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Part - II

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The National Anthem of Sri Lanka

Sri Lanka Matha
Apa Sri Lanka Namo Namo Namo Namo Matha
Sundara siri barinee, surendi athi sobamana Lanka
Dhanya dhanaya neka mal palaturu piri jaya bhoomiya ramya
Apa hata sepa siri setha sadana jeewanaye matha
Piliganu mena apa bhakthi pooja Namo Namo Matha
Apa Sri Lanka Namo Namo Namo Namo Matha
Oba we apa vidya
Obamaya apa sathya
Oba we apa shakthi
Apa hada thula bhakthi
Oba apa aloke
Apage anuprane
Oba apa jeevana we
Apa mukthiya oba we
Nava jeevana demine, nithina apa pubudukaran matha
Gnana veerya vadawamina regena yanu mana jaya bhoomi kara
Eka mavakage daru kela bevina
Yamu yamu vee nopama
Prema vada sema bheda durerada
Namo, Namo Matha
Apa Sri Lanka Namo Namo Namo Namo Matha

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- ආනන්ද සමරකෝන් -

ஒரு தாய் மக்கள் நாமாவோம்
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ஆனந்த சமரக்கோன்
கவிதையின் பெயர்ப்பு

Being innovative, changing with right knowledge
Be a light to the country as well as to the world.

Message from the Hon. Minister of Education

The past two decades have been significant in the world history due to changes that took place in technology. The present students face a lot of new challenges along with the rapid development of Information Technology, communication and other related fields. The manner of career opportunities are liable to change specifically in the near future. In such an environment, with a new technological and intellectual society, thousands of innovative career opportunities would be created. To win those challenges, it is the responsibility of the Sri Lankan Government and myself, as the Minister of Education, to empower you all.

This book is a product of free education. Your aim must be to use this book properly and acquire the necessary knowledge out of it. The government in turn is able to provide free textbooks to you, as a result of the commitment and labour of your parents and elders.

Since we have understood that the education is crucial in deciding the future of a country, the government has taken steps to change curriculum to suit the rapid changes of the technological world. Hence, you have to dedicate yourselves to become productive citizens. I believe that the knowledge this book provides will suffice your aim.

It is your duty to give a proper value to the money spent by the government on your education. Also you should understand that education determines your future. Make sure that you reach the optimum social stratum through education.

I congratulate you to enjoy the benefits of free education and bloom as an honoured citizen who takes the name of Sri Lanka to the world.

Akila Viraj Kariyawasam
Minister of Education

Foreword

The educational objectives of the contemporary world are becoming more complex along with the economic, social, cultural and technological development. The learning and teaching process too is changing in relation to human experiences, technological differences, research and new indices. Therefore, it is required to produce the textbook by including subject related information according to the objectives in the syllabus in order to maintain the teaching process by organizing learning experiences that suit to the learner needs. The textbook is not merely a learning tool for the learner. It is a blessing that contributes to obtain a higher education along with a development of conduct and attitudes, to develop values and to obtain learning experiences.

The government in its realization of the concept of free education has offered you all the textbooks from grades 1-11. I would like to remind you that you should make the maximum use of these textbooks and protect them well. I sincerely hope that this textbook would assist you to obtain the expertise to become a virtuous citizen with a complete personality who would be a valuable asset to the country.

I would like to bestow my sincere thanks on the members of the editorial and writer boards as well as on the staff of the Educational Publications Department who have strived to offer this textbook to you.

W. M. Jayantha Wickramanayaka,
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Contents

Biology

The world of life

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13.1 Classification of organisms

It is believed that life originated on earth about 3.6 billion years ago. It is accepted that the life originated as unicellular organisms and thereafter complex multicellular organisms were evolved gradually. Today about 8.7 million species are living on earth. There is a great diversity among these organisms. Once these organisms are grouped, it is easy to study them and to use them for different purposes.
In figure 13.1 fifteen species of organisms are given. Let's do activity 13.1 to group these organisms.

Activity 13.1

- Identify the species of organisms in Fig. 13.1
- Group the organisms using appropriate criteria
- Compare your grouping with other students in the class

Figure 13.1 - Different species of organisms

You may have grouped the above organisms on the basis of different criteria.

Grouping of organisms into different levels based on their common characteristics is known as classification.

• Significance of classification of organisms

There are various uses of classification of organisms. Let us examine as to what they are,

- Easy to study about organisms
- Ability to identify specific distinguishable characteristics of a given organism
- Ability to get an idea about the whole biosphere by studying about few selected organisms, without studying each and every organism
- Ability to reveal the relationship between different groups of organisms
- Identification of organisms with economical uses to human

Methods of classification of organisms

Aristotle in 4th B.C. introduced the first scientific classification of organisms. Carolus Linnaeus in 18th A.D. introduced a successful classification. All organisms on earth including human is classified into two methods. They are,

- Artificial classification
- Natural classification

Artificial classification

In artificial classification, features such as the presence or absence of locomotive appendages of organisms and habitats etc are considered. It does not depict the evolutionary relationships among organisms. Examples for artificial classification are as follows.

Plants can be grouped as ornamental plants, herbal plants and poisonous plants.

Animals can be grouped as animals with wings and without wings.

There are many weaknesses in artificial classification.

Under the criteria of presence of wings in the above example birds and insects both are included into a single group. But they belong to two groups when considering evolutionary relationships.

Natural classification

A natural classification depicts the evolutionary relationships among living organisms. In natural classification, morphological, physiological. cytological and molecular biological features of organisms are considered. The natural classification possesses below features.

- Explains the natural relationships among organisms of the same species
- Explains the evolutionary relationships among different organisms

E.g. Locomotive appendages - Fins of fish, Feathers of birds, Legs of human

In a natural classification, organisms are grouped into taxonomic levels in a hierarchy of categories.

For extra knowledge

Consider the following examples to identify the taxonomic levels in a hierarchy of categories

Modern Human (Homo sapiens)		**Coconut tree (Cocos nucifera)**	
1. Domain	- Eukarya	1.Domain	- Eukarya
2. Kingdom	- Animalia	2.Kingdom	- Plantae
3. Phylum	- Chordata	3.Division	- Magnoliophyta
4. Class	- Mammalia	4.Class	- Liliopsida
5. Order	- Primates	5.Order	- Arecales
6. Family	- Hominidae	6.Family	- Arecaceae
7. Genus	- Homo	7.Genus	- Cocos
8. Species	- *Homo sapiens*	8.Species	- *Cocos nucifera*

Figure 13.2- Taxonomic levels in a hierarchy of categories

Three Domain system of classification

The most appropriate system to classify organisms is the natural classification. Different scientists have introduced different classification methods from past. One of them is the five kingdom classification system introduced by Robert Whittaker in 1969. Modern classification is the classification introduced by Carl Woese in 1990 with three domains. The 3 domains are,

1. Domain Archaea
2. Domain Bacteria
3. Domain Eukarya

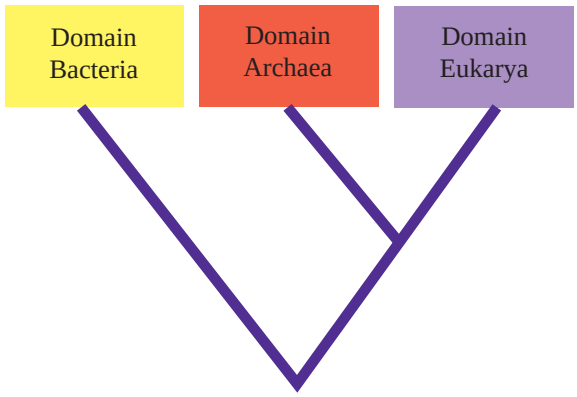


Figure 13.3 - Three domain classification

Domain Archaea

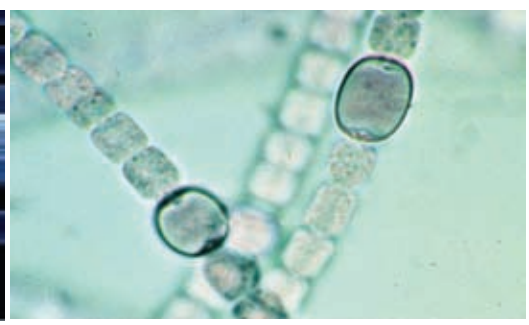
The organisms belong to this domain are prokaryotes (without an organized nucleus). They have the ability to live in extreme environmental conditions like, volcanoes, deserts, hot springs, ocean beds, high saline environments and polar ice caps. They are not sensitive to most antibiotics.That is they cannot be destroyed with antibiotics.

Examples :- Methanogens
Halophiles

Domain Bacteria

The organisms belong to this domain are also prokaryotes. (without an organized nucleus) They are sensitive to antibiotics and sometimes are pathogenic. They can be found every where in the environment. They are the most abundant group of organisms. Bacteria and Cyanobacteria belong to this domain.

Bacteria



Cyanobacteria

Figure 13.4 - Organisms belong to Domain Bacteria

For extra knowledge

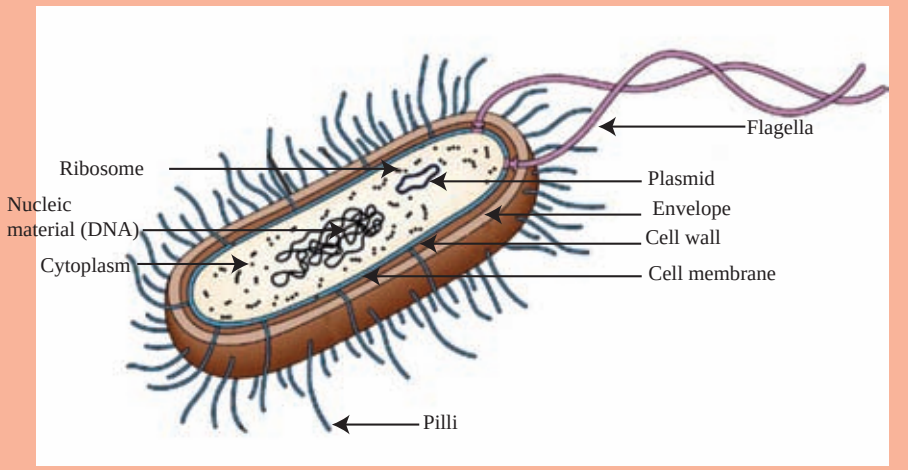


Figure 13.5 - Electron microscopic structure of a typical Bacterial cell

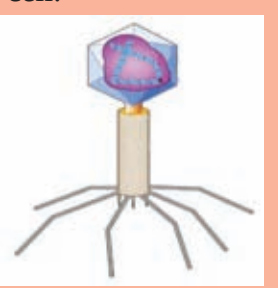
Several harmful and useful effects of Bacteria to human are given below.

- Bacteria cause diseases to human as well as to other organisms
  E.g. :- Tuberculosis, Pneumonia, Diarrhoea, Tetanus, Leprosy.
- Food spoilage
- To produce curd, yoghurt and cheese
- Separation of fibres from coconut husk, agave leaves and to tan leather
- To fix atmospheric nitrogen to increase soil nitrate level
- To decompose dead bodies and structures

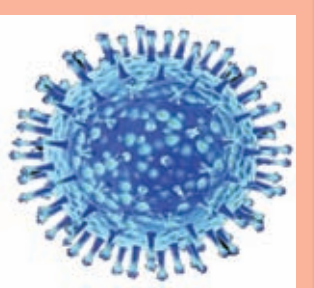
For extra knowledge

Virus was first observed by a Russian scientist named D.J. Ivonouski in 1892. They are not identified as living organisms. They possess both living and non living features. The only living feature of them is the multiplication within a host cell.

AIDS virus



Bacteriophage virus



Bird flu virus

Figure 13.6 - Electron microscopic view of several viruses

Domain Eukarya

The most prominent organisms with a eukaryotic cellular organization belong to this domain. They have the ability to live in different environments. They are not sensitive to antibiotics.
There are 4 kingdoms belong to this domain.

1. Kingdom Protista
2. Kingdom Fungi
3. Kingdom Plantae
4. Kingdom Animalia

Kingdom Protista

Organisms belong to kingdom protista possess an eukaryotic cellular organization. They are either unicellular or multicellular organisms without specialized tissues. They live in environments associated with water and mostly are photosynthetic. Some species are heterotrophic. Algae and protozoans belong to this kingdom.

Algae
E.g. : *Ulva*

Protozoa
E.g. : *Paramecium*

Figure 13.7 - Organisms belong to kingdom Protista

Below are some useful and harmful effects of protists to human.

- Algae act as primary producers, in the food chains of aquatic environments
- Algae involve in forming mutualistic associations with fungi called lichens
- To extract agar which is used to prepare culture media to grow bacteria
- To extract alginic acid used to make ice cream
- Some protozoans cause diseases to human
  E.g. :- Amoebiosis, Malaria, Sleeping sickness

For extra knowledge

Below are some algae belong to kingdom Protista. They are classified according to the colour of them.

Figure 13.8 - Algae with different colours

Kingdom Fungi

A kingdom of organisms with chitinous cell walls and eukaryotic cellular organization. There are unicellular or multicellular fungi species. There are about 1.5 - 5 million species belong to this kingdom. They contribute greatly to decompose organic matter in the environment. They also form symbiotic associations with other organisms.

Figure 13.9 - Fungi mycelium

Figure 13.10 - Reproductive structures of Fungi

Below are some useful and harmful effects of fungi to human.

- As a supplementary for protein - E.g. :-*Agaricus* - Mushroom
- Bread and alcohol fermentation - E.g. :-Yeast
- To produce antibiotics - E.g. :- *Penicillium*
- Decomposition of dead bodies and structures
- To cause diseases to plants and animals - E.g. :- Pityriasis (Aluham) by *Candida* Potato late blight
- Spoilage of food

Activity 13.2

Let us observe *Mucor* on a slice of bread.

Add few drops of water onto a slice of bread and leave it for 2 days. You will see a mycelium of fungi. Obtain small amount of the mycelium using a glass rod, put it on to a glass slide, cover it with a coverslip and observe through the microscope.

Figure 13.11 - Slice of bread affected by Fungi

Table 13.1 - Characteristics of species that belong to Domain Bacteria, Kingdoms of Protista and Fungi

Feature	Bacteria	Protista	Fungi
Structure	Microscopic, unicellular and prokaryotic organisms	Most are microscopic. But some red algae possess large bodies. They are eukaryotes. Mostly unicellular. Some are multicellular without a tissue differentiation.	Most of them are microscopic. But some reproductive structures can be seen with the naked eye. (Mushroom) They are eukayiotic organisms. Some are unicellular some are multicellular. They exist as multicellular mycelium. No tissue differentiation.
Shape	Spherical (coccus), Rod shaped (bacillus), spiral (spirillum), coma shaped (vibrio) are the different shapes of bacteria. Cyanobacteria also exist as single cells, branched or unbranched filaments	Leaf like, horse shoe shaped, and other different shapes	As single spherical cells or fungi mycelium
Nutrition	Mostly heterotrophic. But Cyanobacteria are autotrophic.	Algae are phototrophic. The unicellular animals (Protozoans) are heterotrophic.	All are heterotrophic. Most of them obtain nutrition as saprophytic organisms.
Repro-duction	Mostly perform asexual repro-duction. Bacteria reproduce by binary fission, Cyanobacte-ria by fragmentation and budding	Reproduces asexually. Binary fission, fragmen-tation and spore production.	Mostly reproduce by asexual spores

Distribution	Widely distributed, in air, water, soil and in the body of organisms. Almost everywhere	Marine, Freshwater, damp soil and inside the body of organisms	Live on organic matter and living body. Less in aquatic environments.
Examples	Bacteria, Cyanobacteria	Algae, unicellular animals (*Amoeba, Paramecium*)	Fungi

Kingdom Plantae

It's a kingdom with multicellular organisms known as plants. There are about 287,000 species of plants. Plant cells possess cell walls with cellulose. Plants appear in green colour, because they possess chlorophyll pigments. They can absorb light energy and produce food by photosynthesis.

They reproduce sexually and asexually. The plants in kingdom plantae, can be divided as given below

1. Non- flowering plants
2. Flowering plants

Non-flowering plants

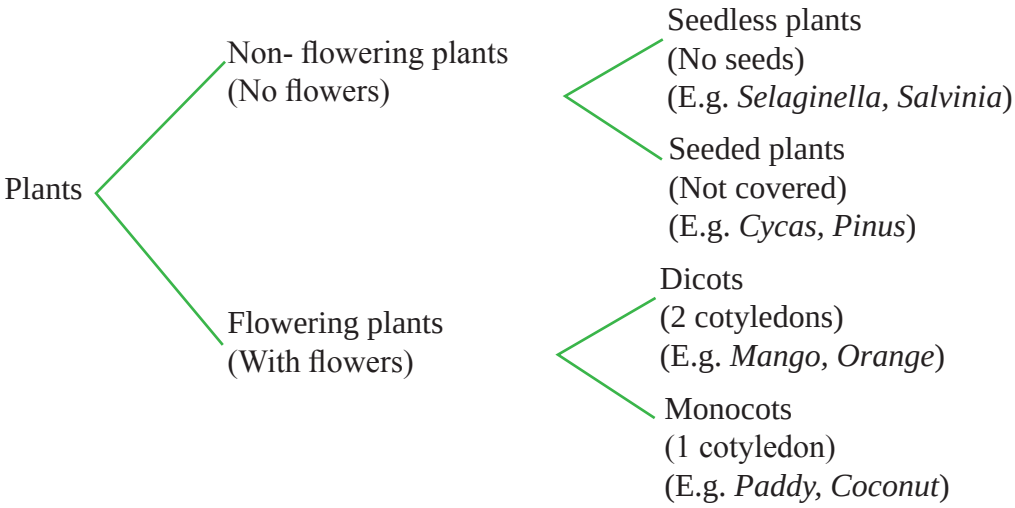
Plants that can not produce flowers are known as non-flowering plants. These non flowering plants again can be divided into two groups according to the ability of producing seeds. They are,

1. Non-flowering, seedless plants
2. Non-flowering seed plants

Non- flowering seedless plants

Plants that do not produce flowers and seeds belong to this type.

Examples :- *Marchantia, Pogonatum, Selaginella, Nephrolepis, Salvinia, Acrosticum, Drynaria*



Marchantia

Pogonatum

Selaginella

Nephrolepis

Salvinia

Acrosticum

Drynaria

Figure 13.12 -Non-flowering seedless plants

Below are features of Non- flowering seedless plants.

13.2 Table - Features of Non- flowering seedless plants

Feature	Special facts
Structure	Small to large sized plants. Some plants lack a tissue differentiation. No stem, leaves and roots. These plants, are known as thallus. Some plants possess differentiated vascular tissues. They possess stem, leaves and roots
Shape	Thalloid body or small fern type
Nutrition	All are autotrophic photosynthetic. Some plants are epiphytes.
Reproduction	Asexual reproduction by spores and fragmentation of vegetative parts. Perform sexual reproduction too.
Distribution	Terrestial environments with low sunlight, shady and wet places.

Non-flowering seed plants

The seeds of these plants are not covered by a fruit. Seeds are naked. Therefore they are known as Gymnosperms.
Examples :- *Cycas, Pinus*

Cycas

Pinus

Figure 13.13 - Gymnosperms

Below are features of Non- flowering seed plants.

Table 13.3 - Features of Non- flowering seed plants

Feature	Special facts
Structure	True tissue differentiation is present. Possess vascular tissues. Root, stem and leaves are present.
Shape	Large in size. Most of them are trees. Straight woody stems. Some are shrubs.
Nutrition	All are autotrophic photosynthetic.
Reproduction	Sexual reproduction by seeds. Asexual reproduction by spores.
Distribution	Distributed in terrestrial environments.

Flowering plants

Plants that produce flowers are known as flowering plants. The seeds that are produced by flowers, (which is the sexual reproductive structure of flowering plants) are covered by a fruit. Therefore they are termed covered seed plants or Angiosperms. These plants are well adapted to life on land and show various adaptations, to conserve water. They can be divided into two groups according to the number of cotyledons in the seed.

(1) Monocotyledonae plants
(2) Dicotyledonae plants

Monocots - Coconut

Dicots - Mango

Figure 13.14 - Flowering plants

Activity 13.3

Uproot a paddy or grass and a Kuppamenia/ Kupameni plants and wash their root system carefully and list out their features.

Comparison between monocots and dicots is given in the table below.

13.4 Table - Features of monocots and dicots

Monocotyledonae	Dicotyledonae
• A single cotyledon in the seed • Stem is unbranched • No tap root. Possess a fibrous root system • Leaves possess a parallel venation. • Trimerous flowers • No secondary growth • The diameter of the stem is even E.g. :- Paddy, Grass, Arecanut	• Two cotyledons in the seed • Stem is branched • Root system with a tap root and lateral roots • Leaves possess a reticulate venation • Tetra or pentamerous flowers • Secondary growth takes place • The base of the stem is broad and tip is thin E.g. :- Chillies, Jak, Blue lotus

Assignment 13.1

Prepare a collection of dried plant parts belong to flowering and non-flowering plants.

Kingdom Animalia

It is a kingdom with animals, who are multicellular. There are about 1, 260, 000 species in this kingdom. They are unable to produce their own food. They are heterotrophic.

Animals belong to kingdom Animalia again can be divided into two groups according to the presence or absence of a vertebral column.

1. Invertebrates
2. Vertebrates

Invertebrates

Organisms without a vertebral column is known as invertebrates. Invertebrates again can be divided into different phyla according to their features. Five main phyla are,

1. Cnidaria / Coelenterata
2. Annelida
3. Mollusca
4. Arthropoda
5. Echinodermata

• Cnidaria/Coelenterata

Diploblastic organisms like Hydra, Sea anemone and Jellyfish belong to this phylum.

Hydra

Sea anemone

Jellyfish

Figure 13.15 - Several species of Cnidaria

Features of Cnidarians

- All are aquatic and mostly marine. Few of them are fresh water dwellers.
- Multicellular body build up of two germinal layers. Therefore known as **diploblastic**.
- A cavity present within the body called **coelenteron** acts as the digestive tract.
- There are 2 forms as **Medusa** and **Polyp**. Medusa can move while Polyps attach to surface.
- They have a **radial symmetry**.
- All are predators. Attack small organisms to paralyze them using Nematocyst / Cnidocyst
- Asexual reproduction is done by budding. Show sexual reproduction too.

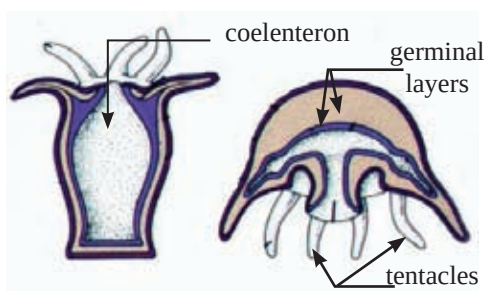


Figure 13.16 - Longitudinal section of a Cnidarian

For extra knowledge

Coral reefs produced by a coral polyp belong to phylum Cnidaria. They play a major role for the survival of marine organisms.

Figure 13.17 - Polyp coral colonies

• Annelida

The first organisms to evolve a body cavity called coelom belong to this phylum. Segmented worms like earthworm, leech, *Nereis* are examples for Annelids.

Earthworm

Leech

Nereis

Figure 13.18 - Several species of Annelida

Features of Annelids

- Live in damp soil, marine and fresh water habitats.
- Multicellular body made up of three germinal layers. Therefore known as triploblastic. Possess a slender, worm like body.
- Body is divided into segments internally and externally. Therefore known as **segmented worms**.

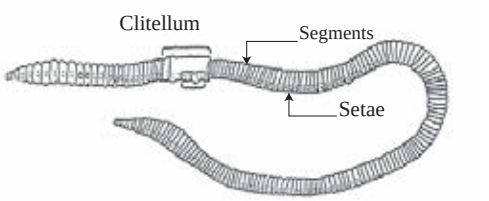


Figure 13.19 - External apperance of an Annelid

- Body shows a bilateral symmetry.
- There is a fluid filled cavity between body wall and the digestive tract. It is known as the **coelom**. It provides an independent movement for the gut wall irrespective of the body movements.
- Some reproduce asexually and some by sexual reproduction.

• Mollusca

Soft bodied triploblastic organisms belong to this phylum. Species such as Snail, Bivalve, Chiton, Slug, Squid, and Octopus belong to this phylum.

Snail Cuttle fish Octopus

Figure 13.20 - Several species of Mollusca

Features of Molluscs,

- Live in terrestrial, fresh water and marine habitats.
- Multicellular, Triploblastic, Soft bodied animals.
- The body is divided into **head**, **muscular foot** and **visceral mass**. The body is not divided into segments.

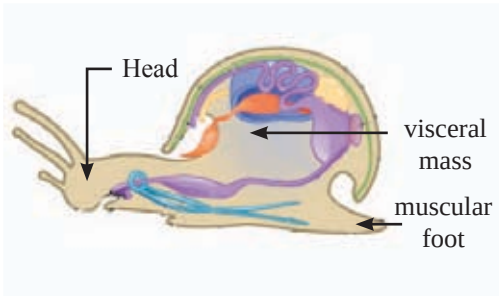


Figure 13.21 - Longitudinal section of a mollusc

- The body is moistened by mucous.
- Some Molluscs possess internal and external shells made up of $CaCO_3$.
- Possess a bilaterally symmetrical body.
- Show sexual reproduction. Most of them are unisexual (produce one type of gamete)

• Arthropoda

This is the phylum with the highest number of species in the animal kingdom. 75% of the animal species belong to this phylum. The class Insecta of this phylum Arthopoda, possesses the highest number of organisms. There are about 950,000 species belong to this phylum. The organisms with jointed limbs, such as Insects (Bee, Butterfly, Cricket, Mosquito) , Spider, Scorpion, Millipede, Centipede, Prawn, Crab, Barnacle belong to this phylum.

Butterfly Spider Scorpion Centipede

Figure 13.22 - Several species of Athropoda

Features of Arthropods

- Live in Marine, fresh water and terrestrial habitats.
- Triploblastic, coelomic and possess jointed limbs. They are known as Arthropods. (Arthro=jointed, pods=legs)
- Body is segmented and several segments collectively form functional segments called Tagma (Head, Thorax, Abdomen).
- There is a chitinous cuticle on the body. It acts as an exoskeleton.
- Some possess special wings.
- Body shows a bilateral symmetry.
- There are separate female and male organisms. They show sexual dimorphism. Carryout sexual reproduction.

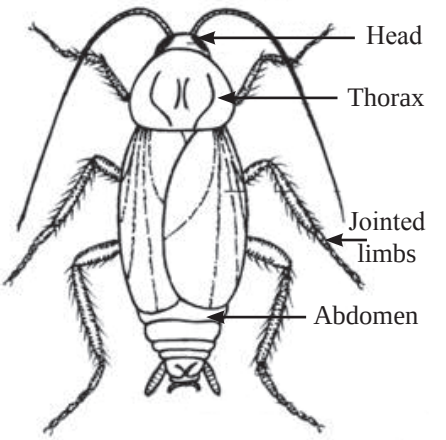


Figure 13.23 - External appearance of an insect

Assignment 13.2

Prepare an insect box using dead insects found in your home.

• Echinodermata

It is a phylum that shows phylogenetic (evolutionary) relationship to phylum chordata. Starfish, Brittle star, Sea urchin, Sea cucumber, Sea lilly belong to this phylum.

Starfish Sea urchin Sea cucumber

Figure 13.24 - Several species of Echinodermata

Features of Echinodermates.

- All are marine.
- Triploblastic. Coelomic. Body is separated into 5 radial arms.
- Possess a sharp spiny body covering.
- Body is star shaped, cylindrical or flower like.
- A highly distributed **water vascular system** present in the body.
- Tube feet present for locomotion and respiration.
- Heart, brain and eyes are absent.
- Body shows **penta radial symmetry**.
- They show sexual dimorphism and carryout sexual reproduction.

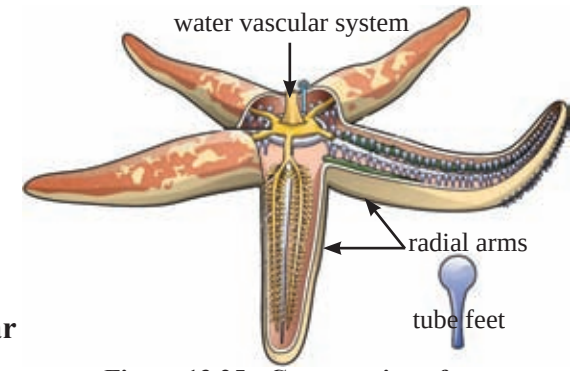


Figure 13.25 - Cross section of an Echinodermate

Vertebrates

An organism with a vertebral column is referred to as a vertebrate. They show below features (Fig. 13.26) at any stage of their life cycle. They can be classified into five groups considering their structural features.

(1) Pisces
(2) Amphibia
(3) Reptilia
(4) Aves
(5) Mammalia

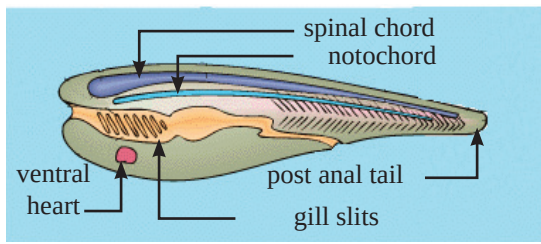


Figure 13.26 - Longitudinal section of a chordate

• Pisces

Fish that are well adapted to live in water belong to this group. They live in fresh water and marine environments. Some have cartilaginous skeleton. Some have bony skeleton.

Butterfly fish Skate Sea horse

Fig 13.27 - Several species of Pisces

Features of fish

- Possess a bony or a cartilage endo skeleton.
- Body is streamline shaped to swim in water.
- Body is covered by scales.
- Possess fins for swimming and balancing.
- Possess a lateral line system to detect vibrations in water.
- Two chambered heart. Single atrium and a ventricle.
- Respiration is done by gills.
- Cold blooded animals. (body temperature changes according to the environmental temperature)
- Eyes are without eye lids.

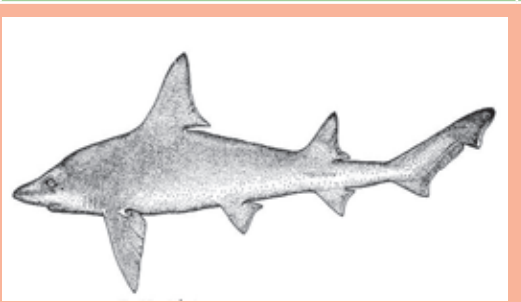
For extra knowledge

The fish live on earth can be divided into two classes considering the endoskeleton. They are,

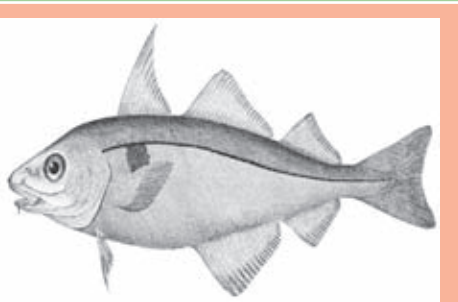
(1) Chondrichthyes - The fish with skeleton made up of cartilages belong to this class

(2) Osteichthyes - The fish with skeleton made up of bones belong to this class

Chondrichthyes	Osteichthyes
• Endoskeleton is made up of cartilage	• Endo skeleton is made up of bones
• Live only in sea	• Live in both sea and freshwater
• About 10% of fish belong to this group	• 90% of fish belong to this group
• Gill slits are not covered bya n operculum	• Gills are covered bya pair ofope rculum Gills are not visible to outside.
• Anterior, ventral mouth	• Terminal mouth
• Heterocercal caudal fin	• Homocercal caudal fin



Chondrichthyes
(Shark, Skate)



Osteichthyes
(Seer fish ,Tilapia, Sea horse)

Figure 13.28 - Classes of Pisces

• Amphibia

Amphibians which need water to complete their life cycle belong to this class. They are the first organisms to invade land during evolution. Frogs, Toads. Salamander, *Ichthyophis* are some animals belong to this class.

Toad

Frog

Salamander

Figure 13.29 - Several species of Amphibia

Features of Amphibians.

- Water is essential to complete the life cycle. (an aquatic stage is present in the life cycle)
- Possess metamorphosis
- Possess a thin mucous skin with glands. No scales on skin.
- Pentadactyle limbs are used for locomotion.
- Possess a three chambered heart with two atria with a single ventricle.
- Respiration is done by lungs, moist skin and buccal cavity.
- They are cold blooded animals (poikilothermic)

• Reptilia

Animals that are well adapted to life on land belong to this class. They live in terrestrial, fresh water and marine ecosystems. Tortoise, Turtle, Snakes, Lizard, Monitor, Iguana and Crocodile are some animals belong to this class.

Tortoise

Crocodile

Cobra

Figure 13.30 - Several species of Reptilia

Features of Reptiles.

- Dry skin without glands. Possess scales on skin.
- Presence of pentadactyle limbs for locomotion.
- Heart with two atria and incompletely divided ventricle.
- Respiration is done by lungs.
- Cold-blooded animals (poikilothermic).
- Possess Internal fertilization.

• Aves

Birds that have adapted for flying belong to this class. The largest bird Ostrich and the smallest bird Humming bird, Jungle fowl, Blue magpie, Kiwi, Duck, Swan, Owl, parrot and penguin are some examples for birds.


Jungle fowl


Ostrich


Penguin

Figure 13.31 - Several species of Aves

Features of birds.

- Possess a light bony endoskeleton.
- Possess a streamlined body for flying.
- Skin is covered by feathers. Scales are restricted only to legs.
- No teeth. A beak that is adapted to different modes of nutrition is present.
- They have eyes with eye lids. Sharp sight.
- Presence of pentadatyle limbs for locomotion. Fore limbs are converted into wings.
- Four chambered heart with two atria and two ventricles.
- Warm-blooded animals (homoiothermic).
- Body temperature is not changed according to environmental temperature.

• Mammalia

Animals that nourish young with milk belong to class Mammalia . Human, Mice, Loris, Monkey, Orung utang, Gorilla, Chimpanzee, Bat, Whale. Dolphin Stag, Deer, Buffalo are some animals belong to this class.

Rilawa/Mandi

Bat

Dolphin

Figure 13.32 - Several species of Mammalia

Features of mammals.

- Skin is covered by hairs. Hair present inside hair follicles.
- Possess Mammary glands, sweat glands and sebaceous glands (produce sebum)
- Possess ear lobes (pinnae)
- Four chambered heart with 2 atria and 2 ventricles.
- Complete double circulation.
- Biconcave red blood cells lacking a nucleus .
- Warm blooded animals. (Homoiothermic)
- Testes present outside the body.
- Internal fertilization.
- Possess a placenta and embryonic membranes.

13.2 Nomenclature of organisms

In each language, an object is named using words. Different names are used to identify organisms. But these names vary according to the language, country and region. The evolutionary relationships are not depicted in those names. Therefore scientists wanted to avoid this situation and to name them using a common name.

• Binomial nomenclature

A successful nomenclature was introduced by a Swedish natural scientist called Carolus Linnaeus in 1753. As it contains two epithets for an organism, it is known as binomial nomenclature.

The methodology to name an organism is regulated by International Commission on Botanical Nomenclature (ICBN) and International Commission on Zoological Nomenclature (ICZN).

• The standards of binomial nomenclature

- The scientific name of a species or species name is composed of two epithets.
- The first epithet is generic name and the second epithet is the specific epithet.
- The species name is given in Latin or Greek.
- The first letter of generic epithet is capital and the other letters are simple.
- When hand written it should be underlined and when printed it should be italicized.

  E.g. :- *Mangifera indica*

For extra knowledge

- Few important scientific names

Man	-	*Homo sapiens*
Asian Elephant	-	*Elephas maximus*
Jungle Fowl	-	*Gallus lafayetti*
Asoka Pethiya	-	*Puntius asoka*
Blue Lotus	-	*Nymphaea stellata*
Na	-	*Mesua nagassarium*
Coconut	-	*Cocos nucifera*

Activity 13.4

Exhibit scientific names of few plants found in your school garden.

Assignment 13.3

Write scientific names of five animals and five plants with the help of news papers, books and internet.

Summary

- Organisms are classified into groups to make it easier to study.
- All organisms are divided into three domains. They are Archaea, Bacteria and Eukarya.
- Prokaryotic organisms that live in extreme environments belong to domain Archaea.
- Bacteria and Cyanobacteria belong to domain Bacteria.
- Protista, Fungi, Plantae and Animalia are the four kingdoms belong to domain Eukarya.
- Kingdom Plantae is divided into two groups considering the fact that flowering and non flowering.
- Kingdom Animalia is divided into two groups considering the fact that the presence or absence of the vertebral column.
- Invertebrates again can be divided into phyla such as Cnidaria, Annelida, Mollusa, Athropoda and Echinidermata.
- Vertebrates are divided into groups like Pisces, Amphibia, Reptilia, Aves and Mammalia.
- Living organisms are named scientifically using binomial nomenclature.

Exercise

(1) State different classification systems of organisms and the scientists who introduced them.

Classification System	Scientist
.....	.....
.....	.....
.....	.....

(2) Compare differences between natural and artificial classification systems.

(3) State 3 domains and organisms belong to them.

Domains	Organisms
.....	.....
.....	.....
.....	.....

(4) State the uses of the coral reefs which is a creation of an organism belong to phylum Cnidaria.

(5) Classify below mammals using a tree diagram.

Bat, Whale, Monkey, Rat, Bear

Technical terms				
Classification	-	වර්ගීකරණය	-	பாகுபாடு
Domain	-	අධිරාජධානිය	-	பேரிராச்சியம்
Hierarchial organization	-	ධූරාවලි සංවිධානය	-	படிநிலை அமைப்பு
Vertebrates	-	පෘෂ්ඨවංශීන්	-	முள்ளந்தண்டுளிகள்
Invertebrates	-	අපෘෂ්ඨවංශීන්	-	முள்ளந்தண்டிலிகள்
Binomial nomenclature	-	ද්වීපද නාමකරණය	-	இரு சொற்பெயரீடு

Continuity of life

14

14.1 Reproduction

The life process that gives rise to a new generation from an existing generation is referred to as reproduction. Reproduction is a characteristic feature of organisms. It is essential to maintain the continuity of life. Reproduction is of two types,

- Asexual Reproduction
- Sexual Reproduction

• Asexual reproduction

Reproduction that occurs by spores or vegetative parts from a matured organism is known as asexual reproduction.

• Sexual reproduction

Reproduction that occurs due to fusion of two gametes produced in sexual structures of male and female organisms is known as sexual reproduction. Structures that are adapted for sexual reproduction can be found in evolutionary advanced organisms. In plants, the structure that is specially formed for sexual reproduction is flower. In animals, there are male and female reproductive systems.
Differences between sexual reproduction and asexual reproduction are given in the table below.

Table 14.1- Differences between sexual and asexual reproduction

Asexual reproduction	Sexual reproduction
• Contributes only one parental organism	• Contribute two organisms which are referred to as maternal and paternal
• Gives rise to offsprings which are more or less like maternal organism	• Gives rise to offsprings with mixed characteristics of parents
• No production of gametes	• Gametes are produced

• Meiosis does not occur • New species are not produced • A large number of offsprings can be produced in a short period of time • Can be seen in primitive plants and animals	• Meiosis occurs • New species with better adaptation to environment are produced • Increase of the number of offsprings is slow • Can be seen in plants and evolutionary advanced animals

14.2 Reproduction of plants

Reproduction of plants or the propagation of plants occurs mainly in two ways.

1. Asexual reproduction
2. Sexual reproduction

• Asexual reproduction of plants

Vegetative reproduction in plants is an asexual reproduction method.

The process of generating new plants from underground or aerial parts of a mother plant is referred to as vegetative reproduction. This gives rise to daughter plants that are identical to mother plant. Vegetative reproduction/Vegetative propagation is of two types.

