SCIENCE
For
Class IX
(English Medium)

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FOREWORD

The Board developed text-books under the National Curriculum Framework, 2005 to keep abreast with the national change for the schools of Manipur. The Board since its inception had been trying to promote eduction for betterment and quality.

The book has been developed in line with the NCF, 2005. Utmost care has been taken to make it suitable to the local needs and schools of Manipur. Every effort has been made to make the book worthwhile. In the course of preparation, a series of meetings was held with the authors, reviewers etc. to bring it to the present form.

I sincerely thank the authors, reviewers and all others who had helped to make the book presentable and suitable for use by the students.

The Board would welcome any suggestions for further improvement of the text-book.

Dr. Chithung Mary Thomas
Secretary

PREFACE TO THE FIRST EDITION

This text book of Science for class ix students covers the revised syllabus of the Board of Secondary Education Manipur, on the basis of NCF – 2005

The book also contains a fairly exhaustive set of questions fromed in accordance with the model paper and pattern. These questions are meant to help the students to learn the topics well and to prepare for answering of question papers.

We hope these attempts will guide the students significently further in the direction of a child centered system of education outlined in the National Curriculum Framework (NCF) 2005.

Further, the book is thus written for the class ix students, keeping in mind their requirements and problems in preparing for the examinations or tests. Suggestions from readers for further improvement are most welcome.

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CONSTITUTION OF INDIA
PART IV A
Fundamental Duties of Citizens

ARTICLE 51A

Fundamental Duties — It shall be the duty of every citizen of India

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wildlife and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excelence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achieve ment.

C O N T E N T S

CHAPTER – 1

Nature of Matter

If we look around us, we see a large variety of things with different shapes, sizes, textures and colours. These include books, pens, tables, chairs, water, plants, animals etc. The food we eat, the clothes we wear, the paper on which we write, the air we breathe – each thing is matter. Ordinarily, we call the things around us matter, but in scientific language, "*matter is defined as anything that occupies space, has mass and can be felt by one or more of our senses".*

Heat, light, electricity, magnetism and sound are not considered to be matter because they have no mass nor do they occupy space.

1.1. Classification of matter:

Depending upon the nature of the components, we can classify matter into different types.

Activity 1.1.

Let the class be divided into Groups A, B, C, D and E.

Let Group A take a beaker containing 50 mL of water,

Group B dissolve 50 mL of water and 0.1 g crystals of copper sulphate or potassium permanganate or any other soluble coloured substance in a beaker.

Group C take 50 mL water and 0.2 g of the same substance in another beaker.

Let group D and E take different amounts of the above substance or common salt and dry sand and mix the components to form a mixture.

Report the observations on the uniformity and texture.

Group A has a pure substance which has a uniform composition throughout.

Groups B and C have obtained a mixture but having uniform composition throughout as in A.

Matters such as in groups A, B and C are said to be *homogeneous*. In groups B and C, we get mixtures in which the substances are completely mixed together and are indistinguishable from one another. They have no visible boundaries of separation between the various components. i.e. they are also homogeneous. Some other examples of such mixtures are salt dissolved in water, and sugar dissolved in water. A mixture of glycerine and water is a homogeneous mixture. Homogeneous mixtures are also called *solutions*. Unpolluted air is also a homogeneous mixture of gases like nitrogen, oxygen, water vapour, carbon dioxide etc. Two or more melted metals also can form homogeneous solutions. When solidified, they remain homogeneous. Such homogeneous mixtures of two or more metals are called *alloys*. A familiar example of alloy is **brass** which is a homogeneous mixture of zinc and copper.

Though both groups B and C have obtained a homogeneous mixture (solution) of two substances, but the intensity of colour of the mixtures is different. This shows that a homogeneous mixture can have a variable composition.

Matters which have uniform composition throughout are called homogeneous matters.

Groups D and E have obtained mixtures, which contain physically distinct parts and have non-uniform compositions. **Matter consisting of two or more components which are unevenly distributed are called heterogeneous matter.**

Heterogeneous matters have visible boundaries of separation between the various components. Mixtures of chalk and water, kerosene and water, air containing dust particles or smoke are examples of heterogeneous matters (mixtures). Muddy river water is also a heterogeneous mixture.

Matter may also be classified as solids, liquids and gases. Substances like wood, iron, steel, sand etc. are solids. Substances like water, milk, fruit juice, petrol, glycerine etc. are liquids. Substances like oxygen, nitrogen, carbon dioxide, water vapour (steam) etc. are gases.

Questions:

1. Define matter. Give four examples of matter.
2. Which of the following are matters?
   Book, chair, heat, smell, pen, hot tea, light, electric bulb.
3. List the points of difference between homogeneous and heterogeneous matters.

1.2. Is matter composed of particles?

In man's search for knowledge, one of the questions he has asked is : *what is matter made of* ? *What makes one matter different from others*?

For a long time, two ideas prevailed regarding the nature of matter. One idea was that matter is *continuous* like a block of wood or rubber. A second idea was that matter is composed of *particles* that are indivisible. Fig. 1.1 illustrates what a piece of material would look like under the extremely high-powered viewing device.

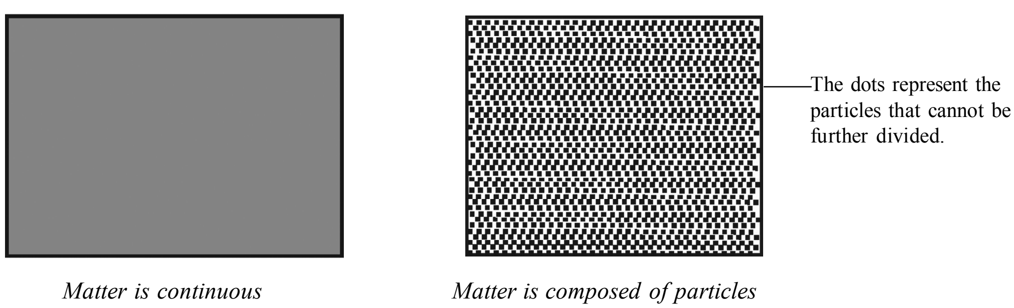


Fig. 1.1

One way of trying to decide between the above alternatives is to find out which idea can best explain experimental results. Let us perform the following experiment t*o prove whether is matter continuous or particulate?*

Activity 1.2.

Take a 100 mL beaker or cylinder. Fill half of it with water and mark the level of water. Dissolve some salt or sugar by stirring with a glass rod. Observe any change in water level. Does the level of water change? What has happened to the salt? Where has it gone?

We can answer these questions if we use the idea that matter is made up of particles. When sugar is dissolved in water, it breaks down into very fine particles. These particles of sugar go into the spaces between the particles of water. Hence there is no change in the volume of water on dissolving sugar in it.

1.3. How small are the particles of matter?

Activity 1.3.

Take 2-3 crystals (0.10 g) of potassium permanganate and dissolve it in 100 mL of water. Stir the mixture with a glass rod to ensure that the solution is homogeneous. Using a pipette or measuring cylinder, remove 10 mL of this solution and put it into another beaker containing 90 mL water to make 100 mL solution. The colour of the solution will become lighter. Keep diluting the solution like this 5 to 8 times till you can detect any pink colour (Fig.1.2).

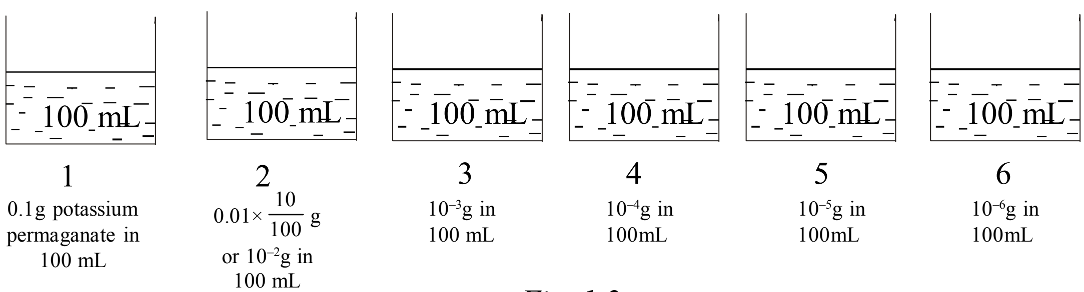


Fig. 1.2.

In the first beaker, in 100 mL of the solution there is $0.1 \times \frac{10}{100}$ or .01 of 10^{-2}g of potassium permanganate. What fraction of a gram of potassium permanganate is there in 1 mL of the diluted solution which you can detect the faint pink colour?

Potassium permanganate can obviously be spread out a great extent. If matter were continuous, an explanation would be that it is extremely *elastic*. If matter is particulate, it is necessary to imagine the particles of solid being separated and spread out in the water. Also, since the smallest amount of potassium permanganate that can be detected in the above experiment is about 10^{-6}g, this may be the maximum mass of any particles that do exist.

So we conclude that there must be millions of tiny particles in just one crystal of potassium permaganate, which keep on dissociating themselves into smaller and smaller particles. Till a stage is reached when the particles cannot be divided further.

The same activity can be done using a few drops of ink instead of potassium permaganate. The colour can be detected even on repeated dilution.

The particles of matter are very small. They are too small to be visible even under powerful microscope.

1.4. Particles of matter have space between them:

In activities 1.2 and 1.3 we have observed that particles of sugar, salt or potassium permanganate got evenly distributed in water. When a solid is dissolved in a liquid, generally there is no change in the volume of the liquid. The fact that there is no change in volume on dissolving sugar or salt in water tells us that there are spaces between the particles of water.

1.5. Particles of matter are continuously moving:

Activity 1.4.

* Put an incense stick in a corner of the classroom. How close do you have to go near it so as to get its smell?
* Now light the incense stick. Can you get the smell even from a distance?

When we light an incense stick in one corner of a room, its fragrance spreads in the whole room quickly. How does it happen?

Activity 1.5.

* Take two glasses or beakers filled with water.
* Put a drop of blue or red ink slowly and carefully along the sides of the first beaker and glycerine or honey (or any other thick liquid) in the same way in the second beaker.
* Leave them undisturbed on the table.
* How long it takes for the ink and the glycerine to spread evenly in the water?
* Record your observations.
* Carry out the experiment in hot water and observe the difference.

Activity 1.6.

* Drop a crystal of potassium permanganate or any other soluble coloured salt into a glass of hot water and another containing cold water.
* What difference do you observe regarding the distribution of the substances in hot and cold water?

In the above activities we observe that particles of matter intermix on their own with each other. They do so by getting into the spaces between the particles. *The intermixing of particles of two or more different types of matter on their own is called diffusion*.

We observe that diffusion becomes faster on heating. Why does this happen?

Particles of matter in solution are continuously moving, that is, they possess kinetic energy. As the temperature rises, particles move faster. We say that with increase in temperature, kinetic energy of particles also increases. And due to faster movements, they mix into each other more quickly.

1.6. Particles of matter attract each other:

Activity 1.7.

* Take a piece of chalk, a brick and an iron nail.
* Try to break them by hammering or cutting.
* Which of them is difficult to break, that is, the particles are held together by stronger force?

There are some forces of attraction between the particles of matter which binds them together. The strength of the force of attraction is different in particles of different kinds of matter. We can move our hand through air very easily because the particles of air are far apart from one another and also the force of attraction between the particles of air is very, very small. It is negligible. We can also move our hand through water in fairly easily because the force of attraction between the particles of water is also small. But we cannot move our hand through a solid body. The force of attraction in a solid is very strong.

Questions

1. Describe what happens when sugar is dissolved in water and there is no increase in volume?
2. Even one or two crystals of potassium permanganate can impart colour to a large volume of water. Which characteristic of matter is illustrated by this observation?
3. What are the characteristics of the particles of matter?

1.7. What are the different states of matter?

If we look around us, we can see that matter exists in three different states — *solid*, *liquid* and *gas*. Can the idea of particles explain these three states of matter?

Let us observe some of their general properties.

Activity 1.8.

Observe a brick, a piece of wood, book, pencil, salt or sugar on a plate. Keep them at different places. Do you notice any change in their shapes? Try compressing them by applying force. What happens when they are hammered, pulled or dropped. Are you able to compress them? We can observe that all these have definite shapes, distinct boundaries and fixed volumes (Fig.1.3). They have negligible compressibility. Solids may break under force but it is difficult to change their shapes. They are rigid.

Let us consider the following.

A rubber band change its shape on stretching but regains the same shape when the force is removed. When excessive force is applied it breaks.

We find that a sponge can be compressed. A sponge has many small holes in which air is trapped. When we press it, the air is expelled out and we are able to compress it.

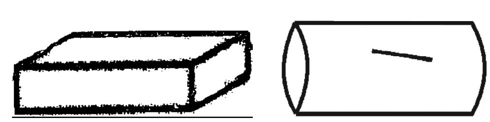


Fig. 1.3 . This block of wood is a solid. It has a definite shape and volume.

Activity 1.9.

* Recall activities 1.2 and 1.3, 1.4. where we saw that solids and liquids can diffuse into liquids. Gases from the atmosphere also diffuse and dissolve in water. The aquatic animals can breathe under water due to the presence of dissolved oxygen in water.

Thus we may conclude that solids, liquids and gases can diffuse into liquids. The rate of diffusion of liquids is higher than that of solids. This is due to the fact that in the liquid state, particles move freely and have greater space between each other as compared to particles in the solid state.

Activity 1.10.

Water, milk, fruit juice, kerosene, petrol etc. are some of the common liquids. Measure 50 mL of a liquid and transfer it into different containers one by one.

Does the shape of the liquid remain the same?

Pour the liquid from one container into another. Does it flow easily?

Fig. 1.4. Water is a liquid. It flows easily. It has no definite shape but has definite volume. It takes the shape of container.

We observe that liquids have no fixed shape but have a fixed volume. They take up the shape of the container in which thay are kept (Fig.1.4). Liquids flow and change shape, so they are not rigid and can be called fluid.

Activity 1.11.

Arrange three 100 mL syringes.

Remove the pistons from all the syringes.

Apply some vaseline on the pistons for their smooth movement.

Close the nozzles of the syringes by rubber corks (as shown in Fig.1.5)

Fill water in the first and pieces of chalk or other solids (common salt or sugar may be used) in the second.

Leave the third syringe unfilled.

Insert the pistons back into the syringes.

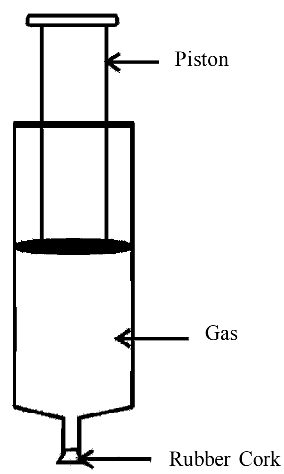


Fig. 1.5.

Now, try to compress the content by pushing the piston in each syringe.

What do you observe?

In which case was the piston easily pushed in?

We find that the piston of the third syringe containing air moves down considerably when pushed in. However, the pistons in the first and second syringes do not move down when we try to compress them.

We have observed that *gases are* highly *compressible* as compared to solids and liquids.

Due to high compressibility, fairly large mass of a gas can be put in a small metal cylinder by compression.

The liquefied petroleum gas (LPG) cylinder (Fig.1.5) that we use in our homes for cooking is a compressed form of the gas.

Suppose we have some cooking gas in a cylinder. If we open the cylinder, we will soon smell the gas all over the room. We sometimes come to know what is being cooked in the kitchen without even entering there, by the smell that reaches us. *How does the smell reach us?*

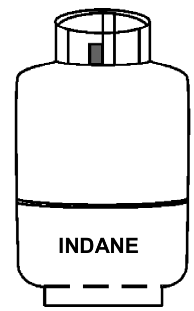
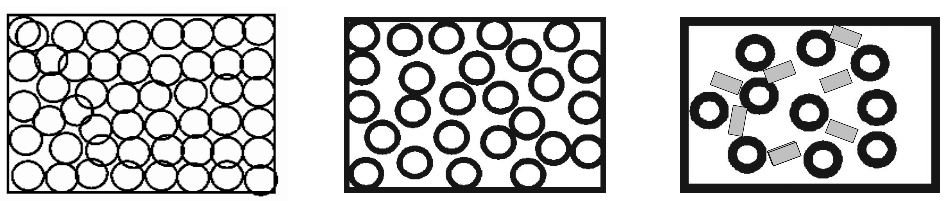


Fig. 1.5. Cooking gas (LPG).

This suggests that particles of the gas in the cylinder and aroma of the food mix with particles of air, spread from the kitchen, reach us and even farther away. The smell of gas reaches us in seconds. This shows that gases diffuse rapidly and occupies the entire space available to it.

The idea that matter is composed of particles can be used to explain the characteristics of solid, liquid and gas. Fig 1.7 illustrates the arrangement of particles in solid, liquid and gas.



SOLID
Particles are arranged in a regular way, close together and held in position. The only motion possible is vibration about their fixed positions

LIQUID
Particles still close to each other, but can move in between one another.

GAS
Particles are much more widely separated, and are moving more rapidly than in a liquid.

Fig. 1.7. Arrangement of particles in solid. liquid and gases.

Let us answer these:

1. When a bottle of perfume was opened in a room, we can smell it even from a considerable distance. Why ?

2. What is diffusion? Give one example of diffusion of gases in a liquid.
3. Give reasons:
   (a) A gas fills completely all the space available to it.
   (b) A book should be called a solid.
   (c) A gas exerts pressure on the walls of a container.

1.8. Can matter change its state?

We all know that water exist as a solid in the form of ice, as liquid water, and as a gas in the form of steam (water vapour).

We like to know how does this change of state take place? What happens inside the matter during this change of matter? What happens to the particles of matter during the change of states?

To answer these questions, let us perform the following experiments:

Activity 1.7.

* Take some crushed ice in a beaker and suspend a thermometer in it (Fig 1.8).
* Note the temperature of ice.
* Start heating the beaker on a low flame.
* Note the temperature when the ice starts melting
* Keep on recording the temperature of melting ice on the thermometer every minute.
* Note the temperature when all the ice has converted into water.
* Why the temperature remains constant when the ice is melting?
* When all the ice has melted, *put a glass rod in the beaker and heat while stirring till the water starts boiling*.
* Note the temperature carefully till most of the water has vaporised.
* Record your observations.
* Why does the temperature remain constant when the water is boiling?

Ice is solid, so the particles of ice are held together by strong force of attraction. On increasing the temperature of solids, the energy of the particles increases. Due to increase in energy, the particles start vibrating more vigorously. A stage is reached when the energy supplied by heat overcomes the forces of attraction between the particles. The particles become somewhat loose, leave their fixed positions and start moving more freely. Thus the solid melts and is converted to a liquid. *The temperature at which a solid melts to become a liquid at the atmospheric pressure is called its melting point.* The melting point of ice is 0°C (273.16 K). The process of melting, that is, change of solid state into liquid state is also known as fusion.

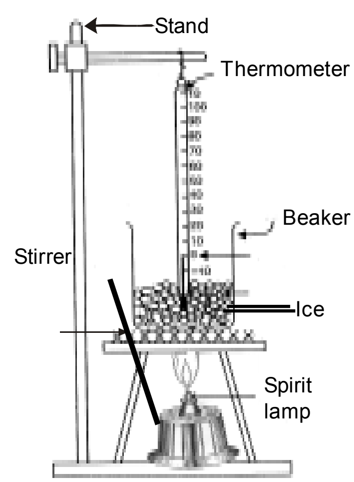


Fig. 1.8. Conversion of ice to water.

The melting point of a solid is an indication of the strength of the force of attraction between its particles. Higher the melting point of a solid substance, greater will be the force of attraction between its particles. For example, the melting point of iron is very high (1535°C). It tells us that the force of attraction between the particles of iron is very strong.

We have observed that the temperature of ice does not change after the melting point is reached, till all the ice melts. This happens even though we continue to heat the beaker, that is, we continue to supply heat. The heat gets used up in changing the state by overcoming the forces of attraction between the particles. As this heat energy is absorbed by ice without showing any rise in temperature, it is considered that it gets hidden in the substance undergoing change and is known as the *latent heat*. The word latent means hidden.

The amount of heat energy required to change 1kg of solid into liquid at its melting point is known as the latent heat of fusion. It has been found by experiments that 3.34×10^5 joules of heat are required to change 1 kilogram of ice to water at its melting point, 0°C. So, the latent heat of fusion of ice is 3.34×10^5 joules per kg. It, therefore follows that particles in water at 0°C (273 K) have more energy than the particles in ice at the same temperature.

Thus we conclude that when a solid melts, its temperature remains the same.

Why we feel cold when we hold a piece of ice in our hand? The piece of ice in our hand starts melting slowly. During the process, ice takes the latent heat required for melting from our hand. Our hand loses heat to ice and we feel it cold.

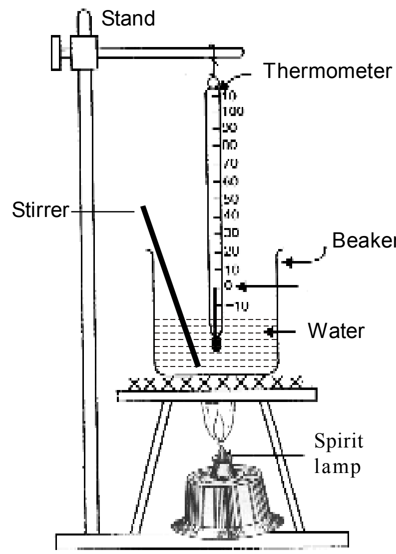


Fig. 1.9 Conversion of water to water vapour

When a solid melts, it absorbs heat to form liquid. The reverse of this is also true. That is, when a liquid freezes to form a solid, an equal amount of heat is given out. For example, when ice melts at 0°C, it absorbs latent heat of fusion to form water. When water freezes at 0°C to form ice, it gives out the same amount of heat.

We have also observed that the temperature of boiling water does not rise even though we continue heating the beaker (Fig.1.9). Why is it so?

When we supply heat energy to water, particles start moving even faster. At a certain temperature, a stage is reached when the particles have energy to overcome (or break) the forces of attraction between water particles. At this temperature the liquid start changing into gas (vapour).

The temperature at which a liquid starts boiling at the atmospheric pressure is called its boiling point. Boiling is a bulk phenomenon, particles from the bulk of the liquid gain enough energy to change into the vapour state. For water this temperature is 100°C (373 K) at one atmospheric pressure. At higher pressure its boiling point is above 100°C.

The heat which is going into boiling water but does not increase its temperature is the energy required to change the state of water from liquid state to gaseous state. This is known as *latent heat of vaporization* of water. So can you define the *latent heat of vaporisation* in the same way we have defined the *latent heat of fusion ?*

The latent heat of vaporisation of a liquid is the quantity of heat required to change 1kg of the liquid to vapour at its boiling point. Thus, particles in steam, that is, water vapour at 100°C (373 K) have more energy than water at the same temperature. This is because particles in steam have absorbed extra energy in the form of latent heat of vaporisation.

When water changes into steam, it absorbs latent heat, and when steam condenses to form water, an equal amount of latent heat is given out.

Wax too shows changes in state similar to those shown by water. Let us observe lighting of a candle (Fig.1.10).

On heating, solid wax (paraffin) melts into liquid wax, which on further heating, is converted into vapours of wax. When we light the candle, the wax around the wick melts. The molten wax rises up the wick and is converted into wax vapour. The wax vapour mixes with oxygen in air and burns [Fig.1.10 A]. In a lighted candle, we can see the solid and liquid states of the wax. We can also see thick white smokes rising from the wick for some time after the candle is put off [Fig.1.10 B]. This is due to condensation of wax vapours.

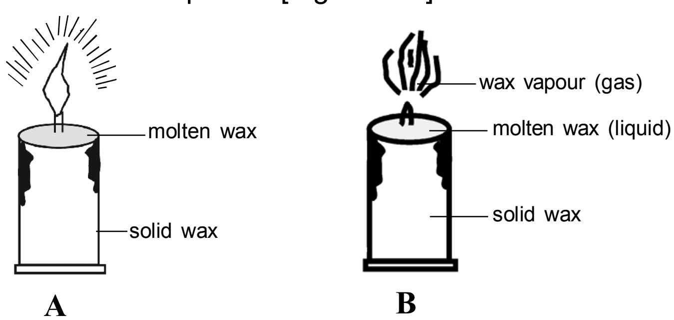


Fig 1.10. Changes in the state of wax.

So, we can infer that the state of matter can be changed into another state by changing the temperature.

Normally, a solid on heating changes into liquid state. The liquid state on further heating changes into gaseous state. Reverse happens when gaseous state is cooled. However, there are solids which on heating directly change into gaseous state, without changing into liquid state and vice versa.

Let us answer these:

1. Why is heat energy needed to melt a solid?
2. Why is temperature remain the same when ice is melted even though we supply heat continuously?
3. Steam and boiling water have the same temperature. But steam cause more severe burns than boiling water. Why?
4. For any substance, why does the temperature remain constant during the change of state?

1.9. Sublimation:

Activity 1.12

* Take some ammonium chloride (or camphor) in a china dish and place the china dish on a tripod stand (Fig. 1.11).
* Cover the china dish with an inverted glass funnel.
* Put a loose cotton plug in the upper, open end of the china dish. Now heat the china dish slowly, and observe.

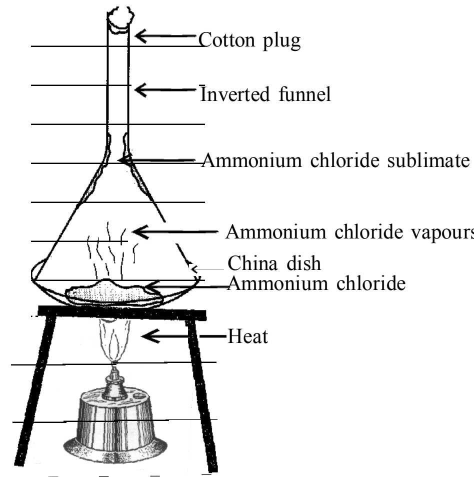


Fig. 1.11. Sublimation of ammonium chloride.

It is observed that the vapours of ammonium chloride rise up and get converted into solid ammonium chloride on coming in contact with the cold, inner walls of the funnel.

The process of changing a solid directly into gaseous state on heating without changing into liquid state and of vapours into solid on cooling, is called sublimation.

$$\textbf{Solid} \underset{\text{Cooling}}{\overset{\text{Heating}}{\rightleftarrows}} \textbf{Vapour}$$

The solid particles formed when the gaseous state of a substance directly changes into solid state is called *sublimate*.

Sublimation occurs in only a few substances. The common substances which undergo sublimation are iodine, camphor, napthalene and anthracene. In many households, small napthalene balls are kept along with woollen and silk clothes, etc., to protect them from the attack of moths and other insects. These napthalene balls disappear with time without leaving any residue. Where did it go ?

Let us answer these.

1. What is sublimation? Name two substances which undergo sublimation.
2. Name one property which is shown by ammonium chloride but not by sodium chloride.
3. Explain why napthalene balls kept inside our cupboard disappear over a period of time?

1.10. Can we change the physical state of matter by changing pressure?

We have already learnt that the distances between the constituent particles in solids, liquids and gases are different. In gases, the particles are far apart. What will happen if we put pressure and compress a gas enclosed in a cylinder? Will the particles come closer? Can increasing or decreasing the pressure change the state of matter?

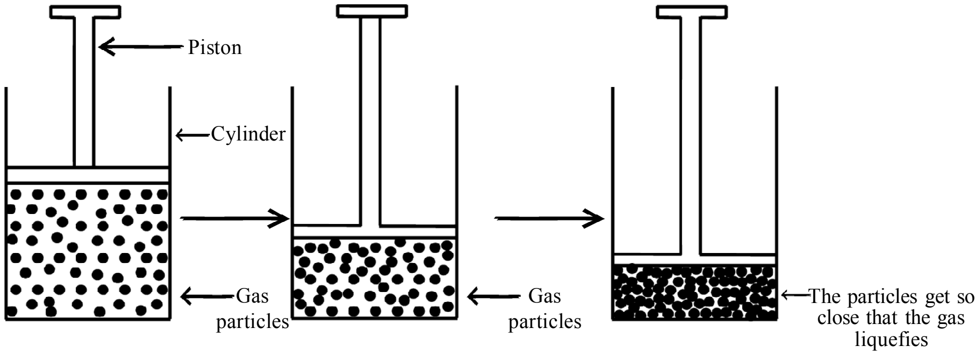


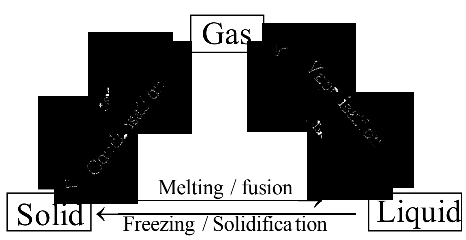
Fig. 1.12. By applying pressure, particles of matter can be brought close together.

When a high pressure is applied to a gas, it gets compressed into a small volume. This is because there was a lot of space between the particles of a gas. When compressed, the particles get so close together that they may liquefy. However, when a gas is compressed too much, then heat is produced due to compression. So, while applying pressure, it is necessary to cool them to take away the heat produced during compression. Cooling lowers the temperature of the compressed gas and helps in liquefying.

Thus, we conclude that *gases can be liquefied by applying pressure and lowering temperature.*

Carbon dioxide and ammonia gas can be liquefied by applying high pressure and lowering the temperature. Solid carbon dioxide is stored under high pressure. It gets converted directly to gaseous state on decrease of pressure to atmospheric pressure without coming into liquid state. For this reason, solid carbon dioxide is also known as dry ice.

Thus, we can say that pressure and temperature determine the state of a substance, whether it will be solid, liquid or gas. The following diagram shows inter conversion of solid, liquid and gas.



It should be noted that all substances cannot be changed from one state to the other. It is because many substances undergo decomposition when strongly heated. For example, sugar in the solid state cannot be changed into liquid sugar because, on heating, it undergo decomposition. The decomposed substance is not sugar.

> ***Let us answer these.***
> 1. What is dry ice? Why is it so called?
> 2. How does applying pressure help in the liquefaction of a gas?
> 3. Suggest a method to liquefy atmospheric gases.

1.11. Evaporation:

Whether heat or change of pressure is always required for changing the state of matter?

We have observed that water, when left uncovered, dries up. Wet clothes also dry up due to changing of water into water vapour. How these happen?

We know that particles of matter are always moving and not at rest. At a given temperature in any gas, liquid or solid, there are particles with different amounts of kinetic energy. In the case of liquids, a small fraction of particles at the surface, having higher kinetic energy, are able to break away from the forces of attraction of other particles and escape in the form of vapour. This *phenomenon of change of a liquid into vapours (gas) below its boiling point is called evaporation*.

1.11.1. Factors affecting evaporation:

Using our common experience, let us find out in which of the following situations, evaporation will be quicker?

(i) Keeping 5 mL of water in a test tube near the window or under a fan.
(ii) Keeping 5 mL of water in an open dish near the window or under a fan.
(iii) Repeating of the above steps on a sunny day and on a rainy day.

We can infer that the rate of evaporation increases mainly on the following factors:

(i) Increase of surface area:

If the surface area of a liquid exposed to the air is increased, the rate of evaporation increases. For example, while putting wet clothes for drying up we spread them out. Can you say why we are able to sip hot tea faster from a saucer than from a cup?

(ii) Increase of temperature:

With the increase of temperature, more particles of the liquid get enough kinetic energy to go into the vapour state (gaseous state). In other words, the rate of evaporation of a liquid increases with rise in temperature and becomes maximum at its boiling point.

(iii) Decrease in humidity:

The amount of water vapours present in air is termed *humidity*. When the amount of water vapours present in air is small, the air appears to be *dry* and we say that humidity is low. On the other hand, when the amount of water vapours in the air is large, the air appears to be *damp* and we say that the humidity is high.

The air around us cannot hold more than a definite amount of water vapour at a given temperature. If the amount of water vapour in air is already high, the rate of evaporation decreases and vice versa.

When the humidity of air is low, then the rate of evaporation is high, and water evaporates more readily and we feel cool and comfortable. During summer, the humidity of air increases. People sweat a lot in such weather. But the sweat from our bodies does not evaporate readily due to high humidity of air. Such weather becomes damp and we feel hot and uncomfortable. This type of weather is experienced during cloudy days.

(iv) Increase in wind speed:

It is a common observation that clothes dry faster on a windy day. With the increase in wind speed, the particles of water vapour move away with the wind, decreasing the amount of water vapour in the surroundings. This increases the rate of evaporation of water.

1.11.2. Evaporation cause cooling:

When we put a little spirit (or petrol) at the back of our hand and wave it around, the spirit evaporates rapidly and our hand feels cold. When spirit changes into vapour, it takes the latent heat of vaporisation from our hand. The hand loses heat and gets cooled. In open vessels, liquid keeps on evaporating. The particles of liquid absorb energy from the surrounding to regain the energy lost during evaporation. This absorption of energy from the surroundings makes the surroundings cold.

During hot summer days, we use earthen pots (called chaphu) to get cold water. The earthen pot has a large number of extremely small pores in its walls. Some of the water continuously keeps seeping through these pores to the outside of the pot. This water evaporates continuously and takes away the latent heat of vaporisation from the earthen pot and the remaining water. The remaining water loses heat and gets cooled.

On a hot day or after doing some physical exercise, our body temperature tends to rise. At this time, our sweat glands give out moisture or sweat on our skin. When the sweat evaporates, it takes the latent heat of vaporisation from our body and keep our body cool. Perspiration (or sweating) is our body's mechanism to keep us cool.

Cotton clothes in hot summer days helps us to keep cool and comfortable. During summer, we perspire more because of the body's mechanism to keep us cool. Cotton, being a good absorber of water helps in absorbing the sweat and exposes it in air for easy evaporation. The evaporation of this sweat cools our body. A fan also increases the rate of evaporation of moisture or sweat from our body and makes us cool and comfortable.

During hot summer days, people sprinkle water on the floor or open ground. Water evaporates by taking the large latent heat of vaporisation from the ground and surrounding air. By losing heat, the place becomes cool and comfortable.

Cite some more examples of cooling due to evaporation from your daily life experiences.

Let us answer these:

1. Why does we perspire on a hot day?
2. How does the water kept in an earthen pot becomes cool during summer?
3. Why are we able to sip hot tea or milk faster from a saucer rather than from a cup?

4. Why do people prefer to use cotton clothes in summer? Why we feel cool and confortable under a tree than under a roof on a sunny day ?
5. What are the factors which affect evaporation?

SUMMARY

* Matter is anything that occupies space, and has mass.
* Matter is made up of particles.
* Matter which has uniform composition throughout is homogeneous and that which consists of two or more components and unevenly distributed is heterogeneous.
* Matter exist in three states — solid, liquid and gas.
* The spaces in between the constituent particles and kinetic energy of the particles are minimum in case of solids, intermediate in liquids and maximum in gases.
* In solids, particles are arranged in a regular way, in case of liquids the particles can slip and slide over each other while for gases, particles move randomly, there is no order.
* The three states of matter are interconvertible.
* The state of matter can be changed by changing temperature and/or by changing the pressure.
* Latent heat of fusion is the amount of heat energy required to change 1 kg of solid into liquid at its melting point.
* Latent heat of vaporisation is the heat energy required to change 1 kg of a liquid to vapour at atmospheric pressure at its boiling point.
* Sublimation is the change of a solid directly into vapour on heating without changing into liquid state and vice versa.
* Boiling is a bulk phenomenon. Particles from the bulk of the liquid gain energy and change into vapour state.
* Evaporation is a surface phenomenon. Particles from the liquid surface gain enough energy to overcome the forces of attraction present in the liquid and change into the vapour state.
* The rate of evaporation depends upon the surface area exposed to the atmosphere, the temperature, the humidity and the wind speed.
* Evaporation causes cooling.

EXERCISES

1. *Define matter. Give four examples of matter?*
2. *Light and sound are not considered to be matter, why?*
3. *Give two processes which provide the best evidence for the motion of particles in matter.*
4. *When we dive in water, we cut through water easily. Which property of matter is shown by this observation?*
5. *Why do gases have neither a fixed shape nor a fixed volume?*
6. *Why do solids, liquids and gases differ in shape and volume?*
7. *Name two gases which are available in compressed form.*
8. *What is diffusion? Give one example.*
9. *What is meant by latent heat of fusion of a solid? How much is the latent heat of fusion of ice?*
10. *Define the term "latent heat of vaporization" of a liquid.*
11. *Define (a) melting point and (b) boiling point of a substance.*
12. *State the various factors which affects evaporation.*
13. *How does evaporation results in cooling effect?*
14. *What are the conditions necessary to liquify gases?*

CHAPTER – 2

Pure substances and mixtures

Nature is full of different materials like rocks, soils, water, air. We also see other materials like milk, tea, coffee, butter, spices, ink, chalk, brass, bronze, copper, silver, gold. We purchase many items like salt, sugar, ghee, mustard oil, honey, turmeric powder from the market. *How many of these materials are pure?* For a common person pure means having no adulteration. But if we observe minutely the constituents of these materials, we can see that all these things are actually mixtures of different substances. For example, milk is actually a mixture of water, fats, proteins etc. To a scientist a *substance is said pure if it consists of only one type of particle.*

2.1. What are Mixtures?

A pure form of matter which cannot be separated into other kinds of matter by any physical process is known as a *substance*. Mixtures contains two or more substances mixed together. For example when sugar is dissolved in water, it can be separated by the physical process of evaporation. However, sugar is itself a substance and cannot be separated by physical processes into other constituents. Similarly sodium chloride, napthalene, copper, iron are substances because each of them contain only one kind of pure matter.

Soil, rocks, minerals, soft drinks, sea water are not single substances. A substance whatever be the source will always have the same characteristic properties. A mixture, on the other hand contains more than one substance and hence will have varying properties.

2. 2. Type of mixtures:

A mixture may be *homogeneous* or *heterogeneous*. A homogeneous mixture has a uniform composition throughout. It has no visible boundaries of separation between the various constituents. Sugar or salt dissolved in water, alcohol water mixture, brass, air, kerosene oil etc are homogeneous mixtures.

Those mixtures in which there are varying proportions of constituent particles and the constituents remain separated are called heterogeneous mixtures. A mixture of sugar and sand, petrol and water, are also heterogeneous mixtures.

Activity 2.1

* Take 100 mL water in four beakers A, B, C and D.
  Add and stir propely using a glass rod :
  (i) Few crystals of sugar or salt in A.
  (ii) One tablespoonful of sugar or salt in B.
  (iii) Chalk powder (or sand powder) in C.
  (iv) Few drops of milk in D.

* Direct a beam of light from a torch through the beaker containing the mixture and observe from the front.
* Leave the mixtures undisturbed for sometime and in the meantime, set up a filtration apparatus.
* Fitter the mixture one after another.
* Observe carefully the differences in the mixtures.

We have (i) two solutions in beakers A and B (ii) a suspension in C and (iii) a colloidal dispersion in D.

What are the characteristics of these three types of mixtures?

2.2.1. Solution:

A homogeneous mixture of two or more substances is called a solution. We have come across various types of solutions in our daily life. Soft drinks like soda water, red tea, saline water, glucose in ampoules are all examples of solutions.

When we add some common salt in water in a beaker and stirred, the salt seems to disappear in water. We get a transparent salt solution. The dissolved salt particles cannot be seen even with a microscope, and the salt does not settle down on keeping. The salty taste of the liquid, however, shows that salt is present in it. This shows that particles of salt are evenly distributed in the solution, that is, there is homogeneity at the particle level.

A solution has a *solvent* and a *solute* as its components. The component of a solution which dissolve the other component in it, that is, the component present in larger amount is called the *solvent.* The component that is dissolved in the solvent that is the component present in lesser quantity is called *solute.*

Examples:

(i) When sugar is dissolved in water, we get sugar solution. In this solution, sugar is the solute and water is the solvent. It is a *solid in liquid solution.*

(ii) A solution of glycerine in water is a *liquid in liquid solution.* Glycerine is the solute and water the solvent.

(iii) Aerated drinks like soda water etc. are *gas in liquid solutions.* These contain carbon dioxide gas as solute and water (liquid) as solvent.

(iv) Normally air is a mixture of *gas in gas.* Its main constituents are Nitrogen (78%), Oxygen (21%) and other gases like carbon dioxide, water vapour etc in small quantities. It is a homogeueous mixture and hence a *solution of gas in gas*.

(v) Usually we think of a solution as a liquid that contains either a dissolved solid, liquid or gas in it. But we can also have *solid solutions*. For example. alloys are mostly homogeueous mixtures of metals and therefore regarded as solutions. For example, brass is a mixture of approximately 30% Zinc and 70% copper. It is prepared by mixing molten zin with molten copper and cooling their mixture. Alloys mostly retain the properties of its constituents and can have variable composition.

Properties of a solution:

(i) A solution is a homogeueous mixture.

(ii) The particles of a solution are extremely small – less than 1nm in diameter (1 nanometre = 10^{-9}m). So, they cannot be seen by naked eye, even with a microscope.

(iii) Particles in a solution cannot scatter light (the path of light is not visible) passing through the solution. This is because of small size of the particles.

(iv) The solute particles cannot be separated from the mixture by filtration, nor they settle down when left undisturbed. So, solutions are very stable.

Concentration of a solution:

Many substances dissolve in water. But can we dissolve any quantity of a solid in a given amount of water?

Activity 2.2

Take 25 mL of water in a beaker.

Add a small amount of common salt to the beaker by means of a teaspoon and stir with a glass rod. Observe what happens.

Add a fresh quantity of salt in the above solution and stir. See if it dissolves.

Add more of the salt to the above solution and stir well. Does it dissolve as readily as in the earlier cases?

Add another quantity of the salt and observe whether it too dissolves.

We find that the first addition of the common salt dissolves readily in water. Second addition also dissolves. The third addition of the salt dissolves rather slowly while the fourth addition does not completely dissolve in the same quantity of water (solvent). This means that one cannot go on dissolving a substance in a solvent endlessly and there is a limit to the solubility of a substance in a solvent. From careful experiment it can be calculated that about 35 g of common salt can be dissolved in 100 g of water at room temperature. No more salt can be dissolved after this. A solution which can dissolve no more of the solute at a given temperature is called a saturated solution.

The solubility of a substance is usually defined as the maximum number of grams of the substance that can be dissolved in 100 g of solvent at a certain temp. It may also be defined as the *amount of the solute present in100 g of the saturated solution at the given temperature.*

If the amount of solute contained in a solution is less than the saturation level, it is called an *unsaturated solution.*

We can repeat the above experiment by taking definite mass of sugar or any other substance instead of common salt and dissolving in a fixed quantity of water. The following table shows the maximum solubility of some substances is grams per 100 grams of water at 30°C.

Table 2.1. Solubility of some substances in water at 30°C

Substance	Solubility in g/100 g of water
1. Common salt (sodium chloride)	36.3
2. Sugar	220
3. Copper sulphate	25
4. Quick lime (Calcium oxide)	0.16

Thus, the solubility of different substances in water varies. The solubility of a majority of substances also increases with temperature.

The *amount* of *solute present in a given amount (mass or volume) of a solution,* or the amount of solute dissolved in a given mass or volume of solvent is termed the concentration of solution.

$$\text{Thus, Concentration of solution} = \frac{\text{Amount of solute}}{\text{Amount of solution}}$$

$$\text{OR, Concentration of solution} = \frac{\text{Amount of solute}}{\text{Amount of solvent}}$$

Concentration of a solution may be expressed in terms of mass by mass percentage or mass by volume percentage.

(i) Mass by mass percentage of a solution

$$= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100.$$

(ii) Mass by volume percentage of a solution

$$= \frac{\text{Mass of solute}}{\text{Volume of solvent}} \times 100$$

Example 2.1

A saline solution contains 30 g of sodium chloride in 250 g. of water. Calculate the concentration of the solution in terms of mass by mass percentage of the solution.

Solution:

Mass of solute (sodium chloride) = 30 g

Mass of solvent (water) = 250 g.

Mass of solution = Mass of solute + Mass of solvent

= 30 g + 250 g

= 280 g.

$$\text{Mass \% of solution} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$= \frac{30}{280} \times 100$$

= 10.71% (nearly)

A solution contains 25 g of glucose dossolved in 250 ml of water. Calculate the concentration of the solution in terms of mass by volume percentage of the solution.

Solution:

Mass of solute (glucose) = 25 g.

Volume of solvent / solution = 250 ml

$$\text{Concentration of solution} = \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

$$= \frac{25\ g}{250\ ml} \times 100$$

$$= 10\ \%\ g.\ ml^{-1}\ (M/V)$$

Example 2.3

A glucose saline solution is labelled as 0.96% (W/V) sodium chloride. How much salt is present in 500 ml of the solution?

Solution:

0.96% (w/v) sodium chloride solution means 0.96 parts by mass of sodium chloride present in 100 parts by volume of solution.

Hence, considering common solutions, it contains 0.96 g of sodium chloride per 100 mL of the solution.

\ Amount of salt (Sodium chloride) present in

$$500\ ml = \frac{0.96\ g \times 500\ ml}{100\ ml}$$

$$= 4.80\ g.$$

Example 2.4

If 10 ml of alcohol is present in 200 ml of its aqueous solution, calculate the concentration of the solution in volume by volume percentage.

Solution :

Volume of solute (alcohol) = 10 ml

Volume of solution = 200 ml

$$\text{Concentration of solution} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

$$= \frac{10\ ml}{200\ ml} \times 100$$

$$= 5\%\ \text{(by volume)}$$

2.2.2. Suspensions:

When some chalk powder is stirred in water contained in a beaker, we can see the fine particles of chalk suspended throughout the water without dissolving in it. If the mixture is kept undisturbed for some time, the chalk particles settle at the bottom of the beaker. This shows that the mixture is unstable. If we filter the mixture through a filter paper, the chalk particles are left behind as a residue on the filter paper and clear water is obtiained as a filtrate.

A heterogenous mixture in which small particles of a solid are spread throughout a liquid without dissolving in it is called a suspension.

Properties of a suspension :

(i) Suspension is a heterogeneous mixture
(ii) The particles in a suspension is larger than 100 nm is diameter and can be seen by the naked eye.
(iii) The particles of a suspension scatter a beam of light passing through it and makes its path visible.
(iv) The particles of a suspension settle down when the suspension is kept undisturbed for some time. They can be separated from the mixture by the process of filtration.

2.2.3. Colloids :

When we stir few ml of milk (or soap powder) in water in a beaker, we get a colloidal dispersion or colloid. The mixture is not perfectly transparent, it is somewhat translucent. The particles of a colloid are uniformly spread throughout the mixture. Due to the smaller size of particles as compared to that of suspension, the mixture appears to be homogeneous. But actually, a colloidal dispersion is heterogeneous consisting of two parts or phases. One part consists of the colloidal particles known as the *dispersed phase*, and the other is the *dispersion medium* which consists of the continuous matter into which the colloidal particles are dispersed.

Although we cannot see colloidal particles with naked eyes because of their small size, yet they are big enough to scatter light. When a beam of light is allowed to pass through the colloidal dispersion, the path of the light beam is illuminated and becomes visible (as observed in activity 2.2). *The scattering of light by colloidal particles is known as Tyndall effect* after the name of the scientist who discovered it (Fig. 2.1).

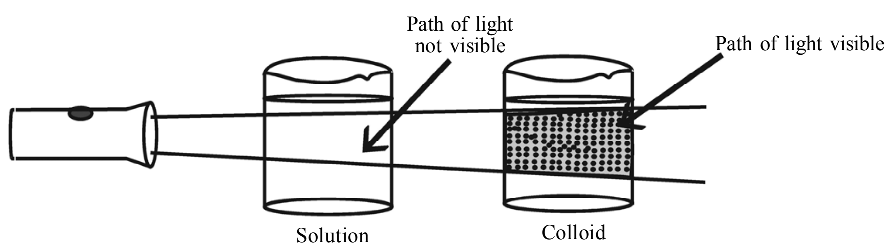


Fig. 2.1. Tyndall effect.

The Tyndall effect is analogous to the scattering of light by dust particles when a beam of sunlight enters a darkened room through a partly opened door or a slit in a wall. The dust particles suspended in air, many of them too small to be seen, look like bright points in the beam of light. We also observe a similar phenomenon when the projector in a darkened cinema hall begins to throw picture on the screen, We can also observe Tyndall effect when we focus our torch light on a rainy night.

Since both the dispersed phase and the dispersion medium may be either a gas, a liquid, or a solid, there are eight types of colloidal systems (Table 2.2). There is no colloidal system in which both the dispersed and the dispersion phases are gases because there is only one phase in any mixture of gases.

Table 2.2 Types of Colloids

Dispersed phases	Dispersion medium	Type name	Examples
Solid	Liquid	Sol jellies.	Mud, starch dispersed in water,
Solid	Gas	solid aerosol	Smoke, dust, automobile exha-ust.
Solid	Solid	Solid sol	Milky glass, coloured gemstone.
Gas	Liquid	Foam	Soap suds, whipped cream
Gas	Solid	Solid foam	Pumice, sponge, foam
Liquid	Gas	Liquid aerosol	Fog, clouds, mist
Liquid	Liquid	Emulsion	Milk, face cream
Liquid	Solid	Gel	Jelly, cheese, butter, shoe polish.

Properties of colloids:

(i) A colloid is a heterogeneous system

(ii) The size of particles of a colloid is in between those in a true solution and those in a suspension. It is between 1nm and 100nm in diameter.

(iii) Colloid scatter a beam of light passing through it and makes its path visible.

(iv) They do not settle down when left undisturbed, that is, a colloid is quite stable and the particles can pass through filter paper.

Let us answer these :

1. What are homogeneous and heterogeneous mixtures? Give examples.
2. How are the size of the particles in a solution, colloid and suspension different from each other?
3. Bring out the differences between sol, aerosol, foam and emulsion.

2.3. Can we get pure substance from mixtures?

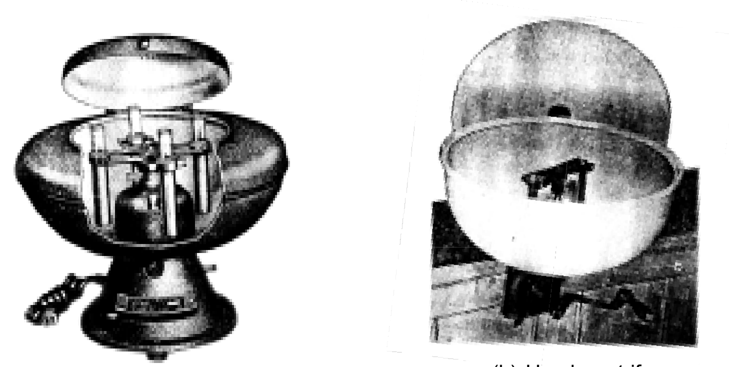
Most of the materials derived from natural sources are seldom pure. They are often mixed with other substances. To study the properties and uses of a substance, it must be first of all obtained in a pure state. The methods employed for the separation and purification of substances depend on the nature of the substance and the impurities present in it.

Heterogeneous mixtures of two or more substances can be separated into their constituents by simple physical methods like handpicking, sieving, sedimentation and decantation, and filtration that we use in our daily life.

Sometimes special techniques have to be used for the separation of the constituents of a mixture.

2.3.1 Separation by Centrifugation:

If we have a mixture of fine suspended particles in a liquid, we can separate it by the process of filtration using filter paper. Sometimes the solid particles in a liquid are very small and pass through a filter paper. For such particles the filtration technique cannot be used for their separation. Such mixtures can be separated by a technique known as *centrifugation*. The principle of the technique is that when the mixture is rotated rapidly, the heavier particles are forced to the bottom and the lighter particles stay at the top. Centrifugation is done by using a machine called *centrifuge* (Fig.2.2) which may be electrically operated or hand driven.



(a) Electric centrifuge (b) Hand cantrifuge

Fig. 2.2. Centrifuge

In this method, the mixure of fine suspended particles in a liquid is taken in a test tube. The test tube is placed in the centrifuge machine and rotated rapidly for some time. The rotative force (centrifugal force), pushes the heavier suspended particles at the bottom of the test tube while the clear liquid being lighter, remains on top. They can now be separated by decantation.

By this method cream is separated from milk. Cream being lighter is collected from the top of the liquid.

Application : The method is found used in

(i) diagnostic laboratories for blood and urine tests.
(ii) dairies and home to separate butter from milk.
(iii) washing machines to expel out water from wet clothes.

2.3.2. Separation by Sublimation :

We have learnt in previous chapter that there are substances which changes directly from solid to gaseous state on heating and vice versa. Ammonium chloride, iodine, camphor, napthalene and anthracene are sublimable substances. They can be separated from their mixtures in salt, sand, earthy materials by the process of sublimation (Fig. 2.3).

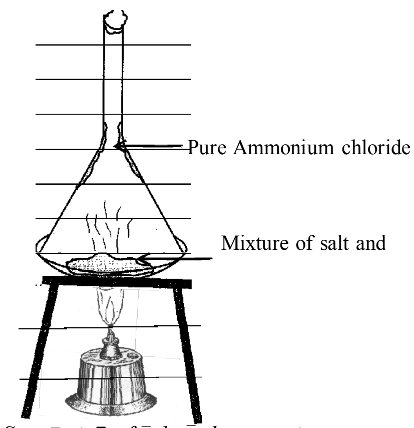


Fig. 2.3. Separation of salt and ammonium

2.3.3. Separation by Chromatography :

Chromatography is a technique used for identification and separation of solutes which are present in a solution in small quantities.

Activity 2.3.

* Take a rectangular sheet of filter paper of approximately 10 cm × 8 cm.
* Draw a pencil line on it, about 2 to 3 cm from its lower edge and put a cross (×) mark at the centre of the line (Fig.2.4a).
* Prepare a mixture by mixing red and blue inks in equal proportions.
* With the help of a dropper, put a drop of the ink on the cross (×) marked on the line. Let the ink dry.
* Fix the paper to the lower surface of the cover of a gas jar with the help of cello tape.
* Lower the filter paper into a jar or beaker containing water so that the drop of ink on the paper is just above the water level and the jar or beaker is kept covered (Fig.2.4b).
* Leave it undisturbed.
* Watch carefully, as the water rises up on the filter paper.
* Record your observations.

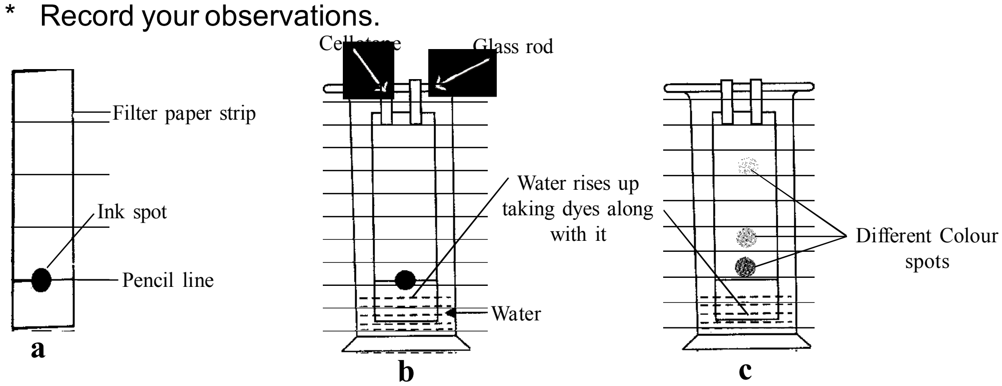


Fig. 2.4. Separation of dyes in ink by paper chromatography.

The ink that we use has water as the solvent and two or more colours (dyes) soluble in it. As the water gradually rises up the filter paper, different dye particles are carried by water at different rates along the filter paper and finally gets separated (Fig.2.4.c). The name chromatography comes from the Greek word kroma which means colour. This technique was first used for separation of colours. So this name was given.

With the advancement in technology, newer techniques of chromatography have been developed. You will learn more about chromatography in higher classes.

Application :

Some of the important applications of chromatography are :

(i) Separation of coloured substances (dyes and pigments) in solution.

(ii) In forensic science to detect and identify trace amounts of drugs in the contents of bladder or stomach and blood.

(iii) To separate small amounts of products of chemical reactions.

2.3.4. Purification by Crystallisation :

Crystallisation is a technique that separates a pure solid in the form of its crystals from a solution.

How can we get pure potash alum from an impure sample?

Activity 2.4.

The process involves the following steps.

* Dissolve the impure solid in a minimum quantity of water to form a solution .
* Filter the impurities out.
* Heat the clear solution gently to get a saturated solution in a china dish. (This can be tested by dipping a glass rod in the hot solution and taking out from time to time. When small crystals form on the glass rod, the solution is saturated).
* Allow the hot saturated solution to cool slowly.
* Crystals of pure solid are formed. Impurities remain dissolved in solution.
* The crystals of pure solid can be separated by filtration and dried.

The process of crystallisation is used to purify a large number of water soluble solids. For example, common salt from sea water contains many impurities. It is purified by crystallisation.

Crystallisation technique is better then simple evaporation technique. Some solids like sugar may get charred on heating to dryness during evaporation. No such problem will be faced in crystallisation. Some impurities may remain dissolved in the solution after filtration. On evaporation these impurities contaminate the solid.

2.3.5. Separation and purification of liquids :

Various methods are employed for separation and purification of liquids depending upon the nature of liquids and the impurities present.

Liquids which do not mix with each other and form separate layers when put in a container are called *immiscible* liquids. For example, oil and water are immiscible liquids. A mixture of immiscible liquids such as kerosene oil and water can be separated by using separating funnel (Fig.2.5).

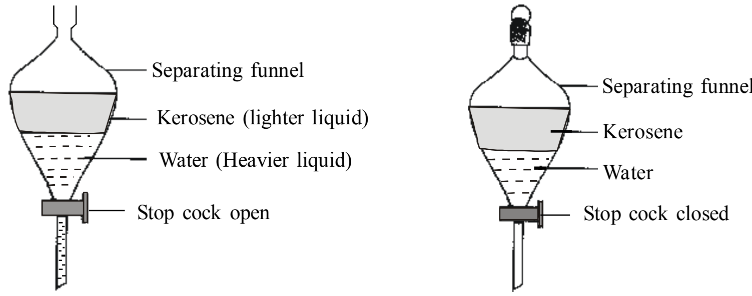


Fig. 2.5. Separation of immiscible liquid mixture.

Liquids which boil under ordinary pressure without decomposition and are associated with non-volatile impurities are generally purified by simple *distillation*. The apparatus is shown in Fig. 2.6. The impure liquid is taken in a distillation flask fitted with a thermometer and heated. The liquid vaporises and the vapours are condensed as they pass through the water condenser. The pure liquid is collected in the receiver while the non-volatile impurity is left behind.

Two or more liquids which mix together in all proportions are called *miscible liquids*. A mixture of miscible liquids having different boiling points can also be separated by distillation. When a mixture of two liquids A and B is heated in the distillation flask, the more volatile liquid A (having lower boiling point), along with a little of high boiling constituent B changes into vapour. The vapours, on being cooled in the condenser, collects in the receiver. The two fractions are further purified by repeating the process a number of times.

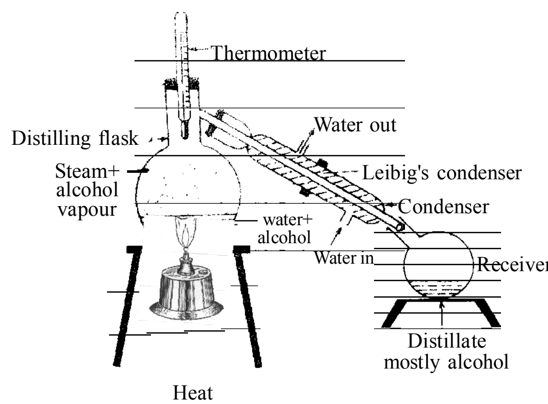


Fig. 2.6. Separation by distillation.

For example, alcohol (or ethanol) and water are completely miscible. Alcohol (ethanol) boils at 78.5°C and water boils at 100°C. So a mixture of the two can be separated by distillation.The distillate is collected at about 80°C. It contains the alcohol and a little water. It is redistilled. The resultant distillate will be richer in alcohol.

Collecting the distillate and redistilling it several times takes a long time. Complete separation is not possible if the difference in boiling points is less than 30°C. If the difference is less, a fractionating column is fitted over the distilling flask. A fractionating column provides a temperature gradient, higher temperature at the bottom and lower temperature at the top. Different types of fractionating columns are available; one is shown in Fig. 2.7.

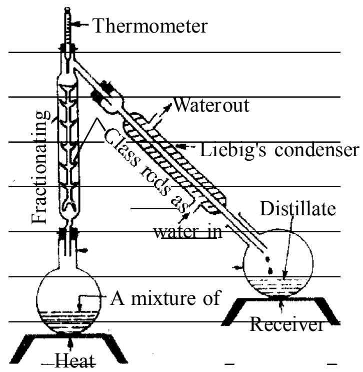


Fig. 2.7. Fractional distillation

Fractional distillation is widely used in industry to purify and separate miscible liquids.

The process is used in the separation of gases from liquid air. Pure air is converted into liquid air. The liquid air is then fractionated to get liquid nitrogen (b.p.– 196°C) and liquid oxygen (b.p – 183°C)

How can we get different gases from air?

The process involves the following steps:

* Air is first filtered to remove dust, then water and carbon dioxide are removed.
* Air is compressed to a high pressure and then cooled.
* The cooled air is then allowed to expand quickly into a chamber through a jet. When air is compressed and then allowed to expand suddenly, its temperature falls.

The phenomenon of producing lowering of temperature when a gas is made to expand suddenly from a region of high pressure into a region of low pressure, is known as Joule Thomson Effect or Joule – Kelvin Effect.

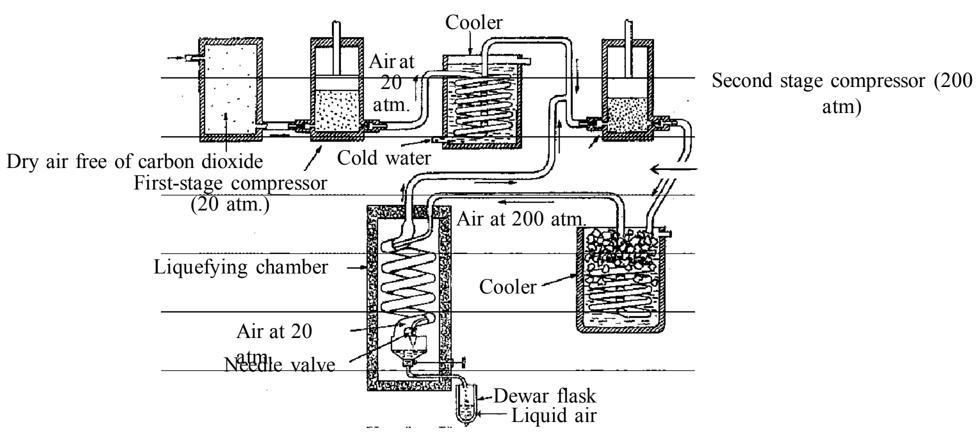


Fig. 2.8 Apparatus for liquefying air.

*The process of compression, cooling and rapid expansion of air is repeated again and again making the air more and more cool. Finally, the air gets so cooled that it becomes liquid.

* Liquid air is a mixture of liquid nitrogen (b.p. – 196°C) and liquid oxygen (b.p. – 183°C).

(Apparatus for liquefying air is shown in Fig.2.8.)

* They can now be separated by fractional distillation, liquid nitrogen with lower boiling point will distill first leaving behind liquid oxygen which distil later.

Similarly, crude petroleum is fractionally distilled to get various fractions, some of which are (i) petroleum gase (ii) gasoline or petrol (iii) kerosene (iv) diesel oil (v) lubricating oil (vi) fuel oil. Fig.2.9. shows a diagrammatic representation of the apparatus used for the fractional distillation of crude petroleum and uses of various fractions.

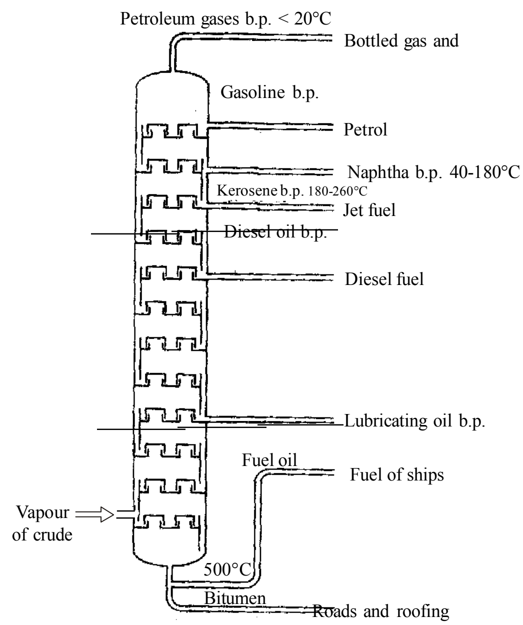


Fig. 2.9. Fractional distillation of

2.3.6. How is water purified for human consumption?

Drinking water should be colourless clear, transparent , and harmless.

In towns and villages, many people get their water supply from water works. The source of water for water works is either a nearby river or lake and needs purification before use. This is done in the following way.

River water is pumped and sent to large *sedimentation* tanks through pipe lines (Fig. 2.10). The coarse suspended impurities get settled in this tank.

From the sedimentation tank, water is sent to a "*loading tank*". Here alum is added to coagulate colloidal particles. They settle down at the bottom of the tank. The precipitate also carries down with it most of the suspended organic matter, including living organisms.

The water is then passed through *filter tanks.* These tanks have fine sand layer at the top, coarse sand layer in the middle and gravel as the bottom layer. These layers act as filters and remove suspended materials that fail to settle out.

The third stage is to remove the harmful microbes that may cause diseases. The clear water from the filter tanks is passed into a disinfecting or chlorination tank. Here, the water is treated with small quantities of chlorine (less than one part per million part of water) to destroy harmful organisms.

This purified water is then stored in large overhead tanks for supply to the homes through pipe lines. A flow diagram of a typical water works is shown in Fig.2.10.

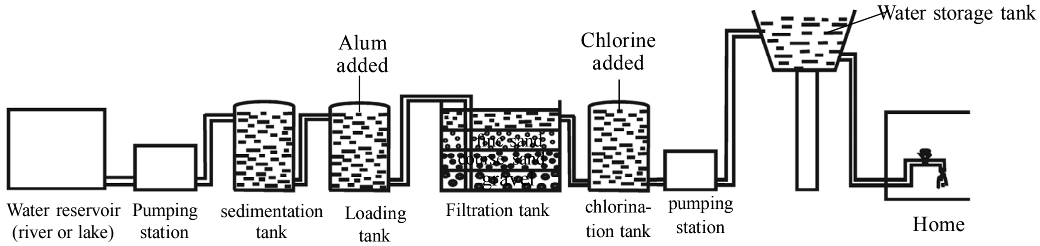


Fig. 2.10. scheme for supply of drinking water.

Let us answer these:

1. How will you separate a mixture of common salt and sand?
2. What process will be used to get camphor from a mixture of camphor and common salt?
3. Name the method used to separate a mixture of chalk powder and water.
4. How can cream be separated from milk?
5. Name the process by which common salt is obtained from sea water.
6. How can common salt be purified?
7. Name the process by which mixture of dyes can be separated from their mixtures.
8. How will you separate water and mustard oil?
9. What types of mixtures are separated by the process of fractional distillation.

2.4. Physical and chemical changes:

Substances possess many features, qualities or characteristics by which they may be identified. We know that each substance has its own characteristic properties. But every substance is liable to change under certain conditions. Almost all of the changes taking place in matter can be classified into two categories: *physical change* and *chemical change* depending on the composition and properties of the original substances and the products of the change.

2.4.1. Physical change

In the previous chapter, we have learnt about a few physical properties of matter. Properties of substances that can be observed and specified like colour, odour, hardness, texture, thermal and electrical conductivity, boiling point, melting point etc are physical properties.

* When we cut a paper into two or more pieces, the size of the paper has changed. But the paper pieces retains all the properties of paper.
* When sugar is dissolved in water, it retains its sweetness. The dissolved sugar can be recovered by evaporation of the solution
* We have learnt that water is changed from its solid state (ice) to the liquid state (water) and from the liquid state to its gaseous state (water vapour). We also know that water can be changed to ice by cooling.
* When ammonium chloride is heated on a china dish, it changes to vapour which, on reaching the cooler part of the funnel (activity 2.3.2) again form solid ammonium chloride.

* When a piece of soft iron like knitting needle is rubbed by a bar magnet several times, it attracts small pieces of iron (it is magnetised). Then when it is dropped on the floor several times, it loses its magnetism.
* When an electric current is switched on an electric bulb, the filament becomes white hot, and hence it glows. The same filament returns to its original state when the current is switched off.

In these changes, the size, physical appearance and the state of the substances are changed. The changes can be reversed by reversing the conditions, hence the changes are temporary. Internal composition of the substances are not changed.

Changes in which the physical properties such as texture, shape, size and the state of substances are made to change but their internal composition remains the same, are called physical changes.

2.4.2. Chemical changes:

Instead of cutting a paper, if it is burnt, it turns to ash. It is mostly carbon, it does not have any of the properties of paper.

Similarly if sugar is charred, the resulting black substance is a different substance altogether.

When milk becomes curd, the taste is different. New substances with different properties are formed. *Changes which results in the formation of new substances which are entirely different from those of the original substance are called chemical changes.*

Activity 2.4.

* Take some washing soda (sodium carbonate) or sodium bicarbonate in a test tube.
* Add to it a few mL of lemon juice or any other acid available.
* Observe what happens.
* Bring a lighted matchstick over the mouth of the test tube.
* Pass the gas into lime water contained in a test tube.
* What happens?
* Draw your conclusions.

We observe that when an acid comes in contact with sodium bicarbonate or carbonate there is brisk effervescence of carbondioxide gas which turns lime water milky. The gas is neither combustible nor a supporter of combustion. We cannot get back the washing soda and the acid from the products. The *change is not reversible.*

Activity 2.5.

* Observe what happens. (Do not look directly to the dazzling white light produced).
* What product is formed?

Magnesium burns with a dazzling light and changes into a white powder. The white powder has entirely different properties from that of magnesium.

We find that when an iron object is left out in moist air, it slowly changes into a brittle, dull brown substance, called *iron rust* Experiment shows that rust is not elementary iron. It is hydrated iron oxide.It is a new substance, i.e. it is entirely different from iron. This is an example of chemical change.

The process of chemical change is also called *chemical reaction.* The original substances taken before the change are called *reactants* while the substances formed as a result of the reaction are called products.

Both water and kerosene oil are liquid . They differ in odour and inflammability. We know that oil burns in air whereas water extinguishes fire. We say that the chemical characteristics and composition of these substances are different. That is, it is the chemical properties that makes oil and water different.

Burning is a chemical change. During a chemical change, one substance reacts with another resulting in the formation of new substances having different chemical composition and properties.

Let us answer these:

1. Name the process by which we get new substances?
2. What is the essential condition for a substance to undergo a change in chemical composition?
3. Classify the following changes as physical or chemical?

(i) Decay of vegetables.

(ii) Formation of clouds

(iii) Burning of a candle.

Give reasons for your answer.

4. How can you say whether or not a chemical change takes place when

(i) milk turns sour.

(ii) iron changes into iron rust?

2.5. Types of pure substances:

We have learnt how to obtain pure substances by processes involving physical changes. Having obtained the pure substance the physical processes can be continually repeated, but no further separation into different substances will take place. For example, pure salt can be obtained by crystallisation (article 2.3.4). It can be redissolved in water, and the water evaporated over and over again, but only salt will be left each time.

It is however possible to melt salt and pass an electric current through it, and this brings about an altogether different change in which an element called sodium and a yellowish green poisonous gas chlorine are obtained. You will learn the details of this process in higher classes.

Sodium chloride (fused) $\xrightarrow{\text{electric current}}$ sodium + chlorine

Similarly, by passing electric current, water can be decomposed to hydrogen and oxygen. An electric current is used to break salt and water into other substances .

Activity 2.6.

* Take some mercuric oxide in a hard glass test tube.
* Clamp the test tube on an iron stand (Fig. 2.11)
* Heat the test tube strongly.
* Notice the change in colour.
* Heat further till the tube is filled with fumes.
* Hold a glowing splinter into the test tube. (splinter is lit and then the flame blown out so that only the tip glows red hot).
* Observe how the wooden splint bursts into flame.
* Observe the shiny appearance on the side of the test tube.

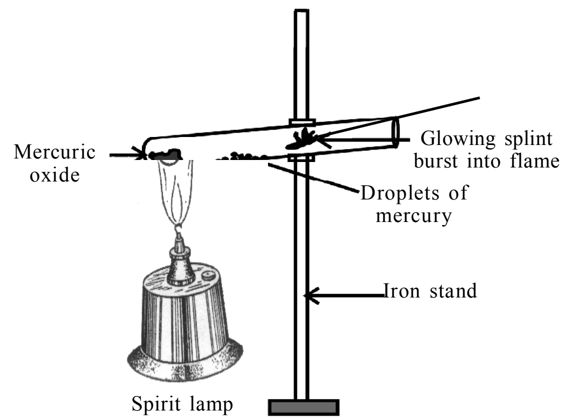


Fig. 2.11. Heating mercuric oxide.

