 9.4). The tall and dwarf varieties are obtained in the ratio of 3: 1. The F2 ratio (3: 1) obtained is known as monohybrid ratio.

- Mendel concluded that the F2 ratio (3: 1) indicates the morphological pattern of trait (for example in case of stem height, it indicates tall verse short), so it is also known as phenotypic ratio (Phenotype: morphological appearance). Genetically, it is further divided into 1: 2:1 (Genotypic ratio) as Pure dominant: hybrid: pure recessive.

4. Reasons behind Mendel's Success

His experiments were highly successful and he was able to discover the pattern of inheritance. The reasons for his success are as follows:

- His choice of experimental organism i.e. garden pea, was extremely good as it generates a large number of generations in a very short duration.
- Pollination of garden pea leads to large number of offsprings due to which the inheritance pattern could be followed in the progeny.
- Furthermore, Mendel studied one trait at a time thereby allowing him to deduce useful interpretations.
- Lastly, his mathematical background played an important role in deducing the results.

Activity 9.3

How monohybrid cross works

Materials

A small bag, either 12 red beads and 12 blue beads or 12 small circles of red paper and 12 small circles of blue paper.

Procedure

1. Shake up your bag of beads or paper circles.
2. Put your hand in the top of the bag and- without looking- pick out two beads/papers circles at a time.
3. Repeat this at least 12 times. Record the combinations you pull out. What are possible color combinations?
4. If the bag contained only red beads or only blue beads what combinations would you get?

5. Test Cross

A test cross is a genetic cross in which an organism showing a characteristic caused by a dominant allele is crossed with an organism that is homozygous recessive; the phenotypes of the offspring can be a guide to whether the first

organism is homozygous or heterozygous.

It is generally used to identify the genotype of hybrid form. The progenies are observed. If all progeny demonstrates only dominant form of trait thereby indicating that unknown genotype must be homozygous for the particular trait. Or, if F1 progeny shows both dominant and recessive form of trait in the ratio of 1: 1 indicating that unknown genotype must be heterozygous for the particular trait.

There can be two possible genotypes of an unknown dominant phenotype as illustrated below.

Possibility 1. If the unknown is homozygous yellow (YY), then crossing with green recessive (yy) gives all yellow offspring (*i.e.*, all Yy) as shown below.

Possibility 2. If the unknown is heterozygous yellow (Yy), then crossing with green recessive results in 50% yellow (Yy) and 50% green (yy) progeny as shown below.

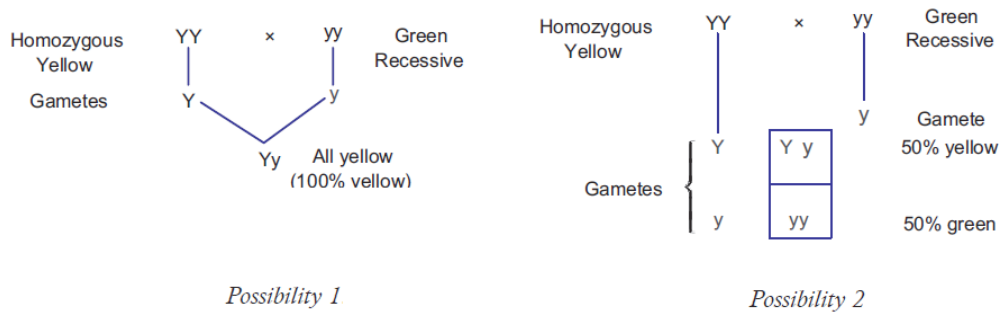


Figure 9.5: Test cross in monohybrid crosses

Application Activity 9.2

1. Complete the table below about the number of chromosomes

Organisms	Body cell (2n)	Gamete (n)
Gorilla	48	24
Fruit fly	8	4
Cotton	52	26

a) How many chromosomes does a gorilla receive from its father?

b) What is the number of sex chromosomes in an egg cell of a fruit fly?

c) What is the number of autosomes in a leaf cell of a cotton plant?

d) What is the number of autosomes in a sperm cell of a gorilla?

2. A plant with terminal flowers stems is crossed with a plant with axial flowers. All F1 plants produced had axial flowers, use genetic diagram to answer the following questions:
   a) Which allele is dominant?
   b) With a punnet square, show the genotypic and phenotypic ratio of the F1 and F2 generation.
   c) If there are 360 plants with axial flowers in the F2 generation, what is the number of plants with terminal flowers?

9.3. Co-dominance, multiple alleles and lethal alleles

Activity 9.3

Analyze the photo below and answer the questions that follow:

The cow observed on the photo has a roan coat colour. The roan coat of this shorthorn cattle is made up of red and white hairs. Alleles that behave like this are said to be codominant. Therefore, cattle with a roan coat are heterozygous for coat color. It is an offspring of a cross between a red bull cattle and white cow. Explain how this mode of transmission differs with complete dominance? Prove it using genetic diagram.

a) Co-dominance

Co-dominance occurs when **both traits appear in a heterozygous offspring**. Neither allele is completely dominant nor completely recessive. For example, roan shorthorn cattle have codominant genes for hair color. The coat has both red and white hairs. The letter **R** indicates red hair color and **W** white hair color.

In cases of codominance, the genotype of the organism can be determined from its phenotype. The heifer below is **RW** heterozygous for coat color.

Figure 9.6. The roan coat in cow

The roan coat of this shorthorn heifer is made up of red and white hairs. Both the red and white hair alleles are codominant. Therefore, cattle with a roan coat are heterozygous for coat color (**RW**).

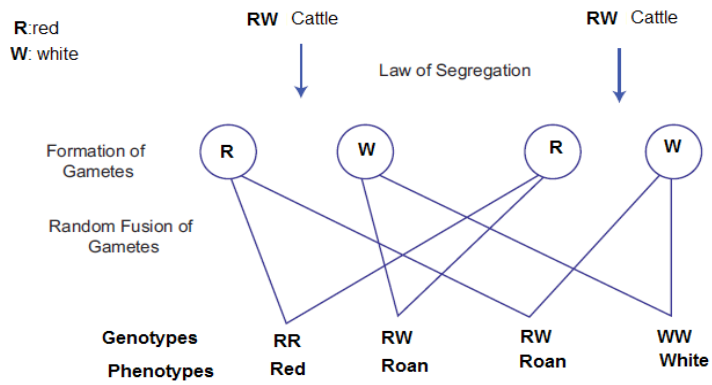


Figure 9.7: *Cross between heterozygous RW cattle demonstrating co-dominance and characteristic phenotypic ratio 1 red: 2 roan: 1 white.*

b) Incomplete Dominance

Incomplete dominance occurs when **the phenotype of the offspring is somewhere in between the phenotypes of both parents**; a completely dominant allele does not occur.

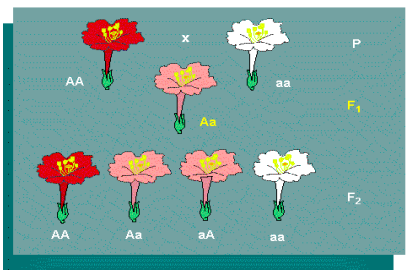


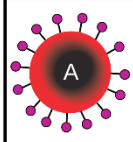
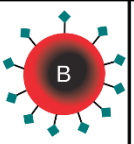
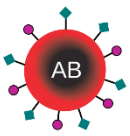
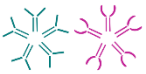
Figure 9.7: Incomplete dominance

c) Multiple alleles

When three or more alleles determine a trait, the trait is said to have **multiple alleles**. The human **ABO** blood group is controlled by a single gene **I** (I stands for **isohaemagglutinogen**) with three alleles: $\mathbf{I^A}$, $\mathbf{I^B}$, and the recessive **i** allele. The gene encodes an enzyme that affects carbohydrates that are found on the surface of the red blood cell. **A** and **B** refer to two carbohydrates found on the surface of red blood cells. There is not an **O** carbohydrate. Type **O** red blood cells do not have either type **A** or **B** carbohydrates on their surface.

The alleles $\mathbf{I^A}$ and $\mathbf{I^B}$ are dominant over **i**. A person who is homozygous recessive **ii** has type **O** blood. Homozygous dominant $\mathbf{I^AI^A}$ or heterozygous dominant $\mathbf{I^Ai}$ have type **A** blood, and homozygous dominant I^BI^B or heterozygous dominant $\mathbf{I^Bi}$ have type B blood. $\mathbf{I^AI^B}$ people have type **AB** blood, because the **A** and **B** alleles are codominant. Type **A** and type **B** parents can have a type **AB** child. Type **A** and a type **B** parent can also have a child with Type **O** blood, if they are both heterozygous (***I^Bi***, ***I^Ai***). The table below shows how the different combinations of the blood group alleles can produce the four blood groups, **A**, **AB**, **B**, and **O**.

Table 9.1: Blood groups

	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red Blood Cell	 A antigen	 B antigen	 A and B antigens	None
Genotypes	I^AI^A, I^Ai	I^BI^B, I^Bi	I^AI^B	ii

d) Lethal Alleles

Sometimes genes have serious effect on development, physiology of the organism in such a way that organism is unable to survive. Such genes are known as **lethal genes**. The particular allele responsible for death of the organism is known as **lethal alleles**. **Lethal allele** can be dominant or recessive.

For example: The dominant allele A in chicken has serious effect on development of the organism and results in following phenotype:

- Aberrant form "creepers" in Heterozygous individual (**Aa**)
- Completely "lethal" in homozygous dominant (**AA**).

When two heterozygous creeper individuals are mated, progeny are obtained in phenotypic ratio of 2 (Creeper): 1(Normal) instead of 3: 1 monohybrid Mendelian ratio (Figure 9.8).

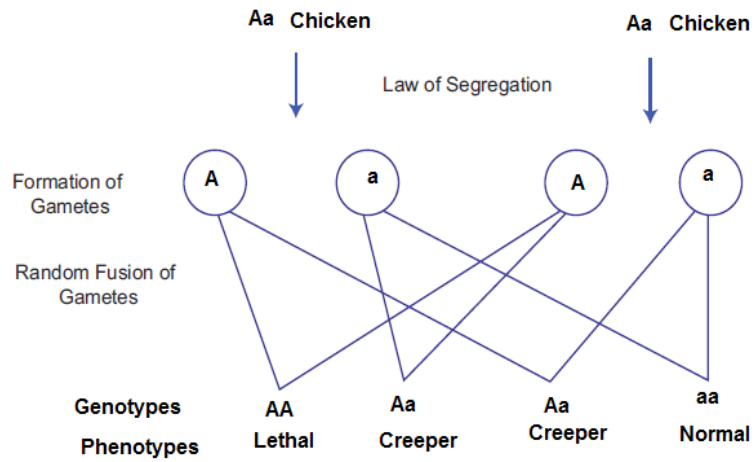


Figure 9.8: *Cross between two creepers chickens demonstrating lethality and characteristic ratio 2 Creeper: 1 normal*

Application Activity 9.3

1. When red-flowered petunia plants are crossed with white-flowered plants, all the resulting F1 plants have pink flowers.
   a) Explain how this is possible using genetic diagrams.
   b) The F_1 plants are crossed to produce an F_2. Draw a genetic cross to show the genotypes and phenotypes of the F_2 plants.
2. A man with blood group B marries a woman with blood group AB. Indicate the type of blood group that their children will not have. Show your working.