- Natural vegetative propagation
- Artificial vegetative propagation

Natural vegetative propagation

Generation of new plants naturally from underground or aerial parts of a mother plant is known as natural vegetative propagation. This occurs from various vegetative parts of a plant. Some examples are given below.

- **Roots**

E.g. :- Curry leaves, Bread fruit, Guava, Slime wood

- **Leaves**

E.g. :- Begonia, Akkapana/Sathaikkaraichchan, Queen of the night (Kadupul)

- **Suckers**

Small plants that rise horizontally from the basal part of stem under the soil are known as suckers.

E.g. :- Paddy, Banana, Pine apple, Chrysanthemum, Hulankeeriya, Kaladuru

- **Runners**

Plant stems that run along the surface of soil connecting the stem to soil by adventitious roots are the runners.

E.g. :- Gotukola/Vallarai, Sweet potatoes, Maharaavana raevula/Ravanan meesai

- **Bulbils**

Special reproductive structure formed by a modification of a vegetative bud or a flower bud is known as a bulbil.
E.g. :- Pine apple, Jute, Hondala

- **Underground Stems**

Stems of plants which grow under the soil are known as underground stems. Vegetative propagation, storage of food and spending dormant period in adverse climatic conditions are some functions of underground stems. Underground stems are categorized into four types according to the external features.
They are;

(I) Rhizome - E.g. :- Ginger, Turmeric, Cannas, Araththa
(II) Corm - E.g. :- Big rooted Taro yam(Habarala/Nersshembu), Cocoyam (Gahala/Shembu),Taro, Elephant foot yam
(III) Bulb - E.g. :- Red onion, Big onion, Leeks
(IV) Stem Tuber - E.g. :- Potato, Coleus potato (Innala)

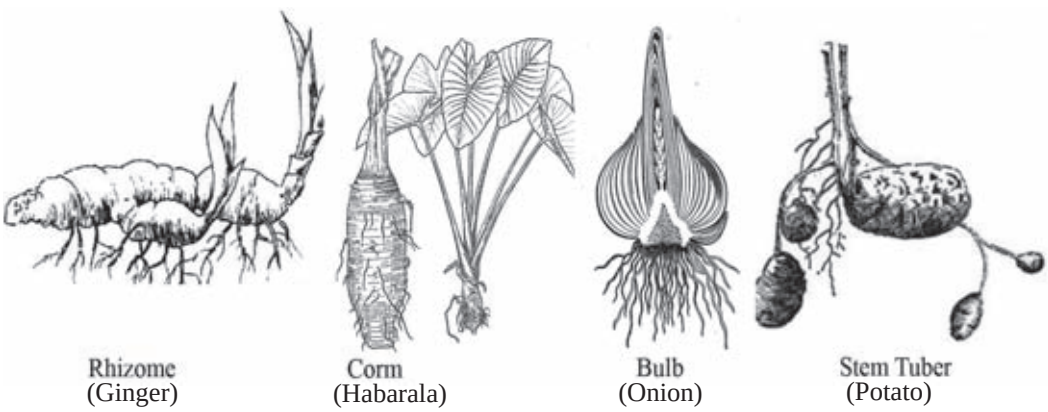


Figure 14.1 – Types of underground stems

Activity 14.1

- Observe the plants in your home garden or in school and identify that are propagated by vegetative parts.
- Tabulate those plants and their methods of propagation.

Artificial vegetative propagation

Production of plants vegetatively by man is known as artificial vegetative propagation. This can be done in several ways.

- Rooting of stem cuttings
- Layering
- Grafting
- Tissue culture

Rooting of stem cuttings

New plants can be obtained by planting stem cuttings of a mother plant. It is more appropriate to select twigs from a healthy plant that do not bear tender leaves, flowers or fruits at that time. This method is widely used for some plants like Rose, Shoe flowers, Ixora, Bougainvillea and Croton.

Assignment 14.1

- Find out and record various agro-chemicals in the market that are used to promote rooting of twigs.
- Prepare a list of plants that cannot be propagated by stem cuttings.
- Investigate the features of a twig that should be selected for quick rooting.

Layering

Initiate rooting while it is still attached to the mother plant is known as layering. Layering is of two types.

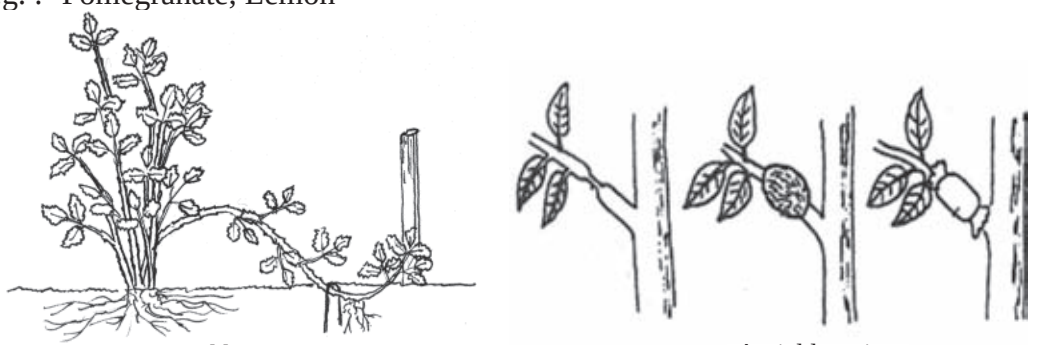
1. Ground layering
2. Aerial layering

- **Ground Layering**

Rooting is initiated from a branch of the plant closer to the ground level by this method. First a small cut is made on the underside of the selected twig. Then the twig is bent and burried under the soil. After few weeks, the twig will develop roots. Then the twig is separated from the mother plant and is planted.
e.g. :- Jasmin, Lemon

- **Aerial Layering**

This method is used for the twigs which are high above the ground. A ring of bark of the twig is removed. A mixture of compost and coir dust is placed round that place and tied with a strip of polythene. After few weeks the twig will develop roots. Then the twig is separated from mother plant and is planted.
e.g. :- Pomegranate, Lemon



Ground layering Aerial layering

Figure 14.2 - Types of Layering

Following are some advantages of layering.

- Plants that do not produce seeds can be propagated successfully.
- Several number of plants can be produced easily.

Activity 14.2

Identify a plant in your home garden, which is suitable for ground layering. Follow the process of ground layering properly. After about two weeks, uproot twig and observe how roots are developed.

Grafting (twig or bud)

Connecting a twig or a bud of a plant to a plant of same or closely related species is known as grafting. Two parts of the plants grafted are mentioned below.

(1) Stock

The rooted part of the plant is known as stock. Following are the characteristics that should be shown by a stock.

- Bearing a strong root system.
- Having a uniform growth.
- Withstanding environmental changes and diseases.

(2) Scion

The twig or the bud taken from another plant and grafted to a stock is known as scion. Following are the characteristics that should be shown by a scion.

- Should be a variety of good characteristics
- Should be free from pests and diseases

In the process of grafting, stock and scion are fused together by their cambium. Therefore grafting can be done only on the dicotyledonous plants, which have cambium tissues. Grafting can be done in two ways as follows.

1. Bud grafting
2. Twig grafting

- **Bud grafting**

Selecting a plant bud as the scion and grafting it to a stock is known as bud grafting It is done as follows.

- Cutting a live bud (which is located above the leaf scar) using a grafting knife.
- Making a cut on the stock and insert the bud into the cut.
- Wrapping the place from bottom to top using polythene strips.
- After few days, when the bud is about to emerge, remove the wrap and re-wrap keeping the bud open.
- Cutting the stem of the stock about 15 cm above, from the bud after about three weeks.

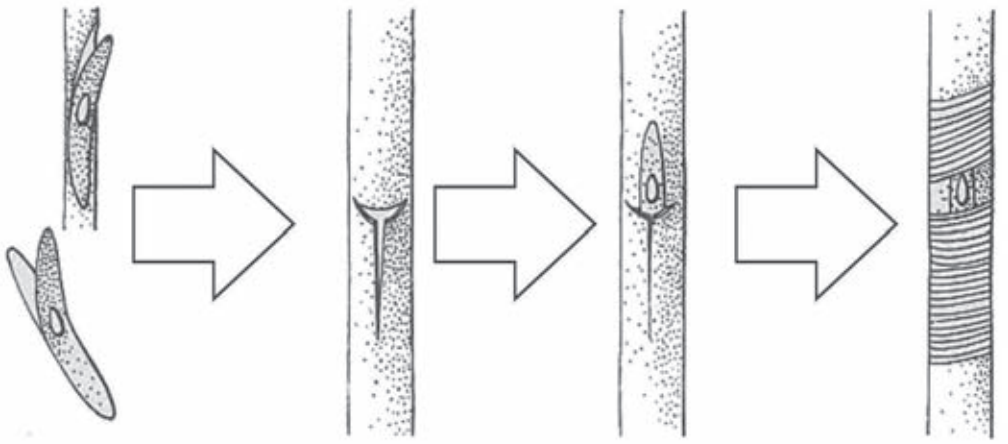


Figure 14.3 – Steps of bud grafting

There are several types of bud grafting according to the shape of the cut on the stock.
E.g. :- T-bud H-bud V-bud

- **Twig grafting**

In this method, a twig of a plant is taken as the scion. Procedure of grafting is given below.

- Selecting a twig of a fruit-bearing plant (It is more suitable to select a twig which has no tender leaves, flowers or fruits).
- Cutting the twig without damaging the cut.
- Fixing the twig to the stock, so that the cambium are contacted.
- Wrapping the place from bottom to top using polythene strips.
- Removing the wrap when the twig is observed to be growing.

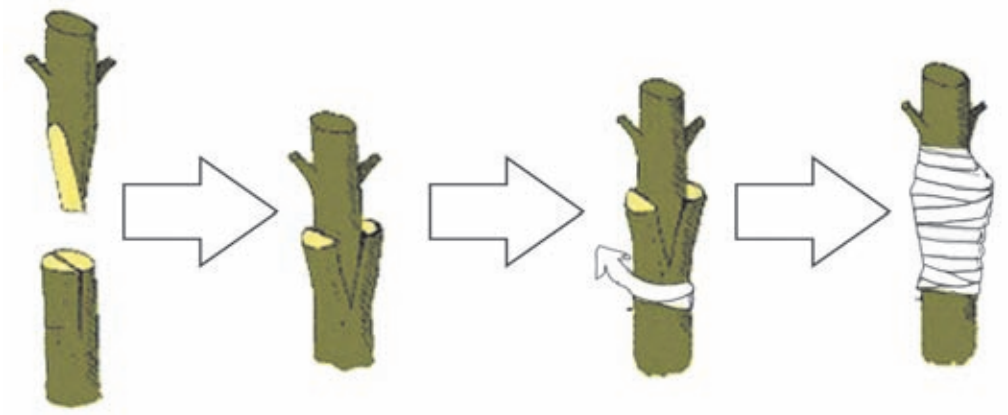


Figure 14.4 – Steps of twig grafting

According to the shapes of the cuts of the edges of stock and scion several types of twig grafting can be done.

E.g. :- Arch grafting, Peg grafting

Activity 14.3

Try to perform a twig grafting or a bud grafting with the assistance of your teacher. If a grafting knife is not available for this, use any other sharp knife.

Following are some **advantages** of grafting and budding.

- Production of offsprings with characteristics of the scion
- Obtaining of disease resistant plants with strong root systems
- Propagation of plants that do not produce seeds successfully

Disadvantages

- Having a short life span
- Not successful with every plant
- Reduce wood value of the trees

Tissue culture

New offsprings, which are identical to the parental plant, can be produced by cultivating any vegetative tissue of a plant in a culture medium under controlled conditions. Offsprings thus obtained are called a **clone.**

Genetically identical clones can be obtained by tissue culture. Generally, tissues are taken from apical buds, lateral buds or root tips for this purpose.

Sucrose, mineral salts, vitamins and plant growth substances are included in the culture medium used for tissue culture. Agar is used to solidify the medium. Sterilized conditions and controlling of temperature and light should be practised for the success of tissue culture.

Following are the principle steps followed in tissue culture

(1) Introducing the part of vegetative tissue, obtained from mother plant, into the culture medium.

(2) Allowing new roots and buds to be developed from the tissue called callus, which is grown from the vegetative tissue introduced.

(3) Separating the plantlets and placing them in test tubes or flasks to grow further.

(4) Gradually let the new plantlets to get adapted to natural conditions to be cultivated in the field.

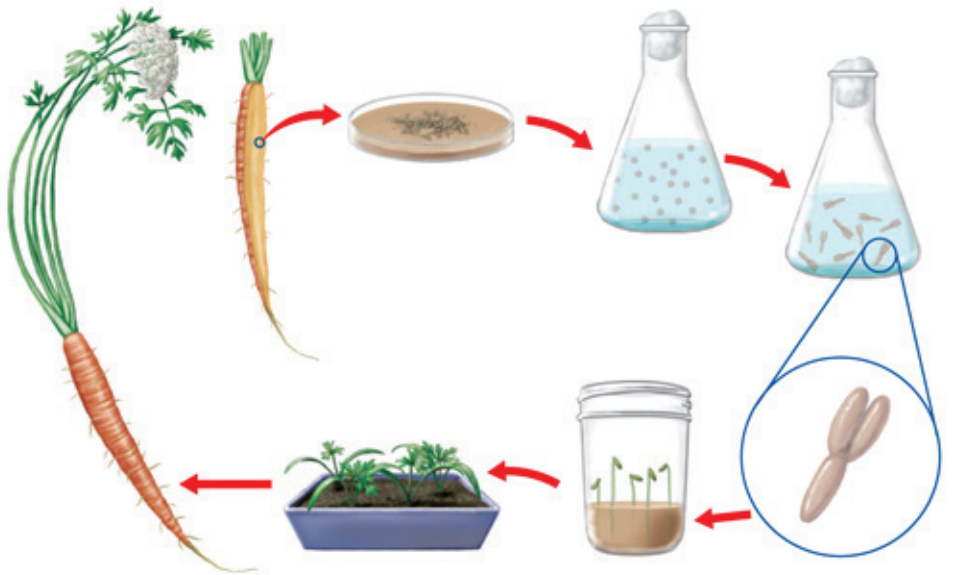


Figure 14.5- Steps of tissue culture

Following are some advantages of tissue culture.

- Production of offsprings which are identical to mother plant.
- Propagating a large number of plants at the same time.
- Production of a large number of plants in a short period of time.
- Propagation of a large number of healthy plants in a limited space.
- Can be obtained a large number of plants using a hybrid tissue with a favourable gene.

Assignment 14.2

- Prepare a list of places, where tissue culture is practising in Sri Lanka, using various sources.
- If possible, visit such a place and study the process of tissue culture.
- Name the plants, which are mostly produced by tissue culture in Sri Lanka.

Advantages of vegetative propagation

- Ability of propagating plants that do not produce seeds successfully.
- Ability of having offsprings that are identical to mother plant.
- Propagation of plants that bear fruits early.
- Ability of propagating selected plants which are resistant to diseases and pests.
- Ability of generating plant varieties which withstand adverse environmental conditions.

Disadvantages of vegetative propagation

- New varieties are not evolved

Sexual reproduction of plants

Seeds are produced by fusion of gametes produced in sexual structures in matured plants. These seeds can grow into new plants.

Flower

The structure that bears sexual parts of a plant is the flower. Parts of a flower are arranged in whorls on the receptacle, which is located at the tip of the flower stalk or pedicel. There are four principle parts of a flower, which are given below.

- Calyx
- Corolla
- Androecium/Stamen
- Gynoecium/Pistil

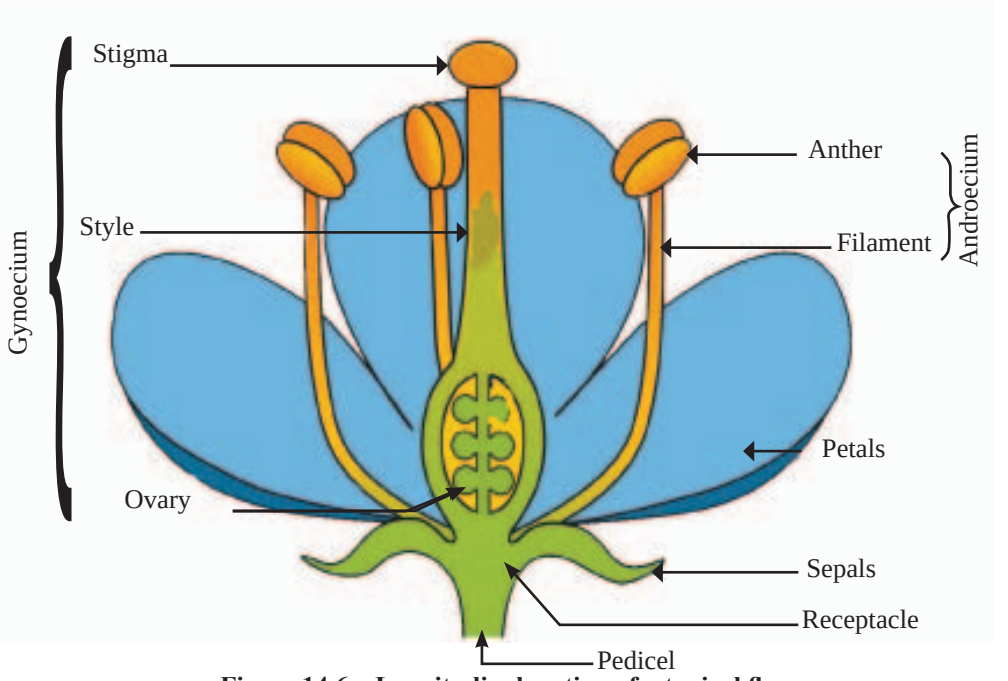


Figure 14.6 – Longitudinal section of a typical flower

Calyx

Calyx is comprised of several sepals. This is the outer-most part of a flower. Calyx is the whorl of sepals located on the receptacle at the tip of the flower stalk (pedicel). This is green in colour. This protects the flower parts, when the flower is in bud stage.

Corolla

Corolla is comprised of a whorl of petals, and is located inner to the calyx. This is white or colourful. Corolla protects the inner flower parts in the bud stage and attracts insects for pollination, when the flower blooms.

Androecium/Stamen

Androecium is the male reproductive structure of a flower. This is comprised of a filament and an anther. There are pollen sacs in the anther which contain pollen. When matured anther bursts and pollen release. Pollen are the male gamete cells of plants.

Gynoecium/Pistil

Gynoecium is the female reproductive structure of a flower. This is comprised of three parts, named stigma, style and ovary. Ovules are located in the ovary. Ovules are the female gamete cells of a flower.

Activity 14.4

- Collect some flowers. Observe and identify their parts using a hand lens.
- Invert a shoe flower and cut longitudinally across the stalk and draw a labelled diagram.

- **Bisexual flowers**

Flowers that consist of both male and female parts are referred to as bisexual flowers.

E.g.: Shoe flower, Passionfruit, Chilli, Kathurumurunga /Agathi

- **Unisexual flowers**

Flowers that consist of either male or female parts are referred to as unisexual flowers. They are of two types.

(1) **Staminate flowers** :- The flowers that have only androecium or stamen.

E.g. :- Sterile flowers of Pumpkin, apical flowers of Corn

(2) **Pistilate flowers** :- The flowers that have only gynoecium or pistil.

E.g. :- Fruit bearing flowers of Pumpkin, fruit bearing flowers of Corn

- **Monoecious plants**

Plants that bear both staminate (male) flowers and pistilate (female) flowers are called monoecious plants.

E.g. :- Pumpkin, Corn, Coconut, Bitter gourd

- **Dioecious plants**

When staminate flowers and pistilate flowers are born separately on two plants, they are called dioecious plants.

E.g. :- Papaw, Vallisneria

Pollination

The process of depositing matured pollen of a flower on the stigma of the flower of the same species is known as pollination. Pollination occurs in two ways.

(1) Self-pollination

(2) Cross-pollination

Self-pollination

The process of depositing matured pollen of a flower on the stigma of the same flower is termed as self-pollination.

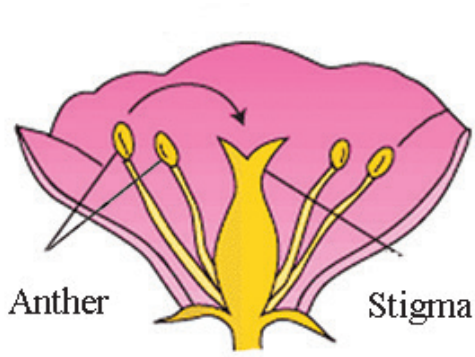


Figure 14.7 - Self- pollination

Cross - pollination

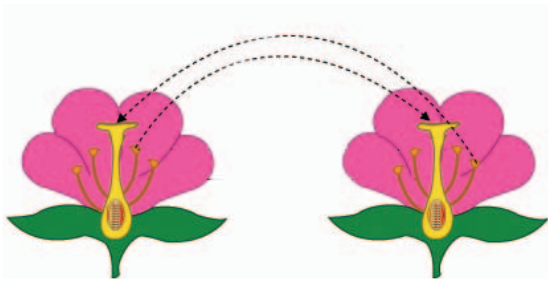


Figure 14.8 - Cross-pollination

Process of depositing matured pollen of a flower, on the stigma of a flower of same plant or a flower of another plant of the same species is termed as cross-pollination.

Cross-pollination allows to mix characteristics of two plants. It helps to give rise to a strong new generation with new characteristics. Therefore some flowers are adapted to avoid self-pollination and promote cross-pollination. Some of those adaptations are mentioned below.

Having unisexual flowers

Bearing of pistilate flowers and staminate flowers separately.

E.g. :- Coconut, Corn

Self – Sterility

Fruits are not developed when pollen of a flower is deposited on the stigma of the same flower.

E.g. :- Passion fruit

Hercogamy

This is the positioning of stamens and stigma of a flower at a distance.

E.g. :- Orchid, Catharanthus

Having extrose stamens

Here, the stigma is positioned straight while stamens are bent aside or stamens are positioned straight while stigma is bent aside.

E.g. :- Jasmin, Lebbek flower (Pinna)

Dichogamy

Here, Stamens are matured earlier than pistil (proterandry) or pistil is matured earlier than stamens (protogyny).

E.g.:- Corn, Tridax

Passion fruit

Orchid

Jasmin

Figure 14.9- Flowers having adaptation to avoid self pollination

Agents of pollination

Factors that contribute the pollination of flowers are known as agents of pollination. There are three principle agents of pollination.

1.Animals
2.Wind
3.Water

Animals

Flowers pollinated by animals are referred to as zoophilous flowers. Among the animals, insects contribute much for pollination. Flowers have adaptations to attract insects for the process of pollintation.

- Flowers having a fragrance
- Flowers being large
- Colourful flowers
- Having nectaries
- Pollen being sticky
- Stigma being sticky
- Stamens and stigma are located in such a way, that they are easily contacted with animals
- Flowers having shapes that cheat insects

Some examples for flowers pollinated by animals are passion fruit, winged bean, Kathurumurunga /Agaththi

Kathurumurunga /Agathi

Thunbergia

Figure 14.10- Flowers pollinated by animals

Wind

Flowers pollinated by wind are referred to as aerophilous or anemophilous flowers. Such flowers usually locate separately as staminate and pistilate flowers. Aerophilous flowers show following adaptations for successful pollination.

- Flowers are born at the apex of the plant
- Large amount of pollen are produced
- Pollen are very small and light
- Stigma is branched
- Flowers are in inflorescences

Examples for flowers pollinated by wind are Paddy, Corn, Grass and Coconut

Paddy

Corn

Coconut

Figure 14.11-Flowers pollinated by wind

Water

Flowers pollinated by water are referred to as hydrophilous flowers. Such flowers usually locate separately as staminate and pistilate flowers. When matured, staminate flower separates from the plant and floats in water. While floating it contacts with a pistillate flower and pollination takes place. Example for a flower pollinated by water is Vallisneria.

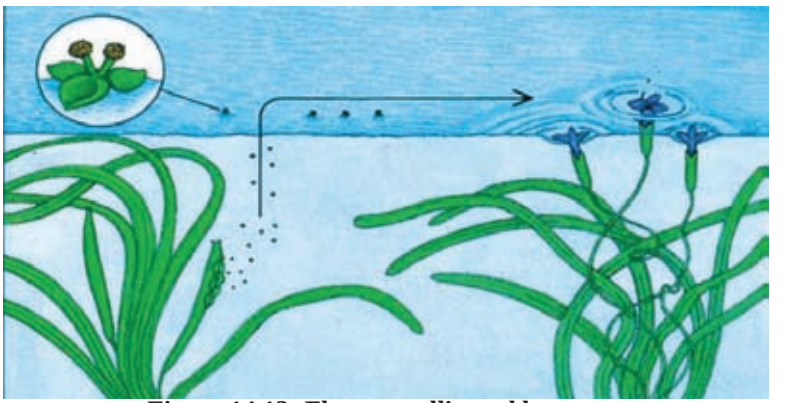


Figure 14.12- Flowers pollinated by water

For extra knowledge

Artificial pollination

The process of depositing the pollen of a flower artificially on the stigma of the same flower or on the stigma of a different flower of the same species is known as artificial pollination. This can be done with fingers or with a brush.
E.g.:- Anthurium, Passion fruit

Figure 14.13 - Performing artificial pollination

Fertilization

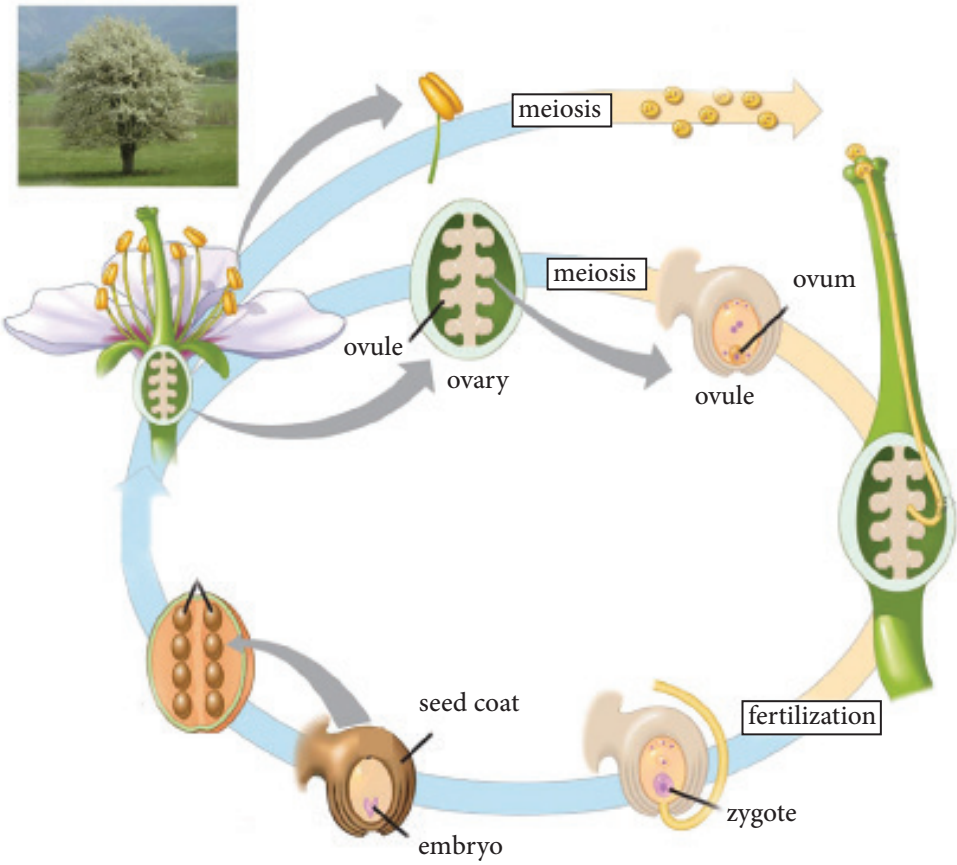


Figure 14.14 - Fertilization of gametes and formation of seeds and fruits of plants

- Pollen are deposited on stigma of the same flower or in another flower of the same species.
- When a pollen grain is deposited on the stigma, it is stimulated by the sugar solution on the stigma and germinates.
- Pollen tube grows through the style towards an ovule in the ovary.
- The male gamete in the pollen cell fuses with the ovum in the ovary and this phenomenon is known as fertilization.

Production of fruits and seeds

After fertilization zygote develops to form an embryo. The flower undergoes several changes after fertilization.

- Ovary develops to form the fruit.
- Wall of the ovary becomes the pericarp.
- Fertilized ovule develops to a seed, and wall of the ovule becomes the testa or the seed coat.
- Normally sepals, petals, stamens and stigma are worn out. But in some flowers, sepals become fleshy and are attached to the pericarp after fertilization.

  E.g. :- Guava, Brinjal, Mangosteen, Rose apple

Process of developing fruits without fertilization is known as parthenocarpy. Artificial growth substances are used to develop fruits in that manner. Such fruits are seedless.

E.g. :- Grapes, Orange, Apple

Dispersal of fruits & seeds

Spreading away of the fruits and seeds from the mother plant is referred to as dispersal of fruits and seeds. Plants fulfil their following requirements by that process.

- Competition for essential requirements is minimized
- New habitats are found
- Diversity is increased
- Protection from pests and agents of diseases

Methods of dispersal of fruits and seeds

There are four principle methods of dispersal of fruits and seeds, as mentioned below.

- By animals
- By water
- By wind
- By explosive mechanism

Assignment 14.3

- Identify and name the agent of dispersal of fruits that you come across.
- Mention two adaptations that each fruit has for its method of dispersal.

Dispersal of fruits and seeds by animals

Fruits and seeds that are dispersed by animals may have following adaptations.

- There are succulent edible parts
  E.g. :- Mango , Papaw
- There are attractive colours
  E.g. :- False fruit of Cashew, Banana
- There are hooks or hairs assist to be attached
  E.g. :- Nagadarana/Maramunthigai, Epala/Amanakku, Love grass (Tuththiri)
- There are shapes and patterns to cheat animals
  E.g. :- Oil castor, Red bead (Madatiya/Manjadi), Olinda/Kunrimani, Bitter gourd

Mango

False fruit of Cashew

Bittergourd

Figure 14.15- Fruits and seeds dispersed by animals

Dispersal of fruits and seeds by wind

Fruits and seeds dispersed by wind have following adaptation.

- Having structures like threads to float in air
  E.g. :- Milk weed (Wara/Erukkala), Cotton, Imbul
- Possess wing – like structures to float
  E.g. :- Hora/Ennei, Gammalu, Drum sticks.
- Fruits and seeds born at the apex of the plant.
  E.g. :- Mahogani, Hora/Ennei
- Seeds being very light
  E.g. :- Orchid
- Production of fruits and seeds in large numbers.
  E.g. :- Grass, Mahogni, Milk weed (Wara/Erukkalai), Cotton

Cotton Hora Mahogani Grass

Figure 14.16 - Fruits and seeds dispersed by wind

Dispersal of fruits and seeds by water

Fruits and seeds dispersed by water possess following adaptations.

- Having porous or fibrous pericarps

  E.g. :- Coconut, Ceylon almond, Sea mango (Diya kaduru/ Kalliththi)

- Possess pericarps that are suit for floatation.

  E.g. :- Lotus

- Having air-filled shells

  E.g. :- Water lily

Coconut Ceylon almond Lotus

Figure 14.17 - Fruits and seeds dispersed by water

Dispersal of fruits and seeds by explosive mechanism

Pericarp of the fruit of some plants explodes and the seeds are dispersed far away. Touch, moisture or dry weather conditions can cause explosion.

E.g. :- Rubber, Ladies fingers, Koodalu, Red bead (Madatiya/ Manjadi)


Rubber


Madatiya/Manjadi

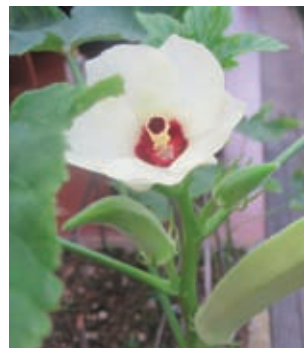

Ladies fingers

Figure 14.18- Fruits and seeds dispersed by explosive mechanism

Germination of seeds

Activation of the embryo in a seed and its development to form a seedling is known as seed germination. Following factors are essential for seed germination.

1) Viability of seed
2) Air (Oxygen)
3) Water or moisture
4) Optimum temperature

When a seed is germinating, water activates the enzymes in the cotyledons, and stored complex food is digested to simple nutrients. The nutrients help to develop the radical and the plumule.

Dormancy of seeds

Sometimes seeds do not germinate, though the essential factors for germination are fulfilled. This condition is known as dormancy.

Seeds show dormancy as an adaptation for adverse environmental conditions. Following factors affect the dormancy of seeds.

1) Embryo being not matured
2) Impermeability of testa for water or oxygen

Various methods are practised to remove the dormancy of seeds before germinating them. Some of them are mentioned below.

1) Storing seeds for some period of time
2) Burning the villi on the seed coat or testa E.g. - Teak seeds
3) Removing the seed coat E.g. - Orange seeds
4) Keeping the seeds in hot water E.g. - Lead tree (Ipil Ipil)
5) Gently cracking the seed coat E.g. - Nelli/Nellikai seeds

Activity 14.5

Design a suitable activity to investigate the external factors for seed germination.

For extra knowledge

Seed germination occurs mainly in two ways.

1) Hypogeal germination
2) Epigeal germination

Hypogeal germination

Here, when the seed germinates, plumule emerges up from the soil, but cotyledon does not emerge up from the soil. Cotyledon and endosperm supply food for the seedling at its early stage. But colyledon does not produce food by photosynthesis. Most of the monocotyledonous plants show hypogeal germination.

E.g. :- Coconut, Corn

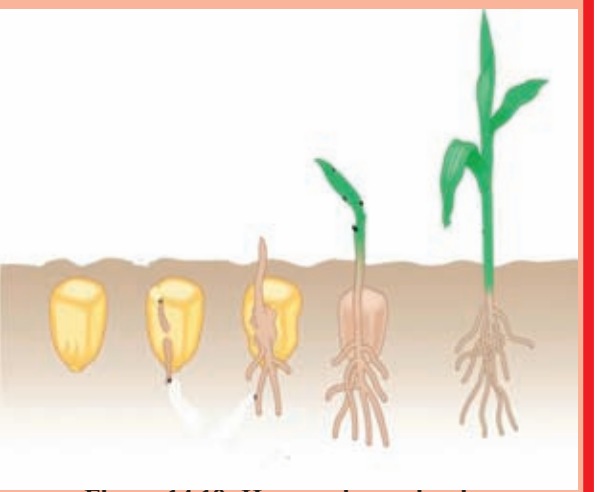


Figure 14.19- Hypogeal germination

Epigeal germination

Here, when the seed germinates, plumule emerges up from the soil, cotyledons also emerge up from the soil. Moreover, cotyledons produce food by photosynthesis in addition to supply stored food for the seedling in its early stage. Most dicotyledonous plants show epigeal germinaton

E.g. :- Bean, Tamarind

Figure 14.20- Epigeal germination

14.3 Reproduction of man

• Puberty (Adolescence)

Sexual maturity or attaining adolescence is referred to as puberty. Secondary sexual characteristcs which differentiate males and females begin to appear from the puberty

• Secondary sexual characteristics

Features that appear in male and female from puberty are known as secondary sexual characteristics.

Secondary sexual characteristics of males

These changes start to appear between the age of 13-16 years. The action of Testosterone hormone is responsible for this.

- Pubertal hair grows on face, chest, under arm pits and in genital areas.
- Shoulders grow wide.
- Larynx enlarges and voice becomes deep.
- Bones and muscles grow faster and the growth of body is accelerated.
- Testes start to produce sperms.
- Genitals start to grow larger.

Secondary sexual characteristics of female

These changes start to appear between the age of 10-14 years. The action of Oestrogen and Progesterone are responsible for this.

- Pubertal hair grows on arm-pits and on genital areas.
- Pubic region widens.
- Mammary glands start to grow.
- Fat deposits in the hypodermis and body becomes fat.
- Bones and muscles grow fast and the growth of body is accelerated.
- Releasing of ova from ovaries (menstrual cycle) starts.

• Process of reproduction

Reproductive cells or gametes should be produced for the process of reproduction. This occurs in reproductive systems.

Male reproductive system

Main parts of the male reproductive system

- **Testes / Testicles**

A pair of testes which are oval in shape are located in a sac called scrotum or testes sac. Sperms are produced in these structures. A testes is comprised of about 250 testical lobules. There are about 1000 convoluted tubules which are called seminiferous tubules in them. Sperm mother cells are produced in seminferous tubules.

- **Pair of epididymis**

All the vas efferens in a testes emerge out of the testes and are opened to a single convoluted tube called epididymis. Sperms are temporarily stored in it.

- **Pair of vas deferens**

The tube that brings sperms from epididymis is called vas deferens. The other end of it is joined to the tube coming from seminal vesicles.

- **Pair of seminal vesicles, prostrate gland and pair of cowper's glands**

These are the glands associated with male reproductive system. These glands secrete a white fluid. This secretion is released into the urethra. This fluid is important to provide nutrition to the sperms and their transportation. Sperms and this white fluid is collectively known as seminal fluid or semen.

- **Penis**

This is the muscular organ which is important in ejection of semen into female reproductive system. This becomes rigid when blood supply is increased. Urethra opens out through penis. The tip of the penis is called glans penis and it is covered by prepuce or foreskin.

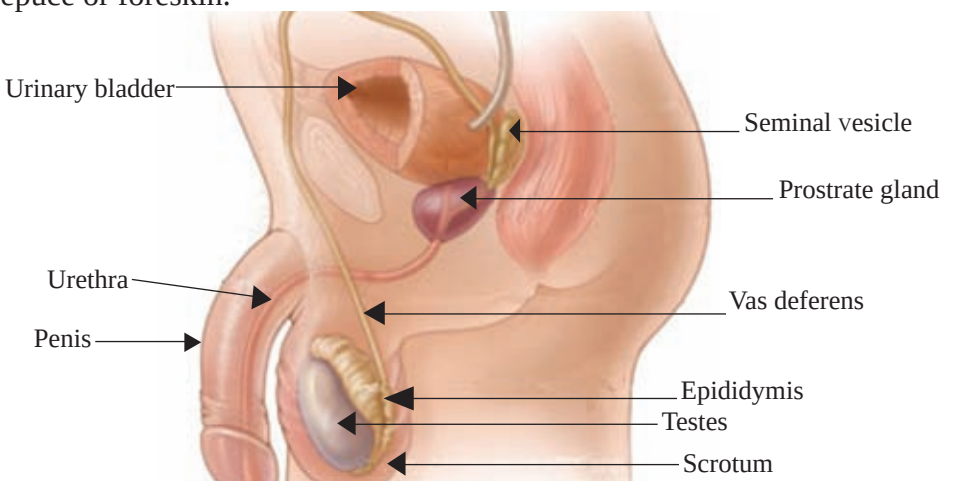


Figure 14.21 - Male reproductive system

Functions of male reproductive system

Production of sperms begins when a male attains his puberty. Sperms are formed from the sperm mother cells which are in the seminiferous tubules. When sperms are temporarily stored in epididymis. During the copulation, sperms pass through vas deferens and are collected to the urethra. At the same time, the secretion of the prostrate gland and Cowper's glands are also mixed with sperms. The secretion mixed with sperms is called seminal fluid or semen. There are millions of sperms in one milliliter (1 ml) of semen.