Actually, on heating, mercuric oxide decomposes by the heat into mercury and oxygen. The mercury vaporises and then liquefies on the cooler parts of the test tube. The oxygen is responsible for the glowing splint to burst into flame, because it supports combustion. It is a chemical change.

Since the process of breaking up pure substance has begun, the question now is, can it be continued?

Is it possible to go on breaking up pure substances?

There are many changes which are carried out in which pure substances are involved; some break down and others build up (when magnesium burns, it combines with oxygen to form magnesium oxide). In breaking down, a stage is reached where it is no longer possible to divide a substance any further. In the case of the experiment already carried out, this stage is reached when mercury and oxygen are obtained from mercuric oxide.

So, pure substances can be broken down into different substances. Some pure substances cannot be further broken down. *A pure substance which cannot be split up into anything else by physical and chemical processes is known as an element.* Robert Boyle (1627-1691) is responsible for this modern idea of an element. In 1661, he published a book entilled "*The sceptical chemist"* in which he suggested that an element should be thought of as a substance which could not be broken down further into other substances.

At present, about 115 elements have been identified. Ninety-two elements are naturally occuring and the rest are synthetic i.e. man made. Majority of the elements are in solid state. Two elements mercury and bromine are liquid at room temperature while the elements, gallium and cesium becomes liquid at a temperature slightly above room temperature (30°C or 303K). Eleven elements are in gaseous state at room temperature.

Elements are normally divided into *metals*, *non-metals* and *metalloids*

Examples of metals are iron, copper, aluminium, tin , lead, zinc, sodium, potassium, mercury, silver, gold, etc. Metals usually show some or all of the following properties:

(i) They have shining appearances called *metallic lustre* on freshly cut surfaces.

(ii) They are *good conductors of heat and electricity*.

(iii) They are *malleable*, that is, they can be hammered into sheets.

(iv) They are *ductile*, i.e, they can be drawn into wires.

(v) They are *sonorous*, i.e., they produce a ringing sound when struck.

(vi) Most of them have *high melting and boiling points*. (Sodium, potassium and gallium however, have low melting points. Mercury is a liquid at room temperature.)

(vii) They have *high tensile strength*. (However, sodium and potassium have low tensile strength).

(viii) They have *silvery-grey or golden yellow colour*.

Non metals usually show some or all of the following properties:

(i) They are not lustrous, sonorous or malleable.

(ii) They are non – ductile.

(iii) They are poor conductors of heat and electricity

(iv) They have low melting and boiling points.

(v) They are generally soft and have low tensile strength.

There are exceptions, however. Graphite carbon and iodine have lustre. Carbon fibre is ductile. Graphite is a good conductor of electricity, it has also a high melting point.

Examples of non -metals are hydrogen, oxygen, nitrogen, chlorine, bromine, iodine, carbon, sulphur, phosphorus etc. Diamond and graphite are carbon.

Some elements have intermediate properties between those of metals and non-metals. They are called *metalloids.* Arsenic, antimony, silicon, germanium are examples.

Compounds:

When two or more elements combine, they produce a variety of substances called compounds. We use and come across many compounds in our daily life. Salt, sugar, water, iron rust, sodium bicarbonate, sulphuric acid etc are all compounds. If is for this reason that elements are regarded as the building blocks of all types of substances.

How is a compound formed?

Activity 2.7.

* Prepare a mixture of iron filings and sulphur.
* Observe the mixture with the help of a magnifying lens. We find that the iron filings and the sulphur powder lie side by side.

* Take a magnet and plough it near the mixture.
* The iron filings will be attracted by a magnet.
* Put a portion of the mixture in a beaker containing water, shake and observe. The dark grey iron powder sinks in water while sulphur powder remains floating on the surface.
* Take a small portion of the mixture in a test tube and pour dilute sulphuric acid into it.

The iron filings react with dilute sulphuric (or hydrochloric) acid and a colourless, odourless gas is evolved. It is hydrogen gas.

* Pour a little of carbon disulphide to a portion of the mixture taken in a test tube. Sulphur powder dissolves in carbondisulphide leaving behind iron filings.

What conclusion can you draw from this experiment?

No new substance is formed just by mixing iron and sulphur. The iron filings and sulphur powder lie side by side and can be separated by easy means.

This shows that a chemical reaction does not take place in the process of just mixing iron and sulphur.

What happens when the mixture is heated?

* Mix 14 g of iron powder and 8 g of sulphur powder intimately.
* Fill about half a test tube with the mixture and heat it in the flame of a spirit lamp.
* Observe what happens.
* Remove the source of heat when the heated portion of the mixture begins to glow. (Once the reaction starts it will continue to do so, and an intense heat is generated in the contents).
* When the reaction stops , cool the test tube and break it carefully.
* Remove the glass pieces with a pair of forceps and powder the substance formed.
* Observe the powdered mass through a magnifying lens.
* Plough a magnet near this powder.
* Drop a small quantity of the powder into a beaker containing water.
* Take a small quantity of the powder into a test tube, and pour dilute sulphuric acid or hydrochloric acid into it.
* Draw your conclusion.

When the mixture of iron and sulphur powder in a definite proportion by mass is heated, a new substance is formed. The colour of the new substance (product) is different form that of the initial mixture. It sinks in water. No iron powder can be separated from this new substance with the help of a magnet, nor sulphur powder be removed by dissolving in carbon disulphide liquid.

When dilute sulphuric or hydrochloric acid is poured into the substance, no hydrogen gas is evolved. Instead it gives hydrogen sulphide gas which have rotten egg smell. The substances iron and sulphur have lost their original properties. A new substance having altogether different properties is formed.

The new substance is a compound of iron and sulphur and is called iron sulphide. The reaction may be represented as follows:

Iron	+	***sulphur***	$\xrightarrow{\text{heat}}$	***Iron sulphide***
(dark grey)		(yellow)		(black)
element		element		compound

Thus, we may define "*compound as a substance composed of two or more elements, chemically combined with one another in a fixed proportion*" The composition of a compound is the same throughout.

Notice the difference between elements, compounds and mixtures as shown in the following figures.

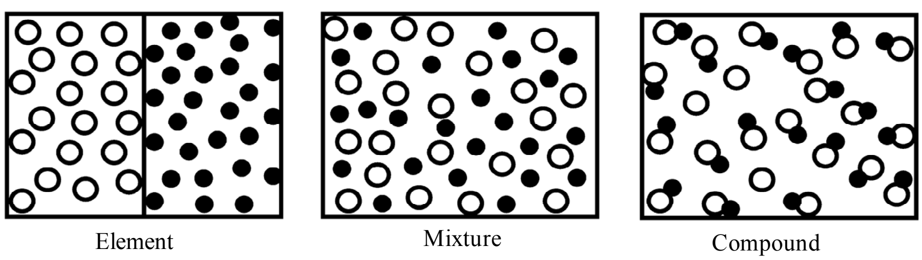


Fig. 2.11. Black and white balls represent different elements. In the middle figure they are simply mixed and remain side by side. But in the right figure, they have combined to form a compound.

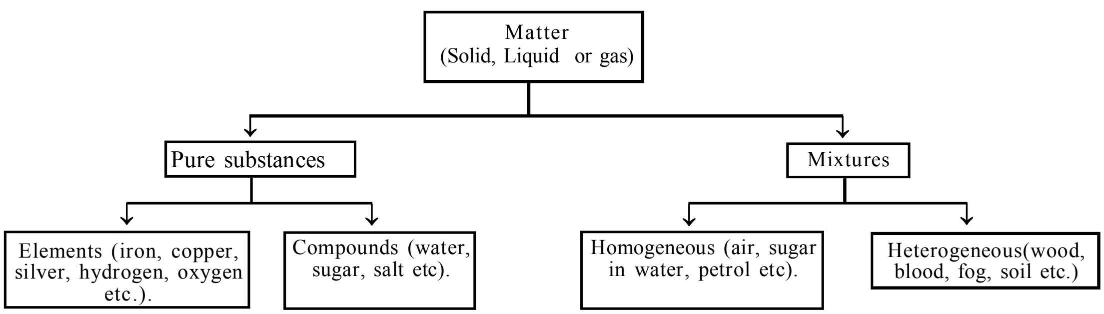
The differences between mixtures and compounds are shown in the following table (table 2.3)

Pure substances and mixtures

Table 2.3. Difference between Mixtures and compounds.

Mixtures	Compounds.
1. Elements or compounds just mix together, not chemically combined and hence no new subs- (compound) is formed.	1. Elements react and combine together to form new substances (compounds). tance
2. A mixture has variable composition and shows the properties of its constituents.	2. A compound has the specific elements combined in a fixed proportion and it has totally different properties.
3. The constituents can be separated fairly easily by physical methods.	3. The components cannot be separated by physical means, but only by chemical or electrochemical means (reactions).
4. The formation of a mixture is a physical change chemical	4. The formation of a compound is a change.
5. A mixture does not have fixed melting point and boiling point.	5. A compound has a fixed melting point and boiling point.

Now we can show the classification of matter as follows:



Let us answer these:

1. Explain why the following are examples of physical changes:
   (i) Mixing of iron and sulphur
   (ii) Boiling of water
   (iii) Sublimation of iodine.
2. Explain why the following are examples of chemical changes:
   (i) Charring of sugar
   (ii) Burning of charcoal
   (iii) Digestion of food.
3. What is meant by saying metals are malleable and ductile?
4. Name one solid, one liquid and one gaseous non- metal.
5. Classify the following into elements, compounds and mixtures:
   graphite, brass, chalk, air, petroleum, sea water, milk, zinc, sodium bicarbonate.
6. List three characteristics by which compounds can be distinguised from mixtures.

SUMMARY

1. A mixture contains two or more elements or compounds mixed in any proportion and not chemically combined together.
2. A mixture can be separated into its constituents (pure substances) by physical processes.
3. A solution is a homogeneous mixture of two or more substances. The substance present in larger proportion in a *solution* is called the *solvent*, and the substance present in smaller proportion, the *solute*.
4. The concentration of a solution is the amount of solute present per unit volume or per unit mass of the solution or solvent.
5. A suspension is a heterogeneous mixture in which small particles of solid visible to the naked eye are spread in a solvent without dissolving in it.
6. A colloid or a colloidal system is a heterogeneous mixture in which particles which are too small to be seen with the naked eye, but is big enough to scatter light are dispersed in a medium called dispersion medium, the particles being called the dispersed phase.
7. Pure substances can be elements or compounds.
8. An element is a substance which cannot be broken down to other simple substances by physical and chemical processes.
9. A compound is a substance formed by two or more elements chemically combined together in a fixed proportion.
10. The properties of a compound are quite different from those of its constituent elements, whereas a mixture shows the properties of its constituent elements or compounds.

EXERCISES

1. *What is sublimation? Give the differences between evaporation and sublimation.*
2. *What are distillation and fractional distillation?*
3. *What separation techniques will you use to separate the following?*
   (a) Common salt from sea water
   (b) Sand and water
   (c) Iodine from a mixture of iodine and sodium chloride
   (d) Different colouring materials from an extract of flower petals
   (e) Butter from milk
   (f) Hydrated copper sulphate from its aqueous solution
   (g) Powdered chalk and sugar

(h) Iron pins from sand
(i) Oil from water

4. *Name three commercial materials obtained from petroleum and state the method used to obtain them*
5. *What is a pure substance? Give three examples each of the two classes of pure substances*
6. *Give the main classification of elements. Mention at least two examples of each type*
7. *Give two pieces of evidences to prove that water is a compound.*
8. *Explain with examples:*
   (a) saturated solution. (b) colloid
   (c) suspension (d) physical changes
   (e) chemical changes.
9. *Classify the following as elements, compounds and mixtures:*
   tap water, distilled water, sugar, paint, filtered tea, air, copper, iodine, wood,soil,soda water.
10. *Which of the following materials fall in the category of a pure substance?*
    (a) iron (b) wood (c) mercury (d) brick
    (e) ice (f) air (g) milk
    (h) carbon dioxide (i) soap
11. *What is Tyndall effect? Which of the following will show Tyndall effect?*
    (a) sugar solution (b) copper sulphate (c) starch solution
    (d) potassium permanganate solution.
12. *Classify the following into physical and chemical changes:*
    (a) Burning of incense stick (b) Sublimation of camphor
    (c) Digestion of food (d) Glowing of electric bulb
    (e) Rusting of iron

CHAPTER – 3

Atoms and molecules

Ancient Indian and Greek philosophers suggested that if we go on dividing matter, a stage will come when particles obtained cannot be divided further. The Indian philosopher Maharishi Kanad called these indivisible particles *parmanu*. The Greek philosopher Democritus called them *atoms* (meaning indivisible). Let us suppose that we have an element iron. If we have a small piece of iron and we start grinding it, it will break into very fine particles which cannot be further subdivided. In a way we will reach a stage when iron particles cannot be further subdivided. This ultimate particle of iron will still possess the properties of iron. Moreover, if iron undergoes chemical change, then this change must start from the ultimate particle. This smallest and ultimate particle of an element is called *atom (Fig.3.1)*.

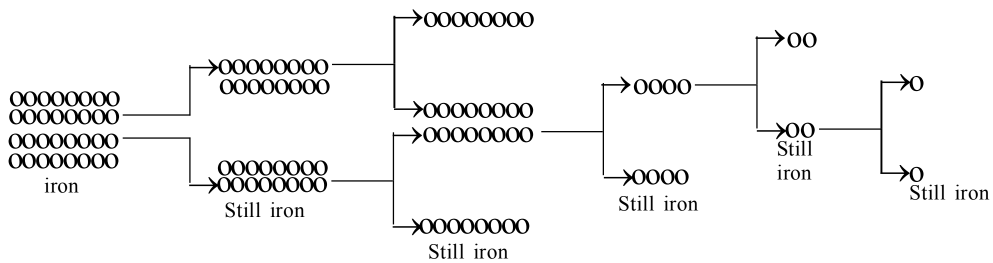


Fig.3.1. Iron divided into very fine particles

All these ideas were based on theoretical considerations and these ideas were validated by experimental works in the eighteenth century.

By the end of the eighteenth century, scientists recognised elements and compounds. They became interested in finding out *how and why elements combine and what happens when they combine.*

3.1. Laws of Chemical Combination:

Is there a change in mass when a chemical change (chemical reaction) takes place?

Activity 3.1.

(1) Take any one of the following pairs of chemicals A and B.

A	B
(i) Barium chloride solution	Dilute sulphuric acid
(ii) Lead nitrate solution	Sodium chloride solution
(iii) Magnesium sulphate solution	Sodium carbonate solution

(2) Take solution of A in a conical flask and some solution of B in a small test tube.

(3) Lower the test tube along with its contents into the conical flask by holding from the free end of a thread tied to its neck.
(4) Fix a rubber cork in the mouth of the flask so that it holds the thread firmly [Fig.3.2(a)].

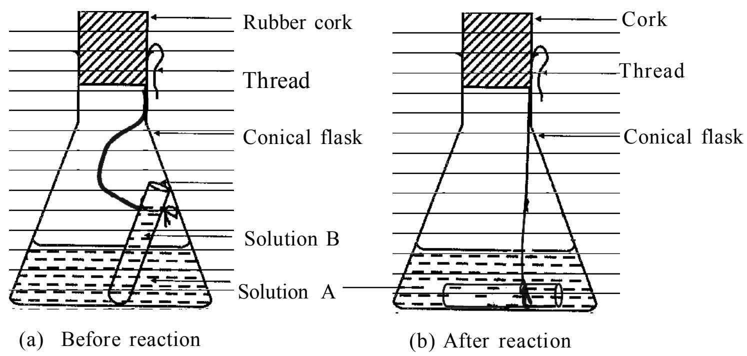


Fig. 3.2. Verification of Law of Conservation of mass.

(5) Find the mass of flask along with its contents by weighing carefully on the balance.
(6) Now tilt and swirl the flask so that the solutions A and B got mixed.
(7) Observe the change in the reaction flask.
(8) Weigh again.
(9) Does the mass of the flask and its contents change?
(10) Does a chemical reaction take place in the flask?

We find that there is no change in mass as a result of a chemical reaction, that is, *mass can neither be created nor destroyed*. This is known as the *Law of conservation of mass.* It was first established by Antoine L. Lavoisier in 1774 after much experimentations.

In 1799, Proust analysed the chemical composition of a large number of compounds and came to the conclusion that the proportion of each element in a compound is fixed. For example, water is a compound which always consists of the same elements, hydrogen and oxygen combined together in the same proportion of 1:8 by mass. If we decompose 9 g of water by passing electric current through it, 1 g of hydrogen and 8 g of oxygen are always obtained. Similarly in pure sodium chloride, sodium and chlorine are always present in the ratio of 23:35.5 by mass, whatever be the method or the source from which it is obtained.

This led to the *law of constant or definite proportions* which says that "*a pure compound always contains the same elements combined in the same proportions by mass",* irrespective of how it is made. Thus vitamin C (ascorbic acid) that has been prepared in the laboratory has the same composition as the vitamin C in fresh fruits and vegetables, and is equally beneficial to us.

Based on the laws of chemical combination, John Dalton put forward his atomic theory of matter in 1808. Dalton's atomic theory could provide an explanation for the law of conservation of mass and the law of definite proportion. The main postulates of the theory may be stated as follows:

(i) Matter consists of very small particles (atoms) which are indivisible.

(ii) Atoms cannot be created or destroyed.

(iii) Atoms of one element are all identical: they have the same mass and the same properties.

(iv) Atoms of different elements have different masses and different properties.

(v) When elements combine to form compounds, the atoms of these elements unite in simple whole number ratios to form compound atoms (now called molecules).

Now think about what happens when powdered iron and powdered sulphur are heated at high temperature. They react vigorously to form the compound iron sulphide (activity 2.7). Dalton pictured such compounds as being composed of two types of atoms. Iron sulphide, for instance, consists of iron atoms and sulphur atoms. Also, because it is impossible to recognise iron and sulphur in iron sulphide, he had to imagine that the iron and sulphur atoms must be compounded or joined together in such a way that their original properties are altered.

Which postulate of Dalton's atomic theory explains the law of conservation of mass?

Since atoms can neither be created nor destroyed (postulate ii), the number and types of atoms taking part in the reaction (reactants) will necessarily be the same as the number and types of atoms in the products. So, the total mass of products is equal to the total mass of reactants.

Which postulate of Dalton's atomic theory explains the law of definite proportions?

Postulates (iii) and (iv) states that atoms of the same element are identical in mass and properties whereas atoms of different elements are different in mass and properties. And, postulates (v) says that different elements combine to form compound atoms in fixed number of ratios. Since the number of atoms, the kind of atoms and the mass of atoms of each element in a compound is fixed, therefore, a compound will always have the same elements combined together in the same proportion by mass.

Now, *an atom is regarded as the smallest particle of an element which can take part in a chemical change*.

You may probably like to think how much of the Dalton's atomic theory, we still accept today in the light of our considerably greater knowledge. For this you have to wait till a later stage.

Let us answer these:

1. Name any two laws of chemical combination.
2. What law of chemical combination was given by
   (a) Lavoisier
   (b) Proust?

3. 10.6 g of sodium carbonate reacted with 7.3 g of hydrochloric acid producing 11.7 g of sodium chloride, 1.8 g of water and 4.4 g of carbon dioxide gas. Show that this data verifies the law of conservation of mass.
4. A pure sample of calcium oxide contains calcium and oxygen in the ratio 5:2 by mass. How many grams of calcium will be required to combine with 32 g of oxygen to form calcium oxide.
5. Which postulates of Dalton's atomic theory can explain:
   (a) Law of conservation of mass and
   (b) Law of constant proportions?

3.2. Molecules:

How do atoms exist?

Dalton believed that all matter is composed of one or more different types of atoms. Each element must therefore consist of one type only, like a wall built of one type of bricks; and each compound must consist of several different types, like a wall built of more than one type of bricks.

Is an atom able to exist independently? It may or may not. According to Amadeo Avogadro, the *molecules*, and not the *atoms* were the smallest material particles that are capable of independent or free existence. A molecule is in general composed of two or more atoms of the same element or of different elements chemically bonded together, which are, of course, indivisible in chemical reactions. Thus, a clear distinction was made between the ultimate particles of matter, viz. the atoms, and the smallest one, capable of free existence with all the relevant properties of the matter, viz. the molecules.

Thus, *a molecule is defined as the smallest particle of an element or compound that is capable of an independent existence and shows all the properties of that substance.*

3. 2.1. Molecules of elements:

Molecules of an element is composed of atoms of the same kind. For example, a molecule of oxygen consists of two atoms of oxygen and hence it is known as a *diatomic molecule*. If three atoms of oxygen unite into a molecule, instead of usual 2, we get ozone. Hydrogen, nitrogen, chlorine molecules also consist of two atom each. The number of atoms constituting a molecule is known as its *atomicity*.

Molecules of some elements, such as helium, neon, argon etc. consist of only one atom of that element. Their molecules are *monoatomic*.

Molecules of metals and some other elements, such as carbon, do not have a simple structure but consists of a very large and indefinite number of atoms bonded together.

Atomicity of some common elements are given in Table 3.1.

Table 3.1. Atomicity of some common elements.

Types of elements	Name	Atomicity
Non-metal	Helium	1 (monoatomic)
	Neon	1 "
	Argon	1 "
	Hydrogen	2 (diatomic)
	Oxygen	2 "
	Nitrogen	2 "
	Chlorine	2 "
	Ozone	3 (triatomic)
	Phosphorous	4 (tetra-atomic)
Metal	Iron	1 (monoatomic)
	Copper	1 "
	Silver	1 "

3.2.2. Molecules of compounds:

Atoms of different elements combine together in definite proportions to form molecules of compounds. For example, water is a compound whose molecules are made up of two atoms of hydrogen and one atom of oxygen. Similarly, a molecule of hydrogen chloride contains one atom of hydrogen and one atom of chlorine combined together. An ammonia molecule is formed when an atom of nitrogen combines with three atoms of hydrogen.

3.3. How big are the atoms and molecules?

If matter is made up of atoms and molecules, how large are the particles? Think of some grains of a solid that can just be seen by our naked eye. We may think of a grain of very finely sieved flour. This has a diameter of about 10^{-1} mm (or 0.0001m) . Using an ordinary microscope it is possible to see pieces of material as small as about 10^{-3} mm (0.001 mm). A modern instrument called the electron microscope is capable of much greater magnification, and this remarkable instrument has detected objects with diameters as small as 10^{-5} mm (0.00001 mm). Clearly, if matter is composed of molecules, the diameter of the constituent particles which make up cannot be larger than about 10^{-5} mm.

In activity 1.3 (chapter 1), it is shown that 0.10g of potassium permanganate can be split into at least 10^{5} parts, so that each part has a mass of about 10^{-6}g. Thus the mass of the particles (molecules) which make up this substance cannot be greater than about 10^{-6}g.

From this evidence and that of electron microscope, it is clear that the particles (atoms or molecules) which appear to exist in all types of matter must be very small indeed. Is it possible to say more precisely how small these particles are?

3.3.1. Finding the approximate size of a molecule:

Activity 3.2.

* Take water in a tray or container (more than 30 cm square so as not to restrict an oil film on the surface)
* Sprinkle the surface of the water with a very thin light powder such as talc powder.
* Put a drop of kerosene on water at the middle of the tray.
* Find out the area of the oil spread out on the water surface pushing the powder away. (Fig. 3.3).
* To find the volume of oil, pour the oil into a burette. Find the volume of fifty drops by running oil from the burette drop by drop and counting the drops.
* Calculate the volume of oil put on the water.
* Finally estimates can be made of the thickness of the oil layer by dividing the volume of the oil by the area it spread out.

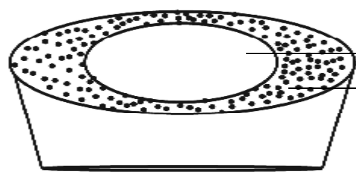


Fig. 3.3

When a drop of oil spreads over the surface of water, it forms a very thin 'skin'. Estimates can be made of thickness of this 'skin'. The smallest values obtained are about 2×10^{-6} mm (0.000002 mm). In this thickness of oil there must be at least one layer of molecules. So oil molecules must be at least as small as 10^{-6} mm in diameter, and they could be even smaller.

3.3.2. Atomic Radii

Since molecules are made up of atoms, they could be even smaller. It is very difficult to imagine anything as small as the atoms. There are about 6×10^{9} people on this planet. There are about 1×10^{11} stars in the milky way. The diameter of our galaxy is about 2.3×10^{17} kilometers. But there are about 6×10^{21} atoms in 1g of silver.

The size of an atom is indicated by its radius which is called atomic radius. Atomic radius is measured in nanometers (nm)

$$1 \text{ nm} = \frac{1}{10^9} \text{ metre}$$

$$= 10^{-9}\text{m}$$

Nowadays, atomic radii can be deduced from X-ray diffraction camera and spectroscopic studies. Atomic radii of some common elements are given below.

Element	Atomic radius	Element	Atomic radius
1. Hydrogen	0.037 nm	Copper	0.128 nm
2. Carbon	0.077 nm	Iron	0.126 nm
3. Oxygen	0.073 nm	Gold	0.144 nm
4. Sulphur	0.104 nm	Sodium	0.191 nm
5. Nitrogen	0.074 nm	Calcium	0.197 nm

3.2.3. Atomic mass:

In his atomic theory, Dalton has proposed that a given element is made up of atoms which have identical masses. The theory could explain the law of constant proportions. This has prompted scientists to measure the mass of an atom directly. However relative atomic masses could be determined using the laws of chemical combinations and the compounds formed.

For example, a compound carbon monoxide is formed by combination of carbon with oxygen. It was found experimentally that 3g of carbon combine with 4g of oxygen to form 7g of carbon monoxide. In other words, carbon combines with 4/3 times the mass of oxygen. Suppose that we have a unit which takes the mass of an atom of carbon as 1, then we would assign the mass of oxygen as $\frac{4}{3}$. It will be more convenient to have these numbers as whole numbers or as near to whole numbers as possible.

Since, 1961, by international agreement, a universally accepted atomic mass unit (amu) has been introduced. In this unit, the mass of one atom of carbon (strictly an atom of carbon-12) is taken as 12 atomic mass units (amu). Earlier atomic mass unit was abbreviated, as "amu", but now, according to IUPAC (International Union of Pure and Applied Chemistry) recommendations, is written as "u"-unified mass). Since a carbon-12 atom has been assigned an atomic mass of exactly 12 u, therefore, the *atomic mass unit has been defined as 1/12 (one-twelfth) the mass of the carbon-12 atom.*

Thus, 1 u = $\frac{1}{12}$ the mass of a carbon -12 atom.

The relative atomic masses of all elements have been found with respect to an atom of carbon-12. The atomic mass is defined as the average relative mass of *an atom of an element as compared to the mass of an atom of carbon taken as 12.*

Relative mass of atoms can be obtained from the masses of elements taking part in a chemical reaction or by an instrument called the mass spectrometre.

The atomic masses of some common elements are given in Table 3.2

Table 3.2 Atomic masses of some common elements

Element	Atomic mass (u)
Hydrogen	1
Carbon	12
Oxygen	16
Nitrogen	14
Chlorine	35.5
Sulphur	32
Sodium	23
Calcium	40
Magnesium	24
Phosphorus	31

Gram atomic mass:

The atomic mass of an element expressed in grams is called the gram-atomic mass of the element.

For example, the atomic mass of oxygen (O) = 16 u

Therefore, gram atomic mass of oxygen (O) = 16 g.

The gram-atomic mass of an element is also called *gram-atom.*

Example:

What is the gram-atomic mass of sodium (Na)?

Solution:

Atomic mass of sodium (Na) = 23 u

Gram atomic-mass of sodium (Na) = 23 g.

Let us answer these:

1. Define an atom.
2. In what unit the radius of an atom is usually expressed?
3. What is a molecule? Explain with an example.
4. What is the difference between the molecule of an element and the molecule of a compound? Illustrate with one example each.
5. What is meant by atomicity? Give example.
6. Define atomic mass. What is meant by saying that atomic mass of Calcium is 40.

SUMMARY

1. Law of conservation of mass states that, the sum of the masses of reactants and products remain unchanged in a chemical reaction.
2. Law of definite proportions states that a pure compound always contains the same elements combined in the same proportions by mass.
3. An atom is the smallest particle of an element which can take part in a chemical reaction.
4. Dalton's atomic theory explains the law of conservation of mass and the law of definite proportions.
5. A molecule is the smallest particle of an element or compound that is capable of independent existence and shows all the properties of that substance.
6. The mass of an atom of carbon -12 is assigned atomic mass of 12 atomic mass units and the atomic mass of other elements are obtained by comparison with the mass of a carbon -12 atom.

EXERCISES

1. *What are the postulates of Dalton's atomic theory?*
2. *3 g of magnesium combines with 2 g of oxygen to produce 5 g of magnesium oxide compound. If 6 g of magnesium is allowed to react with 20 g of oxygen, what mass of magnesium oxide will be produced in the reaction? Name the law which governs your answer.*
3. *Distinguish between atom and molecule of an element.*
4. *Define atomic mass unit.*
5. *Why are atoms regarded as building blocks of all matter?*

Symbols, formulas and equations

Scientists use a shorthand notation to save both time and space when describing atoms and molecules. Each element is represented by a unique symbol. Dalton was the first scientist to use the symbols for elements in very specific sense, such as a *circle* [O] for an oxygen atom, *a circle with a dot* in its centre [⊙] for hydrogen etc.

4.1. Modern symbols of elements:

Berzelius suggested that the first letter of the name of the element in capital should represent a particular element, such as "O" for oxygen, "H" for hydrogen and so on. Examples of this convention include the following (Table 4.1).

Table 4.1. Elements having single letter symbols.

Name of element	Symbol	Name of element	Symbol
Boron	B	Oxygen	O
Carbon	C	Phosphorus	P
Fluorine	F	Sulphur	S
Hydrogen	H	Uranium	U
Iodine	I	Vanadium	V

There are a number of elements, whose names begin with the same letter, for example, barium, bromine, bismuth, beryllium etc. For such elements two-letter combinations are used. The first letter of the symbol is capital and the second letter which is a prominent letter of their English name is small. Examples include the following (Table 4.2).

Table 4.2. Elements having two letter symbols.

Name of element	Symbol	Name of element	Symbol
Aluminium	Al	Lithium	Li
Arsenic	As	Magnesium	Mg
Barium	Ba	Manganese	Mn
Bromine	Br	Nickel	Ni
Bismuth	Bi	Neon	Ne
Beryllium	Be	Calcium	Ca
Silicon	Si	Chlorine	Cl
Platinum	Pt	Cobalt	Co
Zinc	Zn	Chromium	Cr

Symbols of some elements are derived from their Latin or German names. A list of these elements are given below (Table 4.3).

Table 4.3. Elements with symbols derived from Latin names.

Name of element	Latin name	Symbol
Antimony	Stibium	Sb
Copper	Cuprum	Cu
Gold	Aurium	Au
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Potassium	Kalium	K
Silver	Argentum	Ag
Sodium	Natrium	Na
Tin	Stannum	Sn

Significance of the symbol of an Element:

A symbol of an element is not only an abbreviation. It also denotes one atom of that element as well as the mass of an atom. For example, the symbol "Na" represents:

(A) the element sodium

(B) an atom of sodium

(C) the mass of an atom of sodium

Similarly, the symbol for hydrogen, H represents or stands for one atom of the element hydrogen. H also stands for the mass of one atom of hydrogen. H does not symbolise the molecule of hydrogen, because the molecule of hydrogen has two atoms of hydrogen combined together and so H means one atom only of the element.

4. 2. Chemical formula:

How can we symbolise the molecules of an element or of a compound?

We know that a molecule of an element is made up of atoms of the same kind. We have also learnt that atoms of different elements combine in simple numerical ratios to produce compounds . It is therefore, possible to represent the molecule of a substance (element or compound) with the help of symbols of elements present in it. The expression obtained by writing the symbols of the constituent elements side by side and indicating the number of each kind by a subscript figure (placed at the right hand bottom of each symbol) is called a *formula*. For example, a molecule of water contains two atoms of hydrogen and one atom of oxygen. Therefore the formula of water is H_2O. It must be noted that for one atom of an element, no subscript is required as the symbol of an element itself represent one atom of the element.

In the case of molecule of an element, the number of atoms constituting the molecule (atomicity) is written as a subscript after the symbol of that element. For example, a molecule of oxygen is written as O_2. It shows that the molecule contains two atoms of oxygen in combination.

Thus *a chemical formula is a symbolic representation of the composition of the molecule of a substance.*

The molecular formula of some common elements and compounds are given in the following table (Table 4.4).

Table 4.4 Formula of some common substances.

Element	Chemical formula	Compound	Chemical formula
Helium	He	Water	H_2O
Hydrogen	H_2	Common salt	
Oxygen	O_2	(Sodium Chloride)	NaCl
Neon	Ne	Methane	CH_4
Nitrogen	N_2	Ammonia	NH_3
Phosphorous	P_4	Hydrogen Chloride	HCl
Ozone	O_3	Sulphuric acid	H_2SO_4
Chlorine	Cl_2	Nitric acid	HNO_3
Bromine	Br_2	Carbon dioxide	CO_2
Iodine	I_2		
Sulphur	S		

Carbon (C), Sodium (Na), Copper (Cu), Aluminium (Al), Iron (Fe) and all other metals exist as collection of atoms. Such elements are represented by the symbol of their atoms.

4.2.1. Valency:

Atoms combine to form molecules. The combining capacity of an atom of an element to form a molecule is termed valency .

Valency can be used to find out how the atoms of an element will combine with the atoms of other elements to form compounds. Valency can be thought of as hands or arms of that atom. For example, human beings have two arms and an octopus has eight. If one octopus has to catch hold of a few people by their hands so that all the eight arms of the octopus and the two arms of all human beings are locked, how many humans will be held by the octopus? If the octopus is represented by "T" and humans by "M", how can we represent this combination? It comes out to be TM_4. The subscript 4 indicates the number of humans held by octopus.

It is interesting to note that some elements show variable valency. For example, iron combines with chlorine to form two compounds, ferrous chloride ($FeCl_2$) and ferric chloride ($FeCl_3$). In $FeCl_2$, valency of iron is 2 and in $FeCl_3$, the valency of iron is 3.

When a metallic element forms two compounds with another element, the name of the metal in its lower valency state ends with a suffix, "ous" and that in the compound of its higher valency state ends with a suffix "ic", or the valency of the metal is shown within brackets. Thus

Ferrous chloride or Iron (II) Chloride = $Fe Cl_2$

Ferric Chloride or Iron (III) Chloride = $FeCl_3$

Valency of some common metals and non-metals are given in Table 4.5 and 4.6 respectively.

Table 4.5. Valencies of some common Metals

Element	Symbol	Valency
Aluminium	Al	3
Calcium	Ca	2
Copper	Cu	1,2
Iron	Fe	2,3
Lead	Pb	2,4
Zinc	Zn	2

Element	Symbol	Valency
Magnesium	Mg	2
Mercury	Hg	1,2
Potassium	K	1
Silver	Ag	1
Sodium	Na	1

Table 4.6. Valencies of some common non-metals

Element	Symbol	Valency.
Hydrogen	H	1
Fluorine	F	1
Chlorine	Cl	1
Bromine	Br	1
Iodine	I	1
Oxygen	O	2
Sulphur	S	2(4,6)
Nitrogen	N	3 (1,2, 4,5)
Phosphorous	P	3,5
Carbon	C	4

Valencies shown within brackets are not common.

4.2.3. Ions:

Compounds made up of metals and non-metals generally consists of charged species. *The charged species are known as ions.* The charge of the ion may be positive or negative. The positively charged ions are called *cations* and the negatively charged ions *anions.* For example, the compound sodium chloride consists of positively charged sodium ions (Na^+) and negatively charged chloride (Cl^-) ions. Ions may consist of a charged atom or a group of atoms having a net charge on them. A group of atoms carrying a charge is also known as a *polyatomic ion. Thus an ion may be defined as atom or group of atoms having either positive or negative charge.* The compounds which are made up of ions are known as *ionic compounds.* The valency of an ion is equal to the charge on the ion. The valencies of some simple and polyatomic ions are given in Table 4.7.

Table 4.7. Some common, simple and polyatomic ions

Positively charged ions (CATIONS)

Valency	Name of ion	Symbol
1 (Monovalent cation)	Sodium	Na^+
	Potassium	K^+
	Silver	Ag^+
	Cuprous or Cupper (I)	Cu^+
2 (Divalent cation)	Magnesium	Mg^{2+}
	Calcium	Ca^{2+}
	Zinc	Zn^{2+}
	Ferrous or Iron (II)	Fe^{2+}
	Cupric or Copper (II)	Cu^{2+}
3 (Trivalent cation)	Aluminium	Al^{3+}
	Ferric or Iron (III)	Fe^{3+}

Negaively charged ions (ANIONS)

Valency	Name of ion	Symbol
1 (monovalent)	Hydride	H^-
	Chloride	Cl^-
	Bromide	Br^-
	Hydroxide	OH^-
	Ammonium	NH_4^+
	Nitrate	NO_3^-
	Nitrite	NO_2^-
	Bicarbonate (Hydrogen carbonate)	HCO_3^-
2 Bivalent Anion)	Oxide	O^{2-}
	Sulphide	S^{2-}
	Sulphite	SO_3^{2-}
	Sulphate	SO_4^{2-}
	Carbonate	CO_3^{2-}
3 (Trivalent anion)	Nitride	N^{3-}
	Phosphate	PO_4^{3-}
	Phosphide	P^{3-}

4.2.4. Writing chemical formulae:

Knowing the valencies of elements, we can write the formula of their compounds by balancing the valencies of the different atoms which form the compound. The general rules are as follows:

(i) The valencies of the elements (atoms) or the charges of the ions must balance.

(ii) When a compound consists of a metal and a non-metal the name or symbol of the metal is written first. For example, calcium oxide (CaO), sodium chloride (NaCl), zinc sulphide (ZnS) etc, calcium, sodium and zinc are metals and are written on the left, whereas, oxygen, chlorine and sulphur are non-metals, and are written on the right.

(iii) In compounds formed with polyatomic ions, the ion is enclosed in a bracket before writing the number to indicate the ratio.

While writing the chemical formula of compounds, we write the symbols of the constituent elements and their valencies below the symbol. Then we must cross over the valencies of the combining atoms to balance their valencies. The common factor, if there is any, is cancelled out to get a simple whole number ratio.

Example 1.

Formula of hydrogen chloride

Symbols: H Cl

Valency: 1 1

Formula of the compound is HCl

Example 2.

Formula of hydrogen sulphide

Symbol: H S

Valency: 1 2

Formula: H_2S

Example 3.

Formula of ammonia

Symbol: N H

Valency: 3 1

Formula : NH_3

Example 4. Formula of carbon dioxide.

Symbol: C O

Valency: 4 2

Formula : C_2O_4, dividing the formula by common factor 2, we get formula of carbon dioxide as CO_2

Example 5.

Formula of aluminium oxide.

Symbol: Al O

Valency: 3 2

Formula : Al_2O_3

In the formation of an ionic compound, combination takes place between the positive and negative ions in such a way that the resulting molecule as a whole is electrically neutral. In other words, the product of the valency and the number of ions must be the same for both the ions (cations and anions). For this we criss-crossed the charges to get the formula.

Example 6.

Formula of Calcium chloride

Symbol: Ca ↖ ↗ Cl

Charge (Valency): 2^+ ✕ 1^-

Formula: $CaCl_2$

Example 7.

Formula of Magnesium nitrate

Symbol: Mg ↖ ↗ NO_3

Charge: 2^+ ✕ 1^-

Formula $Mg(NO_3)_2$

It is to be noted that we use brackets when we have two or more of the same polyatomic ions in the formula. Here the bracket around NO_3 with a subscript 2 indicates that there are two nitrate groups joined to one magnesium ion.

Example 8.

Formula of ammonium sulphate

Symbol: NH_4 ↖ ↗ SO_4

Charge: 1^+ ✕ 2^-

Formula: $(NH_4)_2SO_4$

Let us answer these:

1. Write down the formula of
   (i) Aluminium nitrate (ii) Zinc sulphide (iii) Calcium hydroxide
   (iv) Aluminium sulphate (v) Iron (II) carbonate
2. Name the following compounds:
   $Cu(OH)_2$, FeS, $Mg_3(PO_4)_2$, $AgNO_3$, $PbCO_3$, $HgBr_2$
3. How many atoms are present in a
   (i) $Al_2(SO_4)_3$ molecule (ii) CO_3^{2-} ion?

4.3. Molecular mass and mole concept:

4.3.1. Molecular mass:

We have discussed the concept of atomic mass in section 3.2.3. Since a molecule is made up of atoms, the concept can be extended to calculate molecular masses. *The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance.* The molecular mass is therefore the relative mass of a molecule expressed in atomic mass units (u). It may be defined as the relative mass of the molecule as compared with the mass of one atom of carbon (C-12) taken as 12 u.

Example 4.1.

Find the molecular mass of water (H_2O)

Solution:

Atomic mass of hydrogen (H) = 1u

,, ,, ,, oxygen (O) = 16u

A water molecule (H_2O) contains two atoms of hydrogen and one atom of oxygen.

$\therefore$ Molecular mass of water (H_2O) = (1×2) + (1× 16)

= 2 + 16

= 18u.

Example 4.2.

Calculate the molecular mass of sodium carbonate (Na_2CO_3)

Solution:

Atomic mass of sodium (Na) = 23

,, ,, ,, Carbon (C) = 12

,, ,, ,, Oxygen (O) = 16

$\therefore$ Molecular mass of Na_2CO_3 = (23 × 2) + 12 + (16 × 3)

= 46 + 12 + 48

= 106.

4.3.2. Calculation of percentage composition from molecular formula:

Can we find out the percentage content of elements present in a compound?

Since a molecular formula gives us the number of atoms of elements which constitute the substance (compound) and also parts by mass of the elements present in the substance, we can calculate the percentage composition of those elements provided the molecular formula of the substance is known.

Example: 4.3

Calculate the percentage composition by mass of the constituents of water.

Solution:

The molecular formula of water is H_2O .

Molecular mass of H_2O = 2 × atomic mass of H atom + atomic mass of 1 O atom

= 2 + 16 = 18 u

$$\therefore \text{ \% of hydrogen} = \frac{2}{18} \times 100 = 11.11$$

$$\text{\% of oxygen} = \frac{16}{18} \times 100 = 88.89.$$

Example 4.4

Calculate the % composition by mass of oxygen in nitric acid.

Solution:

The molecule formula of nitric acid is HNO_3.

Molecular mass of HNO_3 = (1 × H) + (1 × N) + (3 × O)

= 1 + 14 + 48

= 63 u.

$$\therefore \text{ \% composition by mass of oxygen} = \frac{\text{Parts by mass of oxygen}}{\text{Molecular mass of } HNO_3} \times 100$$

$$= \frac{48}{63} \times 100$$

= 76.12.

Example 4.5

Calculate the mass of aluminium present in 34 g of aluminium oxide, Al_2O_3 (atomic mass of Al = 27)

Solution:

Molecular mass of Al_2O_3 = mass of 2 Al atoms + mass of 3 O atoms

= (2 × 27) + (3 × 16)

= 54 + 48

= 102 u.

∴ Mass of Aluminium present in 34g of Al_2O_3

$$= \frac{54\,u}{63\,u} \times 34g$$

= 18 g.

4.3.3 Formula Mass:

The formula unit mass of a substance can be calculated in the same manner as we calculate the molecular mass. The formula unit mass is the sum of the atomic masses of all atoms in a formula unit of a compound. The only difference between the formula unit mass and molecular mass is that we use the word formula unit for those substances whose constituent particles are ions. For example, sodium chloride consists of sodium ion and chloride ions. Its formula unit is NaCl. Hence, the formula unit mass of

NaCl = 23 + 35.5 = 58.5 u.

Example: 4.6

Calculate the formula unit mass of sodium nitrate ($NaNO_3$)

Solution:

Formula unit mass of $NaNO_3$ = 23 + 14 + (16 × 3)

= 23 + 14 + 48

= 85 u.

Gram Molecular Mass:

The molecular mass of a substance (element or compound) expressed in grams is called the gram-molecular mass of the substance. For example, the molecular mass of water (H_2O) is 18 u. Hence, the gram-molecular mass of water (H_2O) is 18 g.

Example 4.7

Calculate gram-molecular mass of methane (CH_4)

Solution:

Molecular mass of methane (CH_4) = Atomic mass of C + 4 × atomic mass of H
= 12 + 4
= 16 u

$\therefore$ gram-molecular mass of CH_4 = 16 g.

Let us answer these:

1. Calculate the molecular masses of
   Cl_2, CO_2, CH_4, NH_3, C_2H_6
2. Calculate the formula masses of
   CaO, K_2CO_3, $NaHCO_3$, H_2SO_4
3. Calculate the gram molecular mass of
   $Al_2(SO_4)_3$ (atomic mass of Al = 27, S = 32)

4.3.4 Mole Concept:

Atomic, molecular and formula masses are just numbers. They are relative numbers and carry no units such as gram (g) or kilogram (kg). They are expressed as numbers and as atomic mass unit (u). In practice and in everyday use, we want to handle substances in grams or kg quantities.

What is the relation between the mass of a substance and those of the atoms or molecules it is made up of ?

The basic unit is the atom or the molecule . We have to find a way to connect the masses of the materials we use everyday with the numbers of atoms or molecules in them. The connection between the everyday world (macroscopic) and the atomic and molecular (microscopic) world is made by the concept of *mole.*

We know that the mass of a hydrogen molecule is 2 a. m. u (u) and that of an oxygen molecule is 32 a. m. u. This means that 2 units of mass of H_2 contain the same number of molecules (one) of H_2 as 32 units of mass of O_2 (also one). If we take two samples, one containing H_2 gas and the other O_2 gas in the mass ratio 2:32, then the first sample must contain exactly as many H_2 molecules as the second contain O_2 molecules.

If the first contains "L" molecules in 2g of H_2, then there must be the same L molecules of O_2 in 32 g of oxygen gas. This also means that the number of grams of any substance equal to its molecular mass (gram molecular mass) must contain "L" molecules. The number of molecules of a substance contained in one gram molecular mass of it will be this fixed number " L". This magic number "L" is experimentally determined and found to be 6.022×10^{23} and is called the *Avogadro number or Avogadro constant* or the *mole*. A mole is thus just a collection of 6.022×10^{23} of the same object. It is thus like the atomic or molecular dozen (12 nos) or gross (144 nos), except that it is just a huge number. One gram of hydrogen is such a large collection of atoms, in fact it has precisely 6.022×10^{23} atoms in it.

A mole of any substance contains the number of elementary particles equal to Avogadro's constant.

It does not matter whether we talk about a mole of atoms, a mole of molecules, a mole of electrons, or a mole of ions, by definition, a mole always contains 6.022×10^{23} elementary particles.

There are 6.022×10^{23} oxygen atoms in a mole of oxygen atoms.

There are 6.022×10^{23} oxygen molecules in a mole of oxygen molecules.

There are 6.022×10^{23} H_2O molecules in a mole of water

There are 6.022×10^{23} Na^+ ions in a mole of sodium ions.

There are 6.022×10^{23} Cl^- ions in a mole of chlorine ions.

There are 6.022×10^{23} electrons in a mole of electrons.

Why is mole so significant?

Besides being related to a number, a mole has one more advantage over other number like dozen or gross. The advantage is that mass of 1 mole of a particular substance is also fixed.

The mass of 1 mole of a substance (element or compound) is equal to its relative atomic or molecular mass in grams (gram atomic or gram molecular mass).

Example 4.7

Relative atomic mass of hydrogen (H) = 1u

gram atomic mass of H = 1 g.

1 u hydrogen has only 1 atom of hydrogen

1 g hydrogen has 1 mole atoms, that is 6.022×10^{23} atoms of hydrogen.

Example 4.8

If 12 g of carbon contains 1 mole of carbon atoms, what is the actual mass of one atom of carbon?

Solution:

$$\text{Mass of 1 atom of carbon} = \frac{12\text{g}}{6.022 \times 10^{23}}$$
$$= 1.99 \times 10^{-23}\ \text{g}.$$

Example 4.9

How many moles are in 20 g of copper metal?

Solution:

The atomic mass of copper is 63.5u

1 mole copper (Cu) = 63.5g.

$\therefore$ Number of moles = $\frac{20g}{63.5g/mol}$

= 0.31mole (nearly)

Example 4.10

How many molecules of oxygen (O_2) are there in 4 g of O_2?

Solution:

Molecular mass of O_2 = 32 u

Gram molecular mass (molar mass) of O_2 = 32 g.

32 g O_2 contains 6.022×10^{23} molecules of O_2

$\therefore$ 4g O_2 contains = $\frac{6.022 \times 10^{23} \times 4}{32}$

= 7.5×10^{22} molecules (nearly)

Example 4.11

How many molecules of water (H_2O) are there in 1 g of H_2O?

Solution:

Molecular mass of H_2O = 18 u

18g H_2O contains 6.022×10^{23} molecules.

$\therefore$ 1 g H_2O will have $\frac{6.022 \times 10^{23}}{18}$ molecules

= 3.346×10^{22} molecules.

The relationship between mole, Avogadro number and mass is given in the following Table (Table 4.8).

Table 4.8. Relationship between mole, Avogadro number and mass.

Mole	No.of particles	Mass
1 mole carbon atoms	6.022×10^{23} atoms of C	12 g Carbon
1 mole of water	6.022×10^{23} molecules of H_2O	18 g water
1 mole of any particle (atoms, molecules, ion)	6.022×10^{23} number of that particle.	Relative mass of those particles in grams
1 mole of molecules	6.022×10^{23} number of molecules	Molecular mass in grams.

A formula of a substance has both *qualitative* as well as *quantitative* meaning. In general, a chemical formula conveys the following information:

(a) *Qualitatively*, it represents:
- (i) The name of the compound.
- (ii) The elements present in the compound.

(b) *Quantitatively*, it represents:
- (i) One molecule of the substance.
- (ii) The number of atoms of various elements which constitute one molecule.
- (iii) The molecular mass of the substance.
- (iv) The number of parts by mass of the elements present in the molecule.
- (v) One mole of the substance.

Let us take the example of CO_2

(a) *Qualitatively*, it represents:
- (i) Carbon dioxide.
- (ii) Carbon dioxide is made up of carbon and oxygen elements.

(b) *Quantitatively*, it represents:
- (i) One molecule of carbon dioxide.
- (ii) One molecule of carbon dioxide consists of one atom of carbon and two atoms of oxygen.
- (iii) Molecular mass of carbon dioxide is $12 + 16 \times 2 = 44u$.
- (iv) 44 parts by mass of carbon dioxide contains12 parts by mass of carbon and 32 parts by mass of oxygen.
- (v) One mole of carbon dioxide i.e. 6.022×10^{23} molecules of CO_2.

Let us answer these:

1. What mass in grams is represented by:
   - (a) 0.44 mole of CO_2
   - (b) 3 mole of NH_3
2. The mass of a single atom M is 3.05×10^{-22} g. What is its atomic mass?
3. Which has more number of atoms, 50g of sodium or 50g of Ca?
   (given atomic mass of Na = 23u, Ca = 40 u)?

4. 4. Chemical equation:

We have learnt that chemical formulas are used in representing molecules and their composition. A chemical reaction also can be represented by chemical equation using symbols and formulas of respective reactants and products.

Let us take the reaction of burning magnesium in oxygen forming magnesium oxide as an example. In words, we can represent it as follows:

Magnesium + Oxygen ® Magnesium oxide.

Using the symbols and formula, this can be written as,

Mg + O_2 ® MgO.

Here, magnesium and oxygen are the *reactants* and magnesium oxide is the *product.* The number of atoms of magnesium in both the reactants and the product is the same. But the number of atoms of oxygen in the reactant and product is not the same. There are two oxygen atoms in O_2. Only one oxygen atom combines with magnesium in MgO. The other atom of oxygen must have combined with another atom of magnesium to form two molecules of MgO. To represent this, we have to put the number 2 before MgO and Mg. Thus we get

2Mg + O_2 ®2 MgO.

Now the total number of atoms on both sides is equal and the equation is balanced.

A *chemical equation is the symbolic representation of an actual chemical reaction with the help of symbols and formulas of respective reactants and products.*

In writing a chemical equation, the reactants and the products are represented by their molecules . For example, elements like hydrogen, oxygen, nitrogen etc. are represented by their molecular formula H_2, O_2, N_2 etc. respectively. However elements such as carbon, sodium, copper, iron etc. are represented by their symbols because they take part in chemical reactions in the form of their atoms.

While writing chemical equations, the following points must be kept in mind:

(i) The reactants (symbols or formula) are placed on the left hand side separated by plus (+) sign which means "reacts with"

(ii) The products are placed on the right hand side separated by plus (+) sign which means "along with"

(iii) The reactants and products are separated by an arrow pointing towards the products (®), or the sign of equality (=) which means 'to produce'.

(iv) Above the arrow, reaction conditions such as catalyst, temperature, pressure etc. may be indicated.

(v) If the product is a gas, it is indicated by an upward arrow (↑) and if the product is a precipitate, it is indicated by a downward arrow (↓).

(vi) Sometimes the physical state of reactants and products are also indicated in a chemical equation.

We know that in a chemical reaction, atoms can neither be created nor destroyed as given by the law of conservation of mass. Hence all the atoms present in reactants must be found in products. The number of atoms present in reactants and products must be equal. Thus *all chemical equations must be balanced*.

Dilute hydrochloric acid reacts with zinc metal to produce zinc chloride and hydrogen gas. To write chemical equation for the reaction, we first write the skeleton equation as follows:

Zn + HCl ® $ZnCl_2$ + H_2

Here, we find that two chlorine and two hydrogen atoms on the product side but only one atom of chlorine and one atom of hydrogen on the reactant side. To balance, we put 2 before HCl.

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

Now the equation is balanced.

Let us take one more example, the reaction between methane and oxygen. Methane (CH_4) burns in oxygen to form water vapour and carbon dioxide (CO_2).

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

To balance hydrogen, we must put 2 as the coefficient of H_2O.

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O.$$

To balance oxygen atoms, we place 2 as the coefficient of O_2 on the reactant side

$$CH_4 + 2O_2 \rightarrow CO_2 + 2\,H_2O$$

The equation is thus balanced.

4.4.1 Information conveyed by a chemical equation

Like symbols and formulas, a chemical equation has also both qualitative and quantitative significance.

Qualitatively, it represents:

(i) What are the reactants and what are the products,

(ii) The composition of reactants and products.

Quantitatively, it represents:

(i) the relative number of each kind of molecules and atoms;

(ii) the relative masses of the reactants and products;

(iii) the number of moles of the reactants and products;

(iv) the volumes of gaseous substances involved.

For example, the chemical equation,

Mg	+	2HCl	$\rightarrow$	$MgCl_2$	+	H_2
24		2(1+35.5) = 73		24 + (2 × 35.5) = 95		2

gives us the following information:

Qualitatively,

(i) It shows that magnesium react with hydrogen chloride to produce magnesium chloride and hydrogen.

Quantitatively, it represents

(i) Two molecules of hydrogen chloride reacts with one atom of magnesium to produce one molecule of magnesium chloride and one molecule of hydrogen.

(ii) 73 parts by mass of hydrogen chloride react with 24 parts by mass of magnesium to produce 95 parts by mass of magnesium chloride and 2 parts by mass of hydrogen.

(iii) Two moles of hydrogen chloride react with one mole of magnesium to produce one mole of magnesium chloride and one mole of hydrogen.

Let us answer these:

1. Verify whether the following equations are balanced or not? If not, balance it.

   (i) $KClO_3$ ® KCl + O_2↑

   (ii) $CaCO_3$ + HCl ® $CaCl_2$ + H_2O + CO_2↑

   (iii) N_2 + H_2 ® NH_3

2. Sodium reacts with water to produce sodium hydroxide and hydrogen gas. Write a chemical equation for the reaction.

POINT TO REMEMBER

* Symbol is the accepted abbreviation of the name of an element
* A symbol represents the name, an atom and the atomic mass of an element.
* A chemical formula is a symbolic representation of the composition of the molecule of a substance.
* The combining capacity of an element is termed valency.
* A charged atom or a group of atoms having a net charge is called an ion.
* The valency of an ion is equal to the number of charges carried by the ion.
* The chemical formula of a compound can be written by balancing the valencies of the elements (atoms) or the charges of the ions.
* A chemical equation represents an actual chemical reaction using symbols and formulas of respective reactants and products.
* The *molecular mass* of a substance can be determined by adding together the atomic masses of all the atoms in a molecule of the substance.
* *Formula mass* is the sum of the masses of all the atoms in the formula of an ionic compound or others where discrete molecules do not exist.
* The molecular mass expressed in grams is termed gram molecular mass.
* The Avogadro constant (L) 6.022×10^{23} is defined as the number of atoms in 12 g of carbon-12.
* The mole is the amount of substance of a system which contains as many elementary units as there are atoms in 12 g of carbon-12.
* 1 mole of atoms has a mass equal to the gram atomic mass.
* 1 mole of particles = 6.022×10^{23} particles of any substance.
* Molar mass is the mass of one mole of a substance.

EXERCISES

1. *What is meant by valency of an element?*
2. *What is meant by the symbol of an element? Explain with examples.*
3. *Give two symbols which have been derived from the Latin names of the elements.*
4. *What is molecule? Explain with an example.*
5. *What is meant by a chemical formula? Write the formula of three elements and two compounds.*
6. *Explain the difference between 2 N and N_2*
7. *Define the molecular mass of a substance.*
8. *Calculate the molecular masses of the following:*
   (a) Ethane, C_2H_6 (b) Calcium carbonate $CaCO_3$
   (c) Copper sulphate, $CuSO_4$ (d) Ethanol, C_2H_5OH
   (e) Acetic acid, CH_3COOH (Atomic masses: Ca = 40, Cu = 63.5)
   (f) Ferrous sulphate (hydrated) $FeSO_4.7H_2O$
9. *Translate the following statements into chemical equations and then balance the equations .*
   (a) Chlorine gas burns in hydrogen gas to give hydrogen chloride.
   (b) Hydrogen sulphide gas burns in air to give water and sulphur dioxide.
   (c) Hydrogen gas combines with nitrogen to give ammonia, NH_3
   (d) Sodium metal reacts with water to give sodium hydroxide and hydrogen gas.
   (e) Aluminium metal replaces iron from ferric oxide Fe_2O_3, giving aluminium oxide and iron.
10. *What is the difference between a cation and an anion? Give examples.*
11. *Name the following compounds. Also write the symbols/ formulas of the ions present in them*
    (a) $CuSO_4$ (b) Na_2SO_4 (c) NH_4NO_3 (d) Na_2CO_3 (e) $CaCl_2$.
12. *Calculate formula masses of the following compounds:*
    (a) Calcium chloride (b) Sodium hydrogen carbonate.
13. *If the valency of carbon is 4 and that of sulphur is 2, work out the formula of the compound of carbon and sulphur. Name the compound.*
14. *An element B shows valencies 2, and 3. Write the formula of its two oxides.*
15. *If the aluminium salt of an anion X is A_2X_3, what is the valency of X? What will be the formula of the magnesium salt of X?*
16. *Define mole.*
17. *How many atoms are there in 0.24 mole of oxygen (O_2)?*
18. *Convert into mole.*
    (a) 12 g of nitrogen gas (b) 15 g of water (c)22 g of carbon dioxide.
19. *What is the mass of*
    (a) 0.2 mole of Chlorine (Cl_2) gas. (b) 0.5 mole of water molecules.
20. *Calculate the number of potassium ions present in 7.45 g of potassium oxide. (at.mass of K = 39u)*

CHAPTER – 5

Structure of the atom

In the previous chapters, we have already learnt that matter is made up of molecules which in turn are made up of atoms. The existence of different kinds of matter is due to differences in atoms constituting them.

Then, what makes the atom of one element different from the atom of another element?

Are atoms really indivisible as proposed by Dalton, or are there smaller constituents inside the atom?

5.1. Charged particles in matter:

One of the first indications that atoms are not indivisible, comes from static electricity and the condition under which electricity is conducted by different substances.

Activity 5.1.

A. (i) Take a glass or ebonite rod and rub it with a silk or fur cloth.
   (ii) Immediately bring the rod near an inflated balloon.
   (iii) Observe what happens.

B. (i) With a plastic comb, comb your hair (dry hair), and bring it near small pieces of paper.
   (ii) Does the comb then attract small pieces of paper?

From the above activities, we can conclude that on rubbing two objects together, they become electrically charged.

Where does this charge come from?

In 1830, Michael Faraday showed that chemical changes occur when electricity is passed through certain solutions called electrolytes. For example, when electricity is passed through water containing a little acid, it is decomposed into hydrogen and oxygen gas. He could calculate the mass of a substance produced by a given quantity of electricity. Thus, Faraday for the first time established relationship between electricity and matter. He stated that electricity is made up of particles called "atoms of electricity". In 1874 G.J. Stoney suggested the name *electron* for the atoms of electricity. However the real credit for the discovery of electron goes to J.J. Thomson.

5.1.1. Discovery of electron:

In 1878, William Crooks, noted that gases are ordinarily poor conductors of electricity. However, when a high voltage charge from an induction coil is applied to tubes filled with gases at very low pressure, it resulted in the production of new kinds of rays. Since these rays travel *from the cathode towards the anode*, they are called cathode rays. Later J. J. Thomson studied the characteristics and the constituents of cathode rays. The apparatus used by him is shown in Fig. 5.1 and the tube used is called a *discharge tube* or a *cathode ray tube*. The cathode rays were found to possess the following characteristic properties (Fig. 5.2, 5.3, 5.4).

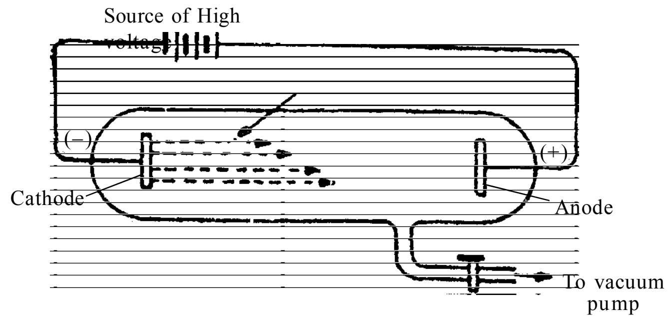


Fig. 5.1. Production of cathode rays

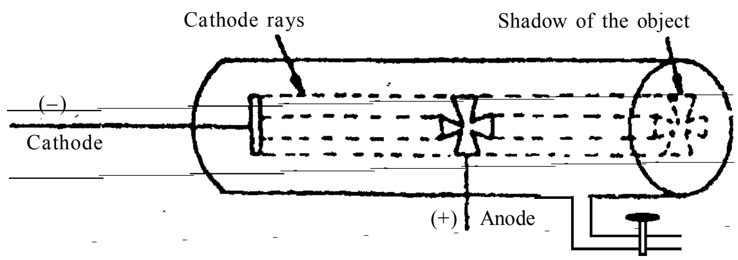


Fig. 5.2. An object in the path of beam of Cathode rays cast a shadow.

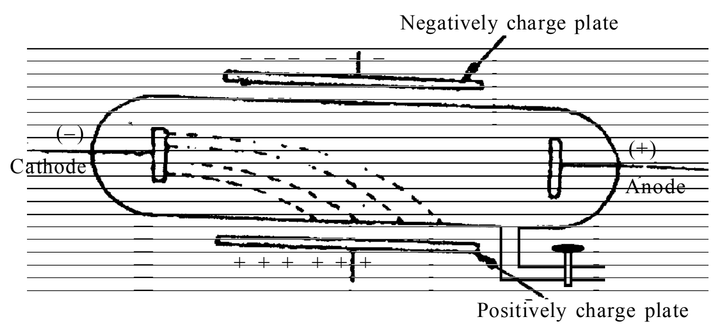


Fig. 5.3. Deflection of the Cathode rays towards a positively charged plate shows that these rays are negatively charged.

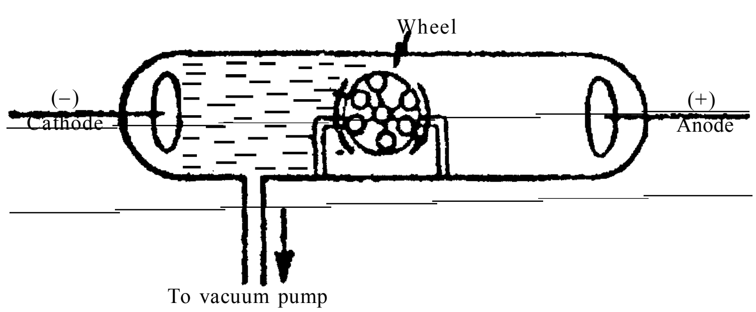


Fig. 5.4. Cathode rays moves a wheel. It shows that the rays consists of particles.

The cathode rays, like light, travelled in a straight line, cast shadows of obstacles but, unlike light, could be bent by electric and magnetic fields. It was thus clear that these rays consisted of charged particles.

Where did these particles come from?

The rays (particles) are emitted from the cathode irrespective of the nature of the metal electrode or the nature of the gas contained in the tube.

Thomson concluded that these negatively charged particles, now called *electrons* are an integral part of all atoms.

Electrons have both definite mass and definite electric charge. It has been found that the mass of the electron is nearly 1/1837 of the mass of hydrogen atom. However, this mass is very small and for all practical purposes, it may be taken as negligible.

The charge of the electron is the smallest known electrical charge. For convenience, this charge has been assigned a value of – 1.

5.1.2. Discovery of Proton:

The formation of cathode rays has shown that all the atoms contain negatively charged particles called electrons. Now, since an atom is electrically neutral, it must contain some positively charged particles to balance the negative charge of electrons. It has actually been found by experiments that all the atoms contain positively charged particles called *protons*.

In 1886, E. Goldstein repeated the cathode ray tube experiment, using a perforated cathode. He demonstrated that positive rays were produced simultaneously with cathode rays. These rays travelled in opposite direction to the cathode (Fig. 5.5). He called these rays *Positive rays* or *Anode rays.*

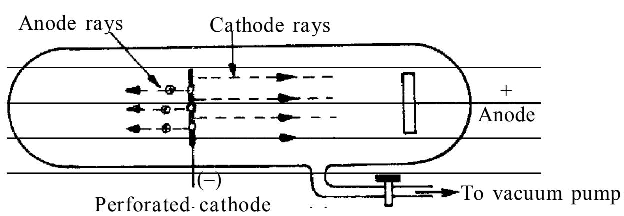


Fig. 5.5

Anode rays consist of positively charged particles. The mass and charge of the anode ray particles depend on the nature of the gas taken in the discharge tube. Different gases give different types of anode rays which contain positively charged particles having different masses and different charges.

Hydrogen gas is the lightest gas and hydrogen atom is the lightest atom. So, the positive particles obtained from hydrogen gas are the lightest and have the smallest charge. These particles were called *Protons*. Goldstein explained that a proton is formed by the removal of the electron from a hydrogen atom. Proton is also a fundamental particle found in the atoms of all the elements. It has been observed that positively charged particles obtained from gases other than hydrogen are multiples of protons.

This means that atoms of other gases consist of more than one proton.

It has been found that the proton is actually a hydrogen atom which has lost its electron. Since the mass of an electron is very small, we can say that the mass of a proton is equal to the mass of a hydrogen atom. But the mass of a hydrogen atom is 1 u, therefore, the relative mass of a proton is 1 u.

The charge carried by a proton has been found to be equal in magnitude but opposite in sign to that of an electron i.e., it has one unit positive charge (+1).

5.1.3. Discovery of the Nucleus (Rutherford's Experiment):

In 1896, Henry Becquerel while conducting experiments with uranium salts found that these salts gave out penetrating radiations spontaneously. The radiation was capable of passing through paper, or even thin sheets of metals, and affected a photographic plate. The phenomenon was called *radioactivity* and the element was called radioactive element.

Soon afterwards, scientists were able to show that three types of radiations called *alpha*, *beta* and *gamma* rays are emitted from radioactive elements. Alpha (a) and (b) were streams of positively and negatively charged particles whereas g-rays carried no charge at all.

Ernest Rutherford was interested in knowing how the protons and electrons are arranged within an atom. In 1911, he directed a stream of alpha particles from a radioactive source towards a very thin gold foil (Fig. 5.6). (He selected a gold foil because he wanted as thin a layer as possible). Alpha particles are doubly – charged helium ions with mass 4 u.

The following observations were made from his experiment:

(i) Most of the alpha (a) particles (nearly 99%) passed through the gold foil undeflected.
(ii) A few of them got deflected through small angles.
(iii) Very few (about one in 100,000) did not pass through the foil at all but suffered large deflections (more than 90 degrees) or even returned back in the direction from which they came.

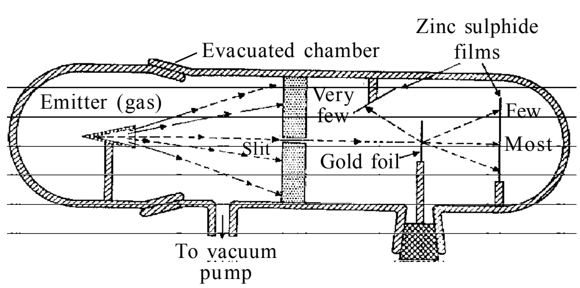


Fig.5.6. A schematic representation of several experiments in which gold foil was bombarded with a beam of alpha particles. Zinc sulphide emits a flash of light when struck by an alpha particle.

Can you correlate these facts and frame theories to explain these observations regarding structure of atom?

Rutherford explained these observations as follows:

(i) Gold is a dense solid. It can hardly be compressed. It means that the atoms of gold actually touch one another (closely packed).

(ii) Since most of the a-particles pass through the gold foil undeflected, there must be a very large empty space within the atom.

(iii) Alpha particles are positively charged and have considerable mass. They can be deflected only if they come close to some heavy, positively charged mass, due to the force of repulsion. Since most of the a-particles are deflected to certain angles, it implies that there is a heavy, positively charged mass present in the atom. Moreover, this mass must be occupying a very small space within the atom because only a few particles suffered large deflections.The positively charged core in which the mass of the atom is concentrated and occupies a small volume in an atom is called the *nucleus*.

(iv) The strong deflections, bouncing or even bouncing back of a-particles from the foil were explained to be the result of a direct collision with the positively charged nucleus of the atom.

(v) The atoms themselves appear to be neutral, since gold is neither attracted nor repelled by charged bodies. It means that in each atom there are just enough electrons outside the positive nucleus to provide a balance of positive and negative charges.

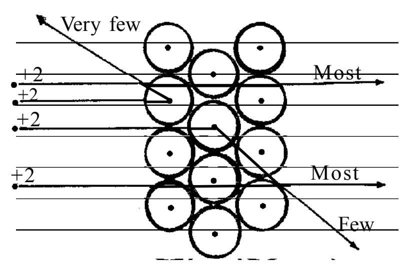


Fig. 5.7. Deflection of α-particles by gold atoms. Rutherford evolved the idea of an atom as a particle that has a definite radius and is mostly empty space, but has a tiny, massive, positive nucleus. The tiny dots at the left represent alpha particles, the spheres represent gold atoms, the tiny dots in the centre of each sphere is the nucleus of the atom.

Rutherford pictured the model of an atom (Fig. 5.7). He put forward the nuclear model of the atom which has the following features:

(i) There is a tiny positively charged centre in an atom called the nucleus. Nearly all the mass of an atom is concentrated in the nucleus. The positive charge of the nucleus is due to the protons. The electrons revolve around the nucleus in well-defined orbits and forms the outside surface (extra nuclear part) of the atom.

(ii) Between the nucleus and the outer electrons is empty space except for other electrons.

(iii) The size of the nucleus is very small compared to the size of the atom.

Present information, obtained largely from x-ray investigations, have indicated that the diameter of an atom is about 10^{-8}cm and that of the nucleus is about 10^{-13} cm, or only 1/100,000 that of the atom.

5.1.4. Atomic number:

Moseley, in 1913 tried to determine the exact number of positive charges present in the nucleus of an atom by studying the nature of the x-rays emitted when different elements were bombarded with cathode rays. (You will learn the details of the process in higher classes). *Moseley* stated that the "*number of positive charges on the nucleus increases from atom to atom by a single electronic unit* ". The number of positive charges is now called the *atomic number* which is 1 for hydrogen, 2 for helium, 3 for lithium, and so on.

Since the subatomic positive particle is, the proton, and as each proton carries one unit positive charge, the *atomic number*, *then, is the number of protons in the nucleus of an atom*. Since the atom, on the whole, is neutral, the number of protons in the nucleus is equal to the number of electrons outside the nucleus. The atomic number is denoted by Z.