9.4. Sex determination and sex linkage

Activity 9.4

1. Explain why when a woman is pregnant, she has equal chance of producing either a baby boy or a baby girl.
2. The **colourbliness** is the vision affection that makes someone to confuse red and green colours while the **haemophylia** is an

affection that makes blood failure to clot.

When a colourblind man get married to a wife with normal colour vision, none of their children will be colour blind but when a man with normal colour vision gets married to a colourblind woman, all their sons will be colourblind whilst none of their daughters will be colourblind.

Explain why diseases such as colourblindness and haemophylia are most frequent in males than in females?

Mostly, the organisms that produce their progeny using sexual reproduction have two sexes, male and female. Occasionally, there are hermaphrodites which have characteristics of both sexes. Sex determination is the biological system which initially determines sex of the organism while development.

9.4.1. System for Sex Determination

Based on whether genes play an important role in sex determination, there are two types of systems:

a) Genetic sex determination in which chromosomes (especially sex chromosomes) play an important role in determining sex of the individual. For example: mammals

b) Non-genetic sex determination in which other environmental factors such as diet, temperature etc., play an important role in sex determination. For example: Certain reptiles

9.4.2. Sex Determination in Humans

In humans and other placental mammals, male and female differ in their chromosome complement. Generally, there are two types of chromosomes, autosomes and sex chromosomes. Generally, in one sex (mostly female), both the sex-chromosomes are alike/**homogametic** (**XX**) and in other sex (male), there are two different/**heterogametic** sex chromosomes (**XY**).

As the females are homogametic (44 autosomes and **XX)**, they produce single type of ovum, containing 22 autosomes and one **X** chromosome while males are **heterogametic** (44 autosomes and **XY**) and therefore, they produce two types of sperm, one containing 22 autosomes and an **X** chromosome while other with 22 autosomes and a **Y** chromosome. It is the sex chromosome present in the fertilizing sperm which determines the sex of an individual. **Y** chromosome has Testis determining factor (TDF) gene which produces testis determining factor which causes primordial gonadal tissue in developing foetus to differentiate into testis. In the absence of TDF, tissue differentiates into ovaries. So, the

- Individuals with **Y** chromosome are genetically male.
- Individuals without **Y** chromosome are genetically female.

Thus, the sex in human is determined at the moment of conception or fertilization of male (sperms) and female gamete (ovum). If ovum gets fertilized by sperm containing an **X**-chromosome, then resulting zygote will have two **XX** chromosomes and will develop into female.

But if ovum gets fertilized by sperm containing a **Y**-chromosome, then resulting zygote will have two **XY** chromosomes and will develop into male. So biologically, father is responsible for sex of the child.

9.4.3. Sex Linkage

There are certain genetic traits, the expression of which depends upon sex of the individual or inheritance of sex chromosomes. The transmission of such traits (or alleles responsible for traits) is tied up or linked with the sex chromosomes; inheritance pattern of such genes is known as **sex-linked inheritance**. The phenomenon is called as **sex linkage**.

Sex linkage was first demonstrated in 1910 by Morgan while working with white-eye (mutant) Drosophila. He carried several breeding analysis with white-eyed male drosophila and red-eye female drosophila. The F1 flies (male and female) are all red-eyed. On mating F1 male and female, he found F2 flies with red-eye and white eye in the ratio of 3 : 1 in accordance with Mendelian monohybrid ratio thereby concluding that white-eye colour is recessive character. In Mendel's cross, expression of recessive trait in F2 is not associated with sex of the individual. Strangely, he observed that all F2 white-eye flies were male just like their grandfather (Table 9.2).

Table 9.2: ***Summary of Morgan breeding experiment of cross between white eye male and red eye female***

Parents	**F1 (Expected Phenotype)**	**F2 (Observed Phenotype)**
Red-eye female flies and white-eye male flies	F1 all red-eye flies	F1 all red-eye flies
F1 male and female	F2 75% red-eye flies (male and female) 25% white-eye flies (male and female)	F2 50% red-eye flies (all female) 25% red-eye male flies 25% white-eye male flies

Morgan explained that the recessive allele must have been associated with **X** chromosome. Males have one **X** chromosome only unlike female which carries two **X** chromosome so they are hemizygous (only one allele for a gene) for **X-**linked genes.

In this experiment, white-eye male parent must have transferred its **X** chromosome to all F1 females and **Y** chromosome to all sons. F1 females are heterozygous carrying one normal **X** chromosome with normal eye colour i.e., red and other **X** chromosome with white eye gene while F1 males had one normal **X** chromosome from their mother, thus had red-eyed and **Y** chromosome from father.

The F2 males obtained their **X** chromosomes from heterozygous F1 mothers. The half of the F2 males received normal **X** chromosome while other half received **X** chromosome with recessive allele hence developed white-eyes (Figure 17.14).

F1 red-eye female flies (XX^w) **X** F1 red-eye male flies (XY)

Chromosomes segregation in the gametes

Female gametes

F2 generation

Male gametes	Gametes	X	Xw
	X	XX Red eye female	X^wY Red eye female
	Y	XX Red eye male	X^wY White eye male

Figure 9.9: *A cross between F1 red-eye male and female representing sex-linked inheritance of trait to F2 generation*

There are two types of sex-linked inheritance:

1. **Genes located on X chromosomes demonstrate X-linked inheritance.** It is of two types' X-linked recessive inheritance and X-linked dominant inheritance.

X-linked recessive inheritance, gene causing a mutant phenotype (variant phenotype) is recessive. It is more common in male. As male has single X chromosome only, they are pure for X-linked genes (hemizygous). While for female to express X-linked recessive trait, both the X chromosome should carry recessive allele. Here, criss-cross inheritance pattern is seen when recessive trait from male are transmitted through their daughter to their grandson. For example:

- Hemophilia A in human, here individuals lack a clotting factor; thus, a minor cut may cause excessive bleeding. It follows X-linked recessive inheritance. Possible genotype and phenotype are illustrated in the **table 9.2**

Table 9.3: Possible genotype and phenotype for haemophilia

Genotype	Phenotype
X^HX^H	Healthy female.
X^HX^h	Healthy female who is a **carrier**.
X^hX^h	Hemophilic female
X^HY	Healthy male.
X^hY	Hemophilic male.

X-linked dominant inheritance: Here, the gene causing for a mutant phenotype (variant phenotype) is dominant. It is less common than X-linked recessive trait. Only a few X-linked dominant traits have been identified. For example:

- X-linked hypophosphatemia is X-linked dominant trait that can cause bone deformity in human.

2. **Genes located on Y-chromosomes demonstrate Y-linked inheritance.** Here, genes are transmitted according to inheritance of Y chromosomes. All males receive Y chromosome from their father, so here Y-linked genes (hence their information) are directly passed from father to son. This type of inheritance is also known as **Holandric** ("wholly male") inheritance.

   It never appears in female. Y chromosome has very few genes. A few traits are Y-linked because Y – chromosome is small seized than X – chromosome. For example:

- Hairy ears trait in human in which bristly hairs grow from ear.

9.4.4. Genetic disorders

Genetic disorders are the diseases which are caused by abnormalities in genetic information of the organisms. Genetic diseases are quite rare in population and their frequency varies from 1: 1000 to 100,000.

There are three types of genetic diseases:

Single gene disorder: caused by abnormalities in single gene so that its product becomes either non-functional or abnormal. **For example:** haemophilia.

Polygenic genetic disorder: caused by abnormalities in more than one gene. **For example:** cancer, diabetes etc.

Chromosomal genetic disorder: caused by change in the structure (deletion, duplication) or number of chromosomes (chromosomes becomes high or less 47, 45 etc). **For example:** Turner's syndrome, klinefelter's syndrome.

a) Single-Gene Genetic Disorder

There are two types:

i). Autosomal-linked disorder: in this case, the affected gene is located on the autosomes and it can be dominant or recessive.

In autosomal dominant, the affected gene allele is dominant in its expression. Only one allele is sufficient to cause the disease in affected person. Affected person will have 50% chance to pass it to offspring if he or she marries a normal person and it inherits in every generation in affected person's family.

For example: Huntington's disease is a neurodegenerative genetic disease that affects muscle coordination.

In autosomal recessive, affected gene allele is recessive. Both copies of allele must be recessive for a person to be affected by the disease. An affected person usually has unaffected parents who each carry a single copy of the mutated gene.

For example: Albinism disease which is characterized by the complete or partial absence of the pigment in the skin, hairs and eyes.

ii). Sex-chromosome linked disorder: here the affected gene is located on the sex chromosome. Inheritance of this genetic disorder depends upon sex of the affected person.

In X-chromosome dominant, the affected gene is dominant and present on the X-chromosomes. The female with X-linked disease (**XX***) when marries a normal man (**XY**), has 50% chance of having an affected offspring.

The male with X-linked disease (**X*Y**) when marries a normal woman (**XX**), has all affected daughters (**XX***) but sons will be unaffected.

For example: X-linked hypophosphatemia which causes bone deformity.

In **X-chromosome recessive**, the affected is recessive and is present on the **X**-chromosome. It is more common in males. The male with X-chromosome linked genetic disease will have normal sons and daughter but pass trait to half of their grandson.

The female with one mutant allele and one normal allele (XX*) will have 50% chance of having affected sons but 100% chance of unaffected daughters.

For example: Haemophilia

Y-linked genetic disease: It is caused by mutation in the gene located on the **Y** chromosome. It only appears in male. The disease is always transferred from father to son.

For example: hairy pinna

Application Activity 9.4

1. Jean is red-green colour-blind, and he has married Josine, who has normal vision. Josine does not know if she is a carrier or not. They have two sons and one daughter. One son is red-green colour-blind. The other two children have normal vision.
   a) Use one or more Punnett squares to work out Josine's genotype.
   b) What is the chance that the couple's next child will be a colour-blind girl?
   c) What is the phenotypic ratio for sons and daughters separately if Josine is NOT a carrier?
2. A carrier hemophilic female married a normal male and produced children. In a full genetic explanation, show the inheritance of sex-linked allele for hemophilia in this family.