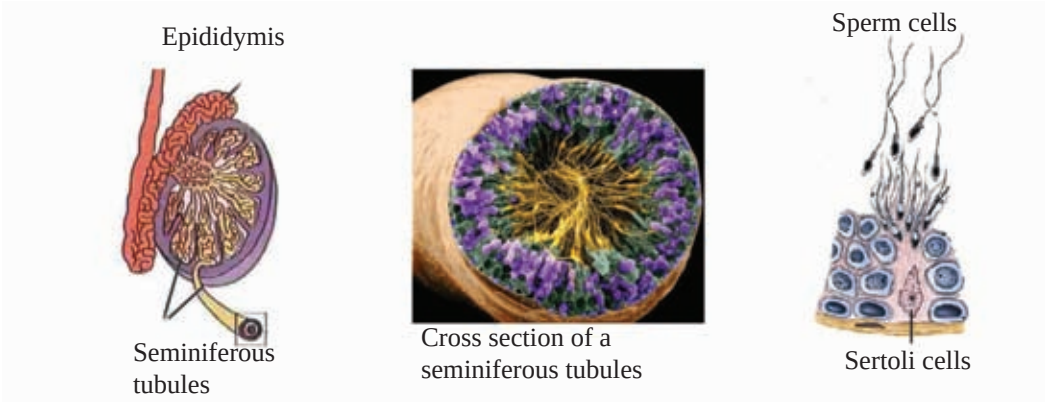


Figure 14.22 - Structure of seminiferous tubule

Process of generating sperms is very sensitive to temperature. The temperature in the testes should be lower than body temperature for the production of healthy sperms. That is the reason for testes to be in a sac called scrotum out side the body. Matured sperm is motile and consists of three parts named head, body and tail.

Activities of male reproductive system

- Production of sperm cells
- Ejection of sperms into female reproductive system
- Production of Testosterone

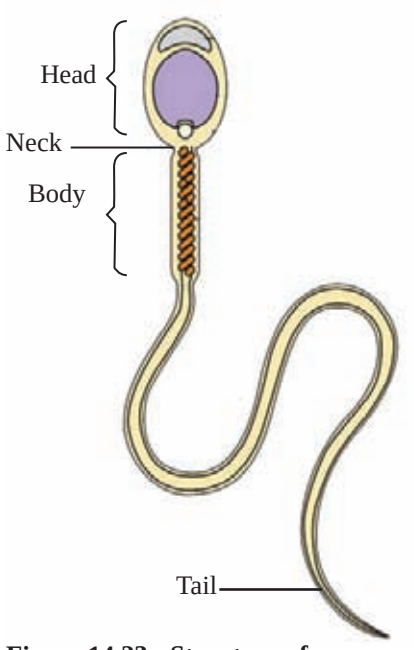


Figure 14.23 - Structure of a sperm under electron microscope

Female reproductive system

Main parts of the female reproductive system

- **Ovary**

There is a pair of ovaries close to the lateral walls of pelvic area in the abdominal cavity. In a cross section of an ovary, there are two zones known as cortex and medulla. Ova are produced in follicles. Each ovary contains primary follicles and various stages of production of ova such as graafian follicles, corpus luteum and corpus albicans. Production of ova starts at the birth of a female.

- **Fallopian tube**

Ovum that comes out of the ovary enters into long muscular tube called fallopian tube. The end of this tube, which is close to the ovary is funnel-like and has finger-like projections called fimbria. These are important in transferring the ovum into fallopian tube.

- **Uterus**

This is a hollow structure positioned in pelvic area. There are three zones in uterus named as fundus, body and cervix. Two follopian tubes are connected to the zone called fundus. The other end of uterus is cervix.

- **Vagina or Endocervical canal**

Vagina starts from the cervix and opens to the exterior from the opening called vulva.

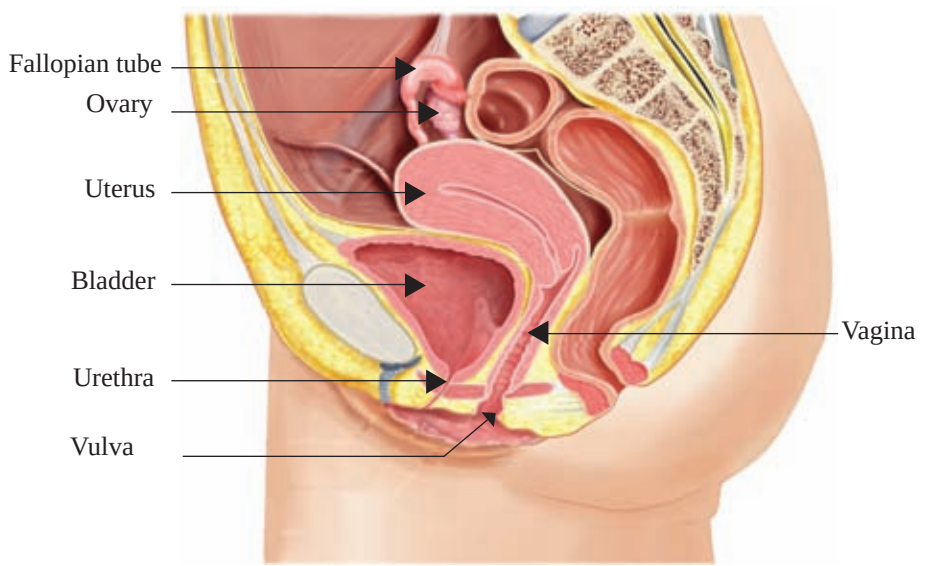


Figure 14.24 - Location of female reproductive system

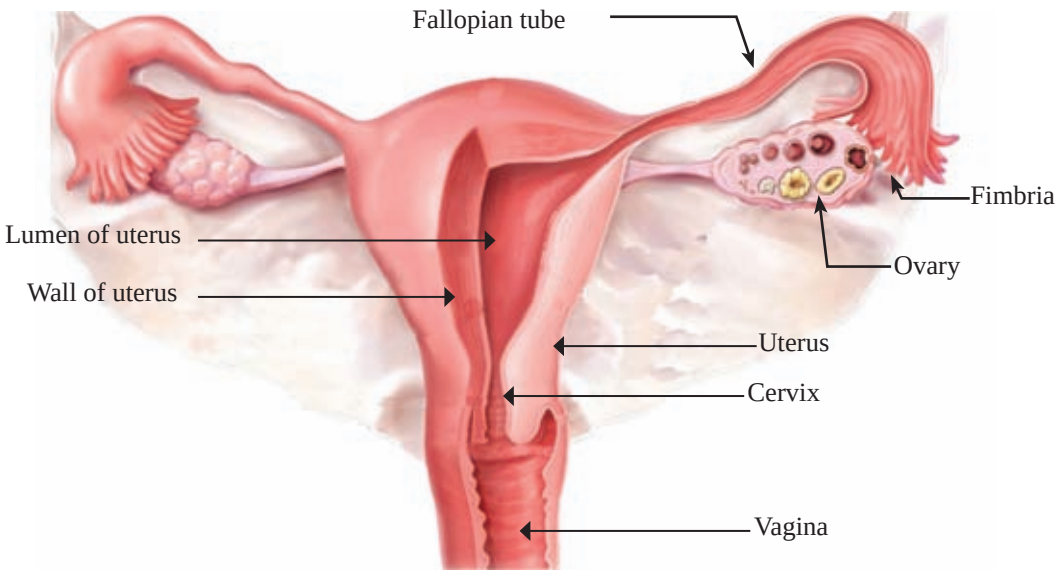


Figure 14.25 - Female reproductive system

Functions of female reproductive system

Production of ova in females initiate since foetal stage. At birth each ovary contains 200 000 - 400 000 primary follicles. Nearing puberty, one of the primary follicles develops to form a multicellular structure called graafian follicle. It reaches the peripheral area of the ovary.

When matured, graafian follicle bursts to release the ovum which is directed towards the fallopian tube by fimbria. Then the ovum passes through the fallopian tube towards the uterus.

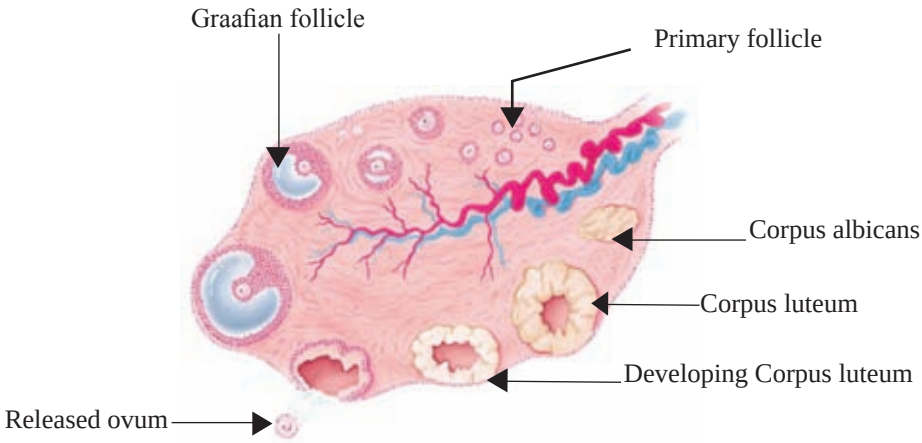


Figure 14.26 - Cross section of an ovary with various stages of ovum

Activities of female reproductive system

- Developing ova which are the female reproductive cells
- Facilitate the developing of foetus
- Production of hormones Oestrogen and Progesterone

• Menstrual cycle

The cyclic process associated with the reproductive systems of sexually matured females as known as menstrual cycle. It takes appoximately 28 days for one menstrual cycle.

Here the pair of ovaries releases the egg cells or ova alternatively. The whole process of menstrual cycle takes place associated with two locations.

1. Changes that take place in the ovary
2. Changes that take place in the uterus

Changes that take place in the ovary

Development and release of ova, which are the female reproductive cells, is the function of ovary. Changes that occur in the ovary can be divided into two stages.

1. Follicular phase
2. Luteal phase

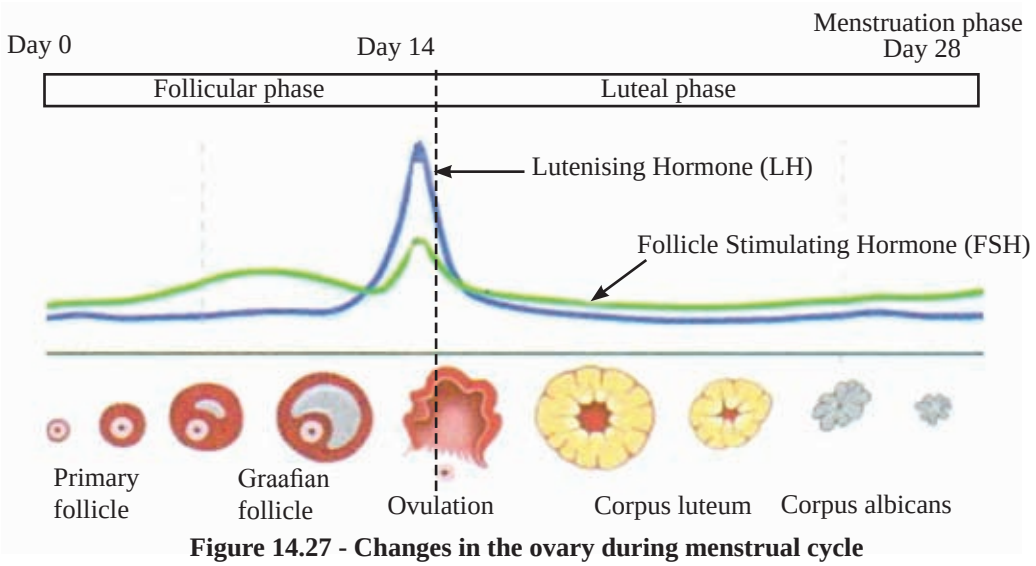


Figure 14.27 - Changes in the ovary during menstrual cycle

• Follicular Phase

This is the initial phase. Under the influence of Follicle Stimulating Hormone (FSH), secreted by pituitary, a primary follicle in the ovary develops to form a graafian follicle, which is ready to release an ovum. This takes about 14 days. During this phase, ovary secrets Oestrogen.

- **Luteal Phase**

This is the final phase. When graafian follicle is matured, it bursts and the ovum inside it, is released from the ovary into the fallopian tube, under the influence of Lutenising Hormone (LH), secreted by pituitary gland. If fertilization does not occur, when the ovum is passing forward through fallopian tube, the remaining part of graafian folicle changes to form corpus luteum and finally to corpus albicans and fades off. This whole process occurs during luteal phase and it takes about 14 days, During this phase ovary secrets progesterone.

Changes that take place in uterus

If an ovum is fertilized, the embryo develops in the uterus. If an ovum is not fertilized, changes that occur in uterus are divided into three phases.

1. Menstrual phase
2. Proliferation phase
3. Secretory phase

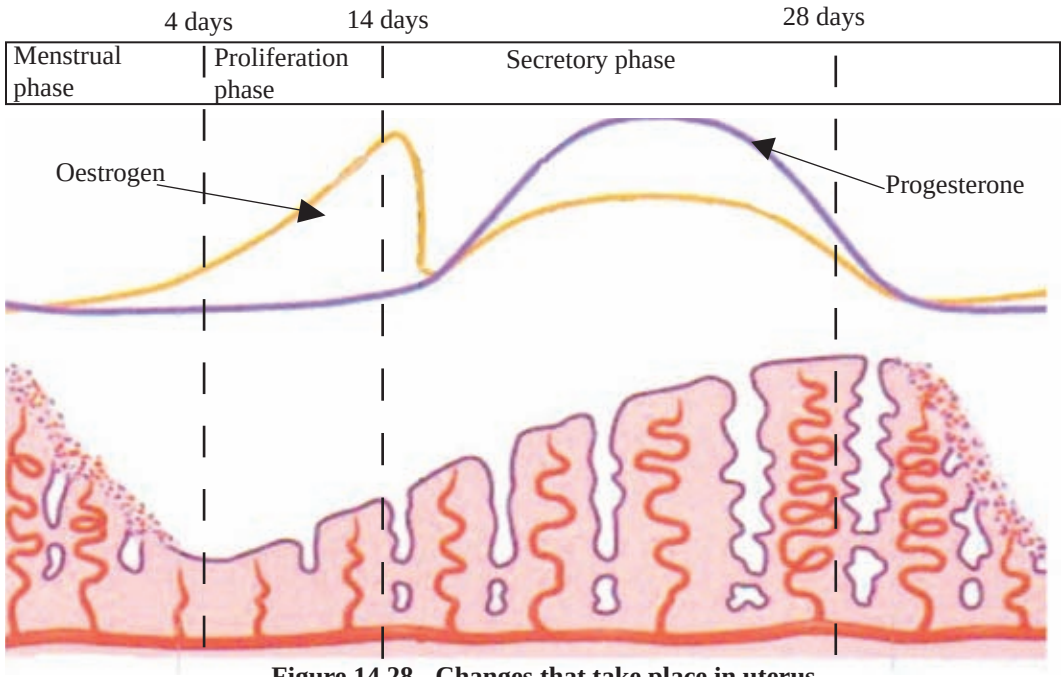


Figure 14.28 - Changes that take place in uterus

- **Menstrual phase**

This is the initial phase. If fertilization does not take place, level of Progesterone decreases. This causes the degradation of the wall of uterus and it is expelled out from the body through vagina with blood. This is referred to as menstrual flow and occurs for about four days.

- **Proliferation phase**

This is the second phase. Degraded wall of uterus starts to re-build because of the influence of Oestrogen. New cell layer and blood capillaries grow on the inner wall of the uterus. It takes about 10 days for this.

- **Secretory phase**

This is the final phase. Uterine wall thicknes and blood supply also increase. Glands on the uterine wall are activated and it becomes secretory. This happens because of the influence of hormone Progesterone. It takes about 14 days for this. Body temperature also increases slightly during this period.

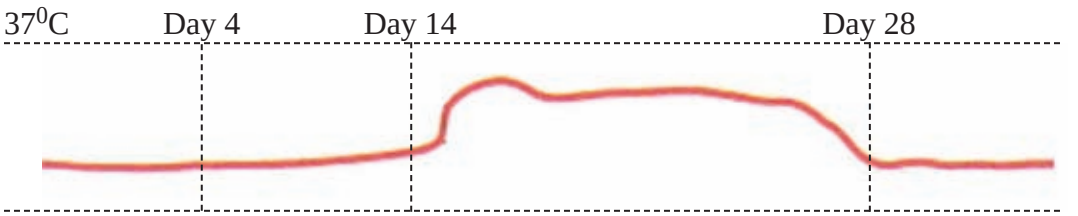


Figure 14.29 - Changes of body temperature during menstrual cycle

Fertilization and Implantation

During the copulation, seminal fluid (semen) is released into the vagina. Sperm cells in semen, swimming in the fluid, pass through uterus towards the upper part of fallopian tube. Then one of the sperms fuses with the ovum passing down towards uterus. Here nucleic matter of the ovum and the sperm fuses together. This phenomenon is called fertilization.

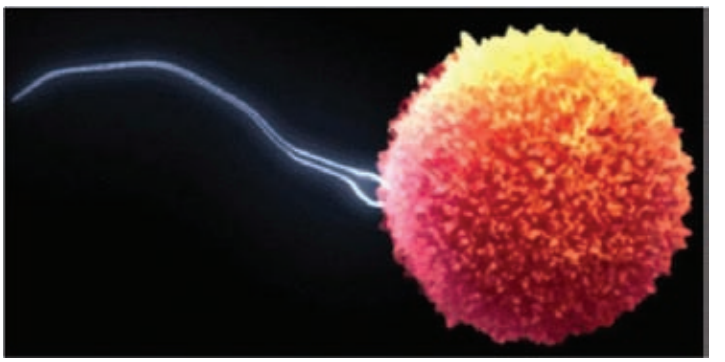


Figure 14.30 - Fertilization of a sperm and an ovum

Fertilized ovum is referred to as zygote. While it is rolling towards uterus, it divides to increase the number of cells. Then it is known as morula. Morula disintegrates the tissues of uterine wall, sinks and deposits in the wall. This is known as implantation or interplantation.

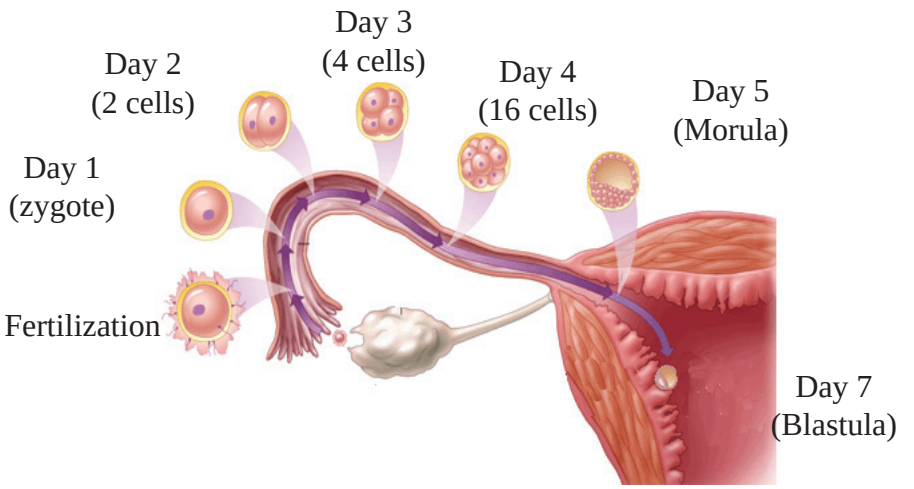


Figure 14.31- From fertilization to implantation

• Development of foetus

After implantation, foetal development occurs with the division of cells. In about six weeks, protective membranes called embryonic membranes develop. There is a fluid in them. Foetus is sunk in this fluid. The place that the embryonic membranes connect with uterine wall is known as placenta. Material exchange from mother to foetus and foetus to mother occurs through umbilical cord. Umbilical cord is the tissue in placental mammals, through which nutrients and oxygen are exchanged between the mother and the foetus. Though nutrients, oxygen and agents of diseases (some disease causing microoganisms like virus) transfer from mother to foetus, blood exchange does not occur through umbilical cord. Removal of excretory products and carbondixoide also occurs through umbilical cord. Principle changes in foetal development with time are given in the table below.

Table : 14.2- Principle changes of foetus with time

Time period (Months)	Principle changes of foetus with time
03	■ Takes human form ■ Head of foetus is large, with respect to other body parts ■ Development of nails starts ■ Male and female sex organs are developed
04	■ Development of skeleton starts ■ Hair begins to grow
05	■ Foetus is completely covered with hair ■ Mother can feel the movements of foetus for the first time ■ Heart beat of foetus can observe from out side (average rate of heart beat is 120-140 per minute)
06	■ Eyebrows and eyelashes have developed
07	■ Eyelids open ■ Skin is in wrinkled nature
08	■ Subcutaneous fat begins to deposit ■ Weight of foetus is about 2 kg
09	■ Nails of fingers have completely grown ■ Testes are positioned in scrotum ■ Body shows a full grown nature ■ Weight of foetus is about $2\frac{1}{2}$ - $3\frac{1}{2}$ kg

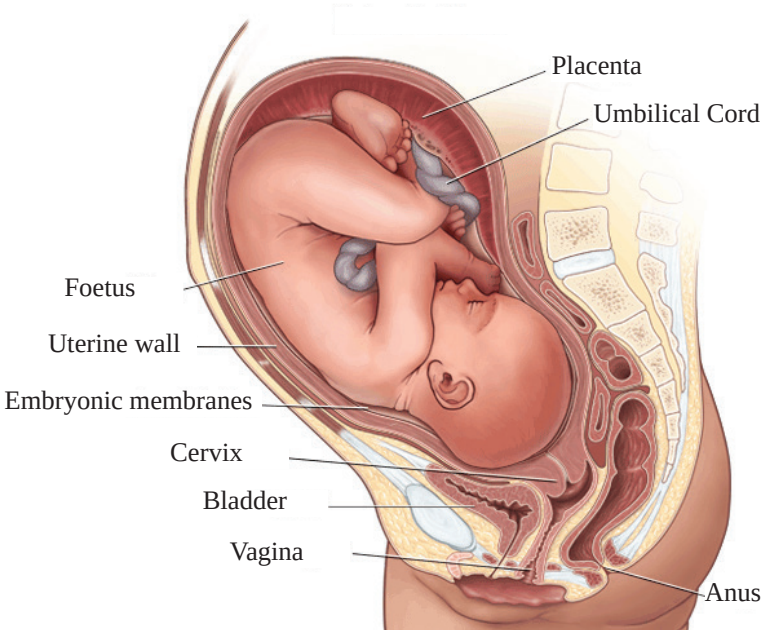


Figure 14.32 - Development of foetus in uterus

• Child birth or Parturition

When it is close to child birth, head of the foetus in uterus, turns towards vagina. After completion of development for about 280 days, foetus is pushed outside through vagina by the contraction of muscles of uterus. This process is known as child birth or parturition. Further contraction of uterine wall, disconnects the placenta and associated tissues.

After parturition the umbilical cord that connected placenta and foetus is cut and tied.

Assignment 14.4

- List out the materials that pass from mother to foetus through umbilical cord.
- List out the materials that pass from foetus to mother through placenta.

Hormonal co-ordination

Human reproduction process is completely regulated by hormones. This can be seen in both males and females. Here several hormones such as FSH, LH, Testosterone, Oestrogen, Progesterone, secreted by several endocrine glands are important.

14.4 Sexually transmitted diseases

Diseases transmit from one person to another, mainly because of a sexual contact and sexual secretions are known as sexually transmitted diseases.These are transmitted due to blood transmission too. Symptoms of such diseases can usually be found on sex organs. About 20 of such diseases are identified so far. Some of them, which are common, are discussed below.

- **Gonorrhoea**

This is transmitted by a bacterium called *Neisseria gonorrhoeae.* Secretions from sex organs, pain, blockage of fallopian tube are some of its symptoms. This disease can be cured and if not treated it will result in blindness and lameness.

- **Syphilis**

This is transmitted by a bacterium called *Treponema pallidum.* After about three months of infection, painless blisters appear on sex organs.They are automatically cured. After about six months, fever and pain in throat appears. If treated in early stages this disease can be cured. Pathogens can exist in blood for a long time and can spread to other organs also.

- **Herpes**

This is transmitted by a virus called *Herpes simplex.* Highly painful blisters on sex organs are the symptoms. This inactivates the nervous system and is deep-rooted. Though it is not fatal, it has no permanent treatment.

- **Acquired Immuno-Deficiency Syndrome (AIDS)**

This is transmitted by *Human Immunodeficiency Virus (HIV).* Symptoms may appear in about 2- 15 years after infection. This may be fatal and cannot be cured. AIDS is transmitted by sexual secretions and blood. To keep off from this disease, risk activities and vectors should be avoided.

It is possible to avoid sexually transmitted diseases by being responsible during sexual activities.

Summary

- Reproduction of organisms is of two types. They are sexual reproduction and asexual reproduction.
- Sexual reproduction is the reproduction, associated with sexual structures and sexual processes.
- The principle method of asexual reproduction in plants is the vegetative propagation by aerial or underground parts.
- Natural vegetative propagation of plants occur by roots, leaves, suckers, runners, bulbils and underground stems
- Artificial vegetative propagation of plants is carried out by methods like stem cuttings, layering, grafting and tissue culture
- Flower, which is the sexual structure of plants, consists of calyx, corolla, androecium and gynoecium.
- Animals, wind and water contribute, for pollination of flowers. Flowers have special adaptations for pollination by each agent.
- After pollination, flowers produce fruits and seeds. Animals, wind, water, and explosive mechanism contribute for dispersal of fruits and seeds.
- Sexual maturity of man is referred to as puberty. Secondary sexual characteristics appear at this stage.
- Male reproductive system produces sperms and female reproductive system produces ova for sexual reproduction.
- Embryo is developed by the zygote which results in the process of fertilization of a sperm and an ovum.
- The cyclic process that is associated with the reproductive system of sexually matured females is menstrual cycle.
- Gonorrhoea, Syphilis, Herpes and AIDS are some of the diseases that are sexually trasmitted.

Exercises

(1) Mention the differences between sexual reproduction and asexual reproduction.

Sexual Reproduction	Asexual Reproduction

(2) State the structures associated with vegetative propagation of plants with examples.

(3) Mention some practical problems that you may face in grafting plants.

(4) "Vegetative propagation is more suitable than sexual reproduction for a better yield in plants". Clarify this idea.

(5) Name the main parts of a flower and write down their functions.

Plant part	Functions
.....	.....
.....	.....
.....	.....
.....	.....

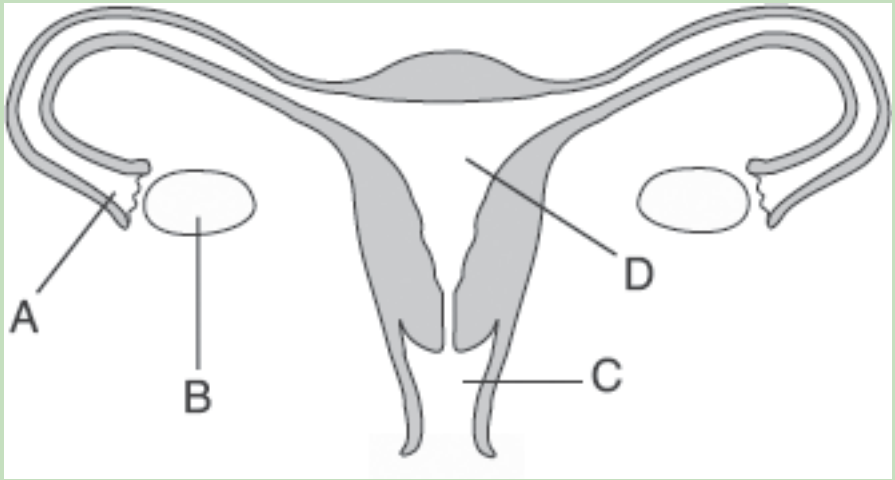
(6) What are the advantages of cross-pollination when compared with self-pollination?

(7) Write down the problems that may arise if dispersal of fruits and seeds does not occur .

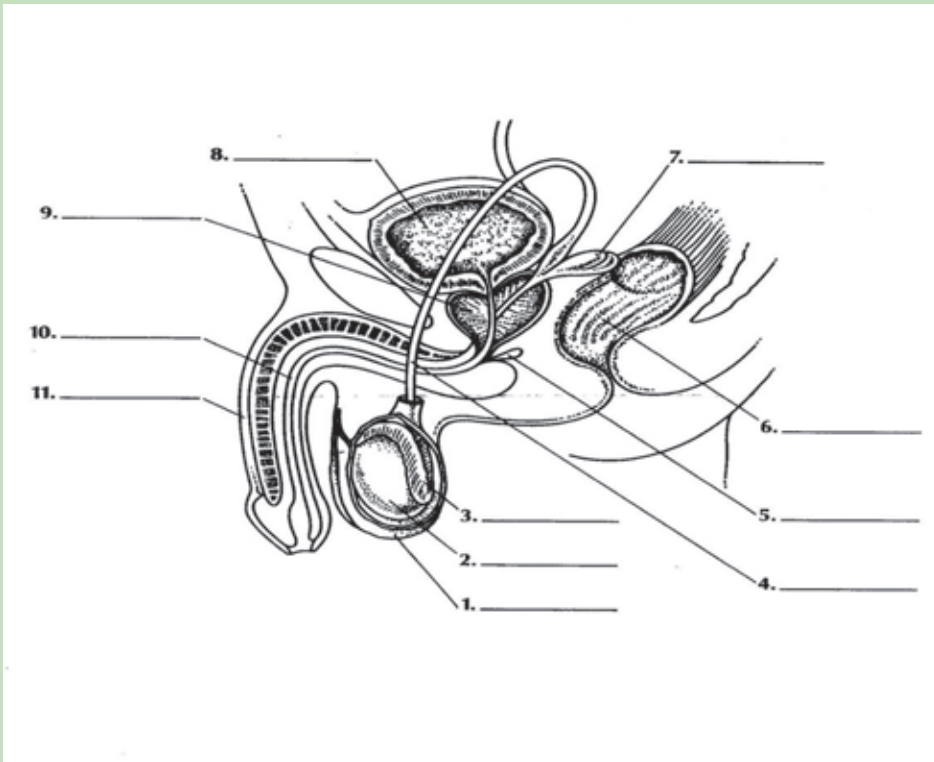
(8) Enlist the changes in males and females during puberty.

Changes occur in males	Changes occur in females

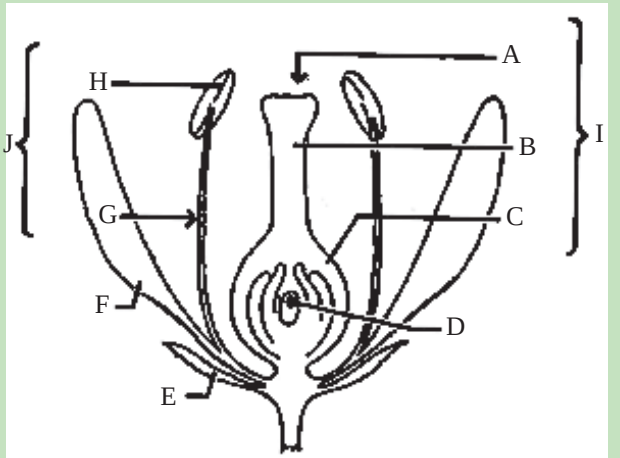
(9) Given below is a diagram of a female reproductive system. Name the parts indicated



(10) Given below is a diagram of a male reproductive system. Name the parts indicated.



(11) A line diagram of a typical flower is given below. Name the parts indicated.



Technical terms				
Reproduction	-	ප්‍රජනනය	-	இனப்பெருக்கம்
Asexual reproduction	-	අලිංගික ප්‍රජනනය	-	இலிங்கமில்முறை இனப்பெருக்கம்
Sexual reproduction	-	ලිංගික ප්‍රජනනය	-	இலிங்கமுறை இனப்பெருக்கம்
Vegetative propagation	-	වර්ධක ප්‍රචාරණය	-	பதியமுறை இனப்பெருக்கம்
Tissue culture	-	පටක රෝපණය	-	இழைய வளர்ப்பு
Pollination	-	පරාගණය	-	கருக்கட்டல்
Fertilization	-	සංසේචනය	-	கருக்கட்டல்
Seed dormancy	-	බීජ සුප්තතාව	-	வித்துக்களின் உறங்குநிலை
Zygote	-	යුක්තාණුව	-	நுகம்
Foetus	-	භ්‍රූණය	-	முதிர் மூலவுரு

Physics

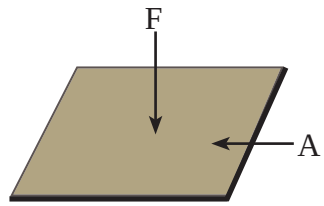
15 Hydrostatic pressure and its applications

15.1 Pressure

Let us review what you have previously learnt about the pressure experienced by surfaces due to solid objects.
Pressure is the force acting on a unit area.

$$\text{Pressure} = \frac{\text{Perpendicular force applied } (F)}{\text{area } (A)}$$

The unit of pressure is Newtons per square meter (Nm^{-2}). As a tribute to the French scientist Blaise Pascal, this unit has been named as the Pascal (Pa).



$$1\ N\ m^{-2} = 1\ Pa$$

Since pressure has only a magnitude, it is a scalar.

Example 1

A cubic shaped box is placed on a table. If the weight of the box is 400 N and the area of the bottom of the box is 0.2 m^2, find the pressure exerted on the surface of the table under the box.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$
$$= \frac{400\ N}{0.2\ m^2}$$
$$= 2000\ Pa$$

Example 2

The pressure exerted by a pile of soil distributed over an area of 8 m^2 of the ground is 150 Pa. What is the force exerted on the ground due to the pile of soil?

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\begin{aligned}\text{Force} &= \text{Pressure} \times \text{area} \\ &= 150\ \text{N m}^{-2} \times 8\ \text{m}^2 \\ &= 1200\ \text{N}\end{aligned}$$

15.2 Hydrostatic pressure

Pressure is exerted not only by solids, liquids also exert pressure. When we place a solid object on a table, a pressure is exerted on the table because the force acting on the table due to the weight of the object spreads over the total contact area between the object and the table.

Similarly, a pressure is exerted on the bottom of a container because, the force acting on the bottom of the container due to the weight of the liquid spreads over the bottom surface of the container. The pressure is exerted by the liquid not only on the bottom of the vessel. The vertical walls of the vessel will also experience the pressure. Apart from this, there are many more characteristics of pressure due to liquids (hydrostatic pressure). Let us investigate these characteristics of hydrostatic pressure.

If you make some holes in a polythene bag, fill it with water and hold it as shown in Figure 15.1, what would you observe? You will observe that water exits through all the holes. Each of these holes exist at a different side of the bag. Water exits from through every hole because water pressure exists at the position of every hole. From this experiment you will observe that the water pressure acts in every direction.

Figure 15.1 – Polythene bag with holes filled with water

Take a plastic bottle with a height of about 25 cm, make several holes at the same level near the bottom and fill it with water. You will see water exiting the bottle as shown in Figure 15.2. You will notice that the horizontal distance traveled by water coming out of every hole is the same. This is because the pressure at the same level of a liquid is the same.

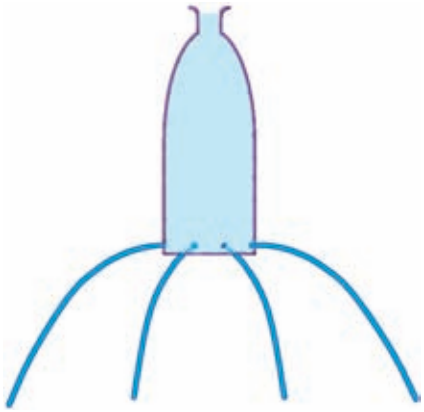


Figure 15.2 – Set-up for comparing the hydrostatic pressure at the same level

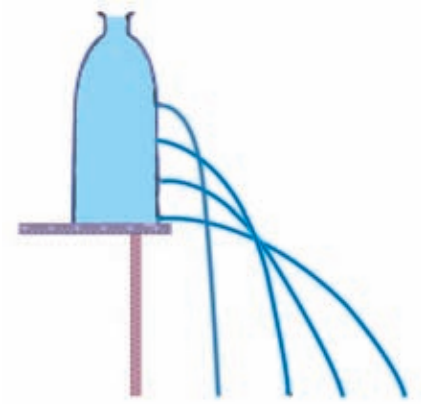


Figure 15.3 - Variation of the pressure with the height of the liquid column

Now let us find out how the height of the water column in a vessel affects the pressure. Make a set of approximately equally spaced holes from top to bottom of a plastic bottle with a height of about 25 cm and fill it with water. Hold the bottle at some height from the ground level as shown in Figure 15.3 and observe how the streams of water leave the bottle.

You will observe that the speed of the streams of water coming from lower holes is greater than the speed of water coming from upper holes. Water exiting a hole has a higher speed when the pressure near that hole is higher. Therefore, it can be concluded that the pressure in a liquid increases with the depth of the liquid.

Let us engage in Activity 15.1 in order to find out how the pressure of a liquid depends on the shape of the liquid column.

Activity 15.1

Dependence of liquid pressure on the shape of the water column

Find five transparent tubes having various shapes as shown by *a*, *b*, *c*, *d* and *e* in Figure 15.4. Fix them to a PVC tube with closed ends as shown, and fill the system with water. Record the vertical heights of the water columns in each tube.

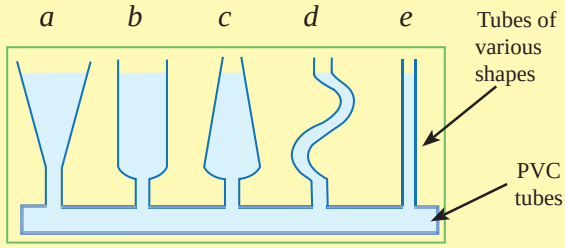


Figure 15.4 - Investigating the dependence of the shape of the water column on the liquid pressure

Tube	Vertical height of water column (cm)
a	
b	
c	
d	
e	

You will notice that the height of the liquid column of each of the tubes is the same. It is clear from the above experiments that the pressure at the equal levels of a liquid is the same. Therefore the pressure at the places where all the tubes are fixed to the PVC tube is also equal. The height of the liquid column of each of the tube is being the same, we can conclude that the pressure due to a liquid column depends only on the height of the liquid column and not on the amount of liquid or the shape of the liquid column.

According to our studies so far on pressure due to a liquid, the liquid pressure has the following characteristics.

(i) The pressure at a certain point in a liquid depends on the height of the liquid column above that point. Pressure increases with the height of the liquid column.

(ii) The pressure at the same level of a liquid is the same.

(iii) At a given point in a liquid, the pressure is the same in all directions.

(iv) Liquid pressure depends on the vertical height of the liquid column. It does not depend on the shape of the liquid column.

If the height of the liquid column is h and the density of the liquid is ρ, the weight of the liquid column above a unit area of the bottom surface of the container is $h\rho g$.

mass of the liquid column = density × volume
= ρ × area of its base × height
= ρ × 1 × h = $h\rho$
weight of the liquid column = $h\rho g$

As we are concerned with the pressure on the base of the column, we divide the force by the area. Since this weight spreads over a unit area, the liquid pressure at the bottom is $h\rho g$. This result is true not only for the pressure at the bottom but for any other depth of a container. If there is a liquid column of height h above any point in a liquid as shown in Figure 15.5, then the liquid pressure P at that point is given by,

$$P = h\rho g$$

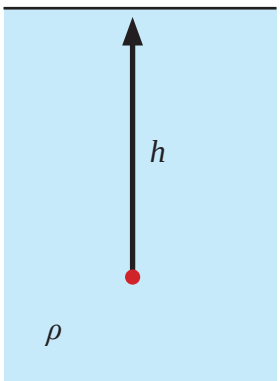


Figure 15.5 - Pressure at a point situated at a depth h in a liquid

When the unit of h is meters (m), the unit of ρ is kg m^{-3} and the unit of g is m s^{-2}, the unit of pressure (P) exerted by the liquid column is N m^{-2}. As mentioned before, the commonly used unit of pressure, the Pascal (Pa), is defined as 1 N m^{-2}.