Thus the atomic number (Z) = Nuclear charge or number of protons.
= Number of electrons.

5.1.5. Discovery of Neutron:

Until 1920, an atom was supposed to consist of two fundamental particles i.e., electrons and protons only. Since electrons have negligible mass, the entire mass of the atom was regarded as the mass of protons in the nucleus. This means that the nucleus must contain protons equal to the mass of the atom (atomic mass). But, the number of protons is equal to the atomic number. This means that atomic mass should be equal to the atomic number. However, it has been found that for all atoms *except hydrogen, the atomic mass is more than the atomic number.* For example, the atomic number of helium is two and, thus, it should have two protons in the nucleus and two extra-nuclear electrons. Therefore, the helium atom should have a mass twice that of the hydrogen atom. However, its mass has been found to be 4 times that of the hydrogen atom (atomic mass of He = 4 u). To solve this problem, Rutherford predicted the presence of some *neutral* particle in the nucleus of the atom.

The neutral particle called *neutron*, was discovered by James Chadwick in 1932 when he bombarded a thin foil of beryllium metal with a-particles.

The neutral particle (neutron) was found to have a mass which is nearly the same as that of hydrogen but no charge.

The discovery of neutrons made it clear that the nucleus of the atom consists of protons and neutrons. Since the electrons have negligible mass, the entire mass of the atom is mainly due to protons and neutrons present in the nucleus. They are collectively called **nucleons*. *The sum of the number of protons and neutrons present in the nucleus of an atom is called the mass number*. The mass number is denoted by (A).

* A few other particles like positrons, mesons, neutrinos etc. were also found to be present in the nucleus at a later stage. But since they have negligible mass, the mass of the nucleus is due to protons and neutrons only.

Thus mass number (A) = No. of protons + No. of neutrons.

It may be noted that the mass number of an element is nearly same as its atomic mass but the latter has certain units of measurements. However, whereas the mass number is always a whole number, the atomic mass of the element may not be whole number always.

From the above studies, it can be summed up that an atom consists of three fundamental particles — electrons, protons and neutrons. Their masses and charges are given in Table 5.1.

Table 5.1. Fundamental Particles of an Atom

Particle	Mass		Charge
	in gram	in u (amu)	(unit charge is 1.062×10^{-19} coulombs)
Electron	9.110×10^{-28}	0.00055	– 1
Proton	1.673×10^{-24}	1.00728	+ 1
Neutron	1.675×10^{-24}	1.00866	No charge

If we know the atomic number and the mass number of an element, we can calculate the number of protons, electrons and neutrons present in the atom.

Example 5.1

The atomic number and the mass number of the element aluminium (Al) is 13 and 27 respectively. How many protons, electrons and neutrons are present in the atom?

Solution:

We know that,

Atomic no. = No. of protons = No. of electrons

$\therefore$ No. of protons = 13

No. of electrons = 13

Mass no. = No. of protons + No. of neutrons

$\therefore$ Number of neutrons = 27 – 13

= 14.

The atomic number and mass number of the first twenty elements are given in Table 5.2.

It is customary to designate an atom by its symbol for the element with the atomic number (Z) at the lower left and the mass number (A) written at the upper left. For example, the element carbon C with mass number 12 and atomic number 6 may be written as

Mass number ® 12

Atomic number ® 6C

Table 5.2. Atomic numbers (Z) and mass numbers (A) of first twenty elements.

Atomic No.	Element	Mass No.	Notation
1	H	1	${}^{1}_{1}H$
2	He	2	${}^{4}_{2}He$
3	Li	7	${}^{7}_{3}Li$
4	Be	9	${}^{9}_{4}Be$
5	B	11	${}^{11}_{5}B$
6	C	12	${}^{12}_{6}C$
7	N	14	${}^{14}_{7}N$
8	O	16	${}^{16}_{8}O$
9	F	19	${}^{19}_{9}F$
10	Ne	20	${}^{20}_{10}Ne$
11	Na	23	${}^{23}_{11}Na$
12	Mg	24	${}^{24}_{12}Mg$
13	Al	27	${}^{27}_{13}Al$
14	Si	28	${}^{28}_{14}Si$
15	P	31	${}^{31}_{15}P$
16	S	32	${}^{32}_{16}S$
17	Cl	35	${}^{35}_{17}Cl$
18	Ar	39	${}^{39}_{18}Ar$
19	K	39	${}^{39}_{19}K$
20	Ca	40	${}^{40}_{20}Ca$

5.1.6. Isotopes and Isobars:

One of the postulates of Dalton's atomic theory states that atoms of the same element are identical in all respects. But later investigations by scientists have shown that there are elements in which atoms have the same number of protons but different number of neutrons. This means that the atoms have the same atomic number but different mass numbers.

The atoms of the same element having the same atomic number but different mass numbers are called isotopes of the element.

Many isotopes were discovered with the help of an instrument called *mass spectrometer*. Hydrogen has been found to have three isotopes known as *protium* (ordinary hydrogen), *deuterium* and *tritium* having mass numbers 1, 2 and 3 respectively. The first isotope contains one proton only (Z = 1, A = 1), the second contains 1 proton and 1 neutron (Z = 1, A = 2), and the third has one proton and two neutrons (Z = 1, A = 3). The term "hydrogen" is strictly used only for the first isotope (${}^{1}_{1}H$) while Deuterium (${}^{2}_{1}D$) and Tritium (${}^{3}_{1}T$) are used to refer to the second and third isotopes respectively. These may be shown as:

Subatomic particles	ISOTOPES		
	$^{1}_{1}H$ (hydrogen)	$^{2}_{1}H$ or $^{2}_{1}D$ (deuterium)	$^{3}_{1}H$ or $^{3}_{1}T$ (tritium)
Proton	1	1	1
Neutron	0	1	2
Electron	1	1	1

Each of them has only one proton and one electron, but differs in the number of neutrons.

The isotopes of other elements do not have special names. They are indicated by giving mass numbers (A value) on the symbol of the element. For example, ^{12}C and ^{14}C are the isotopes of carbon, they are known as carbon -12 and carbon -14 respectively. ^{235}U, ^{238}U and ^{239}U are the isotopes of uranium having mass numbers 235, 238 and 239 respectively.

Many elements consists of atoms which are isotopes, that is, elements are made up of a mixture of isotopes. The chemical properties of isotopes are similar since they have the same number of protons and electrons. Their electronic arrangements are same.

However, the physical properties of the isotopes of an element may be slightly different due to difference in their mass numbers.

When an element has isotopes, question arises, what should be the atomic mass of the element? For example, chlorine occurs in nature in two isotopic forms, with masses 35 u and 37 u in the ratio of 3:1. The mass of an atom of any natural element is taken as the average mass of all the naturally occuring atoms (Isotopes) of that element.

The average atomic mass of chlorine atom on the basis of the above data will be

$$\left[\left(35\times\frac{75}{100}\right)+\left(37\times\frac{25}{100}\right)\right] \text{ or } \frac{35\times3+37\times1}{4} \text{ or } 35.5 \text{ u.}$$

It does not mean that any one atom of chlorine has a fractional mass of 35.5 u. It means that if we take a certain amount of chlorine, it will contain both isotopes of chlorine and the average mass is 35.5 u.

Since the chemical properties of all the isotopes of an element are the same, normally we are not concerned about taking a mixture.

However, there are two types of isotopes. One type of isotopes are stable but another type is unstable. The unstable isotopes emit various types of radiations and penetrating particles. They are called *radioactive isotopes* or just *radioisotopes*. Depending on their special properties, some isotopes are found useful in various fields. Examples include:

(i) Use of an isotope of uranium known as Uranium-235 as fuel in nuclear reactors.
(ii) An isotope of cobalt known as cobalt-60 is used in the treatment of cancer.
(iii) An isotope of iodine (iodine-131) finds application in the treatment of diseases like goitre.

Isobars:

Atoms of different elements i.e., atoms having different atomic numbers may have the same mass number. These atoms are called *isobars*. For example, $^{14}_{6}C$ and $^{14}_{7}N$ do not have the same atomic number, but they have the same mass number. Hence they are isobars of each other. $^{40}_{18}Ar$, $^{40}_{19}K$, $^{40}_{20}Ca$ are also isobars.

Let us answer these:

1. Who proposed the atomic theory?
2. From which electrode do the cathode rays originate?
3. What happens to cathode rays when they are subjected to an electric field?
4. What is the charge of an electron?
5. Where is the mass of an atom concentrated?
6. What are the particles present in the nucleus of an atom?
7. Where are the electrons in an atom found?
8. Which atom contains only two fundamental particles?
9. What led Rutherford to discover the existence of nucleus?
10. Define:
    (a) atomic number and
    (b) mass number.
11. What are isotopes? Give one example.
12. What are cathode rays and how do they differ from positive rays?
13. Give experimental evidence to show that:

(i) the entire mass of an atom is practically concentrated in the nucleus.
(ii) the nucleus of an atom is positively charged.

14. Derive a relationship between atomic number, mass number and number of neutrons in an atom.
15. How many protons, electrons and neutrons are there in the following atoms?

    $^{14}_{7}N$, $^{12}_{6}C$, $^{14}_{6}C$, $^{14}_{8}O$, $^{16}_{8}O$, $^{40}_{19}K$, $^{40}_{18}Ar$

    Which of these are
    (a) isotopes and
    (b) isobars.

5.2. Models of atom:

Dalton's atomic theory had suggested that the atom was indivisible and indestructible. Now at least three fundamental particles (electrons, protons and neutrons) have been discovered to be present inside the atom.

How far Dalton's atomic theory will be tenable in respect of this postulate?

It is considered necessary to find out how electrons, protons (and neutrons) are arranged within an atom. For explaining this, many scientists proposed various atomic models.

5. 2.1. Thomson's Model:

An atom is electrically neutral. It contains positive charges (due to the presence of protons), as well as, negative charges (due to the presence of electrons). Hence, J. J. Thomson assumed that *an atom is a uniform sphere of positive charges with electrons embedded in it.**

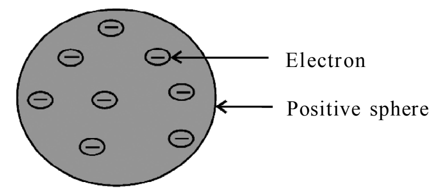


Fig. 5.8 Thomson's model of an atom.

Thus, the atom may be visualised as a pudding or cake of positive charge with raisins (electrons) embedded into it (Fig. 5.8).

This model of atom explains the electrical neutrality of atom, but it failed to stand for a long time as it was not consistent with the experimental results obtained by Rutherford.

5.2.2. Rutherford's model:

With the discovery of the nucleus, Rutherford proposed an atomic model similar to the structure of solar system. Just as in the solar system, the sun is at the centre (having the maximum mass) and the planets revolve around it, in an atom, the nucleus contains the main mass and the electrons revolve around it in orbits or shells.

The outward (centrifugal) force acting on the electrons balances the inward (centripetal) force of attraction exerted on them by the nucleus. This accounts for the stability of an atom.

The Rutherford's model of atom suffers from the following defects:

Any particle in a circular orbit would undergo acceleration. According to the electromagnetic theory, if a charged particle (electron) is accelerated around an oppositely charged particle (nucleus), the electron would continuously radiate or lose energy. So, the revolving electron continuously losing energy will gradually come closer to the nucleus and finally fall into the nucleus. If this were so, the atom should be highly unstable and hence matter would not exist in the form that we know now. But, in reality, this does not happen, we know that atoms are quite stable.

5.2.3. Bohr's model of atom:

In order to remove the drawbacks of Rutherford's model of the atom, Niels Bohr proposed a theory for the structure of atom. According to this theory:

(i) The nucleus is situated at the centre of the atom.

(ii) The electrons revolve around the nucleus in definite circular fixed orbits. These orbits are associated with definite energies and are called *energy shells* or *energy levels*.

* At Thomson's time, no neutron was discovered. Hence, this model of atom later became known as the "raisin pudding" model.

(iii) The orbits or shells are numbered as 1, 2, 3, 4 .....etc. (from the nucleus) or alternatively these are designated as K. L, M, N......etc. shells (Fig. 5.9).

(iv) As long as electron remains in a particular orbit, it does not lose or gain energy. This means that the energy of the electron in a particular energy level shall remain constant. Therefore, these orbits are also called *stationary states.*

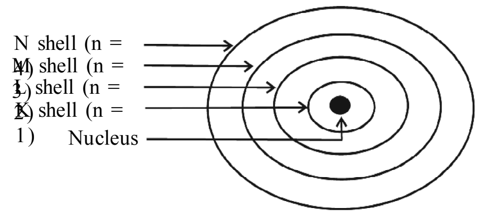


Fig. 5.9. A few energy levels in an atom.

(v) To change from one orbit to another the electron must absorb or emit a quantity of energy exactly equal to the difference in energy between the two orbits.

This model of the atom explains satisfactorily the stability of the atom.

Let us answer these:

1. Which subatomic particle was not present in Thomson's model of the atom?
2. State one drawback of Rutherford's model of atom.
3. Why is an atom neutral inspite of the presence of charged particles in it?
4. How did Neils Bohr explain the stability of the atom?
5. What are the various letters used in Bohr's model to represent electron shells in an atom?
6. Draw a sketch of Bohr's model of an atom with three shells.

5.3. How are electrons distributed in different orbits (shells)?

Based on several experimental observations, Bohr and Bury suggested a scheme for the distribution of electrons in different orbits or shells (energy levels). The scheme consists of the following rules.

(i) The maximum number of electrons that can be present in a shell is given by the formula $2n^2$, where 'n' is the orbit number or energy level index, 1, 2, 3......
Thus,
For the first orbit (n = 1) or K-shell, maximum number of electrons = $2 \times 1^2 = 2$.
For the 2nd orbit (n = 2) or L-shell, maximum number of electrons = $2 \times 2^2 = 8$.
For the 3rd orbit (n = 3) or M-shell, maximum number of electrons = $2 \times 3^2 = 18$.
For the 4th orbit (n = 4) or N-shell, maximum number of electrons = $2 \times 4^2 = 32$, and so on.

(ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8 and the next to outermost known as penultimate orbit cannot have more than 18 electrons.

(iii) It is not necessary for an orbit to be completed before the next orbit starts filling. In fact, a new orbit begins when the previous orbit gets 8 electrons.

5.3.1. Electronic configuration of atoms (Elements):

The hydrogen atom, the lightest of all atoms has one proton in the nucleus and one electron revolving around it. The electron occupy K-shell. A helium atom has a nucleus containing 2 protons and 2 neutrons. Both the electrons revolving around the nucleus are accommodated in the K-shell according to the $2n^2$ rule. (Fig. 5.10).

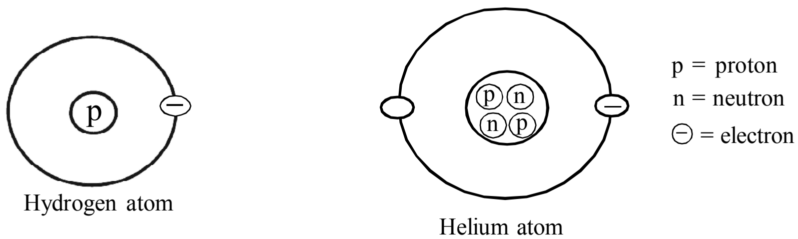
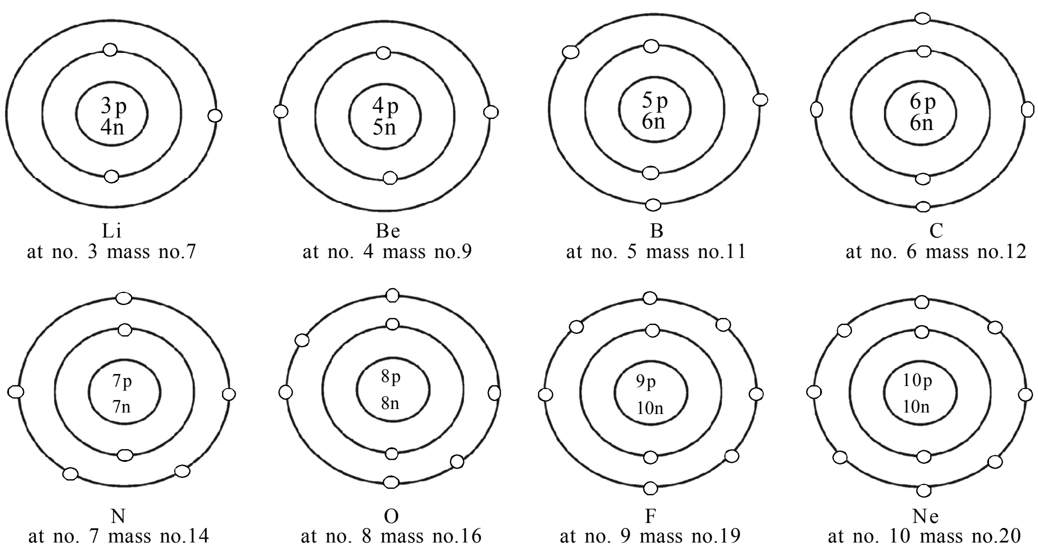


Fig. 5.10.

The distribution of electrons in various shells of an atom is known as its electronic configuration. The precise details of the electronic configuration of atoms will only he dealt in higher classes.

Atomic structures of Lithium to Neon:

For lithium (Z=3), the atom contains 3 electrons. The first 2 electrons are accommodated in the K-shell since it can take in a maximum of 2 electrons only according to the $2n^2$ rule. Now the third electron is naturally accommodated in the L-shell. The electronic structure of the atoms of elements from Li to Ne are shown below



After neon, the next electron goes to the third orbit. The electronic structure of sodium (at.no.11) to Argon (at.no.18) may be shown as follows:

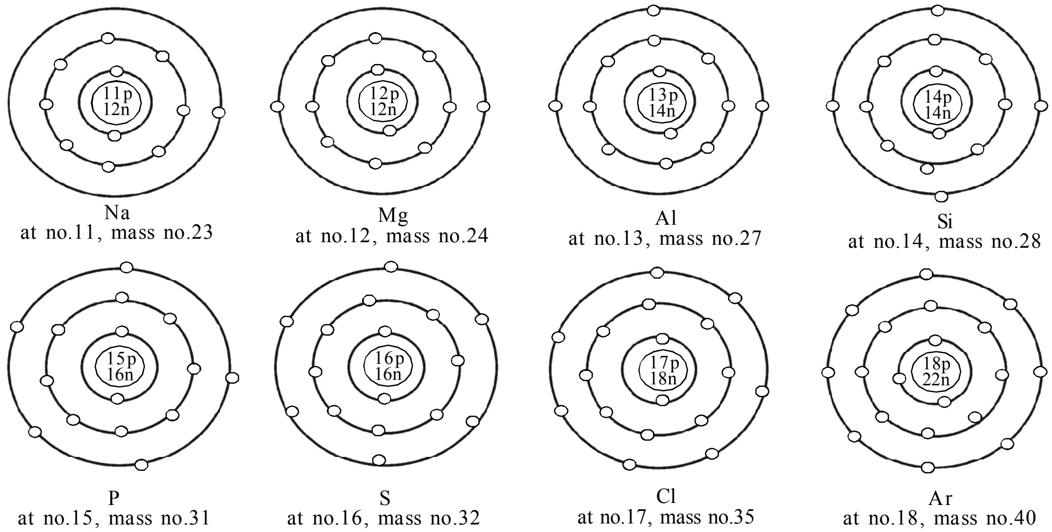


Fig. 5. 11

Exercise:

Write the electronic configuration of potassium (Z = 19) and Calcium (Z = 20)

Solution:

Element	Symbol	At no.	Electrons in shells K, L, M, N
Potassium	K	19	2 8 8 1
Calcium	Ca	20	2 8 8 2

Let us answer these:

1. Write the distribution of electrons in oxygen and sodium atoms.
2. An atom has 2 and 7 electrons in the K and L shells respectively, then what would be the atomic number of the element? Name the element.

5.4. Valence electrons

We have learnt that atoms combine to form molecules. At what part of the atom will the combination take place? Naturally, it will be the outermost shell of an atom. The outermost electron shell of an atom is known as *valence shell. The electrons present in the outermost shell of an atom are known as valence electrons because they determine the combining capacity or valency of the atom.* Only the valence electrons of an atom take part in chemical combinations because they have more energy than the inner electrons of the atom.

From Bohr-Bury scheme, we know that the outermost shell of an atom can accommodate a maximum of 8 electrons except when the outermost shell is K-shell and it can hold a maximum of 2 electrons only. It has been observed that the atoms of elements, having a completely filled outermost shell i.e. 8 electrons show little chemical activity. An outermost shell, which had eight electrons was said to possess an octet in the outermost shell. In other words, the valency of the atoms having octet in their valence shells are zero. These elements are known as *inert* or *noble elements*. Helium, neon, argon, krypton, xenon are inert elements. Since they are all gases, they are also known as inert or noble gas elements. Of these inert elements, the helium atom has two electrons in its outermost shell i.e. K-shell for which it represents full or stable structure.

The combining capacity of the atoms of an element is the tendency to react or form molecules with other atoms of the same or different elements. It was thus explained as the tendency to attain a fully filled outermost shell or stable structure, i.e. octet of electrons in the outermost shell (except Helium structure).

The number of electrons gained, lost or shared so as to make the octet of electrons in the outermost shell, gives us directly the combining capacity or valency of the element.

Example:5.1. What will be the valency of lithium, sodium and potassium?

Solution:

Lithium (Z = 3), sodium (Z = 11) and potassium (Z = 19) atoms contain one electron in each of their outermost orbit or shell (Valence shell).

Li (Z = 3): K-2, L-1.
Na (Z= 11): K-2, L-8, M-1.
K (Z = 19) : K-2, L-8, M-8, N -1.

Each one of them can lose one electron to achieve stable structure.

They have valency of one.

Example 5.2. What will be the valency of Magnesium and Aluminium?

Solution:

Electronic arrangement (configuration) of:

Mg (Z = 12) atom is K-2, L= 8, M = 2. and Al (Z = 13) atom is K-2, L = 8, M = 3.

The valence electrons of Mg and Al are 2 and 3 respctively.

Hence, the valency of Mg and Al will be 2 and 3 respectively.

If the number of electrons in the outermost shell of an atom is close to its full capacity, i.e., octet, then the valency is determined in a different way.

Example 5.3. What will be the valency of fluorine (Z = 9)?

Solution:

Fluorine (at.no. 9) has the configuration: K = 2, L = 7. Fluorine atom has 7 electrons in the outermost (valence) shell. It is easier for fluorine to gain one electron instead of losing seven electrons.

Hence, the valency of fluorine is determined by subtracting seven electrons from the octet and gives us a valency of 1 for fluorine.

Valency can be calculated in a similar manner for atoms having outermost shell (valence shell) close to its full capacity (octet).

Example 5.

What will be the valency of oxygen?

Solution:

The electric configuration of oxygen (Z= 8) is : K= 2, L = 6.

Oxygen has 6 valence electrons, short of 2 electrons to get octet.

Hence, valency of oxygen = (8 – 6) = 2.

Therefore, an atom of each element has a definite combining capacity, called valency. The valency is related to the number of electrons in the outermost orbit or shell of an atom.

Electronic arrangement in various shells (or electronic configuration of atoms) and the composition of the first twenty elements and their valencies are given in Table 5.3.

Table 5.3. Composition of atoms of the first twenty elements with electron distribution in various shells and their valency.

Sl No.	Element	Symbol	Atomic no.	No. of Protons	No. of neutrons	No. of electron	Distribution of electrons				Valency
							K	L	M	N	
1	Hydrogen	H	1	1		1	1				1
2	Helium	He	2	2	2	2	2				0
3	Lithium	Li	3	3	4	3	2	1			1
4	Beryllium	Be	4	4	5	4	2	2			2
5	Boron	B	5	5	6	5	2	3			3
6	Carbon	C	6	6	6	6	2	4			4
7	Nitrogen	N	7	7	7	7	2	5			3
8	Oxygen	O	8	8	8	8	2	6			2
9	Fluorine	F	9	9	10	9	2	7			1
10	Neon	Ne	10	10	10	10	2	8			0
11	Sodium	Na	11	11	12	11	2	8	1		1
12	Magnesium	Mg	12	12	12	12	2	8	2		2
13	Aluminium	Al	13	13	14	13	2	8	3		3
14	Silicon	Si	14	14	14	14	2	8	4		4
15	Phosphorous	P	15	15	16	15	2	8	5		3,5
16	Sulphur	S	16	16	16	16	2	8	6		2
17	Chlorine	Cl	17	17	18	17	2	8	7		1
18	Argon	Ar	18	18	22	18	2	8	8		0
19	Potassium	K	19	19	20	19	2	8	8	1	1
20	Calcium	Ca	20	20	20	20	2	8	8	2	2

Let us answer these:

1. The nucleus of an atom has 7 protons 8 neutrons. What would be the
   (i) atomic number
   (ii) mass number,
   (iii) the number of electrons, and
   (iv) the number of valence electrons?
2. What is the general name of the elements having 8 electrons in the outermost shells of their atoms?
3. The atomic number of an element X is 15.
   (i) Write down the electronic configuration of X.
   (ii) What will be the valency of X?
4. How will you find the valency of chlorine, potassium and sulphur?

SUMMARY

1. Credit for the discovery of electron and proton in an atom goes to J.J. Thomson and E. Goldstein respectively.
2. The relative charge of an electron is, – 1 while that of proton is, + 1.
3. The relative mass of a proton is taken as 1u while that of an electron is taken negligible.
4. Neutron was discovered by J. Chadwick. It has no charge but has a mass of 1 u.
5. The three fundamental particles of an atom are electron, proton and neutrons.
6. J. J. Thomson proposed that electrons are embedded in a sphere of positive charge so that the atom as a whole is neutral.
7. Rutherford's alpha-particle scattering experiment led to the discovery of a tiny positively charged nucleus in the centre of the atom.
8. Rutherford's model of an atom proposed that electrons revolve around the nucleus in definite orbits or shells. The stability of the atom could not be explained by this model.
9. Neils Bohr's model of the atom could successfully explain the stability of the atom and many other phenomena. He proposed that electrons revolve rapidly around the nucleus in discrete energy levels or shells. Each shell can accommodate only a fixed number of electrons.
10. The electron orbits or shells of an atom are represented by numbers 1, 2, 3, 4....etc or designated as K, L, M, N, ...etc.
11. The number of positive charges or the number of protons present in the nucleus of an atom is known as the atomic number of the element.
12. The mass number of an element (atom) is equal to the sum of the no. of protons and neutrons present in the nucleus (or the number of nucleons) of the atom.
13. Elements are identified by the number of protons (atomic number) they possess.
14. Isotopes are atoms of the same element but have different mass numbers.

15. Isobars are atoms having the same mass number but different atomic numbers. They are atoms of different elements having same mass number.
16. Bohr and Bury scheme gives certain rules for the distribution of electrons into different orbits (shells) of an atom.
17. The electrons present in the outermost shell of an atom are called valence electrons and the outermost shell is known as valence shell.
18. Valence electrons determine the valency of an element.

EXERCISES

1. *Name the three subatomic particles present in an atom and compare their properties.*
2. *What atom does not contain neutron?*
3. *Describe the Rutherford's model of an atom. What are its limitations?*
4. *Describe Bohr's model of the atom.*
5. *Explain with examples (i) Atomic number (ii) Mass number (iii) Isotopes and (iv) Isobars. Give any two uses of isotopes.*
6. *The mass number of an element is 40. It contains 19 electrons. What is the number of protons and neutrons in it? What is the atomic number of the element?*
7. *Write the electronic configuration of potassium atom. (Z = 19).*
8. *Explain why, sodium ion, Na^+, has completely filled K and L shells.*
9. *If both K and L shells of an atom are full, what is the total number of electrons in the atom?*
10. *If bromine atom is available in the form of two isotopes $^{79}_{35}Br$ (49%) and $^{81}_{35}Br$ (51%), calculate the average atomic mass of bromine atom.*
11. *Composition of the nuclei of two atomic species x and y are as follows:*

	X	Y
No. of protons	*= 15*	*15*
No. of neutrons	*= 15*	*16*

Give the mass numbers of X and Y. What is the relation between the two species?

12. *What is the relation between the valency of an element and the number of valence electrons in its atom. Explain with examples*
13. *Complete the following table:*

Atomic Number	*Mass Number*	*Number of Protons*	*Number of Neutrons*	*Number Of Electrons*	*Name of the Atomic species*
11	....	....	12	....	....
....	....	11	12	10	....
17	35	....	....	....	....
17	35	....	....	18	....
....	27	13	....	....	....

CHAPTER – 6

Motion

In our daily life we see many objects moving and many at rest. Birds fly, fish swims, car moves, a boy rides a bicycle, dogs and cows move, blood flows through the viens and arteries. Planets, stars, galaxies, atoms and molecules are all in motion. We often see books on table, toys in a box, trees at rest. For an object to be in motion, we notice it, when its position changes with time. A crawling ant is continually changing its position like a man who is walking. Look at the book placed on your study table. The distance of the book from the floor, from walls or from the ceiling of the room remains unchanged since the book is at rest with respect to the room.

However there are situations where the motion is inferred through indirect evidences — for example we use to infer the motion of air by observing the movement of dust and of leaves and branches of trees. Besides, we perceive the phenomena of sunrise, sunset, changing of seasons etc. — what causes them? Is it due to the motion of the earth? If it is true, why don't we perceive the motion of the earth directly?

An object may appear to be moving for one person and stationary for some person. When you are on a moving school bus, the roadside trees appear to be moving backwards. A person standing on the roadside perceives the bus along with the passengers as moving while the roadside trees are at rest. However, you perceive your friends in the moving bus and driver of the bus to be at rest. What do these observations indicate? (Motion is relative)

Out of the motions of object you perceive, some objects may move in straight line, others may move along a circular path, some may rotate about an axis and a few others may vibrate. There may also be situations involving a combination of these.

Activity 6.1

Discuss whether the walls of your reading or class room are at rest or in motion.

Activity 6.2

Have you ever experienced that the bus in which you are sitting appears to move while it is actually at rest on a highway? Discuss and share your experience with your friends sitting in the bus.

Think And Act

Some motions of objects around us are dangerous specially when it is erratic and uncontrolled as observed in a flooded river, a storm or sliding rocks from mountains. On the other hand, controlled motions can be a service to human beings such as in the generation of electric power in hydro electric projects and in nuclear power projects. You list some erratic motion of objects and ways to control them.

In this chapter, we shall first learn to describe the motion of objects along a straight line and then to express such motions through simple equations and graphs. Later, we shall also discuss the ways of describing circular motion of objects.

6.1 Describing Motion

In general, we describe the location or position of an object by specifying a reference point. Let us try to understand by some examples. Let us assume that your school is 3 km north of your house. We have specified the position of the school with respect to the house. In this example the house is the reference point. In another example, when you are asked by the teacher to come to the blackboard in your class, you will move from your seat and walk up to the board. In describing the position of the board your seat is the reference point. We could have also chosen other reference points according to our convenience. Thus, to describe the position of an object we need to specify a reference point called the origin. So you have chosen a convenient point i.e. your house, your seat. The position of the school is described by stating

(i) its distance from the chosen point (your house)
(ii) in which direction (north), as seen from the chosen point.

6.1.1 Motion Along A Straight Line

The motion of a body along a straight line is the simplest type. Let us take up the following example. Consider the motion of an object moving along a straight path, starting from 'O' which is chosen as its reference point (Fig.6.1). At first the object reaches at Z through X and Y. Then it moves back along the same path and reaches X through Y. The total length of the path covered by the object for the journey is

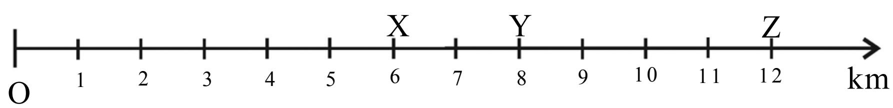


Fig. 61. Positions of an object at different instants on a straight path

OZ + ZX i.e 12 km + 6 km = 18 km. This is the distance covered by the object for the journey. Thus to find the distance covered we need to specify the numerical value only but not the direction of motion. Like distance there are also other quantities which are described by specifying numerical values only. Now, can you find out the distance of the final position of the object in motion from the initial starting point 'O' ? This will give the numerical value of displacement of the object from O to X through Z. In fact this is the shortest distance measured from the initial reference point to the final position of the object, which is known as the displacement.

Considering the example given in (Fig.6.1), can you say that the magnitude of the displacement be equal to the distance travelled by an object? For the motion from O to Z and back to Y, the distance covered = 12 km + 4 km = 16 km. While the magnitude of the displacement is 8 km. Thus the magnitude of displacement i.e. 8 km does not equal to the path length 16 km covered by the object. In the above example, if the object comes back to the starting point O, the final position of the object coincides with the initial starting position then the displacement is zero. However, the distance covered for the journey is OZ + ZO = 12 km + 12 km = 24 km.

Thus the distance and displacement are two physical quantities which are used to describe the overall motion of an object and to locate its final position with reference to its initial position at different instants of time. Hence, the magnitude of displacement from O to Z is 12 km which is also the distance covered by the object.

Activity 6.3

Take a long rope and a metre scale with you walk from one corner to the opposite corner of a rectangular field of sides 15 m and 25m and along the sides of the rectangular field.

Now, measure the magnitude of the displacement from the starting corner to the final corner you arrived at. What difference would you notice between the actual distance covered and magnitude of displacement.

Activity 6.4

In automobiles a device is fitted that shows the distance covered in travelling from one place to another place. That device is called odometer or speedometer. A scooter or car is driven from Imphal to Thoubal. The difference between final reading and initial reading of the odometer is 25 km.

Find out the magnitude of the displacement between Imphal and Thoubal by using the Road Map of Manipur.

Try to answer the Questions

1. In what condition is the distance covered equal to the magnitude of the displacement of an object in motion?
2. Can the distance travelled by an object be smaller than the magnitude of the displacement of the motion?
3. An object covers a distance. Can it have zero displacement? If yes, support your answer with an example.
4. State true or false: (1) Displacement cannot be zero. (2) Magnitude of displacement may be equal to the distance covered (3) Magnitude of displacement is greater than the distance covered.

6.1.2 Uniform and Non-Uniform Motion

Imagine an object moving along a straight line. Let it cover 3m in the first min, 3m in the second min, 3m in the third min, and 3m in the fourth min and so on. For a fast moving object, let it cover 2 m in the first second, 2m in the next second, 2m in the third second, 2m in the fourth second etc. In each of the cases the object covers equal distances in equal intervals of time. As the object covers equal distances in equal and consecutive intervals of time, it is said to be in *uniform motion*. The time interval in such a motion should be small.

On the other hand, in our daily life or day to day life, we come across motions where objects cover unequal distances in equal intervals of time. If you had a car ride sitting next to the driver or during your journey to school by bus, the car or the bus slows down in crowded area and moves fast in uncrowded area. Thus in the above examples the car or the bus covers unequal distances in equal intervals of time. These are the examples of non-uniform motion.

Activity 6.5

Table 6.1 shows the data regarding the motion of two objects or persons A and B. Examine them and try to identify uniform or non-uniform motion.

Table 6.1

Time	Distance covered by	
	A in m	B in m
5.00 am	10	11
5.15 am	20	18
5.30 am	30	24
5.45 am	40	37
6.00 am	50	43

6.2 Speed And Velocity

You know that in a game of cricket there is a signboard showing the bowling speeds of a player as 125 km/hour for example. What do you understand from the signboard?

Different objects in motion may take different amounts of time to cover a given distance. Some of them may move fast while some move slowly. The rate at which objects move can be different or can be same. The method to know the rate of motion of an object is to find out the distance covered by it in unit time. This quantity is referred to as speed. The SI-unit of speed is metre per second (ms^{-1} or m/s). There are other units like centimetre per second (cms^{-1}) or kilometer per hour ($km\ h^{-1}$). To specify the speed we need only its magnitude. In most cases the speed of a moving object may not be constant i.e. non-uniform motion. Therefore, we describe the rate of motion of such objects in terms of average speed which is obtained by dividing the total distance covered by the total time taken to cover the distance i.e.

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

If an object covers a distance x in time t then its speed $v = \frac{x}{t}$ ....(6.1).

Le us try to understand the calculation of speed of an object in motion from the following example. A car covers a distance of 70km in 2h. Its average speed for this journey is $\frac{70\,km}{2\,h}$ = 35km/h. The car might not have travelled at 35km/h for all the time. Sometimes it might have travelled slower and sometimes faster than 35 km/h.

Example 6.1 :

A dog runs 12 m in the first 2 s and 18 m in the next 4 s. What is its average speed?

Solution:

Total distance travelled by the dog = 12m + 18m = 30m

Total time taken = 2s + 4s = 6s

Average speed = $\frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{30\,\text{m}}{6\,\text{s}} = 5\text{ms}^{-1}$

Therefore the average speed of the dog for the motion is 5m/s or 5 ms^{-1}.

6.2.1 Speed with Direction (Velocity)

The rate of motion of any object can be made more meaningful if we specify its direction of motion along with its speed. Thus we have a new quantity called velocity which tells not only how fast the object is moving but also the definite direction in which it is moving. The velocity of an object can be uniform or variable. It can be changed by changing the speed of the object or direction of motion or both. For the motion of an object along a straight line at variable speed the magnitude of its rate of motion can be expressed in terms of average velocity which can be calculated in the same way as average speed in example 6.1. i.e. displacement divided by time taken.

In some motions the velocity of the object may change at a uniform rate. If so, the average velocity is given by the arithmatic mean of initial velocity and final velocity at the beginning and at the end for a given period of time.

Thus, average velocity = $\frac{\text{Initial velocity} + \text{Final velocity}}{2}$

Mathematically, $v_{av} = \frac{u+v}{2}$ ....(6.2)

Both speed and velocity have the same unit as ms^{-1} or m/s. Here, 'u' is the initial velocity and 'v' is the final velocity.

Activity ....6.6. (Estimation of distance):

Measure the time for going from your home to school. If your average speed is 1km/hr, estimate the distance.

Activity .... 6.7.

Observe the lightning and thundering during the rainy season. The sound of thunder takes some time to perceive after you see the lightning. Try to answer why this happens. Measure this time gap between lightning and hearing of thunder using a stop watch or a digital watch. Estimate the distance of the point of lightning, using the speed of sound in air = 332 m/s.

Example 6.2.

At the start of a trip the speedometer of a car reads 8000km and 8225km at the end. Which takes 5 hours. Calculate the average speed of the car in kmh^{-1} and also in ms^{-1}.

Solution:

Distance covered by the car = 8225 – 8000km = 225km

Time taken, t = 5 h

$\therefore$ Average speed of the car, $v_{av} = \frac{s}{t} = \frac{225\,km}{5\,h} = 45\ kmh^{-1}$

Also, $v_{av} = \frac{\overset{15}{\cancel{45}} \times \cancel{1000}\ m}{\underset{12}{\cancel{3600}}\ s} = \frac{\overset{5}{\cancel{15}} \times \overset{5}{\cancel{10}}}{\underset{2}{\cancel{12}\cancel{4}}} = 12.5 ms^{-1}$

The average speed of the car is $45 kmh^{-1}$ or $12.5\ ms^{-1}$.

Example 6.3.

A person goes along a straight road of length 50m and covers 100m by moving from one end to the other end and back along the same road. Find the average speed and average velocity of the person, if he takes 20 minute.

Solution:

Total distance = 50 + 50 = 100m.

Total time taken = 20 min

Average speed $= \frac{\text{Total distance covered}}{\text{Total time taken}}$

$= \frac{100\,m}{20\,min} = \frac{100\,m}{20} \times \frac{1}{60\,s} = \frac{1}{12} ms^{-1}$

Again, total displacement in 20 min = zero m

Average velocity $= \frac{\text{Displacement}}{\text{Total time taken}} = \frac{0\,m}{20\,min} = 0 ms^{-1}$

Thus, his average speed is $\frac{1}{12} ms^{-1}$ and his average velocity = $0 ms^{-1}$.

6.3 Rate of Change of Velocity

In uniform motion of an object along a straight line, velocity remains constant with time, i.e. the change in velocity of the object for any time interval is zero.

However, when the motion is non-uniform, the velocity of the object varies with time. As a result the velocity has different values at different instants of time and at different points of the straight path. Thus the change in velocity of the object during the motion is not zero, for any time interval. Is it now possible to express the change in velocity of the object discussed above?

In order to answer the above question, we have to introduce another physical quantity called *acceleration*, which is a measure of the change in velocity of an object in motion per unit time. Thus, acceleration of an object is rate of change of velocity. That is

acceleration $= \frac{\text{change in velocity}}{\text{time taken}}$

Suppose an object moves along a straight line in a fixed direction. If the velocity of the object increases from an initial value 'u' to the final value 'v' in time 't' then the average acceleration 'a' of the object is, $a = \frac{v - u}{t}$ ....(6.3)

This kind of motion is known as accelerated motion and acceleration is taken to be positive. When the speed of the object decreases i.e. u > v, the object is said to be decelerating. Thus, acceleration is taken to be positive if it is in the direction of velocity and negative when it is opposite to the direction of velocity. The SI unit of acceleration or deceleration is metre per second per second (ms^{-2}).

Acceleration may be uniform or non-uniform. When the velocity of an object travelling along a straight line increases or decreases by equal amounts in equal intervals of time, then the acceleration of the object is said to be uniform. The motion of a freely falling object is an example of uniformly accelerated motion. On the other hand, if the velocity of an object changes in a non-uniform rate as in the case of a car travelling along a straight road increases or decreases its speed by unequal amounts in equal intervals of time, depending on the conditions of the road at different positions, then the acceleration of the car is said to be non-uniform.

Activity ....6.8.

In your day to day life you come across a range of motions in which

(i) acceleration is in the direction of motion.
(ii) acceleration is against the direction of motion.
(iii) acceleration is uniform.
(iv) acceleration is non-uniform. Try to identify each of the above types of motion with one example for each.

Example 6.4.

Starting from home Mr. Tomba paddles his bycycle to attain a velocity of 10 ms^{-1} in 40s after the start. Then he applies brakes so that the velocity reduces to 6ms^{-1} in the next 10s. Calculate the acceleration of the bicycle in both the cases.

Solution:

In the first case:

Initial velocity u = 0; final velocity, v = 10 ms^{-1}; time taken = 40s

From the relation given in equation 10.3., we get

$$a = \frac{v-u}{t}$$

Substituting the given values of u, v and t in the above equation, we get

$$a = \frac{10\,ms^{-1} - 0\,ms^{-1}}{40\,s}$$

$$= \frac{1}{4} ms^{-2} = 0.25\ ms^{-2}$$

In the second case

Initial velocity, u = 10 ms^{-1}; final velocity, v = 6ms^{-1}; time t = 10 s.

$$\text{Then } a = \frac{\left(6\,ms^{-1} - 10\,ms^{-1}\right)}{5\,s} = \frac{-4\,ms^{-1}}{5\,s}$$

$$= -0.8\ ms^{-2}$$

Hence, the acceleration of the bicycle in the first case is 0.25 ms^{-2} and in the second case, it is – 0.8 ms^{-2}.

Try to answer:

1. When is a motion said to be in (i) uniform acceleration? (ii) non-uniform acceleration?
2. A particle is moving with a uniform velocity. What is its acceleration?

6.4 Graphical Representation of Motion

Graph is a very powerful method of presenting information about a variety of events. In newspapers and magazines, we find a number of graphs to present different information. For example, in the telecast of a fifty over one-day cricket match, the score at the end of each over is shown in the form of line graph which can give an overall idea of batting progress of the team. Thus a straight line graph helps in solving a linear equation having two variables.

To study the motion of an object, we can use graphs showing the dependence of distance or velocity on time.

6.4.1 Distance — Time Graphs

The change in position of an object with time can be shown on the distance — time graph adopting a convenient scale of choice. In plotting the graph, time is taken along the x-axis and distance from the reference point is taken along the y-axis. Such graphs can be employed under various situations where objects remain at rest, move with uniform speed, non-uniform speed etc.

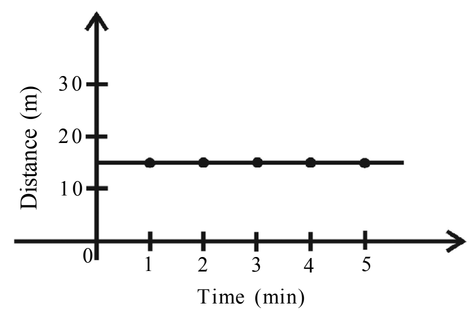


Fig. 6.2. Distance-time graph of an object at rest

We know that the object is at a constant distance from the origin, from the graph, since the line remains parallel to the time-axis, we can infer that the object is at rest.

We know that if an object travels equal distances in equal intervals of time then it moves with a uniform speed. Thus for a motion with uniform speed, a graph of distance travelled against time is a straight line since the distance covered by the object is directly proportional to time, as shown in Fig.6.3. The line OB shows that the distance covered is increasing with time at a uniform rate. If the motion is along a straight path, you can use the term uniform velocity in place of uniform speed, since for motion along a straight path in a direction the distance travelled is exactly equal to the magnitude of the displacement i.e. along Y-axis.

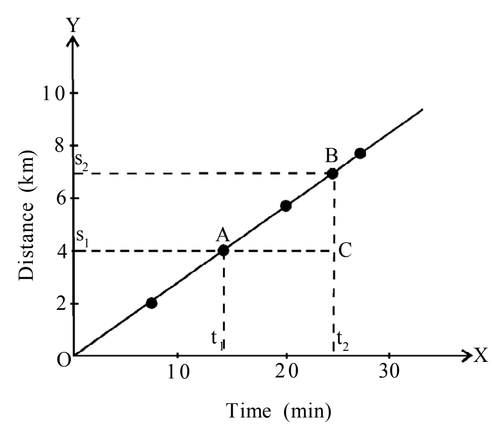


Fig. 6.3. Distance – time graph of an object moving with uniform speed

From the graph we can determine the speed of the object. To obtain the speed, let us consider a small portion AB of the graph in Fig.6.3 and draw a straight line from A parallel to X-axis and from B parallel to Y-axis. These two lines will meet at C. Now AC will denote the time interval ($t_2 - t_1$) taken by the object to cover the distance BC corresponding to the distance ($s_2 - s_1$). The speed 'v' of the object can be expressed as

$$v = \frac{s_2 - s_1}{t_2 - t_1} \quad \text{.....................................6.4.}$$

Hence, the nature of the graph in Fig. 6.3 shows a linear variation of the distance covered by the object with time, in uniform motion.

We can also plot the distance – time graph for a uniformly accelerated motion of an object. The following Table 6.2 shows the distance covered by a car in a time interval of two seconds.

Table 6.2: Distance travelled by a car at regular time intervals

Time in second	Distance in metre
0	0
2	2
4	8
6	18
8	32

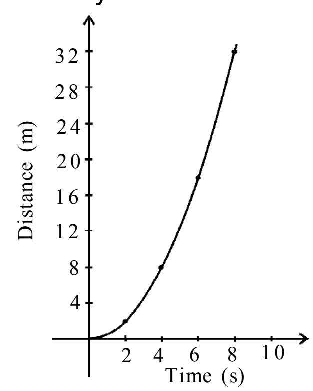


Fig. 6.4: Distance – time graph for motion given in table 6.1

Note that the shapes of the graphs given in Fig.6.3 and Fig.6.4 are different. The nature of the graph in Fig.6.4 shows the non-linear variation between Distance and Time for non-uniform motion.

6.4.2 Velocity — Time graph

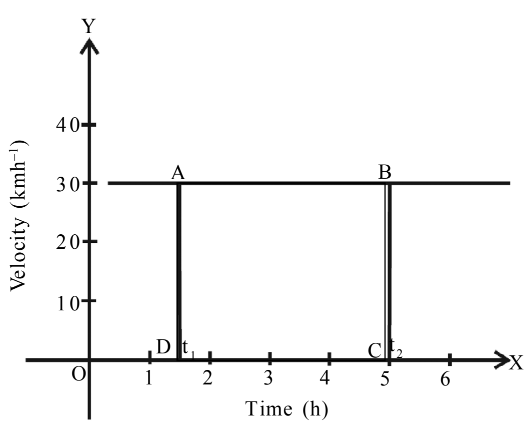


Fig: 6.5: Velocity – time graph for uniform motion of a motor car

The nature of variation of velocity with time for an object moving in a straight line can be represented by a velocity – time graph. In such a graph, time is represented along the X-axis and velocity is represented along the Y-axis. If an object moves with a uniform velocity, its velocity at any instant is the same as shown in (Fig.6.5). It will be a straight line parallel to the X-axis. Fig.6.5 shows the velocity time graph for a motor car moving with a uniform velocity of 30 kmh^{-1}.

We know that the product of velocity and time of any object moving with uniform velocity gives the displacement. Thus the area enclosed by the velocity time graph and time axis, representing the interval of time will be equal to the magnitude of the displacement. To know the distance covered between time t_1 and t_2 from the graph, draw perpendiculars from the points marked A and B corresponding to the time t_1 and t_2 on the graph. Thus the height AD or BC represents the velocity of 30 km/h and length AB represents the time $(t_2 - t_1)$.

Thus the distance 's' moved by the car during $(t_2 - t_1)$ can be expressed as

s = AD × AB = $(30\ kmh^{-1}) \times (t_2 - t_1)$ h.

= $30 \times (t_2 - t_1)$ km

= Area of the rectangle ABCD, which is shaded in Fig.6.5.

Similar to the above, we can study about the motion of an object with non-uniform velocity but uniformly accelerated motion by plotting its velocity – time graph. Let us consider a person sitting by the side of the driver of a car, who is recording its velocity for every 10 seconds from the speedometer, while the car is accelerated. The velocity of the car at different instants of time is given in table 6.3.

Table 6.3: Velocity of a car at regular intervals of Time during acceleration

Time (s)	Velocity kmh^{-1}	Velocity (m/s)
0	0	0
10	18	5
20	36	10
30	54	15
40	72	20

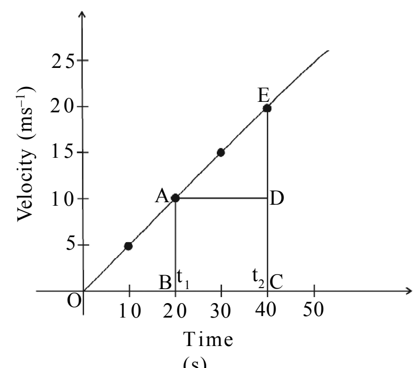


Fig. 6.6: Velocity-time graph for a car, uniformly accelerated

In Fig.6.6, the variation of the velocity with time for a uniformly accelerated motion of a car is shown. The graph shows that velocity changes by equal amounts during equal intervals of time and graph for such motion will always be a straight line.

From the graph we can also determine the distance covered by the car in a given interval of time. If the car were moving with uniform velocity, the distance travelled by it during an interval of time, in Fig.6.5, would be given by the area of the rectangle ABCD. Similarly, for the motion with uniform acceleration, the area ABCDE under the velocity — time graph (Fig.6.6) will give the distance covered by the car during the time interval $(t_2 - t_1)$. That is

s = Area ABCDE

= Area of the rectangle ABCD + Area of the triangle ADE.

$$= AB \times BC + \frac{1}{2} AD \times DE$$

We have discussed the velocity – time graph in the case of uniformly accelerated motion in the above. In the case of non-uniformly accelerated motion, the velocity – time graph can have any shape. The velocity – time graphs of an object (i) whose velocity is decreasing uniformly with time (2) whose velocity varies non-uniformly with time are shown in Fig.6.7 and Fig.6.8 respectively. Try to interpret the motions from the graphs.

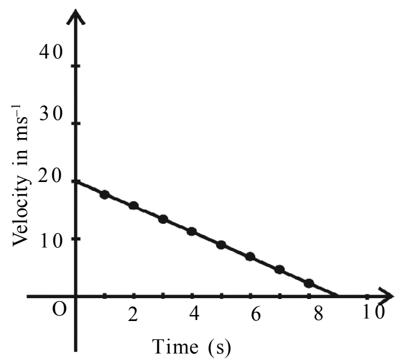


Fig. 6.7: Velocity – time graph of an object, velocity uniformly decreasing with time

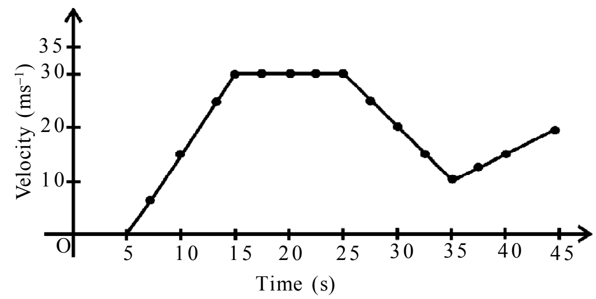


Fig: 6.8: Velocity – time graph of an object with velocity non-uniformly changing with time

Activity .... 6.8.

The times for arrival and departure of a bus at three stoppages A, B, C along with distances of B and C from A are shown in table 6.4. Plot and interpret the distance – time graph for the bus, assuming that it moves with uniform velocity between any two stations.

Table 6.4: Distances of stoppages B and C from A and times of arrival and departure of the bus

Stoppage	Distance from A (km)	Time of arrival (h)	Time of departure (h)
A	0	6.00	06.30
B	60	08.30	09.00
C	90	10.00	10.30

Activity — 6.9.

Tomba and his sister Mema go to school on their bicycles from their house on the same route. But Tomba could reach the school earlier than his sister. The table 6.5 shows the distance covered by each in different times. Plot the distance – time graph for their motions using the same scale and find the velocity of each.

Table 6.5: Distance covered by Tomba and Mema at different times

Time	Distance covered by Tomba (km)	Distance covered by Mema (km)
9.00 am	0	0
9.10 am	2.0	1.5
9.20 am.	2.8	2.2
9.30 am.	3.5	3.0
9.40 am	4.0	3.6
9.50	—	4.0

Try to answer

1. What can you understand about the motion of an object, if the distance – time graph is a straight line parallel to time axis?
2. What will be the nature of distance – time graphs for uniform and non-uniform motion of an object?
3. Which quantity is measured by the area occupied below the velocity – time graph of an object in motion?

6.5 Equations of Motion from the Graphical Representation

For an object moving along a straight line with uniform acceleration, it is possible to relate its velocity acquired, distance covered by it in a certain interval of time by a set of equations which are known as the equations of motion. They are:

$$v = u + at \text{.............}(6.5)$$

$$s = ut + \frac{1}{2}at^2 \text{...............}(6.6)$$

Squaring equation (6.5) and combining with equation (6.6), the acceleration during the motion is given by

$$2as = v^2 - u^2 \text{..............}(6.7)$$

In the above equations, u is the initial velocity of the object which moves with uniform acceleration 'a' for a time t, v is the final velocity and 's' is the distance covered at the end of time interval 't'. The above three relations can be obtained by graphical method (Fig.6.9).

6.5.1 Equation For Velocity — Time Relation of a Motion

Let us consider the velocity–time graph of an object moving under uniform acceleration from an initial velocity u. Thus, you can see that velocity at t = o is u, represented by the point A on the graph. Thereafter it increases to final velocity v at a uniform rate 'a', shown as E on the same graph. Perpendicular lines DC and DE are drawn from the point D on time and velocity axes, respectively, so that the initial velocity of the motion is represented by OA and final velocity is represented by DC and the time interval t is represented by OC, finally the change in velocity during t interval of time is represented by DB = DC – BC, since AB is drawn parallel to OC.

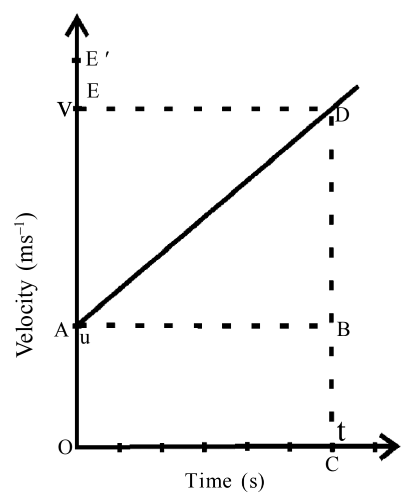


Fig. 6.9: Velocity – time graph to obtain the equations of Motion (with uniform accⁿ)

From the graph we observe that DC = DB + BC = BD + OA

Substituting DC = v; OA = u in the above relation, we get

$$v = BD + u$$

Or, $BD = v - u$ ....(6.8)

From the graph in Fig.10.9, the acceleration of the object is given by

$$a = \frac{\text{change in velocity}}{\text{time taken}} = \frac{BD}{AB} = \frac{BD}{OC}$$

Substituting OC = t in the above relation, we get 'a' = $\frac{BD}{t}$

Or, $BD = at$ ....(6.9)

Using equations (6.8) and (6.9) we get

$$v - u = at$$

Or, $\boxed{v = u + at}$

6.5.2 Equation for position — time relation

Let us assume that during the time 't', the object has covered a distance 's' under uniform acceleration 'a'. From the graph, this distance is obtained by the area enclosed within OADC, under the velocity – time graph AD .

Thus, the distance 's' travelled by the object is given by

s = area OADC (which is a trapezium)

= area of rectangle OABC + area of triangle ADB.

$= OA \times OC + \frac{1}{2} AB \times BD$ ....(6.10)

Substituting OA = u; OC = t = AB and BD = at, we get

$$s = u \times t + \frac{1}{2}(t \times at) = ut + \frac{1}{2}at^2$$

Or, $s = \boxed{ut + \frac{1}{2}at^2}$

6.5.3 Equation for position – velocity relation for the motion

From the above, s = area of the trapezium OADC

$$= \frac{(OA + DC) \times OC}{2}$$

Substituting OA = u; DC = v and OC = t, we get

$s = \frac{(u+v) \times t}{2}$ ....(6.11)

But, from the velocity-time relation (Eq.6.5) we get

$t = \frac{(v-u)}{a}$ ....(6.12)

Substituting 't' from (Eq.10.12) in (Eq.6.11) we get

$$s = \frac{(u+v)(v-u)}{2a} = \frac{v^2 - u^2}{2a}$$

Or, $2as = v^2 - u^2$

i.e. $v^2 = u^2 + 2as.$

Example 6.5.

A car starting from rest accelerates uniformly so as to attain velocity of 144 kmh^{-1} in 20 s. Find (a) its acceleration (b) the distance covered by it for attaining that velocity.

Solution:

We have been given the following quantities:

$$u = 0;\ v = 144\ kmh^{-1} = \frac{144 \times 10^3}{60 \times 60}\ ms^{-1} = 40m/s \text{ and time taken } t = 20s$$

(a) From Eq.(6.5), we know that $a = \frac{v-u}{t} = \frac{40ms^{-1} - 0ms^{-1}}{20s} = 2ms^{-2}$

(b) From Eq.(6.7), we have $2as = v^2 - u^2$

Thus, $2.2.s = 40^2 - 0^2$

$\Rightarrow 4s = 40 \times 40$

$\therefore\ s = \frac{40 \times 40}{4} = 400m$

The acceleration of the car is $2ms^{-2}$ and distance covered by it is 400m.

Example 6.6.

A car accelerates uniformly from 36 kmh^{-1} to 144kmh^{-1} in 20s. Calculate (a) the acceleration of the car (b) distance covered by the car in the interval

Solution:

We have been given the following quantities.

$$u = 36kmh^{-1} = \frac{36 \times 1000}{60 \times 60} = 10ms^{-1}$$

$$v = 144kmh^{-1} = \frac{144 \times 1000}{60 \times 60} = 40ms^{-1}$$

And t = 20s.

(a) From the relation, $v = u + at$, where 'a' is the acceleration

We get $40 = 10 + a \times 20$

$$\therefore\ a = \frac{(40ms^{-1} - 10ms^{-1})}{20s} = \frac{30ms^{-1}}{20s} = 1.5\ m/s^2 \text{ or } 1.5\ ms^{-2}$$

(b) From the relation $s = ut + \frac{1}{2}at^2$ we have

$$s = 10ms^{-1} \times 20s + \frac{1}{2}\ 1.5ms^{-2} \times (20s)^2$$

$$= 200m + \frac{1}{2} \times 1.5 \times 20 \times 20m$$

(the 2 and the 20 are struck out and replaced by 1 and 10)

$= 200m + 300m = 500m.$

The acceleration of the car is $1.5ms^{-1}$ and distance covered by it is 500m.

Example 6.7

A police van moving along a straight highway is brought to a stop by the application of brakes producing an acceleration of $7ms^{-2}$ in the opposite direction to the motion. If the van takes 5s to stop after application of brakes, calculate (i) the velocity of the van when the brakes are applied (ii) distance covered before it stops.

Solution:

We have been given, $a = -7ms^{-2}$; $t = 5s$ and $v = 0ms^{-1}$

(i) From equation (6.5) we know that $v = u + at$

$$o = u + (-7ms^{-2}) \times 5s$$

or, $u = 7 \times 5\ ms^{-1} = 35ms^{-1}$

(ii) From Equation (6.6), we have $s = ut + \frac{1}{2}at^2$

or, $s = 35ms^{-1} \times 5s + \frac{1}{2}(-7ms^{-2}).(5s)^2$

$$= 35 \times 5\ m - \frac{1}{2} \times 7 \times 5m$$

$$= 175m - 17.5m$$

$$= 157.5m.$$

Thus, the velocity of the van when the brakes are applied is $35ms^{-1}$ and will move 157.5m before it stops after the application of brakes.

Example 6.8

The driver of a speedy car applied brakes which can produce an acceleration of $10ms^{-2}$ in a direction opposite to that of the motion. Calculate the distance it travels during 3s which is the time taken by the car before coming to a halt or rest.

Solution:

We have been given, $a = -10ms^{-2}$; $t = 3s$ and $v = 0ms^{-1}$

From Equation $v = u + at$ we get

$$o = u + (-10ms^{-2}) \times 3s$$

or, $u = 30ms^{-1}$

Again, from equation $s = ut + \frac{1}{2}at^2$ we get

$$s = (30ms^{-1}) \times 3s + \frac{1}{2}(-10ms^{-2})(3s)^2$$

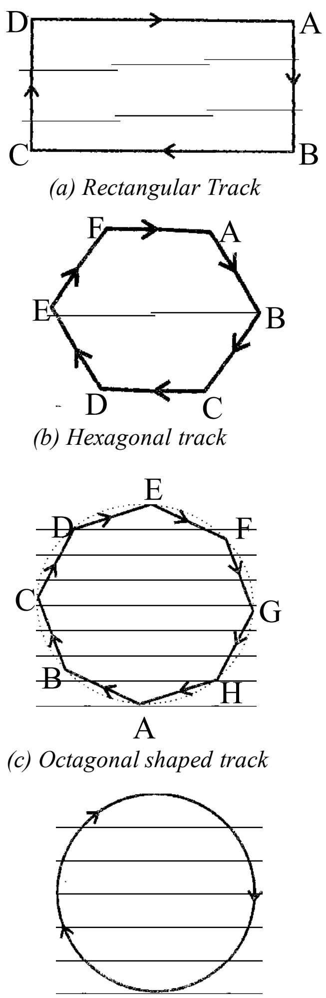
$$= 90m - \frac{1}{2} \times 10 \times 9m$$

$$= 90m - 45m = 45m.$$

Thus the car will cover a distance of 45m before it stops, after the application of brakes.

6.6 Uniform Circular Motion

In the above lessons, we say that whenever the velocity of an object changes, the object is accelerating. The change in velocity may be due to change in its magnitude or the direction of the motion or both. Can you imagine about an example when an object does not change its magnitude of velocity but only its direction of motion? You can learn such a motion from the following.



(a) Rectangular Track

(b) Hexagonal track

(c) Octagonal shaped track

(d) A circular track

Fig. 6.10 (a),(b), (c), (d). The motion of an athelete along closed paths or tracks of different shapes

Let us discuss an example of the motion of a body along a closed path. Fig.6.10 (a) shows the path of an athlete racing along a rectangular track ABCDA at a uniform speed on the straight parts. In order to keep himself on track, he will change the direction at each of the corners. How many times will he have to change his direction of motion in one complete round? He has to change his direction of motion four times.

Let us again consider that the athelete is running along a hexagonal track ABCDEFA as shown in Fig.6.10 (b). In this situation, in order to keep himself on the track, he will have to change his direction of motion six times in one complete round.

Let us think, what will happen if the track were a regular octagon with eight equal sides as shown by ABCDEFGHA in Fig.6.10(c)? It is observed that as the number of sides of the track increases, the athelete has to change his direction of motion more and more often. What would happen to the shape of the track as we go on increasing the number of sides indefinitely? If it is so, you will notice that the shape of the track becomes a circle and the length of each of the sides can be imagined as a point. If the athelete runs with a velocity of constant magnitude on the circular track, the only change taking place in his velocity is due to the change in the direction of motion. Such motion of an athelete along a circular track or path at constant speed is exactly an example of an accelerated motion.

If the athelete takes 't' second to go once around the circular track of radius r (say), the magnitude of his velocity 'v' is given by $v = \frac{2\pi r}{t}$ ....(6.13).

The circumference of the circle of radius r is 2pr and v is actually the speed of the athelete.

Activity 6.10

Take a small stone tied at one end of a piece of string. Rotate the stone on a horizontal circular path by holding the thread at the other end, as shown in Fig.6.11. Now, let the stone go free by releasing the thread. Can you tell the direction in which the stone would move after it has been released.

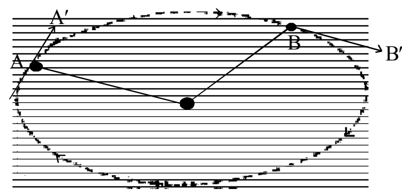


Fig. 6.11: A small stone or any suitable object describing a horizontal circular path with a velocity of constant magnitude

By repeating the above activity and releasing the stone at different points of the circular track, check whether the direction in which the stone moves remains the same or not. If you carefully observe, you will see that when the stone is released at A it will move along AA¢ and when released at B it will move along BB¢. Here AA¢ and BB¢ are the tangents to the circular path at A and B. Thus, on being released the stone moves along a straight line tangential to the circular path. From the above you know that when a body moves in a circular path the direction of motion is not the same at any two points. Thus, the motion in a circle with constant speed is an example of accelerated motion. There are many more familiar phenomena of objects moving under uniform circular motion. They are the motion of the moon and the earth, a satellite in a circular orbit around the earth, a cyclist on a circular track or valodrom at constant speed and so on.

Points to remember

(i) Motion is a change in position and can be described in terms of distance covered or the displacement.

(ii) Motion may be uniform or non-uniform depending on whether its velocity remains constant or changing.

(iii) Speed of motion of an object is distance covered per unit time while velocity is the displacement per unit time.

(iv) The acceleration of an object is the change in velocity per unit time.

(v) The motions of objects can be studied through graphs.

(vi) The motion of an object moving with uniform acceleration can be expressed in equations namely

$$v = u + at \; ; \; s = ut + \frac{1}{2} at^2 \; ; \; 2as = v^2 - u^2$$

where 'u' is the initial velocity of the object which is moving with uniform acceleration 'a' for time 't', 'v' is the final velocity acquired after time 't' or after covering a distance 's'.

(vii) Uniform motion along a straight line is not accelerated but uniform circular motion is accelerated.

EXERCISES

1. *A boy while driving to his school covers at the average speed of 15 km/h. On his return trip along the same route, covers at the average speed of 25 km/h due to less traffic. What is his average speed for the whole trip?*

   (20 km/h)

2. *A motor boat in Loktak lake starting from rest, accelerates along a straight path at a uniform rate of 2.0 ms^{-2} for 10.0s. How far does the boat travel during this time?*

   (100m)

3. *The driver of a car travelling at 72 kmh^{-1} applies the brakes and accelerates uniformly in the opposite direction at the rate of 5ms^{-2}. How long the car will take to come to rest? How far will the car cover before coming to rest.*

   (4s; 40m)

4. *The figure below shows the distance – time graph of three motor-cyclists A, B and C. On the basis of this graph answer the following questions:*

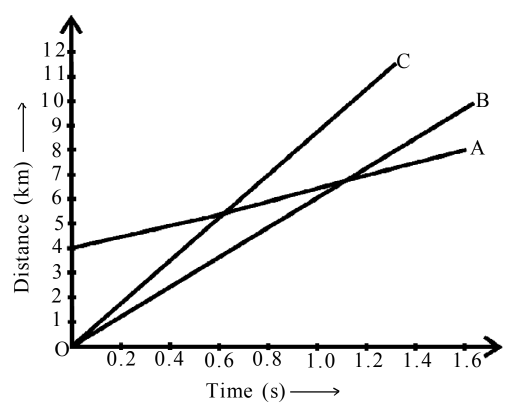


Fig. 6.12

(i) Which of them is travelling fastest.
(ii) Are all the three ever at the same point on the road?

(iii) When B passes A where is C?
(iv) How far did C travel when B meets A.

5. *What type of motion is represented by each of the following graphs?*

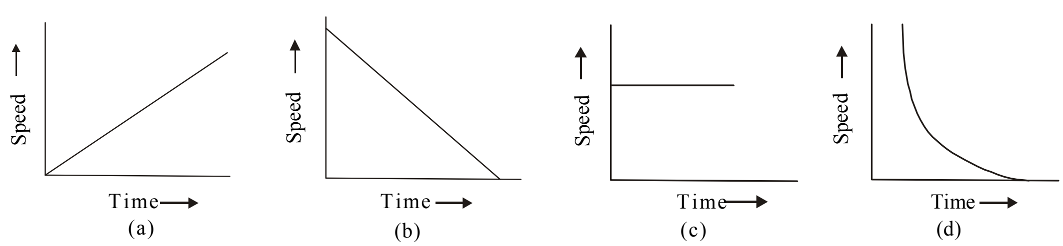


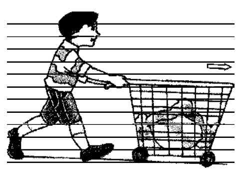
Fig. 6.13

CHAPTER – 7

Force And Laws of Motion

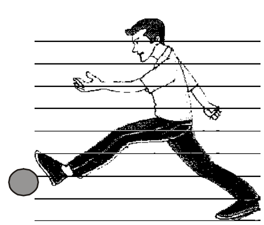
We described the motion of an object along a straight line in terms of its position, velocity and acceleration in the previous chapter. But we have not discussed yet the cause of the motion. In this chapter we have to discover – what causes the motion? Why does the speed of an object change with time? Do all the motions require a cause? In this chapter let us make an attempt to quench all the curiosities. For many centuries, the problem related to motion and its causes had puzzled the scientists and philosophers.

You can see in your daily life that on a ball or any inanimate objects of suitable size when given a small kick or hit, it does not remain moving forever. Such observations suggest that rest is the *"natural state"* of inanimate objects. This concept remained the belief until Galileo Galilei and Isaac Newton developed an entirely different approach to understand the motion of inanimate objects. In our everyday life we observed that inanimate objects cannot start moving at their own accord. In other words some effort is always required to put a stationary object into motion or to stop a moving object. We generally use muscular effort in the form of pushing, pulling or hitting on an object to change its state of rest or of motion. The concept of force is based on this push, pull or hit. Let us now try to understand what is a force. In fact no one has seen or tasted a force but we can see or feel the effect of force. Force can be explained by describing the effect after a force is applied to an object. The ways of bringing (inanimate) objects in motion are pushing, hitting and pulling which are shown in Fig.7.1. They move because a force acts on them

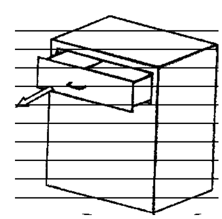


(a)
Pushing a troley

(b)
Bat hitting a cricket ball



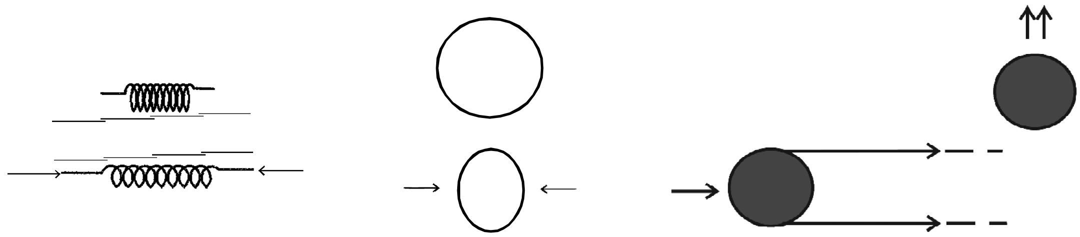
(c)
A kick on a football



(d)
Pulling of a drawer

Fig. 7.1

Try also to learn that a force can be used (i) to change the shape and size of objects (ii) to change the magnitude of velocity of an object (that is to make the object move faster or slower) or to change the direction of motion, from the play of football at your school, as shown in Fig.7.2.