Skills Lab 9

A blood sample is needed and will be drawn from a vein. The test to determine your blood group is called ABO typing. Your blood sample is mixed with antibodies against type A and B blood, and the sample is checked to see whether or not the blood cells stick together (agglutinate). If blood cells stick together, it means the blood reacted with one of the antibodies.

Blood typing is also done to tell whether or not you have a substance called Rhesus factor (Rh) on the surface of your red blood cells. If you have this substance, you are considered Rh^+ (positive). Those without it are considered Rh^- (negative). Rh typing uses a method similar to ABO typing.

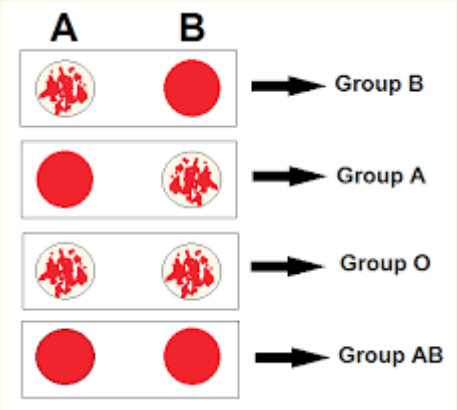


Figure 9.10: blood group determination

END UNIT ASSESSMENT 9

I. Choose whether the following statements are True (T) or False (F)

1. Heredity is the transfer of traits from one parent to offsprings.
2. In the monohybrid cross between tall and dwarf plants, second generation plants are all tall.
3. In codominance, both the alleles of gene are equally expressed.
4. The genes located on same chromosomes are always linked and never assort independently.
5. In humans, XY individual will be male.
6. In recessive genetic diseases, affected person can have one affected and another unaffected homozygous parent.
7. The sex linkage phenomenon was first observed in Drosophila.
8. Non-disjunction of chromosomes can happen at meiosis and mitosis.

II. Multiple Choice Questions

1. Which of the following reasons are true for Mendel's success?
   a) He studied many traits at one time
   b) He worked with pure lines
   c) His model organisms were Homo sapiens
   d) He was a chemist
2. Offsprings produced during first progeny are also known as:
   a) F1 generation
   b) F_2 generation
   c) F3 generation
   d) P generation
3. Mendel was successful in his experiments because garden pea:
   a) Produces large number of offsprings
   b) Has long reproduction cycle
   c) Does not show self-pollination
   d) Has difficulty to grow
4. A gamete has ..... number of alleles for a particular gene:
   a) 0
   b) 1
   c) 2
   d) 3
5. The Phenotypic Mendelian monohybrid ratio can be described as:
   a) 3 : 1
   b) 1 : 2 : 1
   c) 2 : 1
   d) 2 : 2
6. What is Semi-dominance
   a) When both the traits are expressed
   b) When both traits are partially expressed
   c) When both traits are not expressed
   d) When only one trait is expressed
7. Test cross is a cross between
   a) F1 hybrid with any of the parent
   b) F1 hybrid with recessive parent
   c) F1 hybrid with other individual similar to parent
   d) None of the above

III. Long Answers Type Questions

1. Explain the terms gene, locus, allele, dominant, recessive, co-dominant, linkage, test cross, F1 and F2, phenotype, genotype, homozygous and heterozygous.
2. Explain how to conduct a test cross.

3. Explain why monohybrid ratios of 1:2:1 occur.
4. Describe an example of inheritance involving multiple alleles.
5. Explain the effect of lethal genes on phenotype ratios.
6. Explain how the sex is determined in humans and the role of sex related Y genes in determining sex.
7. A woman suffering from red-green colour blindness is very rare, but such a case can arise in families with certain marriages. Give an example of such a marriage and give a full explanation to show how true it is.
8. In maize, the gene for starchy seeds is dominant over that of sugary seeds. Two pure breeding plants were crossed.
   i). What is the phenotype of the first generation seeds?
   ii). These F1 seeds grew into mature plants and were allowed to self-fertilize: what is the expected ratio of starchy to sugary seeds in the second generation plants?
   iii). If this was the practice of a farmer, what was his purpose?
   iv). Describe how the farmer has crossed those two plants? Provide clear identification of the steps followed and a short explanation for each.
9. How can genetic studies be supportive for environment protection? State the role of different genetic aspects to list and cure diseases since ages. What relevance can be cited to support genetics as an important branch of biology?
10. In mice, dominant allele Y is for yellow coat colour while recessive allele y is for agouti coat colour.
    a) The yellow coat colour mice were self-bred. The yellow and agouti mice are produced in the ratio of 2 : 1. What could be the reason for change in Mendelian monohybrid ratio?
    b) What is the genotype of mice having yellow coat colour?

UNIT 10

DIHYBRID INHERITANCE

Key unit competence: Explain the role of genes in inheritance and how genetic disorders occur

Introductory Activity 10

Read the passage below and answer the questions that follow

Suppose that a P3 student asked you to state two physical traits (characters) that can allow him/her to differentiate a Rwandan from a Chinese.

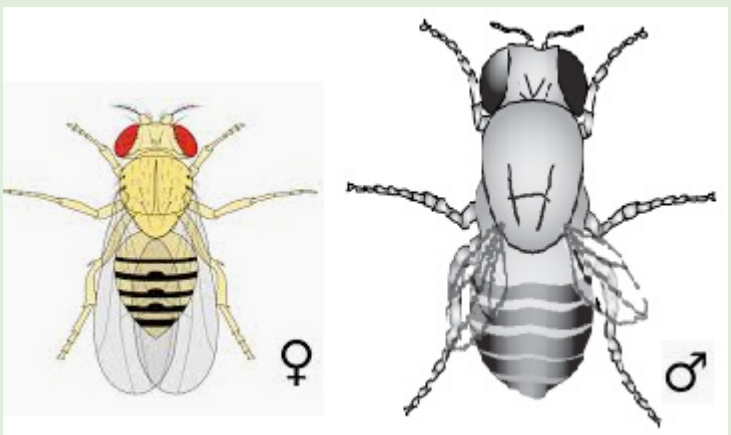
a) What would you tell him/her?

b) Based on the two physical traits mentioned above, predict possible physical treats of children born from a couple of a Chinese and Rwanda.

10.1. Dihydrid inheritance with Free genes

Activity 10.1

The following charts show a female drosophila with long wings and red eyes and a male drosophila with short wings and black eyes. The characters may be located on different chromosomes or located on the same chromosomes.



What will be the character of offspring from the cross between the two parents above if long wings and red eyes characters are dominant over short wings and black eyes characters

Mendel thought how the segregation of alleles for a particular trait at the time of gamete formation (**Principle of segregation**) could be effected with the segregation of alleles for the other traits. With this question in his mind, he carried out similar sets of cross hybridization experiments between parents differing in contrasting set of two traits, (for example, round or wrinkled seed shape and yellow or green seed colour). Such a cross between parents which differs in contrasting form of two traits is known as **Dihybrid cross** or **inheritance**. The F1 progeny generated is known as **Dihybrid**.

The cross was made between the double dominant plants (round seed shape with yellow seed colour) with double recessive parent (wrinkled seed shape with green seed colour) and the following points were observed:

- All round yellow seeds were observed in F_1 generation indicating dominant allele for a gene was expressed in the same manner as in monohybrid cross.
- On self-fertilization of F_1 plants, F_2 seeds were obtained and segregated in the ratio of 9 : 3 : 3 : 1 based on their phenotype.

In addition to parental phenotype combination, two new phenotype combinations/ recombinants (wrinkled and yellow and round and green seeds) were observed. Mendel hypothesized that the allele for different traits separate and assort independently in the gametes (allele for seed shape can assort with any seed colour allele and vice versa) then F_1 plants should produce four types of gametes.

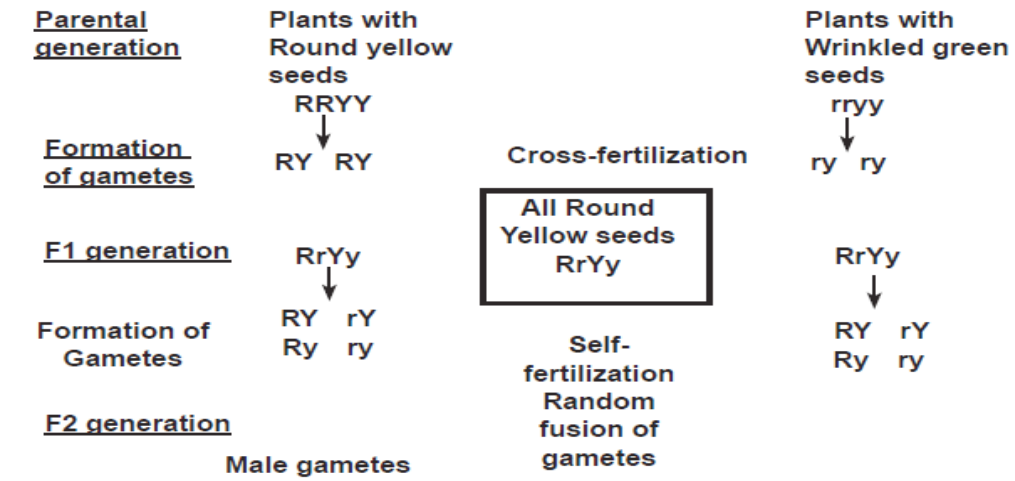
So male and female F_1 plant gametes can fuse randomly and combine in 16 possible ways which can be simply represented by a simple square popularly known as **Punnett's square*** (Figure 10.1).

Mendel observed similar results when he analyzed results of **dihybrid cross** for the other pair of traits as well.

- The dihybrid results did not contradict monohybrid results, the round seeds and wrinkled seeds as well as yellow and green seeds were in ratio of 3: 1. He hypothesized dihybrid cross event as two independent monohybrid cross events.

(***Punnett's square or checker-board:*** square-shaped presentation used to predict result of a particular cross or breeding experiment in which gametes from each parent are placed on the top and left side of the square. This diagram

is used to predict the ratio of genotypes and phenotypes of the individual when gametes from parents randomly fuse. It is named after Reginald C. **Punnett,** who devised the approach.)



	RY	Ry	rY	ry
RY	RRYY (Round and yellow)	RRYy (Round and yellow)	RrYY (Round and yellow)	RrYy (Round and yellow)
Ry	RRYy (Round and yellow)	RRyy (Round and green)	RrYy (Round and yellow)	rrYy (Round and green)
rY	RrYy (Round and yellow)	RrYy (Round and yellow)	rrYY (wrinkled and yellow)	rrYy (Round and yellow)
ry	RrYy (Round and yellow)	Rryy (Round and green)	rrYY (wrinkled and yellow)	rryy (wrinkled and green)

Figure 10.1: *A dihybrid cross between plants with dominant round yellow seeds with plants with recessive traits wrinkled and green seeds through two generations*

The phenotypic ratio is: **9** Yellow - Round: **3** Yellow – wrinkled: **3** green - Round: **1** green : wrinkled.