Example 1

At a certain location, the depth of a certain point in a lake is 1.5 m. Find the pressure exerted by the water at the bottom of the lake at this location. (Density of water = 1000 kg m^{-3}, g = 10 m s^{-2})

Pressure = $h\rho g$
= 1.5 m × 1000 kg m^{-3} × 10 m s^{-2}
= 15 000 Pa

Example 2

The depth of a certain region of the sea is 10 m. Find the pressure exerted at this region by the sea water. (Density of sea water = 1050 kg m^{-3}, g = 10 m s^{-2}).

Pressure = $h \rho g$

= 10 m × 1050 kg m^{-3} × 10 m s^{-2}

= 105 000 Pa

15.3 Transmission of pressure through liquids

Liquids do not get compressed by forces exerted on them. Therefore, the pressure exerted at one point in a liquid can be transmitted to another point in the liquid.

A machine constructed to operate based on this principle is known as hydraulic press. Figure 15.6 illustrates the working principle of a hydraulic press

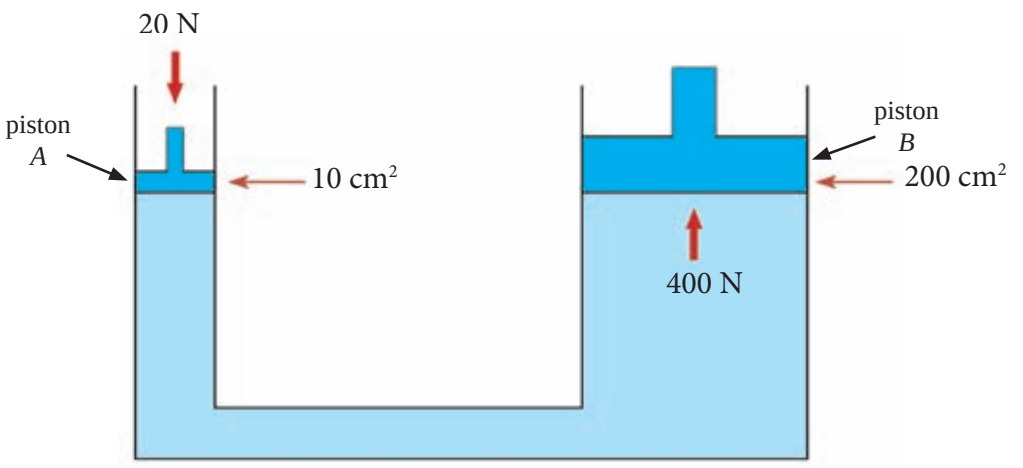


Figure 15.6 - Hydraulic press

It consists of a liquid volume trapped by two pistons A and B on either side of a cylindrical liquid columns. Assume that the area of piston A is 10 cm^2 and the area of piston B is 200 cm^2. If a force of 20 N is applied on piston A, the pressure it exerts on the liquid,

$$P = \frac{F}{A} = \frac{20 \text{ N}}{10^{-3} \text{ m}^2}$$

$$= 2 \times 10^4 \text{ N m}^{-2}$$

$$= 20\,000 \text{ N m}^{-2}$$

$$= 2 \text{ N cm}^{-2}$$

This pressure is transmitted to piston *B* through the liquid. Therefore, pressure at piston *B* is also 2 N cm^{-2}. That is, the fluid exerts a force of 2 N vertically upwards on each 1 cm^2 of piston *B*. Therefore the total force exerted on the total area of 200 cm^2 of piston *B* is 400 N (2 x 200). It is possible to transmit a force of 400 N to the larger piston from a total force of 20 N acting on the smaller piston because it is possible to transmit pressure through the liquid. (Since the forces acting on the pistons of liquid pressure machines are very high compared to the force due to the weight of the liquid column, the force exerted by the liquid column is not considered in calculations).

Hoists that lift vehicles in motor vehicle service stations are built based on the principle of pressure transmission through fluids. Figure 15.7 shows the principle of operation of one type of such hoists.

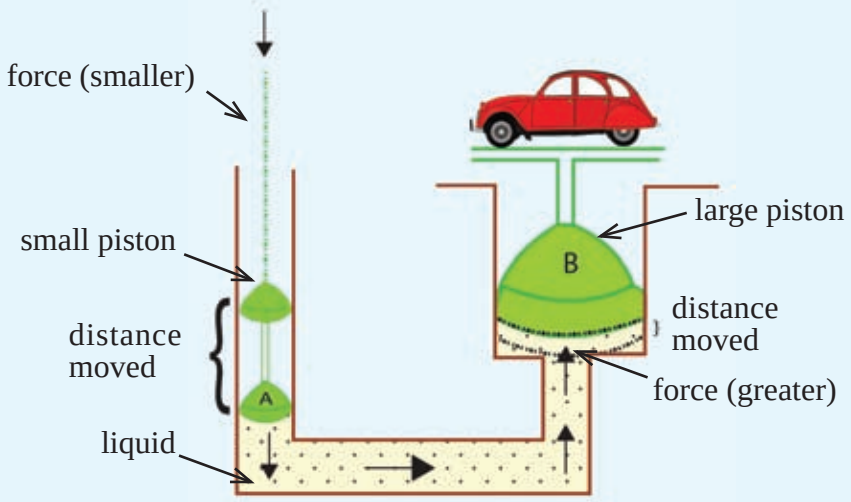


Figure 15.7 - A hoist used to lift vehicles

This hoist is constructed in such a way that the pressure generated in the oil through the small force applied on the small piston is transmitted to the large piston through the oil, transmitting a force equal to the weight of the vehicle placed on the large piston. This force lifts the vehicle.

However, in order to lift a vehicle, the small piston must be moved by a large distance. Because this is difficult, in actual hoists used in service stations, the small piston is replaced by a compressor that pumps oil into the small cylinder.

A jack is used to lift one side of a vehicle when a wheel of the vehicle needs to be detached. Out of the many types of jacks available, the type that is most frequently used is the hydraulic jack. such a jack shown in the figure 15.8 . The hydraulic jack also operates on the principle of pressure transmission.

Here also a force is applied on a small piston. The pressure caused in the oil by this force is transmitted to the large piston through the oil, lifting one side of the vehicle.

Figure 15.8 – Hydraulic jack

Another instance where the principle of liquid pressure transmission is applied is the break system in vehicles. Its principle is shown in figure 15.9.

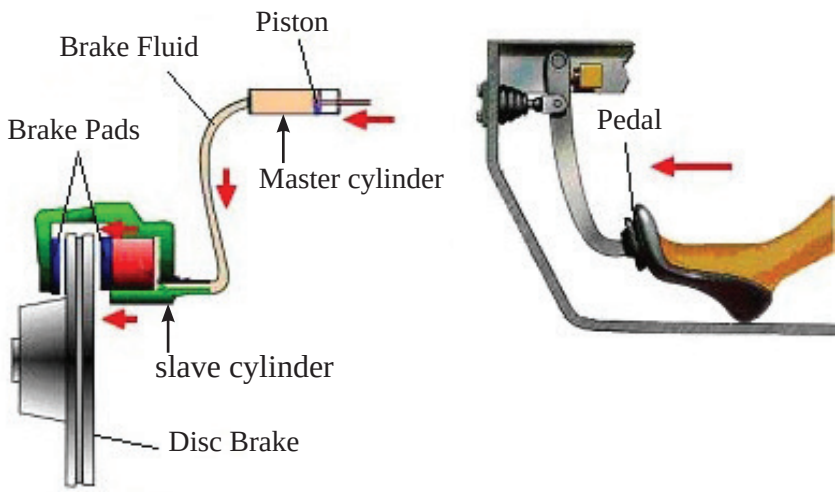


Figure 15.9 – Vehicle break system

In the break system of a vehicle, when the driver applies a force on the break-pedal, it is transmitted to the piston in the master cylinder. This force exerts a pressure on the oil inside the cylinder. This pressure is then transmitted through the oil to the slave cylinder near the wheel. Then the brake-pads connected to the slave cylinder are pressed to apply a pressure on the break-discs or break-drums. Since the cross-sectional area of the slave cylinder is larger than that of the master cylinder, the force applied on the break-pads by the slave cylinder is greater than the force applied by the driver on the break-pedal.

Exercise 15.1

(1) The pressure exerted at the bottom of a container due to a liquid inside it is 1500 Pa. What is meant by "the pressure is 1500 pa"?

(2) Find the pressure exerted by a mercury column of height 10 cm. (Density of mercury is 13600 kg m^{-3}).

(3) The depth of a pond is 1.5 m. Calculate the pressure caused by the water at the bottom of the pond.

(4) The depth at a certain point in the sea is 1 km. Find the pressure exerted by sea water at the bottom of the sea at that point. (Density of sea water is 1050 kg m^{-3}.)

(5) A tank with a length 5 m, width 3 m and depth 2 m is filled with a liquid of density 800 kg m^{-3}.
   (a) What is the pressure at the bottom of the tank due to the liquid ?
   (b) What is the force acting on the bottom of the tank due to that pressure?

15.4 Pressure due to gases

Similar to solids and liquids, gases also exert pressure. There are two ways in which a pressure can be produced by a gas. One is the pressure caused by the weight of a column of gas, similar to the pressure caused by a column of liquid. The atmospheric pressure is produced this way. The other way that a gas can give rise to a pressure is when a compressed gas attempts to expand. From the activity described below you can easily see that a compressed a gas causes a pressure.

Activity 15.2

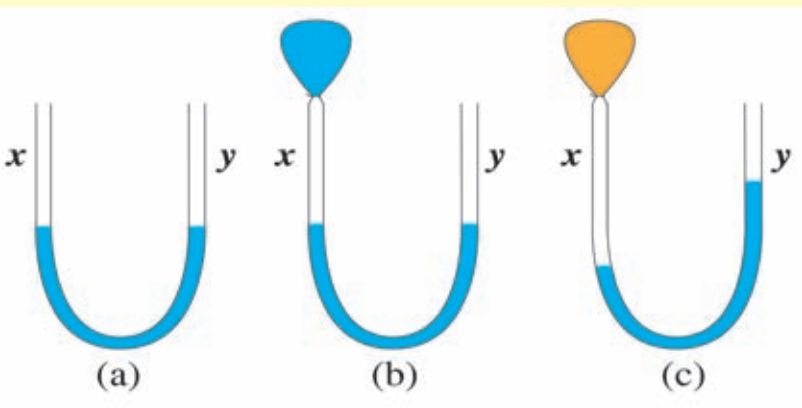


Figure 15.10 – Investigation on gas pressure

- Pour water into a U-tube as shown in Figure 15.10(a). Then the water levels in the two arms *X* and *Y* would become equal.

- Tie the opening of an air filled balloon with a piece of thread making sure that it can be easily untied.

- Next, connect it to the arm *X* of the U-tube as shown in Figure 15.14(b) and tie it with another piece of thread.

- Now slowly undo the knot on the balloon. After removing the knot, you will be able to see that the water level in arm *X* goes down while the water level in arm *Y* goes up. (Figure 15.10(c))

Since the pressure at all points on the same level of a liquid is the same, the liquid levels that are equal before connecting the balloon show that the pressures above the water levels of the two arms are equal.

By filling a balloon with air, we try to restrict a large amount of air inside a limited volume. That is, we compress the air. When we connect the balloon filled with compressed air to arm *X*, the water levels are no longer the same. The higher water level in arm *Y* than the water level in arm *X* shows that the pressure in arm *X* at the liquid surface is higher than the pressure in arm *Y* at the liquid surface. The reason for the higher pressure in arm *X* is the additional pressure exerted on the liquid by the compressed air in the balloon.

Atmospheric Pressure

Earth's atmosphere extends to hundreds of kilometers above the surface of the earth. Similar to the pressure produced at any point inside a container filled with water by the water above that point, a pressure exists at any point in the atmosphere due to the weight of the air above that point. This pressure is known as the atmospheric pressure.

The atmospheric pressure was measured for the first time by the Italian scientist Torricelli. The instrument he used for that purpose is shown in Figure 15.11.

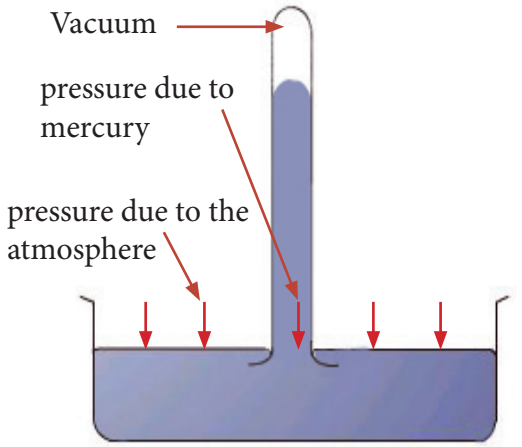


Figure 15.11 – Mercury barometer

This instrument can be made of a glass tube, about one meter long, with one closed end. The tube is filled with mercury, turned upside down while making sure that no air enters the tube, and then immersed in a container of mercury as shown in figure 15.11. When the tube is mounted in up-right position as shown in figure, it would be possible to see that the mercury column in the tube drops by several centimeters, leaving an empty space above the mercury column. The height of the mercury column left inside the tube is about 76 cm.

Torricelli understood that all the mercury in the tube does not flow down to the container because the atmospheric pressure keeps pushing on the mercury surface exposed to the outside. However, the atmospheric pressure is sufficient to balance the pressure of a mercury column with height of 76 cm. Therefore, the height of the mercury column is a measure of the atmospheric pressure. Because no air can enter the space above the mercury column, that space must be a vacuum.

We know that any two points at the same level of a liquid have the same pressure. Accordingly, since the pressure on the mercury surface outside the tube is equal to the atmospheric pressure, a point inside the tube at the same level should also have the atmospheric pressure. By considering the height of the mercury column, the pressure at the point inside the tube can be calculated using the formula $P = h\rho g$. Therefore, the atmospheric pressure must be equal to $h\rho g$.

However, as a convenient unit for measuring pressure, the height of the mercury column is often used. If the experiment is done at the sea level, the height of the mercury column would be 76 cm. If the tube is immersed further into the container with mercury, the height of the mercury column would remain at 76 cm. The space above the column would be reduced in height. If we incline the tube, even though the physical length of the mercury would increase, the vertical height of the mercury column would remain at 76 cm.

While the atmospheric pressure at the sea level is 76 cm Hg, as we move up from the sea level, the height of the air column decreases and the atmospheric pressure decreases. For example, the atmospheric pressure at the top of Everest is about 25 cm Hg. In addition, the atmospheric pressure can change according to the weather.

The instrument constructed using mercury in order to measure the atmospheric pressure is known as the mercury barometer.

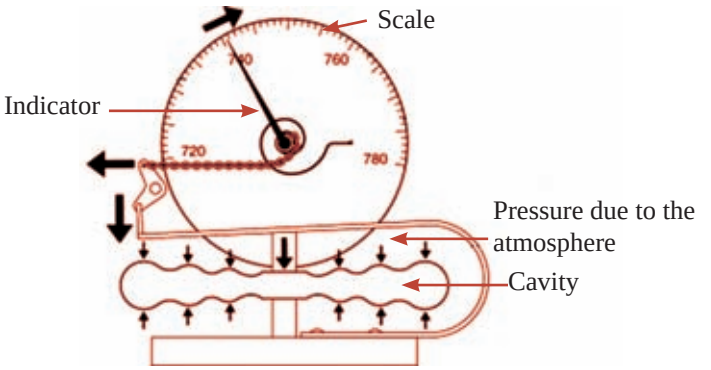


Figure 15.12 – Aneroid barometer

In addition, there are barometers that do not contain a liquid. They are known as aneroid barometers. Figure 15.12 shows an aneroid barometer without a liquid. It has a cavity bounded by thin metallic walls in which air has been evacuated. When the pressure outside barometer varies, the shape of the walls of the cavity also varies. An indicator attached to the cavity walls rotates with the variations of the shape of the walls. The pressure can be read out from an attached scale.

Applications of the atmospheric pressure in daily life

(I) Drinking with the use of a straw

When we drink using a straw, we suck the air inside the straw and that air enters the mouth, reducing the pressure inside the straw. The pressure at the liquid surface outside the straw is at the atmospheric pressure while the pressure inside the straw is less than the atmospheric pressure. Therefore the atmospheric pressure pushes the liquid in the glass into the tube and the liquid moves up through the straw.

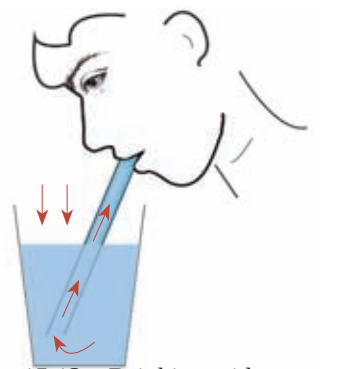


Figure 15.13 – Drinking with a straw

(II) Removing the water in a tank using the siphon method

Figure 15.14 illustrates the use of the siphon method to draw water from the tank *A* situated at a higher level to the tank *B* situated at a lower level. Initially, the tube has to be filled with water and one end pressed with a finger so that water does not flow out and then the tube should be lowered down to of *A*. Thereafter, when the finger is removed, water starts to flow to tank *B* from tank *A*.

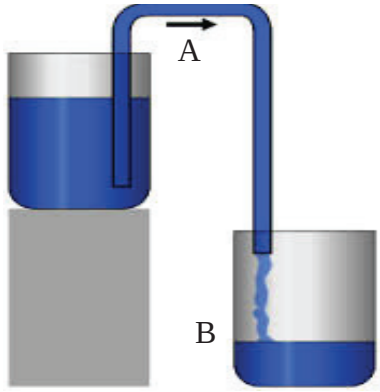


Figure 15.14 – Syphon method

The pressure at the end of the tube in *A* is equal to the sum of the pressures due to the water column in *A* above the end of the tube and the atmospheric pressure. Since the end of the tube in *B* is exposed to the atmosphere, the pressure there is equal to the atmospheric pressure. Therefore, the higher pressure in tank *A*, pushes the water to the other end of the tube at tank *B* which has a lower pressure.

(III) Action of the rubber sucker

When a rubber sucker is pressed onto a glass surface as shown in Figure 15.15, most of the air between the two surfaces is removed leaving only a little air in between the sucker and the glass surface. Then, since the pressure inside the rubber sucker is less than the atmospheric pressure outside, the sucker is held pressed to the surface by the atmospheric pressure. The rubber sucker would function properly only if there is no air flow between the edge of the sucker and the glass surface.

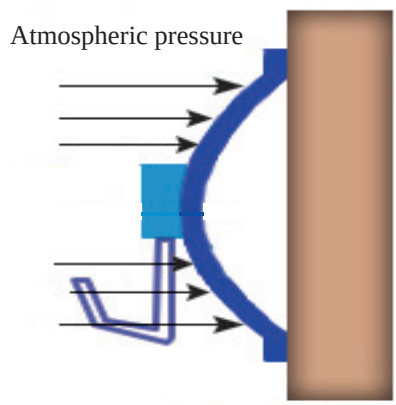


Figure 15.15 – Rubber sucker

Example

(1) The atmospheric pressure at sea level is 76 cm Hg. Taking the density of mercury as 13600 kg m^{-3} acceleration due to gravity as 10 m s^{-2}.

(i) find the atmospheric pressure in Pascals.

(ii) find the height of a water column that can be balanced by the atmospheric pressure. (Density of water is 1000 kg m^{-3}).

Answer

i. Atmospheric pressure $= h \times \rho \times g$

$P = (76 / 100 \text{ m}) \times (13600 \text{ kg m}^{-3}) \times (10 \text{ m s}^{-2})$

$= 103\,360$ Pa

ii. If the height of the water column is h,

$h \rho g = 103360$

$h \times 1000 \times 10 = 103360$

$h = 103360 / 10000$

$h = 10.3360$ m

15.4 Floatation

We know that when we put a stone into a vessel containing water, it would sink while something like a piece of wood would float. Let us investigate what scientific principles lie behind the reasons for some objects to sink in water while some objects to float.

Upthrust

When we press an object that floats on water, such as a plank of wood on a water surface, we experience a force exerted by the water acting upwards. Even for an object that sinks in water, the weight that we feel when it is in water is less than its weight in air. This is becuase water exerts an upward force on objects that are immersed in water. This upward force is known as the upthrust. Not only water, any fluid exerts an upthrust on objects that are immersed or upthrust exerts on floating bodies too in that fluid.

Activity 15.3

- Suspend a piece of metal on a spring balance as shown in Figure 15.16 (a) and measure its weight.

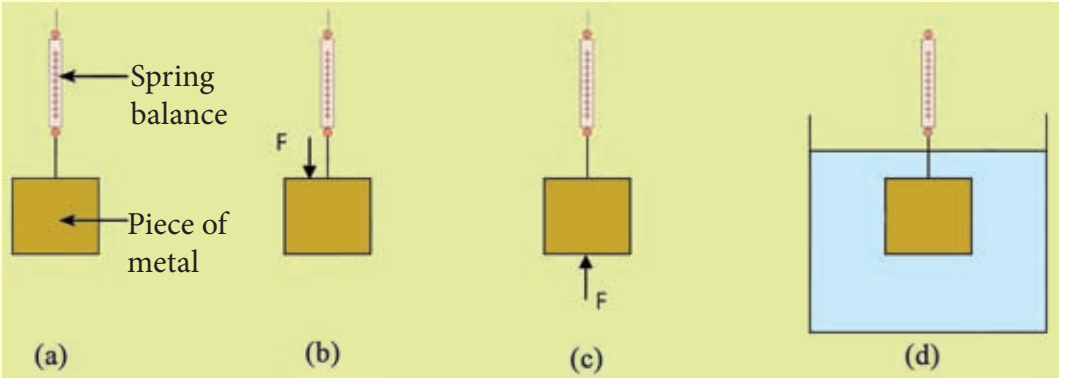


Figure 15.16 – Illustrating the upthrust

- Now exert a downward force on the piece of metal as shown in Figure 15.16 (b). Read the corresponding reading on the spring balance. It would be seen that the spring balance reading has increased as a downward force has acted. then, exert an upward force on the piece of metal as shown in Figure 15.16 (c) and read the spring balance reading. It is obvious that the spring balance reading would decrease as an additional force was exerted upwards. This shows clearly that a downward force acting on the object would increase the spring balance reading while an upward force would decrease the spring balance reading.
- Now immerse the object in water as shown in figure 15.16 (d) and read the spring balance reading. You will observe that the spring balance reading has decreased. According to the explanation given regarding the figure (c), the spring balance reading decreases when an upward force is acting on the object. Therefore, this confirms that an object immersed in a liquid (fluid) experiences an upward thrust exerted by the liquid.

Activity 15.4

- Get a cubic shaped piece of metal and mark by a line where its volume is divided into two equal parts.
- Now hang it on a spring balance and measure its weight in air.
- Get a beaker and measure its weight.
- Now submerge the metal cube in water to each of the levels indicated by the figures 15.17(a), (b), (c) and (d) and record the spring balance readings and the weight of the beaker together with the displaced water each time.

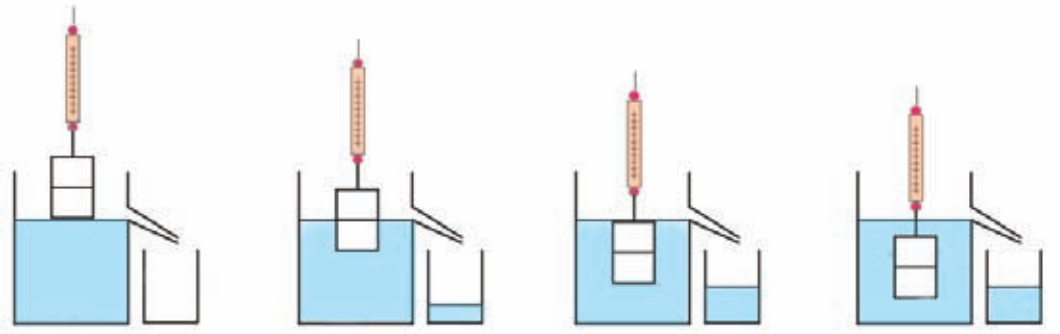


Figure 15.17 – Set-up for measuring the upthrust

Complete the table given below using your measurements.

Stage	Spring balance reading (N)	Weight of beaker with displaced water (N)
(a) -Metal cube near the water surface		
(b) -Metal cube half submerged in water		
(c) -Metal cube fully immersed in water and near the water surface		
(d) -Cube fully immersed in water and far from the water surface		

What conclusions can you draw from the above activity?

Let us assume that thereadings taken by a pupil were as given below.

Stage	Spring balance reading (N)	Weight of beaker with displaced water (N)
(a) - Metal cube near the water surface	1.2	1.3
(b) - Metal cube half submerged in water	0.9	1.6
(c) - Metal cube fully immersed in water and near the water surface	0.6	1.9
(d)- Cube fully immersed in water and far from the water surface	0.6	1.9

The upward thrust and the weight of the displaced volume of water calculated from the readings above are tabulated below.

Stage	Upthrust (N)	Weight of displaced volume of water (N)
(a) - Metal cube near the water surface	0	0
(b) - Metal cube half submerged in water	0.3	0.3
(c) - Metal cube fully immersed in water and near the water surface	0.6	0.6
(d) - Cube fully immersed in water and far from the water surface	0.6	0.6

The conclusion that can be drawn from the results shown in the table above is that when the object is partially or fully submerged in water, the upward thrust acting on the object is equal to the weight of the water displaced by the object. This is known as the Archimedes' principle as it was first introduced by the scientist Archimedes.

Archimedes' Principle

When an object is partially or completely submerged in a fluid, the upthrust acting on it is equal to the weight of the fluid displaced by the object.

The figure 15.18 shows how three different objects A, B and C are submerged in water.

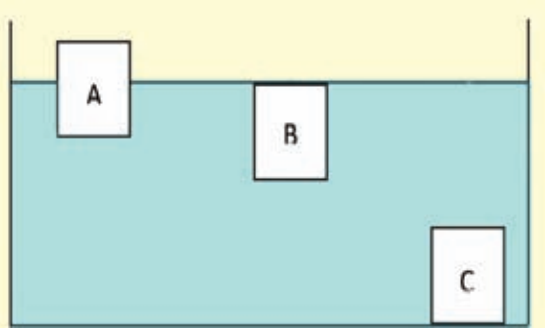


Figure 15.18 - Three different objects placed in water

Object *A* is partially submerged and floating while object *B* is fully submerged and floating. Object *C* is fully submerged and resting at the bottom of the container. Can you think of the reason for this difference? Engage in the following activity in order to understand it.

Activity 15.5

You will need three objects of different materials. One of them (*A*) should float in water, partially submerged. Another one (*B*) should float on water, fully submerged. Such an object could be obtained by filling an appropriate quantity of sand into a bottle that could be properly closed. The third object (*C*) should sink in water.

- Measure the weights of the three objects *A*, *B* and *C*.
- Now measure the apparent weights of the three objects while *A* is floating, partially submerged, *B* is floating, fully submerged and *C* is sunk.

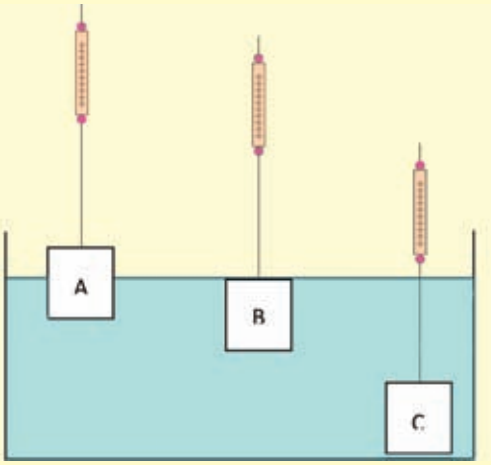


Figure 15.19 - Diagram for activity 15.5

Tabulate the observations and readings in the table given below. Try to fully submerge the floating object by applying an external force.

Object	Weight of the object (N)	Apparent weight of object in water (N)	Is the object partially submerged and floating? / fully submerged and floating? / sunk?
A			
B			
C			

Fill the following table with relevant calculations.

Object	How the object appeared in water	Weight of the object (N)	Upthrust on the object (N)
A			
B			
C			

What conclusion can you draw from your results?

The following table shows the readings and observations made by a student. Let us investigate the results he obtained.

Object	Weight of the object (N)	Apparent weight of object in water (N)	Is the object partially submerged and floating? /fully submerged and floating? / sunk?
A	1.1	0	Floating
B	1.8	0	Fully submerged and floating
C	2.4	0.5	Sunk

The corresponding calculations are shown in the table below.

Object	How the object appeared in water	Weight of the object (N)	Upthrust on the object (N)
A	Partially submerged and floating	1.1	1.1
B	Fully submerged and floating	1.8	1.8
C	Sunk	2.4	1.9

The results obtained from this activity are stated below.

The weight of the object that was partially submerged while floating and the weight of the object that was fully submerged while floating are equal to the upthrust exerted on the objects by water. The weight of the object that sank in water is greater than the upthrust exerted on the object by water.

When a force acting vertically downwards is applied on the object A that was partially submerged while floating, an additional force acting vertically upwards can be experienced. This is because the upthrust is greater than the weight of the object when the object is fully immersed in water giving rise to a resultant force acting upwards. Therefore, when the external force was removed. the object returns to the original position. That is, the object returns to the position where the upthrust is equal to the weight of the object.

The conclusion that could be drawn from this is, that the weight of an object that is partially or fully immersed in a fluid while floating is equal to the upthrust acting on the object and the weight of an object that is fully sunk in the fluid is greater than the upward thrust, the object sinks in the fluid.

That is,

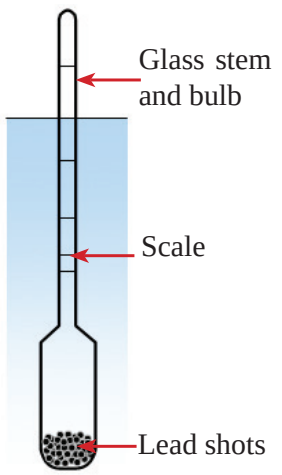
If the upthrust acting on an object fully immersed in a fluid,

(a) is less than the weight of the object, the object sinks in the fluid.

(b) is equal the weight of the object, the object floats in the fluid while being fully submerged in it.

(c) is greater than the weight of the object, the object floats while partially submerged in the fluid so that an upthrust equal to the weight of the object acts on it.

Hydrometer



Hydrometers are used to measure the density of liquids and solutions. It is made of glass. It has a cylindrical stem and a bulb as shown in the diagram. Mercury or lead shots are found inside the bulb to enable it to float vertically in the liquid .The liquid or the solution is taken to a vessel and the hydrometer is put in to it. Then the density of the liquid or the solution can be read directly by the scale given on the hydrometer.

Hydrometer has been made in accordance with the Archimedes' principle. The hydrometer immerses in the liquid to a height so as to displace a weight equal to the weight of the hydrometer. The volume of the liquid or the solution displaced is equal to the volume of the immersed part of the hydrometer. As a small volume of the liquid is displaced in a high density liquid, the hydrometer is immersed to only small depth. But when it is put in a low density liquid it immerses more because more liquid should displace, to produce the upthrust required to balance it.

Exercise 15.2

(1) (i) The depth of a reservoir is 1.2 m. Calculate the pressure at the bottom of the pond due to the water. ($g = 10\ m\ s^{-2}$, density of water = $1000\ kg\ m^{-3}$)

(ii) Find the force exerted by the water on an area of 200 cm^2 at the bottom of the reservoir.

(2) (i) Describe a simple experiment to demonstrate that 'the pressure in a liquid increases with increasing depth'.

(ii) Write down a simple experiment to find out whether the pressure inside a balloon is less than or greater than the atmospheric pressure.

(3) (i) The atmospheric pressure at the sea level is 76 cm Hg. How much is this pressure in Pascals?

(ii) What is the height of a water column that exerts the same pressure as the above pressure?

(4) (i) Write down Archimedes' principle.

(ii) The weight of a piece of metal in air is 20 N. When it is completely immersed in water, its apparent weight is 5 N.

(a) What is the upward thrust exerted on the piece of metal by water?
(b) What is the weight of the water displaced by the piece of metal when it is completely immersed in water?

Summary

- Pressure is produced by liquids and gases as well as by solids.
- The pressure due to a liquid acts in every direction.
- The pressure due to a liquid increases as the depth (height of a column of liquid) increases.
- The formula $P = h \rho g$ is used to find the pressure due to a liquid column where
  h = height of the liquid column
  ρ = density of the liquid
  g = gravitational acceleration
- The space around the earth containing air is known as the atmosphere and the pressure produced by atmospheric air is known as the atmospheric pressure.
- The average value of the atmospheric pressure at the sea level is 76 cm Hg. That is, the atmospheric pressure at the sea level is equal to the pressure due to a mercury column of height 76 cm.
- In order to measure average value of the pressure, the mercury barometer and the aneroid barometer are used.
- When an object is partially or completely submerged in a liquid, an upthrust equal to the weight of the quantity of liquid displaced acts on the object by the liquid.
- When an object is floating on a liquid, the weight of the displaced liquid is equal to the weight of the object.

Technical Terms

Pressure	-	පීඩනය	- அழுக்கம்
Hydraulic jack	-	ද්‍රව පීඩන ජැක්කුව	- நீரியல் உயர்த்தி
Upthrust	-	උඩුකුරු තෙරපුම	- மேலுதைப்பு
Atmosphere	-	වායුගෝලය	- வாயுமண்டலம்
Mercury barometer	-	රසදිය වායුපීඩනමානය	- இரச பாரமானி
Aneroid barometer	-	නිර්ද්‍රව වායුපීඩනමානය	- அனிரொய்ட் பாரமானி

Changes in Matter

Chemistry 16

Objects made of iron rust when exposed to the air. Moth balls become smaller in size when kept exposed to the air. Ice melts and turns into liquid water. We have seen changes in matter like these. To study them further let us do the activity 16.1 given below.

Activity - 16.1

Requirements : A piece of magnesium (Mg) ribbon, about 50 ml of dilute sulfuric acid (H_2SO_4), a few pellets of sodium hydroxide (NaOH), two metal spoons, a moth ball (naphthalene), a box of matches, two 50 ml beakers, a Bunsen burner, a thermometer

Do the activities (i), (ii), (iii) and (iv) and record the observations.

i). Heat a metal spoon strongly in the Bunsen flame and take it away from the flame. Place a moth ball on it and observe. Close it with another spoon quickly. After some time observe the inner side of the spoon.

ii). Hold a piece of cleaned magnesium ribbon with a pair of tongs and burn it.

iii). Measure the initial temperature of a dilute sulfuric acid solution. Add a few pellets of sodium hydroxide to this solution, stir and measure the temperature again.

iv). Put a piece of magnesium ribbon to a beaker containing dilute sulfuric acid.

See whether the observations you obtained through the above activities conform to the following.

i). Moth ball melted and vaporized. A white powder deposited on the inner side of the spoon.

ii). Magnesium ribbon burned with a white bright flame leaving a white powder.

iii). Sodium hydroxide dissolved. The container became hot. The thermometer reading rose.

iv). Magnesium ribbon dissolved liberating gas bubbles. The beaker was heated.

In case (i) above solid naphthalene melted and then turned into a vapour. On the cold surface of the spoon the vapour solidified forming a thin solid layer of naphthalene. When solid naphthalene melted, liquid naphthalene vaporized and naphthalene vapour solidified again, and only the physical state (arrangement of particles) of the given substance changed without giving new substances. Such changes are called **physical changes.**

In the instances from (ii) to (iv), the given substances changed forming new substances. Such changes are known as **chemical changes** or chemical reactions.

Observations such as burning with a flame, evolution of heat, effervescence, change in colour and precipitation can be given as evidences for the occurrence of a chemical reaction.

To investigate physical and chemical changes further, let us study Table 16.1

Table 16.1

Physical changes and relevant observations	Chemical changes and relevant observations
The arrangement of particles which form the substance changes. No new substances are produced.	The existing substances are undergone changes and new substances are formed.
Examples: 1.Crushing stone (lumps ⟶ powder) 2.Melting of wax (solid ⟶ liquid) 3.Vaporization of water (liquid ⟶ gas) 4.Condensation of water vapour into droplets (gas ⟶ liquid)	Examples: 1.Burning firewood (formation of ash, liberation of gases) 2. Heating limestone (formation of calcium oxide, evolution of gas) 3. Heating potassium permanganate (liberation of oxygen) 4. Rusting of iron (formation of rust)

16.1 Chemical Changes

One of the following can happen during a chemical reaction.

- Formation of new substances by the combination of two or more substances.
- Turning one substances into two or more substances.
- Reorganization of initial substances to form new substances.

The substances taking part in a chemical change are called the **reactants**. The new substances produced by a chemical changes are known as the **products**.

During a chemical reaction, reactants turn into products.

Reactants ⟶ products

To study the variety of chemical changes let us engage in activity 16.2.

Activity - 16.2

Requirements:- magnesium ribbon, zinc granules, potassium permanganate, barium chloride, sodium sulphate, boiling tubes, test tubes, a Bunsen burner, an iron plate, a dry ekel , a box of matches, a pair of tongs.

i. Hold a magnesium ribbon in the Bunsen flame with the pair of tongs.
ii. Heat crystals of potassium permanganate in a boiling tube. Insert a glowing splint into the tube.
iii. Take some copper sulphate solution into a test tube and add a clean zinc granule into it.
iv. Take a little barium chloride solution into a test tube and add a little sodium sulphate solution into it.

Complete the Table 16.2 using the above chemical changes.

Table 16.2

Reaction	Nature of the reactants	Observation	Nature of the products
i. Burning magnesium in air	shiny, silvery white metal	Burns with a bright white flame	A white powder
ii.			
iii.			
iv.			

According to the nature of the chemical change, they can be classified into four types. They are as follows.

- Chemical combination reactions
- Chemical decomposition reactions
- Single displacement reactions
- Double displacement (Double decomposition) reactions

• Chemical Combination Reactions

Consider the first reaction of Activity 16.2. In it, magnesium reacts with oxygen in the air forming magnesium oxide.

magnesium + oxygen ⟶ magnesium oxide

$2Mg + O_2 \longrightarrow 2MgO$

Here, two elements have combined to form a new compound.

The formation of a new compound by the combination of elements with elements or elements with compounds or compounds with compounds is known as a chemical combination reaction.

A few other examples for chemical combinations are given below.

carbon + oxygen ⟶ carbon dioxide

$C + O_2 \longrightarrow CO_2$

carbon dioxide + carbon ⟶ carbon monoxide

$CO_2 + C \longrightarrow 2\,CO$

calcium oxide + water ⟶ calcium hydroxide

$CaO + H_2O \longrightarrow Ca(OH)_2$

hydrogen + chlorine ⟶ hydrogen chloride

$H_2 + Cl_2 \longrightarrow 2HCl$

The common reaction for chemical combinations is as follows.

$$A + B \longrightarrow C$$

• Chemical Decomposition Reactions

Reflect on the second reaction in Activity 16.2. In that reaction potassium permanganate decomposes under the influence of heat to form other compounds and elements.

potassium permanganate $\xrightarrow{\Delta}$ potassium manganate + manganese dioxide + oxygen

$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2$

The decomposition of a compound giving other simpler compounds or elements or compounds and elements is known as a chemical decomposition reaction.

Some examples for chemical decomposition reactions are given below.

calcium carbonate $\xrightarrow{\Delta}$ calcium oxide + carbon dioxide

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

hydrogen peroxide $\xrightarrow{\Delta}$ water + oxygen

$2H_2O_2 \xrightarrow{\Delta} 2\,H_2O + O_2$

$$\text{silver oxide} \xrightarrow{\Delta} \text{silver} + \text{oxygen}$$
$$2Ag_2O \xrightarrow{\Delta} 4Ag + O_2$$

The common reaction for chemical decompositions is as follows.

$$A \longrightarrow B + C$$

• Single Displacement Reactions

Focus your attention on the third reaction of Activity 16.2. In that reaction zinc metal reacts with copper sulphate freeing copper metal and forming zinc sulphate.

$$\text{Zinc} + \text{copper sulphate} \longrightarrow \text{zinc sulphate} + \text{copper}$$
$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$$

The reactions in which an element displaces another element in a compound occupying its place and forming another compound are referred to as single displacement reactions.