(a) *A spring elongates or contracts on the application of force*

(b) *A spherical ball becomes oblong on application of force*

(c) *A football changes its direction of motion on application of force*

Fig. 7.2

7.1 Balanced and Unbalanced Forces

Let us take a rectangular block of wood on a horizontal table. The strings A and B are tied at its opposite faces, as shown in the Fig.7.3. Try to apply a force on the block by pulling the string A, then the block will start to move to the right. Similarly, if we pull the string B, then the block will start to move to the left. On the other hand if we pull both strings simultaneously in opposite directions with equal forces, you will find that the block does not move.

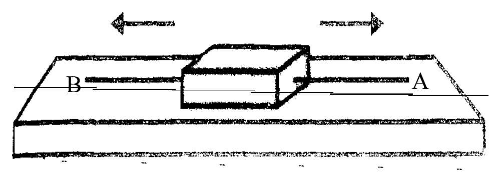
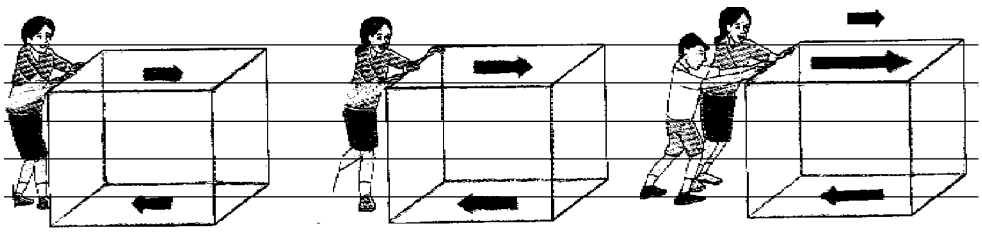


Fig. 7.3: Two forces acting on a wooden block

Let us consider a situation when the opposite forces on the strings A and B are not of equal magnitude. In this situation the block would move in the direction of the force of greater magnitude. Thus the two forces on the block are not balanced i.e. an unbalanced force acts on the block in the direction in which the block moves. The above observation suggests that whenever an unbalanced force acts on a body, then this force will cause the body to move in its direction.

Let us again consider a situation of pushing a box on a floor of rough surface. If you push the block with a small force the box may not move because of the friction in a direction opposite to that of the push, Fig.7.4 (a). This friction force exists between the two surfaces in contact, in this case between the lower surface of the box and the floor's rough surface. Since the friction force balances the push, the box does not move. Now you increase the amount of push i.e. try to push the box harder but the box may not move. If it is so, the friction force still balances the pushing force as shown in Fig.7.4 (b). If you push box harder still by engaging one of your friends in the same direction, the pushing force may be bigger than the friction force as shown in Fig.7.4 (c) then an unbalanced force acts on the box. So the box will start moving in the direction of unbalanced force which is the direction of push.



(a) Push (b) Pushing Harder (c) Pushing with the friend

Fig. 7.4

Let us consider another example in our daily life. Suppose you are riding a bicycle. What happens when you stop pedalling? The bicycle will begin to slow down and finally will come to rest. This is because of the force of friction acting opposite to the direction of motion. In order to keep the bicycle moving you have to start pedalling again as earlier. From this you know that an object maintains its motion under the continuous application of an unbalanced force. However it is not true. An object moves at a uniform speed when there is no net external force applying on it, i.e. when the forces like push or pull and frictional force acting on the object are balanced. If an unbalanced force acts on an object, there will be a change either in its speed or its direction of motion or both i.e. there will always occur an acceleration of the motion. Thus to accelerate the motion of an object, an unbalanced force is required and the change in the speed or in the direction of motion would continue as long as the unbalanced force is acting on the object. However, the object will continue to move with the velocity acquired by it at the instant when the unbalanced force is removed.

7.2 First Law of Motion

Through the observations of the motion of objects on an inclined plane, Galileo deduced that objects move with a constant speed when no force acts on them. He observed that when a marble is made to roll down an inclined plane-I, its velocity increases in magnitude, [Fig.7.5. (a)]. (Here, the marble rolls down under the unbalanced force due to gravity. That is why its velocity is increasing to attain a definite velocity at the bottom of the inclined plane.). However, the velocity of the marble decreases when it climbs up the other inclined plane-II as shown in Fig.7.5. (b). Thus in the case of planes that slope downwards, there is present a cause of acceleration (force of gravity) while on planes sloping upwards there is acceleration opposite to the direction of motion. In second set of experiments Galileo combined two inclined planes I and II together facing each other and highly polished to minimise the friction.

He (Galileo) argued that when a marble is made to roll down the inclined plane I from a height 'h' it would rise up the plane-II to almost the same height (Fig.7.5 c).

He then decreased the inclination or slope of plane-II and repeated the experiment. This time the marble had to travel a longer distance on the plane II to reach almost the same height. If the friction were totally eliminated, the final height reached on the plane-II would be equal to the initial height in plane-I, as a limiting case. If the slope of plane-II is made zero [Fig.7.5. (c)] i.e. horizontal, the marble should move forever because it will never attain the initial height. The unbalanced forces on the marble are zero in this situation. In actual practice, it is difficult to achieve a zero unbalanced force. Thus in practice the marble comes to rest after travelling some distance.

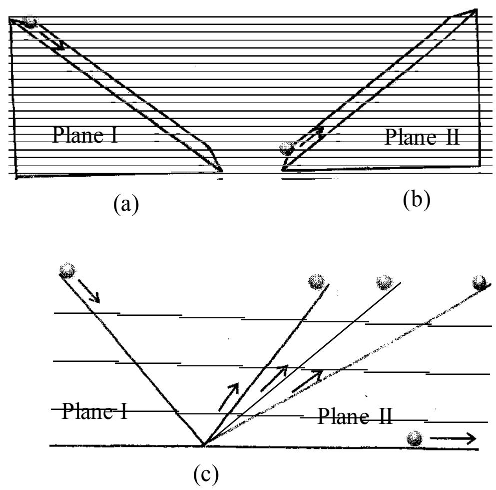


Fig. 7.5: (a) downward motion of marble. (b) upward motion of marble on an ineclined plane (c) motion of marble on combined inclined planes at different incli nations of plane II

Later Sir Issac Newton made a systematic study of Galileo's ideas on force and motion of bodies. He summed up Galileo's findings and presented three fundamental laws that govern the motion of objects. These three laws are known as Newton's laws of motion. The first law is actually a reformulation of Galileo's law of inertia and is stated as:

"Every body continues in its state of rest or of uniform motion in a straight line unless compelled to change that state by an external unbalanced force (applied force)."

The word external specifies that the force must act from outside the body in order to have a change in the velocity or state of rest.

According to the above law all bodies resist a change in their state of motion. The tendency of undisturbed objects to remain at rest or to continue moving with the same velocity is called inertia. Because of this tendency, the first law is also called law of *inertia*. Certain experiences that you come across while travelling in the school bus or van can be explained on the basis of law of inertia. You tend to remain at rest with respect to the seat until the driver applies a breaking force to stop the bus. While doing so your body tends to continue in the same state of motion. That is why your body moves forward. A sudden application of brakes may thus cause injury to us by the impact with the front seat. The passengers are advised to wear safety belts to prevent such accidents while travelling in a car or aeroplane because the safety belts exert a force on our body to make the forward motion slower. An opposite experience is encountered when you are standing in a bus at rest and when it begins to move suddenly. In this situation your body falls backwards. The reason is that your feet being in contact with the floor of the bus, share the motion of the bus but the upper part of the body is still in a tendency of rest.

Similarly, when a motor car makes a sharp turn at high speed, we tend to get thrown outwards i.e. to one side. This is also due to the law of inertia, since we are tending to continue in our straight line motion. The change in direction of motion of the motor car is brought by the unbalanced force generated by the engine.

The fact that a body will remain at rest unless it is acted by an external unbalanced force can be illustrated through the following activities:

Activity 7.1

Make a pile of carom coins on a carom board as shown in Fig.7.6. Try to hit at the bottom coin of the pile using striker. If the hit is strong enough the bottom coin only will move out quickly. Once the lowest coin is removed, the other coins make them fall vertically due to inertia.

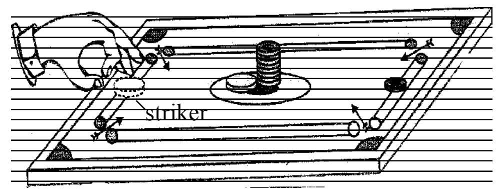


Fig. 7.6: Only the bottom carom coin is removed from the pile, when the fast moving striker hits it

Activity 7.2

Place a coin A on a plane paper B lying over a table as shown in Fig.7.7. Now pull the paper slowly, the coin will be in contact with the paper. If the paper is pulled quickly, on one side as shown, the coin will fall on the table. Another similar activity can be taken up by placing a coin A on a cardboard sheet B over a tumber. When the cardboard sheet is suddenly pulled on one side or is flicked with the fingure, the coin will fall into the tumbler. This is due to the fact that the coin remains at rest because of the inertia even when B is removed quickly or flicked off.

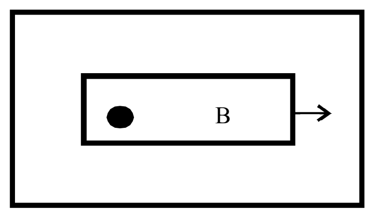


Fig 7.7

Activity 7.3

Place a water-filled tumbler on a tray and hold the tray and turn around a little faster. Then you will find that water spills. Why?

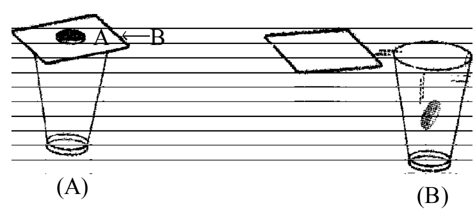


Fig. 7.8: When the card is flicked off with the fingure, the coin A falls in the tumbler

7.3 Inertia and Mass

From the examples and activities, it is known that if the body is moving it tends to keep moving; if it is at rest it tends to remain at rest. This property of a body or an object is called its inertia. Do all bodies have the same inertia irrespective of their respective masses? We know that it is easier to push or pull an empty box on a floor than when the same box is filled with some books or stones on the same floor. Similarly, when you kick a rubber ball it flies away. But if you kick a stone of the size as that of the ball with the same force, it hardly moves. In fact you may get an injury in the foot while doing so. Similarly, in activity (7.2) if lighter coin was used a lesser force would be required to perform the activity. Now you can acertain that a force that is just enough to cause a smaller mass to pick up a large velocity will produce a negligible change in the motion of a larger mass. This is because, in comparison to the rubber ball the stone has a much lesser tendency to change its state of motion. Now you are clear that more massive bodies offer larger inertia. In other words the inertia of a body or an object is related to its mass. We may thus express inertia and mass in the following way: Inertia is the natural tendency of a body to resist a change in its state of rest or of uniform motion. The mass of an object or a body is a measure of its inertia.

Attempt to answer:

1. Which one has greater inertia:
   - (i) a rubber ball and a stone having the same size?
   - (ii) a bicycle and a scooter?
   - (iii) a five rupee coin and a one-rupee coin?
2. Some of the leaves of a tree may get detached if we vigorously shake its branch. Explain why.

7.4 Second Law of Motion

From the study of First law of motion we have found that when an unbalanced force acts on a body, there occurs a change in velocity, that is the body gets an acceleration. We would like to know how the acceleration of a body depends on force applied on it and how to measure a force. Let us think some situation from our everyday life. During the game of table tennis at your school or local club, you must have noticed that if the ball hits a player it does not hurt him, although the velocity or speed of the ball is very high. On the other hand, when a fast moving cricket as fast as the table tennis ball hits a player or a spectator, it may hurt him. We do not pay any attention to a truck when parked along a roadside. But a moving truck at a very low speed, may kill a person when it hits. A small mass such as a pebble from a catapule may hurt a person to some extent whereas a bullet having the mass as that of the pebble fired from a pistol may kill a person. These observations suggest that the impact produced by the objects depends on their mass and velocity together. In other words there should exist some quantity of importance that combines the mass of the object and its velocity. One such property called *momentum* was first introduced by Newton in 1687 and the momentum 'p' is defined as the quantity of motion associated with the body. It is measured by the product of the mass 'm' of the body and its velocity, 'v'.

That is $p = mv$................(7.1).

Momentum has both direction and magnitude. Its direction is the same as that of the velocity. The SI unit of momentum is kilogram-metre per second ($kgms^{-1}$). Since, an unbalanced force acting on a body can produce a change in the velocity of the body, it is therefore clear that an applied unbalanced force will produce a change of momentum.

Let us take up an example which you might have observed frequently that when it is not possible to start an engine of a car with weak battery, the car is pushed with the help of two or more persons. Does the engine start with the sudden push (unbalanced force)? Not yet. But a continuous push over some time, will result a gradual acceleration of the car to a speed which is sufficient to start the engine. This shows that the change in momentum of the car in the above observation is not only determined by the magnitude of applied force but also by the time during which the force is exerted. Thus we can conclude that the force necessary to change the momentum of a body depends on the time rate at which the momentum is changed.

The second law of motion states that the rate of change of momentum of a body is proportional to the applied unbalanced force in the direction of force.

7.4.1 Mathematical Formulation of Newton's Second Law of Motion

Suppose an object of mass 'm' is moving along a straight line at an initial velocity 'u'. Now, a constant force F is applied on it which accelerates it uniformly to a velocity 'v' in time 't'. The initial momentum of the body before applying the force, P_i = mu while its final momentum after time 't' is P_f = mv.

The change in momentum = $P_f - P_i = mv - mu = m(v - u)$

$\therefore$ The rate of change of momentum = $\frac{m \times (v - u)}{t}$

Or, the applied force, $F \propto \frac{m \times (v - u)}{t}$

$$F = \frac{km \times (v - u)}{t} = km\,a \quad ....(7.2)$$

Here, $a = \frac{(v - u)}{t}$ which is the acceleration, the rate of change of velocity.

The quantity 'k' is a constant of proportionality. The unit of force is chosen in such a way that the value of constant k becomes unity. The SI units of mass and acceleration are kg and ms^{-2} respectively. Accordingly, one unit force is defined as the amount that produces an acceleration of $1ms^{-2}$ in an object of mass 1 kg. That is

$$1 \text{ unit of force} = k \times (1\text{ kg}) \times (1\text{ ms}^{-2})$$

Thus the value of k becomes 1. From equation (7.2)

$$F = ma ....(7.3)$$

The unit of force is $kgms^{-2}$ or newton which has the symbol N. Thus, second law of motion provides us a method to measure the force acting on a body.

The second law of motion is often seen in action in our daily life. While playing a game of cricket, you might have experienced that it is easier to catch the fast moving ball by pulling the arms back as soon as the ball touches your palms. This increases the time during which the high velocity of the ball decreases to zero. Thus the acceleration of the ball is decreased and therefore the impact of catching the fast moving ball is reduced. On the other hand, if you keep your palms stationary as you catch the ball then its high velocity decreases to zero in a very short interval of time. Thus the rate of change of momentum is larger. Therefore a larger force would have to be applied for the catch that may hurt very much your palms.

In another observation, the athletes participating in high jump are made to fall either on a thick cushion of sponge or on a sand bed. This is to increase the time of the athelete's fall to stop after the jump. As a result, the rate of change of momentum is decreased and hence the force also. Try to think over how a karate player hits a slab of ice in order to break with a single blow.

The first law of motion can be treated mathematically as a special case of second law of motion, given in Eq.7.3. as,

$$F = ma = \frac{m(v-u)}{t} \quad \text{...............(7.4)}$$

or, $$Ft = m(v-u) = mv - mu \quad \text{........(7.5)}$$

Thus, when F = 0 i.e. there is no unbalanced force acting on the body, v = u for whatever time, t is taken. This means that the body will continue to move with uniform velocity 'u' through out the time 't' or will remain at rest if u = 0.

In Eq.7.5, the quantity 'Ft' is called the impulse of the force 'F' in the time interval 't' and denoted by I. as

$$I = Ft \quad \text{...................(7.6)}$$

From Eq.7.5, we see that the impulse of a force acting on a body is equal to the change in momentum of the body produced by the force. The SI unit of impulse is Ns or $kgms^{-1}$.

Example 7.1

A constant force of 4 N acts on a body of mass 2 kg for 4 s. Assuming the body to be initially at rest, find (i) its velocity when the force stops acting (ii) distance covered in 4 s after the force starts acting (iii) distance covered in the next 5s after the force ceases to act.

Solution:

We have been given that u = 0 ms^{-1} and m = 2 kg and F = 4 N; t = 4 s.

The acceleration $a = \frac{F}{m} = \frac{4\text{ N}}{2.0\text{ kg}} = \frac{4\text{ kg ms}^{-2}}{2\text{ kg}}$

$= 2\ ms^{-2}$

The final velocity at the end of 4 s can be calculated as

$v = u + at = 0\ ms^{-1} + 2\ ms^{-2} \times 4\ s$

$= 8\ ms^{-1}$

The distance covered during 4 s can be calculated as

$$s = \frac{v^2 - u^2}{2a} = \frac{(8\,ms^{-1})^2 - (0\,ms^{-1})^2}{2 \times 2\,ms^{-2}} = \frac{8^2\,m^2s^{-2}}{4\,ms^{-2}} = 16\text{ m.}$$

After the force ceases to act, the body will continue to move at the uniform vel. v = 8 ms^{-1}. The distance s′ covered in the next 5 s after the force ceases to act can be calculated as

$$s' = vt = 8\ ms^{-1} \times 5\ s$$
$$= 40\ m.$$

Example 7.2

A motor car is moving with a velocity of 144 kmh^{-1} and it takes 5 s to stop after the application of a braking force. Assuming the total mass of the motor car and passenger as 1800 kg, calculate the force exerted by the brakes on the motorcar.

Solution:

The initial velocity of the motorcar, u = 144 kmh^{-1}

$$\text{or,} \qquad u = \frac{144 \times 1000\ m}{60 \times 60\ s} = 40\ ms^{-1}$$

The final velocity of the motorcar, v = 0 ms^{-1}, since it is stopped by the braking force.

The total mass of motorcar with the passenger = 1800 kg and time taken to stop it = 5 s.

From Eq. 7.4, we get the magnitude of the force exerted by the brakes as $\frac{m(v-u)}{t}$

$$\text{or,} \qquad F = \frac{m(v-u)}{t}$$

Thus, on substitution, we have $F = \frac{1800\ kg \times (0-40)\ ms^{-1}}{5\ s} = -\ 14400\ kgms^{-2}$

$$= -\ 14400\ N.$$

The negative sign tells us that the force exerted by the brakes is opposite to the direction of motion.

Example 7.3

A constant force of 10 N is applied on two masses m_1 and m_2 in turn and the respective accelerations produced are 10 ms^{-2} and 20 ms^{-2}. What acceleration would this force give, if both the masses are tied together?

Solution:

From Eq.7.3; We have $m_1 = \frac{F}{a_1}$ and $m_2 = \frac{F}{a_2}$

Here, a_1 = 10 ms^{-2}; a_2 = 20 ms^{-2} and F = 10 N.

$$\text{Thus } m_1 = \frac{10\ N}{10\ ms^{-2}} = \frac{10\ kgms^{-2}}{10\ ms^{-2}} = 1.0\ kg$$

$$\text{And } m_2 = \frac{10\ N}{20\ ms^{-2}} = \frac{10\ kgms^{-2}}{20\ ms^{-2}} = 0.5\ kg$$

When the two masses are tied together, total mass, m = 1.0 kg + 0.5 kg.

= 1.5 kg.

Hence, the acceleration 'a' produced in the combined mass 'm' is

$$a = \frac{F}{m} = \frac{10\,N}{1.5\,kg} = \frac{10\,kgms^{-2}}{1.5\,kg} = \frac{20}{3}\ ms^{-2} = 6.67\ ms^{-2}.$$

Example 7.4

The velocity-time graph of a body of mass 1.0 kg sliding along a straight path on a platform is shown in Fig.7. 9. Obtain the force exerted by the platform on the body.

Solution:

The initial velocity of the body is 15 ms^{-1}. Due to the friction force exerted by the platform, the velocity of the body becomes zero in 30 s. Thus u = 15 ms^{-1}; v = 0 ms^{-1}; t = 30 s. Since the graph is a straight line, the acceleration is uniform but against the direction of motion.

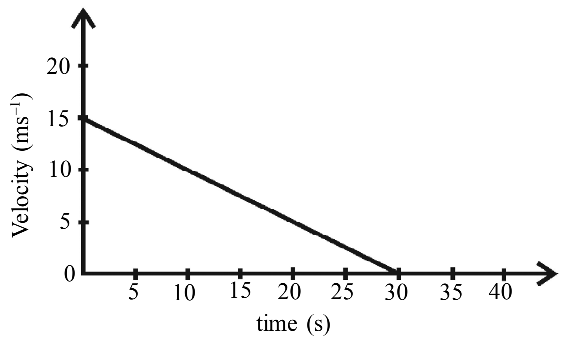


Fig.7.9

Thus the acceleration,

$$a = \frac{v-u}{t} = \frac{0\,ms^{-1} - 15\,ms^{-1}}{30\ s}$$

$= -\,0.5\ ms^{-2}$

Hence, the force F exerted on the body is F = ma = 1.0 kg × (– 0.5 ms^{-2})
= – 0.5 N.

The negative sign implies that the force due to friction exerted by the platform is opposite to the direction of sliding motion.

7.5 Newton's Third Law of Motion

We have seen that Newton's first and second laws deal with the effect of forces when they act on a body. The first law states that unbalanced forces produce a change in the velocity of the body and the second law gives the exact amount of force needed to produce a given acceleration. Unlike the two laws stated above, Newton's third law of motion is the relation between the forces themselves and it states that when one body exerts a force on another body, the other body also exerts a force on the first body. These forces are always equal in magnitude but opposite in direction. These forces act on different bodies and never act on the same body. This means that forces always occur in pairs. Let us consider an example associated in our daily life. In a football match a player looking at the football and trying to kick it with a greater force sometimes collide with a player of the opposite team. Both feel hurt because each of them applies a force on the other, thereby indicating a pair of forces. These two opposing forces are known as action and reaction forces.

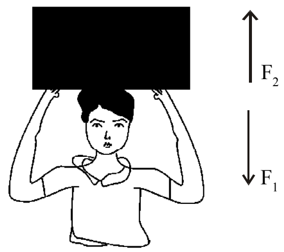


Fig. 7.10

Let us consider some more examples. When you hit a wall with your fist, the wall also hits your fist with same force and you can feel it. If you hit the same wall stronger than the earlier, you can feel more hurting than earlier. Suppose, a heavy load is put on the head of a porter Fig.7.10. The load presses the head in the downward direction. The porter's head pushes the load in the upward direction. These forces are equal in magnitude.

F_1 ® Force applied by the load on the head

F_2 ® Force applied by the head on the load.

Let us consider another example of two identical spring balances connected together as shown in Fig.7.11.

The fixed end of the balance B is attached to a rigid support such as a rigid wall. When the free end of balance A is pulled, it is observed that both the balances show the same reading on their scales. This phenomenon shows that force exerted by the balance A on balance B is equal but opposite in direction to that exerted by the balance B on A. The force exerted by balance A on the balance B is called the *action* while the force exerted by balance B on A is called the reaction. This illustration gives us an alternative statement of Newton's third law of Motion i.e. to every action there is an equal and opposite reaction. It is to be remembered that the action and reaction always act on two different bodies.

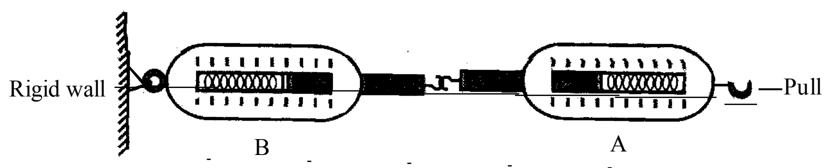


Fig.7.11: Action force and Reaction force are equal

Let us again consider an example that we have experienced in our day to day life. Suppose you are standing at rest and intend to start walking. You have to accelerate and this requires a force in accordance with the second law of motion. Here the force exerted by you is the muscular effort. Is it in the same direction you intend to walk? No, you push the ground backwards. The ground exerts an equal and opposite reaction force on your feet in order to make you walk forward. In fact you are walking in the direction of reaction force. Does the ground also accelerate to the same amount? No, this is because each force of equal magnitude acts on different bodies that may have a different mass. It will be clear from the following illustrations.

(1) When a gun is fired, it exerts a forward force on the bullet. At the same time, the bullet exerts an equal and opposite reaction force on the gun (Fig.7.12). Since the mass of the gun is much larger than that of the bullet, the acceleration of the gun is much less than that of the bullet.

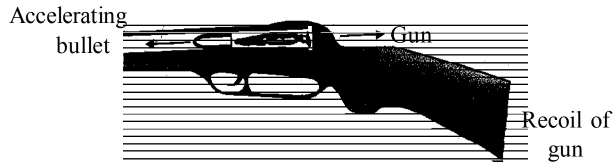


Fig. 7.12: A forward force on the bullet and recoil of gun

(2) When a sailor of a boat jumps forward to the bank of river, the force exerted on the boat makes it move backwards, as shown in (Fig.7.13)

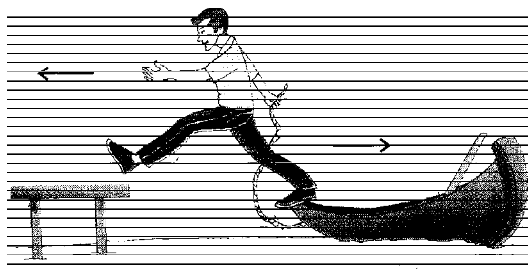


Fig.7.13: As the sailor jumps forward the boat moves backwards

7.6 Conservation of Momentum

Suppose two bodies such as two balls marked 1 and 2 having masses m_1 and m_2 are moving along a straight line in the same direction at different velocities u_1 and u_2 respectively. Let us assume that $u_1 > u_2$, so that m_1 will collide m_2 as shown in the Fig. 7.14 (a) and (b)

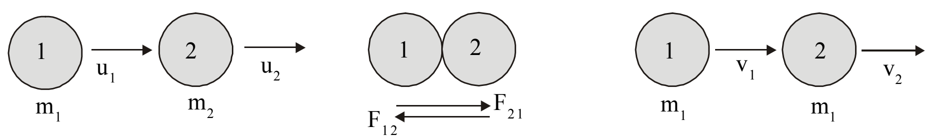


Fig. 7.14. (a) Before collision *(b) During collision* *(c) After collision*

The collision may last for a time 't' and during this interval ball 1 exerts a force F_{21} on the ball 2 and the ball 2 will also exert a force F_{12} on the ball 1. Let 'v_1' and 'v_2' be the velocities of 'm_1' and 'm_2' respectively after the collision, shown in Fig.7.14 (c). From the definition of momentum, the momenta of ball 1 before and after collision are m_1u_1 and m_1v_1 respectively. The change in momentum of ball 1 due to collision is $(m_1v_1 - m_1u_1)$ during the time t. Thus the rate of change of momentum which is equal to F_{12} during the collision will be $\frac{m_1(v_1 - u_1)}{t}$. Similarly, the rate of change of momentum of ball 2 which is equal to F_{21} during the collision, is $\frac{m_2(v_2 - u_2)}{t}$. As there are no other unbalanced forces acting on the balls, we can apply Newton's Third Law of Motion, according to which the force F_{12} exerted by ball 2 on ball 1 (Action force) and the force F_{21} exerted by ball 1 on ball 2 (Reaction force) must be equal and opposite to each other.

That is $F_{12} = -F_{21}$......................(7.7)

or, $$\frac{m_1(v_1 - u_1)}{t} = -\frac{m_2(v_2 - u_2)}{t}$$

$$m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$$

This gives

$$m_1v_1 + m_2v_2 = m_2u_2 + m_1u_1$$

or $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$..........(7.8)

i.e. Total momentum before collision = Total momentum after collision.

From Eq.7.8 we observe that total momentum of the two colliding balls remains unchanged or conserved provided no external unbalanced force acts. This is known as the law of conservation of momentum. The above can be stated as — "Momentum can neither be created nor destroyed – in a closed system consisting of number of bodies colliding with one another, the total momentum of the system remains constant".

7.6.1 Basic Working Principle of Toy Rocket

We have already seen the firing of toy rockets in certain festivals such as Diwali or Panthoibi Iratpa. The movement of the toy rocket is based on Newton's Third Law of motion as well as on the principle of conservation of momentum. In such a rocket, the hot gases produced by rapid burning of fuel rush out as a jet at the bottom and opposite reaction force of the downward going gases pushes the rocket upward with a great speed, as shown in Fig.7.15. Here the momentum of the rocket is equal to that of the hot gases.

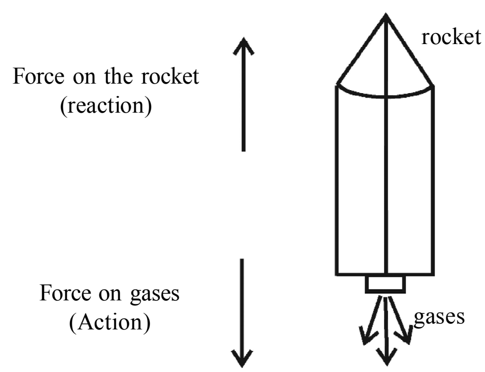


Fig. 7.15: Diagram showing action and reaction in the case of a toy rocket

Activity 7.2

Take a big rubber balloon and inflate it fully and tie its neck with a thread. Fix a soda straw on the balloon using adhesive tape. Pass a strong thread through the straw and fix the two ends on two rigid supports, separated by few metres as shown in Fig.7.16. Keeping the balloon closer to one of the supports, now remove the thread tied on the neck of the balloon. Observe the direction of motion of the balloon. It will move towards B, opposite to the direction of rushing out air.

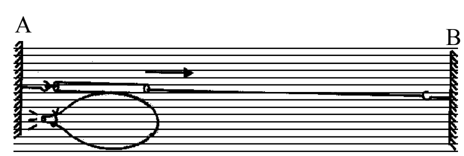


Fig. 7.16

Activity 7.3

Fill a test tube with some water and then place a stop cork at the mouth. Now suspend the tube nearly horizontal by two strings from a support as shown in Fig.7.17. Heat the test tube with a burner till the water boils and vapourises i.e. until the cork blows out.

Observe the directions of motion of the cork and recoil of the test tube. Also observe the difference in the velocity with which the cork appears to fly off and that of the recoil of the test tube in the arrangement.

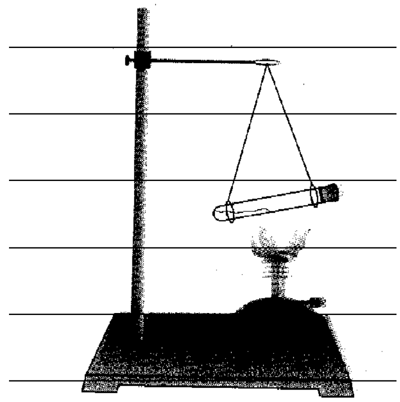


Fig.7.17

Example 7.5.

A bullet of mass 0.02 kg is fired horizontally from a pistol of mass 3 kg. If velocity of the bullet is 200 ms^{-1}, what will be the velocity of recoil of the pistol?

Solution:

Here mass of the bullet m_1 = 0.02 kg

initial velocity of the bullet, u_1 = 0 ms^{-1}

mass of the pistol, m_2 = 3 kg

initial velocity of the pistol, u_2 = 0 ms^{-1}

Total momentum of the pistol and bullet, before firing = (3.00 + 0.02) kg × 0 ms^{-1}

= 0 $kgms^{-1}$

Again, final vel. of the bullet after firing, v_1 = 200 ms^{-1}.

Let 'v' be the velocity of recoil of the pistol.

Total momentum of the bullet and pistol after firing

= 0.02 kg × 200 ms^{-1} + 3.00 kg × v ms^{-1} = (4 + 3v) $kgms^{-1}$

According to the law of conservation of momentum, we have

Total momentum after firing = Total momentum before firing

$$4 + 3v = 0$$

$$\Rightarrow v = -\frac{4}{3} = -1.33 \ ms^{-1}$$

The negative sign shows that the direction of recoil of the pistol is opposite to that of the bullet.

Example 7.6

A boy of mass 25 kg jumps on a stationary skateboard fitted with frictionless wheels having a mass of 3 kg. If the velocity of the boy on jumping is 3m/s horizontally, what is the velocity of the skateboard with the boy? Assume that there is no other external force on the system.

Solution:

Let v be the velocity of the boy and skateboard together at the moment of starting.

Total initial momentum

$= 25 \text{ kg} \times 3 \text{ ms}^{-1} + 3 \text{ kg} \times 0 \text{ ms}^{-1}$

$= 75 \text{ kgms}^{-1}$

Total final momentum after the boy has jumped onto the skateboard

$= (25 + 3) \text{ kg} \times v \text{ ms}^{-1} = 28\, v \text{ kgms}^{-1}$

According to the law of conservation of momentum, the total momentum is conserved, before and after jumping onto the skateboard.

Thus $28\, v = 75$

$$\therefore v = \frac{75}{28} = +2.678 \text{ ms}^{-1}$$

POINTS TO REMEMBER

(i) Force is that cause which produces *the change in the* state of rest or uniform motion of the body on which it acts.

(ii) A force or a set of forces can (a) change the speed of the body (b) change the direction of motion of the body (c) also change the shape of deformable bodies.

(iii) If forces acting on a body produce no acceleration in it, the forces are said to be balanced. If, on the other hand they produced a non-zero acceleration, the forces are called unbalanced.

(iv) The natural tendency of objects/bodies resisting a change in their state of rest or of uniform motion is called inertia. The mass of the body is a measure of its inertia and its SI unit is kilogram (kg).

(v) A stretched spring pulls the bodies connected to its ends whereas a compressed spring pushes the bodies connected to its ends.

(vi) Friction between two surfaces is due to the lack of smoothness.

(vii) Force of friction always opposes the direction of applied force.

(viii) The rate of change of momentum of an object is directly proportional to the applied unbalanced force and takes place in the direction of force.

(ix) The SI-unit of force is kgms^{-2} or newton, represented by the symbol N. A force of 1N produces an acceleration of 1 ms^{-2} on a body of mass 1 kg.

(x) The momentum of a body is the product of its mass and velocity and has the same direction as that of the velocity. Its SI unit is kgms^{-1}. The change in momentum of a body is equal to the impulse of the applied force. The SI unit of impulse is N s.

(xi) To every action there is an equal and opposite reaction and they act on two different bodies. So, when there is action there is reaction.

(xii) The total momentum of a system, where there is no external force, remains conserved.

EXERCISES

1. *Define balanced and unbalanced forces.*
2. *Can non-living objects exert a force? If yes, give two examples.*
3. *Why does the striker move through longer distances when some powder is sprinkled on a carromboard?*
4. *Explain Newton's laws of motion with example.*
5. *Give an example to demonstrate Newton's third law of motion.*
6. *Explain the meaning of inertia. Give appropriate examples to explain the inertia of rest and inertia of motion.*
7. *When you pull your arms back while catching a fast moving cricket ball, the chance of your hand getting hurt is less. Explain on the basis of Newton's laws of Motion.*
8. *When a hung carpet is beaten with a stick, dust particles come out of it. Explain.*
9. *A truck starting from rest travels down a hill with a constant acceleration. It travels a distance of 300 metres in 15 sec. Calculate its acceleration. Find the force actings on it, if its mass is 10 metric tonnes.*

   (1 metric tone = 1000 kg) $\left(\frac{8}{3}\text{ms}^{-2};\ 26666.7\text{ N}\right)$

10. *A force of 15 N acts on a body of mass 0.5 kg. Find the acceleration of the particle.*

    (30 ms^{-2})

11. *The velocity of a body of mass 125 g changes from 10 m/s to 5 m/s in 5 second. Assuming that a constant force acts on it, find the magnitude of the force.*

    $\left(\frac{1}{8}\text{N}\right)$

12. *A coin of mass 25 g is pushed on a table. The coin starts moving at speed of 25 cms^{-1} and stops in 5 s. Find the force of friction exerted by the table on the coin.*

    (0.00125 N)

13. *A hockey ball of mass 200 g travelling at 10 ms^{-1} is struck by a hockey stick so as to return it along its original path with a velocity of 5 ms^{-1}. Calculate the change in momentum occurred in the motion of the ball by the force applied by the hockey stick.*

    (3kgms^{-1})

14. *A horizontal force of 200 N is required to move a wooden cabinet across a floor at a constant velocity. Calculate the friction force exerted on the cabinet.*

(200 N)

15. *Two bodies having each of mass 2 kg are moving in the same straight line but in opposite directions. The velocity of each before collision is 3 ms^{-1}. In the collision they stick together. What will be the velocity of the combined body after collision?*

(Zero)

16. *A sharp object of mass 0.5 kg travelling horizontally at a velocity of 100 ms^{-1} strikes a stationary wooden block of mass 2.5 kg. Therefore the two move together in the same straight line. Calculate the total momentum before and after the impact. Also calculate the velocity of the combined system.*

(50 $kgms^{-1}$; $\frac{50}{3}$ ms^{-1})

17. *A ball of iron of mass 10 kg falls from a height of 0˙8 m. If the downward acceleration of the ball is 10 ms^{-2}, calculate the moentum transfer to the floor by the ball, provided the ball does not rebound.*

(40 $kgms^{-1}$)

18. *An unbalanced force acts on a body. The body must*

(a) remain at rest (b) move with uniform velocity

(c) be accelerated (d) move along a circle

(c)

19. *When a bus suddenly starts, the standing passengers lean backwards in the bus. It is an example of Newton's*

(a) first law of motion (b) second law of motion

(c) third law of motion (d) any one of the above laws of motion

(a)

20. *Action-reaction forces act*

(a) on the same body (b) on different bodies

(c) in the same direction (d) along different lines.

(b)

22. *Suppose a constant force acts on a body initially kept at rest. The distance covered by the body in time t from start is proportional to*

(a) t (b) t^{-1} (c) t^2 (d) t^3.

(c)

CHAPTER – 8

Gravitation

In the previous chapters 6 and 7, you have learnt about motion and force as the cause of motion of bodies. Besides, you know that a force is always needed to change the speed or direction of motion of a body.

In our daily life we have seen that an object dropped from a height above the earth's surface always falls towards the earth. It is said that a falling apple sparked the idea in the mind of Newton that the earth attracts all the objects towards its centre. Newton generalized this idea and stated that the same force is responsible for the motion of the planets around the sun, of the moon around the earth. This force is called the gravitational force.

In this chapter we shall learn about gravitation and universal law of gravitation and shall discuss the motion of bodies under the influence of gravitational force on the earth. We shall also discuss how the weight of a body varies from place to place.

8.1 Gravitation

We know that any object thrown upwards reaches a certain height after which it falls downward. After observing the fall of an apple on Newton, he thought that if the earth can attract an apple, can it not attract the moon which goes around the earth? Is the force the same in both cases? Newton guessed that the same type of force must be responsible in both cases. He argued that in the case of moon's motion round the earth, the moon maintains a constant distance from the centre of the earth, instead of going off in a straight line along the tangent on the circular orbit. This must be due to the attraction by the earth. But we do not really observe the moon falling towards the earth.

Let us try to understand such motion of the moon through the following activity.

Activity 8.1

Take a piece of thread and tie a small pebble at one end. Holding the other end of the thread try to whirl the pebble in a horizontal circular path as shown in Fig.8.1. Observe and note the motion of the pebble. Now, release the thread when the pebble is at any point in its orbit. Again note the direction of motion of the pebble.

In the activity you must have observed that the pebble moves in a circular path with a certain speed and changes its direction of motion continuously at every point of the path. The change in direction involves a change in velocity which is called acceleration. This acceleration is towards the centre of the orbit and caused by a force which keeps the body moving along the orbit. This force must be acting towards the centre and is called the centripetal (meaning 'centre-seeking') force.

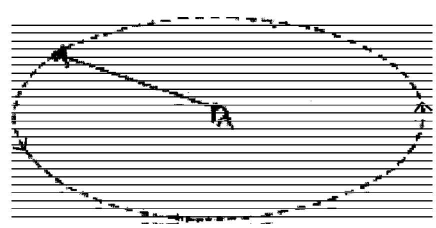


Fig.8.1: A pebble describing a circular orbit/path with a velocity of constant magnitude

In the absence of this force the pebble will fly off along a straight line due to its inertia. Such straight line will be a tangent to the circular path. That is why, whenever you release the thread, the pebble flies off along the tangent to the circular path.

Similarly for the motion of the moon around the earth, centripetal force must be necessary and this centripetal force is provided by the force of attraction between the earth and the moon. Had there been no such force, the moon would not have been seen as at present rather it would pursue a uniform straight line motion.

It is seen that a falling body or apple is attracted towards the earth. We may ask — does the apple also attract the earth? If so, we do not observe the earth moving towards any falling body or falling apple. Why? According to Newton's third law of motion, the apple also does attract the earth, with an equal force. But according to the second law of motion, acceleration is inversely proportional to the mass of the body, for a given force, *[Eq.7.3]*. Since, the mass of the earth is too large compared to that of the apple, the acceleration of earth towards the apple is negligible. So, we do not see the earth moving towards the apple. The same reasoning can be given for, why the earth does not move towards the moon.

We have learnt that in our solar system all the planets go round the Sun. On the same reasoning as above we can say that there exists a similar force between the sun and the planets. From the above facts Newton concluded that all objects in this universe attract each other irrespective of the form of the material of the objects. This force of attraction between objects is called the universal gravitational force.

8.1.1 Universal Law of Gravitation

Every object in this universe attracts every other object with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. The force acts along the line joining the centres of the two attracting objects.

Let two objects A and B having masses M and m lying at a distance 'd' between their centres be considered as shown in Fig.8.2. Let the force of attraction between them be 'F'. According to the above law, the force F is directly proportional to the product of their masses. That is

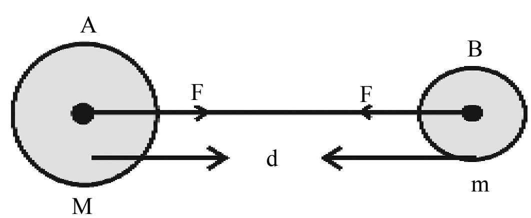


Fig. 8.2: The gravitational force between two objects

$$F \propto M \times m \text{ ....(8.1)}$$

And the force 'F' is inversely propotional to the square of the distance between their cntres. That is

$$F \propto \frac{1}{d^2} \text{ ....(8.2)}$$

Combining Eqs (8.1) and (8.2), we get

$$F \propto \frac{M \times m}{d^2} \text{ ....(8.3)}$$

or, $F = \frac{GM \times m}{d^2}$ ....(12.4)

Where G is called universal gravitation constant or universal constant of gravitation.

From Eq (12.4), $G = \frac{Fd^2}{M \times m}$ ....(12.5)

The SI unit of G is Nm^2kg^{-2}. The accepted value for G is 6.673×10^{-11} Nm^2 kg^{-2}, which was determined by Henry Cavendish (1731 – 1810) by using an extra sensitive balance designed for the purpose.

Compute the value of force of attraction between you and the earth when you are on the surface of it. The mass of the earth is about 6×10^{24} kg and distance of separation between you and centre of the earth, the average radius of the earth, which is about 6400×10^3 m. If you take your mass as 40 kg, the force of attraction will be

$$F = \frac{GMm}{d^2} = \frac{6.673 \times 10^{-11} \times 6 \times 10^{24} \times 40}{(64 \times 10^5)^2} \text{N}$$

$= 0.0390996 \times 10^4 = 391$ N.

Compute the value of the force of attraction between you and your friend sitting closely. Conclude how you do not experience this force.

The law of gravitation is universal because it is applicable to all bodies irrespective of material, shape, size and whether they are celestial or terrestrial.

Example 8.1

The mass of the earth is 6×10^{24} kg and that of moon is 7.4×10^{22} kg. If the distance between the earth and the moon is 3.84×10^5 km, find the force exerted by the earth on the moon and that exerted by the moon on the earth. Take $G = 6.7 \times 10^{-11}$ Nm^2kg^{-2}.

Solution:

The mass of the earth, $M = 6 \times 10^{24}$ kg

The mass of the moon, $m = 7.4 \times 10^{22}$kg

The distance between the earth and the moon,

$d = 3.84 \times 10^5 \times 1000$m

$= 3.84 \times 10^8$m

And $G = 6.7 \times 10^{-11}$ Nm^2 kg^{-2}

From Eq. (8.4), the force exerted by the earth on the moon

$$F = \frac{6.7 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2} \times 6 \times 10^{24} \text{kg} \times 7.4 \times 10^{22} \text{kg}}{(3.84 \times 10^8 \text{ m})^2}$$

$= 2.017 \times 10^{20}$N.

And the force exerted by the moon on the earth is also 2.017×10^{20} N i.e. of the same magnitude, since such force of gravitation is mutual.

8.1.2 Importance of the Universal law of gravitation

This law is an important one since this successfully explained several phenomena which were believed not to be related such as (i) force that binds us to the earth (ii) the motion of the moon round the earth (iii) the motion of planets including our earth round the sun (iv) the tides in the ocean .

8.2 Free Fall And Acceleration due to gravity

The meaning of free fall can be understood if you perform the following activity.

Activity 8.2

Take a small stone and throw it vertically upwards. It will reach a certain height and then will start falling down due to the gravitational force. The downward journey of the stone under the gravitational force alone is called "Free Fall i.e. the object is in free fall".

While falling there is no change in the direction of motion of the objects. But due to the gravitational force of the earth acting on the freely falling objects, there will be a change in the magnitude of the velocity. A change in velocity involves acceleration. Thus whenever objects fall towards the earth an acceleration is involved. This acceleration is called acceleration due to gravity and is denoted by 'g'. The unit of 'g' is the same as that of acceleration, that is (ms^{-2}).

Let 'm' be the mass of the stone used in the activity (8.2). The gravitational force acting on the stone is given by the product of 'm' and acceleration due to gravity 'g', from Newton's second law of motion. Thus the gravitational force F, acting on the falling stone is

$$F = mg \quad ....(8.6)$$

From Eq. (8.4) and (8.6), we get

$$mg = F = \frac{GM \times m}{d^2}$$

$$\Rightarrow g = \frac{GM}{d^2} \quad ....(8.7)$$

Here, M is the mass of the earth; 'd' is the distance of the stone from the centre of the earth.

Let the stone be on or close to the surface of the earth. The distance 'd' in Eq. (8.7) will be equal to R, the radius of the earth

$$\text{Thus, } mg = \frac{GMm}{R^2} \quad ....(8.8)$$

$$\text{or, } \quad g = \frac{GM}{R^2} \quad ....(8.9)$$

We know that the earth is not a perfect sphere. As the radius of the earth increases from the poles to the equator, the value of 'g' is greater at the poles than at the equator. Thus for most calculations, we generally take 'g' to be more or less constant on or at points close to the earth. However, for objects far away from the earth's surface, the acceleration due to gravity of the earth is calculated using Eq.8.7 and 'd' is taken as the distance of the object from the centre of the earth i.e. d = (R + h) where R is the average radius of the earth and 'h' is the height of the point where the object situates from the earth's surface.

The value of 'g' at the surface of the earth is calculated from Eq.(8.9), by taking $G = 6.7 \times 10^{-11}\ Nm^2\ kg^{-2}$; the mass of the earth $M = 6 \times 10^{24}$ kg and radius of the earth $R = 6.4 \times 10^6$ m.

$$\text{Thus, } g = \frac{6{\cdot}7 \times 10^{-11}\ Nm^2\ kg^{-2} \times 6 \times 10^{24}\ kg}{\left(6{\cdot}4 \times 10^6\ m\right)^2}$$

$$= 9.8\ Nkg^{-1} = 9.8\ ms^{-2}$$

Thus the acceleration due to gravity of the earth at its surface is $9.8\ ms^{-2}$. With the increase of distance of the object from the surface of the earth or as we go upwards from the surface of the earth, the value of 'g' goes on decreasing .

N.B. All bodies whether light or heavy; hollow or solid will fall with equal rapidity.

Example 8.2

A stone is thrown vertically upwards and rises to a height 19.6 m. Calculate (i) the velocity with which the stone was thrown (ii) the time taken to reach the maximum height i.e. the highest point.

Solution:

Distance covered = 19.6 m

Final velocity 'v', at the point of maximum height is zero ms^{-1}, while its initial velocity = u ms^1

Acceleration due to gravity, $g = 9.8\ ms^{-2}$

$\therefore$ Acceleration of the stone in the upward direction,

$a = -9.8\ ms^{-2}$, since the motion is upwards it is against gravity of the earth, $(a = -g)$.

From $v^2 = u^2 + 2as$ we get

$$o^2 = u^2 + 2\ (-9.8)\ ms^{-2} \times 19.6\ m$$

$$-u^2 = -2 \times 9.8 \times 19.6\ m^2s^{-2}$$

$$\therefore\ u = \sqrt{2 \times 9{\cdot}8 \times 2 \times 9{\cdot}8} = 2 \times 9.8 = 19.6\ ms^{-1}$$

Again, let 't' s be the time taken to reach the highest point.

From $v = u + at$ we get

$$\Rightarrow o = 19.6ms^{-1} - 9.8\ ms^{-2} \times t$$

$$\therefore\ t = \frac{19.6\ ms^{-1}}{9.8\ ms^{-2}} = 2s.$$

Thus the velocity with which the stone was projected is 19.6 m/s and time taken to reach the highest point is 2 second.

8.3 Mass

In the previous chapters we have learnt that the mass of an object is the measure of its inertia, being larger for greater mass. Inertia of an object remains the same whether it is on the earth, on the moon or even in outerspace. Thus the mass of an object does not change from place to place, i.e. mass remains constant.

8.4 Weight

It is already known to us that the earth attracts every object with a certain force depending on the mass (m) of the object and the acceleration due to gravity (g) for the earth at the point where the object situates. The force with which the earth attracts the body is called the weight of the body on the earth.

Thus, the weight of a body of mass (m) placed on or near the surface of the earth is

$$W = F = \frac{GMm}{R^2} = mg ....(8.10)$$

Where M is the mass of the earth and R is its radius.

The SI unit of weight is the same as that of force, that is newton (N), and is acting vertically downwards; it has both magnitude and direction.

The weight of a body of mass 1 kg is $w = mg = 1\ kg \times (9.8\ ms^{-2})$

$= 9.8\ N.$

This weight is called one kilogram weight written in short as 1 kg wt or 1 kgf.

Since the value of 'g' is constant at a given place, at a given place the weight (w) of an object is directly proportional to its mass (m) i.e. *w µ m*. It is due to this reason that at a given place if the weights of two bodies of masses m_A and m_B are equal then their masses m_A and m_B should be equal, because the mass of an object remains the same everywhere.

8.4.1 Weight of an object on the Moon

From the concept of the weight of an object on the earth, the weight of an object on the moon is the force with which the moon attracts that object when the object is on or very near to the surface of the moon.

Let the mass of the object be (m). By applying the universal law of gravitation, the weight of the object on the moon will be

$$W_m = \frac{G\ M_m \times m}{R_m{}^2} ....(8.11)$$

Where M_m = mass of the moon; R_m = radius of the moon.

Let us now compare the weights of an object of mass (m) when it is on the earth and on the moon, using known values of mass and radius of the celestial bodies given in table (8.1)

Table 8.1

Celestial bodies	Mass (kg)	Radius (m)
Earth	5.98×10^{24}	6.37×10^{6}
Moon	7.36×10^{22}	1.74×10^{6}

Weight of object on the earth,

$$W_e = \frac{G \times 5.98 \times 10^{24} \times m}{(6.37 \times 10^{6})^2}\ N ....(8.12)$$

And weight of the same object on the moon,

$$W_m = \frac{G \times 7.36 \times 10^{22} \times m}{\left(1.74 \times 10^6\right)^2} \text{ N} \ldots\ldots\ldots\ldots\ldots(8.13)$$

Dividing Eq (8.13) by Eq (8.12), we get

$$\frac{W_m}{W_e} = \frac{\cancel{G} \times 7.36 \times 10^{22} \times \cancel{m}}{\left(1.74 \times 10^6\right)^2} \times \frac{\left(6.37 \times 10^6\right)^2}{\cancel{G} \times 5.98 \times 10^{24} \times \cancel{m}} = \frac{298.646 \times 10^{34}}{18.105 \times 10^{36}}$$

$$= 16.495 \times 10^{-2} = 0.16495 \simeq \frac{1}{6} \ldots\ldots\ldots\ldots\ldots(8.14)$$

Thus the weight of the object on the moon = $\frac{1}{6}$ × its weight on the earth.

From Eq. (8.10), we can learn that the acceleration due to gravity of the moon at its surface is about $\frac{9.8}{6}$ ms^{-2} i.e. 1.63 ms^{-2}

Example 8.3

Find the weight of a baby whose mass is 3 kg.

Solution:

The weight of the baby is W = mg

Where m = mass of the baby = 3 kg

g = acceleration due to gravity of the earth = 9.8 ms^{-2}

= 3 kg × 9.8 ms^{-2}

= 29.4 $kgms^{-2}$ = 29.4 N.

Thus the weight of the baby is 29.4 N.

Example 8.4

The weight of an object on the surface of the earth is 18 N. What would be its weight when measured on the surface of the moon?

Solution:

We know that the weight of an object on the moon is always $\left(\frac{1}{6}\right)^{th}$ of its weight on the earth's surface.

Thus, weight of the object on the moon's surface will be

$W_m = \frac{1}{6} \times W_e$ where W_e = weight of the object on the earth's surface and

W_e = 18 N.

$\therefore W_m = \frac{1}{6} \times 18 = 3$ N.

8.5 Measurement of Mass

Let us consider two bodies (A and B) having masses m_A and m_B respectively. The way to compare the masses is to compare the gravitational force exerted by the earth on two bodies. Using Eq (8.8), we get the gravitational forces F_A and F_B as

$$F_A = \frac{GM \times m_A}{R^2} \quad \text{And} \quad F_B = \frac{GM \times m_B}{R^2}$$

Where M = Mass of the earth; R is its radius.

$$\text{Thus} \quad \frac{F_A}{F_B} = \frac{m_A}{m_B} \quad ....(8.15)$$

If the gravitational forces on the two bodies are equal then $m_A = m_B$. Thus, if we can be sure that the earth is attracting the two bodies with equal forces, we can conclude that their masses are equal. A common-balance, also known as equal-beam balance does exactly the job for measuring masses of the bodies. A beam balance is shown in Fig.8.3. Two identical pans are suspended from the ends of a uniform beam which is pivoted at its centre. If the earth attracts the two bodies kept on each of the pans with equal forces then only the beam stays at rest in a horizontal position. In the actual process, the beam is made to remain at rest by placing standard masses on left hand side pan A. These standard masses are the copies of those standard kept at International Bureau of Weights and Measures at Sevres, France.

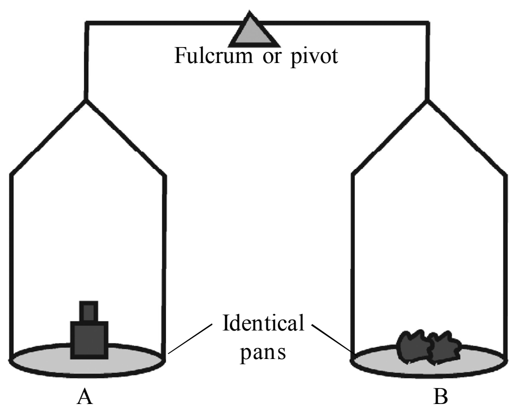


Fig.8.3. Common balance

Once, we have standard masses, we can find the mass of any object by comparing to the standard masses.

8.6 Measurement of weight

We have learnt from the above discussions that mass and weight are two different quantities. The mass of a body is its inherent property and remains the same everywhere in the universe. But the weight of a body varies with place. A body of mass 1 kg has weight 9.8 N at the surface of the earth and about 1.633 N at the surface of the moon. But the mass 1 kg of the body remains 1 kg in all the situations. It must be noted that mass in measured in kilogram whereas weight is measured in newton.

When you stand on a weighing machine, do you get your weight or your mass? The machine measures the apparent weight and converts it to the corresponding mass for earth's surface. For example — if the measured apparent weight is 980 N, the machine will show 980/9.8 = 100 kg. Generally we say that the weight is 100 kg. If the same weighing machine and the object were taken to the moon, it will show a much smaller reading than on the earth's surface.

Similarly, when we suspend a body from a spring balance, we actually measure the apparent weight. In fact, it is the contact force between the spring and the body that extends the spring and gives the measured weight. The common weighing machine and a simple type of spring balance are shown in Fig.8.4.

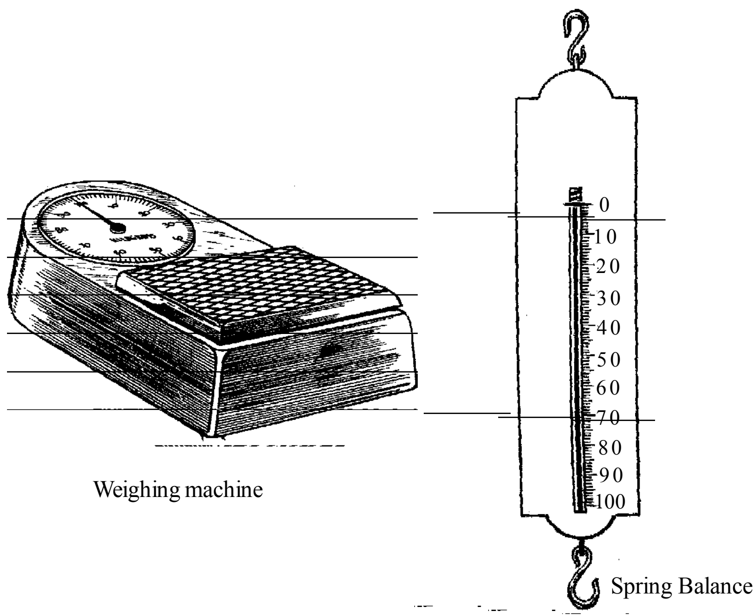


Fig. 8.4: Weighing Machine and simple spring balance

POINTS TO REMEMBER

(i) The gravitational force of attraction between any two bodies or objects is directly proportional to the product of the masses of two bodies and is inversely proportional to the square of the distance between the bodies. The direction of the force is along the line joining their centres and mutual.

(ii) Gravitation is a weak force for small masses, unless large masses are involved.

(iii) The force of gravitation due to the earth is specially called gravity.

(iv) The force of gravity decreases with the increasing height above the earth's surface and also decreases from the pole towards the equator on the surface.

(v) The force by which the earth attracts a body is called the weight of the body on the earth. The weight of a body changes with height above the earth's surface but the mass of the body remains the same everywhere.

(vi) The weight of a body is equal to the product of its mass and acceleration due to gravity at the point where the body is situated.

(vii) If two bodies have equal weights at a given place then they will have equal weights at any other place.

EXERCISES

1. *In which manner the force of gravitation will change when*
   (i) the distance between them is made double
   (ii) the distance between them is reduced to half?
2. *We know that the gravitational force acting on all objects is proportional to their masses. Why then a heavier object does not fall faster than a lighter object?*
3. *If each body in the universe attracts the every other body, why don't two books kept on a table come towards each other and collide?*
4. *Distinguish between 'G' and 'g'.*
5. *Starting from Newton's law of gravitation, show that the value of 'g' decreases as one goes above the earth's surface.*
6. *We know that the earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force which is greater or smaller or the same as the force with which the moon attracts the earth? Give reason for your answer.*
7. *From the universal law of gravitation we have learnt that the moon attracts the earth, why does the earth not move towards the moon?*
8. *What will happen to the force between two bodies, if*
   (i) the mass of one of the them is doubled?
   (ii) the distance between the bodies is doubled?
   (iii) the masses of both are doubled?
9. *What do you mean by the weight of a body? State its unit.*
10. *Suggest two methods of comparing masses of two bodies A & B i.e.* m_A *and* m_B.
11. *When you put an object on a spring balance, do you get the mass of the object or its weight.*
12. *A force of 20 N acts on a body whose weight is 9.8 N on the earth. What is the mass of the body and how much is its acceleration?*

    (1 kg; 20 ms^{-2}).
13. *A stone is released from top of a roof whose height is 19.6 m. Calculate its final velocity just before reaching ground.*

    (19.6 ms^{-1})

14. *A ball which is thrown upwards vertically returns to the earth after 8 s. Find*

    (i) the initial velocity with which it is thrown up.

    (ii) the maximum height it reaches.

    (iii) its position after 5 s.

(i) 39.2 ms^{1} (ii) 78.4 m (iii) 73.5 m

15. *A stone is dropped from a height of 49 m and simultaneously another ball is thrown upwards from the ground with a speed of 40 m/s. When and where do the two stones meet?*

(1.225 s; 41.647 m above the earth).

16. *A particle is taken to a height R above the earth's surface where R is the radius of the earth. The acceleration due to gravity of the earth at that point is*

    (A) 2.45 m/s^2 (B) 3.45 m/s^2

    (C) 4.9 m/s^2 (D) 9.8 m/s^2 (A)

17. *Two bodies A and B of masses 1 kg and 2 kg respectively are dropped near the earth's surface. Let the acceleration of A and B be a_1 and b_1 respectively, then*

    (A) $a_1 > b_1$ (B) $a_1 < b_1$

    (C) $a_1^1 b_1$ (D) $a_1 = b_1$ (D)

18. *When a body is thrown up, the force of gravity is*

    (A) in the upward direction. (B) in the downward direction

    (C) Zero (D) in the horizontal direction. (B)

CHAPTER – 9

Work, Energy And Power

In the previous chapters we have learnt about the ways of describing the motion of objects, the cause of motion of the objects and the universal gravitation. In this chapter we shall study about "work" which is a natural phenomenon and is closely related to energy and power. The term "work" has different meanings. For example — Mr Tomba is working in a factory; Jahera is a great work of Angahal; the machine is in working order; there are a number of worked out problems in this book; let us work out a plan for the next year etc. However in physics the term 'work' has a special meaning. It represents a physical quantity defined in a special way. When an object moves under an applied force, we say that, in physics, the force has done work on the object. When an apple falls on the earth from a tree, the force of attraction of the earth does work on the apple. When we throw a ball, push a book on a table etc we exert a force and we say that this force does work.

Living beings have to perform several basic activities to survive which are known as "life processes". Besides, we are also performing other activities like playing, singing, reading, writing, jumping, running, cycling and thinking. In performing such activities we need energy. That is why all living beings need food. Similarly, animals too get engaged in certain activities. As for example — they jump, run, fight and run away from enemies, find food etc. We also engage some animals to lift weights, carry loads, pull carts, plough fields etc. All such activities need energy which is obtained from the foods they consumed.

Over and above, the machines that we have come across need food in the form of fuels like petrol, diesel or electricity for their working. Now you know that living beings and machines need energy.

9.1 Work

You know that there is a difference in the way we use the term work in day-to-day life and the way we denote it in science. In order to make this point clear let us consider a few more examples.

Suppose a student is preparing for examination. He spend a lot of time in reading books, drawing diagrams, collecting question papers, discussing problems with his friends, performing experiments etc. In doing so, he spends a lot of energy. In common parlance we use to say he is working very hard. If we go by the scientific definition of work, the hardwork of the student may involve very little work.

Suppose, you are trying to push a huge rock or a loaded truck. If the truck or rock does not move inspite of all your effort, for which you get completely exhausted, you have not done any work scientifically since there is no displacement of the objects that you are pushing. Similarly, when you stand still with a load on your head you get tired. In this situation you have exerted yourself and have spent a lot of your energy. According to the way we understand the term 'work' in science, you are not doing any work on the load.

In other activities like climbing up the steps of a staircase, a tall tree, if we apply the scientific definition, these involve a lot of work.

Now, you have learnt that many activities in our day to day life although being considered as work, are not considered as work scientifically. That is why the term work in science is defined in a different way. To understand the way for defining work in science, let us do the following activity.

Activity .... 9.1.

Out of the activities discussed so far in the above and considered to be work, try to ask the following questions and also try to give the answer.

(i) What is the work being done on?
(ii) What happens to the object?
(iii) Who or what is doing the work?

9.1.1 Scientific definition of work

Let us try to understand the way in which we view 'work' and we define it from the point of view of science.

A closer look at the above examples reveals that two conditions are essential for work to be done. They are (i) a force should act on an object (ii) the object i.e. point of application of the force must be displaced. If any one of the conditions does not exist, work is not done. For example, when a boy pushes a book on the table we say that the boy has done a work on the book. The work, however, is done by the force exerted by the boy who is the agent.

Activity ....9.2.

Consider some situations that you have seen in your daily life involving work and try to list them into two groups as (1) involving displacement (2) not involving displacement.

Definition of work

The work done by a force acting on an object is equal to the product of the force and displacement of the object in the direction of force.

9.1.2 Calculation of Work Done by a Constant Force

Let a constant force 'F' act on an object and the object be displaced through a distance 's' along the direction of the force as shown in (Fig.9.1). If W is assumed to be the work done by the force on the object, then from,

Work done = Force × Displacement, we get

$W = Fs$...........(9.1)

Thus work done is equal to the product of magnitude of the applied force by the distance moved in the direction of the force. Hence, work has only magnitude but not direction.

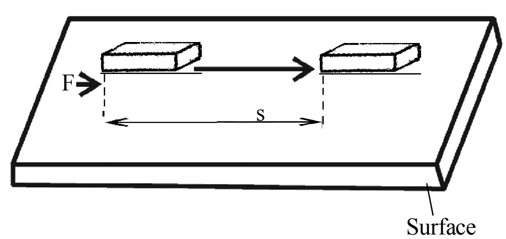


Fig. 9.1

If $F = 1$ N and $s = 1$ m then W will be 1 Nm or joule (J). This is given a separate name 'joule' in honour of the British scientist James Prescott Joule. It is denoted by the letter 'J'. Examine the Fig. (9.1) carefully. What will be the work done when the force 'F' on the object is zero? What will be the work done when the displacement of the object is zero? Thus, it can be referred to the conditions that are to be satisfied to say that a work is done by the force.

Let us consider another example i.e. when the displacement is opposite to the direction of force. If a ball is thrown up, its displacement is in the upward direction whereas the force due to the earth's gravity is in the downward direction. We can say that the angle between the two directions is 180°. In such a situation the work done by the force of gravity i.e. force 'F' is taken as negative. Thus the amount of work done by the force on the object is

$W = F \times (-s)$ or $(-F) \times s$.

Now, it is clear from the above discussions that work done by a force can be either positive or negative. Let us try to understand the above fact from the following activity.

Activity .... 9.3.

Suppose, you are lifting a suitcase from ground floor to the first floor of your house or to a greater height. Work is done by the force exerted by you on the suitcase. So it moves upwards. The force you exerted is in the direction of displacement. However there is the force of gravity acting on the suitcase. Using the principle that work done is negative when the force acts opposite to the direction of displacements and positive when the force is in the direction of the displacement, which one of the forces is doing positive work and which one is doing negative work; give reasons.

Example 9.1

A man lifts a luggage of 25 kg from the ground and puts it on a floor 2.0 m above the ground. Calculate the work done by him on the luggage.

Solution:

Mass of the luggage, m = 25 kg; displacement s = 2.0 m.

The weight of the luggage = mg = $25\ \text{kg} \times 9.8\ \text{ms}^{-2}$

Work done by the man, $W = F \times s = mg \times s$

$\therefore\ W = 25\ \text{kg} \times 9.8\ \text{ms}^{-2} \times 2\ \text{m} = 490\ \text{kgms}^{-2} = 490\ \text{Nm}$

$= 490$ J.

The work done by the man = 490 J.

Try to Answer:

1. When do we say that work is done by a force?
2. What is the expression for the work done when a force is acting on an object in the direction of displacement?
3. What is 1 J of work?

4. In ploughing a paddy field, a pair of bullocks exerts a force of 200 N together. If the length of field is 50 m, how much work is done in the process?

9.2 Energy

Life processes are not possible without energy. It is known that the demand of energy is ever increasing. Where do we get energy from? The biggest energy source for us is the Sun. Most of our energy sources are derived from the Sun. We can also get energy from the nucleus of atoms, the interior of the earth and the tides. Can you imagine the other sources of energy?

Activity .... 9.4.

A few sources of energy are cited above. There are many other sources of energy and try to list them. Discuss among your friends to identify sources of energy due to the Sun and those not due to the Sun.

The word 'energy' is very often used in our daily life by many but in science it carries a definite meaning. Let us discuss some examples.

When a fast moving object like a cricket ball hits a wicket, it is thrown away. Similarly, when objects are raised to a certain height possess capability to perform work, proportional to the heights to which they are raised. In another example water falling from a great height has the capability to rotate turbines connected to an electric generator. You must have seen that when a raised hammer hits a nail placed on a piece of wood, it drives the nail into the wood. We have also observed that when the spring of a toy car is wound and then released, the car starts moving, on the floor. When we press an inflated balloon, we observe that there is change in its original shape which will come back when the pressing force is released or withdrawn. However if we press still hard, the balloon may explode producing a blasting sound. In all the above examples, the objects acquire through different means, the capacity for doing work. Any object having capability to do work is said to possess energy. The objects which do work lose energy whereas the objects on which work is done gain energy.

Let us examine how does an object with energy do work? The object that possesses energy can exert a force on other object. When this is happened, energy is transferred from the former to the latter. The second body may move as it receives energy and therefore do some work. This implies that any object that possesses energy can do work. The energy possessed by a body is measured in terms of its capacity for doing work. The unit of energy is thus the same as that of work done which is in joule (J) in SI-system. Some times, still larger units kilojoule (kJ) or mega joule (MJ) is also used to express the energy possessed by an object (1kJ = 1000 J; 1 MJ = 10^6 J).

9.2.1 Different Forms of Energy

We get energy in different forms. The various forms include mechanical energy (kinetic energy and potential energy), heat energy, chemical energy, electrical energy, light energy, sound energy.

9.2.2 Kinetic Energy

Activity 9.5

Take a heavy but small iron ball and drop it from different heights on mud starting from a lowest height. The ball will create a depression on mud. Increase the height from where the ball is dropped and observe the depth of the depression. Compare the depths and find out the shallowest and deepest.

Discuss and analyse the observations.

Activity 9.6

Set up the experimental arrangement as shown in Fig.9.2. Place a wooden block B of known mass slightly at the left side of pegs D and C whose distance apart is less than the dimension of block A so that, in any case, A can not go beyond CD but the block B can pass through. Keep a heavy metal block on A and place a known mass on the pan so that A will move when the metal block is removed from A.

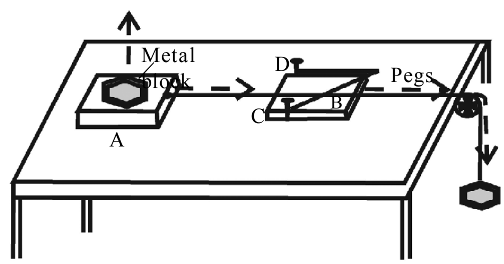


Fig. 9.2

Remove the metal block and note down the displacement of B. This means that work is done on block B as it gains energy.

From where does this energy come?

Repeat the activity by increasing the mass on the pan. Check in which case the displacement of B is larger.

In this activity you know that the moving block A does work and it possesses energy.

You can understand from the above that a moving object can do work. An object moving faster can do more work than an object of identical mass moving relatively slow. We have seen already in our daily life that blowing wind can rotate the blades of a windmill, a moving bullet fired from a gun can pierce a target; moving water can rotate a turbine etc. These observations show that objects in motion possess energy which enables them to do work. We call this energy as kinetic energy. In short, the energy possessed by an object due to its motion is called *kinetic energy*. By definition we say that the kinetic energy of a body moving with a certain velocity is equal to the work done on it to make it acquire that velocity.

Let us try to express how much kinetic energy is possessed by a moving object, in the form of an equation. Let us consider an object of mass 'm' moving with a uniform velocity 'u'. Let it now be displaced through a distance s when a constant force 'F' acts on it in the direction of displacement.

From Eq. (9.1), work done W is ($F \times s$) and this work done will cause a change in its velocity since the force is the cause of acceleration. Let 'a' be the acceleration produced, changing the velocity from 'u' to 'v'.

From $v^2 - u^2 = 2as$, we get

$$s = \frac{v^2 - u^2}{2a} \text{ ....(9.2)}$$

We also know that the force F = ma. After putting 's' in Eq. (9.1) we can write the work done by the force F as

$$W = ma \times \frac{v^2 - u^2}{2a}$$

$$= \frac{1}{2} m(v^2 - u^2) \text{............ (9.3)}$$

If the object were starting from stationary position then

$$u = 0 \quad \text{and} \quad W = = \frac{1}{2} mv^2 \text{.............(9.4)}$$

Thus the kinetic energy possessed by a body of mass 'm' moving with a uniform velocity 'v' at any instant of time is

$$E_k = \frac{1}{2} mv^2 \text{ ....(9.5)}$$

Example 9.2

Suppose a car of mass 2500 kg was moving at a uniform velocity 18 km h^{-1}. What is the work to be done by its engine to increase its velocity to 36 km/h.