Note: The genotypes can be seen in specific locations as seen below in this table where every genotype has a specific colour

Table 10.1. F2 dihybrid inheritance

Gametes	YR	Yr	yR	yr
YR	YYRR Yellow / Round	YYRr Yellow / Round	YyRR Yellow / Round	YyRr Yellow / Round
Yr	YYRr Yellow / Round	YYrr Yellow / wrinkled	YyRr Yellow / Round	Ttrr Yellow / wrinkled
yR	YyRR Yellow / Round	YyRr Yellow / Round	yyRR Green / Round	yyRr Green / Round
Yr	YyRr Yellow / Round	Yyrr Yellow / wrinkled	yyRr Green / Round	yyrr Green / Wrinkled

Ratio of phenotypes: 9 Yellow / Round: 3 green / round: 3 Yellow / Wrinkled: 1 short/Red

Ratio of genotypes: 1 YYRR: 2 YYRr: 1YYrr: 2 YyRR: 4 YyRr: 2 Yyrr: 1 yyRR: 2 yyRr: 1 yyrr

Law of Independent Assortment

From the result of dihybrid cross experiments, Mendel gave the following postulates:

- The dominant allele of a particular gene is expressed in the presence of alleles of other genes for different traits.
- On self-fertilization of F1 plants, F2 plants were observed in the phenotypic ratio 9:3:3:1 (Dihybrid ratio). He concluded that factors for different traits assort segregate and assort independently in the gamete. This is popularly known as Law of Independent Assortment.

a) Significance of Test Crosses in Dihybrid Inheritance

Test cross can be used to differentiate genotype of dihybrid organisms (whether it is homozygous or heterozygous for the traits) which are phenotypically the same for a trait.

For example: plants with similar phenotype rounded seed shape and yellow seed colour can have different genotype RRYY or RrYy. So the genotype of such

plants can be identified by test cross. So, the plant with unknown genotype is crossed with plant with recessive form of both the traits. There are two possibilities.

1. If progeny plants are observed in phenotypic dihybrid test ratio 1 (round and yellow):1 (round and green):1 (wrinkled and yellow):1 (wrinkled and green), then the parent plant must have heterozygous genotype for both the traits (Figure 10.2).

Expected ratio for dihybrid test cross

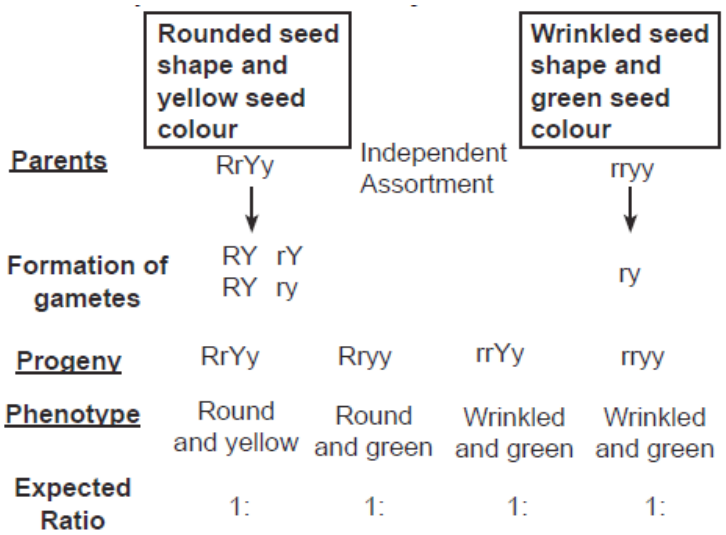


Figure 10.2: Dihybrid test cross ratio when plant has dominant heterozygous genotype for two traits

2. If after the cross all the plants are formed with dominant phenotype i.e., round seed shape and yellow seed colour, it indicates that given parent plant must have homozygous genotype for both the traits.

b) Co-dominance in dihybrid

Co-dominance occurs when both two traits considered appear in a heterozygous offspring or there are intermediate traits. Neither allele is completely dominant nor completely recessive. For example, pink and semi-good smelling fruit may result a cross between white and good smelling fruits with red and bad smelling fruits. The letter **R** indicates red color, **S** bad smelling and **W** white color, **G** for good smelling.

In cases of codominance, the genotype of the organism can be determined from its phenotype. The heifer below is **RWSG** heterozygous for traits.

Application Activity 10.1

1. A homozygous purple-flowered short-stemmed plant was crossed with a homozygous red-flowered long-stemmed plant and the F1 phenotypes had purple flowers and short stems. When the F1 generation was test crossed with a double homozygous recessive plant, the following progeny were produced.
   - 52 purple flower, short stem
   - 49 red flower, short stem
   - 47 purple flower, long stem
   - 45 red flower, long stem

   Explain these results fully.
2. In tomatoes, the allele for red fruit, R, is dominant to that for yellow fruit, r. The allele for tall plant, T, is dominant to that for short plant, t. The two genes concerned are on different chromosomes.
   a) A tomato plant is homozygous for allele R. Giving a reason for your answer in each case, how many copies of this allele would be found in:
      i). A male gamete produced by this plant.
      ii). A leaf cell from this plant.
   b) A cross was made between two tomato plants.
      i). The possible genotypes of the gametes of the plant chosen as the male parent were RT, Rt, rT and rt. What was the genotype of this plant?
      ii). The possible genotypes of the gametes of the plant chosen as the female parent were rt and rT. What was the genotype of this plant?
      iii). What proportion of the offspring of this cross would you expect to have red fruit? Use a genetic diagram to explain your answer.

10.2. Linkage and crossing over

Activity 10.2

According to chromosomes theory of Inheritance, it is the chromosomes which segregate and assort independently in the gametes.

a) what happens to genes located on same chromosome?
b) Do they always remain together or linked (exception to law of independent assortment)?
c) Or, do they segregate and assort independently, if yes what could be the mechanism.

There are cases when genes (present on the same chromosome) for different traits do not show independent assortment, inherit together and behave as if genes are linked; the phenomenon is known as linkage.

For example: two genes for trait flower colour and pollen grain texture in sweet pea (*Lathyrus odoratus*) where blue flower colour (B) allele is dominant over red flower colour (b) and long pollen (L) is dominant over round pollen (l). A test cross was carried out between heterozygous plant with double homozygous recessive plant (bbII), the observed phenotype had higher frequency of parental phenotype (87.4%) and lower frequency of recombinants phenotype (12.6%) in contrast to expected dihybrid test ratio (figure 10.1). It indicated that genes do not assort independently and appear as if they are linked. However, occasionally they may separate therefore resulting in lower frequency of recombinants.

Such genes are identified as linked when present on the same chromosome and do not assort independently and tends to form parental phenotype but occasionally they may separate resulting in low recombinants frequency. This phenomenon is known as linkage.

Table 10.2: *Observed dihybrid test cross frequency exception to law of independent assortment*

Phenotype	**Observed frequency**	**Expected frequency if assorted independently**
Blue and long (parental)	43.7%	25%
Blue and round	6.3%	25%
Red and long	6.3%	25%
Red and round (parental)	43.7%	25%

Now the question arises what could be the possible mechanism for the separation of the genes located on the same chromosomes. The answer is crossing-over or recombination. Crossing-over is the physical exchange of chromosome parts between non-sister chromatids of the homologous chromosomes during meiosis division. The chiasma formation (observed by Janssens in 1909) clearly provides the site at which non-sister chromatids of paired homologous chromosomes cross over. The cross-over event between two gene loci in non-sister chromatids is responsible for formation of recombinant chromatids and their separation.

Significance of Recombination/crossing-over

- The major significance is generation of variations. Due to crossing over, genes even on the same chromosome can be assorted differently. It leads to variations in the progeny. The variations are very useful in nature as it provides raw material on which natural selection can act.

- The frequency of crossing over becomes higher with increase in physical distance between gene loci. So recombinant frequency between two genes can be used to determine distance between genes, hence it helps to create chromosome map.
- The recombination frequency or crossover frequency or **crossing-over value** (COV) is calculated using the formula:

$$Recombination\ frequency = \frac{Number\ of\ individuals\ showing\ recombination \times 100}{Number\ of\ offspring}$$

Application Activity 10.2

Pure-breeding Drosophila with straight wings and grey bodies were crossed with pure-breeding curled-wing, ebony bodied flies. All of the offspring were straight-winged and grey-bodied. Female offspring were then test-crossed with curled-wing, ebony-bodied males, giving the following results.

Straight-wing, grey body	113
Straight-wing, ebony body	30
Curled-wing, grey body	29
Curled-wing, ebony body	115

a) State the ratio of phenotypes expected in a dihybrid test cross such as this.

b) Explain the difference between the expected result and the results given.

c) Calculate the crossover value.

10.3. Mutations

Activity 10.3

Read the sentence below and answer to the questions that follow:

THE BIG FAT CAT ATE THE RAT

a) What would happen if T in the word CAT is replaced by R?

b) What would happen if word **CAT** is doubled ?

c) Which one of the following can have a great effect on the meaning of the sentence: removing one letter or adding one letter to the sentence? Compare the effect to that of the development of body parts.

Mutations are changes in the genetic material of a cell (or a virus). If a point mutation occurs in a gamete, or in a cell that gives rise to gametes, it may be transmitted to offspring and to a succession of future generations. If the mutation has an adverse effect on the phenotype of a human or other animal, the mutant condition is referred to as a genetic disorder, or hereditary disease.

Mutations can broadly be categorized into two types (figure 10.3): gene mutations and chromosomal mutations.