Given below are some examples for single displacement reactions.

$$\text{magnesium} + \text{copper sulphate} \longrightarrow \text{magnesium sulphate} + \text{copper}$$
$$Mg + CuSO_4 \longrightarrow MgSO_4 + Cu$$

$$\text{magnesium} + \text{hydrogen chloride} \longrightarrow \text{magnesium chloride} + \text{hydrogen}$$
$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

$$\text{potassium bromide} + \text{chlorine} \longrightarrow \text{potassium chloride} + \text{bromine}$$
$$2KBr + Cl_2 \longrightarrow 2KCl + Br_2$$

The common reaction for the single displacement reactions is as follows.

$$A + BC \longrightarrow AC + B$$

• Double Displacement Reactions

Consider the reaction (iv) of the Activity 16.2. In that reaction barium chloride and sodium sulphate react giving barium sulphate and sodium chloride.

barium chloride + sodium sulphate ⟶ barium sulphate + sodium chloride

$BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$

A reaction in which an element or a radical contained in a compound is exchanged with an element or a radical in another compound is called a double displacement reaction.

A few other examples for double displacement reactions are given below.

ferrous sulphate + sodium hydroxide ⟶ ferrous hydroxide + sodium sulphate

$FeSO_4 + 2NaOH \longrightarrow Fe(OH)_2 + Na_2SO_4$

calcium chloride + sodium carbonate ⟶ calcium carbonate + sodium chloride

$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$

The common reaction representing double displacement reactions is as follows.

$AB + CD \longrightarrow AD + CB$

16.2 Chemical Equations

A chemical equation is the symbolic representation of a chemical reaction using chemical formulae. When writing chemical equations in the standard form, reactants are written on the left hand side and the products on the right hand side. An arrow indicates the direction of a reaction. For a reaction, there may be several reactants as well as several products.

Reactants + Reactants ⟶ Products + Products

In such instances placing (+) mark between them is the accepted way. Moreover, the reacting substances as well as the substances produced are indicated by their chemical symbols and formulae. To write a chemical equation correctly, one should know chemical symbols and formulae as well.

Now let us try to write the reaction between magnesium and oxygen in the form of an equation.

magnesium + oxygen ⟶ magnesium oxide

$Mg + O_2 \longrightarrow MgO$

According to the law of conservation of mass you have learnt, atoms are neither created nor destroyed during a reaction, so the number of atoms of the respective elements in the reactants should be equal to their number of atoms in the products. Equating the number of atoms of reactants with those of the products is known as balancing the equation.

$$Mg + O_2 \longrightarrow MgO$$

Follow the following steps to balance the above equation.

There are two oxygen atoms in the reactants. Products contain one oxygen atom. To balance oxygen, magnesium oxide cannot be written as MgO_2 because the formula of magnesium oxide produced by the above reaction is MgO. Therefore, 2 is written in front of MgO.

$$Mg + O_2 \longrightarrow 2MgO$$

When writing '2 MgO', two magnesium atoms are present in the products. But there is only one magnesium atom on the reactant side. So, '2' should come in front of Mg. This gives the following equation.

$$2Mg + O_2 \longrightarrow 2MgO$$

This is the balanced chemical equation of the reaction between magnesium and oxygen.

Study carefully how the balanced chemical equation is written for the following reaction also.

Reaction: Aluminium metal reacts with dilute hydrochloric acid forming aluminium chloride and hydrogen.

Write the formulae of the reactants and products correctly on either side of the arrow.

$$Al + HCl \longrightarrow AlCl_3 + H_2$$

Three chlorine atoms and two hydrogen atoms are present in the products. Since the least common multiple of 2 and 3 is 6, write 6 as the coefficient of hydrochloric acid.

$$Al + 6HCl \longrightarrow AlCl_3 + H_2$$

Now there are 6 hydrogen atoms in the products, so write 3 as the coefficient of H_2. As there are six chlorine atoms in the reactants insert 2 as the coefficient of $AlCl_3$.

$$Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

There are two aluminium atoms in the reactants. Hence write 2 as the coefficient of aluminium.

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

This is the balanced chemical equation of the relevant reaction.

The method of balancing chemical equations as described above is known as the **inspection method.**

Balance the following equations by using the above method.

- $Na + O_2 \longrightarrow Na_2O$
- $Al + O_2 \longrightarrow Al_2O_3$
- $N_2 + H_2 \longrightarrow NH_3$
- $H_2 + O_2 \longrightarrow H_2O$
- $KClO_3 \longrightarrow KCl + O_2$

Assignment - 16.1

- Consider the word equations from 1 to 5 given below.
  - » Write balanced chemical equations for the word equations given.
  - » State to which type of reactions do those word equations belong.

1. a. magnesium + oxygen ⟶ magnesium oxide

   b.zinc + copper sulphate ⟶ zinc sulphate + copper

2. a. magnesium + hydrochloric ⟶ hydrogen + magnesium chloride

   b. ferrous sulphate + sodium hydroxide ⟶ ferrous sulphate + sodium hydroxide

3. a. calcium carbonate $\xrightarrow{\text{heat}}$ calcium oxide + carbon dioxide

   b. iron + sulphur ⟶ iron sulphide

4. a.calcium chloride + sodium carbonate ⟶ sodium chloride + calcium carbonate

   b.iron oxide + carbon monoxide ⟶ iron + carbon dioxide

5. a. sodium + oxygen ⟶ sodium oxide

   b.water + sodium ⟶ sodium hydroxide + hydrogen

When words are used to write a given chemical reaction, we face lot of difficulties. Understand this through the following examples.

Given below is the reaction between haematite (Fe_2O_3) and carbon monoxide.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

Writing in words does not show the ratio of atoms of elements constituting compounds. But when written as chemical formulae, the ratio of elements in the compound can be definitely known. Then the equation can be balanced. Once the balanced equation is found, the ratio of masses of the respective elements or compounds that should be mixed to obtain the maxiumum amount of the produts when performing the reaction practically can be calculated. So, writing equations using chemical symbols and formulae not only makes the task easier but also helps calculations.

By the above equation written using the symbols and formulae, following information can be obtained.

» Knowing the relative atomic masses of the elements (Fe =56; O=16; C=12), the relative molar masses can be obtained as $Fe_2 O_3$ = 160 g mol^{-1},

CO = 28 g $mol^{-1}$and CO_2 = 44 g mol^{-1}.

Thus,

(a) three moles of carbon monoxide (CO) is required to react with one mole of haematite (Fe_2O_3).

Hence, 28 x 3g (84 g) of carbon monoxide are required to react with 160 g of haematite.

(b) Two moles of iron are formed in the above reaction.

Thus, 56 x 2 g (112 g) of iron are formed in the above reaction.

(c) Three moles of carbon dioxide are formed in the above reaction.

So, 44 x 3 g (132 g) of carbon dioxide are formed in the above reaction.

16.3 Reactivity of Metals

• Reactions of Metals with Air

We have seen that the objects such as nails, barbed wire and cutting tools made of iron rust fast. But jewellery made of gold do not tarnish even after a long period of

time. Have you inquired into the causes for this difference? You can have an answer for this by studing how metals react with air, water and dilute acids.

Let us carry out Activity 16.3 to investigate how metals react with air.

Activity - 16.3

Requirements: A freshly cut piece of sodium, a cleaned magnesium ribbon about 2 cm long

- Expose the freshly cut piece of sodium and the cleaned 2cm magnesium ribbon to air.
- Observe well the cut surface of the piece of sodium and the magnesium ribbon.
- Record your observations.

It is seen that the lustrous nature of the surface of sodium metal diminishes . We cannot see any noteworthy change in the magnesium ribbon. The reason for the disappearance of the shiny nature of the piece of sodium is that it reacts fast with the components in air. Magnesium does not react fast with the components in air.

When burnt in air, metals like sodium and magnesium react with oxygen to form their oxides.

$$4Na + O_2 \longrightarrow 2\ Na_2O$$
$$2Mg + O_2 \longrightarrow 2MgO$$

When heated in air, the surface of metals like zinc (Zn), iron (Fe) and copper (Cu) becomes dull. Prolonged heating turns them into the oxides.

$$2Zn + O_2 \longrightarrow 2ZnO$$

Metals like silver (Ag), platinum (Pt) and gold (Au) are not converted to their oxides. how strongly they are heated.

Based on these facts, it can be concluded that metals differ in their readiness of reacting with oxygen.

• Reactions of Metals with Water

Some metals react with cold water, hot water and water vapour at different speeds. Hence, it is clear that the reactively of metal towards water differ from one another. To confirm this, let us do activities 16.4 and 16.5.

Activity - 16.4

Requirements: A trough, water, a piece of sodium metal, a red litmus paper

- Under the guidance of the teacher add a small piece of sodium (the size of a seed of green gram) to the water in the trough.
- Record the observations.

The piece of sodium darts on the surface of water swiftly with a hissing sound. The piece of sodium which is small catches fire if it stays motionless. The red litmus paper in the trough turns blue. Sodium reacts violently with water liberating hydrogen gas. Turning red litmus blue shows the formation of an alkaline (basic) solution.

What happens here is that sodium reacts with cold water giving sodium hydroxide, a basic solution and hydrogen.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Activity - 16.5

Requirements: A beaker, water, a cleaned magnesium ribbon

- Put the cleaned magnesium ribbon into the beaker of water. Record the observations.
- Heat the beaker of water with the burner. Record the observations.

Magnesium does not give any observable reaction with cold water. But when reacting with hot water, liberation of gas bubbles can be seen.

Magnesium reacts with hot water giving magnesium hydroxide and hydrogen gas.

$$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$$

Magnesium reacts fast with steam. The products of the reaction are magnesium oxide and hydrogen gas.

$$Mg + H_2O \longrightarrow MgO + H_2$$

Aluminum and zinc do not react with cold water or hot water. On heating in steam, they form the corresponding oxide and hydrogen gas.

$$Zn + H_2O \longrightarrow ZnO + H_2$$

Iron does not react with cold water or hot water. When heated in steam it gives the metal oxide and hydrogen gas.

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

For extra knowledge

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

Pay your attention to the $\rightleftharpoons$ sign in the above equation. It indicates that the above reaction is reversible. That means the products can be formed from the reactants and also the reactants can be formed from the products.

Metals like silver, platinum and gold do not react with cold water, hot water and even with steam. Foregoing facts show that the reactivity of metals with water varies with the metal.

• Reactions of Metals with Dilute Acids

Hydrochloric acid (HCl), nitric acid (HNO_3) and sulphuric acid (H_2SO_4) are the frequently used acids in the laboratory.

Let us engage in Activity 16.6 to study the reactions of metals with dilute hydrochloric acid.

Activity - 16.6

Requirements: About 100 ml of dilute hydrochloric acid solution, identical test tubes, the metals aluminum (Al), copper (Cu), zinc (Zn), magnesium (Mg) and iron (Fe)

Add 100 ml of dilute hydrochloric acid solution each to a few test tubes. Add pieces of metals magnesium, aluminum, zinc, copper and iron with well cleaned surfaces separately to the test tubes and observe. Compare the rate of fizzing.

Gas bubbles evolve fast from the test tubes containing magnesium, aluminum and zinc. Gas bubbles liberate slowly from the test tube containing iron. No gas bubbles are set free from the test tube containing copper.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$

HCl is called hydrogen chloride when it exits as a gas. When hydrogen chloride gas is dissolved in water the solution is called hydrochloric acid.

This shows that the rate of reactions of metals with dilute acids differ according to the type of the metal. It is seen that copper metal does not react with dilute hydrochloric acid. Many metals react with dilute sulphuric acid also liberating hydrogen gas.

$$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$$

However, reactions of metals with concentrated sulphuric acid and nitric acid may give other gaseous products. Metals like potassium (K), sodium (Na) and calcium (Ca) react violently with dilute acids. It may cause even an ignition with explosion. Therefore those reactions must not be tried in the laboratory.

From the above it is seen that the reactivity of metals with acids varies with the metal.

• Reactions of Metals with Solutions of Other Metallic Salts

Let us conduct activity 16.7 in order to explore how metals react with the solutions of salts of metals. Copper sulphate ($CuSO_4$) is a salt of the metal copper (Cu). An aqueous solution of copper sulphate can be prepared by dissolving this salt in water. Let us use the reaction of the metal zinc (Zn) with the copper sulphate solution in this regard.

Activity - 16.7

Requirements :- A beaker, an aqueous solution of copper sulphate, cleaned zinc metal

- Add copper sulphate solution to the beaker.
- Add a zinc granule to it.
- Record the observations.

Copper sulphate solution is blue in colour. It can be observed that the intensity of the blue colour of the solution diminishes with the formation of a brown powder.

Here, the following single displacement reaction occurs.

$$CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu$$

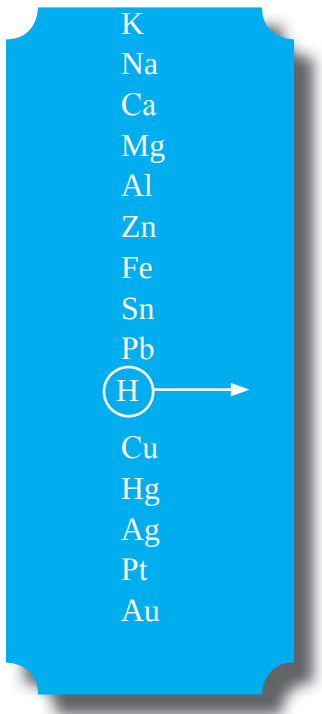
No reaction occurs when copper metal is added to the zinc sulphate solution.

$$ZnSO_4 + Cu \longrightarrow \text{No change is observed}$$

Only a metal which is more reactive can displace another metal from an aqueous solution of it. Accordingly, zinc is more reactive than copper, so it can displace copper from a copper sulphate solution. But, copper cannot displace zinc from a zinc sulphate solution. Thus, of zinc and copper, it can be inferred that zinc is the more reactive metal.

16.4 Activity Series

The reactivity shown by metals with oxygen, water and, dilute acids is different from one another. The activity series is built up on the basis of those observations as well as other data. **The series obtained by the arrangement of metals in the descending order of their reactivity is referred to as the activity series.** The activity series is very important in the studies in chemistry.



Activity series

• Uses of the Activity Series

- Activity series is useful to identify the precautions to be taken when storing metals. The metals with high reactivity such as sodium (Na), potassium (K) and calcium (Ca) should be stored in liquids such as kerosene and liquid paraffin. Because of their high reactivity with air, they react with the components in air if they are kept exposed to air.

- Activity series is useful to find methods that prevent corrosion of metals. Keeping iron in contact with metals like zinc and magnesium that are more reactive than iron to prevent rusting of iron is an example.
- Activity series helps select metals to make electrochemical cells.
- Activity series can be used to decide on the methods suitable for extracting metals. Metals extraction involves the separation of the metal from a natural ore which contains that metal. How the metals occur differs according to their reactivity.
- Reactive metals such as sodium (Na) and potassium (K) cannot be seen as native metals in the natural environment. They are found as very stable ionic compounds in the environment. In order to extract them, electrolysis, a robust method of extracting metals has to be used. These metals are extracted by the electrolysis of their fused (molten) chloride (to be discussed in Grade 11).
- The metals of moderate reactivity such as iron (Fe), tin (Sn), zinc (Zn) and lead (Pb) are extracted by reducing their compounds by other elements or compounds.
- The metals of low reactivity such as Silver (Ag), gold (Au) and platinum (Pt) occur in nature as the native metals mixed with other compounds. They are extracted by the physical methods used to separate the mixtures.

Hence, strong extraction methods such as electrolysis are used to extract metals at the top of the activity series. More simpler physical methods are used to extract metals at the bottom of the activity series.

• Extraction of Iron

Now, let us pay attention to the extraction of iron, a metal which is very important for the life of the human.

For extra knowledge

There are evidences in support of the fact that there had been a wealth of knowledge about extraction of iron in Sri Lanka in the past. Archeological excavations carried out recently in the Samanala wewa area have disclosed that a furnace smelting iron ores had been operated with the aid of monsoonal winds. A group of archeologists succeeded in reconstructing such a furnace and producing iron by smelting the iron ore. Archeological records state that steel for making the ceremonial sword of the Emperor of Arab had been brought in from 'Serendib'.

Iron is a metal placed somewhere in the middle of activity series. Iron is extracted from the iron ore mined from the soil. The main component containing iron in the iron ore is haematite (Fe_2O_3).

The structure used to extract iron is called the blast furnace. This is illustrated in Fig. 16.1.

It is a special furnace about 60 m high. The raw materials are fed into the furnace from the top while hot air is blown in from the bottom. Heating caused by hot air brings about several reactions inside the furnace giving liquid iron. The temperature range within the blast furnace is 1000 ^{0}C – 1900 ^{0}C.

The raw materials used namely iron ore ($Fe_2O_{3)}$, limestone ($CaCO_3$) and coke (C) mixed in the correct proportion and powdered finely are charged from the top of the furnace.

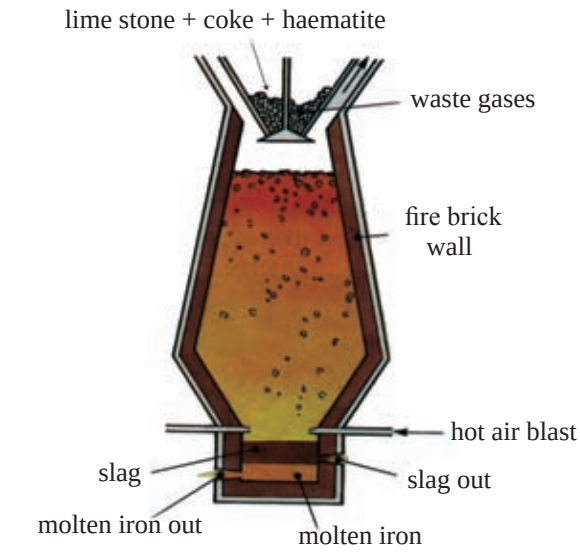


Fig. 16.1 - Blast furnace

During extraction of iron, following reactions occur in the blast furnace.

- Coke burns in air forming carbon dioxide.

$$C + O_2 \longrightarrow CO_2$$

- Carbon dioxide gas reacts with coke giving carbon monoxide gas (CO).

$$CO_2 + C \longrightarrow 2\,CO$$

- Carbon monoxide reduces the iron ore (Fe_2O_3). This produces liquid iron.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

- Calcium carbonate decomposes giving calcium oxide and carbon dioxide.

$$CaCO_3 \longrightarrow CaO + CO_2$$

- Silicon dioxide or silica (SiO_2) and aluminum oxide or alumina (Al_2O_3) present as impurities in the iron ore react with calcium oxide formed by the decomposition of limestone giving the slag, a mixture of calcium silicate ($CaSiO_3$) and calcium aluminate ($Ca\ Al_2O_4$).

$$SiO_2 + CaO \longrightarrow CaSiO_3$$
$$Al_2O_3 + CaO \longrightarrow CaAl_2O_4$$

slag

The slag floats on molten iron. Molten iron and liquid slag are separately flown out.

Assignment - 16.2

1. Collect information about the iron industry in ancient Sri Lanka.
2. Iron is used to make alloys. Prepare a table comprising the alloys of iron, the new properties imparted of them and the uses of items made of those alloys because of those properties.
3. Discuss with the teacher the advantage if any of the existence of the slag in the blast furnace.

• Extraction of Gold

Gold (Au) is a metal that has longer historical relations with the human race than even iron does. There are evidences for the utilization of gold to make coins, various statues and documents. Now, let us see how this metal is extracted.

Gold, which is placed at the bottom of the activity series, does not react with any active component of the atmosphere under normal conditions. Therefore it occurs as the native metal in nature. But it is mixed with other impurities.

A certain amount of impurities can be removed by sifting the ore containing gold. The density of gold is very high. Therefore, when the ore is powdered finely and mixed into a drain of water, gold settles down first on the bottom. The metal separated by such physical methods is purified further by various methods.

For extra knowledge

Presently solvents that dissolve gold have been discovered. When the metal with impurities is dissolved in these solvents, only gold dissolves. In order to get the metal that has gone into the solution, it is displaced by another metal.

16.5 Gases - Their Preparation, Properties and Uses

• Hydrogen (H_2)

In the atmosphere hydrogen occurs in a very small percentage. It is the lightest gas.

Physical and chemical properties of hydrogen gas

- The density of hydrogen is less than that of normal air.
- Its relative molecular mass is 2.
- It is a combustible gas.
- Hydrogen is slightly soluble in water.
- It is colourless.
- The gas is odourless.

In the laboratory hydrogen gas can be prepared by reacting a metal such as zinc or magnesium with an acid such as dilute hydrochloric acid or dilute sulphuric acid.

$$Zn + 2\ HCl \longrightarrow ZnCl_2 + H_2$$

Fig. 16.2 presents a set of apparatus that can be used to collect hydrogen gas prepared by a reaction such as the above.

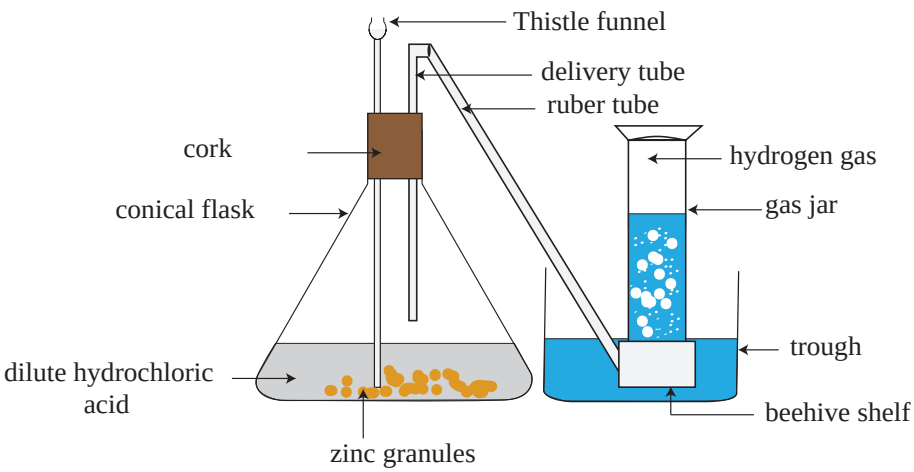


Fig. 16.2 Preparation of hydrogen gas in the laboratory

This method of collecting a gas is known as the downward displacement of water because when the gas enters the gas jar, the water in it is pushed down.
The gas coming from the delivery tube can also be collected by keeping a gas jar as shown in the Fig. 16.3.

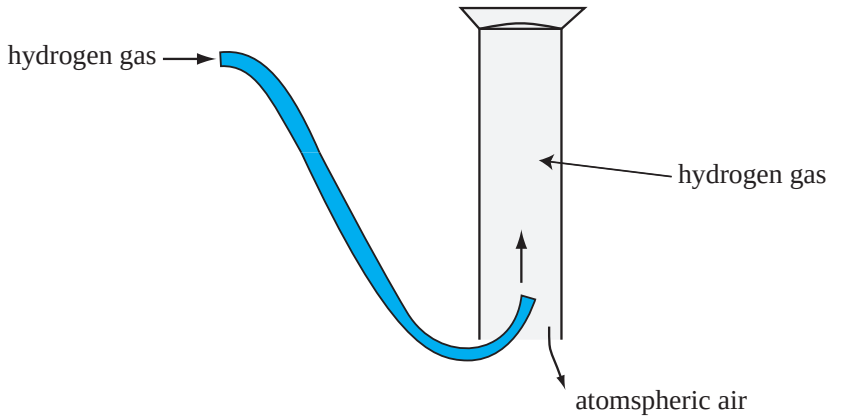


Fig. 16.3 - Collecting hydrogen gas by downward displacement of air

Since the density of hydrogen gas is less than that of the normal air, it moves up the jar. Then the atmospheric air in the jar gets pushed down and removed. This method of collecting a gas is called 'downward displacement of air'.

Activity - 16.8

Requirements: Dilute hydrochloric acid, clean test tubes, zinc granules, a conical flask, a thistle funnel, glass tubes, a rubber tube, a trough of water, a dry ekel, box of matches

- Arrange the apparatus as shown in Fig. 16.2 and collect several samples of hydrogen gas with your teacher (Since a gas jar requires a large amount of gas, use about five test tubes).
- Close well the mouth of the test tubes filled with the gas and take it out of water. Introduce a lighted ekel into this test tube.

What is your observation? The gas burns with a squeaky 'pop'. By this, hydrogen gas can be identified easily.

Uses of hydrogen gas

- Used as a fuel in rocketry
- Production of margarine from vegetable oils
- Production of ammonia gas by reacting with nitrogen (Ammonia is used to produce fertilizers such as urea.)
- Reduction of organic compounds

Assignment - 16.3

Inquire into the substances used to fly a small balloon. Collect the necessary materials and fly several balloons under the guidance of the teacher. Look into the reactions happening.

• Oxygen (O_2)

As regards the composition of normal air, about 20% of it is oxygen gas.

Physical and chemical properties of oxygen

- The density is higher than that of normal air.
- The relative molecular mass is 32.
- A supporter of combustion.
- Slightly soluble in water.
- A colourless and odourless gas.

Some reactions by which oxygen can be prepared in the laboratory are as follow.

1. Heating potassium permanganate ($KMnO_4$)

$$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2$$

2. Heating potassium nitrate (KNO_3)

$$2KNO_3 \xrightarrow{\Delta} 2KNO_2 + O_2$$

3. Decomposition of hydrogen peroxide (H_2O_2)

$$2H_2O_2 \xrightarrow{\Delta} 2H_2O + O_2$$

4. Heating potassium chlorate ($KClO_3$)

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$$

In the laboratory oxygen gas can be prepared by heating potassium permanganate using the apparatus in Fig. 16.4.

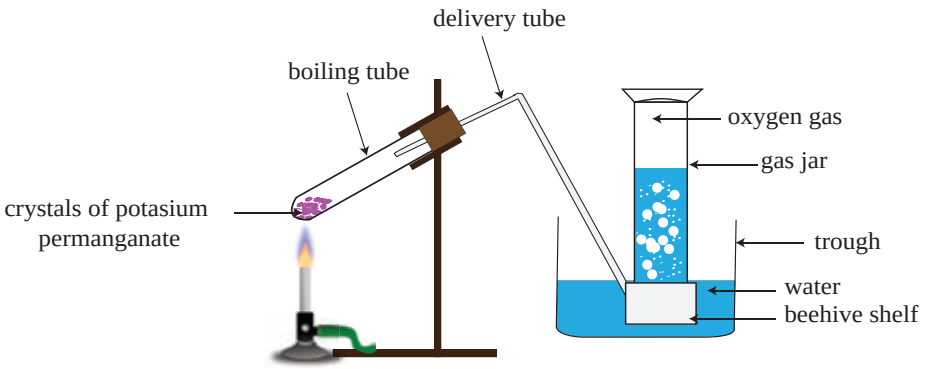


Fig 16.4 - Preparation of oxygen gas in the laboratory

Here, you see that the method of collecting oxygen gas is the downward displacement of water.

Activity - 16.9

Requirement : A stand, a boiling tube, rubber stoppers, a glass tube, rubber tubing, test tubes, a trough of water, a burner, potassium permanganate.

- Under the directions of the teacher set the apparatus as shown in Fig. 16.4 in the laboratory and collect oxygen gas to a few test tubes.
- Do the following test to identify oxygen gas. Take a dry ekel. Light one end of it. When the tip is glowing put out the flame. Take one test tube with oxygen out of water and introduce the glowing splint into it as soon as you open the mouth of the tube.

It is observed that the splint relights with a flame. By this oxygen gas can be identified.

Uses of oxygen gas

- It is essential for the respiration of all organisms.
- When something burns, it reacts with oxygen. Thus, oxygen is essential for combustion.
- It is used during underwater diving and space travel.
- It is used to generate the oxy-acetylene flame used for welding metals.
- Oxygen is used as a raw material in industries such as the production of sulphuric acid and nitric acid.

• Carbon dioxide gas (CO_2)

Carbon dioxide is a gas that contributed to the advent of life on Earth. This gas brought the temperature of the Earth's atmosphere to an optimal level for living organisms and it also acts a raw material for photosynthesis, the process that meets the food requirement of all living beings. Carbon dioxide occurs in a percentage as small as 0.03% by volume in the atmosphere.

Physical properties of carbon dioxide gas

- It is a gas with a density higher than that of normal air.
- Its relative molecular mass is 44.
- It neither burns, nor supports combustion.
- The gas is slightly soluble in water.
- The gas is colourless.
- Carbon dioxide is odourless.

Carbon dioxide gas can be prepared by reacting calcium carbonate ($CaCO_3$) with dilute hydrochloric acid.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

A sample of carbon dioxide gas can be prepared using the set up of apparatus shown in Fig. 16.5.

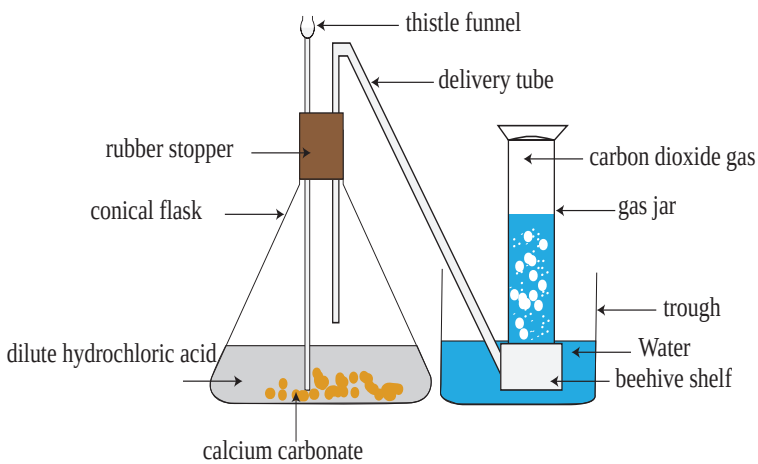


Fig. 16.5 - preparation of carbon dioxide gas in the laboratory

For your attention: Though a little amount of carbon dioxide dissolves in water when it is collected over water, it is not a barrier to collect samples of the gas.

Here also the method used to collect the gas is the downward displacement of water. But, as the density of carbon dioxide is greater than that of normal air, it can also be collected as shown in Fig. 16.6.

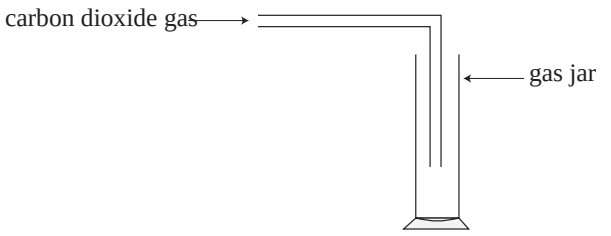


Fig. 16.6 - Collecting carbon dioxide gas by upward displacement of air

Since the density of carbon dioxide gas coming from the delivery tube is high, it reaches to the bottom of the jar. When the gas fills the jar, air inside is displaced upwards. Therefore this method of collecting a gas is known as 'upward displacement of air.

Activity - 16.10

Requirement: a conical flask, a rubber stopper, a thistle funnel, glass tubing, test tubes, a trough of water, dilute hydrochloric acid, calcium carbonate or egg shells, a dry ekel, lime water, box of matches.

- Under the guidance of the science teacher, set the apparatus given in Fig. 16.5 and fill some test tubes with carbon dioxide gas.
- Light a dry ekel and introduce it with the flame into a test tube containing carbon dioxide gas. The flame is immediately extinguished. The gas quickly puts out the glow also.
- Dissolve a little slaked lime ($Ca(OH)_2$) in about 50 ml of water carefully are filter through a filter paper. Add about 5 ml of this solution to a test tube containing carbon dioxide, stopper the tube tightly and shake well. Add the same volume of lime water to a test tube with normal air, stopper and shake well. Compare the colours of the solutions in the two test tubes.

You will see that lime water turns more milky in the test tube containing carbon dioxide. Calcium hydroxide in lime water reacts with carbon dioxide in the test tube as follows.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

The lime water turns milky because the white calcium carbonate so formed is suspended in water.

If more carbon dioxide is passed into the test tube containing the gas suspension, the gas reacts with calcium carbonate forming water soluble calcium hydrogen carbonate or calcium bicarbonate [$(Ca(HCO_3)_{2.}$]. Therefore the milkiness of the solution disappears.

When carbon dioxide is cooled strongly under high pressure, the gas solidifies. When heated the solid carbon dioxide directly turns into the gas without liquefying, so it does not become a liquid like ice. Therefore solid carbon dioxide is known as dry ice. Since the temperature of dry ice (-77^0C) is very much lower than that of ice, it is used as a super coolant. Dry ice is largely used in food preservation. It is also used to create artificial rains.

Uses of carbon dioxide

- Since carbon dioxide is a non-supporter of combustion it is used in extinguishing fires.
- Since carbonic acid (H_2CO_3) formed when carbon dioxide dissolves in water gives a taste, it is used in the production of soda water and fizzy drinks.
- Carbon monoxide gas, the reductant essential for extraction of iron is produced by reacting carbon dioxide with coke.

For extra knowledge

When writing a balanced chemical equations, the physical states related to the reaction are often indicated in front of each reactant and product.

s = solid l = liquid g = gas aq = aqueous

e.g. $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

Summary

- The changes taking place in matter can be classified as physical changes and chemical changes.
- The changes that involve only the change in physical state of a substance without changing its composition such as melting of a solid, vaporization of a liquid, condensation and solidification of a gas following cooling and freezing of a liquid are physical changes.
- The changes that bring about the formation of new substances from the existing substances are known as chemical changes.
- Chemical reactions are of four types-combination, decomposition, single displacement and double displacement.
- A chemical changes can be represented by a balanced chemical equation.
- Symbols of elements and formulae of compounds that take part in a chemical reaction are used to write the balanced chemical equations.
- A lot of information can be drawn from the correctly written chemical equations.
- The Activity Series has been built up by comparing the reactions of metals with air, water, dilute acids and salt solutions.
- Deciding on the methods of metal extraction, identification of methods that prevent corrosion of metals, selection of metals to construct electrochemical cells according to requirement are uses made from the activity series.
- A structure called blast furnace and the raw materials hematite (Fe_2O_3), limestone ($CaCO_3$) and coke are used to extract iron.
- Gold occurs as the native (uncombined) metal in nature because its reactivity is very low. Various physical methods are used to separate gold mixed with impurities.
- Hydrogen, a component of very low abundance in the atmosphere is a useful gas to man.
- Oxygen, a gas present at an abundance of about 20% in the atmosphere is useful for many tasks including respiration and combustion.
- Carbon dioxide present at a percentage of about 0.03% by volume in the atmosphere has contributed to make the Earth suitable for living organizations. It also acts as a raw material for the production of food in plants by photosynthesis.

- Increase in the amount of carbon dioxide in the atmosphere causes global warming.
- According to the properties of gases, different methods are employed to collect them in the laboratory.
- In the laboratory, various methods are used to identify gases.

Exercise

1. Opposite each of the following statements, place a tick (✓) if it is true and a cross (X) if it is false.

   i. Melting of wax is a chemical change. ( )
   ii. A chemical change occurs in a fire place burning firewood. ( )
   iii. Evaporation of Eau de cologne is a physical change. ( )
   iv. Rusting of iron is not a chemical change. ( )
   v. A chemical change occurs when a salt solution is made by dissolving crystals of salt in water. ( )

2. Identify each of the following reactions as combination, decomposition, single displacement and double displacement.

   i. $4Na + O_2 \longrightarrow 2Na_2O$
   ii. $2Ag_2CO_3 \longrightarrow 4Ag + 2CO_2 + O_2$
   iii. $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$
   iv. $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$
   v. $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

3. Write balanced chemical equations for the following reactions.

   i. Sodium and hydrochloric acid react to produce sodium chloride and hydrogen.
   ii. Lead nitrate and dilute sulphuric acid react forming lead sulphate and nitric acid.
   iii. Calcium reacts with water giving calcium hydroxide and hydrogen gas.
   iv. Aluminum and dilute hydrochloric acid react giving aluminum chloride and hydrogen.
   v. Sodium carbonate reacts with dilute hydrochloric acid forming sodium chloride, water and carbon dioxide.

4. Answer the following questions that are based on the metals given below.

Ca, Mg, Cu, Zn, Al, Fe

i. What is the metal that reacts fastest with water?
ii. What is the metal that does not react with dilute hydrochloric acid?
iii. Which metal effervesces fastest with dilute hydrochloric acid?
iv. What is the metal that tarnishes fastest when exposed to air?
v. What are the metals that would not react if put into a copper sulphate solution?
vi. What are the metals that burn easily with a flame forming the oxide?

5. Explain the followings scientifically.

i. Metals like sodium and potassium are stored in kerosene or liquid paraffin.
ii. Copper metal has been in use from ancient times.
iii. Special methods are not essential to prevent tarnishing of objects made of aluminum.
iv. Metals like sodium and potassium have the shortest history of usage.
v. When zinc is added to a copper sulphate solution copper is precipitated. But when copper is added to zinc sulphate solution zinc is not precipitated.

6. Describe the meaning of the following.

Electrolysis Reduction
Corrosion of metals Tarnishing of metals
Extraction of metals

7. Answer the following questions on extraction of iron.

i. Write separately the raw materials, main product and by products.
ii. What are the two methods by which carbon is obtained to produce carbon monoxide that reduces haematite?
iii. How the temperature in the blast furnace rises to 1700^0C though the gas admitted to it is heated to about 650^0C?
iv. Iron is formed from hematite by the following reaction.

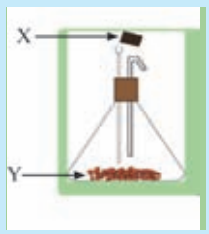
$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

If the mass of haematite reduced is 100 kg, calculate,

a. the mass of iron produced;
b. the mass of carbon monoxide used up; and
c. the mass of carbon dioxide released to the atmosphere.

8. Some instances which use gases are given below. Write the gas used in each of these instances.
   i. Formation of carbonic acid ( )
   ii. Facilitating respiration of critically ill patients ( )
   iii. Making dry ice ( )
   iv. Using as raw materials to produce ammonia ( )
   v. Making margarine from vegetable oils ( )
   vi. Aiding respiration during diving ( )
   vii. Supporting combustion of firewood ( )

9. The figure illustrates a part of a set of apparatus assembled to collect a certain gas.



   i. There is a fault in this set of apparatus. What is it?
   ii. Write two ways of setting this apparatus overcoming the fault.
   iii. Suggest another method to collect the gas without changing the arrangement of equipment.
   iv. Adding a rubber tube, a gas jar and a trough of water, draw the figure of a complete set of apparatus that can be used to collect hydrogen gas.

   v. Name a substance each for X and Y that can be used to prepare hydrogen.
   vi. What gas could be expected to form if X is egg shells and Y is a solution of vinegar?
   vii. A sample of the gas in part (vi) is collected in a test tube. Write how it could be identified.

Technical terms				
Activity series	-	සක්‍රියතා ශ්‍රේණිය	-	தாக்கத்தொடர்
Extraction	-	නිස්සාරණය	-	பிரித்தெடுப்பு
Condensation	-	සනීභවනය	-	ஒடுங்கல்
Combination	-	සංයෝජනය	-	சேர்க்கை
Decomposition	-	වියෝජනය	-	பிரிகை
Displacement	-	විස්ථාපනය	-	இடப்பெயர்ச்சி
Rate	-	ශීඝ්‍රතාව	-	வீதம்
Reversible reaction	-	ප්‍රතිවර්ත්‍ය ප්‍රතික්‍රියාව	-	மீளுந் தாக்கங்கள்
Blast Furnace	-	ධාරා උඟුම්මකය	-	ஊதுலை

Rate of Reactions

Chemistry 17

The cause of most changes around us is chemical reactions. Given below are some of those changes.