Solution:

Mass of the car, m = 2500 kg

Its initial velocity, u = 18 kmh^{-1} = $\frac{\overset{3}{\cancel{18}} \times 10\cancel{00}}{_{2}\cancel{60} \times \cancel{60}}$ ms^{-1}

= 5 ms^{-1}

Similarly, the final velocity v = 36 kmh^{-1} = $\frac{\cancel{36} \times 10\cancel{00}}{\cancel{60} \times \cancel{60}}$ = 10 ms^{-1}

Thus the initial kinetic energy

$$E_{ki} = \frac{1}{2} mu^2 = \frac{1}{2} \times 2500 \times 5^2 \text{ J.}$$

And the final kinetic energy

$$E_{kf} = \frac{1}{2} mv^2 = \frac{1}{2} \times 2500 \times 10^2 \text{ J.}$$

Therefore the require work to be done

$$= E_{kf} - E_{ki} = \frac{1}{2} \times 2500 \times 10^2 - \frac{1}{2} \times 2500 \times 5^2 = \frac{1}{2} 2500 (100 - 25)$$

$$= \frac{1}{2} \times 2500 \times 75 = 1250 \times 75 = 93750 \text{ J.}$$

Try to answer:

1. What is kinetic energy of an object?

9.2.3 Potential Energy

Let us perform some experiment to understand the nature of potential energy possessed by an object.

Activity 9.6

Stretch a rubber band using your hands. Release the band at one of its ends. What happens? The band will regain its original length, because it had acquired energy in its stretched position. How is this energy acquired by stretching?

Activity 9.7

Wind the spring of a toy car with the help of its key to a certain number of rotation and then place it on the floor. Did it move? From where did it acquire energy for the motion? Does the energy acquired depend on the number of windings? Try to test it.

Activity 9.8

Take the spring from a ballpen and compress it. Now release the spring slowly. What happens? How did the spring acquire energy when compressed? Would the spring acquire energy when it is stretched?

Activity 9.9

Lift a marble to a height 'h' and then release on a hard floor. It will certainly fall. After striking the floor, see what happens? It begins to jump to a height vertically. Measure the height attained by it. Repeat by lifting the same marble to a height higher than 'h'. Measure the height through which it jumps from the same floor. Think and discuss.

In the above activities, the energy gets stored due to work done on the objects. You supply energy when you stretch a rubber band or in compressing the spring. The energy supplied in each case is the potential energy since the energy is not used to cause change in velocity or speed of the object.

Similarly, you are doing work while winding the spring of the toy car. The energy supplied while winding the spring is stored as potential energy present in it by virtue of its configuration.

Activity 9.10

Prepare a bow using a bamboo stick as shown in Fig.9.3. and place an arrow made of light and straight stick as shown in the Fig.9.3. Now stretch the string with the arrow in position and then release the arrow. See the motion of the arrow flying off the bow and notice change in the shape of the bow in the two cases i.e. while stretching and on releasing. The potential energy stored in the bow due to the change in configuration is thus used in imparting kinetic energy to the arrow.

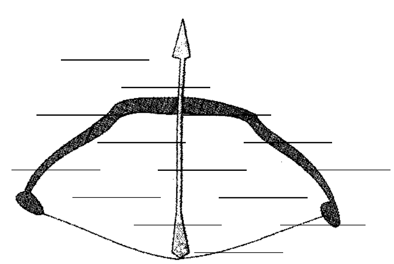


Fig.9.3. Bow and arrow

9.2.4 Potential Energy of an object at a height

The potential energy of an object increases when it is raised from a lower level to a higher level because of work done on it against the gravity while it is being raised. The energy possessed by such an object is called the *gravitational potential energy*. The gravitational potential energy of an object at a point above the ground is defined as the work done by the agent on the object in raising it against the gravity of the earth.

Let us try to obtain an expression of potential energy in the above situation.

Consider an object, say a stone, of mass 'm' raised through a height 'h' from the ground. The minimum force required to raise is equal to its weight 'mg'. The object gains energy equal to the work done on it. Let the work done be W.

Thus, work done, W = force × displacement

= mg × h

= mgh = energy gained by the object, since the work is done on it.

This is the potential energy of the object at a height 'h' above the ground.

That is, E_p = mgh ....(9.6)

If 'm' is in kg; g is in ms^{-2} and 'h' is in 'm' then E_p is in 'J' (joule). It is to be noted that workdone against the gravity is independant of the path but depends only on the initial and final positions of the object. Fig.9.4 shows a case where a block is raised from position A on the ground to a position B above by following two different paths to a height 'h'.

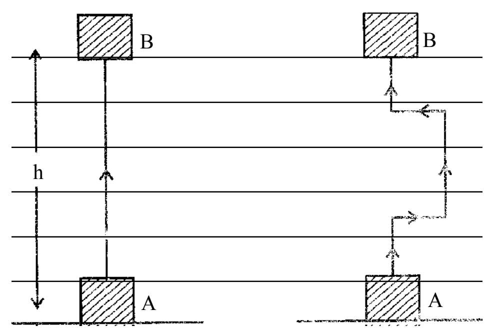


Fig.9.4

Example 9.3

Find the potential energy possessed by an object of mass 15 kg when it is raised to a height of 10 m above the ground. Given g = 9.8 ms^{-2}.

Solution:

Mass of the object, m = 15 kg; displacement or height raised h = 10 m.

Potential energy = mgh = 15 kg × 9.8 ms^{-2} × 10 m

= 1470 J.

Thus the potential energy = 1470 J.

9.2.5 Interconvertibility of Various Forms of Energy

Can we convert energy from one form into another? We have observed in nature a number of instances of conversion of energy from one form to another or others. You can get some idea about the conversion of energy of one form into another form from the following activities:

Activity 9.11

Discuss the following questions with your friends and try to answer:

1. How do green plants produce food to keep them alive?
2. Where do they get the required energy?
3. What kinds of energy conversions are in the water cycle in nature?
4. What makes the air move from one place to other place?

Activity 9.12

You have seen a number of gadgets used in our daily life. Such gadgets involve the conversion of energy from one form to another for their working. Prepare a list of such gadgets and their activities. Identify them bases on the kind of energy conversion that takes place for working them.

9.2.6 Law of Conservation of Energy

You must have learnt that, from the above activities, energy can be transformed from one form to another. At the same time you may ask a question — "What about the total quantities of the different forms of energy"? For the answer to this question, you should remember that — "Whenever energy gets transformed, the total energy remains unchanged". This is the universal law of conservation of energy. According to this law, energy can never be created nor destroyed but total energy before and after the transformation remains the same. It means that when all forms of energy are taken into account, the sum total of energy in the universe is constant. This principle is also valid for an isolated system i.e. any system where no force acts from any agent.

Let us consider a simple example with a ball falling from a height. Its gravitational potential energy decreases as it falls. It may appear that its energy has been lost. But the ball comes into motion and hence it acquires kinetic energy which was zero at the beginning.

Suppose the mass of the ball is 'm' and it is made to fall from a height 'h' above the ground where it is at rest. The total energy of the ball at the start is 'mgh'. As it falls, its potential energy will change into kinetic energy. If 'v' is its velocity at any instant when it falls through a distance 'x' from the starting point, then its potential energy is mg (h – x) and $v^2 - u^2 = 2g.\ x$

But u = o, then $v^2 = 2gx$............(9.6)

Thus its kinetic energy at that point is $\frac{1}{2}mv^2 = \frac{1}{2}m2gx = mgx$............(9.7)

Therefore its total energy at the instant is mg (h – x) + mgx = mgh, which is the total energy at the beginning of fall.

Further, if 'v' is the velocity of the ball when it just touches the ground i.e. after falling through the height h then from above its potential energy is zero (since x = h) and $v'^2 = 2gh$ for which its kinetic energy becomes $\frac{1}{2}mv'^2 = \frac{1}{2}m.\ 2gh = mgh$

Thus total energy at the ground = potential energy at the ground + its kinetic energy at the ground = mgh + 0 = mgh, which is also the total mechanical energy at the beginning of fall.

From the above you have seen that during the falling of the ball, the decrease in potential energy at any point of its path, appears as an equal amount of increase in its kinetic energy. Thus there is a continuous transformation of gravitational potential energy into the kinetic energy.

Let us discuss some more examples on transformation of energy. (i) When we switch on an electric torch the electrical energy derived from the chemical energy stored in the cells (batteries) is converted into heat energy as the filament of the bulb gets heated and heat energy is then transformed into light energy. (2) When a person pushes an object, the energy of the object increases. As the total energy is constant, the person must lose the same amount of energy. That is why when we push a block on a floor, we feel tired. Here, we do work on the block and hence lose our own energy.

Think it over! If the transformation of energy were not happened in the nature, life could not have been possible. Do you agree with this?

9.3 Rate of Doing Work

Activity 9.13

Consider two persons i.e. you and your friend having the same body weight, have to climb to the top of a small hillock of height 10 m (say). Let us say that you take 20 s while your friend takes 25 s, to arrive at the top following the same path.

What is the work done by each? Work done is the same since both have the same body weight. But you take less time than your friend.

Who has done more work in 1s?

You will know that you are doing more work in 1s. In this way all the machines consume or transfer energy at different rates. Agents that transfer energy do work at different rates. Thus a more powerful vehicle could complete a journey in a shorter time than a less powerful one. Thus we classify machines like motor-bykes and trucks of more or less power based on the speed of doing work. In fact, power measures the speed of work done i.e. how fast or slow work is done by.

Power is defined as the rate of doing work or the rate of transfer of energy. If an agent does 'w' amount of work in time 't', then its power is given by the relation: (Power = work/time

$$\text{or} \qquad p = \frac{w}{t} \quad ....(9.8)$$

The unit of power in SI-unit is watt [in honour of James Watt (1736 – 1819)] having the symbol 'W'. Thus 1 W is the power of an agent which works at the rate of 1 joule per second i.e. $1W = 1Js^{-1}$

We use larger rates of energy transfer or power in kilowatt (kW) or megawatt (MW)

1 kilowatt = 1000 watt = 1000 Js^{-1}

1 megawatt = 1000000 watt = 1000000 Js^{-1}

In practice an agent may be doing work at different rates for different intervals of time. In such situation, average power is useful. The average power of an agent is obtained by dividing the total power consumed by the total time taken.

9.3.1 Commercial Unit of Energy

Since the unit joule (J) used for measurement of energy is too small, it is incovenient to express large quantity of energy. As a result a bigger unit called kilowatt hour is used. The symbol for kilowatt hour is (kWh).

Suppose a machine uses 1000 J of energy every second. If this machine is continuously used for 1 hour, it will consume 1 kW × 1 hour

So, 1 kilowatt hour = 1 kWh = 1 kW × 1 hour

= 1000W × 3600 s.

= 3.6×10^6 J.

The unit used for measuring energy consumed in household, industries and commercial establishments are usually expressed in (kWh). Now-a-days unit of electrical energy used during a period, say, of one month, is expressed in kilowatt hour. Here, 1 unit of energy means 1 kWh.

Example 9.4

A man of mass 50 kg runs up a staircase of 20 steps in 15s. If the height of each step is 10 cm, find (i) work done by the man (2) power of the man.

Solution:

Weight of the man = m × g = 50 kg × 9.8 ms^{-2} = 490 N.

Height of the staircase = 20 × 10 cm = 200 cm = 2 m.

Time taken to complete the task = 15 s.

(i) Work done by the man = mg × h

$\Rightarrow$ w = 490 N × 2 m

Thus w = 980 J.

(ii) Power of the man, $p = \frac{w}{t}$

$= \frac{980\text{ J}}{15\text{ s}} = 65.33\ Js^{-1} = 65.33$ w.

Example 9.5

An electric bulb of 100 W and a fan of 40 W are used for 10 hours per day in summer. Calculate the energy consumed by them in 30 days.

Solution:

Power of the bulb = 100 W

And Power of the fan = 40 W

Total power of the bulb and the fan = 100 W + 40 W = 140 W.

= 0.14 kW.

Time for using them in 30 days = 10 × 30 = 300 hours.

Thus, energy consumed in 30 days = Power in kW × time in hour

= 0.14 kW × 300 hours

= 42 kWh

= 42 units of energy.

Therefore the energy consumed by the bulb and fan together is 42 units.

Activity 9.14

Make a careful observation at the electric energy meter installed in your house for the following:

Take the reading of the meter for each day at 7 am.

How many units are consumed during one day? Continue the observation for one week and make a tabulation.

Draw an inference from the data and estimate the units of electrical energy that may be consumed in a month.

Try to compare your estimated value of units with the details given in the monthly electricity bill submitted by the Electricity Department.

Points to remember

(i). Work is said to be done by the force when a force acts on an object and the object moves in the direction of the force.

(ii). Work done on an object by a force would be zero if the displacement of the object is zero.

(iii). Work done on an object by the applied force is measured by the product of the magnitude of the force and distance moved by the object in the direction of the applied force.

(iv). The unit of work done is joule.
1 joule = 1 newton × 1 metre.

(v). The capacity of an object to do work is called energy of the object. Energy and work have the same unit i.e. joule (J).

(vi). The energy possessed by moving object is called its kinetic energy. At any instant, if a body of mass 'm' is moving with a velocity 'v' then its kinetic is $\frac{1}{2}mv^2$.

(vii). The energy possessed by a body due to its change in position or shape is called the potential energy of the body. The gravitational potential energy of a body of mass 'm', raised through a height 'h' from the earth's surface is given by 'mgh'.

(viii). Work done by external applied force on a body is equal to the increase in its energy.

(ix). The sum of the kinetic energy and potential energy of body is called its mechanical energy.

(x). Different forms of energy exist in the nature.

(xi). Energy can be transformed from one form into other form or forms. But the total energy before and after transformation remains constant.

(xii). Power of an agent performing work is defined as the rate of doing work. The SI unit of power is watt, 1 W = 1 J/s.

(xiii). The energy used by a machine or work done by a machine at the rate of 1 kW in one hour is called 1 kWh.

EXERCISES

1. *Calculate the work done by a student in lifting a packet of books of mass 5 kg from the ground and keeping it on a shelf 1.5 m high. (Take g = 10 m/s^2).(75 J).*
2. *A player kicks a ball of mass 500 g placed at the centre of a football ground. The ball leaves his feet with a speed of 4 ms^{-1}. Find the work done by the player on the ball. Does it equal to the kinetic energy of the ball as it leaves? (4 J; yes)*
3. *A ball of mass 2 kg is thrown upwards vertically with a speed of 4.9 ms^{-1}. (a) Find the potential energy when it reaches the highest point. (b) Calculate the maximum height it reaches. (a) 24.01 J. (b) 1.225 m*
4. *A ball is thrown at a certain angle to the ground. It moves along a curve path and falls back on the ground. The initial and final positions of the path lie on the same horizontal line. What is the work done by the force of gravity on the ball? (zero)*
5. *How much time an agent will take to perform 400 J of work at the rate of 20 W?* (20s)
6. *Tomba does 200 J of work in 10 second and his brother Pishak does 100 J of work in 4 scond. (a) Who is delivering more power? (b) Find the ratio of the powers of Tomba to that of Pishak. (a) Pishak (b) 4:5.*
7. *In a certain household 500 units of energy is consumed during one month. Express it in terms of joule. (1.8 × 10^9)*
8. *Read the situations given below carefully and reason out whether work is done or not in the light of scientific term of work.*
   (a) Kamala is swimming in a pond along a straight path.
   (b) Tomba is standing with a load having the same weight as his weight on his head.
   (c) Chaoba pushes a huge stone with all his strength but the rock does not move.
   (d) A horse is carrying a load on its back and moves on a horizontal surface.

9. *The work done by the weight of a 1 kg mass while it is raised through a height of 1 m is*

   (A) 9.8 J (B) – 9.8 J

   (C) Zero (D) $\frac{1}{9.8}$ J. (B)

10. *When a body slides down an inclined plane, it has*

    (A) only kinetic energy.

    (B) only potential enrgy.

    (C) neither kinetic nor potential energy.

    (D) both kinetic and potential energies. (D)

11. *A stone of mass 2 kg falls from a height of 1 m. Its kinetic energy when it reaches the ground is*

    (A) 19.6 J. (B)10 J.

    (C) 9.8 J. (D) Zero. (A)

12. *Two bodies of unequal masses are dropped from a certain height above the ground. At any point of their path, they have equal*

    (A) momenta. (B) potential energy.

    (C) acceleration. (D) kinetic energy. (C)

CHAPTER – 10

Floatation

In the previous chapters we have discussed and studied about motion, the cause of motion, gravitation and workdone by an agent along with power. Another concept that helps us to understand thrust and pressure exerted by a force shall be studied. We shall also discuss the conditions of objects to float in a liquid.

10.1 Thrust and Pressure

Have you ever wondered why heavy duty trucks have much wider tyres than those of motorbikes? Why cutting tools have sharp edges? In order to answer these questions and understand the phenomena involved, we need to know the net force in a particular direction on a surface (thrust) and the force per unit area (pressure) acting on the surface of any object concerned.

Let us try to know the meanings of thrust and pressure by examining the following observations:

Observation 1

Suppose you are trying to fix a drawing sheet or a poster on the black board or on a plank using drawing pins. In doing so, you have to press the head of the pins with your thumb with a force. This force is directed perpendicular to the surface where the drawing sheet or poster is to be fixed. The same force now acts on the smaller area at the tip of the pin.

Observation 2

When you stand on loose sand or mud your feet go deep into them. If you lay down with your back side in contact with the sand or mud your body will not go as deep as in earlier case. In both cases the force exerted on the sand or mud are the same, being the weight of your body.

Observation 3

Take a brick and place it on the freshly prepared cement and sand mixture in different configurations of the brick. At first, you place with the widest area of the brick and next with the smallest area of the same brick on the mixture. You will find that the brick goes deeper in the later case. Here also, the same force is exerted in the two cases, the weight of the brick.

In the above observations you have seen that the force is acting vertically downwards i.e. perpendicular to the surface concerned and is called the thrust. Now you have seen that when you stand on the loose sand, the force which is the weight of your body is acting on an area equal to the area of your feet but when you lay down the same force acts on an area equal to the contact area of the whole backside of your body, which is of larger area than your feet. Thus the effects of the force of same magnitude are different. Similarly, in the other observations thrust is the same but effects are different. Therefore the effect of a given thrust depends on the area on which it acts, being smaller with wider area. The thrust on unit area is called "pressure". Thus

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}} = \frac{F}{A} \quad \text{.........................10.1}$$

Here, F is the thrust and A is the area where thrust acts.

Putting the SI units for thrust and area in the above equation, the SI unit for pressure becomes Nm^{-2} or pascal (Pa) in honour of scientist Blaise Pascal. Let us consider the following example to understand the effect of thrust on different areas.

Example 10.1.

A brick of mass 3 kg is kept on a table. The dimensions of the brick are 30 cm × 12 cm × 7 cm. Calculate the pressure exerted on the table when the brick lies with its sides of dimensions (a) 30 cm × 12 cm and (b) 12 cm × 7 cm. (Take $g = 10\ ms^{-2}$)

Solution:

The mass of the brick = 3 kg

Thus the weight of the brick = $3\ kg \times 10\ ms^{-2} = 30\ N$.

Case (a) Area of the contact side = $30\ cm \times 12\ cm = 360\ cm^2$

$$= \left(\frac{360}{100 \times 100}\right) m^2 = 0.036\ m^2$$

From Eq (10.1), Pressure $= \dfrac{30\ N}{0.036\ m^2} = 833.3\ Nm^{-2}$

= 833.3 Pa

Case (b) Area of the contact side = $12\ cm \times 7\ cm = 84\ cm^2$

$$= \left(\frac{84}{100 \times 100}\right) m^2 = 0.0084\ m^2$$

From Eq (10.1), Pressure $= \dfrac{30\ N}{0.0084\ m^2} = 3571.4\ Nm^{-2}$

= 3571.4 Pa.

From the above example we have seen that the same force acting on smaller area exerts a larger pressure and a smaller pressure on a larger area. This is the reason why drawing pin or iron nail has pointed tip, knives have very sharp edges, buildings have wide foundations and heavy duty trucks have wider tyres.

10.1.1 Buoyancy

Have you ever tried to lift water from pond, household reservoir or from a well with a bucket? Have you felt that the bucket of water is heavier when it is out of the water? Have you ever felt lighter when you go deeper into the water on the steps of the pond? Have you ever had a swim in a pond and felt lighter? Have you ever thought why a ship made of iron does not sink in water but while the same amount of iron in the form of a sheet or bulk would sink in water? These questions can be answered by taking buoyancy into consideration. At first let us try to know the meaning of buoyancy by performing an activity.

Activity 10.1

Take an empty glass or plastic bottle whose mouth is closed with air tied stopper. Put it in water contained in a bucket. You will see that it floats. Submerge it into the water forcibly. You will feel an upward push exerted by the bottle. The upward push will increase as you submerge the bottle, deeper and deeper till it is immersed completely. Now, release the bottle and see what happens? It will bounce back to the surface. This shows that water exerts a force on the bottle in the upward direction. The above activity can also be done in other non-volatile and stable liquid, if available. Inspite of gravitational force acting on the bottle in the downward direction, the bottle does not stay inside water when it is released. How can you immerse the bottle in water?

In the above activity, you have learnt that water exerts an upward force on the bottle. That is why the bottle comes up to the surface of water in the original position. This shows that the upward force exerted on the bottle by water is larger than the weight of the bottle due to the gravitational attraction of the earth.

To keep the bottle completely immersed, the upward force exerted on the bottle must be balanced using an externally applied force on the bottle in the downward direction, having a magnitude at least equal to the difference between the upward force on the bottle and its weight acting vertically downwards.

The upward force exerted by the water on the bottle is known as upthrust or buoyant force. In fact, as cited above, all objects experience a force of buoyancy when they are immersed in a fluid (liquid or gas). This phenomenon is known as buoyancy. The magnitude of the buoyant force depends on the density of the fluid and volume of the immersed body.

10.1.2 Why objects float or sink when placed on the surface of a liquid say water?

Let us perform the following activity in order to get an answer to the above question.

Activity 10.2

Take a beaker and fill with water. Put an iron nail on the surface of water. Observe what happens.

The iron nail sinks because the upthrust of water acting on the nail is less than the force on the nail due to the gravitational attraction i.e. the weight of the nail acting in the downward direction. That is why the nail sinks, shown in Fig.10.1.

In the above activity, if the liquid were mercury (Hg) the nail will float on the surface of mercury by submerging a small portion.

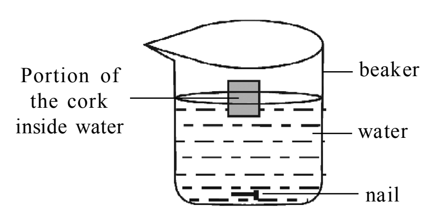


Fig. 10.1: An vion nail sinks in water while the cork floats

Activity 10.3

Take water in a beaker. Put an iron nail and a piece of cork having equal masses. Observe what happens.

You will see that the cork floats while the nail sinks. This happens because of the difference in their densities, which is the mass per unit volume of each of them. This shows that the density of cork is less than that of water, as shown in the figure (10.1). This also shows that the upthrust of water on the cork is greater than the weight of the cork. In the case of iron nail, the density of iron is greater than the density of water. This means that the upthrust of water on the *iron nail* is less than the weight of the nail acting vertically downwards. That is why the iron nail sinks.

Thus we have learnt that objects of density less than that of the liquid floats on the liquid by submerging some portion of the body, while the objects whose density is greater than that of the liquid will sink in the liquid.

Try to answer:

1. Kitchen knives have very sharp edges and if the edge is not so sharp it is not easy to cut vegetables. Give reason why?
2. Why is it difficult to hold school bags and heavy canvas bags with straps made of thin and strong strings.
3. What is buoyancy?
4. Can we use objects which dissolve in water or in the experimental liquid? Can we use objects which absorb the liquid?

10.2 Archimede's Principle

Activity 10.4

Take a piece of stone or a glass marble and tie it to one end of a light spring.

Suspend the stone or marble by fixing the other end of the spring at a rigid support as shown in Fig:10.2. Note the position of the pointer 'A', which is the elongation of the spring due to the weight of the marble. Now slowly deep the marble in the water in a container as shown in the Fig:10.2.

Observe what happens to the position of the pointer on the scale.

You will observe that the pointer goes up, i.e. elongation of the spring decreases as the marble is gradually lowered into the water. However, no further change in the position of the pointer will be observed as soon as the marble gets fully immersed in water. What have you learnt from the decrease in the elongation of the spring?

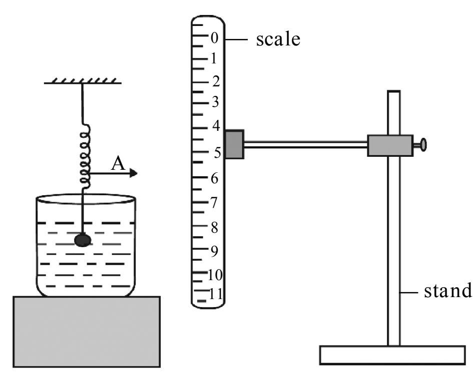


Fig. 10.2: Pointer goes up when the marble is immersed in water

It is already learnt that the elongation produced in the spring is due to the *weight of body* suspended at the lower end of the spring. Since the decrease in the extension can also be made if you push up the marble slightly, you could infer that some force acts on the marble in the upward direction. As a result the net force acting on the spring decreases and hence the elongation also decreases. This upward force exerted by the liquid (water) is known as the force of buoyancy.

Let us try to know the answers to the following questions. What is the magnitude of the buoyant force experienced by a body when immersed in a liquid? Is it the same for a given solid body, in all fluids? Do all bodies of same mass experience the same buoyant force when immersed completely in a liquid? etc. The answer to these questions can be given after going through Archimede's Principle, stated as follows:

When a solid body is immersed partly or fully in fluid (liquid as well as gas), it experiences an upward force that is equal to the weight of the fluid displaced by the body.

Thus you can explain, now why a further decrease in the elongation of the spring was not observed in activity 10.4, as soon as the marble was immersed fully in water. You must also note that marble or stone is solid and does not dissolve in water and does not absorb water also.

Archimede's Principle has many applications. It is used in designing ships and submarines. Lactometers which are used to determine the purity of a sample of milk, hydrometers for determining the density of liquids, are based on this principle.

Example 10.2

A cubical block of metal is of mass 1.5 kg volume 150 c.c. If the density of water is 1000 kg. m^{-3}. Will it immerse or float? What will be its weight in water?

Solutions:

Mass of the block, m = 1.5 kg.

Vo*l*. of the block, $v = 150 \text{ c.c.} = \frac{150}{100 \times 100 \times 100} m^3$

$= 1.5 \times 10^{-4} m^3$

Thus, density of the metal = $\frac{m}{v} = \frac{1.5 kg}{1.5 \times 10^{-4} m^3}$

$= 10^4 \text{ kg } m^{-3}$.

Thus, the block will immerse completely in the water, since its density is greater than that of water.

From Archimede's Principle, the weight of the displaced water = $(1.5 \times 10^{-4} m^3 \times 1000 \text{ kg. } m^{-3} \times g)$ N.

Taking density of water as 1000 kg m^{-3}.

Thus, upthrust on the block = $(1.5 \times 10^{-1} \times g)$ N.

The downward force, which is the weight of block= $1.5 \times g$ N

$\therefore$ The resultant downward force = $(1.5 g - 1.5 \times 10^{-1} g)$ N.

$= (1.5 - 0.15)g$ N= $(1.35g)$ N.

Hence, the block would weight 1.35 kg.

10.2.1 Experimental Demonstration of Archimede's Principle

Take a solid block of a substance which sinks in a liquid say, water and also does not dissolve in water; a spring balance; two measuring cylinders and a cylindrical container A having volume larger than the volume of the solid.

Fix the spring balance at a suitable support and suspend the arrangement to the spring balance as shown in Fig.10.3 (a) and record the reading of the balance accurately. Now, immerse the solid in water contained in measuring cylinder and record the reading of the spring balance and the increase in volume of water in the measuring cylinder as accurately as possible, as shown in the Fig.10.3. (b). The reading of the spring balance will be smaller than that in the earlier case [Fig.10.3 (a)]. The difference in the readings of spring balance is the loss in weight of the solid when immersed in water.

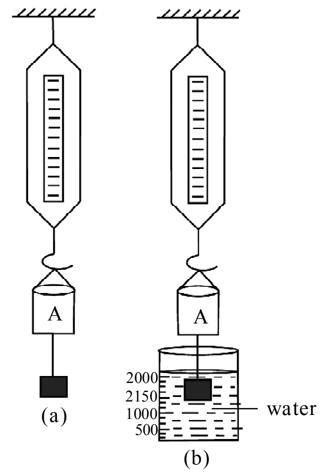


Fig. 10.3: Experimental arrangment to verify Archimede's principle

Now, take water equal in volume to that increase in the volume when the solid is completely immersed in water as shown in (b), using another measuring cylinder. Then, pour the water into the container A. Record the new reading of the spring balance. Certainly, you will observe that this reading on the spring balance will be equal to that in fig. 10.3 (a). This shows that the loss in weight of the solid due to buoyancy is exactly equal to the weight of the displaced water, after completely immersing the solid in water. Thus, Archimede's Principle is verified.

10.3 Floatation

You have learnt that some body floats while some body sinks in the same liquid, activity 10.2 and 10.3. Why does a bowl prepared from a sheet of metal float whereas the same sheet in the form of a plate sinks?

You have learnt that when a body is placed in a fluid two forces act on the body. They are (i) weight of the body acting in downward direction and (ii) upthrust equal to the weight of the displaced liquid in the upward direction. If the force mentioned in (i) is greater than that mentioned in (ii) the resultant is acting downwards and the body will sink. On the other hand, if the condition is reversed i.e. downward force due to the weight is smaller than the upward force due to the upthrust or buoyancy then resultant force is in upward direction and body floats. This is the situation for the floating cork in activity 10.3. Thus in the case of cork, activity 10.3, has a weight equal to the weight of the displaced liquid. That is why the cork floats on water.

The weight of a body in a fluid is called its apparent weight. For a body floating in a liquid, its weight is equal to the weight of the liquid displaced. Similarly a solid body whose density is smaller than the density of the liquid where it is placed it floats in the liquid.

Let us try to answer

1. Your weight is 50 kg on a weighing machine. Is your mass more or less than 50 kg.
2. You have a bagful of cotton and iron rod of the same mass, say 50 kg, when measured using a weighing machine. In reality one is of heavier mass than the other. Can you say which one is heavier? Explain why.

10.4 Relative density

You have learnt in previous classes that density of a substance is defined as mass of a unit volume of it and is expressed in kg m^{-3} (kilogram per metrecube) and remains constant. Therefore density of a substance is one of its many characteristic properties. It is different for different substances. For example the density of mercury is 13600 kgm^{-3} while that of water is 1000 kgm^{-3}. The density of a given sample of a substance can help us to determine its purity e.g. the density of pure gold sample is 19300 kg m^{-3}.

Very often, the density of a substance is expressed in comparison with that of water as a convenient means. Thus, the relative density of a substance is the ratio of its density to that of water. The relative density of a substance is also called its specific gravity.

$$\text{Relative density or specific gravity of a substance} = \frac{\text{Density of the substance}}{\text{Density of water}}$$

Since, the relative density is a ratio of similar quantities, it has no unit i.e. a pure number.

Example 10.3.

The relative density of a substance is 10.8. The density water is 10^3 kgm^{-3}. What is the density of the substance?

Solution:

Relative density of the substance = 10.8

$$\text{From, Relative density} = \frac{\text{Density of the substance}}{\text{Density of water}}, \text{ we get}$$

Density of the substance = Relative density of the substance × density of water.

$= 10.8 \times 1000\ kgm^{-3}$

$= 10800\ kgm^{-3}$

$= 1.08 \times 10^4\ kgm^{-3}$.

Floatation

Points to remember

(i) Pressure on a surface or at a point is thrust perunit area and its SI unit is Pa (pascal).

(ii) All objects experience a force of buoyancy when they are immersed in a fluid.

(iii) All bodies in solid form having density less than that of the liquid in which they are immersed, float on the surface of the liquid by projecting some portion above the surface. If the bodies are of density larger than that of the liquid in which they are immersed than they sink in the liquid.

(iv) Whenever any body floats in a liquid, the weight of the floating body is equal to the weight of the liquid displaced by the body.

(v) Density of a substance is equal to the product of its relative density by the density of water. The unit for density is the same as that for the water.

EXERCISES

1. *What is thrust? State its direction of action.*
2. *In which direction does the buoyant force on an object immersed in a liquid act? State the magnitude of buoyant force.*
3. *Why does a block of plastic or cork come up to the surface of water when they are released under water?*
4. *The volume of a solid block of mass 180 gm is 100 cm^3. If the block is placed in water of density 1gm/cm^3, will it float or sink? Explain.*

   (sink; density of substance of block is 1.8 gm cm^{-3} which is larger than that of water)
5. *A lump of plastic of relative density 0.4 has a mass of 10 gm. It is placed in water. Calculate the volume of the lump projecting above the surface of water. (Take the density of water as 1 gm cm^{-3}).*

   (15 cm^3)

CHAPTER – 11

Waves and Sound

In our day to day life, we could hear sounds from various sources like human beings, cattles, birds, machines, vehicles, radio, televisions, bells, conch, pena, drums etc. You have also learnt that sound is one of the different forms of energy known to us, which can produce a sensation of hearing in our ears. In the previous chapters you have learnt about mechanical energy, chemical energy and the conservation of energy.

Whenever we speak or clap a sound is produced. In doing so we are utilising our energy, i.e. sound energy is obtained from the energy of our body. Which form of energy is used to produce sound? In this chapter we shall study to understand how sound is produced and how it is transmitted from the source to the ear receiving it through a medium.

11.1 Production of Sound

Sound is produced by the vibrational motion of a body. Let us take up the following activities to understand how sound is produced.

Activity 11.1

You have acquinted with tuning fork in the previous class (class VII). Take a tuning fork and set it vibrating by striking one of its prongs on a rubber pad. And then bring it close to your ear but not touching. Touch one of the prongs of the vibrating tuning fork with your fingure. Share what you have experienced on touching with your friends.

In the next observation, suspend a table tennis ball or a small plastic ball with the help of a thread from any available support. (Threading through the plastic ball can be done with a big needle and a thread putting a knot at the other end). Touch the ball gently with the prong of a vibrating tuning fork as shown in Fig 11.1. Observe what is happening and discuss with your friends.

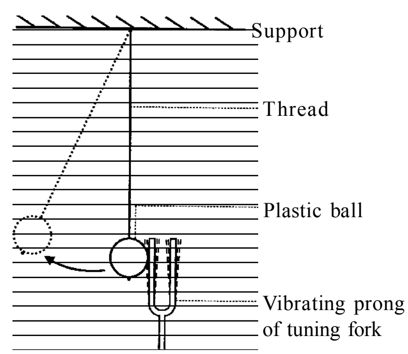


Fig.11.1: Vibrating tuning fork touching the plastic ball which was at rest

Activity 11.2

Fill a glass tumbler with water up to the brim. Gently touch the water surface with one of the prongs of a vibrating tuning fork as shown in Fig.11.2 (a). Again, in the next observation dip the vibrating tuning fork in water as shown in Fig.11.2 (b).

Observe the surface of water in the tumbler in both cases. Discuss with your friends why this happens.

"Does the school bell give sound by itself ?.

From the above activities you can conclude that sound is produced only when the sounding objects are set into vibrations.

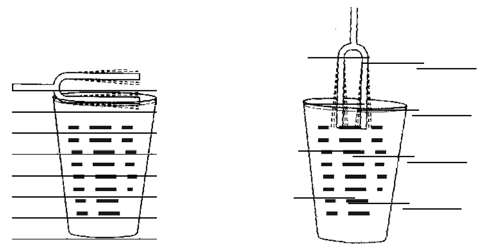


Fig.11.2(a) *Fig.11.2(b)*

There are other means to produce sound from sounding objects. The means are plucking in sitar, guitar; rubbing in pena, violin; beating in pung, dhulok, drum; blowing in flute, clarionet, hexaphone; and shaking different objects. In all the above cases, we set the objects vibrating and only then sound is produced. The term vibration means a kind of rapid to and fro periodic motion of an object. Similarly, the sound of human voice is produced due to the vibration of the vocal cords. You must have seen a bird flapping its wings and accompanying a sound. Also try to understand how the buzzing sound accompanying a mosquito or a bee is produced. Keep a rubber band stretched between two fixed nails on the plank of desk or bench then pluck. You can hear a sound.

Activity......................11.3.

Prepare a list of different musical instruments so far available in your surrounding and discuss with your class-mate that which part or parts of the instrument vibrates or vibrate to produce sound from each of them.

11.2 Propagation of Sound

Vibrating objects produce sound. The matter or substance through which sound is transmitted is called a medium. The medium may be solid. liquid or gas and is extending from the source to the listener. As the object vibrates during the generation of sound, it sets the particles of the medium around it vibrating but they do not move bodily from the source to the listener.

In fact, the particle of the medium just in contact with the vibrating object is first displaced sideways from its equilibrium or rest position. It then exerts a force on the adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position.This process continues with the particles in the medium till the sound reaches the ear of the listener. This disturbance created by a source of sound in the medium travels through the medium but not the particles of the medium since the medium does not move as a whole. Here a wave is said to be produced.

A wave is a periodic disturbance that moves through the medium when the particles of the medium induce the neighbouring particles into motion. This type of propagation of disturbance can be experienced when you drop an object on the surface of water in a pond or lake as shown in Fig.11.3 (a) and (b).

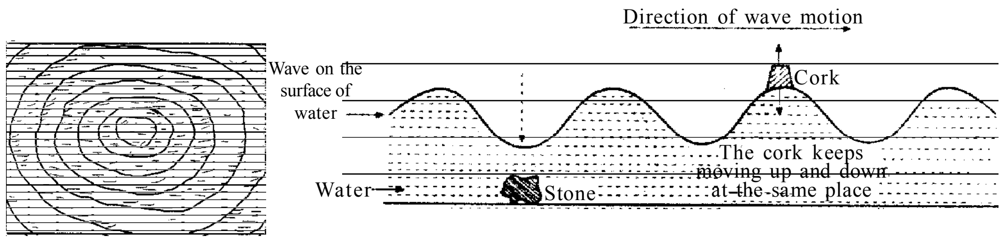


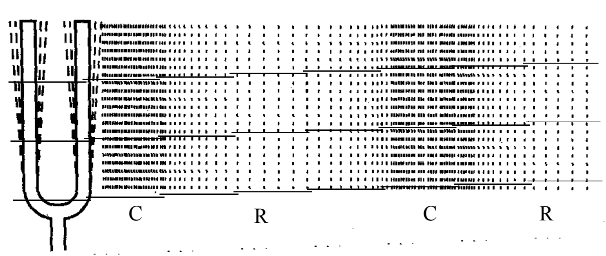
Fig.11.3: (a) circular water waves

(b) The floating particles only move up and down at the same place but are not carried away

As the disturbance reaches the floating particles, they move up and down periodically. The particles donot move forward themselves but the disturbance is carried forward in the direction of propagation.

This is what actually done during the propagation of sound in a medium, hence the sound can be visualised as a wave. Such waves are characterised by setting the particles in a medium through the transformation of mechanical energy of the particles in the medium and are called "mechanical waves".

Most of the sounds listened by you come through air. When a vibrating object moves forward, it pushes and compresses the air adjacent to it creating a region of high pressure called compression i.e. a compressed region (C) shown in Fig.11.4. This compression moves forward from the vibrating object. When the vibrating prong moves backwards in course of its motion, it creates a region of low pressure called rarefaction (R) as shown in the same figure. As the prong vibrates back and forth rapidly, a series of compressions and rarefactions is formed in the air along the direction of propagation. This series of compressions and rarefactions constitutes the sound wave. The number of air particles per units volume is larger in the compression regions than that in the rarefaction regions, because of higher pressure in compression and lower pressure in rarefaction. Thus, the propagation of sound can be visualised as propagation of density variations or pressure variations in the medium through which sound propagates. Since the compressions and rarefactions move parallel to the direction of propagation, the sound waves are called longitudinal waves.



C → Compression
R → Rarefaction

Fig.11.4: A vibrating tuning fork creating compression and rarefaction in succession

11.2.1 Sound waves need a medium for propagation

Any mechanical wave such as sound wave always needs a material medium like air, water (liquid), wood, steel etc. for its propagation. As such, sound waves cannot travel in vacuum. This property can be demonstrated by the following experiment.

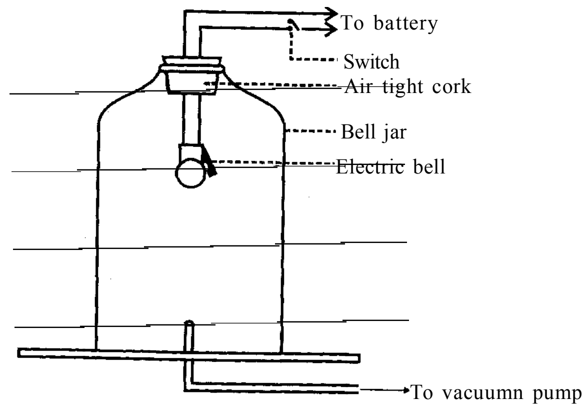


Fig.11.5: Bell jar experiment to show that sound cannot propagate in vacuum

Arrange the electric bell inside the bell jar and then place the jar on the platform of the vacuum pump. Now, close the switch S and you will be able to hear the sound of the bell. Now start the vacuum pump. Air will be pumped out of the bell jar gradually and sound will become fainter even though the bell is working with the same current from the battery. After some time when the air inside the jar is very less, you will be able to hear a very feeble sound. Now, stop the vacuum pump and allow the air to enter the jar slowly. As it continues, the sound will be louder. What will happen if the air inside the bell jar is completely pumped out ?

Try to answer:

1. How sound is produced by bell at your school? Observe and explain.
2. The sound waves are also called mechanical wave. Why?

11.2.2 Sound Waves Are Longitudinal Waves

You have learnt from the above that sound propagates as longitudinal wave. This very property can be seen experimentally from the following activity 11.4.

Activity 11.4

Take a long slinky of plastic and hold one end of it and fix the other end at a rigid support. Then stretch the slinky as shown in Fig.11.6 so that it must remain horizontal above the ground. Now, give it a sharp push towards the fixed end. What do you notice?

Try to move your hand pushing and pulling the slinky alternately through a small displacement along it and observe the features carefully. Any distinguishing mark on the slinky will move back and forth parallel to the direction of propagation of the disturbance.

The regions where the turns of the slinky become closer are called compressions (C) and the regions where the turns of the slinky are apart are called rarefaction (R). Now, you can see a series of alternate compressions and rarefactions throughout the length of slinky. This would be the same pattern in the case when sound propagates through air. Now you can compare the propagation of disturbance in a slinky with the propagation of sound in a medium. Besides, we have seen that the turns or particles of the slinky do not move from one place to other but they simply oscillate back and forth about their mean positions of rest parallel to the direction of propagation of disturbance along it.

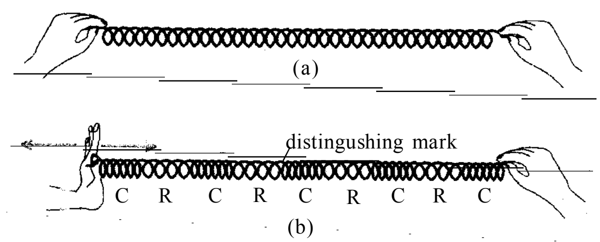


Fig.11.6: Longitudinal wave along a slinky

This is exactly how a sound wave propagates. That is why sound waves are said to be longitudinal waves.

There is also another type of wave, called transverse wave. In these waves the particles of the medium do not oscillate parallel to the direction of propagation but oscillate up and down, similar to the motion of floating bodies on the wave propagating over the surface of water see Fig.11.3 (b), about mean or average position when they are at rest. The direction of oscillation is perpendicular to the direction of propagation of the wave. Example of transverse wave is light i.e. light is a transverse wave. However, for light the oscillations are not of the particles of the medium or their pressure or density. Therefore light is not a mechanical wave. You will study more about transverse waves in higher classes.

11.2.3 Characteristics of A Sound Wave

A sound wave can be described by its three characteristics. They are (1) frequency (2) amplitude (3) speed.

You have learnt that when a sound wave propagates in a medium, the value of density and pressure of the medium changes above and below the average value. A sound wave, during its propagation, is shown graphically indicating how density and pressure of the medium change. Fig.11.7 (a) and (b) represent density and pressure variations respectively of the medium during the propagation of sound wave.

We already know that compressions are regions where particles are crowded together and represented by a level higher than the average. Thus the peak in the diagramatic representation represents the maximum value of compression. As a result, the compressions are the regions of high density as well as high pressure. Opposite to the compressions, rarefactions are the regions of low density as well as low pressure and are represented by a level lower than the average value. The lowest level or valley denotes the minimum of density as well as pressure. By convention, the peak is called the crest and the valley is called the trough of the wave, as shown in Fig.11.7 (c). The distance between two consecutive crests or troughs is called wavelength of the wave and is represented by I (lamda, a Greek latter). Its SI unit is metre (m).

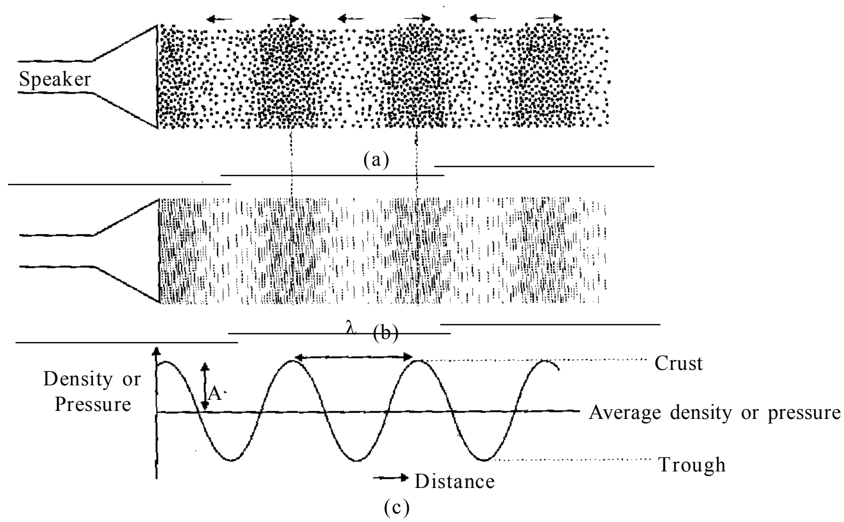


Fig. 11.7: Propagation of sound as Density variation (a); Pressure variation (b); (c) represents graphically the density and pressure variation

Suppose you are beating a drum. How many times you are beating the drum per unit time is called the frequency of beating of the drum. In other words the term frequency tells us how frequently an event occurs. From the discussions above we know that when sound is propagating from a source in a medium, the density of the medium oscillates between a maximum value to a minimum value. The event of change of density from maximum value to a minimum value then again to the maximum value is called one complete oscillation. The number of such complete oscillation per unit time is the frequency of the sound wave. If we can count the number of the compressions or rarefactions that cross a region in a unit time, we will get the frequency of the sound wave. It is usually represented by u(Greek letter 'nu'). Its SI unit is hertz (symbol, Hz): In honour of Heinrich Rudolf Hertz, born on 22 February, 1857 in Hambung, Germany.

The time taken by wave to produce two consecutive compressions or two consecutive rarefactions crossing a fixed point in the medium through which sound is propagating is called the time period of the wave. This is equal to the time taken for one complete oscillation in the density or pressure of the medium. If is represented by the symbol 'T' Its SI unit is second (S).

Thus the frequency and time period of a wave are related as

$$u = \frac{I}{T} \quad \text{.......................} \quad (11.1)$$

You must have heard the different musical instruments viz, pena, violin, flute, sitar etc. being played at the same time in an orchestra. The different sound waves travel to the same medium, that is air, at the same speed and arrive at your ear at the same time. But the sounds we receive are giving different sensation. This is due to the different characteristics associated with each of the sound waves. The characteristic of each sound wave is called its *pitch* and this is how the brain interprets the frequency of an emitted sound. The faster the vibration of the source, the higher is its frequency and the higher is the pitch, as shown in Fig 11. 8. Thus a high frequency or a high pitch sound corresponds to more number of compressions and rarefactions passing a fixed point of the medium in unit time. Objects of different sizes under different conditions vibrate at different frequencies to produce sound waves of different pitch.

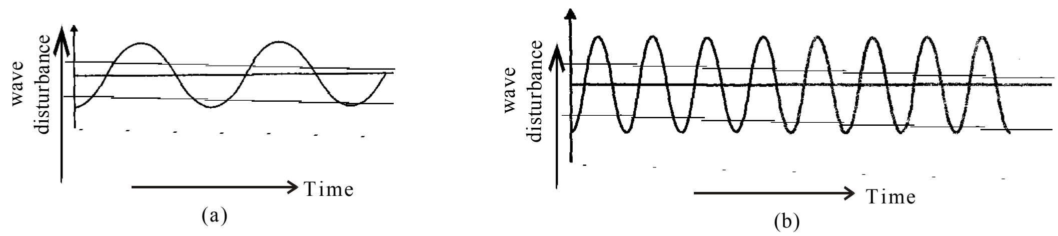


Fig.11.8: (a) Wave shape for a low pitched sound (b) That for a high pitched sound

The magnitude of the maximum disturbance in the medium on either side of the mean value of density or pressure of the medium is called the amplitude of the wave, which is represented by the letter 'A' in Fig.11.7 (c). For sound the unit for amplitude is that of density or pressure. The amplitude of sound determines its loudness or softness.

The amplitude of sound wave depends upon the force with which a sounding object is made to vibrate. As an example, if we strike a table lightly, we hear a soft sound because the material of the table produces sound of less amplitude i.e. of less energy. If we hit the same table hard we can hear a loud sound. You try to explain.

A loud sound is associated with higher energy and can travel a larger distance than a soft sound. As sound wave moves away from the source, its amplitude as well as its loudness decreases. Fig.11.9 shows the wave shapes of a loud and a soft sound having the same frequency.

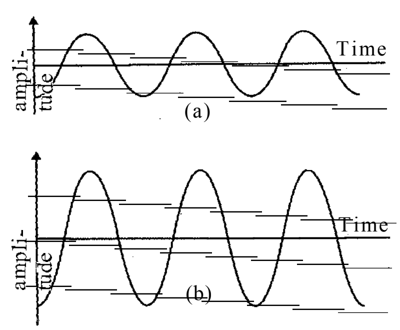


Fig. 11.9: (a) soft sound has small amplitude while (b) louder sound has large amplitude

The other characteristic of sound which enables us to distinguish one sound from another having the same pitch and loudness is called *quality* or *timbre.* The sound which is more pleasant on hearing is said to be of a rich quality. A sound of single frequencies is called a *tone* whereas the sound which is produced due to a mixture of several frequency is called a *note*. A note is more pleasant to listen than a tone. Still there is also sound which is unpleasant to the ear and sound of this type is called *noise.* The musical sound is pleasant to hear and is of rich quality.

The speed of sound wave is defined as the distance which a compression or a rarefaction travels per unit time. We know that the wavelength (l) of the sound wave is the distance travelled by the sound wave in one time period (T) of the wave. Thus, the distance travelled by the wave in unit time, which is speed by definition will be given by

$$v = \frac{\lambda}{T} = \frac{\text{distance travelled } (\lambda)}{\text{time taken (T)}}$$

or $v = l\,u$.................... (11.2) $\because \frac{l}{T} = \upsilon$

That is, speed = wavelength × frequency.

N.B. The speed of sound remains almost the same for all frequencies in a given medium, under the same physical conditions.

The amount of sound energy crossing through a unit area per second is called the intensity of sound. You should not treat loudness and intensity as two interchangeable terms. They are not the same. Loudness measures the amount of sensation produced in the ear and hence depends upon the listener. Thus two sounds of equal intensity may produce different loudness when peceived by us. We may hear one as louder than the other simply because our ear detects it better.

Example 11.1

A sound wave has a wavelength 50 cm and of frequency 670 Hz. How long will its take to travel a distance of 1.34 km?

Solution:

Given, frequency, u = 670 Hz and wavelength l = 50 cm = 0.5m.

From, speed of sound = wavelength × frequency, we get

$$v = lu = 0.5 \text{ m} \times 670 \text{ Hz}$$
$$= 335 \text{ m/s}.$$

Then, the time taken by the sound wave to travel a distance, d = 1.34 km = 1340 m is

$$t = \frac{d}{v} = \frac{1340 \text{ m}}{335 \text{ m/s}} = 4\text{s}.$$

Thus, the sound wave will take 4s to travel a distance of 1.34 km.

Try to answer:

1. What are wavelength, frequency, amplitude and periodic time of a sound wave? Which of the above quantities does not change when sound passes through different media?
2. What is the relation between frequency, wavelength of a sound wave and its speed in a medium.
3. Distinguish between intensity and loudness of sound.

11.2.4 Speed of Sound in Different Media

We know that the sound of thunder is heard a little later than the accompanying flash of light is seen. From this we can make out that sound travels with a speed which is much less than the speed of light. Sound propagates at a finite speed through a medium, depending on the temperature of the medium. The speed of sound in a medium increases with increasing temperature. For example, the speed of sound in air at 0°C is 331 ms^{-1} and 344 ms^{-1} at 22°C. Besides, the speed of sound is different in different media and decreases when we go from solid medium to gaseous medium. The different speeds of sound at a particular temperature in various media are listed in Table 11.1 below, for information.

Table 11.1: Speed of sound in different media at 25ºC.

Nature of Medium	Substance	Speed in ms^{-1}
Solid	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
	Sea water	1531
Liquid	Distilled water	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

N.B. Try to understand, in which media – air, water or iron, does sound travel fastest at a particular temperature, from the above table.

11.3 Reflection of Sound

You might have perceived the sound of clapping by you when you clap hands standing at large distance from high wall or boundary wall of your school. This is the case where a sound wave strikes a hard surface like wall, it rebounces from that surface and comes back to the original medium. This phenomenon associated with sound wave is called the reflection of sound.

Like light sound is reflected at the surface of solid or liquid and follows the same laws of reflection as you have studied in earlier classes. The directions of incident sound and reflected sound make equal angles with the normal at the point of incidence and the three are in the same plane. Unlike light, obstacles of large size which may be polished or rough can reflect sound waves.

Activity 11.5

Prepare two long pipes out of chart or drawing paper. Arrange them on a table near a wall as shown in Fig.11.10. Keep a table clock near the open end of one of the pipes as shown and try to listen the sound of the clock at the open end of the other pipe. Adjust the positions of the pipes so that you can hear the sound of the clock with maximum loudness. Now, measure the angles subtended by the pipes with the normal to the surface of the wall and see the reletionship between the angles.

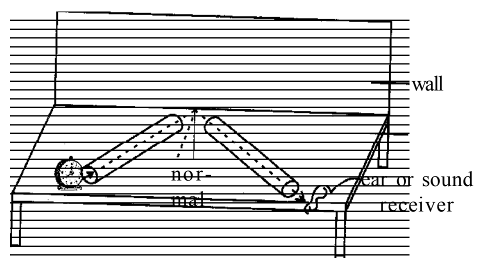


Fig. 11.10: Reflection of sound

11.3.1 Echo

You have learnt from the above that the process by which a wave changes its direction is reflection of wave. When the sound bounces back it is called an echo. As an example, when we shout or clap near a suitable reflecting object such as a tall building or a mountain or cliff we will hear the same sound after a time interval. Thus echoes are formed by the repeated reflection of the sound. This sound which we hear is called an echo.

In order to hear an echo, practically, there should exist a minimum distance between the source of sound and the reflecting surface or equivalently the time interval between the original sound and the reflected sound must be at least 0.1 s. This is so, because the sensation of sound persists in our brain for about 0.1 s. If we take speed of sound to be 344 m/s at a given temperature say at 22°C in air the sound must travel to the reflecting surface and reach back to the listener on reflection after 0.1 s or more. Hence, the total distance covered by the sound from the source to the reflecting surface and back to the position of source be at least 344 m/s × 0.1 s = 34.4 m i.e. distance covered by sound during 0.1s. Thus for hearing an echo clearly, the minimum distance between the source and reflecting surface must be half of the distance of 34.4 m i.e. 17.2 m. Repeated echoes may be heard due to successive or multiple reflections. The rolling of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds and the land.

11.3.2 Reververation

Have you ever shouted in an empty room of your house surrounded by walls? The sound will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation of sound. This is an undesirable effect in public auditorium and big halls. The reverberation can be reduced by covering the roofs and walls of the auditorium with sound-absorbent materials like compressed fibreboard, rough plaster or draperies. The seat materials are also selected on the basis of their sound absorbing properties.

Example 11.2

An echo returned in 4s. What is the distance of the reflecting surface from the source, given that the speed of sound is 340 ms^{-1}?

Solution:

Given, Speed of sound, v = 340 ms^{-1}

Time taken for hearing the echo, t = 4s

Distance travelled by the sound = v × t = 340 × 4

= 1360m

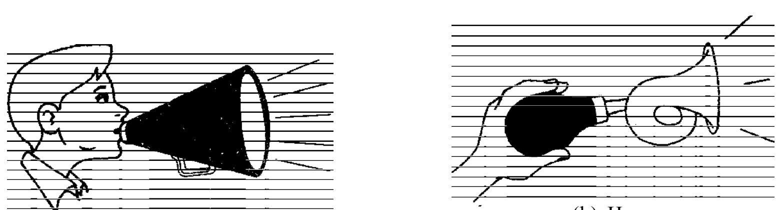
Since, the sound travels twice the distance between the source and surface, the distance between the source and surface is 1360/2 = 680m.

11.3.3 Uses of Echo or Multiple Reflection of Sound

1. Stethoscope is an instrument used by doctors for listening to the sounds produced within the human body and animals, chiefly in the heart or lungs. In this instrument the sound of the patient's heart beat reaches the doctor's ears by multiple reflection of sound from the boundary of the pipe, as shown in Fig.11.11.

Fig. 11.11: Stethoscope

2. Megaphones or loudhailers, horns are all designed so that sound will travel in a particular direction without spreading in all directions as shown in the Fig.11.12 (a) and (b)



(a) Megaphone

(b) Horn

Fig.11.12: (a) Megaphone (b) Horn

A tube followed by a conical opening is used to reflect the sound successively, in these instruments. This design is to guide most of the sound waves from the source to the audience in the forward direction.

3. You might have seen the curve shaped structures at the ceiling of cinema halls and auditorium. This is to reflect sound wave in order to reach all corners of the hall or auditorium. In very large halls, a large curved surface is sometimes placed at the stage so that sound waves after reflecting from the surface spread equally across the length and width of the hall. Such curve surface is called soundboard and is shown in Fig.11.13.

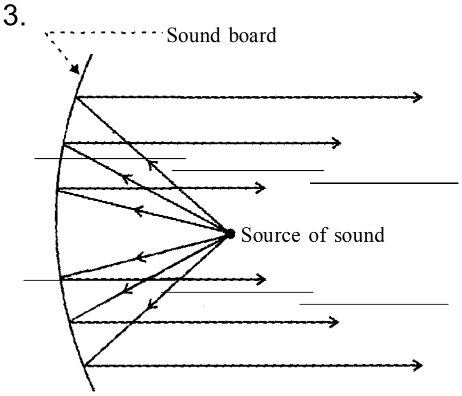


Fig. 11.13: Sound board and reflection of sound

11.4 Range of Hearing

Through investigation it is accepted that the audible range of sound for fuman beings extends from about 20 Hz to 20,000 Hz. Children under the age of five and some animal such as dogs can hear up to 25 kHz (1 Hz = one cycle/sec;1 kHz = 1000 cycle/sec). As people grow older their ears become less sensitive to higher frequencies.

Sounds having frequencies less than 20 Hz are called infrasonic sound. Human ear cannot perceive infrasonic. Rhinoceroses communicate using infrasound of frequency as low as 5Hz. Whales and elephants produce sound in the infrasound range. It is observed that some animals get disturbed before earthquakes.

Earthquakes produce low- frequency infrasound before the main shock waves begin which possibly alert the animals. Frequencies higher than 20 kHz are called ultrasonic or ultrasound. Ultrasound is produced by dolphins, bats and porpoises. Moths of certain families have very sensitive hearing equipments. These moths can hear the high frequency squeaks of the bat and know when a bat is flyging nearby and are able to escape the capture Rats also play games by producing ultrasound.

11.5 Ultrasound And Its Application

Ultrasounds or ultrasonics are high frequency mechanical waves. Such waves can travel along the well defined paths even in presence of obstacles and exhibit the properties of audible sound waves. Ultrasounds are used in industries (cleaning, detection of flaws or cracks), for medical purposes (echocardiography, ultrasound scanner, breaking of small stones formed in kidneys; sterilization) and navigation purposes.

(a) Cleaning – It is used to clean electronic components, spiral tubes and odd shaped parts located at hard to-reach slaces in glass-wares. Objects to be cleaned are placed in a cleaning solution where the ultrasound waves is sent into. Due to shaking at ultrasonic frequency the particles of dust, grease and dirt get detached and drop out. Thus the objects get thoroughly cleaned.

(b) Detection of flaw – The defects like cracks or flaws which are invisible from outside sometimes present in metal blocks used in the construction of buildings, bridges, heavy machines and also in scientific equipments. Such defect reduces the strength of the structures. Ultrasound can be used to detect such defects. In the process, ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. The ultrasound gets reflected back from the boundary of flaws or cracks, if present at all and the transmitted waves can not reach the detector as shown in Fig.11.14.

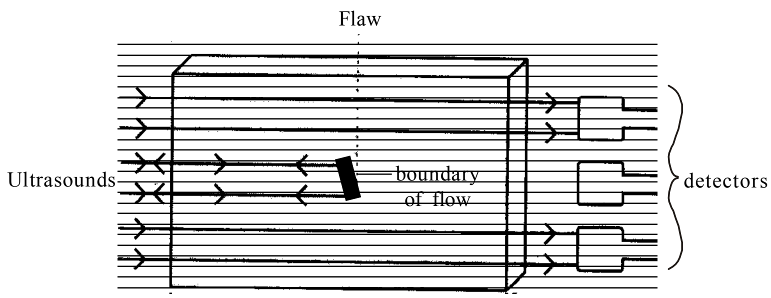


Fig.11.14: Ultrasound is reflected back from the defective locations

(c) Echocardiography– It is a technique in which ultrasonic waves are made to reflect from various parts of the heart and to form the sonic image of the heart.

(d) Ultrasound scanner– This is an instrument used for getting images of internal organs of human body by using ultrasonic waves. It helps the doctors to detect abnormalities in the organs such as liver and stones in gall bladder, uterus, kidney etc of the patient. In this technique the ultrasound waves are made to travel through the tissues of the body and to get reflected from a region where there is a change of tissue density. The reflected waves are converted into electrical singnals that are used to generate images of the organs. Finally, these images are then displayed on a monitor or printed on a film, to be used by the doctors for diagonosis. This technique is called "Ultrasonography" which is also used for examination of the foetus during pregnancy to detect congenial defects and growth abnormalities.

Ultrasound may be employed to break small stones formed in the kidneys into fine grains. These grains get flushed out with urine.

(e) Sterilization – Ultrasonic waves can destroy unicellular organisms. Bacteria perish under the action of ultrasonic waves and this principle is used in the sterilization of water and milk.

(f) Navigation – Ultrasonic waves are used to measure the depth of seabed, direction and speed of under water objects in a device known as SONAR which stands for SOund Navigation And Ranging. Sonar consists of a transmitter and a detector for ultrasonic waves. Both are installed in a boat or a ship as, shown in the diagram of Fig.11.15.

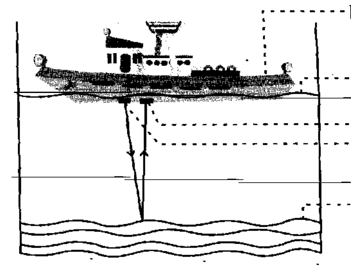


Fig. 11.15

The waves generated by the transmitter travel through the water and after striking the object on the seabed which cannot be seen by the eyes, get reflected back and are received bythe detector. Actually, the detector transforms the reflected ultrasonic waves into electrical signals exactly interpreting the pattern of object on the seabed. The distance of the object reflecting the sound can be estimatd by knowing the speed of sound in water and time lag between the transmitted and recieved signals of sound. If 'd' is the distance or depth of the seabed then the total distance traversed by the signal inside the water is 2d. Thus 2d = v × t where 'v' is the velocity of sound in seawater and 't' is the the time elapsed between the transmitted and received signals. The method is also called echo-ranging and the technique is used to determine the depth of the sea and to locate underwater icebergs,sunken ships, valleys and hills etc.

Example 11.3

The time elapsed between the transmitted and received signals of a sonar system of a ship is 3.5 sec. If the velocity of sound in sea water is 1532m/s, find the depth of the sea bed from the ship.

Solution:

Time between the signals, t = 3.5 sec

Speed of ultrasound in seawater = 1532m/s

Distance travelled by ultrasound signal = 2d

Where d is the depth of the seabed in metre.

Thus, 2 d = speed of sound in seawater × time

$= 1532 \times 3.5 = 5362$ m.

$$\therefore d = \frac{5362}{2} = 2681 \text{ m.}$$

Hence, the depth of the seabed is 2.681km.

11.6 Structure of Human Ear

We can perceive sound with the help of an extremely sensitive device called 'ear'. How do we hear? It is established that the auditory nerve of our ear converts the pressure variations in air with audible frequencies into electric-like signals that travel to the brain via the auditory nerve. The auditory aspect of human ear is described below. The outer ear which is called 'pinna' collects the sound from the surroundings. The collected sound passes through the auditory canal. At the end of the auditory canal there is a thin membrane called the ear drum or tympanic membrane. When the compression of the wave reaches the ear-drum the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly, the eardrum moves outward when a rarefaction reaches it, in turn. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear the pressure variations are turned into elecrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve and the brain interprets them as sound.

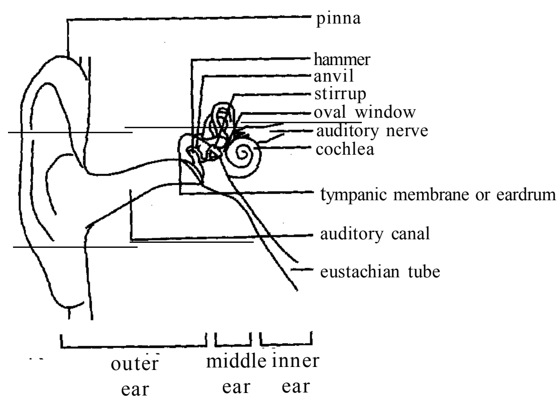
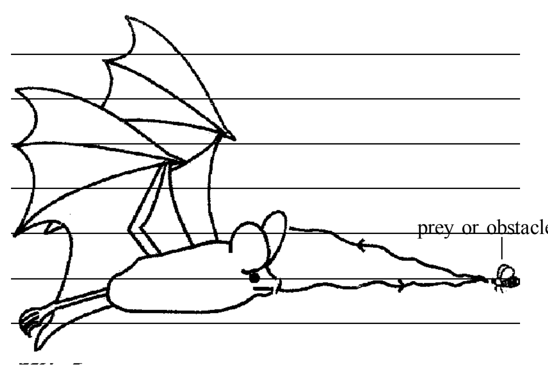


Fig. 11.16: Auditory parts of human ear.

(1) Hearing Aid: A hearing aid is an electronic device operated with the help of battery and used by persons with hearing loss. The hearing aid receives sound through a microphone. The microphone converts the sound waves to electrical signals. These electrical signals are amplified by an amplifier. The amplified signals (electrical) are given to a speaker of the hearing aid which converts the amplified signals to sound and sends to the ear for clear hearing.

(2) Ultrasonic squeaks of bat: As mentioned ealier, bats search out their prey and fly in dark night by emitting and detecting the reflections of Ultrasonic waves. The high pitched Ultrasonic squeaks of the bat are reflected from the obstacles in the form of prey and returned to the bat, as shown in the figure. The nature of reflections reveals the bat where the prey is and what is it like. It is also of the opinion that some marine mamals use ultrasound for navigation and location of prey in the dark.



POINTS TO REMEMBER

(i) When a disturbance created in a medium travels to another part without involving a transfer of any material with it, the motion of the disturbance is called wave motion.

(ii) A wave does not transfer material from place to place but it transfers energy wherever it travels.

(iii) Sound is produced due to vibration of different objects.

(iv) Sound travels as longitudinal wave through a material medium, forming suceessive compressions and rarefactions in the medium.

(v) Since sound wave belongs to mechanical wave, it cannot travel in vacuum.

(vi) In the propagation of sound wave the change in density from one maximum value to the minimum value again to the maximum value and vice-versa, makes one complete oscilation.

(vii) The distance between two adjacent compressions or rarefactions is called one wavelength 'l' of the wave.

(viii) The time taken for one complete oscillation is called the time period or periodic time of the wave.

(ix) The number of complete oscillations per unit time is called the frequency 'u', $u = \frac{1}{T}$ or uT = 1.

(x) The speed 'v' of sound wave in a medium is given by relation, v = u × l and depends on the nature and temperature of the propagating medium.

(xi) The incident and reflected sound waves make equal angles with the normal to the reflecting surface at the point of incidence and the three lie in the same plane.

(xii) For hearing a distinct reflected sound from a source, the time interval between the original sound and the reflected sound must be at least 0·1s, which is the persistence of sound.

(xiii) Repeated reflections of sound in an auditorium is the cause of reverberation.

(xiv) The pitch, loudness, intensity of sound are determined by the corresponding wave properties.

(xv) The amount of sound energy passing through unit area in one second is called the intensity of sound.

(xvi) The normal audible range of hearing for human ear lies in the range of 20Hz –20 kHz.

(xvii) Sound waves with frequencies less than 20 Hz ae termed "infrasonic" and those above 20 kHz are termed 'ultrasonic'.

(xviii) Ultrasound had applications in industry, medical and navigation (SONAR).

EXERCISES

1. *Define sound and explain how is it produced ?*
2. *Explain the formation of compressions and rerefactions in air near a source of sound.*
3. *Difine wavelength, periodic time and frequency of a wave.*
4. *Derive the relation between wavelength, frequency and time period of a periodic wave.*
5. *When you call your friend by name, do you produce a wave pulse of sound or a periodic wave?*
6. *Show graphically how density of air varies with distance when a periodic sound wave travels in it. Show the graphs for two instants of time differing by half of periodic time.*
7. *Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?*
8. *Does sound follow the same laws of reflection as light does? Expain.*
9. *Describe an experiment to show that sound needs a medium to propagate.*
10. *Give two practical applications of reflection of sound waves.*
11. *What is loudness of sound? On which factors does it depend?*
12. *Explain the working and application of a SONAR.*
13. *A sound waves travels in a medium at a speed of 340m/s. If its wavelength is 1·7cm, What is the frequency? Will it be an audible sound?*

    (20×10^3 Hz; audible)
14. *Explain the working of human ear.*
15. *A source of sound produces 20 crests and 20 troughs in 0.2s. Find the frequency of the wave.*

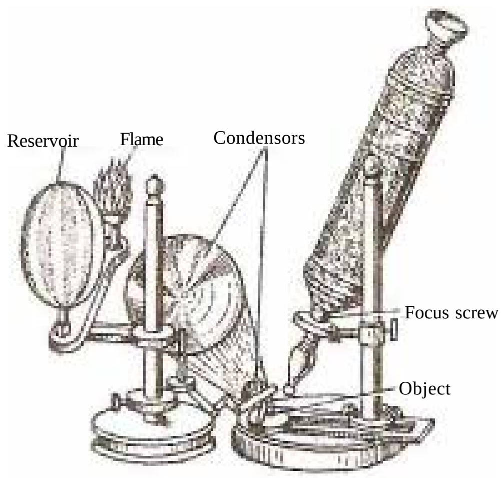
    (100 Hz)
16. *The time period of a periodic wave is 0.02s. At a particular position there is a crest at t = 0. A trough will appear at this position at 't' equal to*

    (A) 0.005s (B) 0.01s
    (c) 0.015s (d) 0.02s (B).

CHAPTER – 12

The fundamental unit of life : Cell

Cell is a Latin word that means a little room. It was first discovered by ROBERT HOOKE in 1665, while examining a thin section of cork, which is a substance obtained from the bark of a tree called cork oak (*Quercus suber*). He observed in the section of cork many small compartments that resembled the structure of a honeycomb. This observation was made through his own microscope (Fig.12.1). Robert Hooke called these small compartments as **cells**. It may be considered as an insignificant or small incident but it has occupied a very significant place in the history of science.



(i)


(ii)

Fig.12.1: (i) Robert Hook's microscope

(ii) Cork cell as seen under microscope and a twig of cork ork

12.1 What are living organisms made up of ?

Activity 12.1

Let us take a fleshy leaf from inside an onion bulb. With the help of a pair of forceps, we can peel off the skin (called epidermis) from the concave side (inner layer) of the onion and put immediately in a watch-glass containing water to prevent the peel from getting folded or dry. What do we do with this onion peel?