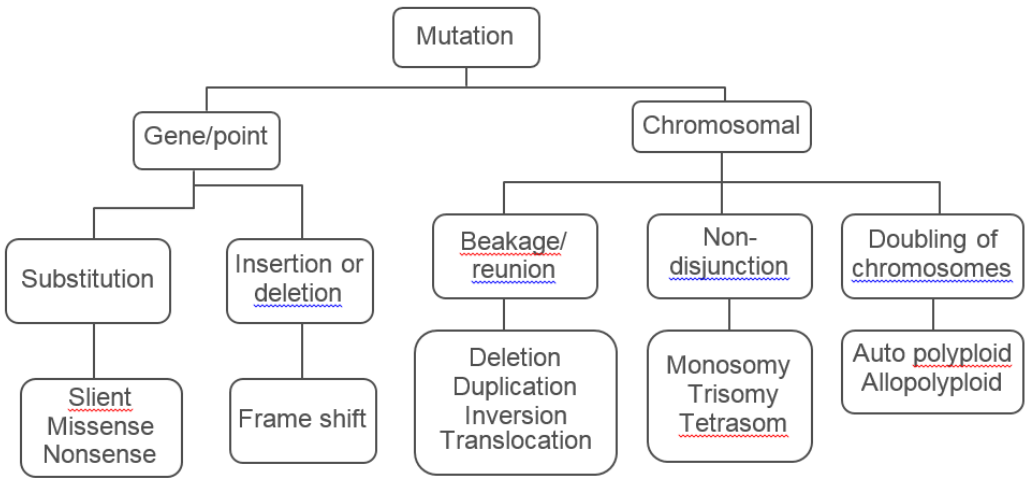


Figure 10.3:Types of mutation

1. Gene Mutations (Point mutation)

A gene mutation is a permanent alteration in the DNA sequence that makes up a gene, such that the sequence differs from what is found in most people.

Gene mutations involve single nucleotides and can occur by one of the following mechanisms:

Substitution is the replacement of one base by another. One purine replaced by another purine or pyrimidine replaced by another pyrimidine is called **transition**. However, pyrimidine replacing purine or purine replacing pyrimidine is called **transversion**.

Silent mutation, when the triplet codon continues to code for the same amino acid because genetic code is degenerated, or the amino acid substituted has similar chemical property causing no change in the function of the protein or the change has occurred in non-coding region of DNA.

Missense mutation, when substitution of a base produces a codon that causes incorporation of a different amino acid. If the amino acid added is chemically similar to the original amino acid, it is called **conservative missense mutation** but if the amino acid added is chemically dissimilar, it is called **non-conservative missense mutation**.

Nonsense mutation, when substitution of a base leads to the formation of a stop codon, terminating protein synthesises at that point. Polypeptide, thus formed, is incomplete and hence non-functional.

I**nsertions** are mutations in which extra base pairs are inserted into a new place in the DNA.

Deletions are mutations in which a section of DNA is lost, or deleted.

a) Cause of gene mutations

Natural exposure of an organism to certain environmental factors, such as ultraviolet light and chemical carcinogens (e.g., aflatoxin B1), also can cause mutations. A common cause of spontaneous gene mutations is the deamination of cytosine to uracil in the DNA double helix. Another cause of spontaneous mutations is copying errors during DNA replication.

b) Effect of gene mutations

When a mutation alters a protein that plays a critical role in the body, it can disrupt normal development or cause a medical condition. A condition caused by mutations in one or more genes is called **a genetic disorder**. In some cases, **gene mutations** are so severe that they prevent an embryo from surviving until birth. Examples of gene mutations are:

Sickle cell anemia is a genetic disease with severe symptoms, including pain and anemia. Sickle cell anemia (sickle cell disease) is a disorder of the blood caused by inherited abnormal hemoglobin (the oxygen-carrying protein within the red blood cells). The abnormal hemoglobin causes distorted (sickled appearing under a microscope) red blood cells.

The disease is caused by a mutated version of the gene that helps make hemoglobin a protein that carries oxygen in red blood cells. People with two copies of the sickle cell gene have the disease. People who carry only one copy of the sickle cell gene do not have the disease, but may pass the gene on to their children.

The mutations that cause sickle cell anemia have been extensively studied and demonstrate how the effects of mutations can be traced from the DNA level up to the level of the whole organism. Consider someone carrying only one copy of the gene. She does not have the disease, but the gene that she carries still affects her, her cells, and her proteins.

Color blindness (or, more accurately, color vision deficiency) is an inherited condition caused by gene mutation and affects males more frequently than females. Red-green color deficiency is the most common form of color blindness.

Haemophilia is a mostly inherited genetic disorder that impairs the body's

ability to make blood clots, a process needed to stop bleeding. This results in people bleeding for a longer time after an injury, easy bruising, and an increased risk of bleeding inside joints or the brain.

2. Chromosomal mutation

Chromosomal mutation is any change or error that occurs within the chromosome. Unlike gene mutations that involve the alteration of a gene or a segment of DNA in the chromosome, chromosomal mutations occur and change the entirety of the chromosome itself.

a) Causes of chromosomal mutation

A chromosome mutation is an unpredictable change that occurs in a chromosome. These changes are most often brought on by problems that occur during meiosis (division process of gametes) or by mutagens (chemicals, radiation, etc.). Chromosome mutations can result in changes in the number of chromosomes in a cell or changes in the structure of a chromosome. Unlike a gene mutation which alters a single gene or larger segment of DNA on a chromosome, chromosome mutations change and impact the entire chromosome. Abnormal chromosome numbers result from non-disjunction, or the failure of chromosomes to separate correctly during cell division.

b) Effect of chromosomal mutation

Some disorders caused by the non-disjunction of chromosomes are:

- **Trisomy 21: Down Syndrome**

One of the most common chromosome abnormalities is Down Syndrome, due to non-disjunction of chromosome 21 resulting in an extra complete chromosome 21, or part of chromosome 21. Down syndrome is the only autosomal trisomy where an affected individual may survive to adulthood. Individuals with Down Syndrome often have some degree of mental retardation, some impairment of physical growth, and a specific facial appearance. With proper assistance, individuals with Down Syndrome can become successful, contributing members of society. The incidence of Down Syndrome increases with maternal age.

- **Abnormal Numbers of Sex Chromosomes**

Sex-chromosome abnormalities may be caused by non-disjunction of one or more sex chromosomes. Many conditions are known in which there are an abnormal number of sex chromosomes.

An X chromosome may be missing (XO), or there may be an extra one (XXX or XXY). There may also be an extra Y chromosome (XYY). Any combination of X and Y chromosomes, as long as there is a Y chromosome, will produce a male (up to XXXXY). These individuals can lead relatively normal lives, but they cannot have children. They may also have some degree of mental retardation. These syndromes include Klinefelter's syndrome, Turner syndrome and trisomy X.

- **Klinefelter's syndrome** is caused by the presence of one or more extra copies of the X chromosome in a male's cells. Extra genetic material from the X chromosome interferes with male sexual development, preventing the testicles from functioning normally and reducing the levels of testosterone.

  Triple X syndrome (trisomy X) results from an extra copy of the X chromosome in each of a female's cells. Females with trisomy X have a lower IQ than their siblings.

- **Turner syndrome** results when each of a female's cells has one normal X chromosome and the other sex chromosome is missing or altered. The missing genetic material affects development and causes the characteristic features of the condition, including short stature and infertility.

  Some organisms have more than two complete chromosome sets. The general term for this chromosomal alteration is polyploidy, with the specific terms triploidy (3n) and tetraploidy (4n) indicating three or four chromosomal sets respectively.

▪ **Alterations of chromosome structure**

Breakage of a chromosome can lead to four types of changes:

- A deletion removes a chromosomal segment.
- Duplication repeats a segment.
- An inversion reverses a segment within a chromosome.
- A translocation moves a segment from one chromosome to another non-homologous one. The most common type of translocation is reciprocal, in which non-homologous chromosomes exchange fragments. Nonreciprocal translocations, in which a chromosome transfers a fragment without receiving a fragment in return, also occur.

3. Effect of environment on the expression of phenotype

It is not always true that phenotype is completely reflected by genotype. Although our phenotype is governed by our genotype, environment also plays a very important role. It is the close interaction between genotype and environment that determines the phenotype shown by any individual. This can be appreciated by the following examples:

a) A person who has normal genes for making haemoglobin but lacks sufficient iron in the diet develops anaemia. Phenotype of this individual can be reversed by including sufficient iron in the diet.

b) Individual with normal genes can make adequate amounts of thyroid

hormone, thyroxine; yet, in the absence of sufficient dietary iodine, he may develop hypothyroidism.

c) Surrounding temperature can have an important influence on phenotype of individuals by affecting kinetic energy of reacting substances. Plant evening primrose shows red flowers when grown at 23°C and white flowers when grown at 18°C. Siamese cats and Himalayan rabbits (Figure 18.16) show white fur on all parts except nose, ears and paws, as the wild type enzyme responsible for pigment production is functional at the lower temperature present in extremities, but it loses its catalytic Activity at the slightly higher temperature found in the rest of the body.

d) Individuals who are born with a deficiency of phenylalanine hydroxylase enzyme needed to convert phenylalanine to tyrosine, concentration of phenylalanine builds up in the body, especially in the brain causing neurological damage. Phenylalanine free diet allows them to lead a near normal life, without showing the effects of mutation.

4. Significance of mutations

Mutations have played very important roles as discussed below.

Role in evolution:

a) Mutations play the most important role of creating new alleles. If there were no different alleles, all individuals would be homozygous at all loci. Presence of different alleles in individuals of a population is responsible for the diversity seen in any population. For example, blood group alleles IA, IB and IO. So mutation can bring about change in genetic constitution of an organism. So mutations bring genetic polymorphism in population which may or may not lead to evolution.

b) Furthermore, it has been observed that certain African countries show higher incidence of sickle cell allele as compared to other regions. Sickle cell allele somehow confers protection against malaria and hence occurs with higher frequency in those regions where malaria is prevalent. Individuals homozygous for sickle cell allele do not survive as oxygen transport to tissues is affected and individuals homozygous for the normal allele may suffer from malaria. Hence, mutant allele in this case happens to confer an advantage in the heterozygous condition.

c) Mutations have another very important consequence. Rapid rate of mutation in bacteria and viruses has helped them evolve resistance not only to our immune system but also to various antibiotics. Thus, treatment against diseases caused by these microbial organisms is becoming increasingly difficult.

i). Role in genetic research: Humans have around 20,000 genes. Although, scientists know the functions of a number of genes, vast majority of the genes have still not been assigned function. To study the function of a gene, researchers induce mutations in specific genes and look for possible effects. Thus, induced mutagenesis is helping us gain insight into genetics of cell cycle control points and hence the cells becoming cancerous. Cytogenetic studies have revealed a high degree of correlation between chromosomal rearrangements and leukaemias.

ii). Mutations play an important role in agriculture as well by providing diversity of alleles which may confer stress resistance, yield and regional adaptability.

d) Every day, we are exposed to a large number of chemicals in our environment such as food additives, colouring agents in food items, textile dyes, cosmetics, pesticides, industrial compounds and so on. Some of these chemicals have mutagenic effects, and can cause genetic diseases.

Application Activity 10.3

Suggest why:

a) A mutation in which one nucleotide of a triplet code is altered often makes no difference to the protein molecule coded by the DNA.

b) The addition or deletion of three nucleotides in the DNA sequence of a gene often has less effect on the encoded protein than the addition or deletion of a single nucleotide.