- Rusting of iron
- Ripening of fruits
- Digestion of food
- Manufacturing yoghurt from milk
- Burning firewood
- Reaction of zinc with a dilute acid
- Reaction of sodium metal with water
- Ignition of petrol
- Blast of a cracker

Assignment - 17.1

- Prepare a list of chemical changes including the above changes.
- Considering rates of chemical reactions that take place in those changes, tabulate them as given below.

Fast reactions	Slow reactions
i.	.....
ii.	.....
iii.	.....

The speeds of various chemical reactions vary. Reactions like ripening of fruits, digestion of food and rusting of iron are slow. But combustion of petrol, reacting zinc with dilute acid and blasting of a cracker are comparatively fast.

Accordingly, some reactions are instantaneous or rapid, while some others are very slow. There are reactions that take place in a second, in a minute, in an hour, during several days, during several months or even during several years.

When a chemical reaction occurs, reactants are used up and new products are formed. This can be easily understood by considering the following reaction.

$$\underbrace{CaCO_3(s) + 2HCl(aq)}_{\text{Reactants}} \longrightarrow \underbrace{CaCl_2(aq) + H_2O(l) + CO_2(g)}_{\text{Products}}$$

The rate of this reaction can be determined by the speed of loss of reactants or by the speed of formation of products. What is observable easily in this reaction is the rate of disappearance of calcium carbonate or the rate of evolution of carbon dioxide.

Rate of reaction is the amount of change occurred in unit time.

That is ;

$$\textbf{Rate of reaction} = \frac{\textbf{Amount of reactants used up}}{\textbf{Time taken}} \text{ or } \frac{\textbf{Amount of products formed}}{\textbf{Time taken}}$$

How is the rate of a reaction determined ? There are two principal ways for this.

i. Measuring the amount of reactants used up or the amount of products formed during a given period of time.
ii. Measuring the time taken for loss of a given amount of reactants or formation of a given amount of products.

17.1 Factors Affecting the Rate of Reactions

When a chemical reaction occurs, the chemical bonds between the particles of reactants (atoms or molecules) are broken. Different products are formed as a result of building of new bonds.

Particles of the reactants should collide with one another for this breaking and building of bonds.

Factors that affect the rate of reactions are given below.

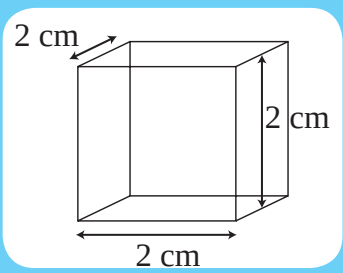
- Surface area of reactants
- Temperature at which the reaction occurs
- Concenration of reactants (Pressure for gaseous reactants)
- Presence of catalysts

• Surface area of reactants

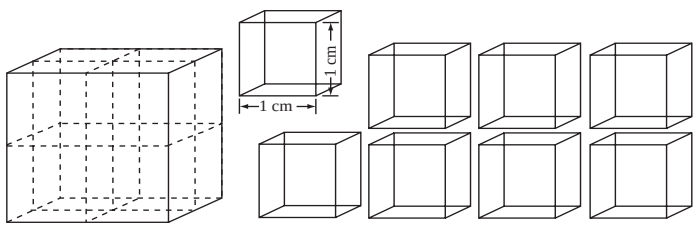
A large log of wood can easily be burnt when it is split into small splints. Physicians advise to chew food well for easy digestion. What is the reason for all this ?

When a solid reacts with a liquid or a gas, the reaction occurs only on the surface of the solid. The reason for this is that the particles of reactants collide only on the surface of the solid. Let us carry out assignment 17.2, for further clarification.

Assignment - 17.2



- Consider a cube of marble ($CaCO_3$), of a side 2 cm, put into dilute hydrochloric acid solution. Calculate the surface area of marble that comes into contact with the acid.
- Suppose that marble cube is cut into 8 small cubes, a side of each is 1cm in length.



- Calculate the total surface area of the marble cubes touching the acid, if those 8 small cubes are put into the acid solution.

Surface area of one side of the large cube	= 2 cm X 2 cm	= 4 cm^2
Total area of 6 sides	= 4 cm^2 X 6	= 24 cm^2
Surface area of one side of a small cube	= 1 cm X 1 cm	= 1 cm^2
Total area of 6 sides of one small cube	= 1 cm^2 X 6	= 6 cm^2
The total surface area of 8 small cubes	= 6 cm^2 X 8	= 48 cm^2

Accordingly it is clear that the surface area increases, when a large cube is divided into small cubes.

Let us carry out the activity 17.1 to find out, how surface area of reactants affects the rate of a reaction.

Activity - 17.1

Requirement : Calcium carbonate chips and powder of equal mass, dilute hydrochloric acid, two beakers, a stop watch

- Add equal volumes of acid into two beakers.
- Add calcium carbonate chips into one beaker with hydrochloric acid and using the stop watch measure the time taken by the chips to disappear. Repeat the same procedure using calcium carbonate powder.

Gas bubbles evolve faster in the beaker with calcium carbonate powder. It is observable that calcium carbonate powder disappears faster than the chips. That is, the reaction occurs in a shorter period of time.

Accordingly the rate of reactions in those two instances can be ascertained, comparing the time taken for equal amounts of reactants to be used up.

$$\text{Rate of reaction} = \frac{\text{Amount of the reactants used up}}{\text{Time taken}}$$

Above activity confirms that the rate of a reaction increases when calcium carbonate powder is used. Therefore it can be concluded that the rate of reactions increases when the surface area of the reactants is increased. The cause for this is that, the number of collisions between the particles of reactants increases when their surface area is increased.

Assignment - 17.3

- Surface area of reactants is increased to increase the rate of reactions in day - to- day life.
- Prepare a list of such instances.

• Temperature of the reaction

Food spoils because of biochemical reactions. Refrigerators or deep freezers are used to keep food unspoilt for a long time. This implies that the rates of biochemical reactions are reduced at low temperatures.

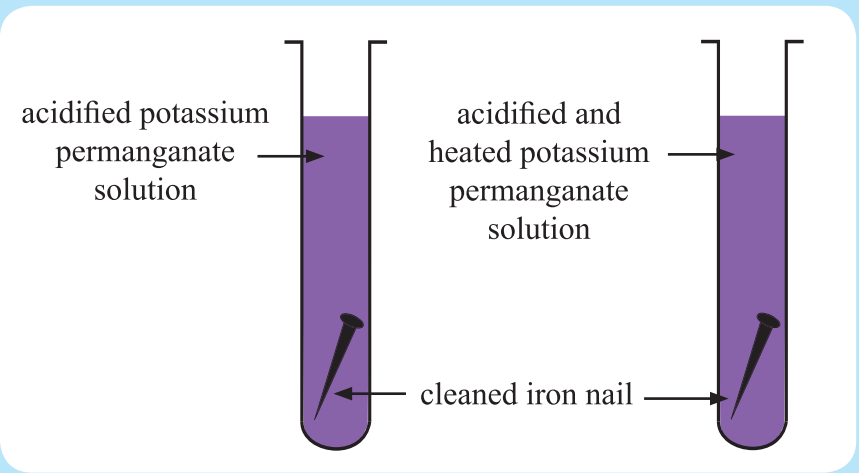
It is experienced that sugar dissolves more readily in hot water than in cold water.

Let us engage in activity 17.2 to find out how temperature affects the rate of reactions.

Activity - 17.2

Requirement : Two iron nails, water, dilute potassium permanganate solution dilute sulphuric acid, a stop watch, two test tubes, a burner.

- Prepare a very dilute potassium permanganate solution.
- Add equal volumes of dilute potassium permanganate solution into the two test tubes. Acidify them with equal volumes of sulphuric acid. Heat one test tube to a fairly higher temperature.
- Add equal number of cleaned iron nails equal in size, into the two test tubes.
- Using the stop watch, measure the time to disappear the colour in each.



In the above activity, it is observed that the time taken to decolourise potassium permanganate solution at higher temperature is less. Therefore it can be concluded that the rate of reactions increases with the increase in temperature. At a higher temperature, the kinetic energy of the reacting particles is greater. This increases the number of collisions per unit time among them thus increasing the rate of the reaction.

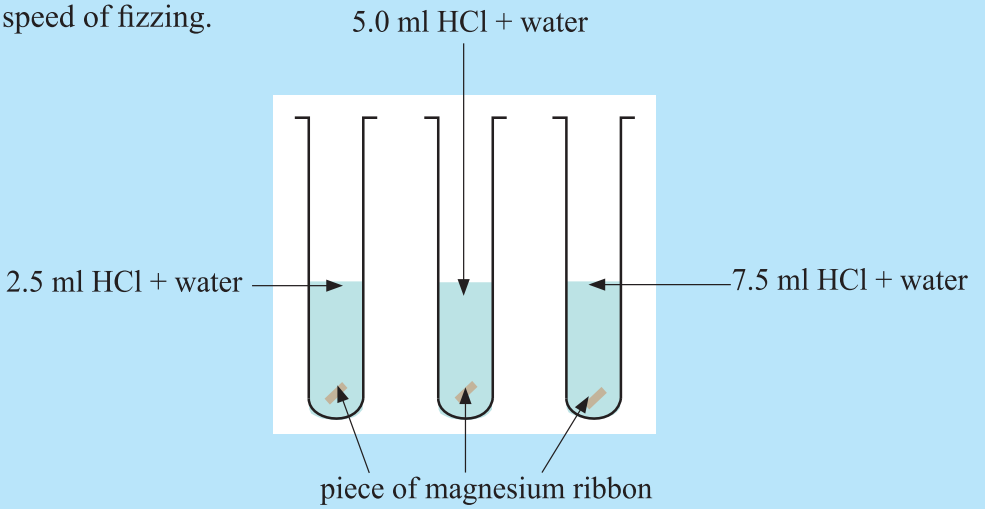
• Concentration of reactants

Let us carry out the activity 17.3 below, to find out how concentration of reactants affects the rate of reactions.

Activity - 17.3

Requirement : Three pieces of cleaned magnesium ribbon of equal surface area, three test tubes, dilute hydrochloric acid, water

- Take three test tubes and add 15 ml of water to each tube. Mark water level of each tube with a rubber band and empty the water. Add 2.5 ml, 5.0 ml, and 7.5 ml of dilute hydrochloric acid to the three test tubes, and fill water to the rubber band mark of each tube.
- Introduce to each test tube a piece of magnesium ribbon and observe the speed of fizzing.

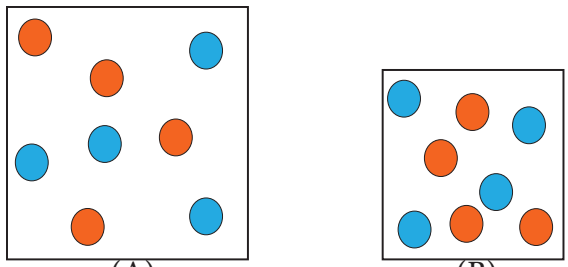


It is observed that the speed of evolution of gas bubbles is higher when the concentration of hydrochloric acid is high. So, it is clear that the rate of reaction increases with the increase in concentration of hydrochloric acid.

When the concentration of reactants is increased, the number of particles of reactants in a unit volume increases. Therefore the number of collisions of reactants per unit time increases. This is why the rate of a reaction increases, when the concentration of reactants is increased.

• Pressure of gaseous reactants

When gaseous reactants are involved, the rate of reaction can be increased by increasing the pressure. Consider the instances A and B illustrated in Fig.17.1.



High pressure condition Low pressure condition

Fig. 17.1

Masses of reactants in the case of A and B are the same. But the pressure of the reactants in B is higher than that of A, as the volume of B is reduced. Then the rate of reaction in B is higher than that of A, because the number of collisions of reactants per unit time is higher in B.

• Catalysts

Catalysts are the substances that increase the rate of a reaction, without being chemically consumed during the reaction. Given below is an activity to find out the effect of a catalyst on the rate of a chemical reaction.

Activity - 17.4

Requirement **:** Two test tubes, a solution of fresh hydrogen peroxide, 0.2 g of manganese dioxide

- Add equal volumes of fresh hydrogen peroxide solutions into the two test tubes.
- Tip accurately weighed 0.2 g of manganese dioxide into one of the test tubes.
- Observe the speed of evolution of gas bubbles from the above test tubes.
  $2H_2O_2(aq) \longrightarrow 2H_2O\ (l) + O_2(g)$
- When the reaction is over, filter the solution with manganese dioxide, dry the residue and weigh it.

The speed of evolution of gas bubbles is higher in the test tube with manganese dioxide. Manganese dioxide has increased the rate of this reaction. Since the mass of manganese dioxide remains the same, it has not been consumed during the reaction. That is, manganese dioxide has acted as a catalyst for this reaction.

In addition to the substances that speed up reactions, there are substances that reduce the rate of reactions. These are known as inhibitors.

e.g. A few drops of sulphuric acid can be used to reduce the rate of dissociation of hydrogen peroxide.

Small amount of a catalyst is sufficient for a large amount of reactants. Catalysts are specific for each reaction. The catalyst is not chemically changed during a reaction though its physical nature may change. Catalysts are widely used in various industries and in industrial processes. Some facts on this are given in Table 17.1.

Table - 17.1

Chemical industry	Catalyst used
Haber process of manufacturing ammonia	Porous iron
Contact method of manufacturing sulphuric acid	Vanadium pentoxide
Manufacturing nitric acid by oxidizing ammonia	Platinum
Manufacturing margarine by hydrogenation of unsaturated fats	Nickel

For extra knowledge

- Enzymes necessary for biochemical reactions in organisms like respiration, digestion, photosynthesis and protein synthesis are also biological catalysts. Some synthetic biological catalysts are used as detergents.

Knowledge of the factors affecting rate of chemical reactions can be effectively used in day - to - day life as well as in various chemical industries.

For extra knowledge

Calalytic converters

In modern motor vehicles, there is a part fitted to the exhaust system called catalytic converter. Its function is the conversion of pollutant gases like carbon monoxide and nitric oxide into non - pollutant gases. Catalysts in these converters increase the rate of following reactions.

$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$

$2NO(g) + 2CO(g) \longrightarrow N_2(g) + 2CO_2(g)$

Assignment - 17.4

Study the catalysts used in various chemical industries and chemical processes as well as the biological catalysts or enzymes involved in biochemical reactions. Prepare a booklet using the information collected. Libraries as well as printed and electronic media can be used for this purpose.

Summary

- Various chemical reaction occur at various speeds.
- Rate of a reaction is the amount of change taking place in unit time.
- Factors affecting the rate of reactions are;
  - » surface area of reactants (physical nature);
  - » temperature at which the reaction occurs;
  - » concentration of reactants (pressure for gaseous reactants); and catalysts.
- Knowledge of rate of reactions is widely applied in chemical industries and chemical processes.
- Knowledge of rate of reactions is important for day - to - day activities also.

Exercises

1. What do you mean by the rate of a chemical reaction ?
2. One factor that affects the rate of reactions is the presence of catalysts. State three other factors that affect the rate of reactions.
3. Briefly explain, how each factor you stated above, changes the rate of a reaction.
4. What is a catalyst ?
5. Equal masses of calcium cabonate chips and powder are separately reacted with equal volumes of dilute hydrochloric acid. Time taken and mass of calcium carbonate used up are given in the table below.

Time /min		1	2	3	4	5	6	7	8	9	10	11	12
Mass of $CaCO_3$ used up/g	Chips	2.1	2.9	3.5	3.9	4.2	4.4	4.5	4.6	4.7	4.8	4.8	4.8
	Powder	3.1	4.0	4.4	4.6	4.7	4.8	4.8	4.8	4.8	4.8	4.8	4.8

I. Draw the graphs for both instances above, on the same grid.

II. In which instance, is the rate of reaction higher?

III. Explain the reasons for the difference of rates of reaction in these two instances.

Technical Terms				
Reaction	-	ප්‍රතික්‍රියාව	-	தாக்கம்
Rate of reaction	-	ප්‍රතික්‍රියා ශීඝ්‍රතාව	-	தாக்கவீதம்
Chemical changes	-	රසායනික විපර්යාස	-	இரசாயன மாற்றம்
Surface area	-	පෘෂ්ඨ වර්ගඵලය	-	ஊக்கி
Reactant	-	ප්‍රතික්‍රියක	-	தாக்க மேற்பரப்பு
Catalysts	-	උත්ප්‍රේරක	-	தாக்கிகள்
Produts	-	ඵල	-	விளை
Concentration	-	සාන්ද්‍රණය	-	செறிவு
Inhibitors	-	නිශේධක / මන්ධක	-	நிரோதியுள்
Precipitate	-	අවක්ෂේපය	-	வீழ்படிவு
Residue	-	අවශේෂය	-	மீதி

Physics

18 Work, energy and power

18.1 Work

You have learnt before, that an object is said to have done work if its position or shape changed under the action of a force applied on it. Let us investigate further about work.

If we place an object on a horizontal plane as shown in Figure 18.1 and apply a constant force of 1 N on it until it moves a distance of 1 m along the direction of the force, the work done by the force is defined to be one Joule (1 J).

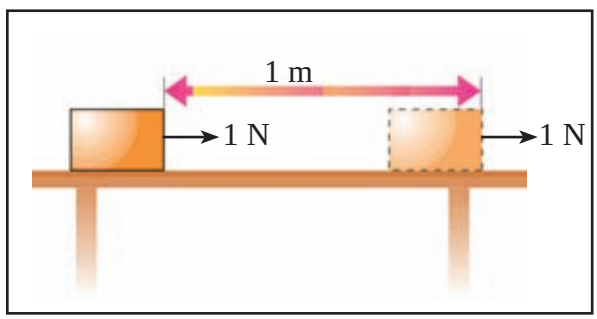


Figure 18.1 – Moving an object by 1 m under the action of a force of 1 N

If a constant force of 2 N acts on the object until it moves by 1 m in the direction of the force, then the work done on the object is 2 J.

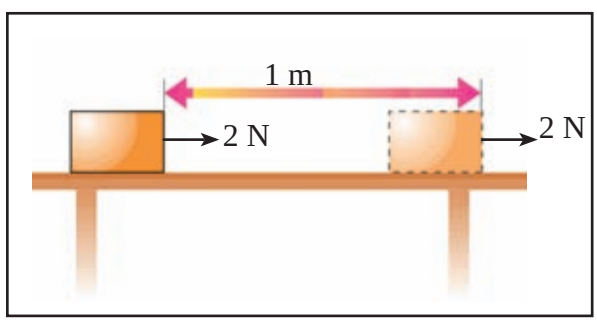


Figure 18.2 – Moving an object by 1 m under the action of a force of 2 N

Similarly, if a constant force of 3 N acts on the object until it moves by 1 m in the direction of the force as shown in Figure 18.3, then the work done on the object is 3 J.

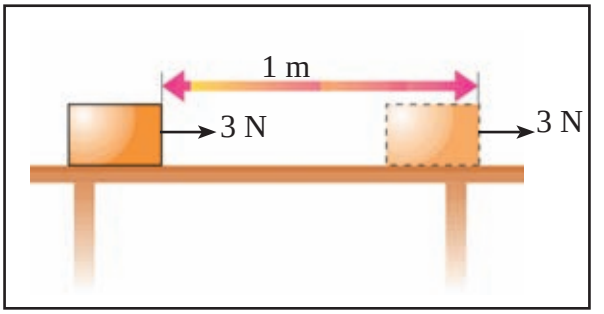


Figure 18.3 – Moving an object by 1 m under the action of a force of 3 N

Therefore,
Work done by a force = Magnitude of the force × distance moved in the direction of the force

Example 1

What is the work done, if a force of 7.5 N acts on an object and displaces it by 8 m in the direction of the force?

Work done = Magnitude of the force × distance moved in the direction of the force
= 7.5 N × 8 m
= 60 J

Example 2

The weight of an object is 40 N. What is the work done in lifting the object by a vertical distance of 2 m?

Force that mast be applied vertically upwards to lift the 40 N weight = 40 N
Height to be lifted = 2 m
Work done = 40 N × 2 m
= 80 J

Example 3

The mass of an object is 5 kg. Find the work done in lifting it upwards by 3 m.

Mass of the object = 5 kg
Weight of the object = mg
= 5 kg × 10 m s^{-2}
= 50 N
Force needed to lift the weight = 50 N
Height to be lifted = 3 m
Work done = 50 N × 3 m
= 150 J

Exercise 18.1

Copy the table given below in your exercise book and fill in the blanks.

Force	Displacement of force	Work done
20 N	2 m	.....
.....	80 cm	24 J
15 N	.....	22.5 J
0.75 N	8 m	.....

18.2 Energy

Energy is the ability to do work. The unit for measuring energy is the same unit Joule that is used to measure the work done. We need energy to do various tasks. There are different forms of energy that help us to do work.

Examples

Heat energy
Electric energy
Magnetic energy
Mechanical energy
Light energy
Sound energy

Out of these different forms of energy, we will discuss mechanical energy here. There are two forms of mechanical energy and they are known as potential energy and kinetic energy.

Kinetic energy

The energy possessed by an object due to its motion is known as kinetic energy.

As shown in Figure 18.4, project an object (*A*) with a certain velocity along a horizontal floor so that it collides with a light trolley (*B*). After the collision, the trolley would move some distance before coming to rest. Next, project the object with a higher velocity. Now the trolley will move a longer distance before coming to rest.

Figure 18.4 – Pushing an object with a velocity

In this case, part of the kinetic energy of the moving object is transferred to the trolley setting the trolley in motion. When a higher initial velocity is given to the object, more energy is transferred to the trolley and it moves a longer distance.

Similarly, push objects of various masses with the same velocity towards the trolley. You will observe that the trolley would move further when knocked on by larger masses.

From these results, it is clear that the kinetic energy depends on the two factors, velocity and mass.

The following equation, which involves the two factors velocity and mass is used to calculate the kinetic energy of a moving object.

$$E_k = \frac{1}{2}mv^2$$

Where, m = mass of the object

v = velocity of the object

E_k = kinetic energy

When the unit of mass is kg, and the unit of velocity is m s^{-1}, the unit of kinetic energy is J (Joule).

Example 1

The mass of an object is 6 kg. Calculate its kinetic energy when it is moving at a velocity of 4 m s^{-1}.

$$\text{Kinetic energy} = \frac{1}{2} mv^2$$
$$= \frac{1}{2} \times 6 \times 4^2$$
$$= 48 \text{ J}$$

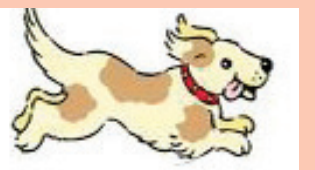
Example 2

Calculate the kinetic energy of an object of mass 4 kg at an instant that it is moving with a velocity of 2 m s^{-1}.

$$\text{Kinetic energy} = \frac{1}{2} mv^2$$
$$= \frac{1}{2} \times 4 \times 2^2$$
$$= 8 \text{ J}$$

Exercise 18.2

1) The mass of a dog is 10 kg. If its kinetic energy is 20 J at a certain instant, what would be the velocity it is running at?



(2) The kinetic energy of an object of mass 500 g is 9 J when it is moving with a certain velocity. Calculate the velocity of the object at that instant.

Potential energy

The energy stored in an object due to its position or due to a change in its form is known as potential energy.

When we lift an object upwards by a certain distance, we perform work on the object. That is, we expend some energy to bring the object to its new position. That energy is stored in the object as potential energy.

Let us find the energy required to lift an object of mass 3 kg by a distance of 2 m as shown in Figure 18.5 .

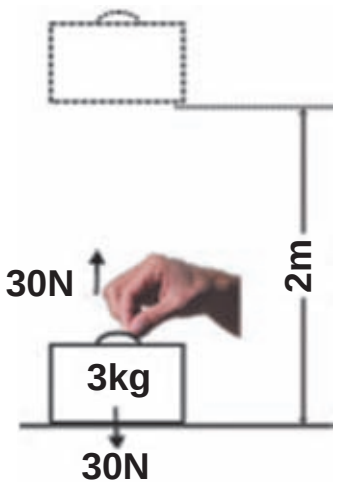


Figure 18.5 - Doing work against gravity

Weight of the 3 kg mass = 3 kg × 10 m s^{-2} = 30 N

Force required to lift the object = 30 N

Height that the object is lifted = 2 m

Work done on the object = 30 N × 2 m

= 60 J

Work done = mass of the object × gravitational acceleration × vertical distance lifted

Work done = Weight of the object × vertical distance lifted

Weight of the object = mass of the object × gravitational acceleration

Since the work done is 60 J the energy stored in the object at a height of 2 m is 60 J. That is the potential energy of the object at a height of 2 m is 60 J.

Since work is done against gravitational attraction, this potential energy is known as gravitational potential energy.

In the above example if we take, m as the mass of the object,

g as the acceleration due to gravity and

h as the vertical distance to the object, then

potential energy = mgh

The work done in lifting an object vertically upwards is stored in the object as potential energy. This energy is converted back into kinetic energy when the object is released. Let us do the following activity to show that the potential energy of an object is greater when its vertical position is higher.

Activity 18.1

Figure 18.6 – Variation of the potential energy with height

- Spread some clay on the floor, to a thickness of about 3 cm.
- Release a fairly heavy weight from a vertical height of about 0.5 m from the clay surface.
- Observe the depth of the depression caused on the clay surface at the point of contact where the weight fell.
- Repeat the above procedure by releasing the weight from various heights, make sure that the same part of the weight comes in contact with the clay surface each time it falls.
- Each time observe the depth of the depression on the clay surface.

You will observe that the depth of the depression increases as the original height of releasing the weight increases. The energy required to form a depression on the

clay surface was given by the falling weight. Your observations will confirm that the energy of the weight increases as the height of the fall increases.

It will be clear to you from this activity that the potential energy stored in an object increases in proportion to the height it is positioned.

Activity 18.2

- Fill about $\frac{1}{4}$ th of the height of a plastic bottle with sand and allow it to fall from a height of about 1 m onto the clay surface.
- Observe the depth of the depression formed on the clay surface as before.
- Next fill about ½ of the plastic bottle with sand and release from the same height as before.
- Now fill the plastic bottle completely with sand and release it from the same height.

You will observe that the depth of the depression on the clay surface increases with the mass of the object. It will be clear to you that the potential energy of an object increases with increasing mass.

When the length of a rubber band or a spring is increased by stretching it upon applying a force, its shape changes and the work done by the displacement of the force is stored in the rubber band or the spring. This potential energy is known as **elastic potential energy.**

Figure 18.7 - Stretching a spring

Suppose that the bicycle riding fast along a horizontal road had to climb up a hill as shown in the figure 18.8. Even though the rider might not try to pedal the bicycle now, it is possible for the bicycle to reach the hilltop due to the velocity he had at first. However, his velocity would decrease as the bicycle moves upward. Therefore, the kinetic energy of the bicycle would gradually decrease as it moves up.

If he was able reach the hilltop in this manner, the rider would be able reach the bottom of the hill without pedaling the bicycle. As he moves down the hill, his velocity would increase gradually. In turn, the kinetic energy of the bicycle would increase gradually.

Figure 18.8 - Riding a bicycle up of a hill

When the bicycle reached the bottom of the hill after riding along the flat road, it had some kinetic energy. When it went up the hill, its kinetic energy decreased until it reached a minimum value at the hilltop while its potential energy increased up to a maximum value. When the bicycle started its decent after reaching the hilltop, its potential energy begins to decrease while the kinetic energy begins to increase. From this example, it would be clear to you that kinetic energy can transform into potential energy and potential energy can transform back into kinetic energy.

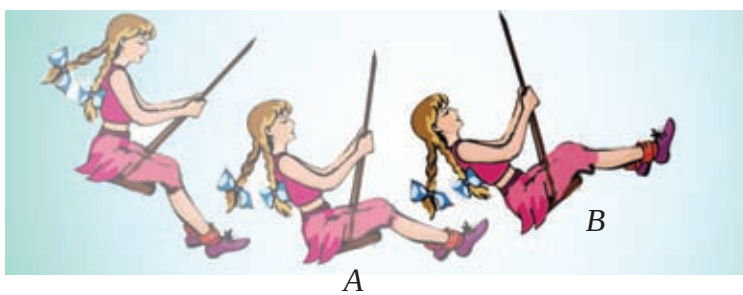


Figure 18.9 - Movement of a swing

You have seen swings in motion. When the child in the swing shown Figure 18.9, moves from the lowest point *A* to the highest point *B*, the kinetic energy decreases

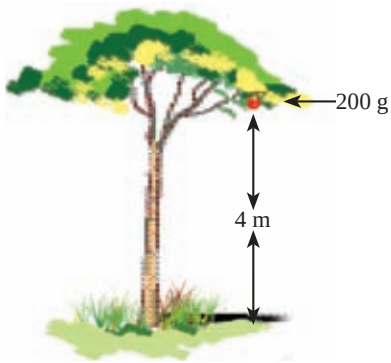
gradually. However, as she reaches a higher vertical level at *B*, the potential energy increases gradually. Therefore, as the child moves from point *A* to *B*, the kinetic energy of the system gets converted into potential energy. At *B* the velocity is zero and all the kinetic energy has transformed into potential energy. Thereafter, when the child swings back to point *A*, the potential energy gets transformed back into kinetic energy.

Example 1

Find the gravitational potential energy of an object of mass 7.5 kg at a vertical height of 4 m.

$$\begin{aligned} \text{Potential energy} &= mgh \\ &= 7.5 \text{ kg} \times 10 \text{ m s}^{-2} \times 4 \text{ m} \\ &= 300 \text{ J} \end{aligned}$$

Example 2



A fruit on a tree has a mass of 200 g. The vertical height to the fruit from the ground level is 4 m. Find the gravitational potential energy of the fruit.

$$\begin{aligned} \text{Gravitational potential energy} &= mgh \\ &= \frac{200 \text{ kg}}{1000} \times 10 \text{ m s}^{-2} \times 4 \text{ m} \\ &= 8 \text{ J} \end{aligned}$$

Instances where potential energy is used in daily life

1. Water stored in high reservoirs is allowed to fall down to a lower level, transforming the initial potential energy of the water into kinetic energy and this kinetic energy of the falling water is used to rotate a turbine to generate electricity.

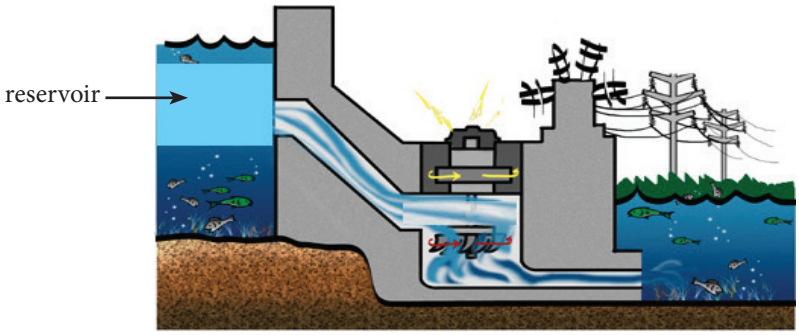


Figure 18.10 - Potential energy is used to generate electricity.

2. Pile and Tower

Pile is used to tighten the loose soil in construction sites before laying the foundation of buildings. This is done by lifting the pile to some height and releasing it to fall down onto the ground below.

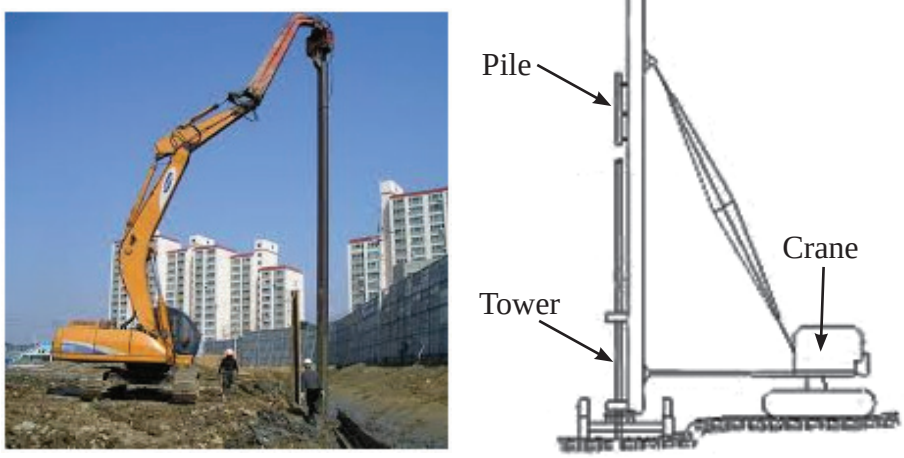


Figure 18.11 - Pile and tower.

3. Sledge hammer

In breaking stones and cutting firewood, sledge-hammer is used. When cutting wood, an iron wedge is inserted into the piece of wood to be cut and the lifted sledge-hammer is released on to the wedge. The potential energy of the sledge-hammer at the point of release transforms into kinetic energy whereby it collides on the wedge with a large velocity. The kinetic energy of the sledge-hammer gets transferred to the wedge which passes through the piece of wood, separating it into pieces.

Figure 18.12 - Using sledge hammer

18.3 Power

The amount of work done in a unit time or the rate of doing work is known as power.

If 600 Joules of work is done in 10 s,

$$\text{rate of doing work or power} = \frac{600\ \text{J}}{10\ \text{S}}$$
$$= 60\ \text{J s}^{-1}$$

One Joule per second (1JS^{-1}) is defined as a Watt (1W). Hence the power indicated above is 60W. That is the unit of power is Watt (W) .The following equation is used to calculate the power.

$$\text{Power} = \frac{\text{work done (J)}}{\text{time spent (s)}}$$

Example 1

The time taken to lift a mass of 5 kg to a height of 8 m is 10 s. Calculate the rate of doing work (power).

$$\text{Mass of object} = 5\ \text{kg}$$
$$\text{Weight of object} = mg$$
$$= 5\ \text{kg} \times 10\ \text{m s}^{-2}$$
$$= 50\ \text{N}$$

Therefore, force exerted to lift the object = 50 N

Height lifted = 8 m

Work done = 50 N × 8 m

= 400 J

$$\text{Power} = \frac{400\ \text{J}}{10\ \text{s}}$$

= 40 W

Example 2

What is the work done in a minute by a machine operating with a power output of 100 W?

Power = 100 W

= 100 J s^{-1}

Time = 1 minute

= 60 s

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

Work done during 10 s = power × time

= 100 W × 60 s

= 100 J s^{-1} × 60 s

= 6000 J

Miscellaneous exercises

(1) (i) A child lifts a bag of mass 4 kg to a height of 1.5 m. What is the work done? (g = 10 m s^{-2})

(ii) If the child took 3 seconds to do the work above, what is the rate of doing work (power)?

(2) A mass of 800 g was projected vertically upwards at a velocity of 20 m s^{-1}.

(i) What is the kinetic energy of the object just as it is projected?

(ii) How long will it take to reach the maximum height?

(iii) What is the maximum height it would reach?

(iv) What is its potential energy at the maximum height?

(3) A child of mass 35 kg climbs up a stair case to a vertical height of 4 m.

(i) What is the amount of work he does?

(ii) If he took 1 minute to climb the stairs, what is his rate of doing work or power?

Summary

- The work done by a force is equal to the product of the magnitude of the force and the displacement along the direction of the force.

  That is, work = Magnitude of the force × distance moved in the direction of the force

- If there is no energy loss, the work done is equal to the energy expended.
- The unit of measuring work and energy is the Joule (J).
- The two forms of mechanical energy are the potential energy and the kinetic energy.
- The kinetic energy of an object depends on its mass and the velocity.

Kinetic energy is calculated using the following equation:

Kinetic energy = $\frac{1}{2} mv^2$

m = mass (kg)
v = velocity (m s^{-1})

There are three factors that affect the gravitational potential energy.

1. Mass (m)
2. Gravitational acceleration (g)
3. Height (h)

The following equation is used to calculate the gravitational potential energy.

Gravitational potential energy = $m\ g\ h$

- The potential energy of an object changes when its shape changes.
- When an object moves upwards under gravity, there is a loss in its kinetic energy and this lost kinetic energy is transformed into potential energy.

Technical Terms

Work	-	කාර්යය	-	வேலை
Energy	-	ශක්තිය	-	சக்தி
Mechanical energy	-	යාන්ත්‍රික ශක්තිය	-	பொறிமுறை சக்தி
Kinetic energy	-	චාලක ශක්තිය	-	வெப்பசக்தி
Potential energy	-	විභව ශක්තිය	-	அழுத்த சக்தி
Power	-	ජවය	-	வலு

Physics

19 Current electricity

19.1 Static electricity and current electricity

Electricity is a very important form of energy to us. In the modern world, many instruments are manufactured in a way that they could be operated using electricity. House hold equipment such as Electric bulbs, electric irons and electric fans are some of the examples. Electricity basically has two forms, static electricity and current electricity.

You have learnt in grades 7 and 9 that static electricity consists of charges that are deposited on the surfaces of insulators and that they do not flow. Now let us investigate the behavior of static electricity.

Rub a drinking straw well with a cotton material (Figure 19.1) and bring it close to tiny bits of paper as shown in Figure 19.2. You will observe that the bits of paper get attracted to the straw rubbed with the piece of cotton cloth. Also bring another straw that was not rubbed with a cotton cloth close to tiny pieces of paper. You will notice that the bits of paper would not be attracted to the straw.

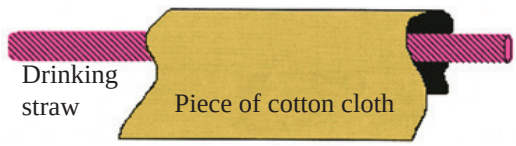


Figure 19.1 – Rubbing a straw with a piece of cotton cloth

Rub a plastic rod, pen or a comb against your hair and bring it near tiny bits of paper or tiny pieces of rigifoam. You will observe that these tiny pieces being attracted to the items rubbed with hair. Figure 19.2 shows little bits of rigifoam being attracted to a rubbed comb. Try the above with a plastic rod that was not rubbed with hair. You will observe that the rigifoam pieces do not get attracted to it.

Figure 19.2 – Tiny pieces of rigifoam attracted to a comb charged by rubbing

When some objects are rubbed, they acquire a force to attract little pieces of paper, dust and other light materials. Such objects acquire this attractive power through the static electric charges generated by rubbing.

You have observed that objects such as a drinking straw or a comb attract tiny bits of paper only after rubbing them and if the objects are not rubbed, they cannot attract bits of paper.

How are static electric charges that give certain objects an attractive power generated? All materials are composed of atoms. Atoms consist of tiny particles known as electrons, protons and neutrons. Protons are 'positively' charged particles while electrons are 'negatively' charged particles. Neutrons do not have a charge. They are neutral.

Protons and neutrons are found in the centre of an atom known as the nucleus (Figure 19.3). Electrons are found rotating around the nucleus. Only electrons can be removed from an atom easily. If electrons are removed from the atoms on the surface of an object after rubbing it with a piece of cloth, positive charges are generated on the surface of the object. That is, the surface is positively (+) charged. If the object receives electrons from the piece of cloth after being rubbed with the cloth, then the surface of the object acquires a negative charge. That is, the surface gets negatively (–) charged.

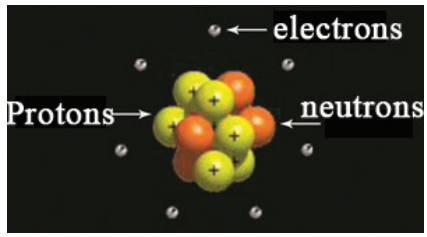


Figure 19.3 – Subatomic particles in an atom

Charges that are found stationary on an object in this manner are known as electrostatic charges**.**
When such accumulated electrostatic charges begin to move, they give rise to an electric current.