Let us take a glass slide, put a drop of clean water on it and transfer a small piece of the peel from the watch-glass to the slide. Make sure that the peel is perfectly flat on the slide. A thin camel hair paint brush to help you to transfer the peel. Now, put a drop of iodine solution on this piece followed by a cover slip. It is necessary to take care to avoid air bubbles while putting the cover slip with the help of a mounting needle. Even you ask teacher for help. In this way, we have prepared a temporary mount of onion peel. We can observe this slide under low and high powers of compound microscope (Fig.12.2)

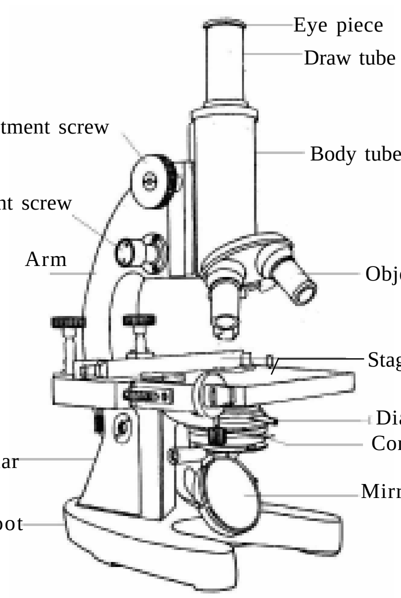


Fig.12.2: A compound microscope

What do we observe as we look through the lens? Can we draw the structures that we are able to see through the microscope, on an observation sheet? Does it look like as seen in Fig.12.3 ?

We can try preparing temporary mounts of peel of onions of different sizes and we can observe whether they have similar structures or different structures. These structures look similar to each other and together form a big structure like an onion bulb. We have found here from this activity that onion bulbs of different sizes have similar small structures visible under a microscope. The cells of the onion peel will look identical, regardless of the size of the onion they are taken from.

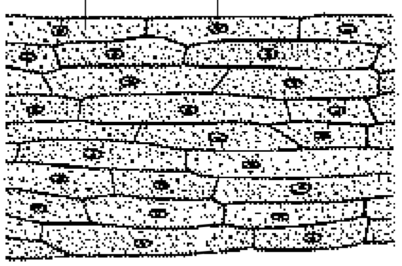


Fig.12.3: Onion cells

These small structures that we notice are the basic building units of the onion bulb. These structures are called **cells**. Not only onions, but all organisms that we observe around us are also made up of cells. Yet, there are many organisms made up of single cells living on their own. The discovery of microscopic world is possible with the inventions of magnifying lenses of various powers.

More to know

Robert Hooke first discovered CELLS in 1665. With the help of a primitive microscope, he observed the cells in a cork slice. With the improved microscope, **Anton von Leeuwenhoek** in 1674 discovered the free living cells in pond water for the first time. **Robert Brown** in 1831 discovered the nucleus in the cell. It was **Purkinje** in 1839 who coined the term '**protoplasm**' for the fluid substance of the cell. **Jacob Matthias Schleiden** in 1838 and **Theodor Schwann** in 1839 independently asserted that all the plants and animals are composed of cells and that the cell is the basic unit of life. This joint finding forms the basis of the **cell theory**. The cell theory was further refined by **Virchow** in 1855 by presenting that all cells arise from pre-existing cells. With the invention of the electron microscope by **Knoll** and **Ruska** in 1932, it was possible to observe and understand the complex structure of the cell and its various organelles.

In some organisms, a single cell may constitute the whole body as in *Amoeba, Chlamydomonas, Paramoecium, Bacteria etc.* These are called **unicellular** organisms (*uni* = single). On the other hand, in many organisms such as some fungi, plants and animals, many cells are grouped together in a single body and assume different functions of it to form various body parts. These are called **multicellular** organisms (*multi* = many). Can you find out the names of some more unicellular organisms?

Activity 12.2

You can try preparing temporary mounts of leaf peels, roots tips of onion or even peels of onions of different sizes. Find out what answers to the following questions would be :

a) Do all cells look alike in terms of shape ad size?

b) Do all cells look alike in structures?

After having performed the activities mentioned above, you will be able to know that all the cells of multicellular organisms are not look alike in terms of shape, size and structures. There are some basic similarities among all cells of higher organisms in having plasma membrane, a cytoplasm with organelles and a nucleus.

Some organisms can also have cells of different kinds. Look at the Fig.12.4 showing various types of cells.

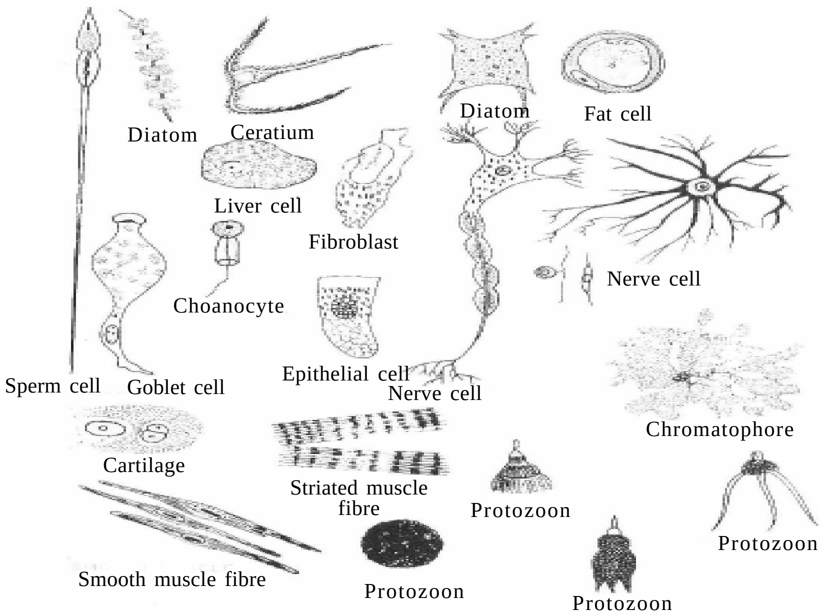


Fig.12.4.: Different kinds of cells

Cells are different in shape and size not only in different organisms but also in different parts of the same organism. They may be oval, spherical, discoid, columnar, polygonal, spindle shape etc. The shape of the cell is usually related with its specific function. Some cells like *Amoeba* have changing shapes. In some cases the cell shape could be more or less peculiar for a particular type of cell; for example, nerve cells have a typical shape. Each living cell has the capacity to perform certain basic functions that are characteristic of all living forms. Each cell has certain specific components within it known as **cell organelles** performing specific functions, such as forming new material in the cell, getting rid of the waste materials from the cell and so on. Because of these organelles a cell is able to live and perform all its functions. These organelles together constitute the basic unit called the cell. It is interesting that all cells are found to have the same organelles, no matter what their function is or what organism they are found in.

The size of the cells varies from very small cells of bacteria (0.2 to 5.0 m) to the very large egg of the ostrich (170 mm).

Try to Answer the questions

1. Who discovered cell and how?
2. Give and example of two multicellular organisms?
3. What is the size of the egg of Ostrich?

12.2 The Structural organisation of a Cell

It is learnt that each cell has special components called **organelles**. These organelles perform various functions. You will come across in almost every cell, the three features: **plasma membrane, nucleus** and **cytoplasm** that are responsible for all activities performed inside the cell and interactions of the cell with its environment. (Fig.12.5).

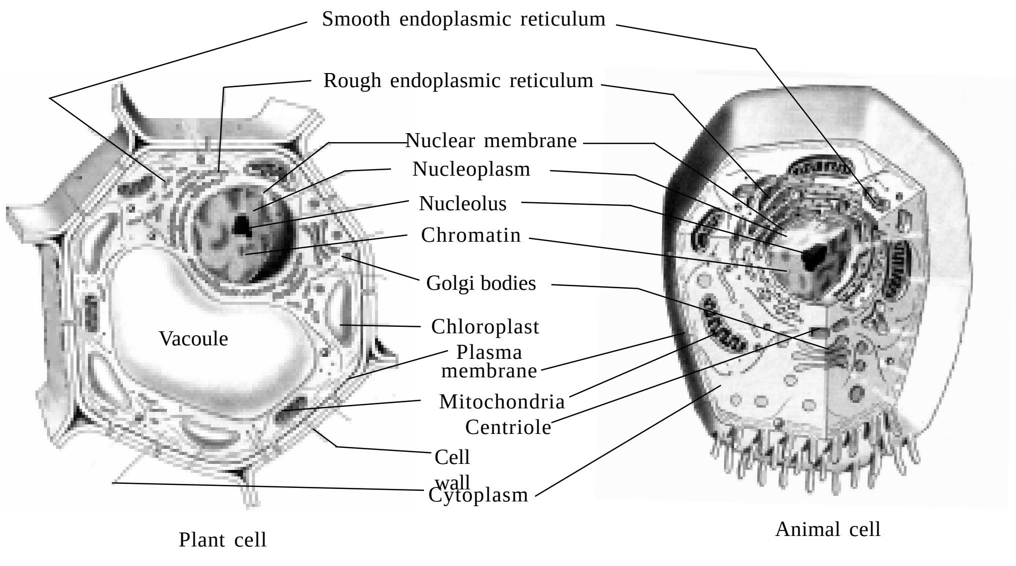


Fig.12.5: Structures of Plant and animal cells

12.2.1 Plasma membrane

Plasma membrane is the outermost covering of the cell. This separates the contents of the cell from its external environment. It is present in cells of plants, animals and microorganisms. The plasma membrane controls the movement of some materials in and out of the cell. It also prevents movement of some other materials. The cell membrane, therefore, is called a **selectively permeable membrane**.

The plasma membrane is flexible, living, thin, delicate, elastic, selectively permeable membrane. This is made up of organic molecules called lipids and proteins. But, it can not be observed under the light microscope. We can only observe the structure of the plasma membrane only through an electron microscope. The cell engulfs in food and other material from its external environment because of the flexibility of the cell membrane. Such processes are known as **endocytosis**. *Amoeba* acquires its food through such processes. Transportation of substances across the plasma membrane will be discussed in chapter 16.

Activity 12.3

Find out about electron microscopes from resources in the school library or through the internet. Discuss it with your teacher.

12.2.2 Cell Wall

In Plant cells, there is another rigid outer covering called **cell wall** which lies outside the **plasma membrane**. The cell wall is mainly composed of **cellulose** which is a complex substance and provides structural strength to plants.

When a living plant cell loses water through osmosis there is shrinkage or contraction of the contents of the cell away from the cell wall. This phenomenon is known as **plasmolysis**. We can observe this phenomenon by performing the following activity:

Activity 12.4

Mount the peel of a *Rheo* leaf in water on a slide and examine the cells of leaf under the high power of a microscope. Note the small green granules, called **chloroplasts**. They contain a green substance called **chlorophyll**. Put a strong solution of sugar or salt on the mounted leaf on the slide. Wait for a minute and observe under a microscope.

Now place some *Rheo* leaves in boiling water for a few minutes. This kills the cells. Then mount one leaf on a slide and observe it under a microscope. Put a strong solution of sugar or salt on the mounted leaf on the slide. Wait for a minute and observe it again. We can see that only living cells, and not dead cells, are able to absorb water by osmosis.

Cell walls allow the cells of plants, fungi and bacteria to survive in a very dilute (hypotonic) external media without bursting. In such media the cells tend to take up water by osmosis and it swells, building up pressure against the cell wall which in turn exerts an equal pressure against the swollen cell. Because of their walls, such cells can withstand much greater changes in the surrounding medium than animal cells.

12.2.3 Nucleus

The nucleus is an important, centrally located spherical cellullar component. The nucleus consists of two layers covering called **nuclear membrane**. The nuclear membrane separates nucleus from cytoplasm. The nuclear membrane has many pores (the **nuclear pores**) and encloses the liquid ground substance, the **nucleoplasm**. Nuclear pores allow the transfer of materials between nucleoplasm and the cytoplasm.

The nucleus contains **chromosomes**. Chromosome is visible clearly during the cell division, as rod-shaped structures. Chromosomes are mainly composed of DNA (Deoxyribo Nucleic Acid), RNA (Ribo Nucleic Acid) and protein. DNA molecules contain information necessary for constructing and organising cells. Functional segments of DNA are called **genes,** which are hereditary units. In a cell which is not dividing, this DNA is present as part of **chromatin material**. Chromatin material is visible as entangled mass of thread like structure. Whenever the cell is about to divide, the chromatin material gets organised into chromosomes. Attaching to the chromatin materials, there is another spherical structure known as **Nucleolus**. (Fig.12.5). Nucleolus disappears and reappears during cell division stages. It is involved in synthesis of ribosomal RNA and ribosome.

Activity 12.7

Let us take a glass slide with a drop of water on it. Using an ice-cream spoon or toothpick, you can gently scrape the inside surface of the cheek. With the help of a needle we can transfer this material and spread it evenly on the glass slide kept ready for this. To colour the material we can put a drop of methylene blue solution on it. Now the material is ready for observation under microscope. Do not forget to put a cover-slip on it without allowing forming air bubbles. Then observe it under a high power of microscope. You will observe a spherical or oval dot-like structure, called nucleus near the centre of the cheek cell. These similar structures are found in onion peel cells too.

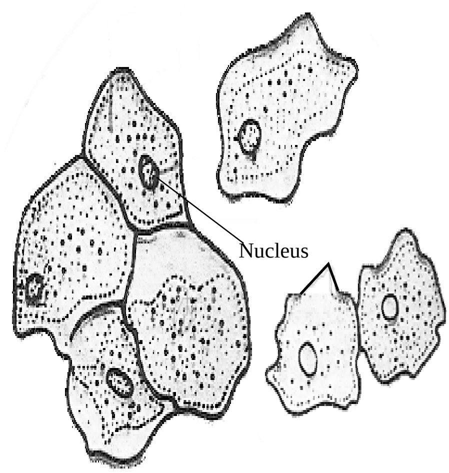


Fig. 12.6: Cheek cells showing nucleus

Nucleus is funtionally known as brain of the cell or controlling chamber of the cell because it controls all the activities of the cell.

The nucleus plays a central role in cellular reproduction. Cellular reproduction is the process of dividing a single cell to form two new cells. It also plays a crucial part, along with the environment, in determining the way the cell exhibit at maturity, by directing the chemical activities of the cell.

The nuclear region of the cell is undefined in some organisms like *bacteria*. Such an undefined nuclear region lacking nuclear membrane and containing only nucleic acids is called a **nucleoid**. Such organisms are called **prokaryotes** (*pro* = primitive or primary; *karyote* = *karyon* = nucleus). Organisms with cells having a nuclear membrane are called **eukaryotes** (*eu* = true).

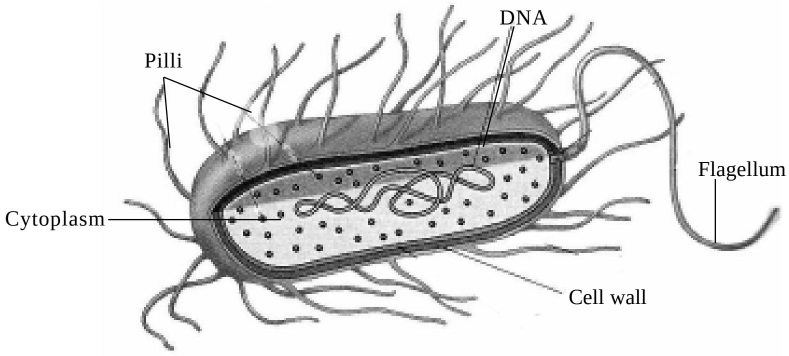


Fig. 12.7: A bacterium cell

Poorly organised parts of the cytoplasm in prokaryotes perform many of the functions like the chlorophyll in photosynthetic prokaryotic bacteria is associated with bag like membranous structures, **vesicles** but not with plastids as in eukaryotic cells.

12.2.4 Cytoplasm

We can see a large region of each cell enclosed by the membrane when we observe the temporary mounts of onion peel as well as human cheek cells. This region, between the plasma membrane and nuclear membrane, is called **cytoplasm**. The cytoplasm is the fluid content inside the plasma membrane. It also contains many specialized cell organelles that perform various specific functions for the cell. Cell organelles are enclosed by membranes.

In prokaryotic cell, there is no well defined nuclear region and membrane-bound cell organelles. On the other hand, in the eukaryotic cells there is nuclear membrane as well as membrane-enclosed organelles.

The importance of membranes can be understood with the example of viruses. Viruses do not show characteristics of life due to lack of membranes. They show the characteristics of life when they enter a living body and use its cell machinery to multiply.

Differences between prokaryotic and eukaryotic cells.

Prokaryotic Cell	Eukaryotic Cell
1. Size : generally small (1–10mm) 1mm = 10^{-6} m	1. Size: generally large (5 – 100 m)
2. Nuclear region is not well defined .	2. Nuclear region is well defined and surrounded by a nuclear membrane.
3. It has single chromosome	3. It has more than one chromosome.
4. Membrane – bound cell organelles absent	4. Membrane – bound cell organelles like mitochondria, chloroplasts, Golgi bodies etc. present

Try to answer the questions

1. Why is plasma membrane called a selectively permeable membrane?
2. What is the main chemical component part of plant cell wall?
3. How does *Amoeba* acquire its food?

12.2.5 Cell organelles

Cell has to perform various functions with the help of its different membrane-bound organelles. Cell has to synthesise substances like protein by **ribosomes**; has to secrete cell products. Membrane is a remarkable structure of the cell. Every cell is enclosed by a membrane to keep its own contents separate from the external environment. A lot of chemical activities are required by large and complex cells, including cells from multicellular organisms, to support their complicated structure and function. To keep metabolic activities of different kinds separate from each other, these cells have developed membrane-bound organelles within themselves. Eukaryotic cells distinguish themselves from prokaryotic cells in having membrane-bound organelles within themselves. **Cell organelles** are the living part of the cell and each of them has a definite shape, structure and function. Examples are nucleus, endoplasmic reticulum, Golgi apparatus, lysosomes, mitochondria, plastids etc. We have already discussed about the nucleus in a previous section. In this section, we will talk about the rest of the cell organelles one after another. Some of these organelles are visible only with an electron microscope.

12.2.5 (i) Endoplasmic reticulum (ER)

The endoplasmic reticulum (ER) consists of an interconnected system of membrane bound flattened sacs in the cytoplasm. These are known as **cisternae** (Singular : Cisterna). It may assume the form of **tubules** or round or oblong bags known as **vesicles**. The ER membrane is similar in structure to that of the plasma membrane. ER is connected to the outer membrane of the nucleus on the one end and to the plasma membrane on the other end. ER is of two types – Rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). RER looks rough under a microscope because it has **ribosomes** attached to its surface. The ribosome, present in both prokaryotic and eukaryotic cells, are the sites of protein synthesis. ER transports the synthesised proteins to various places in the cell according to their need. The SER is without ribosomes and helps in the manufacture of fat molecules or lipids. Some of these proteins and lipids help in membrane biogenesis, which is a process of building cell membrane. Some other proteins and lipids function as enzymes and hormones. ER always forms an interconnected system though it varies greatly in appearance in different cells.

Thus, one important function of the ER is to transport proteins between various regions of the cytoplasm or between the cytoplasm and the nucleus. It also functions as a cytoplasmic framework providing a surface for some of the biochemical activities of the cell. It also provides the pathway for the distribution of nuclear material from one cell to the other. SER is involved in the process of detoxification of many poisons and drugs in the liver cells of the group of animals called vertebrates.

12.2.5. (ii) Golgi Apparatus

The Golgi apparatus was first described by **Camillo Golg**i. It consists of a system of membrane-bound fluid-filled vesicles, vacuoles and flattened cisternae (closed sac). Cisternae are arranged approximately parallel to each other in stacks (placed one above the other). These membranes of Golgi apparatus connect with that of ER and therefore, form another portion of a complex cellular membrane system.

Golgi apparatus pack and dispatch the materials synthesised near the ER to various targets inside and outside the cell. The functions of Golgi apparatus include the storage, modification and packaging of products in vesicles. In some cases, complex sugars may be made from simple sugars in the Golgi apparatus. The Golgi apparatus is also involved in the synthesis of plasma membrane, lysosomes and cell wall.

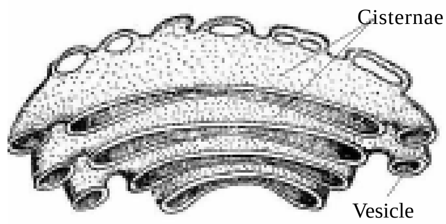


Fig.12.8 : Golgi apparatus

12.2.5 (iii) Lysosomes

Lysosomes are simple, tiny, single membrane-bound sac like structures. They are evenly distributed in the cytoplasm. They are filled with digestive enzymes that are made by RER. Lysosomes destroy any foreign materials which enter the cell such as bacteria and virus. They also remove the worn-out organelles to keep the cells clean. For this reason this organelle is considered to be a kind of waste disposal system of the cell. Lysosomes are able to carry out all this functions because they contain powerful digestive enzymes capable of breaking down all organic materials. During the disturbance in cellular metabolism, for example, when the cell gets damaged, lysosomes may burst and the enzymes digest their own cell. Therefore lysosomes are also known as the **suicide bags** of a cell.

12.2.5 (iv) Mitochondria

The name **mitochondrion** comes from two Greek words, "*mito*" meaning "filament" and "*chondros*" meaning "grain". The number of mitochondria per cell may depend on the cell type. Each mitochondrion has two membranes-outer and inner. The outer membrane is porous while the inner membrane is deeply folded to increase a large surface area for **ATP** (Adenosine triphosphate). These folded finger like structures are called **cristae**, the inner surface of which are attached with many tennis racket like structures known as **oxysomes** or **F_1 particles**. The inner cavity of mitochondrion is filled with proteinous semi-solid substance called **matrix**. Inside matrix DNA, ribosomes and phosphate granules are found present (Fig.12.9).

Mitochondria can synthesize their own proteins with the help of their own DNA and ribosomes. So they are regarded as semi-autonomous organelles of the cell. They are self-replicating organelles ie, they have the power to divide.

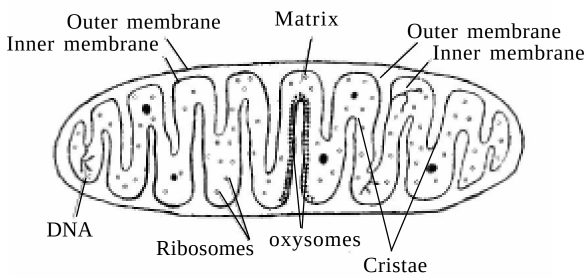


Fig.12.9: Structure of a mitochondrion

Functionally mitochondria are regarded as the sites for cellular respiration. They use molecular oxygen from the air to oxidise food substances like carbohydrate etc. to release energy in the form of ATP, Carbon dioxide and water molecules. ATP is known as energy currency of the cell. It is used by the body to perform various activities. As the organelle provides the required energy of the cell, mitochondria are also known as "Power House " of the cell.

12.2.5 (v) Plastids

Plastids are found in almost all plant cells. Plastids are similar to mitochondria is their external structures and also have their own DNA and ribosomes, and they are self-replicating organelle. There are three types of plastids – (i) leucoplasts (ii) chloroplasts and (iii) chromoplasts.

Leucoplasts are colourless or white plastids. They store starch, oils and protein granules and hence, are found in many storage parts of the plant.

Chloroplasts are green coloured plastids. They are found in all the green parts of the plants like leaves, young stems etc. A chloroplasts has two membranes – an outer and an inner membrane with an intermediate space between them. Inside the inner m embrane there is a semi-liquid substance known as **Stroma**. Spreading in stroma, there are many membrane bound discoid shape structures, **thylakoids**, pilling one above another in the form of stack of coins known as **Grana** (Singular : **granum**). Grana are interconnected by intergrana or stroma lemellae, an unstacked membranous structure. Chlorophyll and carotenoid pigments are located in these membrane system (Fig.12.10). Functionally chloroplasts are regarded as sites for photosynthesis.

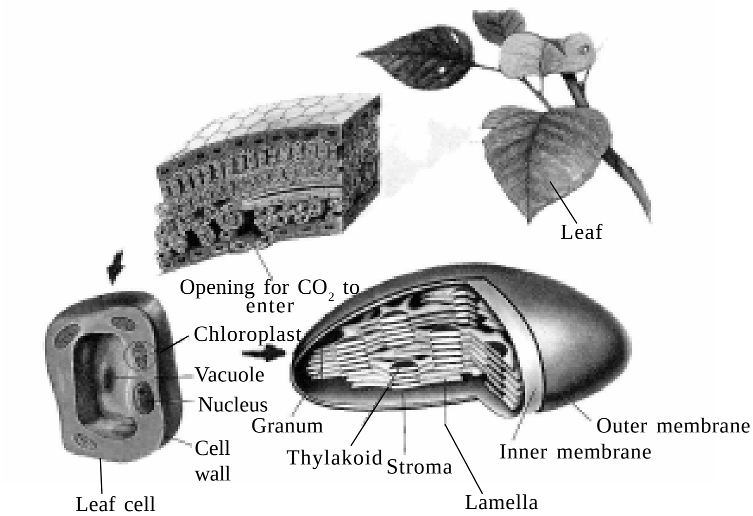


Fig. 12.10: Chloroplast from a leaf cell

Chromoplasts are coloured other than green plastids. They are found in the coloured flowers and other coloured parts of the plant. They help the plant to attract insects and birds for their pollination and dispersal of fruits and seeds.

12.2.5 (vi) Cytoskeleton

A wide variety of cells (both prokaryotes and eukaryotes) possess cytoskeleton system. It plays important role in maintaining their structure, function and behaviour. It is mainly consists of (i) **microtubules** which are elongated, cylindrical and unbranched, non-membranous structures present in all actively dividing and elongating cells (Fig.12.11). (ii) **microfilaments** which are long rod-like structures of variable length. And (iii) **Intermediate filaments** which are intermediate between micro-tubules and microfilaments in size.

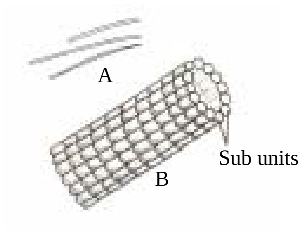


Fig. 12.11 : (A) Microtubules (B) A part

12.2.5 (vii) Vacuoles

Vacuoles are fluid- or solid-filled and membrane bounded spaces. The vacuolar membrane is called **tonoplast**. They are a kind of storage sacs for solid or liquid contents. In animal cells, vacuoles, if present, are small in size and temporary. They store water; glycogen and proteins. In plant cells vacuoles are very large and distinct. The central vacuole of some plant cells may occupy 50 – 90% of the cell volume. In plant cell, vacuoles are full of **cell sap** and provide turgidity and rigidity of the cell. Many important substances of life of the plant cell are stored in vacuoles. These include amino acids, sugars, various organic acids and some proteins. In single celled organisms like Amoeba, the food vacuole contains the food items that Amoeba has consumed. In some unicellular organisms, specialised vacuoles also play important roles in expelling excess water and some wastes f

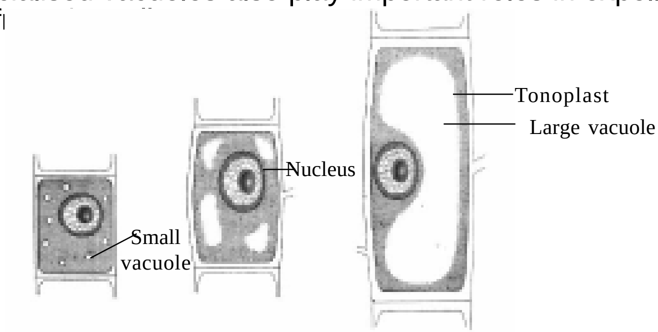


Fig.12.12 : Diagram showing formation of a central vacuole in plant cell

The cell has a basic structural organisation as each cell acquires its structure and ability to function because of the organisation of its membrane and organelles in specific ways. This helps the cells to perform functions like respiration, obtaining nutrition, and clearing of waste material, or forming new proteins.

Thus, the cell is the fundamental structural unit of living organisms. It is also the basic functional unit of life.

Try to answer to questions

1. Can you name two organelles that contain their own DNA and ribosomes?
2. Why are lysosomes called as suicide bags of the cell?
3. Name the organelle which is regarded as "power house" of the cell?
4. What ATP stands for?
5. Where do the ribosome get synthesis?

12.3 Cell Division

A cell never appears spontaneously but is always formed from some pre-existing cells. This was stated by **Rudolph Virchow in** 1855. In his words "*Omnis cellula – e – cellula*" meaning cells arise from cells. Cell gradually increases in bulk till it reaches a certain limit in size and divides into two similar daughter cells. By cell division we mean division of the nucleus i.e. nucleus is first divided into two and then division of the cytoplasm follows. Division of the nucleus is known as **Karyokinesis** (*Karyo* – nucleus; *kinesis* – division) and division of the cytoplasm is called **cytokinesis** (*cyto* – cytoplasm; *kinesis* – division). Cell division is important because growth is characteristics of living organisms and growth is initiated by cell division. The nucleus may divide in three ways: (i) amitosis (ii) mitosis and (iii) meiosis.

12.3.1 Amitosis

It is also known as Direct nuclear division. It is a simple process. Here, the nucleus constricts in the middle into a dumb – bell form and the two nuclei of approximately equal sizes are formed. Division of the cytoplasm soon takes place by constrictions, so that two new daughter cells are formed. It is found in lower forms of plants and animals such as protozoa.

*12.3.2 Mitosis/Karyokinesis/Equational Divi*sion

This takes places in the somatic cells (*soma* – body) of all higher plants and animals. Here, the contents of nucleus and cytoplasm of the cell are equally divided into two, hence called **Equational division**. Mitosis involves karyokinesis and cytokinesis as mentioned above.

Karyokinesis is completed into four successive stages :

(i) **Prophase** (the early phase) : This is the first stage of mitosis, where the chromatin condenses to form **chromosomes**. Chromosomes are dupplicated to form two chromatids attached to a single **centromere**. Nucleolus and nuclear membrane dissolve and spindle fibres begin to form.

(ii) **Metaphase** : It is a short phase when the nuclear membrane and nucleolus completely disappear. The chromosome arrange themselves at the equator. Each of the chromosomes has spindle-fibre attachment region, called centromere, to which a fibre remains attached. Other fibres of the spindle (supporting fibres) extend from pole to pole.

(iii) **Anaphase** : Centromeres of the chromosomes are duplicated longitudinally to form two daughter chromosomes. Groups of daughter chromosomes separate and move to opposite poles.

(iv) **Telophase** : It is also known as reconstruction phase. This is the last phase when chromosomes have reached the poles. Nuclear membrane and nucleolus reappear, and two daughter nuclei are formed.

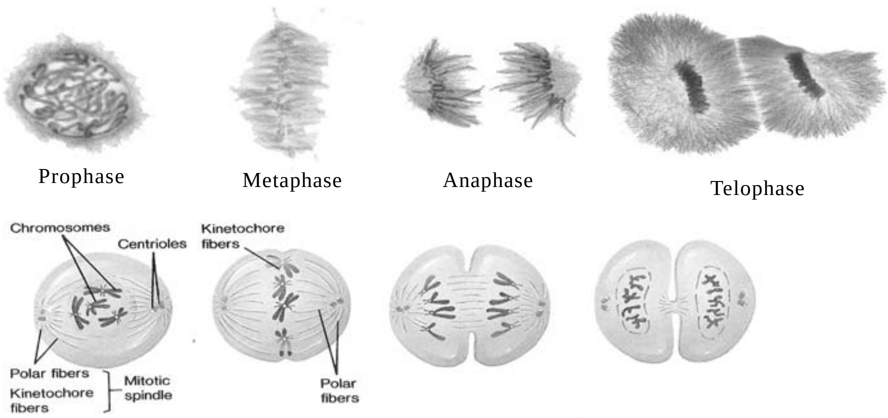


Fig.12.13 : Different stages of Mitosis in Animal cell

Cytokinesis (Division of cytoplasm) : It usually follows the telophase. In animal cells, a furrow appears at the beginning of telophase. This furrow constriction deepens and ultimately divides the cytoplasm into two daughter cells. In plant cells, there is a formation of cell plate between the two groups of chromosomes. The cell plate grows from middle towards periphery and finally develop into cell wall. Thus, two daughter cell are formed.

Significance of Mitosis

1. Mitosis maintains uniformity among the daughter cells. All the cells in the multicellular organisms possess the same number of chromosomes.
2. Mitosis helps in repairing old and damaged cells by producing new cells.
3. Mitosis helps in the growth of the multicellular organisms.
4. Mitosis helps in increase of individuals in unicellular organisms.

12.3.3 Meiosis : (Gr.*meioum* = to less; *osis* = state)

Meiosis is a special type of cell division in which the chromosome number of a diploid parent cell is reduced to half. It is restricted to only reproductive cells. It is also known as **reduction division** as it forms four daughter cells, each having half the number of chromosomes of the parent cell. This method involves two divisions, of which the first division is **reductional** and second one is **mitotic** or **equational**. Both divisions are completed under four successive stages each, as in mitosis. They are listed as follows:

1. Meiosis I (Reduction Division):

(i) **Prophase I :** It is of very long duration and completed under five successive sub stages i.e. leptotene, zygotene, pachytene, diplotene and diakinesis.
Leptotene (G. *leptos* = fine; *tene* = thread): Here nucleus enlarges in size and chromatin condenses to form long and coiled filamentous individualised chromosome.
Zygotene (G. *zygon* = yolk; *tene* = thread): Here shortening and thickening of

chromosomes start. Pairing of homologous chromosome takes place due to force of attraction. This process is called **synapsis**. The synapsed chromosome is known as **bivalent**.

Pachytene (G. *pachus* = thick; *tene* = thread): Shortening and thickening of chromosomes still continue. Each chromosome in the bivalent is duplicated forming a tetrad. **Crossing over** or exchange of segments of homologous chromatids at the fixed points, takes place.

Diplotene (G. *diplos* = double; *tene* = thread): Shortening and thickening of chromosomes continue. Force of repulsion takes place in between homologous chromosomes. This leads to separating of chromatids at the centromere and proceeds towards the ends. However, the paired chromosomes remain attached at one or more points. Such point of attachment is called **chiasmata** (singular,chiasma).

Diakinesis (G. *di* = two; *kinesis* = movement): Shortening and thickening of chromosomes will continue and chiasmata will move to the terminal region of bivalent.

(ii) **Metaphase I :** Nuclear membrane and nucleolus completely disappear. Bivalents move to the equatorial plane. Of the bivalents centromeres are away from the equatorial region, which is occupied by chromosome arms. Spindle fibres are formed and they get attached to the centromere of the bivalents.

(iii) **Anaphase I :** The two chromosomes of bivalent start moving to poles and thereby complete the reduction in number of chromosome.

(iv) **Telophase I :** Groups of chromosome arrive at the respective poles and chromosomes starts uncoiling and elongate. Nuclear membrane and nucleolus reappear and thus two daughter **haploid** nuclei are formed.

Meiosis I is followed by meiosis II or equational division. It is completed in four successive stages as in mitosis. Those stages are known as Prophase II, Metaphase II, Anaphase II and Telophase II. In Anaphase II, duplication of chromosome is completed. And in Telophase II, four daughter nuclei are formed (Fig.12.14).

Cytokinesis : The division of nucleus is followed by the division of cytoplasm. In plant cells, cell walls are laid down resulting in the formation of four haploid cells. In animal cells, cytokinesis is completed by furrowing method in the formation of four haploid cells.

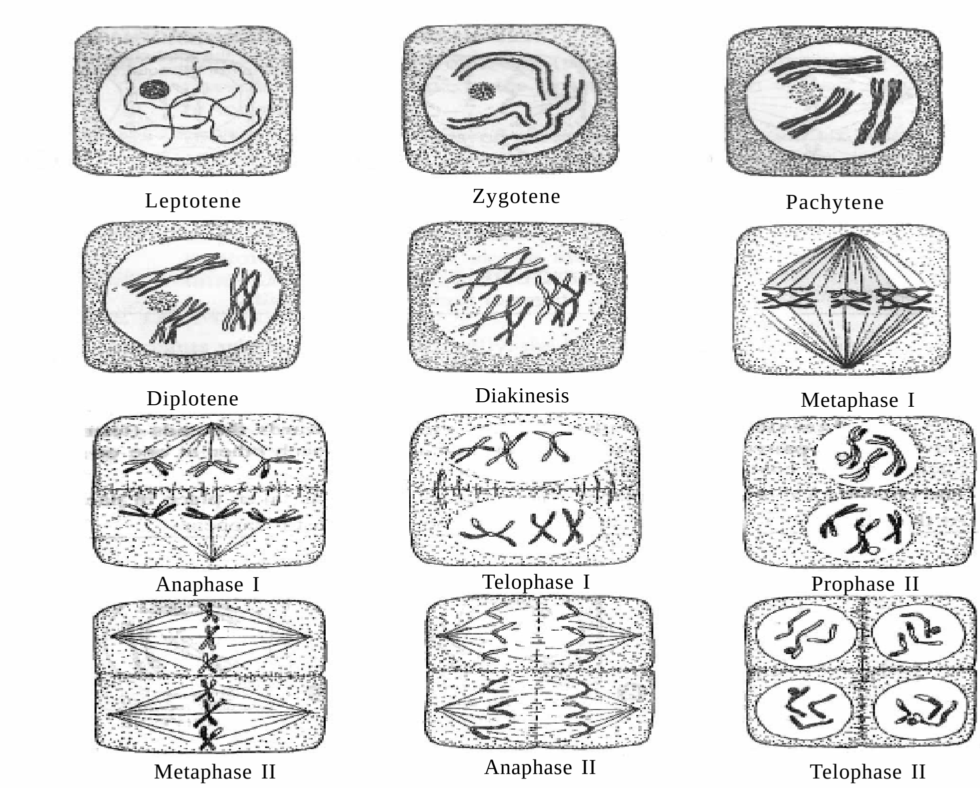


Fig. 12.14 : Different stages of Meiotic division in plant cell

Significance of Meiosis:

Meiosis is a must for all sexually reproducing organisms. It keeps chromosome number constant of an individual from generation to generation. Meiosis also plays an important role in specific character of individual species. It also results in the occurrence of variance in nature.

Comparison of Mitosis and Meiosis

Mitosis	Meiosis
1. Mitosis occurs in somatic cells of all plants and animals.	1. Meiosis occurs in germ cells all sexually reproducing organisms.
2. It includes only one division which is equational.	2. It includes two divisions in which the first one is reductional and the second one is equational.
3. It gives rise to two daughter cells which are identical to each other and to the parent cell.	3. It results in the formation of four daughter cells which differ from parent cell.
4. Prophase is comparatively short	4. Prophase of meiosis I is comparatively longer and divided into five sub stages.
5. Synapsis and tetrad chromosome do not occur.	5. Synapsis and bivalent formation occur.
6. No exchange of chromosome materials	6. Exchange of chromosome material takes place during crossing over.
7. It has no varience in nature.	7. It has varience in nature.

12.4 Chromosome (*Chroma* = Colour; *Soma* = body)

The term chromosome was first given by Waldeyer in 1888 for the coloured thread like structures seen during cell division stages. Metaphase chromosome consists of two chromatids attached to a single centromere whereas anaphase chromosome consists of a single chromatid with its own centromere. Chromosomes are the most important component of the cell carrying hereditary materials. Chromosome's shapes or types are determined by the position of the centromere which is a unstained part of the chromosome. Accordingly, chromosomes are (i) metacentric (ii) sub metacentric (iii) acro-centric and (iv) telocentric chromosome as shown in the Fig.12.15.

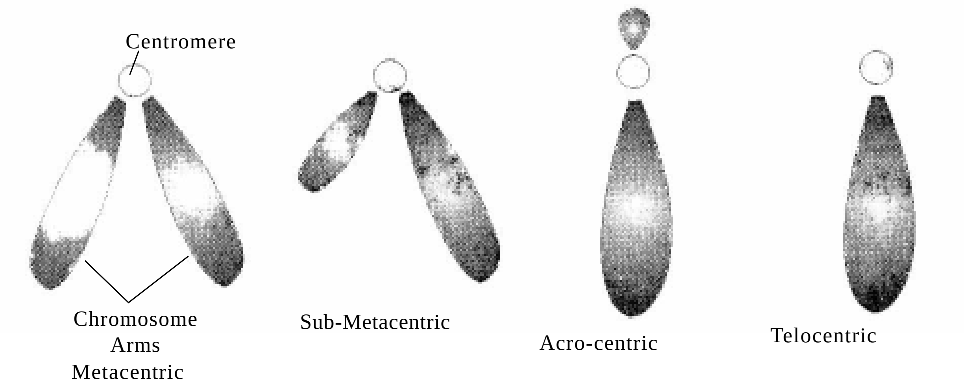


Fig.12.15 : Different types of chromosome

(i) Metacentric chromosome : Here both the arms are more or less equal in length and it takes the shape of letter 'V'.

(ii) Sub-metacentric chromosome : Here one arm is shorter than the other and it takes the shape of letter 'J' or 'L'.

(iii) Acrocentric chromosome : Here the smaller arm is very short and it cannot bend and it takes the shape of letter 'I'.

(iv) Telocentric chromosome : Centromere occupies one terminal end of the chromosome and it takes the shape of letter 'I'.

There is definite number of chromosome of each species in its cells. Thus the cells of potato has 48, rice has 24, onion has 14, mouse cell has 40, dog has 64, and we human beings have 46 chromosomes. These chromosome exist in pairs or two copies. The members of each pair is called **homologous chromosomes** and total number of chromosome in its cell is the **diploid number**. Thus, you have 46 homologous diploid chromosomes in your body.

Try to answer the questions

1. Who stated, *omnis cellula-e-cellula*?
2. Why do you called mitosis as eqational division?
3. Meiosis is known as reductional division. Why?
4. In which stage of meiosis, crossing over takes place?

POINTS TO REMEMBER

* The cell is the fundamental organisational unit of life.
* Cells are enclosed by a plasma membrane composed of lipids and proteins.
* The cell membrane is an active part of the cell. It regulates the movement of materials between the interior of the cell and outer environment.
* In plant cells, a cell wall composed mainly of cellulose is located outside the cell membrane. It is absent in animal cell.
* The presence of the cell wall enables the cells of plants, fungi and bacteria to exist in hypotonic media without bursting.
* The nucleus in eukaryotes is separated from the cytoplasm by double-layered membrane and it directs the life processes of the cell.
* The ER functions both as a passageway for intracellular transport and as a manufacturing surface.
* The Golgi apparatus consists of stacks of membrane-bound vesicles that function in the storage, modification and packaging of substances manufactured in the cell.
* Most plant cells have large membranous organelles called plastids, which are of three types – leucoplasts, chloroplasts, and chromoplast. Chloroplast is responsible for photosynthesis.
* Cytoskeleton consists of microtubules, microfilaments and intermediate filaments.
* Presence of vacuoles is characteristic feature of plant cells.
* Cell division is of three types – amitosis, mitosis and meiosis.
* Amitosis is found in lower organisms, where cells is directly divided into two.
* Mitosis occurs in the somatic cells to increase the number of individual in unicellular organisms or to increase to number of cells in multi cellular organisms.
* Mitosis consists of four successive stages – Prophase, Metaphase, Anaphase Telophase, and followed by the division of the cytoplasm or cytokinesis, forming two daughter cells.
* Meiosis occurs in all the sexually reproducing organisms at the time of formation of eggs and sperms.
* Occurence of variance in organisms is due to meiosis.
* Chromosomes are carriers of hereditary characters.
* Chromosome is of four types based on the position of centromere.
* Number of chromosome is definite in an individual.

EXERCISES

1. Why the cell is called the structural and functional unit of life ?

2. Make a comparison and write down the ways in which plant cells are different from animal cells.

3. How is a prokaryotic cell different from a eukaryotic cell ?

4. Why is the plasma membrane called a selectively permeable membrane ?

5. What would happen if the plasma membrane ruptures or breaks down ?

6. What would happen to the life of a cell if there was no Golgi apparatus ?

7. Which organelle is known as the power house of the cell ? Why?

8. Where do the lipids and proteins constituting the cell membrane get synthesised?

9. Can you name two organelles that contain their own genetic materials ?

10. If the organisation of a cell is destroyed due to some physical or chemical influence, what will happen ?

11. Where are proteins synthesised inside the cell ?

12. Differentiate between mitosis and meiosis.

13. Draw a metaphase chromosome.

14. Diagrammatically differentiate a metaphase chromosome from an anaphase chromosome.

15. Draw and label different stages of mitosis.

16. Draw a neat labelled sketch of ultrastructure of a plant cell or an animal cell.

17. Describe the stages of prophase 1st of meiosis.

CHAPTER – 13

Tissue

In the previous chapter, it is learnt that all living organisms are made of cells. In unicellular organisms (e.g. *Amoeba*, *Paramecium*, etc.), there is only a single cell in its body, i.e. a single cell performs all basic functions of the organism. For example, in *Amoeba*, a single cell carries out its movement, intake of food and respiratory gases (O_2), intracellular digestion, metabolism, respiration and excretion. However, in multicellular organisms (e.g. a human being) there are millions of cells. Most of these cells are specialised to carry out a few functions efficiently. These functions are taken up by different groups of cells. So, we can say that there is a division of labour in the multicellular organisms. For example, in human beings, muscle cells contract and relax to cause movement, nerve cells carry messages, blood flows to transport oxygen, food, hormones and waste material (CO_2) and so on. In the same way, in plants, vascular tissues conduct food from leaves and water from roots to the other parts of the plant. Thus, we know that cells, which are specialised in one function, are grouped together and form a **tissue**. A tissue is arranged and designed in such a way that it provides the highest possible efficiency of function. Blood, phloem, muscle etc. are all examples of tissues.

A group of cells similar in structure and work together to perform a particular function forms a tissue.

13.1 Why are Plants and Animals made of different Types of Tissues?

Plants and animals are two different types of organisms. They are distinctly different in their structures and functions. Plants can manufacture their own food by the process of photosynthesis. Therefore, plants are also known as **autotrophic organisms**. Plants are stationary or fixed – they don't have to move from one place to another to look for their food. Since they don't expense or require much energy, most of the tissues of the plants are supportive, as they provide them only structural strength. Most of these tissues such as xylem, phloem etc. are dead tissue; they provide mechanical strength as they do not contain living protoplasm.

Animals, on the other hand, are **heterotrophic** as they depend on others for their food. They have to move around in search of food, mates and shelter. Hence, they consume more energy as compared to plants. Most of the tissues they have, are living i.e. they contain protoplasm.

Another difference between animals and plants is in the pattern of growth. The growth in plants is limited to certain regions, while this is not so in animals. There are some tissues in plants that divide throughout their life. These tissues are localized in certain regions. Based on the dividing capacity of the tissues, various plant tissues can be classified as **growing** or **meristematic tissue** and **permanent tissue.**

In contrast to plants, growth in animals is more uniform. So, there is no such demarcation of dividing and non-dividing regions in animals.

The fundamental difference between the two major groups of organisms is structural organisation of organs and organ system is more specialised and localized in complex animals than complex plants.

13.2 Plant tissues

13.2.1 Meristematic (*Meristos* = divided) tissue

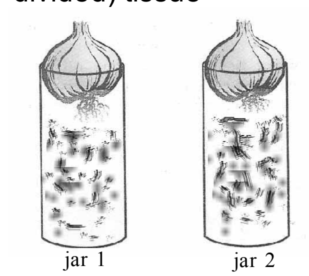


Fig.13.1: Observation of growth of roots in onion bulbs

Activity 13.1

Let us take two glass jars and fill them with water. Now, take two onion bulbs and place one on each jar. Observe the growth of roots in both the bulbs for a few days. Measure the length of roots on day 1, 2 and 3. On day 4 cut the root tips of the onion bulb in jar 2 by about 1 cm. After this, observe the growth of roots in both the jars and measure their lengths each day for five more days and record the observations in tables, like the table below.

Length	Day 1	Day 2	Day 3	Day 4	Day 5

From the above observations, answer the following questions:

1. Which of the two onion bulbs has longer roots? Why?
2. Do the roots continue growing even after you have removed their tips?
3. Why would the tips stop growing in jar 2 after you have cut them?

Meristematic tissues are made up of dividing cells. They help in increasing the length and girth of the plant. Meristematic cells are similar in structure and have uniform thin cellulose cell wall. They are spherical, oval, polygonal or rectangular in shape. They are compactly arranged i.e. no intercellular spaces present between them. They possess dense or abundant cytoplasm with prominent nuclei (Fig.13.2). Vacuoles are absent in them; if present, small in size and many in number.

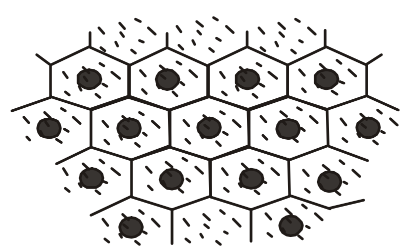


Fig. 13.2: Meristematic tissue

Meristematic tissues, depending on the region where they are present, are classified as **apical**, **intercalary** and **lateral**

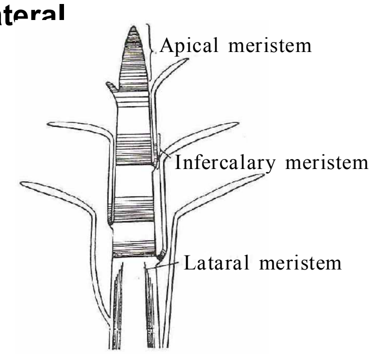


Fig.13.3: Different types of meristems on the basis of position in plant body.

Apical meristem tissues are situated at the growing tips of stems and the root i.e. at shoot apex and root apex. These tissues are also present at the apices of leaves. They bring about the elongation of the roots and stems, resulting in increase in height of the plants.

Intercalary meristem is the meristem found at the base of the leaves or internodes, e.g. stems of grasses and other monocots. Their main function is to increase the length of organ in which they occur.

Lateral meristem tissues are situated along the sides of the stem and roots. These tissues are responsible for the growth in thickness. **Cork cambium** (found beneath the bark) is an example of lateral meristems.

13.2.2 Permanent tissue

The cells formed by meristematic tissue take up a specific role and lose the power to divide and ultimately attain their definite form. Consequently, they form a permanent tissue. This process of taking up a permanent shape, size, and a function is called differentiation. Permanent tissues are classified into two types – simple and complex.

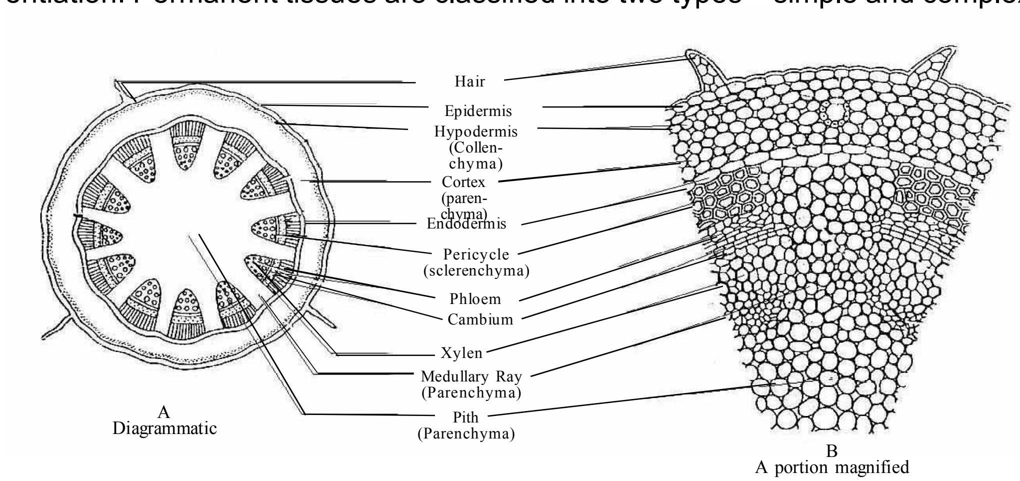


Fig. 13.4 : Section of a Dicot stem (Sunflower)

Activity 13.2

Let us take a few cm. long sunflower stem and with help of your teacher cut into very thin cross sections or slices. Now, stain the sections with safranin and wash in water. Place one neatly cut section on a slide, and put a drop of glycerine. Cover with a cover-slip and observe the various types of cells and their arrangement. Compare it with (Fig. 13.4.)

Now, answer the following on the basis of your observation:

1. Are all cells similar in structure?
2. How many types of cells can be seen?
3. Can you think of reasons why there would be so many types of cells?

You can also try to cut sections of sunflower roots. You can even try cutting sections of roots and stem of different plants.

(1) Simple permanent tissue

The simple tissues consist of a group of similar type of cells forming uniform structures and performing the same functions. The common simple tissues found in plant bodies are **parenchyma**, **collenchyma** and **sclerenchyma** and these names are derived from the cell types of which these are composed.

Parenchyma is the basic packing tissue formed by a few layers of cells. They are found present in all the soft parts of the body. viz, root, stem, leaves, flowers, fruits etc. They are living cells having thin cell walls. There are spaces between cells (intercellular spaces) in this tissue, so they are loosely packed, [Fig.13.5]. Parenchyma cells have living protoplasm containing nucleus and surround a large central vacuole. They have the capability of cell division even though they are permanent tissues. When parenchyma contains chlorophyll, it is known as **chlorenchyma** and performs photosynthesis. A parenchyma is called **aerenchyma** when there is a large air cavity in between cells to give buoyancy to the aquatic plants and help them float. The function of parenchyma is to store food and water.

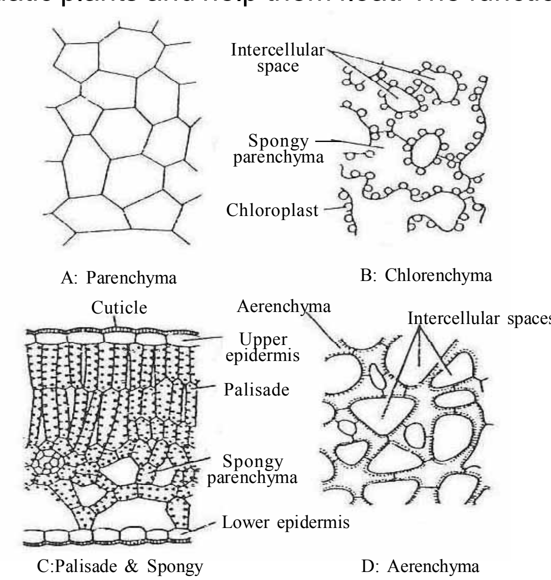


Fig. 13.5: Different kinds of parenchyma

Collenchyma provides the flexibility and mechanical support in plants. It allows easy bending in various parts of a plant (leaf, stem) without breaking. It shows many features similar to parenchyma but there is deposition of extra cellulose and pectin at the corners of the cells in collenchyma. The cells of this tissue are living, elongated and irregularly thickened at the corners. There is very little intercellular space. There are three types of collenchymatous tissues in different plants namely, **Angular**, **Lacunar** and **Lamellar** (Fig.13.6). They are found in dicot stem and leaf stalks just below the epidermis.

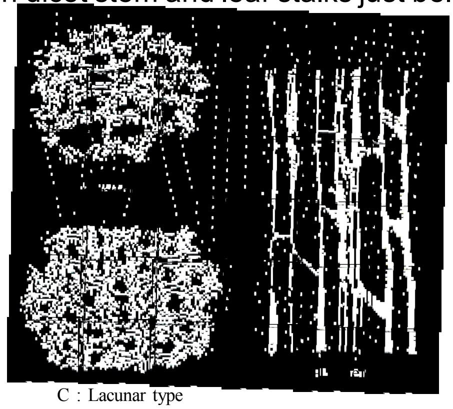


Fig.13.6: Different types of collenchyma

Sclerenchyma is the tissue which makes the plant hard and stiff. We have seen the husk of a coconut. It is made of sclerenchymatous tissue. Sclerenchyma cells are dead cells and do not contain protoplasm. The cell walls are regularly thickened with lignin.The cells are long and narrow, hence called **fibres** (Fig.13.7 (ii).

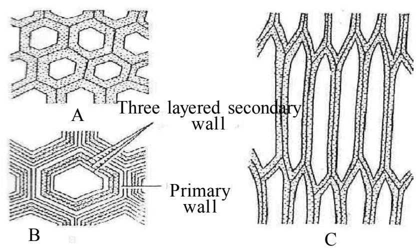


Fig.13.7: (i) A & BTransverse section and C. Longitudinal section of Sclerenchyma

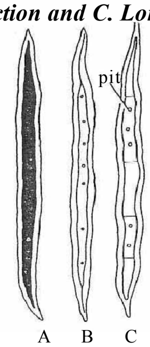


Fig.13.7: (ii) Sclerenchmatous Fibres

Due to thickened cell walls, there is no inter cellular space between the cells (Fig.13.6). They are located in stems, around vascular bundles, in the veins of leaves and in the hard covering of seeds and nuts. They provide strength to the plant parts.

The outermost layer of cells that you observed in Fig.13.4 is called **epidermis**. The epidermis is usually present in the outermost layer of the plant body such as leaves, flowers, stem and roots. It is formed by a single layer of cells. The epidermis may be thicker in some plants found in very dry habitats, since protection against water loss is significant. Epidermal cells on the aerial parts of the plant often secrete a waxy, water-resistant chemical substance known as **cutin** which is deposited to form a definite layer on their outer surface called **cuticle**.This aids in protection against loss of water, mechanical injury and invasion by parasitic fungi. Cells of epidermal tissue form a continuous layer without intercellular spaces since it has a protective role to play. Most epidermal cells are relatively flat. The main function of the epidermis is to protect the plant from desiccation (loss of water from plant body), infection and mechanical injury.

In roots, the outer most layer is called **epiblema**, not epidermis of stems. This is because their outer walls are not thickened with cuticle. The epiblema cells of roots usually bear long hair like structures known as **root hairs** that help the plants to absorb water from the soil.

The epidermis of leaf is not continuous. There are small pores here and there. These pores are called **stomata** (Fig.13.7). A Stoma is bounded by the two kidney or bean shaped, specialised epidermal cells, known as **guard cells**. The inner wall of guard cells arethicker than the outer walls. A guard cell contains chloroplasts, a unique feature which differentiate it from other epidermal cells. In the day time stomata remain open and close at night. Its opening and closing stomata are due to turgidity and faccidity of the guard cells.They are concerned with transpiration (loss of water in the form of water vapour) as well as with the gaseous interchange between the atmosphere and the internal tissues of plants during photosynthesis and respiration of plants.

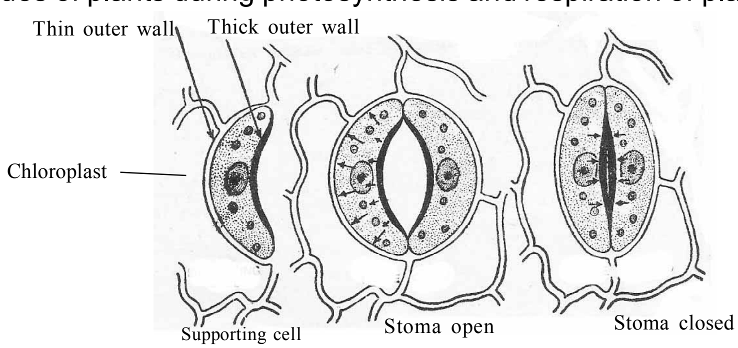


Fig.13.8: Opening and closing of stomata

As plants grow older, the outer protective tissue (epidermis) undergoes certain changes. A strip of secondary meristem, called **phellogen** or **cork cambium** replaces the epidermis of the stem. The layer of the cells which is cut off by cork cambium on the outer side ultimately becomes the several-layer thick cork or the bark of the tree. Cells of cork are dead and compactly arranged without intercellular spaces (Fig.13.6).The cells of the cork are heavily thickened by the deposition of a chemical (fatty acid) called suberin in their walls that makes them impervious to gases and water.

(2) COMPLEX PERMANENT TISSUE

We have discussed the different types of tissues which are all made of one type of cells. They look like each other. Such tissues are called Simple permanent tissues. However, there is another type of permanent tissue known as complex tissue. Complex tissues are made of more than one type of cells. All these cells coordinate to perform a common function. Complex tissues transport water, mineral salts (nutrients) and food material to various parts of plant body. The only Complex tissues of great importance are **xylem** and **phloem**. They are both conducting tissues and constitute a vascular bundle. They are also known as **vascular** or **conductive tissue**, which is a distinctive feature of the higher plants. It is the one feature that has made possible their survival in the terrestrial environment. Can you see different types of cells in the vascular bundle in Fig.13.4 showing a section of stem?

Xylem is composed of cells (elements) of four different types: tracheids, vessels, xylem parenchyma, and xylem fibres (Fig.13.9). All xylem elements have thick lignified walls, and are dead cells except xylem parenchyma. Tracheids and vessels are tubular structures but vessels are shorter and wider than tracheids. Tubular structures of both tracheids and vessels allow them to transport water and minerals vertically. The parenchyma stores food and helps in the lateral conduction of water. Fibres are mainly supportive in function. The main function of xylem is to carry water and mineral salts upward from the root to different parts of the plants. It also provides mechanical strength to the plant body because of lignified walls of tracheids, vessels and sclerenchyma of xylem.

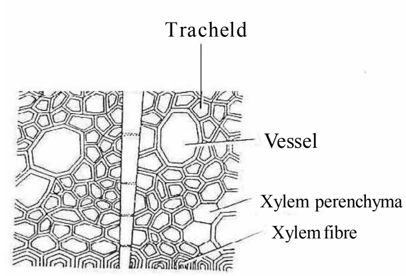


Fig.13.9: (i)T.S. of xylem showing its components

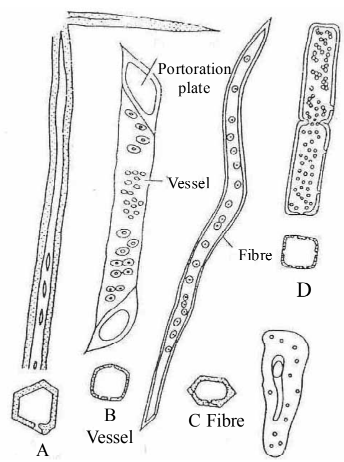


Fig.13.9: (ii) Elements of xylem

Phloem contains tubes like xylem but has no mechanical function. Phloem is composed of four types of elements: **sieve tubes**, **companion cells**, **phloem sclerenchyma** and **phloem parenchyma** (Fig.13.10). Sieve tubes are tubular cells with walls perforated by numerous pores (sieve plates or sieve pores). All the phloem cells are living cells except for phloem sclerenchyma. Phloem sclerenchyma is also known as bast fibres which provide mechanical support to the plant. Phloem transports photosynthetically prepared food materials from leaves to other parts of the plants.

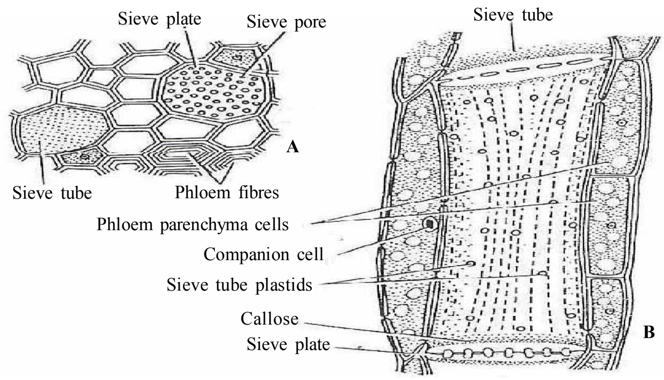


Fig.13.10: A. T.S. of phloem showing its elements B. L.S. of phloem

Try to answers the quetions

1. What is a tissue?
2. Name the simple tissues of plants.
3. Classify meristems on their position in the plant body.
4. What is the function of Apical meristem?
5. What are the constituent elements of xylem and phloem?
6. How do stomata open?

13.3 ANIMAL TISSUES

While breathing, we can actually feel the movement of our chest. How do and what makes this body parts move? We have specialised cells in our body called muscle cells, to perform this life activity. The contraction and relaxation of these muscle cells result in movement.

During breathing we inhale oxygen gas along with air. Where does this oxygen go? It goes to our two lungs and then is transported to all cells of the body through blood. Can you imagine why cells need oxygen? Mitochondria present in the cells, utilize the oxygen in the generation of energy in the form of ATP molecules. Blood flows and connects different parts of the body. It carries oxygen and food to all cells. It also collects metabolic wastes (e.g. carbon dioxide) from all parts of the body and carries them to the liver and kidney for disposal.

Thus, blood and muscles are both examples of tissues found in our body. Animal tissues can be classified, on the basis of functions they perform in the body, as **epithelial tissue**, **connective tissue**, **muscular tissue** and **nervous tissue**. Muscle forms muscular tissue and blood is a type of connective tissue

13.3.1 EPITHELIAL TISSUE

Epithelial tissue is the simplest tissue. It is the covering or protective tissue in the animal body (as epidermis of plants). Cells of these tissues are tightly packed and form a continuous sheet. They indeed contain a small amount of cementing material between them and almost no intercellular spaces. It covers most organs and cavities within the body. It also forms a barrier to keep separately different body system. The skin, the lining of the mouth, the lining of the blood vessels, lung alveoli and kidney tubules are all made of epithelial tissue. Various epithelial cells play an important role in regulating the exchange of materials between the body and the external environment and also between different parts of the body. An extracellular fibrous basement membrane separates epithelium from underlying tissue.

Epithelial tissue may be simple, i.e. composed of a single layer of cells, or stratified, i.e. made up of several layers of cells.

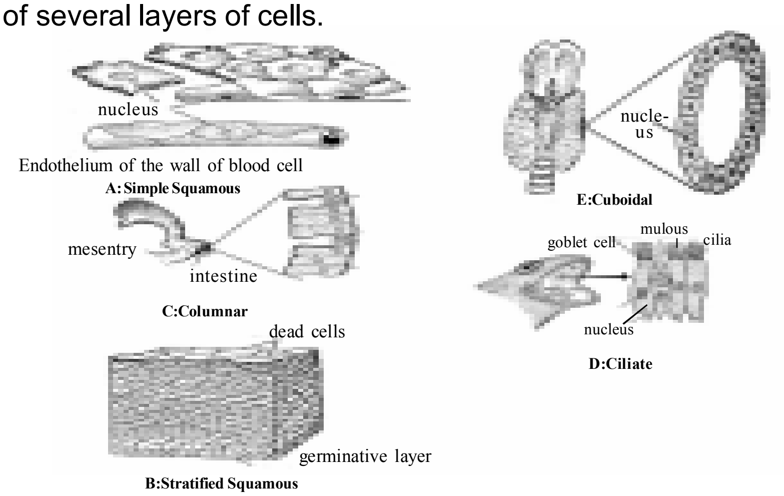


Fig. 13.11: Types of epithelial tissues

Epithelial cells form an outer layer of the skin and protect the underlying cells from drying and injury. It helps in absorption of water and nutrients and also helps in elimination of waste products.

Epithelial tissue can be classified depending on the structures and function they perform, as squamous epithelium, columnar epithelium, ciliated epithelium, cuboidal epithelium and glandular epithelium

Squamous epithelium can be further divided into two types such as simple and stratified squamous epithelium. Simple squamous epithelial cells are extremely thin, flat and irregularly shaped cells (Fig.13.11 A). It forms a delicate lining of blood vessels, and cavities found in alveoli, oesophagus, mouth etc. it forms a selectively permeable surface through which transportation of substances occur. Stratified squamous epitheliums are arranged in patterns of layers as found in skin where epithelial cells are arranged in many layers to prevent wear and tear (Fig.13.11 B). This epithelium is highly resistant to mechanical injury and is water proof.

Columnar (meaning 'pillar-like') epithelium is tall epithelial cell having nucleus towards the base. It is present in the inner lining of the stomach and intestine, where absorption and secretion occur. It facilitates movement across the epithelial barrier.

Certain columnar epithelial tissue has cilia, which are hair-like projections on the outer surfaces of epithelial cells. Such type epithelium is ciliated columnar epithelium (Fig.13.11 D). It is found in the respiratory tract. The movement of cilia pushes the solid particles (e.g. mucus) forward to clear it.

Cuboidal epithelium consists of the cube – like (cubical) cells (Fig.13.11 E). It is found in the lining of kidney tubules and ducts of salivary glands, where it provides mechanical support. It also helps in the absorption, excretion and secretion.

Epithelial cells often acquire additional specialization as gland cells, which can secrete substances at the epithelial tissue folds inward, and a multicellular gland is formed. This is glandular epithelium.

13.3.2 CONNECTIVE TISSUE

The cells of connective tissues are widely separated from one another, with a large amount of intercellular substances between them (Fig.13.12). The intercellular substances are the matrix which may be jelly like, fluid, dense or rigid. The nature of matrix will be different depending on the function of the particular connective tissue.

Take a drop of blood on a slide and observe different cells present in it under a microscope and compare them with Fig.13.12.A.

Blood is a fluid connective tissue. It has a fluid or liquid matrix called plasma. The plasma contains blood corpuscles or cells such as red blood cells (RBCs), white blood cells (WBCs) and platelets. It contains proteins, salt and hormones. Blood flows and transports gases, digested food, hormones and waste materials to different parts of the body. Different blood cells perform different functions such as, RBCs carry oxygen to the tissues for oxidation, WBCs fight diseases and platelets help in clotting of blood.

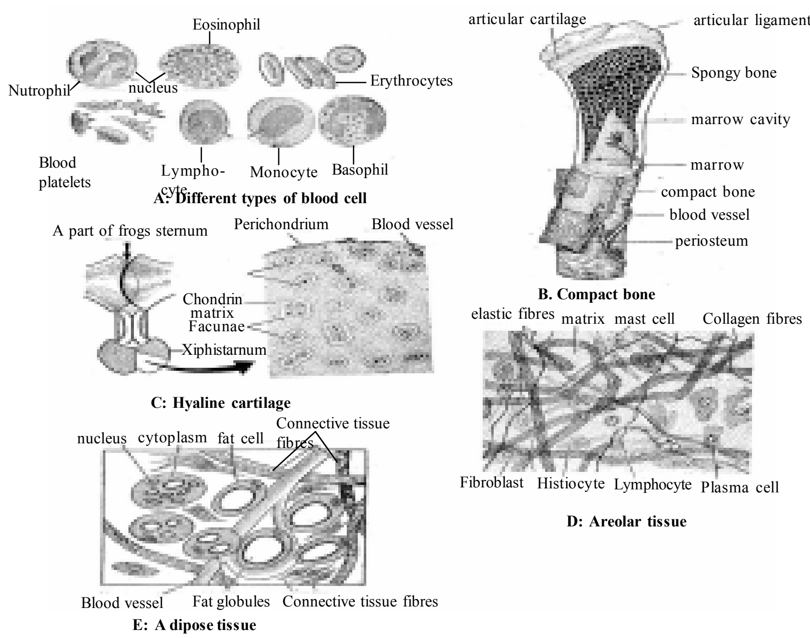


Fig.13.12: Different types of connective tissue

Bone is a connective tissue that provides shape and support to the body. It also protects the main organs of the body and anchors the muscles. It is a strong and nonflexible tissue. Bone cells are embedded in a hard matrix that is composed of calcium and phosphorus compounds that are responsible for its hardness.

Ligament is also a connective tissue that connects bones to bones. This tissue is highly elastic and has considerable strength but contains very little matrix. Tendons are also another connective tissue that connects muscles to bones. They are fibrous and inelastic tissue with great strength but its flexibility is limited.

Another type of connective tissue is cartilage. It has widely spaced cells. The solid matrix is composed of proteins and sugars. It provides support and flexibility to the body parts. It makes bone surfaces smooth at joints. It is present in the nose, ear, trachea and larynx. The cartilage of the ears can be folded, but the bones in our arms cannot be bended.

Areolar connective tissue is a loose tissue found between the skin and muscles, around blood vessels and nerves and in the bone marrow. It fills the space inside the organs, supports internal organs and helps in repair of tissues after injury.

Adipose tissue is a type of loose connective tissue that is specialised to store fats. It is found below the skin and between internal organs. The cells of this tissue are filled with fat globules. Storage of fats also lets it act as an insulator and reduces the loss of heat from body.

13.3.3 MUSCULAR TISSUE

Muscular tissues are made of muscles cells. Muscles cells are elongated and large-sized. They are also called muscles fibres (Fig.13.12). Muscles contain special proteins called contractile proteins, which is responsible for movement in our body by contracting and relaxing.