Skills Lab 10

A Rwandan rabbit farmer had a huge market of supplying rabbit meats in Kigali hotels. He gets a loan from SACCO with the purpose of solving the problems of rabbit meat scarcity according to the market.

After a deep analysis of the market, he decides to increase the quantity of meat production by improving his farming (Removing bad breeds and introducing good breeds) and by increasing rabbit population in his farm.

As student-teacher in Y2 you are called by this rabbit farmer in selection of good breeds to rear that should be introduced in her/his farm and to remove from it non-productive breeds; to show him how to handle and place rabbits in cages according to age and sex; to show him rabbits feeds at each rabbit growth level and to select rabbit breeds to cross between them.

The rabbit cages are well constructed.

Farm where to buy new breeds is available.

All kinds of rabbit feeds are available.

The farmer has materials, equipments and labour required

Tasks:

- Perform selection of rabbit breeds
- Perform principles of rabbit breeds crossing
- Observe, record, interpret and present the findings.

END UNIT ASSESSMENT 10

I. Choose whether the given statements are True (T) or False (F)

1. Mutations can broadly be categorized as somatic and germ-line, depending on whether mutation occurs in a somatic cell or gamete.
2. When breaks occur in chromosomes, their structures do not change.
3. Induced mutation happens due to mutagens (agents that induce mutations).
4. Removal of amino group from a base is called deamination.
5. Albinism is caused by an autosomal recessive mutation.
6. Haemophilia A and Haemophilia B are a result of mutations in different genes.
7. There is no interaction between genotype and environment that determines the phenotype shown by any individual.
8. Sickle cell anaemia is due to a dominant sex-linked allele.
9. Mutagens are DNA sequences which get changed due to radiations and chemicals.
10. Mutation has important role in bacterial resistance to antibiotics.

II. Multiple Choice Questions

1. A point mutation that changes a codon specifying an amino acid into a stop codon is called

   a) missense mutation b) nonsense mutation

c) Frame shift mutation d) silent mutation

2. Sickle cell anaemia results because of
   a) deletion mutation c) substitution mutation
   b) insertion mutation d) chromosomal mutation
3. Which of the following is not ionising radiation
   a) X rays b) cosmic rays c) UV rays d) alpha rays
4. Which of the following chemicals can affect non-replicating DNA?
   a) nitrous acid c) bromouracil
   b) Acridine dyes d) None of the above
5. Phenotype of individual depends upon
   a) environment only c) environment and genotype
   b) genotype only d) mutagens

III. Long Answer Type Questions

1. Describe the types of mutation and causes of mutations.
2. Explain the significance of mutations.
3. Explain that gene mutation occurs by substitution, deletion, inversion and insertion of base pairs in DNA. Outline how such mutations may affect the phenotype.
4. In an experiment, a homozygous tomato plant with a purple hairy stem was crossed with a homozygous tomato with a green, hairless stem. Both purple and hairy are dominant. The F1 plants were allowed to self pollinate to produce an F2. The F2 seeds were planted and the resulting phenotypes are shown below:

Purple, hairy stem	150
Purple, hairless stem	48
Green, hairy stem	15
Green, hairless stem	15

   a) What is the ratio of phenotypes in the F2?
   b) What was the expected ratio of phenotypes? Why?
   c) Why do you think there is a difference between the observed and expected results?

5. Answer the following question on genetics

a) Define the words below

i). Allele

ii). Locus

iii). Autosome

iv). Homologous chromosome

b) State and explain the laws of Mendel.

c) Some coat colours in cats are sex linked. Black coat colour is codominant to ginger. A cat that has one allele for black and one for ginger is tortoiseshell. The gene for this coat colour is carried on the X chromosome. Describe the genotype and phenotype of the offspring of a cross between a pure breeding black female cat and a ginger male cat.

UNIT 11

PHOTOELECTRIC EFFECT

Key unity competence: Evaluate the photoelectric effect

Introductory Activity 11

The above picture is a section of Solar panels that were installed in Rwamagana District to supplement the area in supplying power using solar (sun) energy.

They are very many and they were installed in such a way that each panel supplement the other and much power is generated.

a) Basing on the knowledge you have about solar panels, briefly explain how a solar panel works.

b) Why do you think it was necessary to install these panels in a plain area not may be in a forest?

c) Do you think the amount of energy/power generated during hot season is equal to that one generated during rainy season? Explain your reasoning.

d) Imagine the same project is started in Northern Province like in Gicumbi district, would the project generate the same power as that in Rwamagana?

e) Explain the scientific phenomena that lead to generation of electricity using solar panels.

11.1. Concept of Photoelectric Effect

Activity 11.1

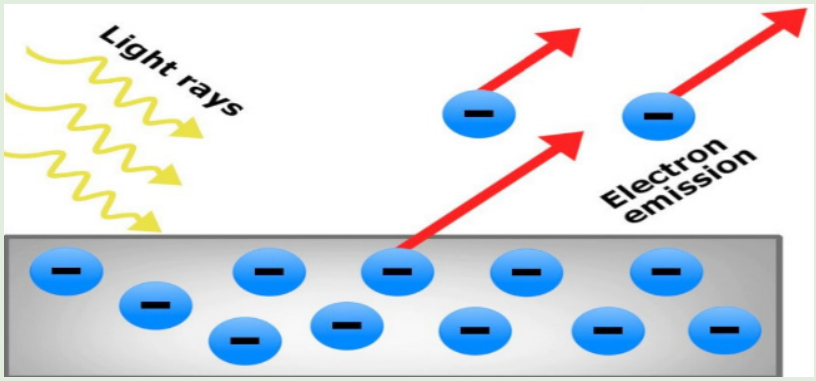


Figure 11.1: Photoelectric effect

The above diagram, shows how particles are ejected from a metal surface after absorbing radiations of a certain frequency.

a) Using knowledge of conduction of electricity, explain why particles were able to break off from the surface as shown in the figure.

b) Discuss some of the factors you think can accelerate or decelerate the rate of emission of particles.

c) Assuming the metal surface was replaced by another of less conductivity, explain how the rate of emission would be affected.

d) How important is phenomena in daily life?

Photoelectric effect is a phenomenon in which electrically charged particles are released from or within a material when it absorbs electromagnetic radiation. The photoelectric effect occurs when light above a certain frequency (the threshold frequency) is shone on metal causing electrons to escape from the metal. The escaping electrons are called photoelectrons. A material that exhibits photoelectric effect is said to be **Photosensitive.**

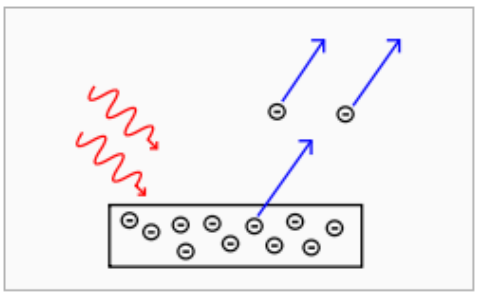


Figure 11. 2: Photoelectric Emission

11.1.1. Photon, work function and Planck' Constant

The photon is the fundamental particle of visible light. Einstein argued that the light is absorbed in quanta of energy equal to Planck's constant (h) times light frequency, hf, by electrons, one at a time.

Work function is minimum amount of energy which is necessary to start photoelectric emission. If the amount of energy of incident radiation is less than the work function of metal, no photo electrons are emitted. In other words, a photoelectric work function must be supplied before the electron can be ejected.

11.1.2. Einstein's equation of photoelectric emission

Since electrons are held in the metal by attractive forces, some minimum energy is required just to get an electron out through the surface. The minimum energy required to release the photoelectron from the metal surface is called the **work function**, ϕ, of the metal. An electron that has received this minimum energy has no kinetic energy once outside the metal. For photoelectric emission to occur, the energy of the photon must be equal to or greater than the work function. If the photon's energy, E, is *just* enough to release a photoelectron, then its frequency is called the **threshold frequency**, f_0:

$$E = hf_o = \phi$$

Where h is the Planck constant $h = 6.63 \times 10^{-34}\ J \cdot s$

If the energy of the photon is greater than the work function, then the photoelectron can acquire some kinetic energy. By energy conservation:

Photon energy = Work done in releasing the electron + Kinetic energy of electron.

This can be written by **Einstein's equation** of photoelectric emission as

$$E = \phi + K_{\max}$$

Where

- $K_{\max} = \frac{1}{2} m v_{\max}^2$ is the maximum kinetic energy of the photoelectron
- $E = hf$ *Photon energy or* energy of the absorbed photons
- $\phi = hf_o$ *Work function or Work done in releasing the electron*

When the photon energy just equals the work function, $\phi = hf_o$ and therefore

$$\frac{1}{2}mv_{\max}^2 = 0$$

In such a case, no photoelectric effect is observed. This happens when the frequency is at threshold level, f_{co} and therefore $\phi = hf_o$

Work function of several metals are shown in Table 11.1

Table 11.1: Work function of several metals

Metal	Work function (J)	Work function (eV)	Meta l	Work function (J)	Work function (eV)
Na (Sodium)	$3{\cdot}8\times10^{-19}$	2.4	Fe (iron)	$6{\cdot}9\times10^{-19}$	4.3
Al (Aluminum)	$3{\cdot}6\times10^{-19}$	4.3	Ag (Silver)	$6{\cdot}9\times10^{-19}$	4.3
Ca (Calcium)	$4{\cdot}5\times10^{-19}$	2.8	Pb (Platinum)	$1{\cdot}0\times10^{-19}$	6.4
Cu (copper)	$7{\cdot}0\times10^{-19}$	4.4	Lead	$6{\cdot}4\times10^{-19}$	4.0

Example 11.1

1. Antimony-cesium has a threshold wavelength of 700 nm. What is its work function in joules?

   Answer

   Using the equations $\phi = hf_o$ and $c = \lambda_o f_o$ and substituting in the resulting equation for ϕ gives:

   $$\phi = \frac{hc}{\lambda_o} = \frac{(6.63\times10^{-34}\ J.s)(3\times10^{8}\ m/s)}{700\times10^{-9}\ m} = 2.84\times10^{-19}\ J$$

   The maximum kinetic energy of the emitted electrons can be measured by using a variable voltage source and reversing the terminals so that electrode C is negative and P is positive. The electrons emitted from P will be repelled by the negative electrode, but if this reverse voltage is small enough, the fastest electrons will still reach C and there will be a current in the circuit. If the reversed voltage is increased, a point is reached where the current reaches zero—no electrons have sufficient kinetic energy to reach C. This is called the ***stopping potential*, or *stopping voltage***, and

from its measurement, can be determined using conservation of energy (loss of in potential energy = gain in kinetic energy):

$$K_{\max} = eV_{co}$$

The minimum potential (or maximum negative potential) for which photoelectric effect is observed **is Cut-off potential.** It is given the symbol V_{co}.