In order to find out how to generate an electric current from electrostatic charges let us engage in Activity 1.

Activity 19.1

Items required: A piece of a PVC tube, a piece of polythene, a neon bulb, conducting wires, a stand

- Arrange the set-up by connecting the conducting wires to the neon bulb as shown in Figure 19.4. Connect one terminal of the neon bulb to the earth

- Charge the PVC rod by rubbing with polythene.
- Touch the terminal of the neon bulb with the charged rod.
- Repeat the above steps several times and observe the lighting of the neon bulb.

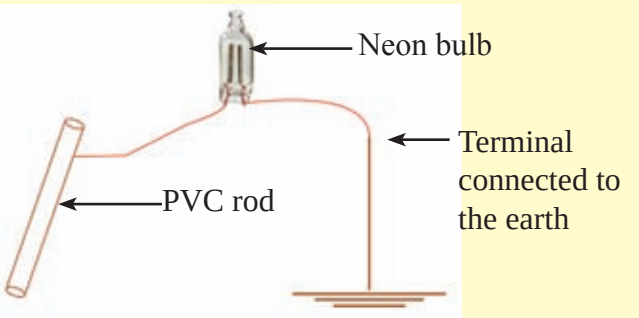


Figure 19.4 – Lighting up of the neon bulb when the electrostatic charges generated by rubbing the PVC rod flow through the bulb.

Electrostatic charges are stored on the surface of the PVC rod rubbed by polythene. When it touches the conducting wires, the stored static charges begin to flow out via the conducting wires. When these charges flow through the neon bulb, it lights up. When static electric charges begin to flow in this manner, it is known as an electric current.

A current of electric charges flowing through a conductor is known as an electric current.

19.2 Electricity flowing through conductors

• Conductors

Materials that allow a current of electrons to pass easily through it are known as conductors. All metals conduct electricity easily. All metals such as copper, aluminum and iron are electric conductors. The electrons in the outermost shell of metallic atoms can be easily detached from the atom. A large number of such detached electrons from the outermost shell of metal atoms are in random motion in the regions between metal atoms as shown in Figure 19.5. These electrons are known as free electrons

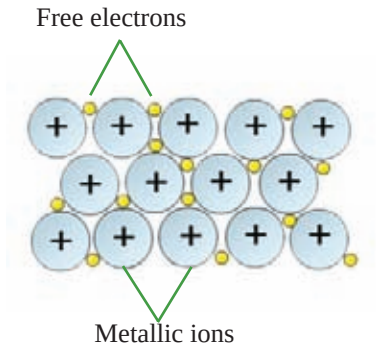


Figure 19.5 – Free existence of electrons in the outermost shell of metallic atoms

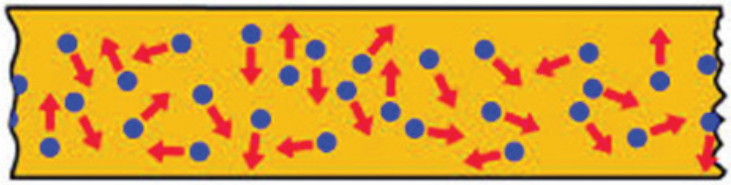


Figure 19.6 – Free electrons in a metal

The reason for electricity to flow easily through metals is the existence of free electrons. Let us consider the process that takes place when the ends of such a metallic conductor is connected to a dry cell as shown in Figure 19.7.

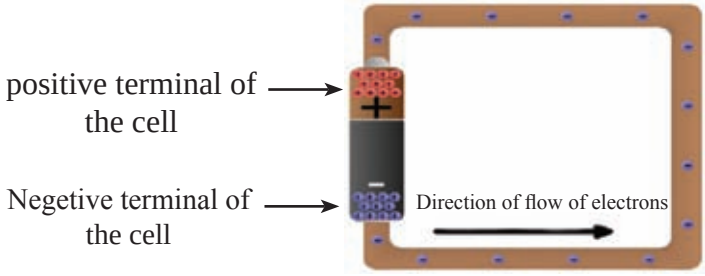


Figure 19.7 - Flow of electrons through a conductor

The negative terminal of a cell has the ability to repel electrons. Its positive terminal has the ability to attract electrons. Therefore, whenever the positive and negative

terminals of a cell are connected by a conductor, electrons begin to flow from the negative terminal of the cell to the positive terminal via the conductor. This flow of electrons is possible because of the presence of free electrons in metals. That is, the free electrons that are in random motion in a metal begin to move from the negative terminal of the cell to the positive terminal along the same direction as a result of connecting the electric cell.

The actual flow of electrons takes place from the negative to the positive terminals of the cell via the conductor. However, conventionally the direction of the electric current is considered to be in the opposite direction to that of the electron flow. That is, when an electron current flows from the negative to the positive terminal, a conventional electric current is said to flow from the positive to the negative terminal. The directions of the electric current flow and the electron flow are illustrated in Figures 19.8 and 19.9.

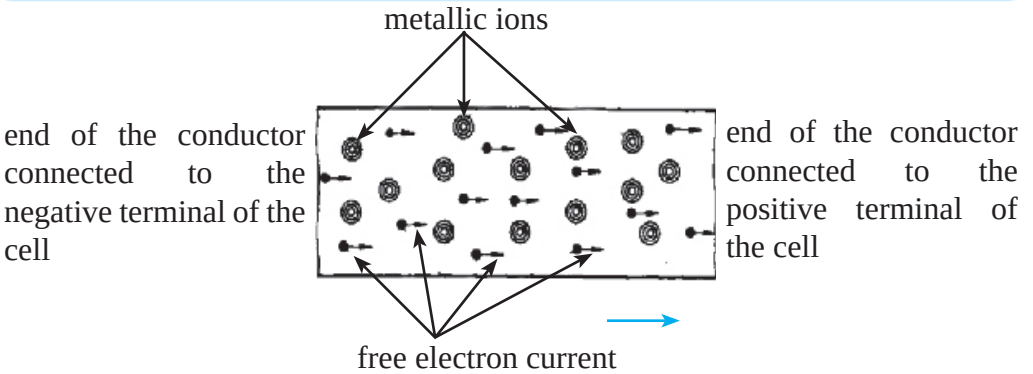


Figure 19.8 – Flow of electric current through a conductor

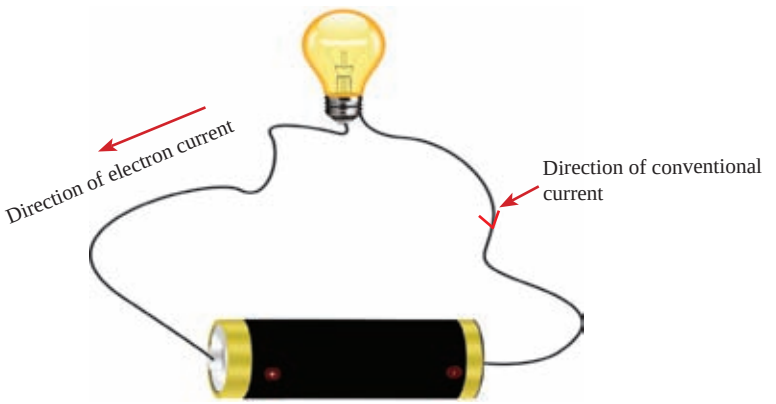


Figure 19.9 – Directions of the conventional electric current and the free electron current

The SI unit used to measure the electric current is known as the Ampere (A) and the instrument used to measure electric current is known as the ammeter

(a) (b)

Figure 19.10 - (a) An ammeter (b) Digital multimeter as an ammeter

If we need to measure the current flowing through a conductor, it is necessary to connect the ammeter to the circuit in such a way that the entire current passing through the conductor passes through the ammeter as well.

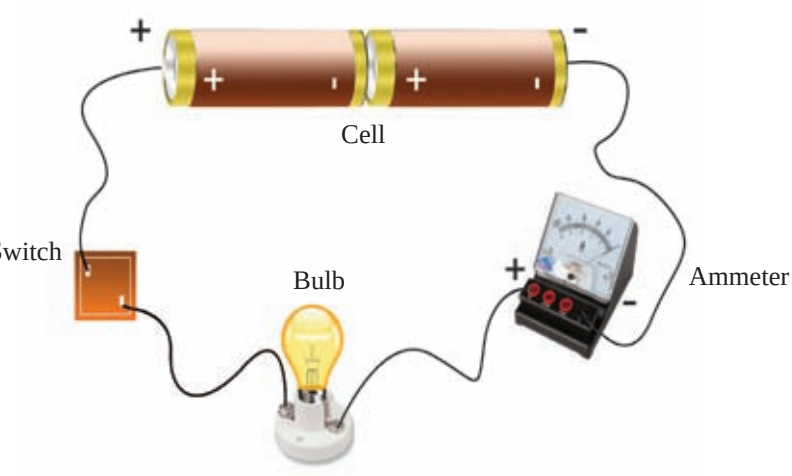
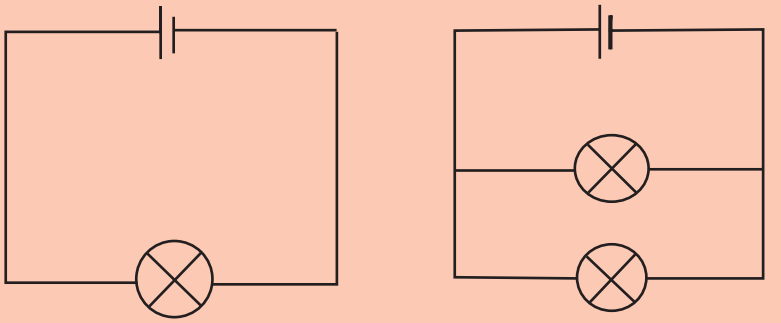


Figure 19.11 - Connecting an ammeter to a circuit

Exercise 19.1

Mark the currents flowing through the circuits given below by arrow heads.



19.3 Potential difference and the electromotive force

It is a well-known fact that the speed of water flow through pipe lines is larger for water tanks positioned at higher locations. The reason for the higher flow speeds with higher positions of the tank is the larger pressure difference between the water tank and the place where the water is utilized.

The current flowing in an electric circuit is analogous to the water flow from a water tank. Here, the source of electricity acts like the water tank and the pressure difference between the two ends of a water carrying tube corresponds to the electric pressure difference arising due to the electrons being pushed by the negative terminal of the source of electricity through the conductor.

This electric pressure difference is known as the potential difference. The unit used to measure the potential difference is the Volt (V). The force by which the negative terminal of the electric source releases electrons to the external circuit is known as the electromotive force. (EMF)

The electromotive force of a cell is equal to the potential difference between the terminals of the cell when electricity is **not drawn from the cell**.

When an electric current is drawn from a cell, the current also passes through the cell itself. The cell too has an electric resistance. Then a potential difference arises across the resistance of the cell. When this potential difference is subtracted from the electromotive force of the cell, the potential difference that provides an electric current to the external circuit can be obtained.

Since the potential difference between two points in a circuit is measured in Volts, it is also known as the voltage.

Figure 19.12 - A voltmeter

The instrument used to measure the voltage is the voltmeter. In order to measure the potential difference between two points in a circuit, the two terminals of the voltmeter should be connected across the two points as shown in the figure 19.13.

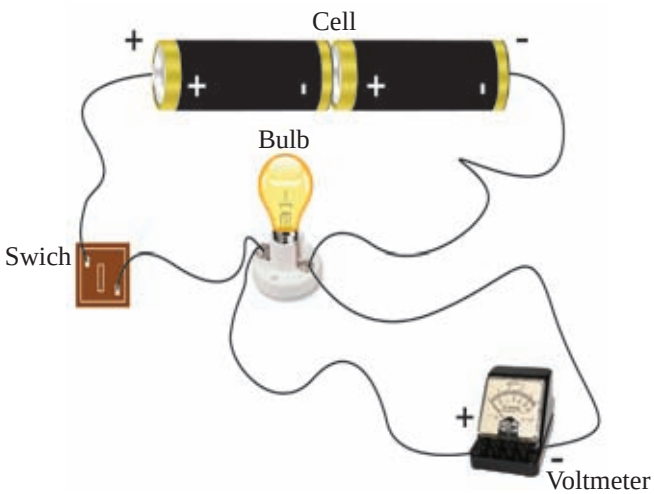


Figure 19.13 - Connecting a voltmeter to a circuit

In order to verify that there should be a potential difference between the terminals of a cell for a current to flow, let us engage in the following activity.

Activity 19.2

Items required: two dry cells, conducting wires, a voltmeter, an ammeter, a bulb

- As shown in Figure 19.14 (a), there are three different ways to connect the two dry cells to the bulb. In all three ways, the voltmeter is used to measure the voltage across the bulb. The ammeter is connected to the circuit to measure the current passing through the bulb. Figure 19.14 (b) shows the circuit diagrams corresponding to the above three possible connections.
- Connect the circuits as shown in each of the three circuit diagrams of Figure 19.14 (a) and observe the lighting of the bulb.
- Record the potential difference across the bulb and the current passing through it for each circuit.

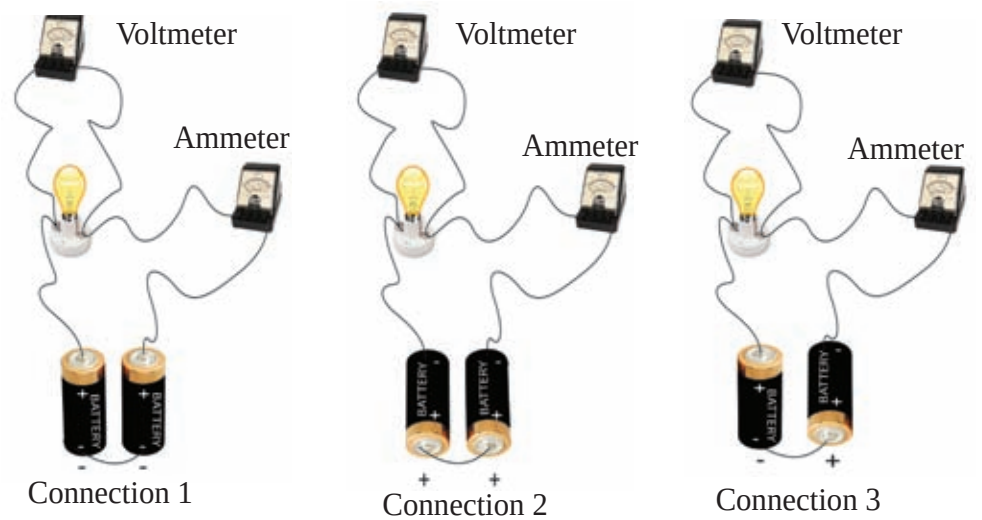


Figure 19.14 (a) Circuit connections for Activity 19.2

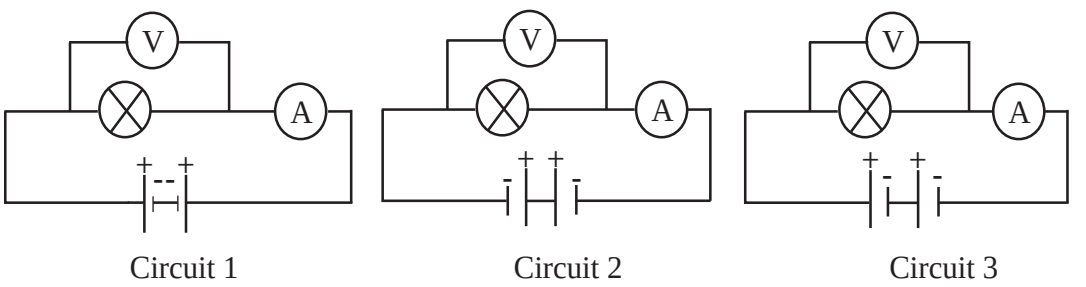


Figure 19.14 (b) Circuit diagrams for each of the connections of 19.14 (a)

- Tabulate your results in the table given below.

Connection	Current	Potential difference	Bulb lights up/does not light up
1			
2			
3			

In the first instance, the positive terminals of the two cells are connected to the two terminals of the bulb. Therefore there is no potential difference across the bulb. As there is no potential difference, there won't be a current flow through the bulb. This will be evident from your observations.

In the second connection, the negative terminals of the two cells are connected to the terminals of the bulb. Here also there does not exist a potential difference across the battery and there won't be a current flow through the bulb.

In the third connection, the positive terminal of one cell and the negative terminal of other cell are connected to the terminals of the bulb. Here, there will be a potential difference across the bulb and a current flow through the bulb only in the third connection.

From this activity we can conclude that in order for a current to flow through a conductor, it is necessary for a potential difference to exist across it.

19.4 Relationship between the current flowing through a conductor and the potential difference across the conductor

When a potential difference is applied across a conductor, a current flows through it. Let us now investigate whether there is a relationship between the current passing through a conductor and the potential difference across the conductor.

Activity 19. 3

Items required: a nichrome wire coil, a voltmeter, an ammeter, a rheostat, two dry cells, connecting wires, a switch

- The voltmeter is used to measure the voltage affecting the conductor (nichrome coil).
- The ammeter is used to measure the current passing through the conductor (nichrome coil).

Figure 19.15 - Rheostat

- The rheostat (Figure 19.15) is used to vary the current and the potential difference across the nichrome coil.

The circuit symbol used for the rheostat is

- Connect the circuit shown in Figure 19.16 using the items above.

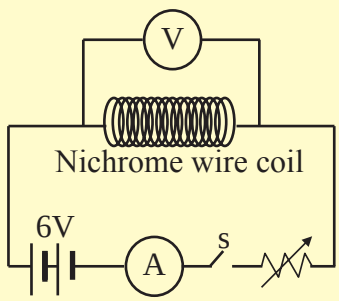


Figure 19.16 - Circuit diagram for the activity

- Close the switch (s) and quickly obtain the readings of the voltmeter and the ammeter and turn off the switch. The reason for quickly turning off the switch is to prevent the temperature of the nichrome coil from rising. It is essential to maintain a constant temperature throughout the activity.
- After sometime adjust the rheostat, close the switch and take another set of readings.
- Repeat the above steps to take at least five sets of readings.

By changing the current through the circuit using the rheostat, obtain readings for the potential difference across the nichrome coil and the current and tabulate the results in the table given below.

	Voltage difference (V)	Current (A)	V/A
1			
2			
3			
4			
5			

Find the ratio Voltage (V)/Current (I) for each data set. You will observe a constant value for the above ratio if the temperature of the coil was maintained at a constant value.

This relationship was first discovered by the German scientist George Simon Ohm. This law is known as Ohm's law.

Ohm's Law

Figure 19.17 – George Simon Ohm

When the temperature of a conductor remains constant, the current (I) passing through the conductor is directly proportional to the potential difference (V) across it.

That is, at constant temperature, $I \propto V$
Therefore, V/I= constant
This constant is known as the electrical resistance of the conductor.
The unit for measuring the resistance is the Ohm (Ω).
That is, $\frac{V}{I} = R$ Where R is the resistance of the conductor.

The unit for measuring the resistance is the Ohm (Ω).

If a current of one Ampere (1A) passes through a conductor for a potential difference of one Volt (1V) across it, then its resistance is defined to be one Ohm (1Ω).

Ohm's law can be expressed in the form of an equation as $V=IR$, where V is the potential difference, I is the current and R is the resistance.

The instrument used to measure the resistance is known as the **Ohm meter**.

If a graph is plotted using your data, with the voltage difference in the y axis and the current in **x** axis it will take the form shown by Figure 19.18 .

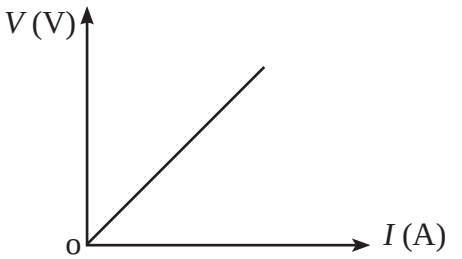


Figure 19.18 - The way that current varies with the potential difference

Example 1

A current of 1.5 A is flowing through a bulb which has a resistance of 6Ω . Find the potential difference across the bulb.

By applying V = IR for the bulb

$$V = 1.5 \times 6$$

Voltage difference across the bulb = 9 V

Exercise 19.2

1. When a bulb is connected to a 12 V power supply, a current of 0.5 A flows. What is the resistance of the filament of the bulb of that instance?
2. A nichrome wire coil has a resistance of 10 Ω. When it is connected to a power supply, a current of 0.6 A flows. What is the potential difference between the terminals of the power supply?
3. The resistance of a nichrome wire coil is 6 Ω. When it is connected to a power supply of 3 V,what is the current flowing through it?

19.5 Factors affecting the resistance of a conductor

The resistance of a segment of a conductor depends on the following factors.

(i) Area of cross section of the segment of conductor
(ii) Length of the segment of conductor
(iii) Material composition of the conductor

Let us do Activity 4 in order to investigate the influence of each of the above factors on resistance.

Activity 19.4

Items required: three segments of nichrome wire of length 1 m having different cross-sectional areas, a copper wire segment and several segments of iron wires with the same length as the nichrome wires and having a cross-sectional area equal to the nichrome wire with the lowest cross-sectional area, two dry cells, an ammeter, a switch, a board of wood with a length of about 1 m and a breadth of about 20 cm.

Connect the circuit shown in Figure 19.19 using the items above.
Connect the terminal X to the end of each conductor and record the current passing through each conductor.

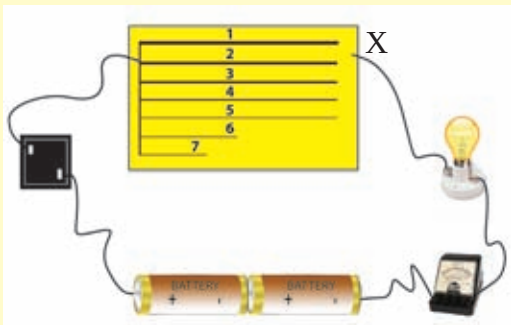


Figure 19.19 - Circuit for studying the factors that affect the resistance of a conductor

In the above figure, the numbers indicate the following segments:

1 – nichrome wire with the largest cross-sectional area
2 – nichrome wire with the medium cross-sectional area
3 – nichrome wire with the smallest cross-sectional area
4 – thin copper wire
5 – thin iron wire
6 and 7 – iron wires with unequal lengths

(wires used in 4,5,6 and 7 above should have equal cross-sectional areas)

Conductor	Ammeter reading (current) A
1	
2	
3	
4	
5	
6	
7	

(a) What conclusion can you draw from the readings obtained for the wires 1, 2 and 3?
(b) What can you conclude from the readings for the wires 3, 4 and 5?
(c) What can you say from the readings for the wires 5, 6 and 7?

According to Activity 4, it will be clear that the current flowing in each of the above instances are different. The reason for this is the differences in the resistances in each instance. According to this activity, three main factors that affect the resistance of a conductor can be stated.

That is, (i) Area of cross-section of the conductor
(ii) Length of the conductor
(iii) Material of the conductor.

How each of them affects the resistance is mentioned below.

- The resistance decreases when the cross-sectional area is increased.
- The resistance increases when the length is increased.
- For wires having the same length and cross-sectional areas but made of different metals, the currents flowing for the same potential difference are different. The reason for this is the difference in the factor known as the "**resistivity**" which depends on the material.

19.6 Resistors

In order to control the water flow through a tube, a tap can be used. What is done here is the use of an obstacle to control the water flow. The electric current flowing through a conductor can also be controlled in a similar manner. You may have already understood what could be done in the case of a conductor. By increasing the resistance of a circuit, the current flow through the circuit can be decreased. In order to change the resistance of a circuit, many circuit components with various

resistances that could be connected to the circuit have been found. They are known as resistors.

Figure 19.20 – Controlling the water flow through a pipeline

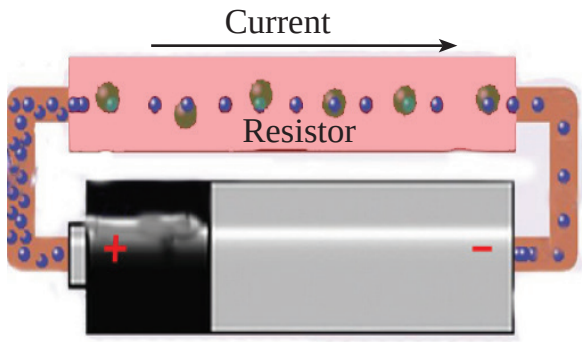


Figure 19.21 – Controlling the current flow through a conductor using a resistor

Let us do Activity 19.5 in order to understand the action of resistors.

Activity 19.5

Items required: A small torch bulb, a switch, resistors having resistances 5 Ω, 10 Ω, 20 Ω, connecting wires, two dry cells, an ammeter

- Connect the circuit shown in Figure 19.22.

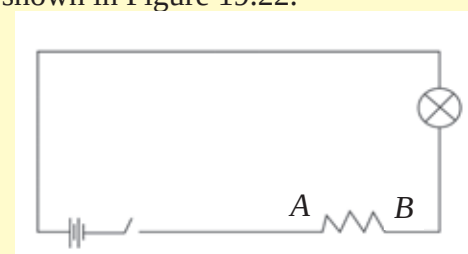


Figure 19.22 – Circuit diagram for Activity 5

- Observe the brightness of the bulb by connecting each of the resistors between *A* and *B*. Record your observations in the table given below.

Resistor value	Brightness of the bulb
5 Ω	
10 Ω	
20 Ω	

In this activity you will observe that the brightness of the bulb decreases as the resistor value increases.

It will be clear that the current through a circuit decreases with the increase of resistance.

Types of resistors

Various types of resistors with various values for the resistances have been invented. Let us consider a few such varieties.

1. Fixed value resistors
2. Variable resistors
3. Light dependent resistors

• Fixed value resistors

By depositing thin films of carbon on insulators or by winding a material with a high resistance materials like nichrome, resistors having various values for the resistance are fabricated. Their resistances cannot be changed.

Eg. : fixed value resistors with resistances 10 Ω, 100 Ω, 1.2k Ω

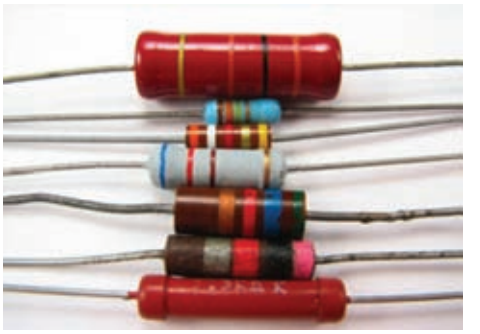


Figure 19.23 – Some different fixed value resistors

In Figure 19.23, a few different resistors are shown while Figure 19.24 shows the circuit symbols used for fixed value resistors.

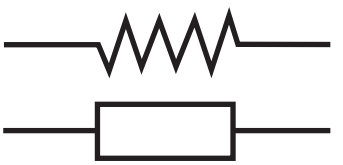


Figure 19.24 – Symbols used for resistors

• Resistor colour code

Often, the value of a resistor is indicated in coded form by colour bands marked on its body. The coding system of marking the resistor value using colored bands is known as the colour code method.

Figure 19.25 – Resistor values marked on the body of resistors using the color code method

(i) Resistors with four color bands

In this method, four color bands are marked on the resistor as shown in Figure 19.25. Three of them are marked close together while the fourth one is marked slightly away from them.When the three closely spaced bands are placed to the left, the first two bands from the left indicate respectively the first and second digit of the value of the resistor.

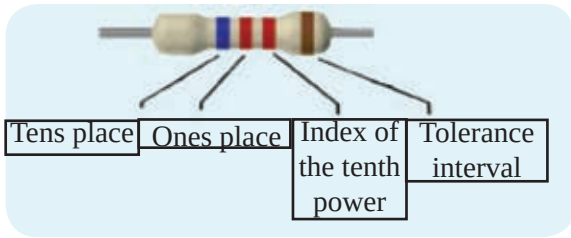


Figure 19.27 - Resistor with four colour bands

The value assigned to each color is given in Table 19.1. In order to find the coded value of resistor, the number given by the first two color bands should be multiplied by a power of ten. The power which ten should be raised to (index of the tenth power) is given by the value of the third band. The index of this value is given in column 1 of Table 19.1. In addition to this, the indices corresponding to gold and silver are -1 and -2 respectively. That is, in order to represent the resistor values for decimal valued resistances, gold and silver bands are used. The fourth band marked apart from the other three indicates the range that the resistor value can vary (tolerance interval). Table 19.2 shows the values assigned to the tolerance color codes.

Table 19.1 – Resistor color codes

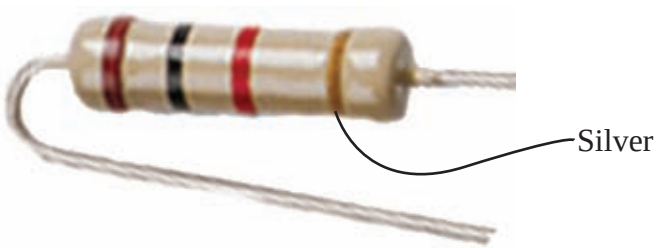
Number	Colour	Number to be multiplied by According the color of the third or fourth band
0	Black	$10^0 = 1$
1	Brown	$10^1 = 10$
2	Red	$10^2 = 100$
3	Orange	$10^3 = 1000$
4	Tellow	$10^4 = 10000$
5	Green	$10^5 = 100000$
6	Blue	$10^6 = 1000000$
7	Purple	$10^7 = 10000000$
8	Gray	$10^8 = 100000000$
9	White	$10^9 = 1000000000$
-1	Gold	$10^{-1} = 0.1$
-2	Silver	$10^{-2} = 0.01$

Table 19.2 – Color codes to resistor tolerance

Color	brown	red	gold	silver	No fourth color band
Tolerance value	± 1%	± 2%	± 5%	± 10%	± 20%

Example 1

The figure below shows a permanent resistor purchased from the market.



(i) Find its resistance value.

(ii) What is the tolerance value of this resistor?

(iii) What is the true range of values that this resistor could have?

Solutions

		1st digit	2nd digit	
(i)	Value of resistor	brown	black	red
		1	0	10^2
		= 1000 Ω		

(ii) Tolerance value of resistor = 10%

(iii) Tolerance = 10%

Amount of variation = $1000 \times \frac{10}{100}$ = 100 Ω

Range of the true value of resistor = (1000-100) Ω - (1000 +100) Ω

= 900 Ω - 1100 Ω

Exercise 19.3

1. A resistor marked with orange, orange, yellow and gold colored bands is provided to you.

   (i) Find the value of the resistor.
   (ii) What is its tolerance?
   (iii) Find the range of values that the resistor could have.

• Variable resistors

Resistors fabricated so as to allow a variation in the resistance as desired are known as variable resistors. The resistor value can be varied manually or turning using a screw in an by appropriate direction. There are many types of variable resistors such as pre adjustment resistors, rheostats and volume control resistors.
Figure 19.27 (a) shows several variable resistors and Figure 19.27 (b) shows symbols used for variable resistors.

Rheostat

Pre-adjustment resistor

Volume controller (rotatable variable resistor)

Figure 19.27 (a) – Various types of variable resistors

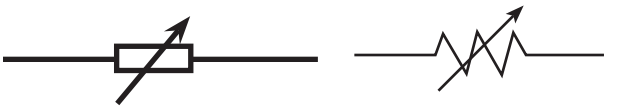


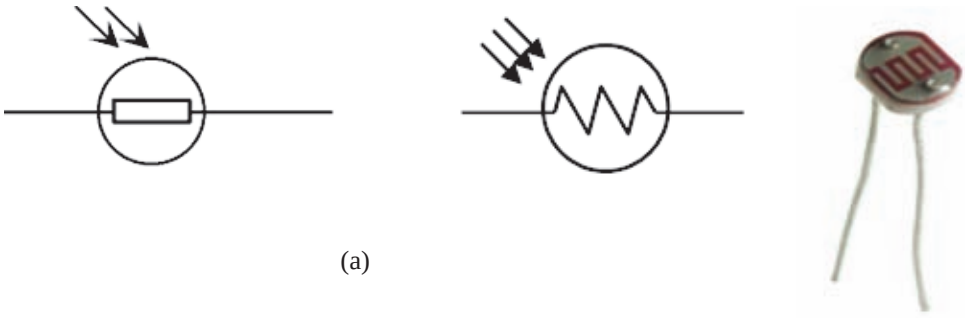
Figure 19.27 (b) – symbols used for variable resistors

Variable resistors are used to control the volume of radios, to adjust electronic circuits and to vary currents in laboratory experiments.

• Light Dependent Resistors

Light dependent resistors (LDR) are fabricated using chemicals such as cadmium sulfide. Value of the resistance depends on the intensity of light.

In the dark when the light intensity is low, these resistors have a high resistance. In the presence of light, their resistance decreases. Light dependent resistors are used in control circuits of instruments that need to operate based on the amount of light falling on them.



(a) (b)

Figure 19.28 (a) Symbols used for light dependent resistors (b) Appearance

19.7 Combination of resistors

Resistors are used to control the current passing through a circuit as desired. When it is difficult to find a resistor with the required resistance, it is possible to use many resistors to obtain the required value. There are two basic methods of combining resistors.

1. Series combination of resistors
2. Parallel combination of resistors

Series combination of resistors

When the resistors are connected in such a way that the same current flows through each of the resistors as shown in Figure 19.29, it is known as a series combination of resistors. Figure 19.29 shows three resistors R_1, R_2 and R_3 connected in a series combination.

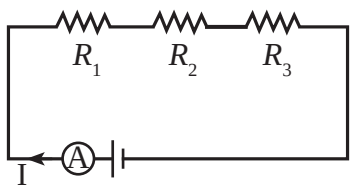


Figure 19.29 – A series combination of resistors in a circuit

If the current passing through the circuit is I, using $V=IR$,

Potential difference across the resistor $V_1 = I.\ R_1$
Potential difference across the resistor $V_2 = I.\ R_2$
Potential difference across the resistor $V_3 = I.\ R_3$

When resistors are connected in series, the sum of the potential differences across the resistors is equal to the supply voltage difference.

Therefore,

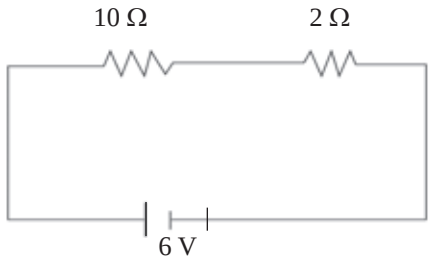
$$V = IR = I.R_1 + I.R_2 + I.R_3$$

$$R = R_1 + R_2 + R_3$$ where R is the equivalent resistance.

The equivalent resistance is the resistance of a single resister that could be used in place of all three resistors. In a series combination of resistors, the equivalent resistance is equal to the sum of all the resistors.

Example 1

The figure shows a 10 Ω resistor and a 2 Ω resistor connected to a 6 V power supply.



1. Find the equivalent resistance of the system.
2. What is the current passing through the circuit?

Solution

(i) Equivalent resistance $= R_1 + R_2$
$= 10\ \Omega + 2\ \Omega$
$= 12\ \Omega$

(ii) Apply $V = IR$ in order to find the current passing through the circuit.

$$V = IR$$
$$I = \frac{V}{R}$$
$$= \frac{6}{12}$$
$$= 0.5\ \text{A}$$

Parallel combination of resistors

A combination of resistors in which the total current is divided among the resistors as shown in Figure 19.30 is known as a parallel combination of resistors.

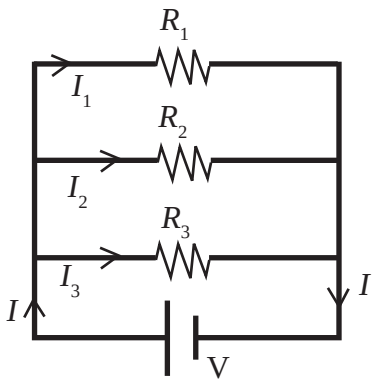


Figure 19.30 – A parallel combination of resistors in a circuit

In this circuit, the total current is divided among each of the resistors. That is, the total current in the circuit is the sum of the currents passing through each of the constituent resistors.

$$I = I_1 + I_2 + I_3$$

Substituting for I in terms of V and R according to Ohm's law,

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_1} + \frac{V}{R_1}$$

where R is the equivalent resistance. It is clear from this that the equivalent resistance of a parallel combination of resistors can be expressed by,

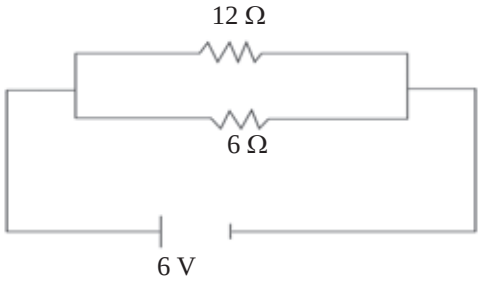
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The reciprocal of the equivalent resistance of a parallel combination of resistors is equal to the sum of the reciprocals of each of the constituent resistors.

Example 1

A 12 Ω resistor and a 6 Ω resistor are connected as a parallel combination in a circuit.

(i) Find the equivalent resistance of the circuit.
(ii) Find the current flowing through the circuit.
(iii) What is the current passing through each resistor?



(i)

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{12} + \frac{1}{6}$$

$$= \frac{1+2}{12}$$

$$\frac{1}{R} = \frac{3}{12}$$

$$R = 4\ \Omega$$

(ii) By applying V=IR for the current passing through the circuit,

$$I = \frac{V}{R}$$

$$= \frac{6}{4}$$

$$= 1.5\ \text{A}$$

(iii) Let us find the current passing through the 12 Ω resistor.

Since the potential difference across the 12 Ω resistor is 6 V,

$$I = \frac{V}{R}$$

$$= \frac{6}{12}$$

$$= 0.5\ \text{A}$$

Now let us find the current passing through the 6 Ω resistor. Since the potential difference across the 6 Ω resistor is 6 V, apply $V=IR$.

$$V = IR$$
$$I = \frac{V}{R}$$
$$= \frac{6}{6}$$
$$I = 1\ \text{A}$$

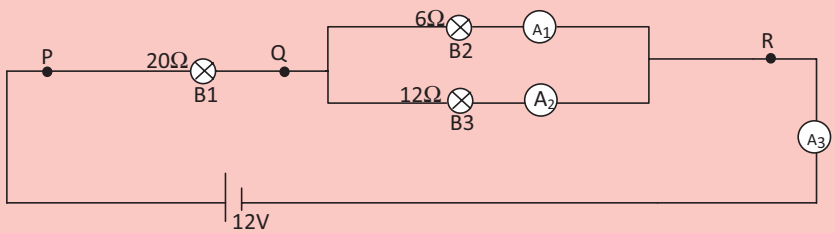
Exercise 19.4

(1) Ruvan needs a resistor of 3 Ω and another one with 40 Ω. But he could only find some resistors with resistances 20 Ω and 9 Ω.

(i) Briefly explain how you could make a combination of resistors having a resistance of 3 Ω.

(ii) Give a figure using symbols showing how you could make a combination of resistors having a resistance of 40 Ω.

(2) The figure below shows a circuit connected with three bulbs having different filament resistances. A 12 V potential difference is supplied to the two ends. The resistance of connecting wires can be neglected.



(i) What is the equivalent resistance between Q and R?

(ii) Find the equivalent resistance between P and R.

(iii) Which ammeter shows the total current passing through the circuit?

(iv) Find the total current passing through the circuit.

(v) What is the potential difference between P and Q?

(vi) Find the potential difference between Q and R.

(vii) What is the current passing through the bulb B1?

(viii) If the bulb B2 burns out, find the current passing through the circuit.

For extra knowledge

Electric Shock

Electric shock occurs when the human body becomes part of a path through which electrons can flow. A complete Circuit and a voltage difference are necessary for current to flow.