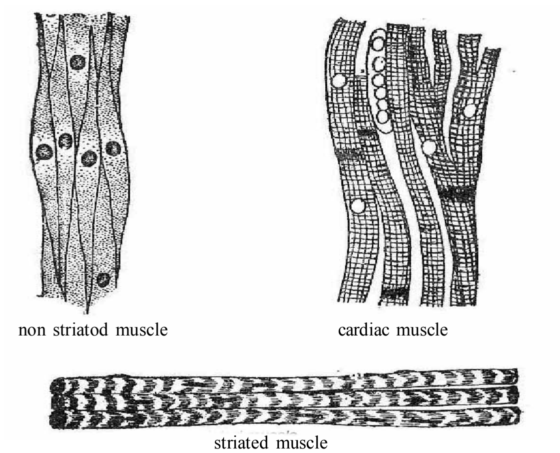


Fig.13.13: Different types of muscle fibres

There are three types of muscles fibres depending on their location, structure and function they perform: **striated muscles**, **smooth muscles**, **cardiac muscles**

Striated muscles show alternate light and dark bands or striations. The cells of this tissue are long, cylindrical, unbranched and multinucleate (having many nuclei). Striated muscles are also known as voluntary muscles. Since we can move muscles present in our limbs when we want them to, and stop when we so decide. These muscles are also called skeletal muscles since they are mostly attached to bones and are responsible for body movement.

Smooth muscles do not move at our will so they are also called as **involuntary muscles** like the movement of food in alimentary canal or the contraction and relaxation of blood vessels. Smooth muscles control such movements. The cells are long with pointed ends (spindle-shaped) and uninucleate (having a single nucleus). They are also found in the iris of the eye, in ureters and in the bronchi of the lungs. They are also called unstriated muscles because they do not bear any bands, stripes or striation across the muscles.

Cardiac muscles are involuntary, striated and nonfatigued fibres. They are cylindrical, branched and uninucleate. The muscles of the heart show rhythmic contraction and relaxation throughout life. The contraction and relaxation of the heart muscles help to pump and distribute blood to various parts of the body.

Now, you can compare the structures of different types of muscular tissues and note their shape, number of nuclei and position of nuclei within the cell.

13.3.4 NERVOUS TISSUE

Cells of the nervous tissue are the most highly specialised cells for being stimulated and then transmitting the stimulus very rapidly from one place to another within the body. The brain, spinal cord and nerves are all composed of the nervous tissue. Nerve cells or neurons are the highly specialised cells present in the nervous tissue (Fig.13.13). A neuron consists of a cell body, dendrites and axon. A cell body or cyton contains a nucleus and cytoplasm. Dendrites are long thin hair-like parts arising from cell body. Axon is a single long part. An individual nerve cell may be up to a metre long.

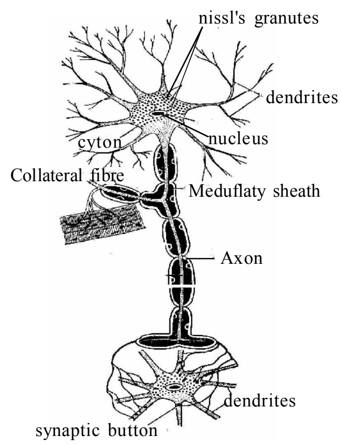


Fig.13.14: A neuron cell in the nervous tissue.

The functional combination of nerve and muscle tissue is fundamental to most animals as this combination enables animals to move rapidly in response to stimuli.

Try to answer the questions

1. What are the four main types of animal tissues?
2. Name the tissue responsible for movement in our body.
3. Name the type of epithelial tissue present in the inner lining of stomach and intestine.
4. What is the function of WBC?
5. What are the functions of areolar tissues?
6. What does the neuron look like?

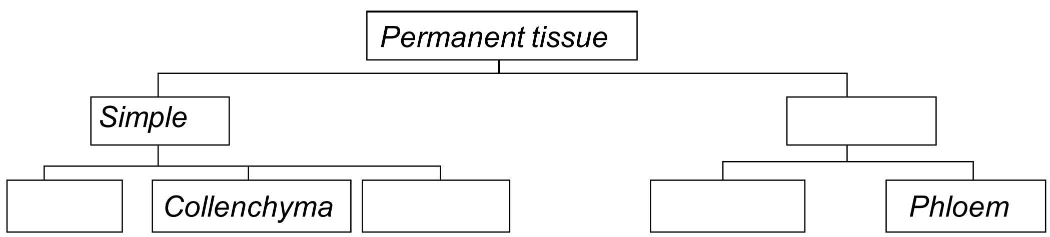
POINTS TO REMEMBER

* Tissue is a group of cells similar in structure and function.
* Plant tissues are of two main types – meristematic and permanent.
* Meristematic tissue is the dividing tissue present at the growing regions of the plant. They are meant for growth of an organ.
* Permanent tissues are derived from meristematic tissue till they lose the ability to divide. They are classified as simple and complex tissue.
* Three types of simple tissues are parenchyma, collenchyma and sclerenchyma. Xylem and phloem are types of complex tissues.
* Animal tissues can be epithelial, connective, muscular and nervous tissue.
* Epithelial tissue is classified as squamous, cuboidal, columnar, ciliated and glandular, depending on shape and function
* The different types of connective tissues in our body include blood, bone, tendon, ligament, cartilage, areolar tissue and adipose tissues.
* Striated, unstriated and cardiac are three types of muscle tissues. They perform movement by contraction and relaxation.
* Nervous tissue is made of neurons that receive and conduct impulses.
* An impulse is the passage of electrical activity along the axon of a nerve cell.

EXERCISES

1. *Define tissue.*
2. *What is the utility of tissues in multicellular organisms?*
3. *Name types of simple tissue.*
4. *Where is apical meristem found?*
5. *Which tissue makes up the husk of coconut?*
6. *What are the constituents of phloem?*
7. *What are the elements that make up the xylem tissue?*
8. *Differentiate simple tissue and complex tissue of plants.*
9. *Differentiate between parenchyma, collenchyma and sclerenchyma on the basis of their cell walls.*
10. *What are the stomata and what are the functions of stomata?*
11. *Name the tissue responsible for movement in our body.*
12. *What does a neuron look like?*
13. *Give three features of cardiac muscles.*
14. *What are the functions of areolar tissue?*

15. *Diagrammatically show the difference between the three types of muscle fibres.*
16. *What is the specific function of the cardiac muscle?*
17. *Differentiate between striated, unstriated and cardiac muscles on the basis of their structures and site/ location in the body.*
18. *Draw a labelled diagram of a neuron.*
19. *Name the following.*
    a. Tissue that forms the inner lining of our mouth.
    b. Tissue that connects muscle to bone in humans.
    c. Plant tissue that transports food.
    d. Tissue that stores fat in our body.
    e. Connective tissue with a fluid matrix.
    f. Tissue present in the brain.
20. *Identify the type of tissue in the following: skin, bark of tree, bone, lining of kidney tubule, vascular bundle.*
21. *Name the regions in which parenchyma tissue is present.*
22. *What is the role of epidermis in plants?*
23. *How does the cork act as a protective tissue?*
24. *Complete the table:*



CHAPTER — 14

Biological Diversity

Biological diversity is the variation of life forms, including plants and animals, occurring within a given ecosystem, locality or on the entire Earth. It is often used as a measure of the health of biological systems. The word **biodiversity** is considered more popular and effective in terms of communication than *biological diversity.* It is generally used to equate to a concern for the natural environment and nature conservation. The term "natural heritage" is also used to mean the biodiversity, though it is a less scientific term, but more easily understood by the people interested in conservation.

The most straightforward definition of biodiversity is "variation of life at all levels of biological organization". Biodiversity is also a measure of the relative diversity among organisms present in different ecosystems. "Diversity" in this definition includes diversity within a species and among species, and comparative diversity among ecosystems. Ecologists often used to define biodiversity as the "totality of genes, species, and ecosystems of a region"

The 1992 United Nations Earth Summit in Rio de Janeiro defined "biodiversity" as "the variability among living organisms from all sources, including, '*inter alia*', terrestrial, marine, and other aquatic ecosystems. It is the definition adopted by the United Nations

Convention on Biological Diversity.

The **Convention on Biological Diversity**, known informally as the **Biodiversity Convention**, is an international treaty that was adopted in Nairobi on 22 May 1992. The Convention has three main goals, viz. 1. conservation of biological diversity (or biodiversity); 2. sustainable use of its components; and 3. fair and equitable sharing of benefits arising from genetic resources. In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document regarding sustainable development. The Convention was opened for signature at the **Earth Summit** in Rio de Janeiro in Argentina on 5 June 1992 and entered into force on 29 December 1993.

Robert. M. May of the Oxford University, in his article ' *How many species are there on earth?*' published in *Science* in 1988 stated that the number of species living on the earth could be in the range 10 million to 50 million. Out of this, the total number of species actually named and recorded is only around 1.5 million.

Biodiversity is generally equated to the taxonomic richness of a geographic area. Hence, a thorough knowledge of the diverse taxonomic variability of plants and animals, etc of a place is a pre-requisite before taking up steps for conservation of its flora and fauna. Thus, in this chapter, let us look into the different aspects of taxonomic classification of the various forms of life occurring on our earth.

14.1 Basic issues in scientific naming of plants and animals

Whenever we come across an unknown new organism, whether plant or animal, the first thing we usually do is trying to identify that organism as to which group or kind of organisms it belongs. Once identified, the next thing that we have to do is to find a name for the organism.

The first step of finding out to which group the unknown organism belongs is known as **identification.** The second step of giving a name to the newly discovered and identified organism is known as **naming**. However, giving a name to a new organism is no easy task. One has to follow a system of rules and regulations according to which a new name for a new organism can be proposed. **Nomenclature** is a term that refers to a system for naming organisms. In biology the system is said to be "binominal" (earlier spelled 'binomial') which means that two names are used to specifically identify every organism.

14.2 Binominal system of nomenclature

The binominal system of nomenclature was introduced by Carolus Linnaeus in 1758. According to this system, a scientific name of a species of organism should made up of two Latin or Latinized words. The first word represents the genus to which the organism belongs (**generic name**). The second word is the name of the species of organism (**specific name**). The genus name should always begin with a capital letter while the specific name should never begin with a capital letter. When printed, two words are to be **italicized**, and when handwritten, they should be **underlined** separately. The specific name may be formed by Latinizing the name of a revered person, name of a locality, colour, etc.

14.3 Hierarchy of classification

A hierarchy is a systematic framework for biological classification in which taxonomic groups are arranged in an ascending series of levels with ever-increasing inclusiveness. It was first introduced by Linnaeus in 1758. Hence, it is also known as **Linnaean hierarchy**.

The present hierarchy of classification has six basic levels or categories, as follows-

Phylum (for animals) and **Division** (for plants)
Class
Order
Family
Genus
Species

Phylum is the highest taxonomic category under a **Kingdom**. The botanical counterpart of a phylum is **Division**. A phylum includes animals which possess a common characteristic feature. For example, Phylum **Chordata** includes all animals with a notochord. In the same way, Division **Thallophyta** includes plants that do not have a well-differentiated body design with roots, stems and leaves.

Class is the taxonomic category between Phylum and Order. A class is a large group of organisms, who share certain common characteristics. For example, Class **Mammalia** includes warm-blooded animals with fur or hair, mammary glands, etc. Similarly, Class **Insecta** includes all insects, which possess three pairs of jointed legs and their body is divisible into three parts, viz. head, thorax and abdomen.

Order is a taxonomic category between Class and Family. An **order** is a subgroup under a class, which is divided based on the presence of certain characters. Order Lepidoptera (butterflies and moths) under class Insecta, for example, are characterized by minute scales on their wings, a soft-bodied herbivorous larval form (caterpillar), mouthparts in the adult specialized for feeding on nectar, an order liquid foods, etc.

Family is a taxonomic category between Order and Genus. A family is a group of organisms among which the differences are quite minor, e.g. Equiidae, which includes horses and their relatives.

Genus is the category between Family and Species. Only very closely related species are grouped together in a single genus. The genus is just like the surname of a person, whereas the species is the first name. So *Canis lupus*, the wolf, is distinguished from *Canis familiaris*, the domesticated dog. Although very similar they are still distinct species, but belong to the same genus.

Species is the basic taxonomic unit used to define a definite **kind** of living organism. Any two individuals are said to belong to the same species if they are able to interbreed and produce fertile offsprings.

Taxonomic classification of man

Phylum	**Chordata**
Class	**Mammalia**
Order	**Primates**
Family	**Hominidae**
Genus	***Homo***
Species	***Homo sapiens***

Activity 14.1 : Write down the taxonomic classification of man.

14.4 Basis of classification

Classification is the ordering of animals into groups on the basis of their relationships.

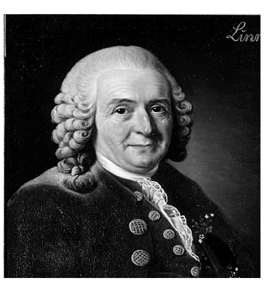


Fig.14.1: Carolus Linnaeus (1707-78)

Taxonomy is that branch of biology dealing with the classification and naming of organisms. The ancient Greek philosopher **Aristotle** was the first to classify animals on the basis of their way of living, actions, habits and body parts. His great contributions to biology earned him the title "father of biological classification". British naturalist **John Ray** was credited with revising the concept of naming and describing organisms. He introduced the term "species" as a reproducing unit. During the 1700s, Swedish botanist **Carolus Linnaeus** Fig.14.1. classified all the then known organisms into two large groups namely Kingdoms **Plantae** and

Animalia. Most of the principles of taxonomy that we are presently following were introduced by Linnaeus. Hence, he is aptly called as the “father of taxonomy”. The two kingdom system of biological classification introduced by Linnaeus was later found insufficient. **Robert H Whittaker** in 1969 proposed five kingdoms namely **Plantae, Animalia, Fungi, Protista,** and **Monera**. Other schemes involving an even greater number of kingdoms have lately been proposed, however most biologists employ Whittaker’s five kingdom system.

14.4.1 Two-Kingdom Classification of Linnaeus

The **Two-kingdom classification** was proposed by Carolus Linnaeus in 1758. It was one of the earliest schemes of natural system of classification. According to this system, all the living organisms may be grouped into two kingdoms, viz. **Kingdom Plantae** and **Kingdom Animalia**. It means that a living organism can be either a plant or an animal. However, the two-kingdom classification had many drawbacks. For example, there are organisms which may be placed in both the kingdoms, and also there are organisms that cannot be placed in both the two kingdoms. The followers of the two kingdom system were not able to find a proper place for fungi, which are not neither green in colour nor had roots and leaves like a plant. Another problem was that of *Euglena,* a microscopic organism with chlorophyll, like a plant but having muscle fibres like an animal. Moreover, bacteria with prokaryotic cells were placed together with higher plants with eukaryotic cells. Single –celled microscopic protozoans are grouped together with multicellular massive animals like whales, elephants, etc.

14.4.2 Five Kingdom Classification of Whittaker

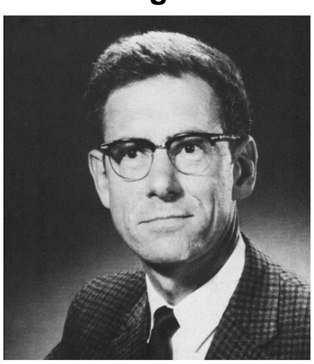


Fig.14.2: Robert H. Whittaker (1920-1980)

American ecologist Robert H. Whittaker (Fig.14.2) in 1969 created the five-kingdom classification that accounted for prokaryote and eukaryote distinctions. In this system, all prokaryotes were placed in the kingdom **Monera**. The remaining eukaryotes were separated by differences mostly in structure. Plants and animals were easily separated into their own kingdoms, **Plantae** and **Animalia**. It was decided that because fungi were neither plant nor animal and subsisted by decaying or decomposing organic matter, they should be placed in their own kingdom **Fungi**. Everything else was clumped into the kingdom **Protista**. The protists included all eukaryotes that did not clearly fit into the kingdom Plantae, Animalia and Fungi.

Advantages of the five kingdom system

The advantage of the five kingdom classification system is that there is far less overlap and confusion as compared to the original two kingdom classification system as proposed originally by Linnaeus. While placing organisms in any one of the five kingdoms, the following three characteristic features are considered:

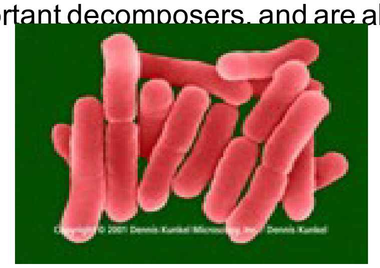
1. The kind of cells that make up the organism.
2. The number of cells that make up the organism.
3. The method by which the organism obtains food.

The five kingdoms used in the system are

1. Kingdom Monera,
2. Kingdom Protista,
3. Kingdom Fungi,
4. Kingdom Plantae, and
5. Kingdom Animalia.

14.4.3 Kingdom Monera (About 10,000 known species)

Kingdom Monera includes all the prokaryotic organisms including bacteria, cyanobacteria, etc. (Fig.14.3). This group of living organisms does not have any internal membranous organelles such as a nucleus, Golgi apparatus, endoplasmic reticulum, etc. They do have a nucleoid region containing a chromosome organized into a circle, and they also have ribosomes for protein synthesis. Some forms are responsible for causing disease in humans. Most are important decomposers, and are also important in the recycling of nutrients.



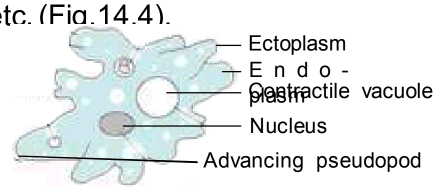
Bacteria

Cynobacteria (*Anabaena*)

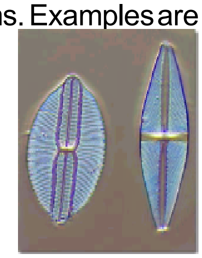
Fig.14.3: Examples of Monera

14.4.4 Kingdom Protista (About 250,000 known species)

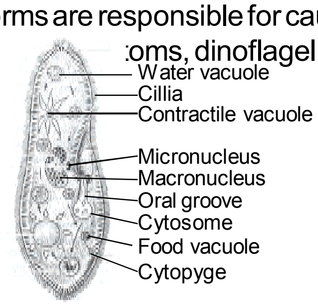
Members of the Kingdom Protista are generally unicellular, eukaryotic organisms, although some multicellular forms are also included. Some forms are responsible for causing disease in humans and other organisms. Examples are proto: :oms, dinoflagellates, etc. (Fig.14.4).



Amoeba



Diatoms



Paramecium

Fig.14.4: Examples of Protista

14.4.5 Kingdom Fungi (About 100,000 known species)

The organisms included in the Kingdom Fungi are eukaryotic, heterotrophic organisms that mainly serve as decomposers, important to the recycling of materials. Some forms are responsible for causing disease in plants and animals including humans. Their cell walls are made up of cellulose and chitin. Reserved carbohydrates stored in their cells are glycogen. Examples include molds, *Agaricus*, *Penicillium*, *Rhizopus*, yeasts, mushrooms, rusts, smuts, etc. (Fig.14.5).

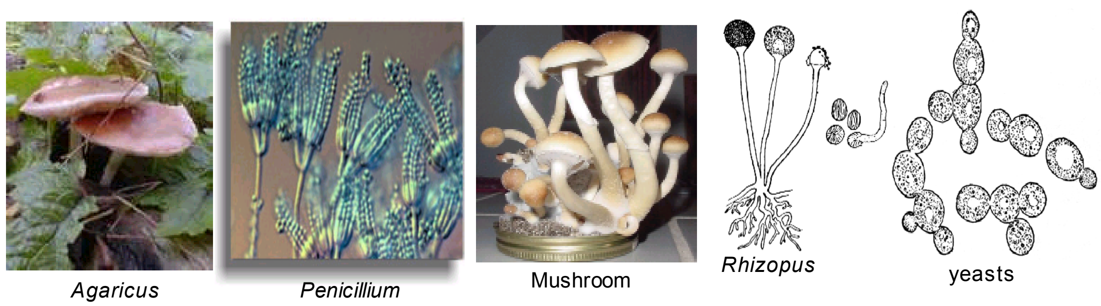


Fig.14.5: Examples of fungi

14.4.6 Kingdom Plantae (About 100,000 known species)

Kingdom Plantae includes the 'plants', which are multicellular, eukaryotic, **photosynthetic** and autotrophic organisms that form the basis of the food web in terrestrial ecosystems. Examples include mosses, liverworts, ferns, conifers and flowering plants.

14.4.7 Kingdom Animalia (About 1,000,000 known species)

Kingdom Animalia includes the animals of this world and represents the largest of the five kingdoms. Animals are multicellular, eukaryotic, heterotrophic organisms. Animals generally have the greatest degree of system development since they generally have senses for detecting food and mobility to capture it. Animals represents all the consumer levels of the food web in any ecosystem. Their wastes and dead bodies, however, are consumed by fungi and bacteria.

14.5 PLANTAE

14.5.1 Thallophyta

Thallophyta includes autotrophic plants without true roots, stems or leaves. The plant body is known as a **thallus**. Their zygote does not develop into multicellular embryo within the female reproductive structures. They are typically nonvascular without a water-conducting system of cells (i.e. without xylem tissue). The thallus ranges from microscopic, unicellular forms in *Chlamydomonas,* diatoms*,* dinnoflagellates (*Ceratium*) etc, filamentous in *Spirogyra, Ulothrix* and to the giant macroscopic seaweeds (*Laminaria*), *Fucus* etc. (Fig.14.6).

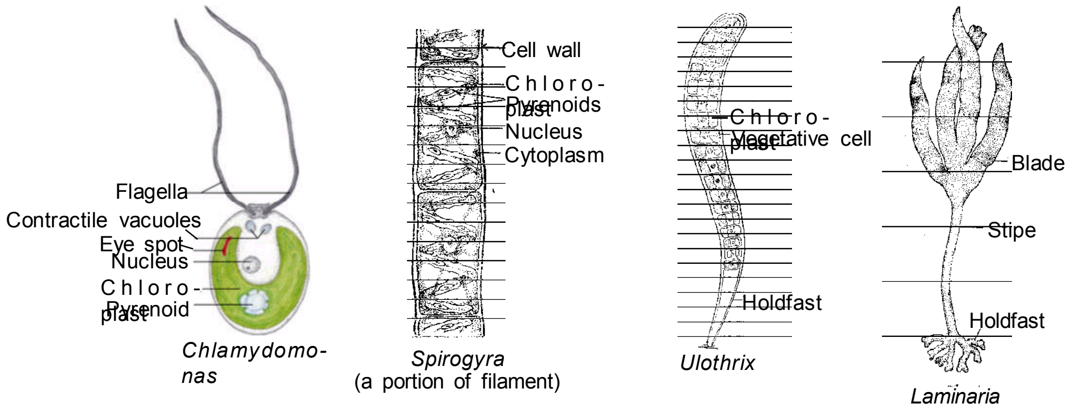


Fig.14.6: Examples of Thallophyta (algae)

14.5.2 Bryophyta

Division Bryophyta (Greek *Bryon* = moss; *phyton* = plant) includes mosses and liverworts, which are plants more advanced than algae but more primitive than pteridophytes. They are very small and inconspicuous plants found in humid and shady places. Their vegetative structures are adapted for terrestrial life. But, their male reproductive structures require water for movement. Hence, bryophytes are also known as amphibians of the plant kingdom. During rainy season they form a green carpet on damp surfaces of soil, walls, rocks or barks of trees.

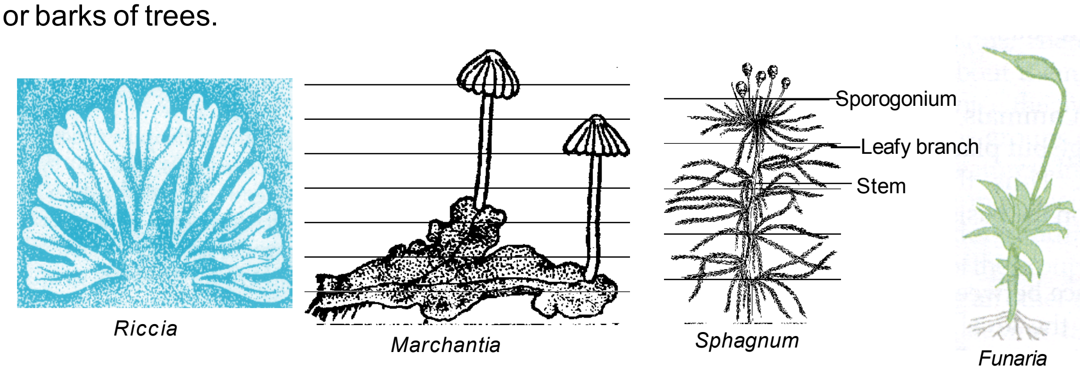


Fig. 14.7: Examples of Bryophytes

In liverworts (*Riccia, Marchantia*), the plant body or thallus is flat, green, lobed or forked. They remain attached to the substratum by thin rhizoids. But, in mosses (*Sphagnum, Funaria*), the plant body consists of an erect, branched, stem-like structure which bears leaf-like outgrowths. The lateral branches are fully covered with the leaf-like structures. The mosses also attach themselves to the substratum by thin root-like rhizoids (Fig.14.7).

14.5.3 Pteridophyta (Greek. *Pteridos*-fern; *Phyton*-plant)

Pteridophytes or ferns are seedless vascular plants. Their reproductive structures are called **sporangia** which are born in clusters on spots called **sori** on the underside of leaves or **fronds**. The fronds arise from subterranean, creeping **rhizomes** and from trunks of tree-like forms (called tree ferns). Examples are water ferns such as *Azolla* and *Salvinia*, clover-leaf fern such as Marsilea, Horsetail (*Equisetum*), common Indian fern (*Dryopteris*) etc. (Fig.14.8).

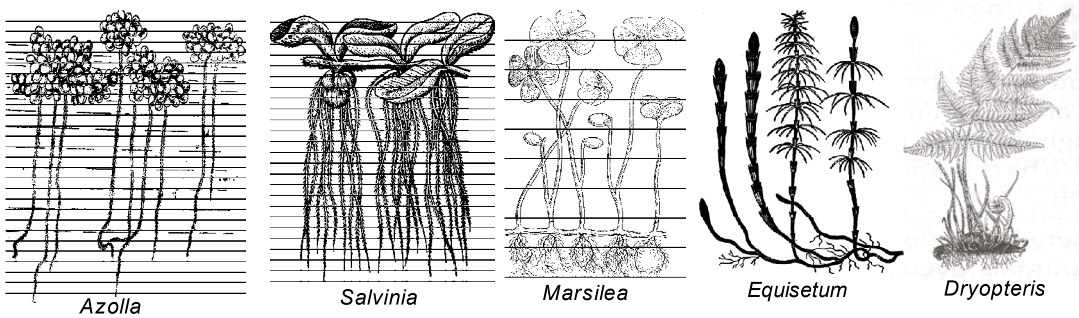


Fig.14.8: Some examples of Pteridophytes

14.5.4 Spermatophyta (Greek. *Sperma*-seed; *Phyton*-plant)

Division Spermatophyta (also known as **phanerogams**) comprises the seed-bearing plants. Seed-bearing plants may be further divided into **Gymnosperms** and **Angiosperms**. Gymnosperms are Tracheophytes with naked seeds. Angiosperms are flowering plants which bear their seeds enclosed within ripened ovary (fruit).

14.5.5 Gymnosperms

Gymnosperms are divided into the following divisions:

Division Cycadophyta (Cycads)
Division Ginkgophyta (Maidenhair Tree)
Division Gnetophyta (*Gnetum* & *Welwitschia*)
Division Coniferophyta (Cone-Bearing Trees & Shrubs)

14.5.5 (i) Cycadophyta (Cycads)

These are palm-like plants with large seed and pollen cones. They flourished during the days of the dinosaurs and undoubtedly were a major food supply for herbivorous dinosaurs. The cycads were so numerous in Mesozoic times that this era is often called the Age of Cycads and Dinosaurs. Cycads are dioecious species with pollen cones and seed cones produced on separate male and female individuals. In some species, the enormous pollen and seed cones may reach 3 feet in length and may weigh up to 90 pounds, the largest of all living cone-bearing plants. Examples : *Cycas* (**Yendang**) (Fig.14.9).

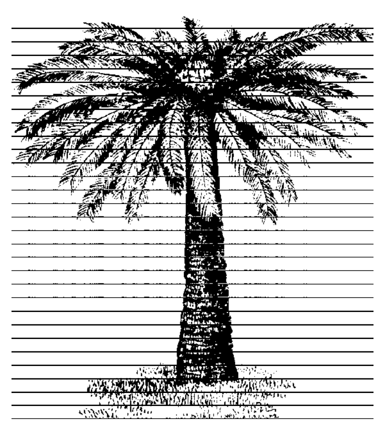


Fig. 14.9 : A Cycas plant

14.5.5(ii) Ginkgophyta (Maidenhair Tree)

The Gingkophytes are medium-sized dioecious trees with tall and branched stems. The leaves are similar in shape to the maidenhair fern (*Adiantum*). Reproductive structures, namely pollen sacs and ovules, are borne on dwarf shoots known as **strobili** (Singular strobilus). Seeds are borne in pairs. Division Gingkophyta has only one living representative ***Ginkgo biloba***. It is a true living fossil dating back 185 million years (Fig.14.10).

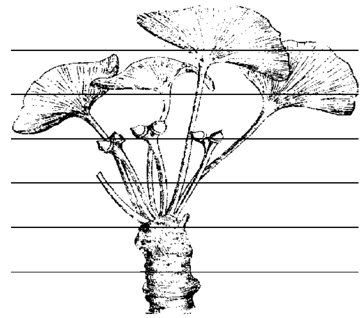
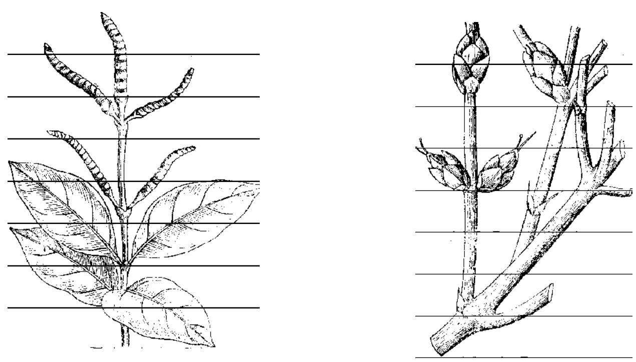


Fig. 14.10 : A twig of Ginko biloba

The seeds of *Gingko* are edible. An essential oil is also obtained from the seeds. The timber is used for making poles, furniture, building materials, etc.

14.5.5(iii) Gnetophyta (Gnetum & Welwitschia)

Division Gnetophyta is a remarkable plant division including *Ephedra, Gnetum* and *Welwitschia*. The stems of *Ephedra* are jointed with small scale-like leaves at the nodes. The bizarre, shredded, wind-blown leaves of Welwitschia arise from a woody caudex on the desert floor. In general habit *Gnetum* looks like an angiospermic plant. This division includes species with vessels and other characteristics typically found in flowering plants (Fig.14.11).



A twig of *Gnetum*

A twig of *Ephedra*

Fig. 14.11: Examples of Gnetophyta

14.5.5(iv) Coniferophyta (Cone-Bearing Trees & Shrubs)

Member of this division are commonly known as **conifers**. Conifers constitute dominant forest vegetation in temperate parts of the world and regions of high altitude. In India, conifers are mainly confined in the Himalayas and adjoining areas. Most are trees, while some are shrubby species. The stem is much branched.Reproductive structures are borne on cones or strobili. Seeds are borne on the surface of woody scales, the overlapping scales forming a cone. Important examples include pine (*Pinus*), fir (*Abies*), spruce (*Picea*), hemlock (*Tsuga*), larch (*Larix*), juniper (*Juniperus*), cypress (*Cupressus*), Yew (*Taxus*).etc. Conifers also include the tallest (redwood tree) and most massive (giant sequoia tree) living organisms. Some species (especially pines) require fire for seed germination and regeneration. Some are common ornamental plants eg. *Thuja*, *Araucaria* etc. (Fig.14.12).

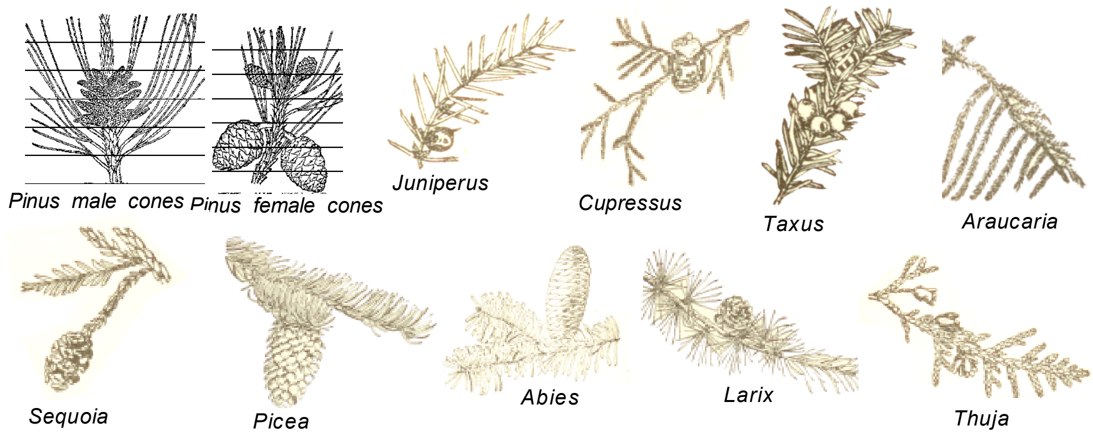


Fig.14.12 : Some examples of Coniferophyta

14.5.6 Angiosperms

Angiosperms are represented by the Division Anthophyta or flowering plants.

Division Anthophyta includes the flowering plants, a large group including many familiar plants in a wide variety of habitats. They form the largest group in the plant kingdom. More than 90% of all plants on earth are angiosperms. There are over 250,000 species in this group. They are found almost everywhere in every possible type of habitat and climate.

Anthophytes may be annual, biennial or perennial herbs, shrubs, trees, climbers, twiners and lianes. They may be as minute as a pin head, e. g. *Wolffia microscopica.* On the other hand, they may be as massive as a 300 feet high tree e.g. *Eucalyptus regnans.*

In flowering plants, the ovules are borne in the closed sporophyll known as the **carpel**. The microsporophyll and megasporophyll are arranged in flowers which may be unisexual or bisexual . The pollen grains are received on the stigma of carpel. Fertilization takes place through formation of pollen tubes.

Flowering plants provide us cereals, pulses, vegetables, fruits, fibres, timbers, gums, resins, tannins, dyes, spices, sugar, starch, condiments, rubber, paper, medicines, tea, coffee, tobacco, fats, oils and several other useful products.

Flowering plants are divided into two groups (classes), as follows:

14.5.6(i) Monocotyledoneae (Monocots)

Monocots have the following features:

1. One cotyledon inside seed;
2. Parallel leaf venation;
3. Flower parts in 3's or multiple of 3's;
4. They include *Lilium*, *Amaryllis*, *Iris*, *Agave*, *Yucca*, orchids (*Vanda*), duckweeds, grasses, maize (*Zea mays*), rice (*Oryza sativa*), wheat (*Triticum aestivum*), palms, etc. (Fig.14.13).

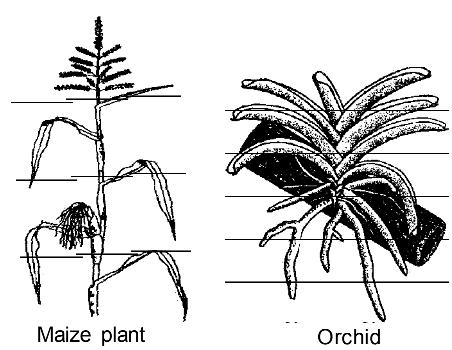


Fig.14.13 : Some examples of monocot plants

Class Dicotyledoneae (Dicots)

Dicots have the following features:

1. Two cotyledons inside seed;
2. Branched or net-like leaf venation;
3. Flower parts in 4's or 5's;
4. They include most species of flowering herbs, shrubs and trees (Fig.14.14).

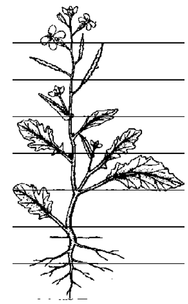


Fig.14.14 : A Dicot plant (Mustard)

14.6 ANIMALIA

14.6.1 Porifera (Sponges)

Phylum Porifera includes sponges, which are simple multicellular aquatic animals that remain fixed to a rock or substratum under water. Most of them are marine, but some species live in fresh water. The cylindrical, globose or irregular bodies of sponges are radially symmetrical. Their body wall is supported by an internal skeleton of minute **spicules** made of calcium carbonate, silica, or a fibrous collagen protein called **spongin**. The body wall is perforated by numerous pores called **ostia** that connect to internal canals and chambers lined by flagellated collar cells called **choanocytes**. Sponges are filter-feeders, taking in microscopic plankton brought in by miniature currents created by the choanocytes.

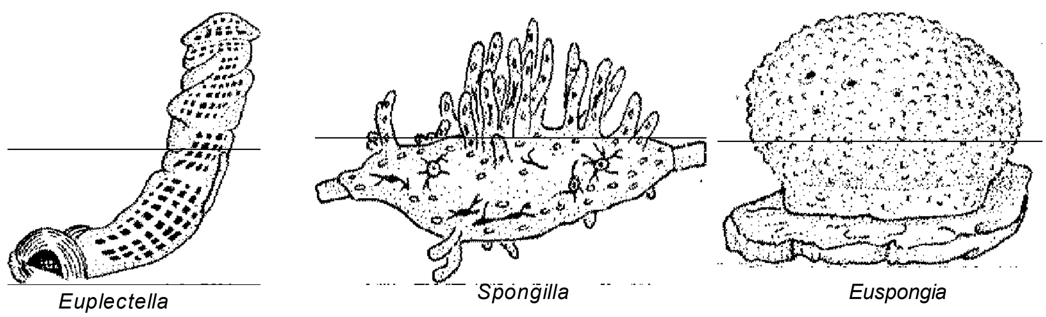


Fig.14.15 : Examples of Porifera

Marine examples of phylum Porifera are ***Euspongia*** (bath sponge), ***Euplectella*** (Venus' flower basket), ***Chalina*** (dead man's finger), etc. ***Spongilla*** and ***Myenia*** are freshwater sponges occurring mostly in running waters (Fig.14.15).

14.6.2 Cnidaria

Phylum Cnidaria includes diverse forms of mostly marine aquatic animals. The name 'Cnidaria' comes from the Greek word "**cnidos**," which means *stinging nettle*. All these animals possess a kind of stinging cells called **nematocysts**. The nematocysts are found on elongated, arm-like structures called **tentacles**. When touched the nematocysts eject barbed threads that inject a paralyzing poison into the body of the prey.

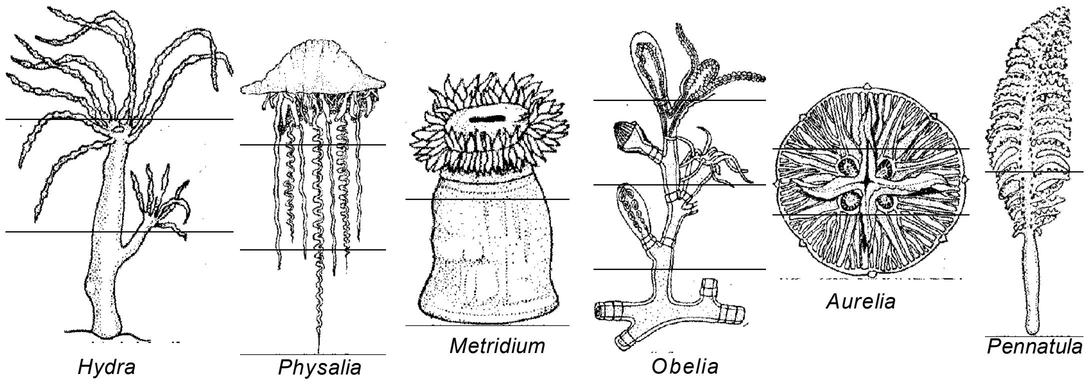


Fig.14.16: Some examples of Cnidaria

Cnidarians have a radially or bilaterally symmetrical body. The life cycle of most of them includes a sedentary or fixed generation called **polyp** and a free-swimming generation called **medusa**.

Many thousands of cnidarians live in the world's oceans, from the tropics to the poles, from the surface to the bottom. Some even burrow. A smaller number of species, for example, *Hydra*, are found in fresh water rivers and lakes.

Examples : True corals (*Tubipora*), sea anemones (*Metridium*), sea pen (*Pennatula*), Australian sea wasp (*Chironex fleckeri*), Portuguese-man-of war (*Physalia*), Obelia, Hydra, true jellyfish (*Aurelia*) (Fig.14.16).

14.6.3 Ctenophora

Phylum Ctenophora (Greek for "comb-bearers") have eight "comb-like rows" of fused *cilia* arranged along the sides of the animal. These cilia beat synchronously and propel ctenophores through the water. Some species move with a flapping motion of their lobes or undulations of the body. Many ctenophores have two long tentacles, but some do not possess any tentacle.

Ctenophores, variously known as comb jellies (*Pleurobranchia)(Fig.14.17)*, sea gooseberries, sea walnuts, or Venus's girdles (*Velamen*), are voracious predators. They share several superficial similarities with cnidarians, but they lack stinging cells. Instead, ctenophores possess sticky cells called **colloblasts** or lasso cells with which they capture their prey. In a few species, special cilia in the mouth are used for biting gelatinous prey.

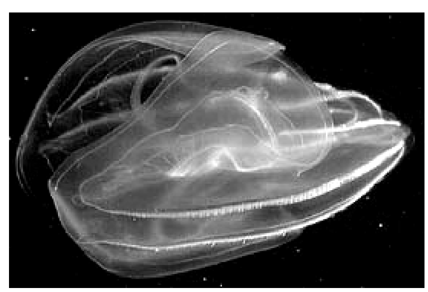


Fig.14.17 : *Pleurobranchia*

Although most ctenophores swim, one group creeps along the bottom of the seas. Most of the species are predators preying on other animals, for instance with echinoderms, sponges, or benthic cnidarians. Many of the ctenophores are *bioluminescent*, i. e. are able to give off light.

14.6.4 Platyhelminthes (Flatworms)

Phylum Platyhelminthes includes worm-like animals with dorso-ventrally flattened, leaf or ribbon-like, bilaterally symmetrical triploblastic body. Their digestive tract is branched and without an anus. Digestive system is absent in parasitic forms. Parasitic forms possess adhesive structures like hooks, spines and suckers. Their excretory organs are called flame cells. A person can get infected with tapeworm by eating poorly or ill -cooked beef or pork containing the encysted bladder worm (tapeworm cyst).

Examples : Free-living flatworms, (*Planaria*), liver flukes (*Fasciola hepatica*), tapeworms (*Taenia solium*) (Fig.14.18).

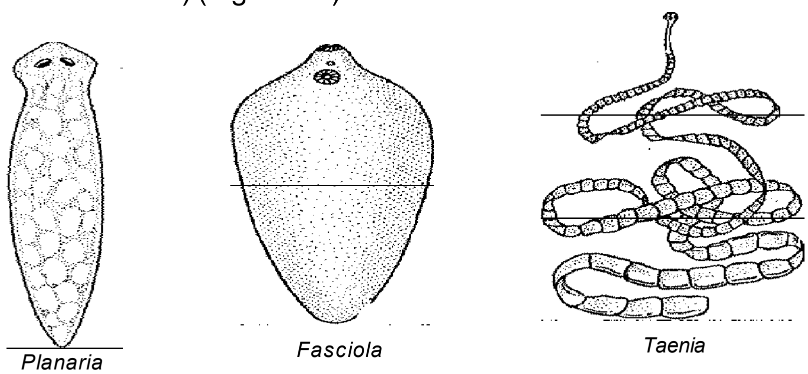


Fig.14.18 : Some examples of Platyhelminthes

14.6.5 *Nemertea (Ribbon Worms)*

Phylum Nemertea includes free-living marine worms with a distinctive eversible proboscis consisting of a long, hollow tube. They have an unsegmented body covered with cilia. Like flatworms, ribbon worms are acoelomates (without a coelom), but they do have a complete digestive system.

Example: Ribbon worm (*Lineus longissimus*) (Fig.14.19).

Fig.14.19: Lineus longissimus

14.6.6 Rotifera (Wheel animalcules)

Rotifers are common microscopic animals living in fresh water, particularly among plants and debris. They possess a rotating ciliated wheel organ called **corona** at the anterior end that resembles the head of an electric shaver, hence the name **wheel animalcule**.

Examples are *Brachionus, Philodina*, etc.(Fig.14.20).

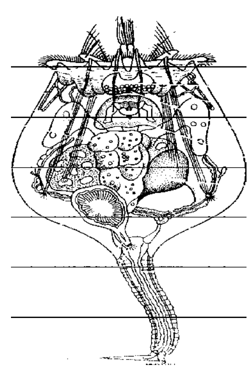


Fig.14.20 : Brachionus

14.6.7 Gastrotricha (Gastrotrichs)

Gastrotricha are microscopic (0.06-3.0 mm in body length) free-living, acoelomate, aquatic worms inhabiting the bottom of marine or freshwater habitats. In fresh waters they are a ubiquitous component of periphyton and benthos and also of the plankton. Gastrotrichs are microphagous, detritivorous, benthic community. Gastrotrichs swallow their food, which is made up of microalgae, bacteria and small protozoans, by means of the powerful sucking action of the muscular pharynx. They are preyed upon by turbellarians. The phylum is cosmopolitan with about 690 species. Example is *Chaetonotus* (Fig.14.21).

Fig.14.21 : Chaetonotus

14.6.8 Nematomorpha (Horsehair Worms)

The adults are very long, thin, hair-like worms that are free-living in water; the immature (larval) stage is usually parasitic on insects. People once thought that dark hairs from a horse's tail at a watering hole miraculously came to life, hence they are called horsehair worms. Example is *Gordius* (Fig.14.22).

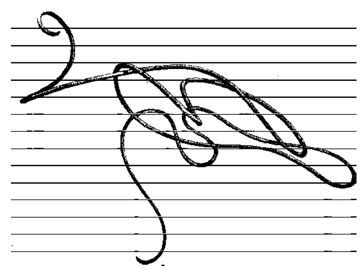


Fig.14.22 : Gordius

14.6.9 Nematoda (Nematodes)

This is a large phylum of worms, often called round worms or thread worms. Some of them are free living in soil or water, while many are parasitic forms on plants and animals. Important parasitic forms include hookworms (*Ancylostoma duodenale*), pinworms (*Enterobius*), human round worm *(Ascaris lumbricoides)* and trichinosis worm (*Trichinella spiralis*). Hookworm larvae burrow into the skin between the toes and eventually migrate into the intestines (Fig.14.23).

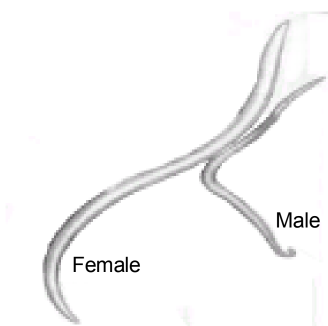


Fig.14.23: Ascaris

The disease **trichinosis** is caused by eating undercooked meat (especially pork) containing microscopic cysts of larval *Trichinella spiralis*. If ingested, the larval cysts can eventually migrate into skeletal muscle tissue. **Elephantiasis** is caused by minute filarial worms of the genus *Wuchereria* that invade lymphatic vessels; the filarial worms obstruct the flow of lymphatic fluids causing body extremities to swell to gargantuan proportions; microscopic filarial larvae causing elephantiasis are spread by blood-sucking female mosquitoes. Other dreaded parasitic worms in the phylum include the Guinea worm (*Dracunculus medinensis*) and the giant kidney worm (*Dioctophyma renale*).

14.6.10 Acanthocephala (Spiny-Headed Worms)

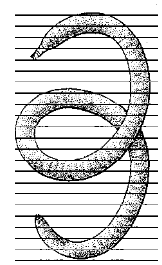


Fig. 14.24 : Echinorhynchus

This phylum includes small round worms that are intestinal parasites of vertebrates. These parasitic worms possess a proboscis at the anterior end which is covered with hooks for attachment to the wall of the intestines. Usually a crustacean or insect serves as an alternate host for young stages of its life cycle. Example is *Echinorhynchus* (Fig.14.24).

14.6.11 Bryozoa (Bryozoans)

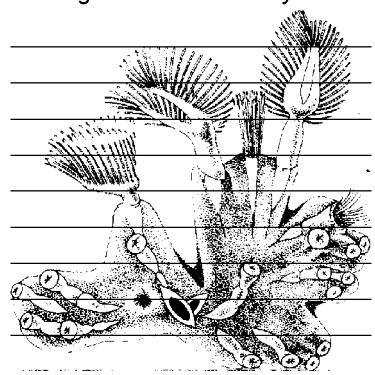


Fig.14.25 : Lophopus

Bryozoans form coral-like colonies in the ocean and fresh water. They are often called "moss animals" because of their delicate branched colonies. Each animal has a fringe of tentacles around its mouth. Freshwater bryozoans produce disc-shaped, chitinous reproductive bodies called statoblasts which are sometimes very abundant in wolffia samples. Example is *Lophopus* (Fig.14.25).

14.6.12 Tardigrada (Tardigrades)

Fig 14.26 : Macrobiotus

Tardigrades are minute creatures that live on moist mosses and lichens. They have short legs with minute claws and are sometimes called **water bears**. Like rotifers, they are able to roll up into a ball and survive long periods of desiccation, a phenomenon called **anabiosis**. Example:*Macrobiotus* (Fig.14.26).

14.6.13 Brachiopoda (Brachiopods)

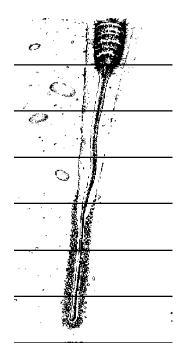


Fig.14.27 : Lingula

Brachiopods are primitive marine bivalve animals attached to rocks by a fleshy stalk. Although they superficially resemble bivalve molluscs, they are really quite different. In brachiopods, the two valves enclose the body dorsally and ventrally instead of laterally as in mollusks. The bivalve shells may be hinged (articulate) or without hinges (inarticulate). In addition, the ventral valve is usually larger than the dorsal, and is usually attached to the substratum directly or by means of a cordlike stalk . Brachiopod shells are abundant in the fossil record, dating back to the Cambrian Period (500 million years ago). There are approximately 280 species of living brachiopods.Example: *Lingula* (Fig.14.27).

14.6.14 Annelida (Segmented Worms)

Phylum Annelida includes the true worms such as earthworms, leeches, etc. They are triploblastic and bilaterally symmetrical. They have an elongated body composed of many segments. Each segment is provided with fine bristle-like **setae** for locomotion. They have a true coelom between the body wall and wall of the digestive canal. They are mostly aquatic, marine as well as freshwater. Some of them are terrestrial, burrowing or tube-living. Some of them are parasites sucking blood from vertebrate animals.

Examples : Clamworms (*Nereis*), sea mouse (*Aphrodite*), earthworms (*Pheretima, Lumbricus*), leeches (*Hirudo, Hirudinaria, Glossiphonia*), etc. (Fig.14.28).

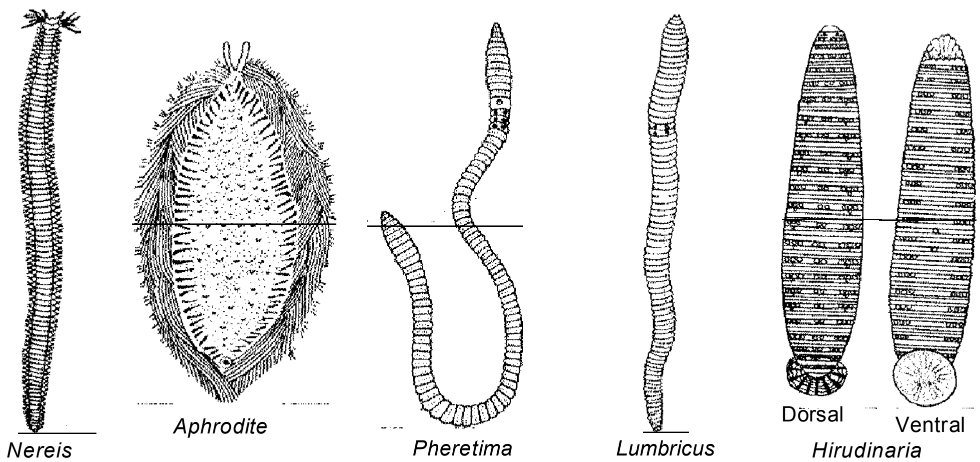


Fig.14.28 : Some examples of Annelida

14.6.15 Sipunculoidea (Peanut Worms)

Peanut worms have a slender, gourd-shaped body. The anterior end of the body is retractile, with short hollow tentacles around the mouth. Peanut worms (phylum Sipunculoidea) are named after their shape when fully contracted, which resembles a peanut pod. These interesting worms live in burrows under rocks of the intertidal zone. Example : *Sipunculus* (Fig.14.29).

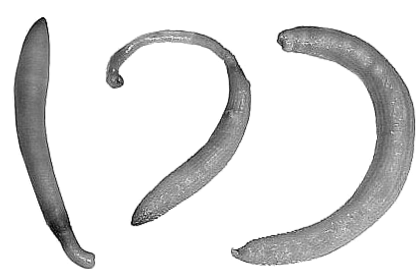


Fig.14.29 : Sipunculus

14.6.16 Arthropoda (Arthropods)

The body of arthropods is bilaterally symmetrical, triploblastic and metamerically segmented. All body parts are covered with chitinous exoskeleton. The body is usually divisible into head, thorax and abdomen; head and thorax are fused in some. All of them possess jointed legs. While growing up, the chitinous exoskeleton is shed at intervals and replaced from within by a new one. This is known as moulting.

Examples : Walking worms (*Peripatus*), shrimps and prawns (*Palaemon*), crabs (*Cancer*) barnacles (*Balanus*), ant (*Formica*), bees (*Apis*), silkworm (*Antheraea*), Housefly (*Musca*), mosquito (*Anopheles, Culex*), body louse (*Pediculus*), bedbug (*Cimex*), centipedes, (*Scolopendra*), millipedes (*Julus*), spiders (*Araenia, Tarantula*), ticks (*Ixodus*), King crab (*Limulus*), etc. (Fig.14.30).

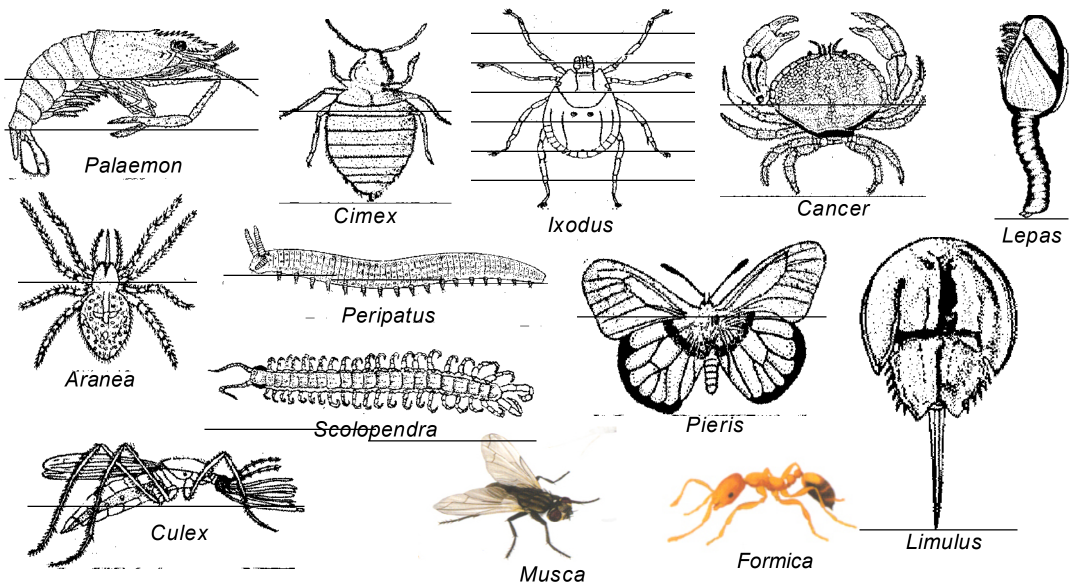


Fig.14. 30 : Some examples of Arthropoda

14.6.17 Chaetognatha (Arrow Worms)

These are small, transparent marine worms with bristles or hooks around the mouth. They have paired fins on the main body trunk and a terminal tail fin for locomotion. Although very small, they have well-developed digestive and sensory systems, and a true coelom.

Fig.14.31 : Sagitta

These planktonic marine animals are only about 5-10 mm in length, about the size of duckweeds of the genus **Wolffia**. They have a torpedo-shaped body with lateral and caudal fins that superficially resemble the feathers of an arrow. The head is covered by a rounded hood that is retracted when the arrow worm feeds. During feeding, the arrow worm captures small planktonic organisms, including copepods and other chaetognaths, using minute spines or bristles around the mouth. Example : Arrow worms (*Sagitta*)(Fig.14.31).

14.618 Mollusca (Molluscs)

In Mollusks, the body is soft with bilateral symmetry, often covered by a mantle that secretes a calcareous shell. They usually have an anterior head and a ventral muscular foot for locomotion.

Examples: Chitons (*Chiton)*, tooth shells (*Dentalium*), univalve snails & limpets, *(Pila, Vivipara, Achatina*), bivalve mussels (*Unio*, *Mytilus*), octopus & squids *(Octopus, Loligo, Sepia)*, etc. (Fig.14.32).

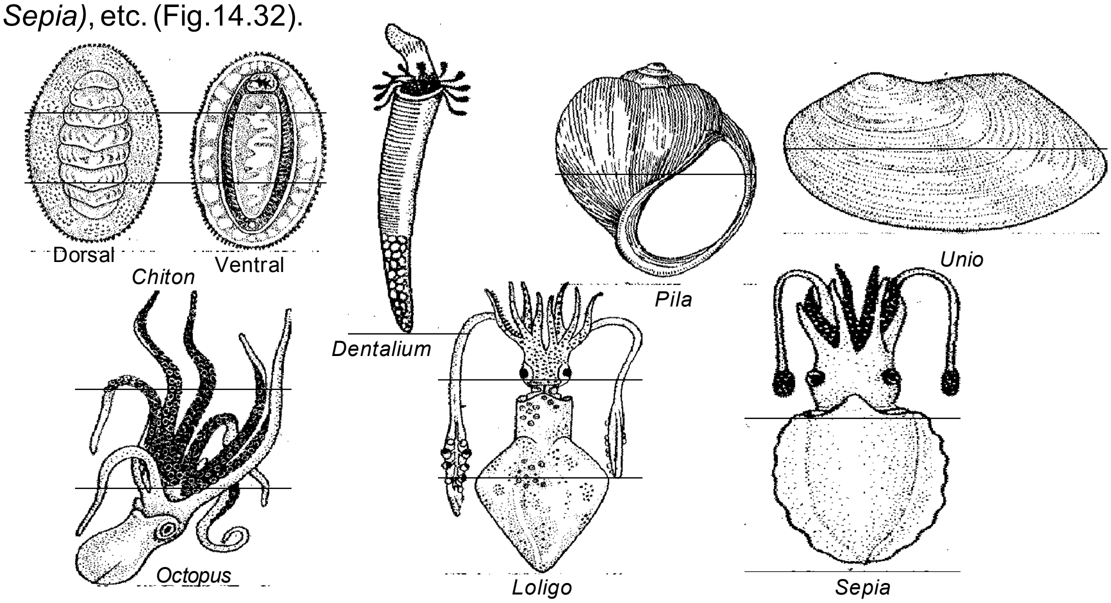


Fig.14.32 : Some examples of Mollusca

14.6.19 Echinodermata (Echinoderms)

Echinoderms have a radially symmetrical body, usually with 5 or more radiating arms. The body is distinguishable into the dorsal or **aboral** side and the ventral or **oral** side. Their body wall bears calcareous plates, often with external spines. They possess a water vascular system and external tube feet for locomotion.

Examples : Sea lilies (*Antedon)*,starfishes (*Asterias*), brittle stars (*Ophiothrix*), sea urchins (*Echinus*), sea cucumbers (*Cucumaria), etc.*(Fig.14.33).

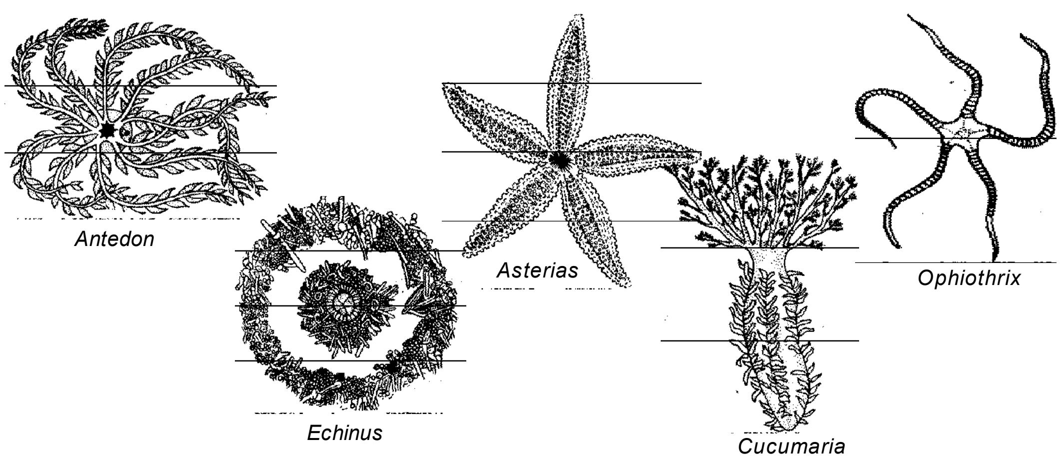


Fig.14.33 : Some examples of Echinodermata

14.6.20 Hemichordata (Acorn Worms)

Phylum Hemichordata includes a small group of marine invertebrates that were once thought to have a short **notochord**, the supportive axial rod that characterizes the phylum Chordata. Hemichordates do possess gill slits or pharyngeal clefts that are also found in chordates. Examples : *Balanoglossus* (Fig.14.34).

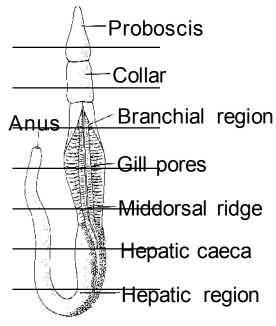


Fig.14.34 : Hemichordata (Balanoglossus)

14.6.21 Chordata (Chordates)

Phylum Chordata is characterized by the presence of (at some stage of development or throughout their life) an axial rod-like structure called **notocord** to support the body. They also possess a single dorsal **tubular nerve cord**, a series of **pharyngeal gill slits**, and a **tail** behind the anus.

Phylum Chordata is subdivided into three major subphyla:

1. Subphylum **Urochordata** includes primitive chordates known collectively as tunicates e.g. *Ascidia* (Fig.14.35). They have the notochord in their tail region.

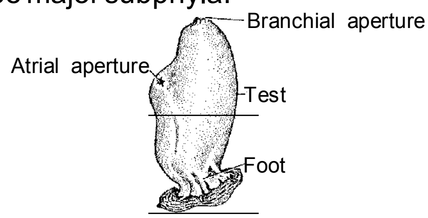


Fig. 14.35 : Ascidia

2. Subphylum **Cephalochordata** includes lanceolets. Their notochord extends throughout the length of the body, e.g. *Amphioxus* (Fig.14.36).

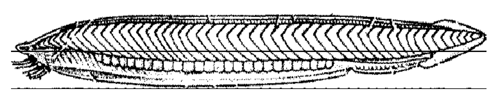


Fig.14.36 : Amphioxus

3. Subphylum **Vertebrata** includes chordates in which the notochord becomes transformed into a vertebral column. Their skeleton is composed of cartilage or true calcareous bones

Sub-phylum vertebrata is divided into eight major classes:

1. Class **Ostracodermi** includes primitive, fish-like jawless animals which have become extinct, e.g. *Cephalepsis*.
2. Class **Cyclostomata** includes eel-like jawless and scaleless fishes with a circular mouth, e.g. hagfishes (*Myxine*), lamprey (*Petromyzon*) (Fig.14.37).

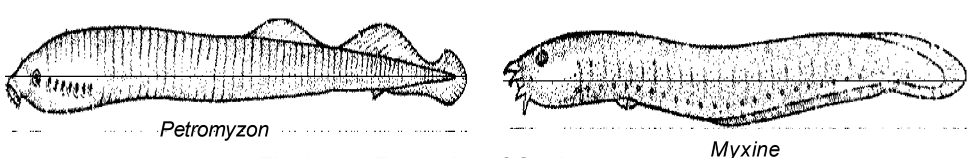


Fig.14.37 : Examples of Cyclostomata

3. Class **Placodermi** includes extinct, armoured fishes with jaws, e. g. *Climatius* (Fig.14.38).

Fig.14.38 : Climatius

4. Class **Chondrichthyes** includes mostly marine fishes with cartilaginous endoskeleton and placoid scales, e.g. shark (*Scoliodon*) and sting ray (*Trygon*) (Fig.14.39).

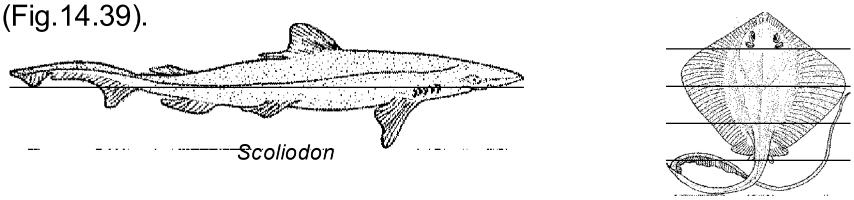


Fig.14.39 : Examples of Cartilaginous fishes

5. Class **Osteichthyes** includes fishes with bony endoskeleton, body with or without scales; scale types are cycloid and ctenoid, e. g. **Pengba**, (*Osteobrama belangeri*), climbing perch (*Anabas*), lung fishes (*Protopterus*), sea horse (*Hippocampus*), Rohu (*Labeo*), Katla (*Catla*), **Porom** *(Ophiocephalus),* **Shareng** *(Wallago),* **Ngakra** *(Clarias)etc.* (Fig.14.40).

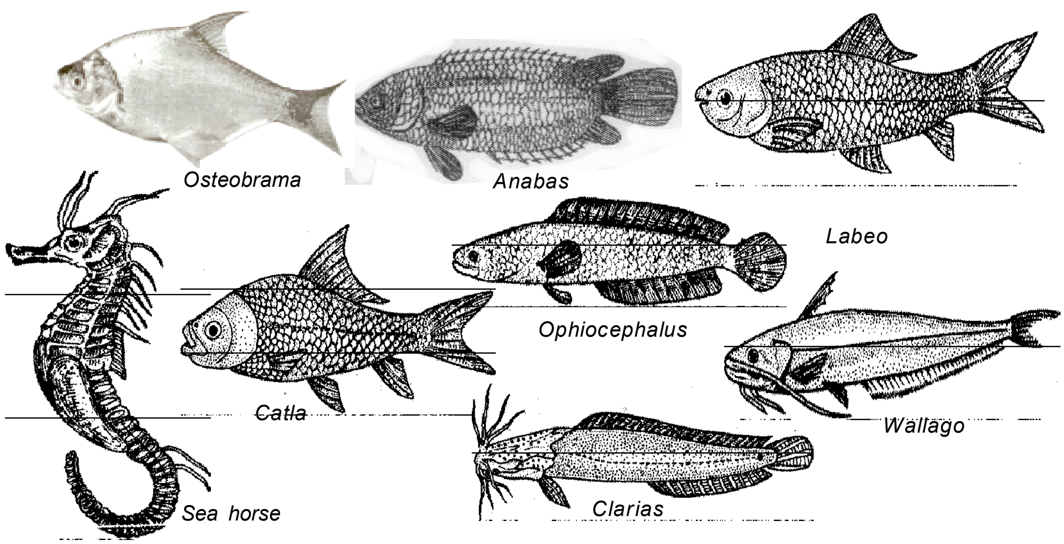


Fig.14.40: Some examples of of fishes

6. Class **Amphibia** includes toads (*Bufo melanostictus*), frogs (*Rana tigerina*) and salamanders (*Tylototriton verrucosus*), which are the first group of four-limbed land vertebrates. Their larval stages are aquatic and fish-like. Their skin is always kept moist and used as an accessory respiratory organ (Fig.14.41).

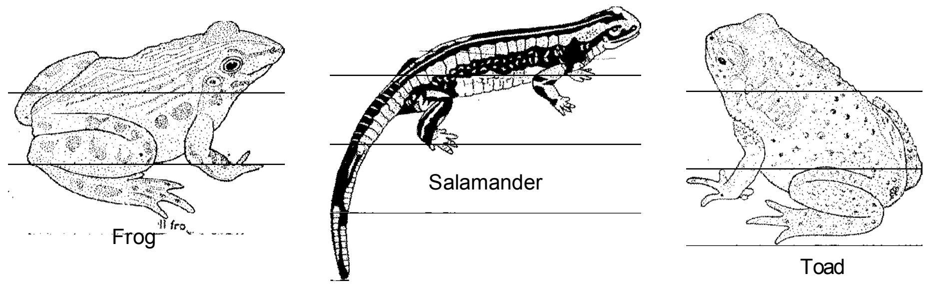


Fig.14.41 : Some examples of Amphibia

7. Class **Reptilia** or reptiles are fully terrestrial tetrapods with dry scales covering the body. They are cold-blooded and respire only with lungs. Examples are Garden lizard (*Calotes*), Wall lizard (*Hemidactylus*),Cobra (*Naja naja*), Ajgar (*Python*), Crocodile (*Crocodilus*), etc. (Fig.14.42).

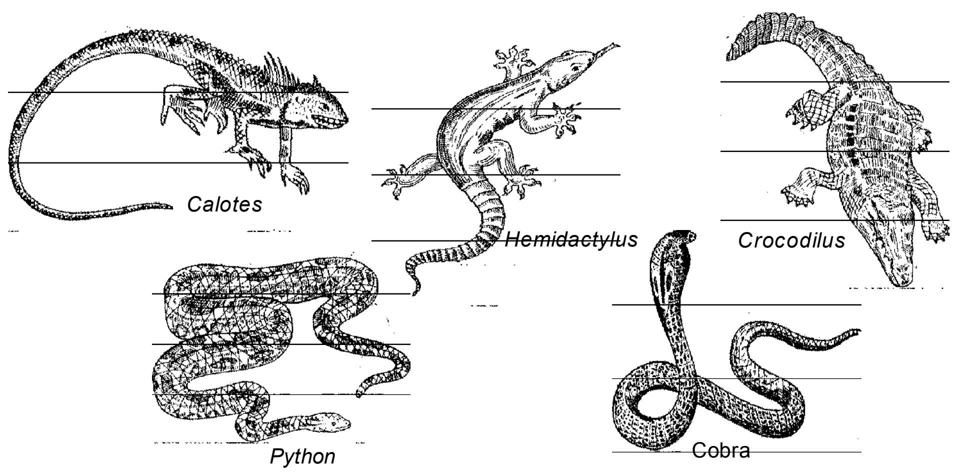


Fig.14.42 : Some examples of Reptiles

8. Class **Aves** includes all kinds of birds which are the only vertebrates with feathers that cover the body. Their forelimbs are modified into wings for flight. However, some of them are flightless birds. Examples are sparrow (*Passer domesticus*), crow (*Corvus macrorhynchos*), Parrot (*Psittacula*), Owl (*Bubo*), Ostrich (*Struthio*), etc. (Fig.14.43); and

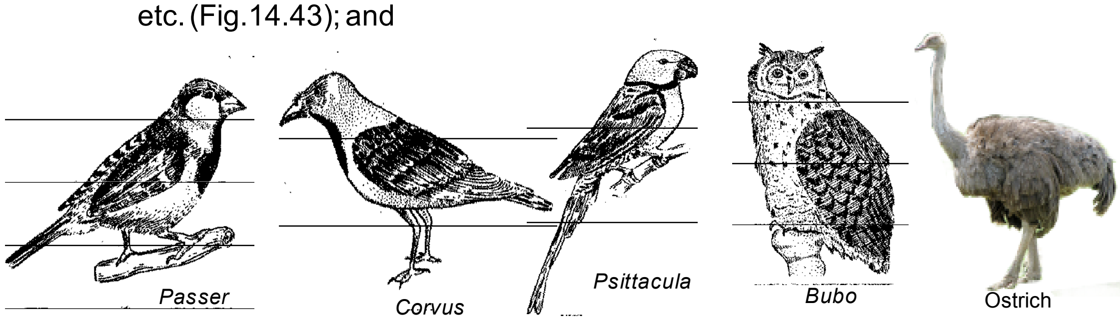


Fig.14.43 : Some examples of birds

9. Class **Mammalia** includes mammals which are warm-blooded animals with hair covering the body. Females suckle their young ones with milk from the mammary glands. They respire only with lungs. Examples are rat (*Rattus rattus*), dog (*Canis familiaris*), spiny anteater (*Echidna*), kangaroo (*Macropus*), brow-antlered deer (*Cervus eldi eldi*), monkey (*Macaca*), chimpanzee (*Pan*) man (*Homo sapiens*) etc. (Fig.14.44).