The stopping potential is independent of the radiation intensity. It varies for different substances

At the cut-off potential, the p.d. across the cell is reversed to stop the ejected photoelectrons since energy is given by:

$$E = eV = eV_{co}$$

Where e is the charge on an electron and V is the cut-off potential, this is the energy required to stop the fastest photoelectrons.

A graph of V_o as a function of f turns out to be a straight line, verifying **Einstein's equation for photoelectric effect** Equation,

$$V_o = \frac{hf}{e} - \frac{\phi}{e}$$

From such a graph we can determine

- the work function ϕ for the material
- a value of Planck's constant,
- the threshold wavelength for material

Example 11.2

1. What is the shortest-wavelength X-ray photon emitted in an X-ray tube subjected to 50 kV?

Answer

The electrons striking the target will have a KE of 50 keV. The shortest-wavelength photons are due to collisions in which all of the electron's KE is given to the photon so

$$K = \phi = \frac{hc}{\lambda} \Leftrightarrow \lambda_o = \frac{hc}{eV} = \frac{(6.63\times10^{-34}\ J\cdot s)(3\times10^{8}\ m/s)}{(1.6\times10^{-19}\ C)(5.0\times10^{4}\ V)} = 2.5\times10^{-11}\ m = 0.025\ nm$$

11.1.3. Factors affecting photoelectric emission

Assuming monochromatic light, the two important properties of a light wave are:

- Its **intensity** of light is the rate of energy flow per unit area when the radiation is directed normally to the cross section area:

$$I = \frac{W}{tA} = \frac{P}{A}$$

- Its f**requency** (or wavelength)

When these two quantities are varied, the **experimental** results of **photon theory** make the following predictions:

- **Light intensity**

Law 1: *If the light intensity is increased (means more photons are incident), the number of electrons ejected increases and their maximum kinetic energy of the ejected electrons remains the same, provided the light frequency remains the same.*

In a monochromatic beam, all photons have the same energy $E = hf$. Increasing the intensity of the light beam means increasing the number of photons in the beam, but does not affect the energy of each photon as long as the frequency is not changed.

- **Characteristic of the material being illuminated**

The minimum frequency (or maximum wavelength) for which photoelectric effect is observed is called **Threshold frequency.** It is also called **cut-off frequency** and given the symbol f_{co} *or* f_o. *T*hreshold frequency varies for different materials**.**

Law 2: *Within the region of effective frequencies, that is higher than the threshold frequency, the maximum kinetic energy (K_{max}) of the photoelectrons is directly proportional to the frequency of the incident radiation according to Einstein's equation for photoelectric effect*

$$K = hf - \phi$$

where $\phi = hf_0$

This relationship is plotted in Fig 11.1

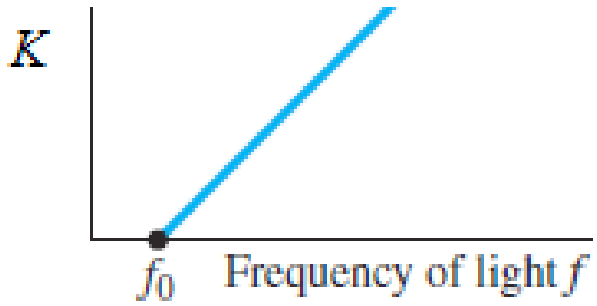


Figure 11.1: Graph of kinetic energy against frequency of light

The maximum kinetic energy of ejected electrons increases linearly with the frequency of incident light. No electrons are emitted if $f < f_o$ where $hf_o = \phi$, no matter how great the intensity of the light.

Law 3: *If the frequency f is less than the "cut-off" frequency* f_0 *where* $f_0 h = \phi$ *no electrons will be ejected, no matter how great the intensity of the light*

That is characteristic of the material being illuminated. For a given material, monochromatic light with a frequency below a minimum **threshold frequency** produces *no* photocurrent, regardless of intensity. For most metals the threshold frequency is in the ultraviolet (corresponding to wavelengths between 200 nm and 300 nm), but for other materials like potassium oxide and caesium oxide it is in the visible spectrum (between 380 nm and 750 nm).

- **Time of released**

Law 4: ***Electrons*** *are emitted from the surface of the metal instantaneously even at low light intensities*.

The incident light energy arrives at the surface in small packets and there is a one-to-one interaction between photons and photoelectrons. In this interaction, the photon's energy is imparted to an electron that then has enough energy to leave the metal. This is in contrast to the wave theory in which the incident energy is distributed over a large area of the surface metal.

- **Stopping voltage**

Law 5: *The stopping potential does not depend on intensity, but does depend only on frequency*.

The only effect of increasing the intensity is to increase the number of electrons per second and hence the photocurrent *i*. If the intensity of light is held constant but the frequency is increased, the stopping potential also increases. In other words, Greater intensity at a particular frequency means a greater number of photons per second absorbed, and thus a greater number of electrons emitted

per second and a greater photocurrent. The greater the light frequency is, the higher the energy of the ejected photoelectrons is.

Example11.3

1. a) What is the kinetic energy and the speed of an electron ejected from a sodium surface whose work function is $\phi = 2.28\,eV$ when illuminated by light of wavelength

   i) 410 nm ii) 550 nm

b) Determine the lowest frequency or the longest wavelength needed to emit electrons from sodium.

Answer

a) We first find the energy of the photons $E = hf = \dfrac{hc}{\lambda}$

If the energy is greater than ϕ then electrons will be ejected with varying amounts of K with a maximum of $K = hf - \phi$

i). For $\lambda = 410\,nm$ then

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\ J\cdot s)(3\times10^{8}\ m/s)}{410\times10^{-9}\ m} = 4.85\times10^{-19}\ J = 3.03\,eV$$

The maximum kinetic energy an electron can have is given by

$$K = 3.03 - 2.28 = 0.75\,eV = (0.75\,eV)(1.6\times10^{-19}\ J/eV) = 1.2\times10^{-19}\ J$$

$$\text{Since } K = \frac{1}{2}mv^2 \Leftrightarrow v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(2.2\times10^{-19}\ J)}{9.1\times10^{-31}\ kg}} = 5.1\times10^{5}\ m/s$$

Most ejected electrons will have less K and less speed than these maximum values.

ii). For $\lambda = 550\,nm$ then

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\ J\cdot s)(3\times10^{8}\ m/s)}{550\times10^{-9}\ m} = 3.61\times10^{-19}\ J = 2.26\,eV$$

Since this photon energy is less than the work function, no electrons are ejected

11.1.4. Applications of photoelectric effect

The photoelectric effect has a number of applications. Digital cameras, studying nuclear processes, chemically analysing materials based on their emitted electrons, image intensifiers and night-vision scopes use it to convert light energy into an electric signal that is reconstructed into an image.

On the moon, sunlight striking the surface causes surface dust to eject electrons, leaving the dust particles with a positive charge. The mutual electric repulsion of these charged dust particles causes them to rise above the moon's surface, a phenomenon that was observed from lunar orbit by the Apollo astronauts.

a) Photo emissive cells

These are used in reproduction of sound in a film sound track and also in controlling lift doors. Photo emissive cells are also used in security alarms. The symbol for a photo emissive cell is shown below. Light falling on the cathode ejects electrons which are attracted to the anode and a current flow.

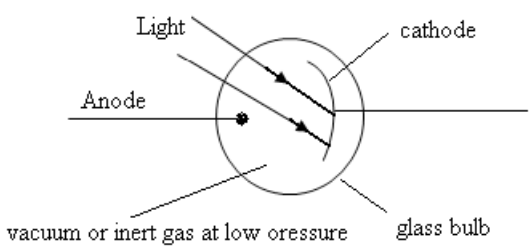


Figure11. 4 : Photo emissive cells

b) Photovoltaic cells

In photovoltaic cells, the ejected electron travels through the emitting material to enter a solid electrode in contact with the photo emitter (instead of travelling through a vacuum to the anode) leading to the direct conversion of radiant energy to electrical energy. Photovoltaic cells are used in calculators and light exposure metres in cameras. They can also drive small machines.

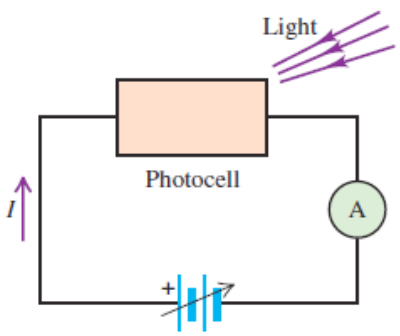


Figure 11.5: Photovoltaic cells

Note that A semiconductor photocell in a circuit; the more intense the light falling on the photocell, the greater the conductivity of the photocell and the greater the current measured by the ammeter (A).

c) Photoconductive cells

Examples of photoconductive cells are photodiodes, photo resistors (light-dependent resistors, LDR) and phototransistors. These work on the principle that light reduces the resistance of some semiconductor materials such as calcium sulphide.

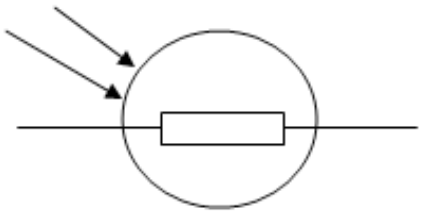


Figure 11. 6: Photoconductive cells

Application Activity 11.1

1. The work function for lithium is $4.6\times10^{-19}J$
   a) Calculate the lowest frequency of light that will cause photoelectric emission
   b) What is the maximum energy of the electrons emitted when the light of frequency $7.3\times10^{14}Hz$ is used ?
2. Selenium has a work function of 5.11eV. what frequency of light would just eject electrons?

11.2. Thermionic emission

Activity 11.2

The figure above shows how particles can be emitted from a metal surface.

a) Explain why there was a need to connect the filament to the source of electricity?

b) What special characteristic(s) should the filament possess to be used?

c) Explain different factors that affect the rate of emission of particles from the surface of the filament.

d) Discuss some areas /devices where this set up may be used

Thermionic emission called also thermo electronic emission means the discharge of electrons from a metal surface when it is electrically heated. It is widely used as a source of electrons in conventional electron tubes (e.g., television picture tubes) in the fields of electronics and communications. The phenomenon was first observed (1883) by Thomas A. Edison as a passage of electricity from a filament to a plate of metal inside an incandescent lamp.