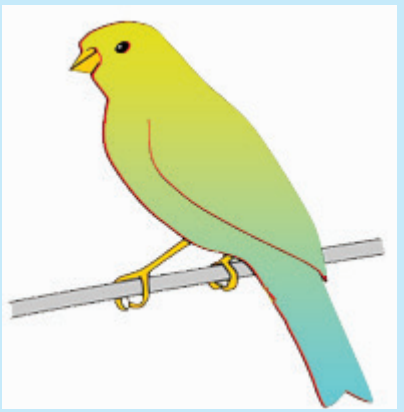


Figure 19.31

Without two contact points on the body for current to enter and exit, there is no hazard of shock. These two points should also be of different voltages. This is why birds can safely rest on high-voltage power lines without getting shocked: they make contact with the circuit but the two points they touch have the same voltage.

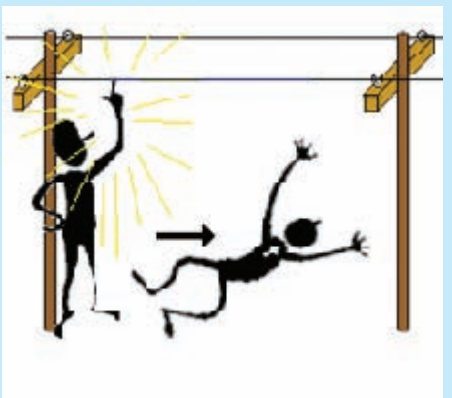


Figure 19.32

This might lend one to believe that it's impossible to be shocked by electricity by only touching a single wire. Like the birds. Unfortunately, this is not correct. Unlike birds. people are usually standing on the ground when they contact a "live" wire. One side of a power system will be intentionally connected to earth ground, and so the preson touching a single wire is actually making contact between two points in the circuit the wire earth ground.

Ohm's Law and Electrical Safety

"It's not voltage that kills, its current!" is a common phrase heard in reference to electrical safety. While there is an element of truth to this,there's more to understand about shock hazards than this simple adage.If voltage presented no danger, why do they display signs saying: DANGER -- HIGH VOLTAGE !?

The principle that " current kills" is essentially correct. However, electric current doesn't just occur on its own, there must be voltage available to motivate electrons

to flow through a victim. A person's body also presents resistance to current, which must be taken into account. Taking ohm's Law for voltage, current,and resistance, and expressing it in terms of current for a given voltage and resistance, we have this equation:

$$I = \frac{V}{R} \qquad \text{Current} = \frac{\text{Voltage}}{\text{resistance}}$$

The amount of current through a body is equal to the amount of voltage applied between two points on that body, divided by the electrical resistance offered by the body between those two points. Obviously, more the voltage difference between the two points, easier the current flow through any given amount of resistance. Hence, high voltage implies high potential for a large amount of current to flow through your body, which will injure or kill you.

Conversely, the more resistance a body offers to current, slower the electron flow for any given amount of voltage. just how much voltage is dangerous depends on how much total resistance is in the circuit to oppose the flow of electrons.

Body resistance is not a fixed quantity. It varies from person to person and from time to time. There are so many variables in the human body affecting body resistance. It varies depending on how contact is made with the skin: is it from hand-to-hand, hand-to-foot, foot-to-foot, hand-to-elbow, etc.

Summary

- By rubbing certain materials on one another, electrons are exchanged between them.
- An electric current is a flow of electric charges.
- The direction of the conventional current is from the positive terminal to the negative terminal.
- The potential difference between the two terminals of a cell when a current is not passing through it is known as the electromotive force of the cell.
- Ohm's law states that the current passing through a conductor is proportional to the potential difference across it when the temperature of the conductor is constant.
- The property that obstructs the flow of current through a circuit is its electrical resistance.
- There are two main methods of connecting resistors in a circuit.

  1. Series connection
  2. Parallel connection

- A single resistance equal to the total resistance of a system of resistors is known as the equivalent resistance.

Technical Terms

Static electricity	-	ස්ථිති විද්‍යුතය	-	நிலைமின்னியல்
Current electricity	-	ධාරා විද්‍යුතය	-	ஓட்ட மின்னியல்
Electric current	-	විද්‍යුත් ධාරාව	-	மின்னோட்டம்
Resistance	-	ප්‍රතිරෝධය	-	தடை
Voltmeter	-	වෝල්ට් මීටරය	-	வோல்ற்றுமானி
Ammeter	-	ඇම්මීටරය	-	அம்பியர்மானி
Potential difference	-	විභව අන්තරය	-	அழுத்த வித்தியாசம்
Electromotive force	-	විද්‍යුත් ගාමක බලය	-	மின்னியக்க விசை
Equivalent resistance	-	සමක ප්‍රතිරෝධය	-	சமவலுத் தடை

Inheritance

20

20.1 Diversity among organisms

You know that there are large numbers of plant and animal species in the biosphere. One species can be identified separately from another species by observing their external features. We get this ability as these species possess inherited features. Inherited characters are the features that transmit from generation to generation.

Although there are common characteristics for a species all the organisms belong to a single species are not similar.

- The body features of every human is not similar. There are many differences among them (Fig - 20.1).

Figure 20.1 - Diversity of human living in different areas in the world

You can identify differences within species like cats and parrots (Fig 20.2).

Figure 20.2 - Diversity of cats and parrots

- Rose and Orchid plants that grow in your home garden also produce flowers with different colours and sizes (Fig-20.3).

Figure 20.3 - Roses and Orchids of different colours & sizes

You can observe Tomato and Brinjal plants that grow in your home garden with fruits of different shapes (Fig-20.4).

Figure 20.4 - Different varieties of Tomatoes and Brinjals

We will consider few common inherited characteristics of human species.

• Common inherited characteristics in human population

We will identify different common inherited characteristics observed in human in the pictures below.

Figure 20.5 - Skin colour (Complexion) -white, fair, dark

Figure 20.6 - Curly and straight hair

Figure 20.7 - Fused or free earlobes

Figure 20.8 - Ability to fold the tongue

Figure 20.9 - Position of the thumb when the fingers are crossed

Figure 20.10 - Dimpled and normal cheeks

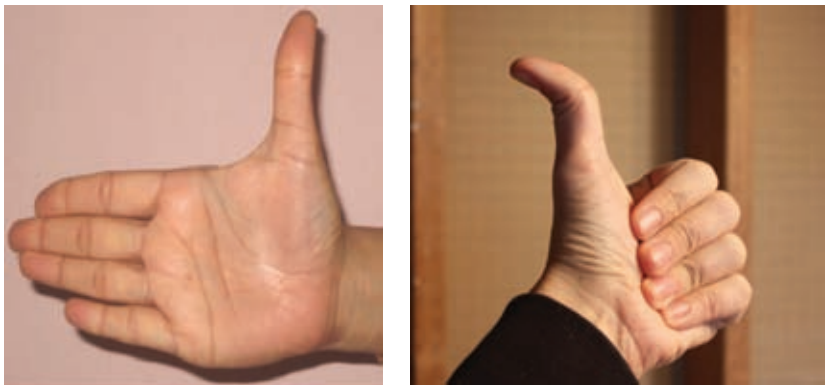


Figure 20.11- Straight and curved thumb

Figure 20.12 - Widow's peak on forehead

Activity 20.1

- Prepare a table using above inherited characteristics of your mother's and father's relatives.
- Using above information identify characteristics and skills that have transmitted from generation to generation.
- Study whether you or your brother, sister or any other relative has got a new characteristic which was not found in any relative of the generation.

According to the observation of the above activity it is revealed that most of the mother's and father's characteristics have passed to the next generations. But you may have found new characteristics in your brother, sister or any other relative which is not found in any relative. If you further study previous generations you may find that particular characteristic in them. It is clear that inherited characteristics may pass evading from one generation to the next.

There are some rare inherited characteristics. Identify them using the pictures below.

Figure 20.13 - Syndactyly

Figure 20.14 - Polydactyly

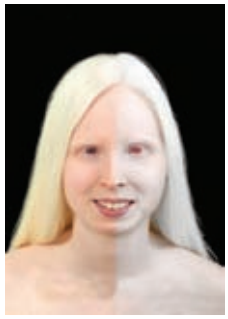


Figure 20.15 - Albinism

Figure 20.16 - Brown or blue eyes

Transmission of inherited characteristics is common to all organisms. Other than human other plants and animals possess inherited characteristics. Do the assignment 20.1 to determine those characteristics.

Assignment 20.1

- Select few plants or animals found in your home garden.
- Record few characteristics of them which have not changed for the past time period.

It is clear that according to the collected information the nature of complexion, ears, teeth, foot, wings, skin pattern, beak are inherited characteristics. Taste of fruits, colour of flowers, nature of pods and seeds and height of the plant are also inherited characteristics.

For extra knowledge

Non inherited characteristics

The characteristics which appear due to the changes of the environment, nutrition, exercises and activities are not inherited.

Example :- Growth of muscles by exercises, corns in toes and scars on skin

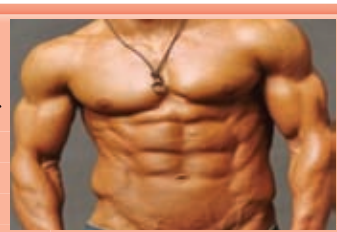


Figure 20.17 - Growth of muscles due to exercises

Figure 20.18 - Gregor Mendel

The first person to study about the transmission of inherited characteristics is an Austrian priest, and a science graduate Gregor Mendel. He is honoured as the father of genetics.

20.2 Mendel's experiments about inheritance

He used the garden pea (*Pisum sativum*) plant for his experiments in 1865. He has used that partcular plant for his experiment because of its special features.

The reasons to select the garden pea plant for his experiment are as follows.

- Can be easily grown
- Can obtain the yield within a short time period
- Can obtain pure breeding plants. (The selected characteristics are not changed for many generations)
- Presence of easily observable contrasting characters (eg: Yellow/green seeds, tall/short plants).
- Naturally self pollinating. When necessary, cross pollination is also possible
- Ability to obtain offsprings by breeding and can continue the generations

He observed 7 contrasting characters and tested one character at a time

The procedure he followed for the tall and short character was as follows,

- Cultivation of pure breeding tall and short plants. These parental generation was known as P
- Pollens of tall plants were deposited on stigma of short plants, and vice versa
- Obtain new seeds by cross-pollination and plant them to obtain the next generation. All plants were tall and they are referred to as F_1 generation
- Allow self-pollination to take place within F_1 generation
- The resultant seeds were planted to obtain the F_2 generation. The tall to short plant ratio was 3 : 1.

It was a question to Mendel that, what has happened to short character in F_1 generation. According to Mendel's opinion, the tall character was dominant and short was recessive.

The feature which was recessive in F_1 generation reappear in F_2 generation. It was an important observation. As Mendel used a single pair of contrasting characters at a time, it was known as **Monohybrid cross**.

Assignment 20.2

Mendel has used large number of samples and repeatedly done the experiments to confirm his conclusions. Analyse how Mendel has carried out his experiment according to scientific method.

• The inherited pattern of a Monohybrid cross

The results obtained from the Mendel monohybrid cross using 7 different contrasting characters are given in the table below.

Table 20.1- The results of the experements of Mendel

Character	Cross	F_1 generation	F_2 generation		Closest ratio
			Dominant	Recessive	
Colour of the flower	Purple x white	Purple	Purple 705	White 224	3 : 1
Colour of the seed	Yellow x Green	Yellow	Yellow 6022	Green 2001	3 : 1
Shape of the seed	Round x Wrinkled	Round	Round 5474	Wrinkled 1850	3 : 1
Shape of the Pod	Inflated x Constricted	Inflated	Inflated 882	Constricted 299	3 : 1
Colour of the Pod	Green x Yellow	Green	Green 428	Yellow 152	3 : 1
Position of flower	Axial x terminal	Axial	Axial 652	Terminal 207	3 : 1
Height of the plant	Tall x Short	Tall	Tall 787	Short 277	3 : 1

It is clear that all above characters, are inherited in the same manner. One feature is completely hidden in F_1 generation and it reappears in F_2 generation. This is the recessive feature. In both generations all the plants were with the features of P generation. No pea plants were with intermediate characters. Mendel assumed that it was because two different factors determine a single characteristic. In genetics, symbols are used to denote those factors. The standard is that the dominant factor is denoted by a capital letter and the recessive by a simple letter.

Accordingly,

» For tall feature **T**,

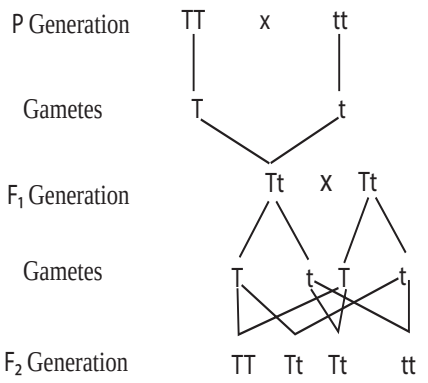
» For Short feature **t** is used

For each inherited feature 2 factors are involved.

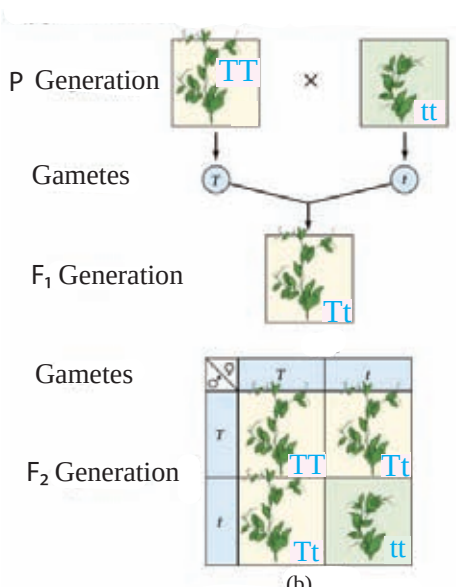
- Pure breeding Tall plants **TT**
- Pure breeding short plants **tt**.
- The tall plants with recessive short feature **Tt**.

When two factors are similar, they are known as homozygous, (TT, tt) when the factors are not similar they are known as heterozygous (Tt).The monohybrid cross of pea plant, considering tall and short character can be expressed using symbols as below. (Fig - 20.19 (a))

Punnett square (Fig - 20.19 (b))which was introduced by a scientist called Punnett can be used to show the occurrence of F_2 generation.



(a)



(b)

Figure 20.19 - Monohybrid cross of *Pisum sativum*

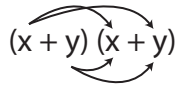
Assignment 20.3

- Select another pair of contrasting feature of pea plant using 20.1 table.
- State pure breeding dominant character or pure breeding recessive character using symbols.
- Build up a punnett square to show the inheritance of this monohybrid character.

• Explanation of patterns of inheritance using probability

When any two different objects combine randomly, the result will take place according to a particular pattern.

As an example consider random combination of X & Y objects.



xx + xy + xy + yy

Two characters present in parents inherit into offsprings randomly. Carryout below activity to identify the probability (Probability means the ability of an incident to happen.)

Do you know ?

The probability of getting the head or the tail when tossing a coin is 1/2

The bead experiment is similar to relationships of probabilities using two coins at a time. To find out Head – Head, Head – Tail, Tail – Head, Tail – Tail probabilities, the probabilities obtained from each coin has to be multiplied.

Then the probability is $1/2 \times 1/2 = 1/4$

When the same incident takes place in two ways (Eg. getting Head – Tail and Tail – Head) is the total of separately taken probabilities.

That is $1/4 + 1/4 = 1/2$

Activity 20.2

Identification of probability patterns obtained by a bead experiment

- Divide the class into 4 to 5 groups.
- Provide 2 vessels with mixture of 50 white beads (W) & 50 red beads (R) to each group (instead of beads, can use buttons or seeds with two different colour can be used)
- Take out a bead from two vessels at a time & note the colour of two beads with tally marks in the relevant column and return them into the same vessels.
- Likewise continue it for 50 times & tabulate results.
- Present the results to the class.

	RR	RW	WR	WW
1 st Group	𝍸 𝍸 ///	𝍸 𝍸 //	𝍸 ///	𝍸 𝍸 𝍸 /
2 nd Group	...	...	...	...
Total	...	...	...	...

Fill the above table using results obtained by the above practical using tally marks

Calculate,

I. Times of Red - Red beads & probability of getting Red - Red.

ii. Times of Red – White & Probability of getting Red – White.

iii. Times of White – Red & Probability of getting White – Red.

iv. Times of White – White and probability of getting White – White beads.

Using those probability values, find out the ratio of RR: RW: WR:WW.

Let's analyse the Mendel's results using the probability results obtained by the bead experiment.

From 1st & 2nd vessels.

i) The probability of getting Red – Red = 1/4

ii) The probability of getting White - White = 1/4

iii) The probability of getting Red – White = 1/4

iv) The probability of getting White – Red = 1/4

In (iii)rd & (iv)th instances, both show the same incidence, both vessels,

i) The probability of getting Red – Red =1/4

ii) The probability of getting White – White = 1/4

iii) The probability of getting Red – White = 1/4 + 1/4 = 2/4

The ratio between probability is = 1/4 : 2/4 : 1/4

1 : 2 : 1

According to Mendel's monohybrid cross, the ratio of F_2 genotypes, TT, Tt, tt is

1 : 2 : 1

Similarly the probability ratio of bead experiment compatible with the genotypes of F_2 generation.

20.3 Basic concepts of genetics

• Gene concepts about inheritance

Mendel said that the features of an organism is determined by a special particular factors. The identified particular factor is named as genes later.

In gene concept, as a standard the dominant feature is denoted by a capital letter and the recessive by a simple letter. We have already used these letters in Mendel monohybrid cross.

If two genes are similar for a given feature of an organism, it is said that this organism is **homozygou**s for that feature, or else that organism possesses homozygous genes.

If two genes are not similar then that organism is **heterozygous**, or else that organism possesses heterozygous genes.

Example :-

Gene for round seed is R, Gene for wrinkled seed is r

- Homozygous situations, RR or rr
- Heterozygous situations Rr

• Gene expression

The combination of a gene pair for a particular character is known as gene expression of that organism.

Example :- Rr, rr, Rr

• Phenotype & Genotype

The feature that externally appears is known as phenotype. The gene composition to determine that feature is known as genotype.

Examples :-

- The phenotype of round seed heterozygote is round. The genotype is Rr
- The phenotype of round seed homozygote is round. The genotype is RR
- The phenotype of wrinkled seed homozygote is wrinkled. The genotype is rr

• Nature of genetic material & genes

Scientists have identified that the **Deoxy ribo Nucleic Acid (DNA)** present in chromosomes acts as the genetic material that transmits features of organisms from generation to generation.

The double helical structure of DNA was first discovered by two scientists named **Watson and Crick** in 1953.

According to the sequence of base pairs in DNA strand, different genetic information are stored.

The features of organisms are determined by the sequence of base pairs. Accordingly a gene is a specific base sequence in a DNA molecule responsible for a particular character. In other way, gene is a specific segment of DNA for a particular character.

The genes that determine large number of features in an organism and transmit them from generation to the next are present in chromosomes. Each gene has a particular location in a chromosome.

For extra kowledge

A DNA molecule is a clockwise twined double helical structure of two strands that run anti parallel to each other. The two strands are joined by Adenine, Thymine Cytosine & Guanine nitrogenous base pairs. These combinations in DNA are denoted as A – T, C – G (Fig - 20.20) A for Adenine, T for Thymine, C for Cytosine & G for Guanine.

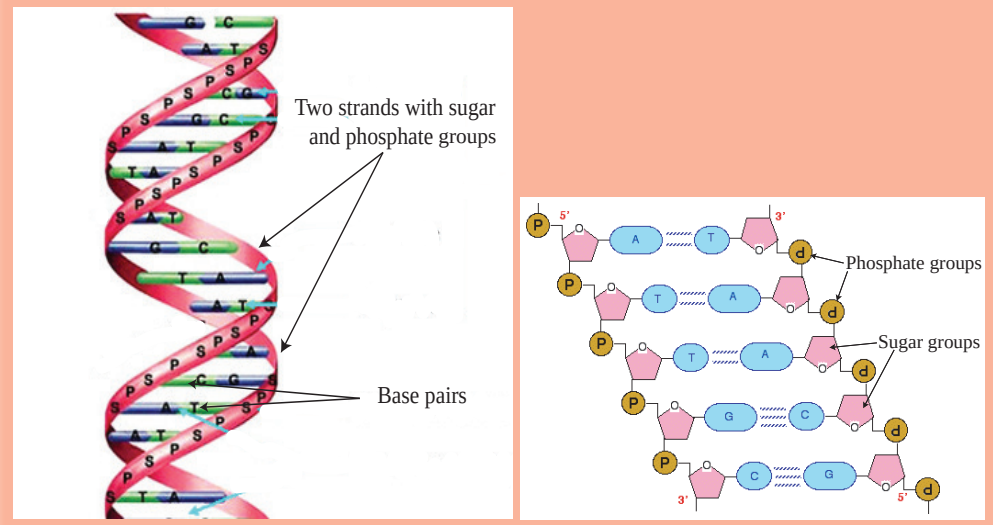


Figure 20.20 - Double helical model of a DNA molecule

• Gene linkage

A pair of chromosomes that are arranged to the same sequence of characters are known as homologous chromosomes. They are same in length, width and the location of centromere. An organism receives this homologous chromosomes from its parents, one from mother and the other from father. A pair of genes that determine a particular character are present in complementary locations of homologous chromosomes. It is clear in Mendel's experiment that during gamete formation, these genes, independently segregate.

A scientist called **Morgan** also did experiments about genetics. He got unexpected phenotypic ratios, and found out that, the genes do not segregate always independently. The genes that present in the same chromosome which are not segregated independently are known as **linked genes**. Morgon discovered the gene linkage.

20.4 Heredity of human

Transmission of inherited characters to next generation is known as heredity. The process by which those characters transmit is known as inheritance. You have already learnt that the characters of organisms pass to the next generations by the genes of chromosomes. The behaviour of genes & chromosomes during inheritance has mentioned above in gene linkage & meiosis.

The behaviour of chromosomes during sex determination of human is discussed under inheritance.

Even though the chromosomes in a nucleus of a cell are different in shape & size, the number of them is constant for a species. It is a unique feature of a species. Below are the number of chromosomes present in nuclei of different organisms.

Table - 20.2

Organism	Number of chromosomes	Organism	Number of chromosomes
Pine apple	50	Paddy	24
Garden Pea	14	Tomato	24
Onion	16	Horse	33
Maize	20	Mouse	40
		Human	46
		Chimpanzee	48
		Carp	104

20.5 Sex determination of human

You may prefer to know how your gender is determined. This incidence is known as sex determination. We will look at how the sex is determined.

There are 46 chromosomes, or 23 pairs of chromosomes, in a human cell. Out of those 23 pairs, 22 pairs are autosomal chromosomes and the remaining pair is the sex chromosomes.

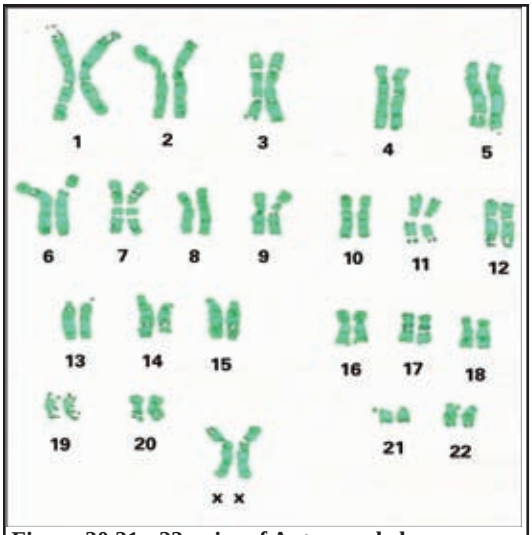


Figure 20.21 - 22 pairs of Autosomal chromosomes and sex chromosome pair of a female

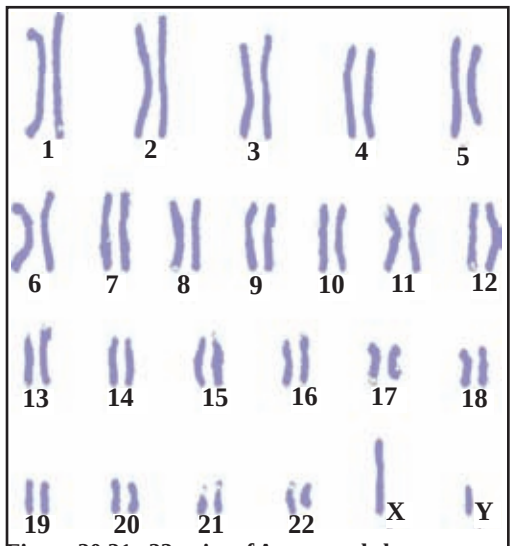


Figure 20.21 - 22 pairs of Autosomal chromosomes and sex chromosome pair of a male

Two sex chromosomes of a female are similar in structure and shape. They are known as X chromosomes. The sex chromosomes of a male are different from each other. They are known as X and Y chromosomes. The Y chromosome is smaller than X. The X chromosome of males is similar to the X chromosome of females.

During formation of an egg from an egg mother cell and sperms from sperm mother cell the pair of sex chromosomes separate. A sperm contains 22 autosomal chromosomes and only a single sex chromosome. An egg possesses only a X chromosome and a sperm contains a X or a Y chromosome.

When an egg gets fertilized with a sperm, there may be two X chromosomes or X and Y chromosomes in the zygote.

A zygote with two X chromosomes produces a girl. X and Y chromosome produces a boy. Accordingly the factor that needs to determine a boy is received from the father and not the mother. The sex determination is shown in the diagram 20.23. The probability of getting a girl or a boy is 50% .

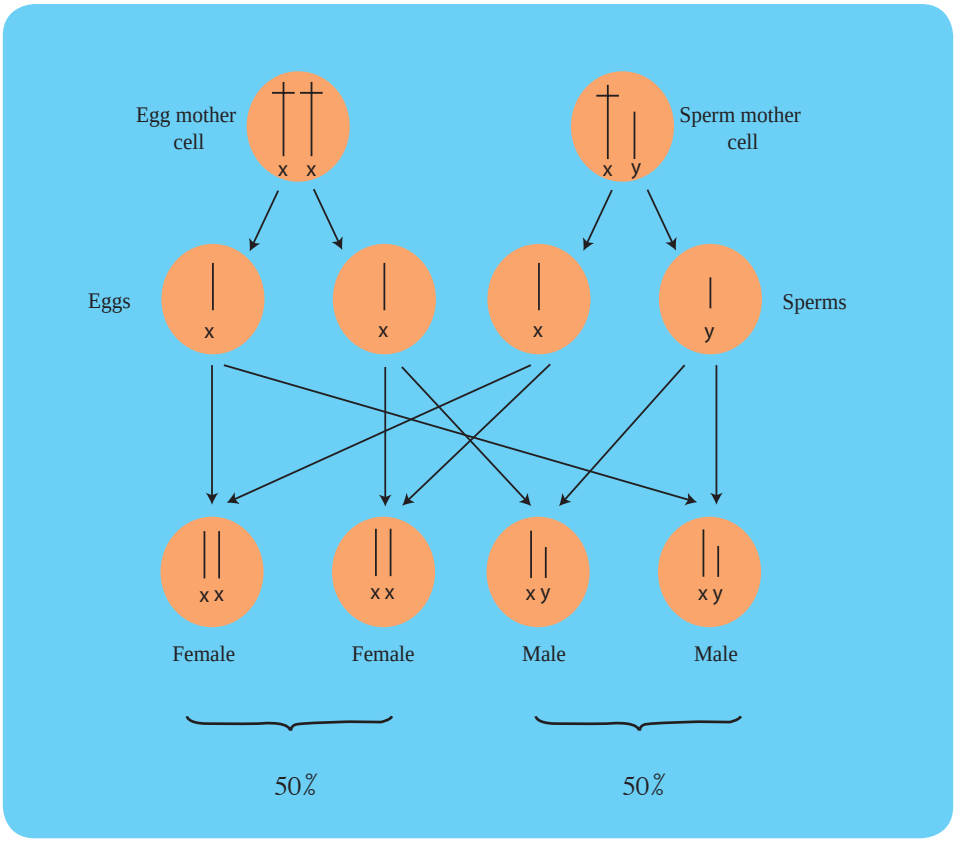


Figure 20.23 -Sex determination of human

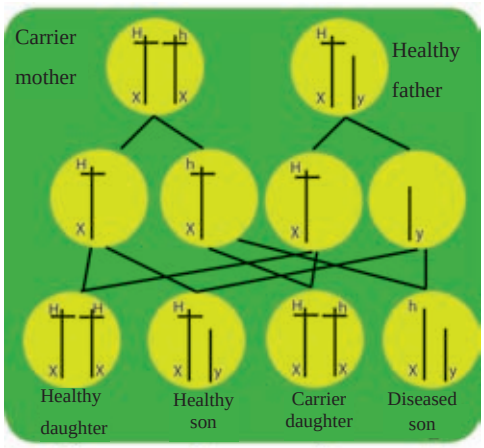
20.6 Human inherited disorders

- Genetic disorders due to sex linked inheritance

Even though X and Y chromosomes determine the human sex, all the genes present on those sex chromosomes, are not used in determination of sex. Most of the genes on X and Y chromosomes, determine other features as autosomal chromosomes. As Y chromosome is shorter than X chromosome, most of the genes complementary for X are absent in Y. Accordingly, in males for most of the X linked genes, there are no complementary genes in Y.

Therefore most of the genes in X, whether they are dominant or recessive, they are phenotypically expressed in males. But as females possess a pair of X chromosomes, X linked genes are paired. They phenotypically express a recessive character only when they are present as double recessive genes. We will consider several genetic disorders, occur due to sex linked recessive genes.

• Haemophilia



h - Recessive gene for Haemophilia

H - Dominant gene of the recessive gene for Haemophilia

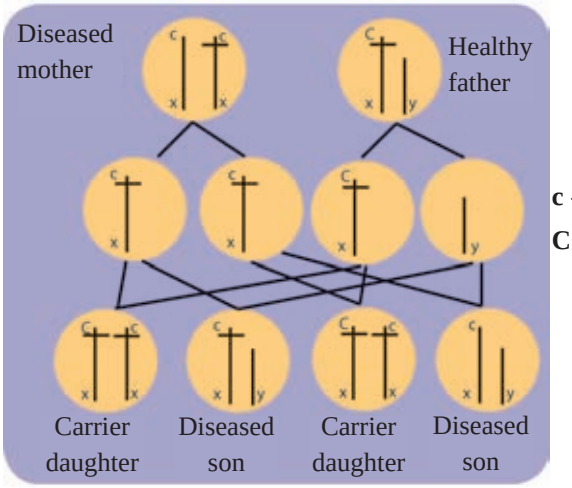
Figure 20.24 - Inheritance of Haemophilia

Haemophilia which occurs due to a X linked recessive gene only present in males in the population. When a wound or cut occurs, it is essential to clot blood. At that time when a blood clot is formed, it stops excessive bleeding.
Haemophilic patient's, blood does not clot. Therefore they die because of bleeding.
Females act as carriers for this disease.

• Colour blindness (Red – Green colour blindness)

This is the most common sex linked inherited disease. The reason for this disease is, a recessive gene in X chromosome. The sufferer cannot distinguish red colour from green colour. This is common among males rarely occur in females. When a colour blind female is married to a healthy male the inheritance of colour blindness is as in the below diagram.

The chance to show the sex linked inherited diseases in females is low, the chance of getting those diseases in female children is high if they are married to blood relatives. The reason for that is the female that joined the family is most probably a carrier.



c - Recessive gene for colour blindness

C - Dominant gene of the recessive gene for colour blindness

Figure 20.25 - Inheritence of colour blindness

• Gene mutations & related inherited disorders

Due to a change in DNA of a chromosome, the mutations occur in a single gene, are known as gene mutation. When a naturally active gene is mutated, it gets inherited, we will look at few genetic disorders that occur due to a mutated gene.

Do you know ?

Occurence of gene mutations takes place due to several reasons. They are

- Spontaneous without any external effects
- Due to radiations
- Due to chemicals

• Albinism

Natural complexion is due to a pigment called Melanin. This disorder occurred due to a mutation of the gene which is responsible for the production of the above pigment present in an autosomal chromosome.

The features of this disorder are the abnormal white colour of skin, hair and eye lashes. Albinism occurs when gene is present as recessive homozygous condition. Not only human but also animals become albino. (Fig - 20.26)

Figure 20.26 - Albone child & Albone peacock

• Thalassemia

This is a condition that occurs due to a mutation in a gene responsible for the production of haemoglobin. Haemoglobin is a protein that acts as a carrier for O_2 transportation in blood. Due to reduction of haemoglobin production in thalassemic patients, the main symptom is anaemia. Homozygous recessive tt, condition is diseased. Heterozygous Tt condition is the carrier. There are several areas in Sri Lanka with higher number of thalassemic patients. The reason for that may be the marriages between blood relatives.

For extra knowledge

Mutations can occur due to changes in the number of chromosomes

- Due to the presence of a single X chromosome, a mutated condition called Turner's syndrome occurs. They are females lacking sexual maturity and mental retardation.
- Due to presence of XXY as sex chromosomes, this mutated condition called Kleinfelter's syndrome occurs. Though they are males, they are feminised, sterile individuals.
- Down's syndrome is a mutated condition due to the presence of three copies of 21st autosomal chromosome. They are short and mentally retarded.

• Application of knowledge of inheritance

Since long time man has understood that by selecting animals and plants with better qualities, can produce quality hybrid plants and animal varieties. Cows that can produce higher volume of milk, hens that produce large number of eggs, chicken with higher growth rate, crops with high yield or pest resistant, fleshy seedless fruits (Fig-20.27) are examples of genetic applications to improve quality of animal or plant products.

Figure 20.27 - Improved seedless oranges

When principles of genetics were identified, production of hybrid plants and animals becomes a technology. It was first applied among some wheat cultivators in America. The economy was developed as they have used improved wheat varieties. Now in Sri Lanka, crop research centres and breeding centres have achieved a considerable development in gene technology.

Large sized fruits or vegetables, improved grains and livestock have been used fulfilling the needs of the greatly increasing population. If we have not used genetically modified high quality products, we would not be able to fulfill the high demand of food.

Figure 20.28 - Improved vegetables & fruits

20.7 Genetic engineering

New technology is being used to produce a recombinant DNA molecule, which is formed by combining DNA fragments of different sources. This field is known as Recombinant DNA technology.

This field is highly popularized as genetic engineering or gene technology.

The genotype of an organism can be altered by removing or adding extra DNA fragments into genome.

We will look at the application of gene technology in food and agriculture, medical and industrial fields.

Food and Agricultural field

Examples for plants and animals with better qualities that has produced using recombinant DNA technology.

- Weedicide resistant crops - By inserting a gene obtained from a bacterium.
- Pest resistant crops - By inserting a gene obtained from a soil bacterium.
- Rice enriched with vitamin A (Golden rice) A gene that produces vitamin A in carrot is obtained and inserted into paddy.
- A tomato resistant to cold weather - By inserting a gene obtained from a fish living in mud of cold countries.
- High productive (flesh and milk) cattle and milk with high nutritious value. Food produced by genetically modified organism (Genetically modified food).

Industrial field

Below are some instances where bacteria produced by gene technology are being used in industrial field.

- Production of enzymes such as Amylase.
- Production of some amino acids. (To produce MSG - Monosodium Glutamate.)
- Production of vitamins by (Cyanobacteria e.g :- vitamin B_{12} and E)
- As a remedy to the pollution by fossil fuel combustion and other waste material.

Medical field

Gene technology is used in different sections of medical field.

- Production of Insulin - Human gene related to Insulin production is inserted into *E coli* bacteria.
- Production of proteins including growth hormones – By inserting relevant gene into a bacterium.
- Use of developed bacteria and fungi in production of antibiotics.
- Insertion of genes that is responsible for the formation of arteries in the embryo into patients with artery blockages (patients to carryout bypass surgery) to induce growth of new arteries.
- Replacement of the diseased gene by a healthy gene. (gene therapy)
- Use of DNA technology to confirm the identity of a person in forensic medicine. For the identification of a criminal blood sample, semen, hair or DNA of any other part of the body obtained from a site of crime are used. Identification of the criminal by checking the compatibility of the DNA of those samples with the suspects, DNA.

Summary

- The diversity among organisms in the biosphere is because of the inherited features of each species.
- Inherited features are the characters that transmit from generation to generation.
- Within the same species too the organisms possess differences.
- There are common and rare inherited characters in human populations.
- The field that study about the way that the inherited characters are transmitted is known as genetics.
- Gregor Mendel was the first person to carryout experiments regarding inherited characters of plants.
- Mendel concluded that two factors, different to each other which are responsible for determining, a character of the pea plant.
- These factors that determine characters, later identified as genes. One of these is a dominant gene and the other is a recessive gene.
- The pattern of inheritance of a monohybrid cross can be expressed in a chart.
- The pair of genes, responsible for a particular feature can be shown in a gene expression.
- The externally expressed feature of an organism is phenotype.
- The gene composition that determines a particular phenotype is the genotype.
- The material that transmits features from generation to generation is the DNA in chromosomes.
- A specific nitrogenous base sequence of DNA is known as a gene.
- The number of chromosomes in nucleus is constant for a species.
- The pair of chromosomes that are similar in length, width and location of centromere is known as the homologous chromosome.
- The pair of genes responsible for a particular character present in complementary locations of the homologous chromosomes.

- The genes that are present in the same chromosome and that cannot be segregated independently are known as linked genes.
- The sex of human is determined by the way of association of sex chromosomes during fertilization.
- A zygote with two X chromosomes gives rise to a girl and a zygote with X and a Y chromosome gives rise to a boy.
- Genetic disorders occur due to recessive sex linked genes and mutations in DNA.
- There is a high chance of getting genetic disorders in children resulted in marriages between blood relatives.
- There is a possibility of fulfilling the demand for food with genetically modefied high quality products.
- There is a considerable development in agriculture, industrial and medical fields due to gene technology.

Exercise

1. Red – green colour blindness is an inherited disease. Select the correct genotype of a carrier female.

   1) X^oX^o 2) X^cX^o 3) X^cY 4) X^cX^c

2. What is the percentage of parental genotypes received to the progeny if BB x bb cross is done ?

   1) 100% 2) 75% 3) 50% 4) 0%

3. Parents with normal complexion, got a child with white skin.

   i) Is it possible to happen?

   ii) Explain your answer with the knowledge of genetics.

4. An improved organism by recombinant DNA technology has,

1. Changed its genotype only
2. Changed its phenotype only
3. Changed its genotype and phenotype both
4. No effect on genotype and phenotype both

5. If you are given with a homozygous yellow seed plant where the green colour (G) is dominant and yellow colour (g) is recessive. How do you find out the genotype of the green coloured seed plant? Explain your answer.

6. Sum of the genes in an organism is known as “genome”. Under human genome project, it has started to arrange the base sequence of genes (map) in chromosomes. Which is the statement that shows the harmful effect of the above to human?

1. Use of gene technology as a remedy for genetic disorders.
2. Ability to produce human with special features.
3. Ability of the life insurance firms to identify the applicants, health conditions easily.
4. As a remedy for food problem using improved plants and animals by gene technology.

Technical terms				
Inheritance	-	ප්‍රවේණිය	-	பிறப்புரிமையியல்
Heredity	-	ආවේණිය	-	நிறமூர்த்தம்
Genetics	-	ප්‍රවේණි විද්‍යාව	-	பரம்பரையலகு
Chromosome	-	වර්ණදේහය	-	பரம்பரை வெளிப்பாடு
Gene	-	ජානය	-	பரம்பரைத் தொடர்பு
Gene expression	-	ජාන ප්‍රකාශනය	-	பிறப்புரிமையியலுக்குரிய பாதிப்பு
Gene linkage	-	ජාන ප්‍රතිබද්ධය	-	இலிங்க நிர்ணயம்
Sex determination	-	ලිංග නිර්ණය	-	மரபுரிமை
Genetical disorders	-	ජානමය ආබාධ	-	மரபு வழித்தொடர்பு