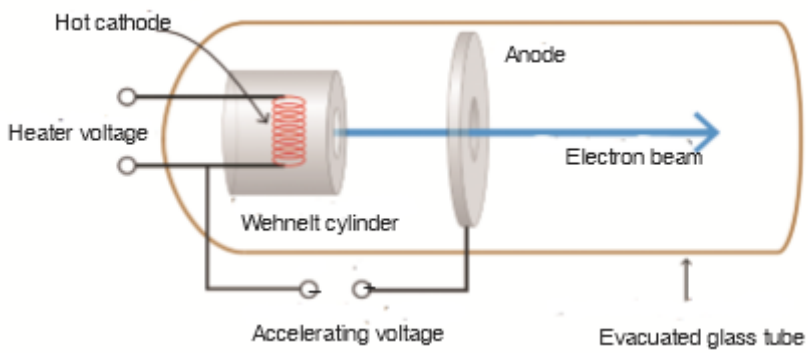


Figure 11.7: Thermionic emission

In thermionic emission, the heat supplies some electrons with at least the minimal energy required to overcome the attractive force holding them in the structure of the metal. This minimal energy, called the work function, is the characteristic of the emitting material and the state of contamination of its surface.

Applications of cathode rays

a) Cathode ray oscilloscope

A Cathode Ray Oscilloscope (CRO) also called Oscillograph is an electronic test instrument generally used in a laboratory to display, measure and analyze various waveforms of electrical circuits. It is a very fast X-Y plotters that can display an input signal versus time or other signal. The waveform can be analyzed for properties such as amplitude, frequency, rise time, time interval, distortion, and others. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram. It is thus used in the sciences, medicine, engineering, automotive and the telecommunications industry.

Cathode ray oscilloscopes use luminous spots which are produced by striking the beam of electrons and this luminous spot moves in response variation in the input quantity. Nowadays, with the help of transducers it is possible to convert various physical quantities like current, pressure, acceleration etc. to voltage thus it enables us to have visual representations of these various quantities on cathode ray oscilloscope.

The main part of cathode ray oscilloscope is cathode ray tube (CRT) which is also known as the heart of cathode ray oscilloscope.

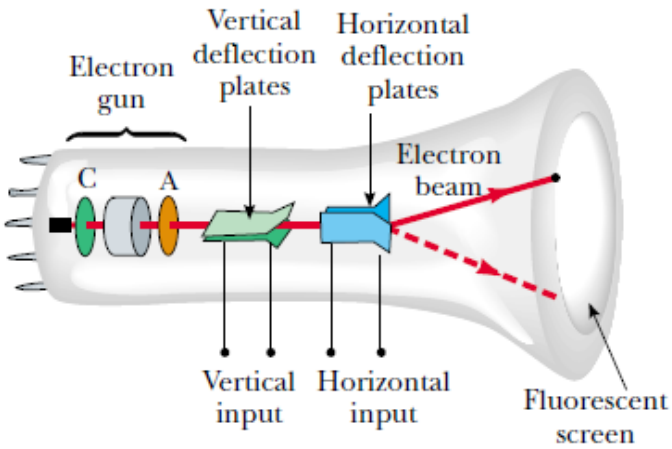


Figure 11. 8: Cathode Rays oscilloscope tube (C.R.O tube)

This tube is used to obtain a visual display of electronic information in oscilloscopes, radar systems, television receivers, and computer monitors.

The CRT is a vacuum tube in which a beam of electrons is accelerated and deflected under the influence of electric or magnetic fields. The electron beam is produced by an assembly called an electron gun located in the neck of the tube. These electrons, if left undisturbed, travel in a straight-line path until they

strike the front of the CRT, the "screen," which is coated with a material that emits visible light when bombarded with electrons. Electrons leaving the hot cathode C are accelerated to the anode A. The beam of electrons produced is called Cathode rays. In addition to accelerating electrons, the electron gun is also used to focus the beam of electrons, and the plates deflect the beam.

In an oscilloscope, the electrons are deflected in various directions by two sets of plates placed at right angles to each other in the neck of the tube. An external electric circuit is used to control the amount of charge present on the plates. The placing of positive charge on one horizontal plate and negative charge on the other creates an electric field between the plates and allows the beam to be steered from side to side. The vertical deflection plates act in the same way, except that changing the charge on them deflects the beam vertically.

Functions of a Cathode Ray Oscilloscope

A cathode ray oscillography is essentially an electrostatic instrument which consists of a high evacuated glass tube. The features of a CRO (Cathode ray oscilloscope) can be split into 3 main sections: The **electron gun,** the **deflection system** and the **fluorescent screen.**

- ***Electron Gun:*** The role of this section is to produce electrons at a high, fixed, velocity and focus them on the screen. This is done through a process known as thermionic emission. A filament in the cathode is heated to the point where its electrons become loose. An anode with a high voltage applied to it accelerates the electrons towards the screen due to electrostatic attraction. On the way, the electrons pass through a series of control grids which control the brightness of the image produced. The more negative the grid, the darker the image and vice versa.
- ***Deflection system:*** The role of the deflection system is to control the image produced by controlling the position that the electrons hit the screen. It consists of two perpendicular sets of Electric/Magnetic fields. This allows control over both horizontal and vertical axes. By controlling the Voltage applied to the fields, it is possible to vary the deflection through Electrostatic force/Motor effect.
- ***Fluorescent screen:*** The role of this part is to display where the electrons are hitting the CRT. It is a screen coated with a material that emits light when struck by electrons. The CRO is a perfect voltmeter as its input resistance is very high. It is usually placed in parallel with a component. The voltage is measured on the vertical axis, which is controlled by the Y-plates. It can also be used as an ammeter by placing it across a resistor of known resistance. The CRO is used to analyze waveforms. It can be used to determine the peak voltage of an a.c. waveform and the period, which in turn allows one to work out its frequency.

b) Televisions

A CRT TV works by having the electron beam "**scan**" the screen at a **rate faster than our eyes can perceive**. This means that it shoots across the screen like a machine gun, and the images we see are actually made from many **fluorescent dots**.

The fluorescence caused by the beam striking the screen **lasts a bit longer** so that the next scan can be made without the previous image disappearing. It scans twice each time, first filling in the odd "holes" then the even ones. Each scan is about 1/50 of a second.

Colour CRT TVs has **electron guns** rather than a single one, a **shadow mask,** and a **modified fluorescent screen**. The 3 electron guns are needed as there are **three primary colours** (Red, Green and Blue) that can be adjusted in different amounts to create any colour.

The colours are formed as a result of the **shadow mask,** which is a layer with holes in it that **controls the angle** of the incoming electron beams. This is because the fluorescent screen is separated into **multi-coloured phosphors** that are placed adjacent to each other at small intervals. Thus it isn't actually a single coloured pixel, but rather 3 very small pixels that join together to form a larger dot.

Application Activity 11.2

1. CRO stands for ……..
   a) Cathode ray oscilloscope
   b) Current resistance oscillator
   c) central resistance oscillator
   d) Capacitance resistance oscilloscope
2. How does a cathode work
3. What are the uses of cathode rays

Skills lab: *Demonstration of the Photo-electric Effect*

Using a zinc plate with a gold leaf electroscope (or a coulomb meter)...

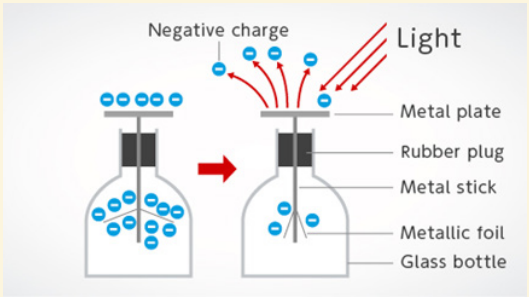


Figure 11.9: Zinc plate with a gold leaf electroscope

- Clean a zinc plate with fine emery paper or steel wool.
- Attach the plate to the top disc on a gold leaf electroscope, so there is good electrical contact.
- Charge the zinc plate and inner assembly of the electroscope negatively, e.g. by rubbing the zinc plate with a polythene rod which has been rubbed with wool or fur. [Charging by induction using a perspex rod is more reliable, but might be considered too confusing!]
- The leaf should now be raised, because the leaf and the back plate are both charged negatively and repel each other. The leaf should temporarily rise further if the charged polythene rod is brought near the zinc plate.
- Place an ultraviolet lamp near the zinc plate. Switch it on. The leaf should be seen to fall.
- *Safety note*: Don't look at the ultraviolet lamp (when it's turned on!)] Clearly the plate (and inner assembly of electroscope) is losing charge.
- Repeat the procedure, but charging the zinc plate and inner assembly of the electroscope *positively*, e.g. by rubbing the plate with a charged perspex rod.
- Observe and report what happen

END UNIT ASSESSMENT 11

1. Sodium has a work function of 2.3 eV. Calculate:
   a) Its threshold frequency,
   b) The maximum velocity of the photoelectrons produced when the sodium is illuminated by light of wavelength 5×10^{-7} m,
   c) The stopping potential with light of this wavelength.
   d) The longest-wavelength light that can cause photoelectron emission

from sodium?

$h = 6.63 \times 10^{-34}\ J.s$, $c = 3 \times 10^{8}\ m/s$, 1 eV=1.6x10^{-19} J, mass of electron m = 9.1 x 10^{-31} kg.)

2. Estimate how many visible light photons a 100 W light bulb emits per second. Assume the bulb has a typical efficiency of about 3% (that is, 97% of the energy goes to heat).
3. Compute the energy of a photon of blue light of wavelength 450 nm.
4. As red light shines on a piece of metal, no electrons are released. When the red light is slowly changed to shorter wavelength light (basically progressing through the rainbow), nothing happens until yellow light shines on the metal, at which point electrons are released from the metal. If this metal is replaced with a metal having a higher work function, which light would have the best chance of releasing electrons from the metal?
   a) Blue
   b) Red
   c) Yellow would still work fine.
   d) We need to know more about the metals involved.
5. A beam of red light and a beam of blue light have equal intensities. Which statement is true?
   a) There are more photons in the blue beam.
   b) There are more photons in the red beam.
   c) Both beams contain the same number of photons.
   d) The number of photons is not related to intensity.
6. Which of the following is necessarily true?
   a) Red light has more energy than violet light.
   b) Violet light has more energy than red light.
   c) A single photon of red light has more energy than a single photon of violet light.
   d) A single photon of violet light has more energy than a single photon of red light.
   e) None of the above.
   f) A combination of the above (specify)

7. If a photon of energy E ejects electrons from a metal with kinetic energy K , then a photon with energy $E/2$

   a) will eject electrons with kinetic energy $\frac{K}{2}$.

   b) will eject electrons with an energy greater than $\frac{K}{2}$.

   c) will eject electrons with an energy less than $\frac{K}{2}$.

   d) might not eject any electrons.

8. Determine the wavelength of an electron that has been accelerated through a potential difference of 100 V.

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