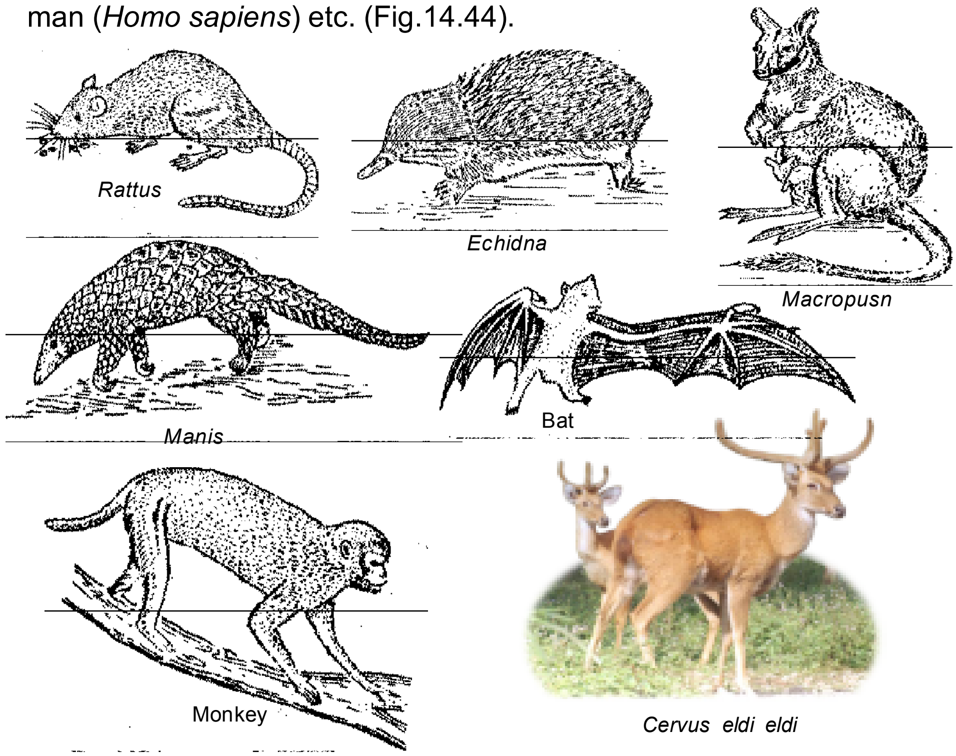


Fig. 14.44: Some examples of Mammmals

POINTS TO REMEMBER

* Biological diversity is the variation of life forms, including plants and animals, occurring within a given ecosystem, locality or on the entire Earth.
* The number of species living on the earth could be in the range from 10 million to 50 million.
* The total number of species actually named and recorded till now is only around 1.5 million.
* The first step of finding out to which group the unknown organism belongs is known as identification.
* The second step of giving a name to the newly discovered and identified organism is known as naming.
* The binominal system of nomenclature was introduced by Carolus Linnaeus in 1758.

* A hierarchy is a systematic framework for biological classification in which taxonomic groups are arranged in an ascending series of levels with ever-increasing inclusiveness.
* The hierarchy of classification has six basic levels or categories, viz. Phylum (for animals) and Division (for plants), Class, Order, Family, Genus and Species.
* Classification is the ordering of animals into groups on the basis of their relationships.
* Taxonomy is the branch of biology dealing with the classification and naming of organisms.
* Robert H Whittaker in 1969 proposed the five kingdom system of classification.
* Five kingdom classification is based on the kind of cells that make up the organism; the number of cells that make up the organism and the method by which the organism obtains food.
* Kingdom Monera includes all the prokaryotic organisms including bacteria, cyanobacteria, etc.
* Members of the Kingdom Protista are generally unicellular, eukaryotic organisms, although some multicellular forms are also included.
* Fungi are eukaryotic, heterotrophic organisms that mainly serve as decomposers and play important role in recycling of materials.
* Plants are multicellular, eukaryotic, photosynthetic and autotrophic organisms that form the basis of the food web in terrestrial ecosystems.
* Animals are multicellular, eukaryotic, heterotrophic organisms which represent the consumer levels of the food web in any ecosystem.
* Thallophyta includes autotrophic plants without true roots, stems or leaves.
* Pteridophytes or ferns are seedless vascular plants.
* Bryophyta, also known as amphibians of the plant kingdom, includes mosses and liverworts.
* Division Spermatophyta comprises the seed-bearing plants.
* Gymnosperms are tracheophytes with naked seeds while Angiosperms are flowering plants which bear their seeds enclosed within ripened ovary (fruit).
* The cycads were so numerous in Mesozoic times that this era is often called the Age of Cycads and Dinosaurs.
* Division Gingkophyta includes the only living representative *Ginkgo biloba*, which is a true living fossil dating back 185 million years.
* Conifers constitute dominant forest vegetation in temperate parts of the world and regions of high altitude.
* Division Anthophyta includes the flowering plants, which form the largest group

in the plant kingdom. More than 90% of all plants on earth are angiosperms.

* Flowering plants may be as minute as a pin head, e. g. *Wolffia* microscopica or as massive as a 300 feet high tree, e. g. *Eucalyptus*.
* Flowering plants provide us cereals, pulses, vegetables, fruits, fibres, timbers, gums, resins, tannins, dyes, spices, sugar, starch, condiments, rubber, paper, medicines, tea, coffee, tobacco, fats oils and several other useful products.
* Monocots have only one cotyledon inside the seed and parallel leaf venation.
* Dicot plants have two cotyledons inside the seed and branched or net-like leaf venation.
* Porifera includes sponges, which are simple multicellular aquatic animals that remain fixed to a rock or substratum under water.
* All cnidarian animals possess a kind of stinging cells called nematocysts.
* Ctenophora have eight "comb like rows" of fused cilia arranged along the sides of the animal.
* Platyhelminthes include dorso-ventrally flattened, leaf or ribbon-like, bilaterally symmetrical worms with, triploblastic body.
* Nemertea includes free-living marine worms with a distinctive eversible proboscis consisting of a long, hollow tube.
* Rotifers possess a rotating ciliated wheel organ called corona at their anterior end.
* Nematomorpha are very long, thin, hair-like worms that are free-living in water.
* Nematoda or nematodes include round worms or thread worms.
* Acanthocephala are small intestinal parasites of vertebrates. They possess a proboscis at the anterior end with hooks for attachment to the wall of the intestines.
* Tardigrades are minute creatures with short legs with minute claws and are sometimes called water bears.
* Brachiopods are primitive marine bivalve animals attached to rocks by a fleshy stalk.
* Mollusca include animals with soft, bilaterally symmetrical body, usually covered by a calcareous exoskeleton or shell.
* Annelida include the true worms such as earthworms, leeches with triploblastic, bilaterally symmetrical and elongated segmented body.
* Sipunculoidea or peanut worms have a slender, peanut or gourd-shaped body.
* Arthropoda includes animals with bilaterally symmetrical, triploblastic and metamerically segmented body covered with chitinous exoskeleton. They possess jointed appendages.
* Chaetognatha or arrow worms are small, transparent marine worms with bristles or hooks around the mouth.
* Echinoderms have a radially symmetrical body, usually with 5 or more radiating arms.

* Hemichordata includes a small group of marine invertebrates that were once thought to have a short notochord, the supportive axial rod that characterizes the phylum Chordata.
* Chordata is characterized by the presence of a notocord to support the body, a single dorsal tubular nerve cord, a series of pharyngeal gill slits, and a tail behind the anus.
* Urochordata or tunicates include primitive chordates that have the notochord in the tail region.
* In Cephalochordata, notochord extends throughout the length of the body.
* Vertebrata includes chordates in which the notochord becomes transformed into a vertebral column.

EXERCISES

1. *What is biological diversity?*
2. *What is meant by identification and naming?*
3. *Write what you know about binominal nomenclature.*
4. *What is taxonomic heirarchy? Who had introduced it?*
5. *Define classification.*
6. *Define taxonomy.*
7. *Who is known as the father of biological classification?*
8. *Why Linnaeus is called as father of taxonomy?*
9. *Who had proposed the five kingdom classification?*
10. *What are the advantages of the five- kingdom system over the two-kingdom system of classification?*
11. *Write down the three important bases of the five-kingdom classification.*
12. *Write briefly on the following:*
    (a) Kingdom Monera,
    (b) Kingdom Protista,
    (c) Kingdom Fungi,
    (d) Kingdom Plantae, and
    (e) Kingdom Animalia.
13. *Write down the salient features of the following:*
    (a) Thallophyta,
    (b) Pteridophyta
    (c) Bryophyta
    (d) Spermatophyta
    (e) Cycadophyta

(f) Ginkgophyta

(g) Gnetophyta

(h) Coniferophyta,

14. *Write down the salient features of the following:*

(a) Porifera,

(b) Cnidaria,

(c) Platyhelminthes,

(d) Rotifera,

(e) Gastrotrica,

(f) Nematoda,

(g) Mollusca,

(h) Annelida,

(i) Arthropoda,

(j) Echinodermata.

15. *Write down three basic features of Chordata.*
16. *Enumerate the living classes under subphylum Vertebrata.*
17. *Write briefly on the following classes:*

(a) Chondrichthyes,

(b) Osteichthyes,

(c) Amphibia,

(d) Reptilia,

(e) Aves and

(f) Mammalia.

CHAPTER – 15

Human Diseases

According to the World Health Organization (WHO), health is a state of complete physical, mental and social well-being. A person without any physical or mental disease or infirmity is said to be healthy. A healthy person has the ability to lead a socially and economically productive life.

The biological term for health is *homeostasis*, which is an organism's ability to efficiently respond to destabilising effects of various internal as well as external factors and effectively restore and sustain a state of balance in the body. In other words, the term 'health' is used to describe a person's overall state of physical well-being.

There are four general determinants of health, viz. human biology, environment, lifestyle and healthcare services.. Thus, health is maintained and improved not only through the advancement and application of health science, but also through the efforts and intelligent lifestyle choices of the individual.

Leading a hygeinic lifestyle, eating a nutritious diet, exercising to reduce body fat and attain physical fitness, managing stress, and avoiding smoking, consumption of alcohol and other forms of substance abuse are simple ways of one's lifestyle that generally improve one's health.

Mental health is a concept that refers to an individual's emotional and psychological well-being. It is the state in which an individual is able to use his or her cognitive and emotional capabilities, function in society, and meet the ordinary demands of everyday life.

15.1 HEALTH AND ITS FAILURE

Overall health of a person may become degraded due to many reasons, such as lack of adequate nutritious food, lack of physical exercise, unfavorable environmental conditions, diseases, etc. Out of these, diseases represent the most important reason that degrades the health of a person.

15.2 DISEASES AND ITS CAUSES

A disease is an abnormal condition of an organism that impairs bodily functions. In human beings, "disease" is often used more broadly to refer to any condition that causes discomfort, abnormal functioning of the body, distress, social problems, and sometimes, death to the person afflicted, or similar problems for those in contact with the person. In this broader sense, it sometimes includes injuries, disabilities, disorders, syndromes, infections, deviant behaviours, and atypical variations of structure and function. While many diseases are biological processes with observable alterations of organ function or structure, others primarily involve alterations of behaviour.

15.2.1 Causes of disease

A number of different factors intrinsic or extrinsic to a person can cause disease. Examples of intrinsic factors are genetic defects or nutritional deficiencies. Environmental exposure, such as to second hand smoke, infection with a disease-causing microorganism, etc. are examples of extrinsic factors. Many diseases result from a combination of intrinsic and extrinsic factors. For many diseases a cause cannot be identified.

The extrinsic factors that cause diseases can be broadly classified into categories like social, psychological, environmental factors. Environmental factors include toxic chemicals (e.g. acetaldehyde in cigarette smoke, pesticide residues in water, etc.) and infectious microorganisms (e.g. *Bacillus tuberculosis*, smallpox, poliovirus).

Pathology is the study of diseases. The subject of systematic classification of diseases is referred to as *nosology*. Its cause is referred as its *etiology*. The broader body of knowledge about human diseases and their treatments is medicine. Many similar (and a few of the same) conditions or processes can affect non-human animals (wild or domestic). The study of diseases affecting animals is *veterinary medicine*.

15.2.2 Symptoms

A symptom is a sensation or change in health function experienced by a patient. Symptoms may be loosely classified as strong, mild or weak. It is somewhat different to a sign, which is the evidence of the presence of a disease or disorder. Examples of symptoms are fatigue or tiredness, pain, nausea etc. In contrast, elevated blood pressure, or abnormal appearance of the retina, would be a medical sign indicating the nature of the disease.

A symptom may also be a physical condition which indicates a particular illness or disorder. An example of a symptom in this sense of the word would be a rash. However, correctly speaking, this is known as a sign, as would any indication detectable by a person other than the sufferer without any verbal information from the patient.

A symptom can be defined as any feature which is noticed by the patient. A sign is noticed by the doctor or others. It is not necessarily the nature of the sign or symptom which defines it, but who observes it. Clearly then, the same feature may be noticed by both doctor and patient, and so is at once both a sign and a symptom. Some features, such as pain, can only be symptoms. A doctor cannot feel a patient's pain (unless he is the patient!). Others can only be signs, such as a blood cell count measured by a doctor or in a clinical laboratory.

Medical usage sometimes distinguishes a disease, which has a known specific cause or causes (or etiology), from a *syndrome*, which is a collection of signs or symptoms that occur together. However, many conditions have been identified, yet continue to be referred to as syndromes. Furthermore, numerous conditions of unknown etiology are referred to as diseases in many contexts.

15.3 INFECTIOUS DISEASE

An **infectious disease** is a clinically evident disease resulting from infection with pathogenic microbial agents, including virus, bacteria, fungi, protozoa, multicellular parasites, and aberrent proteins known as prions. These pathogens are able to cause disease in animals and plants.

Infectious diseases are usually known as **contagious diseases** (also called communicable diseases) due to their potentiality of transmission from one person or species to another. Transmission of an infectious disease may occur through one or more of diverse pathways including physical contact with infected individuals. These infecting agents may also be transmitted through liquids, food, body fluids, contaminated objects, airborne inhalation, or through disease-spreading orgaisms called vectors.

15.4 SOME COMMON DISEASES SPREAD BY MICROBES

15.4.1 DIARRHOEA

Diarrhoea is a common disease characterized by an increase in the frequency of bowel movements with a decrease in the form of stool (greater looseness of stool). Generally, it is a condition during which the patient passes a liquid or watery stool in an increased frequency than normal.

15.4.2 What are the causes of diarrhoea?

The looseness of stool in diarrhoea is caused by increased water in the stool. During normal digestion, food is kept liquid by the secretion of large amounts of water by the stomach, upper small intestine, pancreas, and gallbladder. Food that is not digested reaches the lower small intestine and colon in liquid form. The lower small intestine and particularly the colon absorb the water, turning the undigested food into a more-or-less solid form. Increased amounts of water in stool can occur if the stomach and/or small intestine secrete too much fluid, the distal small intestine and colon do not absorb enough water, or the undigested, liquid food passes too quickly through the small intestine and colon for them to remove enough water.

Some pathogenic viruses, bacteria and parasites cause increased secretion of fluid, either by invading and inflaming the lining of the small intestine. Inflammation stimulates the lining to secrete fluid. These pathogens may also produce toxins (chemicals) that also stimulate the lining to secrete fluid but without causing inflammation. This can increase the rapidity with which food passes through the intestines, reducing the time that is available for absorbing water.

15.4.3 Acute and chronic diarrhoea

Diarrhoea generally is divided into two types, acute and chronic. Acute diarrhoea lasts a few days or up to a week. Chronic diarrhoea can be last more than three weeks. It is important to distinguish between acute and chronic diarrhea because they usually have different causes, require different diagnostic tests, and require different treatment.

Acute diarrhoea

The most common cause of acute diarrhoea is infection by microbes (viral, bacterial, and parasitic protozoan pathogens). Bacterial food poisoning can also cause acute diarrhoea. A third important cause of acute diarrhoea is medications, such as intake of certain antibiotics, etc.

Viral gastroenteritis: Viral gastroenteritis or viral infection of the stomach and the small intestine is the most common cause of acute diarrhoea worldwide. Symptoms of viral gastroenteritis are nausea, vomiting, abdominal cramps, and diarrhoea that typically last only 48-72 hrs. The patients with viral gastroenteritis usually do not have blood or pus in their stools and may have little fever.

Viral gastroenteritis may occur in a single individual (sporadic form) or among groups of individuals (in an epidemic form). Sporadic diarrhoea probably is caused by several different viruses and may be spread by person-to-person contact. The most common cause of epidemic diarrhoea (e.g., on cruise ships) is calciviruses (Astroviridae). The calciviruses are transmitted by food that is contaminated by sick food-handlers or by person-to-person contact.

Food poisoning: Food poisoning is a brief illness that is caused by toxins produced by bacteria. The toxins cause abdominal pain (cramps) and vomiting and also cause the small intestine to secrete large amounts of water that leads to diarrhoea.

Staphylococcus aureus is an example of a bacterium that produces toxins in food before it is eaten. Typically, food items such as salad, meat or sandwiches with creamy filling (mayonnaise), etc. become contaminated with *Staphylococcus* if left un-refrigerated at room temperature overnight. The bacteria multiply in the food and produce toxins. *Clostridium perfringens* is an example of a bacterium that multiplies in food (usually canned food), and produces toxins in the small intestine after the contaminated food is eaten.

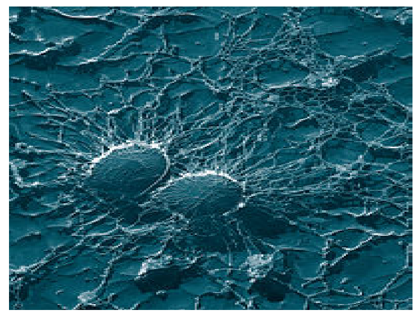


Fig. 15.1. Staphylococ-

Traveller's diarrhoea: *Escherichia coli* is a bacterium which is a normal inhabitant of the small intestine and colon. Many strains of *E. coli* are non-pathogenic, i.e. they do not cause disease in the intestines.

Certain strains of E. coli, however, are pathogenic i.e. they can cause disease in the small intestine and colon. These pathogenic strains of E. coli cause diarrhoea either by producing toxins or by invading and inflaming the lining of the small intestine and the colon, thus causing enterocolitis. Traveller's diarrhoea usually is caused by a pathogenic strain of *E. coli* that produces a diarrhoea-inducing toxin.

Fig. 15.2. Escherichia

Tourists visiting foreign countries with warm climates and poor sanitation can acquire this bacteria by eating contaminated foods such as fruits, vegetables, raw meat, water, and ice cubes. Toxins produced by the bacteria cause the sudden onset of diarrhoea, abdominal cramps, nausea, and sometimes vomiting. These symptoms usually occur 3-7 days after which they generally subside within 3 days.

Bacterial enterocolitis: Disease-causing bacteria usually invade the small intestines and colon and cause enterocolitis (inflammation of the small intestine and colon).

Bacterial enterocolitis is characterized by signs of inflammation (blood or pus in the stool, fever) and abdominal pain and diarrhoea. *Campylobacter jejuni* is the most common bacterium that causes acute enterocolitis. Other bacteria that cause enterocolitis include *Shigella, Salmonella,* and pathogenic E. coli. These bacteria usually are acquired by drinking contaminated water or eating contaminated foods such as vegetables, poultry, and dairy products.

15.4.4 Complications of diarrhoea

Dehydration occurs when there is excessive loss of fluids and minerals (electrolytes) from the body due to diarrhoea, with or without vomiting. Dehydration is common among adult patients with acute diarrhoea who have large amounts of stool, particularly when the intake of fluids is limited by lethargy or is associated with nausea and vomiting. It is common in infants and young children who develop viral gastroenteritis or bacterial infection. Patients with mild dehydration may experience only thirst and dry mouth. Patients with moderate to severe dehydration faint on standing due to a reduced volume of blood that lowers blood pressure, a diminished urine output, severe weakness, kidney failure, confusion, acidosis (too much acid in the blood), and coma.

Electrolytes (minerals) are lost with water when diarrhoea is prolonged or severe, and electrolyte deficiencies may occur. The most common mineral deficiencies occur with sodium and potassium.

Finally, there may be irritation of the anus due to the frequent passage of watery stool *containing irritating substances*.

15.4.5 When should the doctor be called for diarrhoea?

Most episodes of diarrhoea are mild and of short duration and do not require the attention of a doctor. The doctor should be consulted when there is:

i. High fever (temperature greater than 101 F);
ii. Moderate or severe abdominal pain or tenderness;
iii. Bloody diarrhoea that suggests severe intestinal inflammation;
iv. Diarrhoea in persons with serious underlying illness, for example, diabetes, heart disease, and AIDS;
v. Severe diarrhoea that shows no improvement after 48 hours;
vi. Moderate or severe dehydration;
vi. Prolonged vomiting that prevents intake of fluids orally;
vii. Acute diarrhoea in pregnant women because of health concern of the foetus;
viii. Diarrhoea that occurs during or immediately after completing a course of antibiotics;
ix. Diarrhoea after returning from journey to a place with poor sanitation;
x. Diarrhoea that develops in patients with chronic intestinal diseases such as colitis;
xi. Acute diarrhoea in an infant or young child.

15.4.6 How can dehydration be prevented and treated?

Oral rehydration solutions (ORS) are liquids that contain a carbohydrate (glucose or rice syrup) and electrolytes (sodium, potassium, chloride, and citrate or bicarbonate). Originally, the World Health Organization (WHO) developed the WHO-ORS to rapidly rehydrate victims of the severe diarrhoeal illness cholera. The WHO-ORS solution contains glucose and electrolytes. The glucose in the solution is important because it forces the small intestine to quickly absorb the fluid and the electrolytes. The purpose of the electrolytes in the solution is the prevention and treatment of electrolyte deficiencies. Presently, convenient premixed commercial ORS products that are similar to the WHO-ORS are available for rehydration and prevention of dehydration. Most of the commercially available ORS products contain glucose.

15.4.7 How is diarrhoea treated?

Antibiotics: Metronidazole is a very effective anti-diarrhoea medication. It is an effective antibiotic against certain protozoal infections, especially Giardia. A common use of this medication would be the treatment of colitis, which may or may not be caused by inflammatory bowel disease. However, antibiotics, many of which are available, should be taken only with a doctor's advice.

Absorbents: Absorbents are compounds that absorb water. Absorbents that are taken orally bind water molecules in the small intestine and colon and make diarrhoeal stools less watery. They also may bind toxic chemicals produced by bacteria that cause the small intestine to secrete fluid.

Anti-motility medications: Anti-motility medications are drugs that relax the muscles of the small intestine and/or the colon. Relaxation results in slower flow of intestinal contents. Slower flow allows more time for water to be absorbed from the intestine and colon, reduces the water content of stool. Cramps, due to spasm of the intestinal muscles, also are relieved by the muscular relaxation. Absorbents and anti-motility medications should not be used without a doctor's advice. These medications should not be used in children younger than two years of age.

15.5 TYPHOID or ENTERIC FEVER

Typhoid, or Enteric fever is a disease caused by infection of *Salmonella typhi* leads. This disease is characterized by the sudden onset of a sustained high fever, severe headache, nausea, and loss of appetite. Other symptoms include constipation or diarrhoea, enlargement of the spleen, possible development of meningitis, and general malaise in most cases. If not treated timely, typhoid fever results in mortality rates ranging from 12-30% while timely treatment can bring 99% survival.

15.5.1 Infection with *Salmonella typhi*

Salmonella typhi is a Gram negative pathogenic bacterium. The infection of humans by *Salmonella typhi* occurs through the faecal-oral route from infected individuals to healthy ones. Poor hygiene of patients can lead to secondary infection, as well as consumption of snails from polluted water bodies. The most common source of infection, however, is drinking water contaminated by urine and faeces of infected individuals. Once ingested, the organisms multiply in the small intestine over the period of 1-3 weeks. Then, the bacteria move across the intestinal wall, and spread to other organ systems and tissues. The innate defence mechanisms of the host are weakened and is not able to prevent infection.

Infection of healthy persons with *S. typhi* has only been shown to occur often from carrier individuals. 2-5% of previously infected individuals become chronic carriers who show no signs of disease, but actively shed viable organisms capable of infecting others. A good example is "**Typhoid**" **Mary Mallon**, who was a food handler responsible for infecting at least 78 people and killing 5 of them. These highly infectious carriers pose a great risk to public health due to their lack of disease-related symptoms.

Fig.15.3 Salmonella typhi

The damage caused by typhoid fever is reversible and limited if treatment is started early. This leads to a mortality rate of less than 1% among treated individuals who have an antibiotic-susceptible strain of *S. typhi*, making the outcome and prognosis for patients a positive one.

15.5.2 Symptoms

Typhoid fever is characterized by the following symptoms:

1. Continuous fever as high as 40°C (104°F) with profuse sweating,
2. Rosy spots on the lower chest and abdomen,
3. Slow heart beat,
4. Delirium with Headache and Cough.
5. Bleeding from the nostrils,
6. Abdominal pain, gastroenteritis, diarrhoea and dehydration

Widal test

The Widal test is a serological test for Enteric fever introduced by Georges-F. Widal, a French physician. It is a demonstration of Salmonella agglutinating antibodies in the blood. It is used as a presumptive diagnostic test for Enteric fever.

15.5.3 Prevention:

A vaccination for typhoid fever is available. However, it can lose its effectiveness after several years, so a booster vaccination may be necessary.

Other preventives for typhoid fever are:

1. Using water that has been boiled or chemically disinfected for:
   a. drinking or preparing beverages such as tea or coffee
   b. brushing teeth
   c. washing face and hands

   d. washing fruits and vegetables
   e. washing utensils and food preparation equipments
   f. washing the surface of tins, cans, and bottles that contain food or beverages
2. Eating food or drinking beverages only from hygienic sources
3. Any raw food such as fruits, vegetables, salad greens, unpasteurized milk and milk products, raw meat, shellfish, etc. could be contaminated and should be avoided during epidemics.

Taking antibiotics is not a preventive for typhoid fever.

It is important to remember that the danger of typhoid fever does not end when symptoms disappear. You could still be carrying *Salmonella typhi* and the illness could return, or you could pass the disease to other people. People who have typhoid fever should:

- take the prescribed antibiotics.
- wash hands after using the bathroom.
- have a series of stool cultures - to ensure that the *Salmonella typhi* bacteria are no longer present.

15.6 MALARIA

Malaria is one of the most common infectious diseases and an enormous public-health problem. The disease is caused by protozoan parasites of the genus *Plasmodium*. The most serious forms of the disease are caused by *Plasmodium falciparum* and *Plasmodium vivax*, but other related species can also infect humans. These human-pathogenic *Plasmodium* species are usually referred to as malarial parasites.

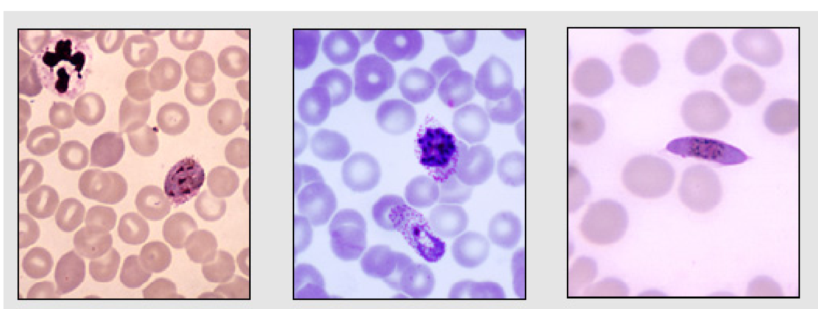


Fig. 15.4 Plasmodium falciparum in blood

Malaria parasites are transmitted by female *Anopheles* mosquitoes. The parasites multiply within red blood cells, causing symptoms like anaemia, light headedness, shortness of breath, etc. Other general symptoms are fever, chills, nausea, flu-like illness, and in severe cases, coma and death. Malaria transmission can be reduced by preventing mosquito bites with mosquito nets and insect repellents, or by mosquito control measures such as spraying insecticides inside houses and draining standing water where mosquitoes lay their eggs.

Presently, no vaccine is available for malaria; preventative drugs must be taken continuously to reduce the risk of infection. Prophylactic drug treatments are often too expensive for most people living in endemic areas. Malaria infections are treated through the use of antimalarial drugs, such as quinine or artemisinin derivatives, although drug resistance is increasingly common.

15.6 1 Symptoms

Symptoms of malaria include fever, shivering, arthralgia (joint pain), vomiting, anaemia caused by haemolysis (destruction of blood cells), haemoglobinuria, and convulsions. There may be the feeling of tingling in the skin, particularly with malaria caused by *P. falciparum*. The classical symptom of malaria is cyclical occurrence of sudden coldness followed by rigor and then fever and sweating lasting four to six hours. The fever occurs every two days in *P. vivax* and *P. ovale* infections, while every three for *P. malariae*. *P. falciparum* infected patients can have recurrent fever every 36-48 hours or a less pronounced and almost continuous fever. Children with malaria frequently exhibit abnormal postering, a sign indicating severe brain damage. Malaria has been found to cause cognitive impairments, especially in children. It causes widespread anaemia during a period of rapid brain development and also direct brain damage. This neurologic damage results from cerebral malaria to which children are more vulnerable.

Severe malaria is almost exclusively caused by *P. falciparum* infection and usually arises 6-14 days after infection. Consequences of severe malaria include coma and death if untreated. Young children and pregnant women are especially vulnerable. Enlarged spleen, severe headache, cerebral ischemia, enlarged liver, hypoglycemia, and bloody urine with renal failure may occur. Severe malaria can progress fast and cause death within hours or days. In the most severe cases of the disease fatality rates can exceed 20%, even with intensive care and treatment. In endemic areas, treatment is often less satisfactory and the overall fatality rate for all cases of malaria can be as high as one in ten.

Chronic malaria is caused both by *P. vivax* and *P. ovale*, but not in *P. falciparum*. Here, the disease can relapse months or years after exposure, due to the presence of latent parasites in the liver.

15.6. 2 Prevention and disease control

Female *Anopheles* mosquito is a vector of malaria and mosquito control is a very effective way of reducing the incidence of malaria. Methods used to prevent the spread of disease, or to protect individuals in areas where malaria is endemic, include prophylactic drugs, mosquito eradication and the prevention of mosquito bites. There is currently no vaccine that will prevent malaria, but this is an active field of research.

Efforts to eradicate malaria by eliminating mosquitoes have been successful in some areas. Malaria was once common in the United States and southern Europe, but the draining of wetland breeding grounds and better sanitation, in conjunction with the monitoring and treatment of infected humans, eliminated it from affluent regions.

Several drugs, most of which are also used for treatment of malaria, can be taken preventively. Generally, these drugs are taken daily or weekly, at a lower dose than would be used for treatment of a person who had actually contracted the disease.

Quinine was used starting in the seventeenth century as a prophylactic against malaria. The development of more effective alternatives such as quinacrine, chloroquine, and primaquine in the twentieth century reduced the reliance on quinine. Today, quinine is still used to treat chloroquine resistant *Plasmodium falciparum*, as well as severe and cerebral stages of malaria, but is not generally used for prophylaxis.

Mosquito nets help keep mosquitoes away from people, and thus greatly reduce the infection and transmission of malaria. The nets are not a perfect barrier, so they are often treated with an insecticide designed to kill the mosquito before it has time to search for a way past the net. Since the Anopheles mosquitoes feed at night, the preferred method is to hang a large "bed net" above the center of a bed such that it drapes down and covers the bed completely.

The distribution of mosquito nets impregnated with insecticide (often permethrin or deltamethrin) has been shown to be an extremely effective method of malaria prevention, For maximum effectiveness, the nets should be re-impregnated with insecticide every six months.

15.7 TUBERCULOSIS

Tuberculosis (abbreviated as TB for *Tubercle bacillus*) is a common and deadly infectious disease caused by *Mycobacterium tuberculosis*. This disease commonly infects the lungs (as pulmonary TB) but can also affect the central nervous system, the lymphatic system, the circulatory system, the urinogenital system, bones, joints and even the skin. Other mycobacteria can also cause tuberculosis, but these species do not usually infect healthy adults.

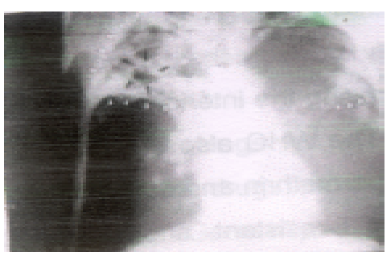


Fig. 15.5 : Chest X-ray showing TB infection

Over one-third of the world's population has been exposed to the TB bacterium, and new infections occur at a rate of one per second. Not everyone infected develops the full-blown disease, and so, latent TB infection with no visible symptoms is very common. However, 10% of latent infections will progress to active TB disease, which, if left untreated, kills more than 50% of its victims.

In 2004, 14.6 million chronic active TB cases, 8.9 million new cases, and 1.6 million deaths, were recorded, mostly in developing countries. In addition, a rising number of people in the developed world are contracting tuberculosis because their immune systems are compromised by immunosuppressive drugs, substance abuse or HIV/AIDS.

The rise in HIV infections and the neglect of TB control programs have resulted in resurgence of tuberculosis. The emergence of drug-resistant strains has also contributed to this new epidemic. The World Health Organization declared TB a global health emergency in 1993.

15.7.1 Symptoms

Symptoms of tuberculosis include chest pain, coughing up blood, and a productive, prolonged cough for more than three weeks. Other symptoms are fever, chills, night sweats, appetite loss, weight loss, pale complexion, and often a tendency to fatigue very easily.

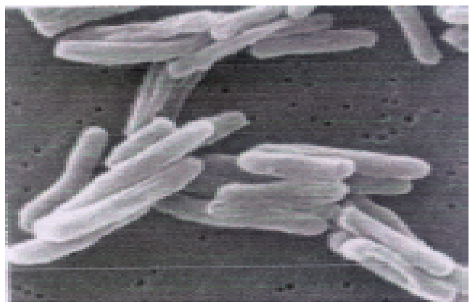


Fig.15.6 : Mycobacterium tuberculosis under Electron microscope

In some cases, the infection moves from the lungs to other body parts, causing other kinds of TB more common in immunosuppressed persons and young children. Newly infected sites include the pleura, the central nervous system in meningitis, the lymphatic system in scrofula of the neck, urogenital tuberculosis, bones and joints in Pott's disease of the spine.

15.7.2 Transmission

When people suffering from active pulmonary TB cough, sneeze, speak, kiss, or spit, they expel infectious minute aerosol droplets. A single sneeze, for instance, can release up to 40,000 droplets. People with prolonged, frequent, or intense contact are at high risk of becoming infected. A person with active but untreated tuberculosis can infect 10–15 other people per year. Others at risk include people in areas where TB is common, people who inject illicit drugs (especially when sharing needles), residents and employees of high-risk congested areas, medically under-served and low-income ethnic minority populations, children exposed to infected adults, HIV/AIDS patients with lowered immunity, people who take immunosuppressant drugs, and health care workers.

Transmission can only occur from people with active, not latent, TB. The probability of transmission from one person to another depends upon the number of infectious droplets expelled by a carrier, the effectiveness of ventilation, the duration of exposure, and the virulence of the *M. tuberculosis* strain. The chain of transmission can therefore be broken by isolating patients with active disease, and starting effective anti-tuberculous therapy. After two weeks of such treatment, people with non-resistant active TB generally cease to be contagious

15.7.3 Prevention

TB prevention and control takes two parallel approaches. In the first, people with TB and their contacts are identified and then treated. Identification of infections often involves testing high-risk groups for TB. In the second approach, children are vaccinated to protect them from TB. Unfortunately, no vaccine is available that provides reliable protection for adults. However, in tropical areas where the incidence of atypical mycobacteria is high, exposure to nontuberculous mycobacteria gives some protection against TB.

Many countries use BCG (Bacillus Calmette-Guerin) vaccine as part of their TB control programs, especially for infants. This was the first vaccine for TB and developed at the Pasteur Institute in France between 1905 and 1921. However, mass vaccination with BCG did not start until after World War II. The protective efficacy of BCG for preventing serious forms of TB (e.g. meningitis) in children is greater than 80%; its protective efficacy for preventing pulmonary TB in adolescents and adults is variable, ranging from 0 to 80%.

Several new vaccines to prevent TB infection are being developed. The first recombinant tuberculosis vaccine entered clinical trials using mice in the United States in 2004. A very promising TB vaccine, MVA85A, is currently in phase II trials in South Africa by a group led by Oxford University, and is based on a genetically modified virus.

Fig. 15.7:Robert koch

The bacillus causing tuberculosis, *Mycobacterium tuberculosis*, was identified and described on March 24, 1882 by **Robert Koch**. He received the Nobel Prize in physiology or medicine in 1905 for this discovery. Koch did not believe that bovine (cattle) and human tuberculosis were similar, which delayed the recognition of infected milk as a source of infection. Later, this source was eliminated by the pasteurization process. Koch announced a glycerine extract of the tubercle bacilli as a "remedy" for tuberculosis in 1890, calling it 'tuberculin'. It was not effective, but was later adapted as a test for pre-symptomatic tuberculosis.

15.8 HEPATITIS

Hepatitis is a disease which is characterised by injury to the liver. A group of viruses known as the **hepatitis viruses** cause most liver damages worldwide. Hepatitis can also be due to toxins (notably alcohol), other infections or from autoimmune processes. It may occur in a person without any clinical symptoms and the affected person may not feel ill. Symptoms appear when the disease impairs functions of the liver such as removal of harmful substances from blood, regulation of blood composition and production of bile to help digestion.

Hepatitis may of two types, viz, 1. *Acute hepatitis* when it lasts less than 6 months, and 2. *chronic hepatitis* when it persists longer.

15.8.1 Causes

Acute hepatitis may occur due to the following causes:

- Viral Hepatitis: Hepatitis A to E (more than 95% of viral cause), Herpes simplex, adenoviruses.
- Non viral infection: toxoplasma, Leptospira, etc,
- Alcohol,
- Toxins: *Amanita* toxin in mushrooms, Carbon tetrachloride, asafoetida,
- Drugs: Paracetamol, amoxycillin, anti tuberculosis medicines, etc.
- Circulatory insufficiency,
- Pregnancy,
- Auto immune conditions.

Chronic hepatitis may occur due to the following causes:

- Viral Hepatitis: Hepatitis B with or without hepatitis D, Hepatitis C (Hepatitis A and E do not lead to chronic disease)
- Auto immune conditions
- Alcohol
- Drugs,
- Heredity.

15.8.2 Signs and symptoms

Acute Hepatitis may occur with mild symptoms requiring no treatment to serious hepatic failure needing liver transplantation. Acute viral hepatitis are more likely to be without any symptoms in younger people. In individuals showing symptoms the illness may last 2 to 6 weeks.

Initially, nonspecific flu-like symptoms, common to almost all acute viral infections may occur along with malaise, muscle and joint aches, fever, feeling sick or vomiting, diarrhoea and headache. More specific symptoms, which can be present in acute hepatitis from any cause are:

i). profound loss of appetite,

ii). aversion of smoking among smokers,

iii). dark urine,

iv). yellowing of the eyes and skin i.e. jaundice, and

v). abdominal discomfort.

During the early stages of the **Chronic Hepatitis**, majority of patients will show no symptoms, or mild symptoms, abnormal blood tests being the only sign. Depending on the extent of liver damage or the cause of hepatitis, symptoms related to acute hepatitis will appear. Jaundice can be a late feature and may indicate extensive damage. Other features include abdominal fullness from enlarged liver or spleen, low grade fever and fluid retention. Extensive damage and scarring of liver i.e. cirrhosis leads to weight loss, easy bruising and bleeding tendencies.

15.8.3 Types of hepatitis

Hepatitis A

Hepatitis A or infectious jaundice is caused by a picornavirus. It is transmitted by the consumption of contaminated food. It causes an acute form of hepatitis and does not have a chronic stage. The patient's immune system makes antibodies against Hepatitis A that confer immunity against future infection. People with Hepatitis A are advised to rest, drink adequate water and avoid alcohol. A vaccine is available that will prevent infection from hepatitis A for life. Hepatitis A can be spread through personal contact, consumption of raw contaminated food or drinking contaminated water. This occurs primarily in third world countries. Strict personal hygiene and the avoidance of raw and unpeeled foods can prevent infection. Infected people excrete the hepatitis A virus with their faeces two weeks before and one week after the appearance of jaundice. The time between the infection and the start of the illness can run from 15 to 45 days, and approximately 15% of sufferers may experience relapsing symptoms from six months to a year following initial diagnosis.

Hepatitis B

Hepatitis B is caused by a hepadnavirus, which can cause both acute and chronic hepatitis. Chronic hepatitis develops in the 15% of patients who are unable to eliminate the virus after an initial infection. Identified methods of transmission include blood transfusion, (now rare), tattoos (both amateur and professionally done), sexually (through sexual contact), or through contact with blood or bodily fluids, or via mother to child by breast feeding. Blood contact can occur by sharing syringes in intravenous drug use, shaving accessories such as razor blades, or touching wounds on infected persons.

Patients with chronic Hepatitis B have antibodies against Hepatitis B, but these antibodies are not enough to clear the infection that establishes itself in the DNA of the affected liver cells.

A vaccine is available that will prevent infection from Hepatitis B for life. Hepatitis B infections result in 5,00,000 to 12,00,000 deaths per year worldwide due to the complications of chronic hepatitis, cirrhosis, and liver cancer. Hepatitis B is endemic in a number of South-East Asian countries, making cirrhosis and liver cancer big killers.

Hepatitis C

Hepatitis C is caused by a Flavivirus. It can be transmitted through contact with blood (including through sexual contact) and can also cross the placenta. Hepatitis C may lead to a chronic form of hepatitis, culminating in cirrhosis. It can remain asymptomatic for 10-20 years. Patients with Hepatitis C are susceptible to severe hepatitis if they contract either Hepatitis A or B. So, all Hepatitis C patients should be immunized against hepatitis A and hepatitis B if they are not already immune. The virus can cause cirrhosis of the liver.

Alcoholic hepatitis

Ethanol, mostly in alcoholic beverages, is a significant cause of hepatitis. Usually alcoholic hepatitis comes after a period of increased alcohol consumption. Alcoholic hepatitis is characterized by various symptoms, which may include feeling unwell, enlargement of liver, development of fluid in the abdomen, and modest elevation of liver blood tests. Alcoholic hepatitis can vary from mild with only liver test elevation to severe liver inflammation with development of jaundice, prolonged prothrombin time and liver failure. Severe cases are characterized by either obtundation (dulled consciousness) or the combination of elevated bilirubin levels and prolonged prothrombin time; the mortality rate in both categories is 50% within 30 days of onset.

Alcoholic hepatitis is distinct from cirrhosis caused by long term alcohol consumption. Alcoholic hepatitis can occur in patients with chronic alcoholic liver disease and alcoholic cirrhosis. Alcoholic hepatitis by itself does not lead to cirrhosis, but cirrhosis is more common in patients with long term alcohol consumption. Patients who drink alcohol to excess are also more often than others found to have hepatitis C. The combination of Hepatitis C and alcohol consumption accelerates the development of cirrhosis in Western countries.

Other toxins that cause hepatitis are Amatoxin in certain mushrooms, White phosphorus-an industrial toxin, Paracetamol when taken in an overdose, Carbon tetrachloride (a dry cleaning agent), Chloroform, etc.

Obstructive jaundice is the term used to describe jaundice due to obstruction of the bile duct (by gallstones or external obstruction by cancer). If longstanding it leads to destruction and inflammation of liver tissue.

Hepatitis awareness

World Hepatitis Awareness Day (1st October) is an annual event organised by several worldwide hepatitis advocacy groups to raise awareness of infectious hepatitis and demand action to curb the spread of the disease and treat people who are infected.

15.9 HIV and AIDS

AIDS (acquired immune deficiency syndrome) is a condition in humans in which the immune system begins to fail, leaving the body prone to life-threatening opportunistic infections. It is caused by a retrovirus named as human immunodeficiency virus or HIV (Family:Retroviridae; Genus: Lentivirus), which kills or impairs cells of the immune system and progressively destroys the body's ability to fight infections and certain cancers. The term AIDS applies to the most advanced stages of an HIV infection.

HIV primarily infects vital cells in the human immune system such as helper T cells (specifically CD4+ T cells), macrophages and dendritic cells. HIV infection leads to low levels of CD4+ T cells. When CD4+ T cell numbers decline below a critical level, cell-mediated immunity is lost, and the body becomes progressively more susceptible to opportunistic infections. Healthy adults usually have CD4+ T-cell counts of 1,000 or more in the blood. All HIV-infected people with AIDS may have fewer than 200 CD4+ T cells. In addition, many other clinical conditions affect people with AIDS.

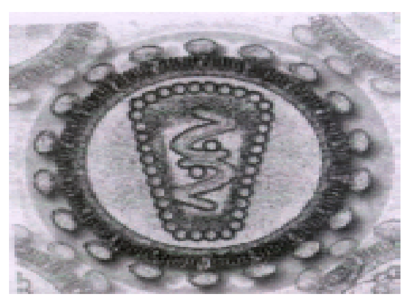


Fig. 15.8: Human Immuno deficiency Virus (HIV)

Two strains of HIV

HIV-1 is thought to have originated in southern Cameroon after jumping from wild chimpanzees (*Pan troglodytes troglodytes*) to humans during the twentieth century. HIV-1 is the virus that was initially discovered and termed LAV.

HIV-2 may have originated from the Sooty Mangabey (*Cercocebus atys*), an Old World monkey of Guinea-Bissau, Gabon, and Cameroon. HIV-1 is more virulent. It is easily transmitted and is the cause of the majority of HIV infections globally. HIV-2 is less transmittable and is largely confined to West Africa.

15.9.1 How is HIV/AIDS transmitted?

HIV is present in the blood, semen, vaginal fluid, pre-ejaculate, or breast milk of infected persons. Within these bodily fluids the virus occurs as both free virus particles and virus within infected immune cells. It is transmitted from one person to another by the following ways:

1. **Sexual Contact:** HIV is spread most commonly by sexual contact with an infected partner. The virus enters the body through the epithelial mucous lining of the sexual organs (vagina, vulva, and penis), rectum, or mouth during sexual activity.
2. **Blood Contamination:** HIV may also be spread through contact with infected blood. However, due to the screening of blood for evidence of HIV infection, the risk of acquiring HIV from blood transfusions is extremely low.
3. **Needles:** HIV is frequently spread by sharing needles, syringes, or drug use equipment with someone who is infected with the virus. Transmission from patient to healthcare worker, or vice-versa through accidental pricking with contaminated needles or other medical instruments, also occurs.
4. **Mother-to-child transmission.** The transmission of the virus from mother to child can occur in the uterus during the last weeks of pregnancy and at childbirth. In the absence of treatment, the transmission rate between the mother and child is 25%. However, where drug treatment and Caesarian section are available, this can be reduced to 1%. Breastfeeding also presents a risk of infection for the baby.

HIV/AIDS cannot be spread through non bloody body fluids such as:

1. Saliva,
2. Sweat,
3. Tears,
4. Casual contact such as sharing food utensils, towels, and bedding,
5. Swimming pools,
6. Telephones,
7. Toilet seats, and
8. Biting by insects (such as mosquitoes).

15.9.2 What are the symptoms of HIV/AIDS?

Most people may develop a flu-like illness within 3-6 weeks after exposure to the HIV virus. Generally, many people do not develop any symptoms at all when they first become infected. In addition, the symptoms that do appear, which usually disappear within a week to a month, are often mistaken for those of another viral infection. The initial temporary symptoms may include:

1. sore throat,
2. fever,
3. headache,
4. malaise, and
5. enlarged lymph nodes.

Persistent or severe symptoms may not appear for 10 years or more, after HIV first enters the body in adults, or within two years in children born with an HIV infection. This "asymptomatic" period (during which no symptoms are observed) of the infection is highly variable from person to person. But, during the asymptomatic period, HIV is actively infecting and killing cells of the immune system. Its most obvious effect is a decline in the blood levels of CD4+ T cells (also called T4 cells), which are the key infection fighters of the body's immune system. The virus initially disables or destroys these cells without causing symptoms.

As the immune system deteriorates, complications begin to surface. The following are the most common complications, or symptoms, of AIDS. However, each individual may experience symptoms differently. Symptoms may include:

1. lymph nodes may remain enlarged for more than three months;
2. lack of energy;
3. weight loss;
4. frequent fevers and sweats;
5. persistent or frequent yeast infections (oral or vaginal);
6. persistent skin rashes or flaky skin;
7. pelvic inflammatory disease that does not respond to treatment;
8. short-term memory loss.

Some people develop frequent and severe herpes infections that cause mouth, genital, or anal sores, or a painful skin viral infection known as **shingles**. Children may have delayed development or failure to thrive.

During the course of the HIV infection, the number of CD4+ T cells gradually decline, although some individuals may have abrupt and dramatic drops in their counts. The symptoms of an HIV infection may resemble other medical conditions. Hence, it is necessary to consult a physician for a diagnosis.

15.9.3 How is HIV/AIDS diagnosed?

Early HIV infection often causes no symptoms, and must be detected by testing a person's blood for the presence of antibodies (disease-fighting proteins) to HIV. These HIV antibodies generally do not reach levels high enough to detect by standard blood tests until one to three months following infection, and may take as long as six months. People exposed to HIV should be tested for HIV infection as soon as possible.

When a person is most likely to be infected with HIV and yet antibody tests are negative, a test for the presence of HIV itself in the blood is used. Repeat antibody testing at a later date, when antibodies to HIV are more likely to have developed, is always recommended. Rapid testing techniques are now available with results in less than 30 minutes.

15.9.4 Are we getting close to finding a vaccine for AIDS?

Even with extensive prevention efforts from multiple government and private agencies, HIV is still spreading worldwide. Many clinical trials are underway in an attempt to develop a vaccine against HIV, which could protect against infection and disease. According to the National Institute of Allergy and Infectious Disease (NIAID), an effective HIV vaccine, given before exposure to HIV, could have a number of possible outcomes including:

1. Preventing infection in most people,
2. Preventing infection in some people,
3. Preparing a person's immune system to block continued infection and eliminate the virus (vaccines against measles, mumps and polio work this way)
4. Delaying or preventing the onset of illness or AIDS

NIAID says that although the goal is to develop a vaccine that is 100 percent effective and protects everyone from infection, even a vaccine that only protects some people could still have a major impact on controlling the epidemic. They are quick to caution, however, that "even if an HIV vaccine is developed, education and other prevention efforts will be needed so that people continue to practice safe behaviours."

The National AIDS Control Organization (NACO), under the Ministry of Health & Family Welfare, is the nodal organization for formulation of policy and implementation of programs for prevention and control of HIV/AIDS in India.

NACO launched the third phase of National AIDS Control Programme in July 2007. The overall goal of NACP III is to halt and reverse the epidemic in India over the next five years by integrating programmes for prevention,care, support and treatment. The specific objectives of NACP III are to reduce the incidence of new infections by:

- Sixty percent in high prevalence states to reverse the epidemic; and
- Forty per cent in the vulnerable states so as to stabilize the epidemic.

Three key focus areas within NACP III which relate directly to children are

- prevention of HIV infection among high-risk populations and adolescents;
- prevention of parent-to-child transmission; and
- treatment of AIDS

The Red ribbon is an international symbol of AIDS awareness that is worn by people all year round and particularly around World AIDS Day to demonstrate care and concern about HIV and AIDS, and to remind others of the need for their support and commitment.

The theme for World AIDS Day 2007 on December 1 is "Stop AIDS in Children"

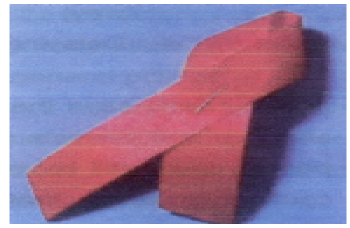


Fig. 15.9: The red Ribbon

15.10 RABIES

Rabies (Latin: rabies, "madness, rage, fury") is a viral zoonotic (transmitted from animals) disease that causes acute encephalitis or inflammation of the brain in mammals. In non-vaccinated humans, rabies is almost invariably fatal after characteristic neurological symptoms have developed, but with prompt vaccination after exposure to the virus, death of the patient may be prevented. There are only six known cases of a person surviving untreated rabies.

The rabies virus is a Lyssavirus. The virus has a bullet-like shape with a length of about 180 nm and a cross-sectional diameter of about 75 nm (1nm = 1/1000?). One end is rounded or conical and the other end is planar or concave. The lipoprotein envelope carries knob-like spikes composed of Glycoprotein G. Spikes do not cover the posterior end of the virus particle. Beneath the envelope is the membrane or matrix protein layer. The core of the virion consists of helically arranged ribonucleoprotein. The genome is unsegmented linear RNA.

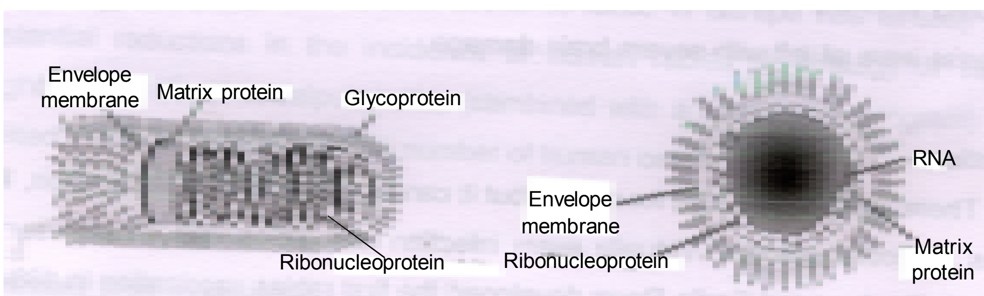


Fig.15.10: Longitudinal and cross-sectional schematic view of rabies virus

15.10.1 Transmission and symptoms

Any mammal, including humans may become infected with the rabies virus and develop symptoms. Most animals can be infected by the virus and can transmit the disease to humans. Infected dogs, cats, bats, monkeys, raccoons, foxes, skunks, cattle, wolves, provide the greatest risk to humans. Rabies may also spread through exposure to infected domestic farm animals, groundhogs, weasels and other wild carnivores. Squirrels, rodents and rabbits are seldom infected.

The virus is usually present in the nerves and saliva of a rabid (rabies infected) animal. The route of infection is usually by a bite. In many cases the affected animal is exceptionally aggressive, may attack without provocation, and exhibits otherwise uncharacteristic behaviour. Transmission may also occur via an aerosol through mucous membranes; transmission in this form may have happened in people exploring caves populated by rabid bats. Transmission between humans is extremely rare, although it can happen through transplant surgery, or, even more rarely, through bites or kisses.

After a typical human infection by bite, the virus directly or indirectly enters the peripheral nervous system. It then travels along the nerves towards the central nervous system. During this phase, the virus cannot be easily detected within the host, and vaccination may still confer cell-mediated immunity to prevent symptomatic rabies. Once the virus reaches the brain, it rapidly causes encephalitis and symptoms appear. It may also inflame the spinal cord producing myelitis.

The period between infection and the first flu-like symptoms is normally two to twelve weeks, but can be as long as two years. Soon after, the symptoms expand to slight or partial paralysis, cerebral dysfunction, anxiety, insomnia, confusion, agitation, abnormal behavior, paranoia, hallucinations, progressing to delirium. The production of large quantities of saliva and tears coupled with an inability to speak or swallow are typical during the later stages of the disease. This can result in "hydrophobia", where the victim has difficulty in swallowing, shows panic when presented with liquids to drink, and cannot quench his or her thirst. The disease itself was also once commonly known as hydrophobia, from these characteristic symptoms. Death almost invariably results two to ten days after the first symptoms. The few humans who are known to have survived the disease were all left with severe brain damage.

15.10.2 How rabies can be prevented ?

There is no known cure for rabies, but it can be prevented by vaccination, both in humans and other animals. Virtually every infection with rabies was a death sentence, until Louis Pasteur and Emile Roux developed the first rabies vaccination in 1885. This vaccine was first used on a human on July 6, 1885 on a nine-year old boy Joseph Meister (1876–1940) who had been mauled by a rabid dog.

The vaccine consisted of a sample of the virus harvested from nervous tissue of infected, dead rabbits. The virus was weakened by allowing it to dry. Similar nerve tissue-derived vaccines are still used now in some countries. Though much cheaper than modern cell culture vaccines, they are not as effective and carry a certain risk of neurological complications.

The human diploid cell rabies vaccine (H.D.C.V.) was started in 1967. Human diploid cell rabies vaccines are made using the attenuated Pitman-Moore L503 strain of the virus. Human diploid cell rabies vaccines have been given to more than 1.5 million humans as of 2006. Newer and less expensive purified chicken embryo cell vaccine, and purified Vero cell rabies vaccine are now available.

New Zealand and Australia have never had rabies. However, in Australia, the Australian Bat Lyssavirus occurs normally in both insectivorous and fruit eating bats (flying foxes) from most mainland states. Scientists believe it is present in bat populations throughout the range of flying foxes in Australia.

Rabies and dogs

Three stages of rabies are recognized in dogs. The first stage is a one to three day period characterized by behavioral changes and is known as the prodromal stage. The second stage is the excitative stage, which lasts three to four days. It is this stage that is often known as furious rabies due to the tendency of the affected dog to be hyperreactive to external stimuli and bite at anything near. The third stage is the paralytic stage and is caused by damage to motor neurons. Incoordination is seen due to rear limb paralysis and drooling and difficulty swallowing is caused by paralysis of facial and throat muscles. Death is usually caused by respiratory arrest.

Fig.15.11

15.11 NUTRITION

Nutrition is the way our body takes in and uses food. Foods that provide nutrition are called **nutrients**. Nutrients give us energy, brings growth, help repair body tissues, and regulate body functions. Therefore, each nutrient can be vital to our health.

There are six different types of nutrients. They are carbohydrates, proteins, fats, vitamins, minerals and water. Carbohydrates (essentially sugars and starches) supply us with energy while fibres keep the guts clean and healthy. Proteins build up and repair our body muscles, and make up hormones and enzymes. Fats are required for proper functioning of cells and the whole body. They also represent stored reserve food. The vitamins and minerals are so important that the proper functioning of the human body is affected if they are not present in the proper quantity. Water is required for proper functioning of all body parts. It is also required to flush out the waste products and remove the toxins from our body.

We need energy for all activities, including riding a bike, taking a test in school, or sleeping. The energy we use can also be called calories. A **calorie** is a measure of energy content in one or more foods. The more calories we eat, the more energy we will have. We get the calories from some of the nutrients.

A **balanced diet** is a combination of the various essential nutrients in the proper proportion. Carbohydrates are found in starches, sugars and fibres. Unrefined starchy foods like rice, bread, and potatoes in their skin are considered to be the best as they contain more vitamins, contain fibre and regulate the release of energy. Refined sugar and products containing it are termed as “empty calories” because they do not contain any nutrients. They only have energy giving properties. In contrast natural sugars present in fruits and vegetables are good for health. These carbohydrates should make up at least 40-50 percent of our diet.

Next on the list are proteins, the builders of muscle. Fish, milk, milk products, beans nuts, grains, soy and wheat germ all contain protein. These should be consumed in such a way that they account for about 20-30 percent of your diet.

Fats should not be excluded from the diet. What we need to do is to ensure that saturated fats be used sparingly. Polyunsaturated fats, which we get from different sources including fish oil, are considered to be more beneficial. Milk, butter, cheese, soy oil, olive oil, all contains fats. Fats should account for at least 30 percent of our diet.

Vitamins are vital for the human body for fighting infection and aiding bone growth, promoting cell production and boosting the immune system. Vitamin A and Riboflavin are found in milk, butter, fish and vegetables, thiamine in whole grain nuts and seeds, Niacin is found in milk, Vitamin B6 is found in spinach, broccoli and bananas, Vitamin C is found in green vegetables and citrus fruits, vitamin D is found in milk, Vitamin E is found in vegetables, rice, and bran, and Vitamin K is found in wheat germ, vegetable oil and whole grain bread and cereal.

Minerals like calcium which are necessary for bone growth and healthy teeth, copper which is require for the metabolism of iron. Magnesium which is involved with the functioning of the nerves and spinal cords, and sodium, potassium, phosphorous and zinc can be found either in milk, grains, vegetables, fruits, cereals, yogurt or wheat germ. Water is a vehicle for mixing of food with enzymes for transport of nutrients in various parts of the body and elemination of wastes etc. Drinking 8 glasses of water a day is good for health.

So, nutrition and a balanced diet contribute towards our good health. The body metabolism is increased with the right kind of breakfast foods. Regular moderate exercise will ensure that you look good, at keep in good healt ad feel good.

15.11.1 Malnutrition

Malnutrition is a general term used for a condition caused by an improper or insufficient diet. It most often refers to **undernutrition** resulting from inadequate consumption, poor absorption, or excessive loss of nutrients. The term can also encompass **overnutrition**, resulting from overeating or excessive intake of specific nutrients. An individual will experience malnutrition if the appropriate amount of, or quality of nutrients comprising a healthy diet are not consumed for an extended period of time. An extended period of malnutrition can result in starvation, disease, and infections.

Malnutrition is the lack of sufficient nutrients to maintain healthy body functions and is typically associated with extreme poverty in economically developing countries. Malnutrition as the result of inappropriate dieting, overeating or the absence of a "balanced diet" is often observed in economically developed countries (eg. as indicated by increasing levels of **obesity**).

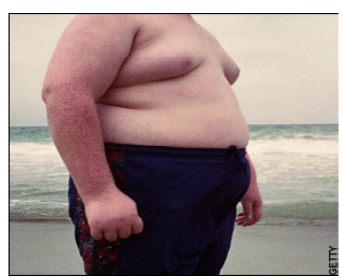


Fig. 15.12: An obese

Most commonly, malnourished people either do not have enough calories in their diet, or are eating a diet that lacks protein, vitamins, or trace minerals. Common forms of malnutrition include **protein-energy malnutrition** (PEM) and **micronutrient malnutrition**. PEM refers to inadequate availability or absorption of energy and proteins in the body. Malnutrition are commonly referred to as **deficiency diseases**.

As of 2006, malnutrition continues to be a worldwide problem. According to the Food and Agriculture Organization (FAO) of the United Nations, "850 million people worldwide were undernourished in 1999 to 2005, the most recent years for which figures are available" and the number of malnourished people has recently been increasing. An orange ribbon is used to raise awareness of malnutrition in the world.

15.12 PROTEIN-ENERGY MALNUTRITION (PEM)

15.12.1 Kwashiorkor

Kwashiorkor is a type of malnutrition with controversial causes, but it is commonly believed to be caused by insufficient protein intake. It usually affects children aged 1 – 4 years, although it also occurs in older children and adults. Jamaican pediatrician **Cicely D. Williams** introduced the name '**Kwashiorkor'** in her article in the international scientific journal **Lancet** in 1935. When a child is breast-fed, it receives certain amino acids vital to growth from the mother's milk. When the child is weaned, if the diet that replaces the milk is high in starches and carbohydrates, but deficient in protein, as is common in some parts of the world where the bulk of the diet consists of starchy food, or where famine has struck, the child may develop kwashiorkor.

Derivation of kwashiorkor

The name is derived from one of the languages of coastal Ghana and means "one who is physically displaced" reflecting the development of the condition in the older child who has been weaned from the breast milk.

Symptoms of **kwashiorkor** include

1. a swollen abdomen known,as a pot belly,
2. discoloration of the hair, and
3. depigmented skin.

Fig .15.13: Symptoms of kwashiorkor

The swollen abdomen is generally due to two causes: First cause is the accumulation of fluid in the peritoneal cavity. It is also thought to be attributed to the effect of malnutrition on lowering plasma proteins in blood, resulting in increased osmotic movement of water through the capillary wall. A second cause may be due to a grossly enlarged liver due to fat deposition.

Victims of kwashiorkor fail to produce antibodies (disease-fishing substances of the body) following vaccination against diseases including **diphtheria** and **typhoid**.

Generally, the disease can be treated by adding food energy and protein to the diet; however, mortality can be as high as 60% and it can have a long-term impact on a child's physical growth and, in severe cases, affect mental development.

Possible causes of kwashiorkor

It is now accepted that protein of kwashiorkor deficiency, in combination with energy and micronutrient deficiency, is an important cause of kwashiorkor.

Ignorance of nutrition can be a cause. Parents who feed their child mostly carbohydrate foods may fail to recognize malnutrition because of the oedema caused by the syndrome and the child may appear well-nourished despite the lack of dietary protein.

Other protein malnutrition syndromes include **marasmus** and **cachexia**, although the latter is often caused by underlying illnesses.

15.12.2 Marasmus

Marasmus is a form of severe protein-energy malnutrition characterised by energy deficiency. In dry climates marasmus is the more frequent disease associated with malnutrition.

A child with marasmus looks emaciated and the body weight may reduce to less than 80% of the normal weight for that height.

Marasmus occurs more frequently in infants below one year whereas kwashiorkor usually occurs after 18 months of age.

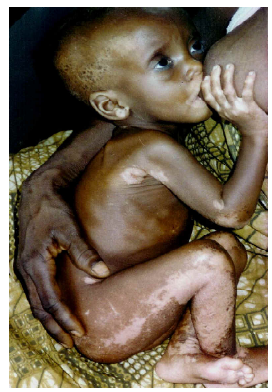


Fig.15.14: Marasmus signs

Signs

The common characteristic signs of protein-energy malnutrition are dry skin, loose skin folds on the buttocks and armpit, drastic loss of adipose tissue from normal areas of fat deposits like buttocks and thighs etc. The afflicted persons are often fretful, irritable, and voraciously hungry. There may be alternate bands of pigmented and depigmented hair, or flaky paint appearance of skin due to peeling.

15.13 SCURVY

Scurvy is a deficiency disease that results from insufficient intake of vitamin C, which is required for proper collagen synthesis in humans. The chemical name of vitamin C, ascorbic acid, is derived from the Latin name of scurvy, **scorbutus**. Scurvy is due to a prolonged deficiency of vitamin C in the diet and takes about 4 to 8 months to develop clinical signs.Scurvy leads to the formation of liver spots on the skin, spongy gums, and bleeding from all mucous membranes. The spots are most abundant on the thighs and legs, and a person with the ailment looks pale, feels depressed, and is partially immobilized. In advanced stages of scurvy there are open, suppurating wounds and loss of teeth. Untreated scurvy is invariably fatal. However, since full recovery is achieved with the resumption of normal vitamin C intake, death from scurvy is rare in modern times.

Fig.15.15 :Scorbutic gums of a patient

Fig.15.16: Girl with a scorbutic tongue

In infants, scurvy is sometimes referred to as **Barlow's disease,** named after Sir Thomas Barlow (1845–1945), a British physician who described it.

Scurvy was at one time common among sailors, pirates and others who were on ships that were out to sea longer than perishable fruits and vegetables could be stored and by soldiers who were similarly separated from these foods for extended periods. It was described by **Hippocrates** (c. 460 BC–c. 380 BC). Its cause and cure have been known in many native cultures since prehistory. For example, in 1536, the French explorer **Jacques Cartier**, exploring the St. Lawrence River, used the local natives' knowledge to save his men who were dying of scurvy. He boiled the needles of the arbor vitae tree (Eastern White Cedar) to make a tea that was later shown to contain 50 mg of vitamin C per 100 grams. However it was a Scottish surgeon in the British Royal Navy, **James Lind** (1716–1794) who first proved it could be treated with citrus fruit in experiments he described in his 1753 book, *A Treatise of the Scurvy*.

15.13.1 Symptoms

Some important symptoms of scurvy are -

i) gradual weakening and muscle pain,
ii) dark purplish spots on tongue, skin on legs due to internal bleeding,
iii) bleeding from all mucous membranes including conjunctiva,
iv) Opening of scars and bone fractures that had healed many years before,
v) spongy tender gums, often leading to tooth loss,
vi) sunken eyes, and
vii) pale skin,

15.13.2 Prevention

Scurvy can be prevented by a diet that includes certain citrus fruits such as oranges or lemons. Other good sources of vitamin C are fruits such as Indian gooseberry (Heikru), guava, papaya, passion fruit and strawberries. It can also be found in some vegetables, such as tomatoes, capsicum, broccoli (greenish cauliflower), potatoes, cabbage, spinach and papaya, as well as some pickled vegetables.

15.13.3 Food preparation

Vitamin C in most food sources decomposes during the cooking of food. Normal boiling water at 100°C is not hot enough to cause any significant destruction of the nutrient, which only decomposes at 190°C. However, vitamin C doesn't leach in all vegetables at the same rate; research shows broccoli seems to retain more than any other. Research has also shown that fresh-cut fruit don't lose significant nutrients when stored in the refrigerator for a few days.

Activity 15.1 collect some locally available vitamin C rich fruits and vegetables. You can use the list from the following table.

The following table shows the relative abundance of Vitamin C in different sources.

Table 15.1: Relative abundance of Vitamin C in some fruits and vegetables.

Food sources			Vitamin content
Common name	**Scientific name**	**Local name**	**(mg / 100g)**
Indian gooseberry	*Emblica officinalis*	**Heikru**	720
Red /Chinese Date	*Ziziphus jujuba*	**Boroi achouba**	500
Apple Guava	*Psidium guajava*	**Pungdon**	100
Lychee	*Litchi chinensis*	**Litchi**	70
Papaya	*Carica papaya*	**Awathabi**	60
Strawberry	*Fragaria orientalis*	**Heijampet**	60
Orange	*Citrus sinensis*	**Komla**	50
Lemon	*Citrus limon*	**Champra**	40
Cauliflower	*Brassica oleracea* var.*botrytis*	**Kobi thamchet manbi**	40
Passion fruit	*Passiflora edulis*	**Sitaphon**	30
Mustard	*Brassica campestris*	**Hangam**	30
Mango	*Mangifera indica*	**Heinou**	20

15.14 GOITRE

G**oitre**, (or **goiter)**, also called a **bronchocele**, is a disease characterised by enlargement of the thyroid gland seen as a prominent swelling in the neck, just below **Adam's apple** or larynx, due to an enlarged thyroid gland. It is most pronounced in simple goitre, which is caused by prolonged iodine defficiency in the diet. More common is toxic goitre or hyperthyroidism, caused by overactivity of the thyroid gland. Goitre was previously common in many areas that were deficient in iodine in the soil. The condition now is practically absent in affluent nations, where table salt is supplemented with **iodine**. However, it is still prevalent in India, Central Asia and Central Africa.

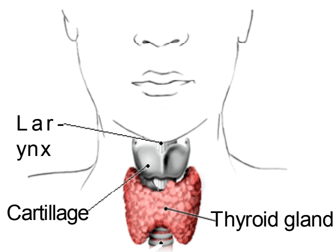


Fig. 15.17: Thyroid gland

Fig.15.18: A goitre patient

15.14.1 Causes

Important causes of goitre are:

- Prolonged Iodine deficiency in diet.
- Hashimoto's thyroiditis, an autoimmune disease characterized by inflammation of the gland.
- Graves-Basedow disease, a thyroid disorder characterized by hyperthyroidism.
- Inborn errors of thyroid hormone synthesis, causing congenital hypothyroidism
- Thyroid cancer

15.14.2 Symptoms

- Swelling of the thyroid gland, which may cause breathing and swallowing problems if the goitre is large enough and presses on the windpipe and oesophagus.
- Diminished power of concentration and problems with memory may also occur.
- Depression, emotional upsets and irritability is observed.
- Feeling tired and sleeping excessively.
- Increased appetite.
- Sweaty moist palms.
- Rapid heartbeat.
- Deteriorating or slowing growth rate.
- Dry, thickened skin and brittle hair.
- Slow reflexes.

Famous goitre sufferers

President **George H. W. Bush** and his wife **Barbara Bush** both were diagnosed with Graves disease and enlarged thyroid glands, within 2 years of each other. In the president's case, the disease caused hyperthyroidism and cardiac dysrhythmia. North Korean Communist leader **Kim Il-sung** (1912 – 1994), was also a goitre patient.

15.15 Night blindness (Nyctalopia)

Nyctalopia (Greek for "*night blindness*") is a condition making it difficult or impossible to see in relatively low light. It is a symptom of several eye diseases. Night blindness may exist from birth, or be caused by injury or vitamin A deficiency.

15.15.1 What are the causes of night blindness?

The most common cause of nyctalopia is deficiency of retinol, or vitamin A, found in fish oils, liver and dairy products. The retina is well supplied with an important chemical substance called rhodopsin, or "visual purple". Light falling on the retina brings about certain chemical changes in the rhodopsin and other substances present in the rods and cones. These changes occur very rapidly, but large quantities of vitamin A are needed to bring this about. If there is any marked deficiency of vitamin A, night blindness may occur. This can usually be corrected by administering suitable amounts of vitamin A in the diet.

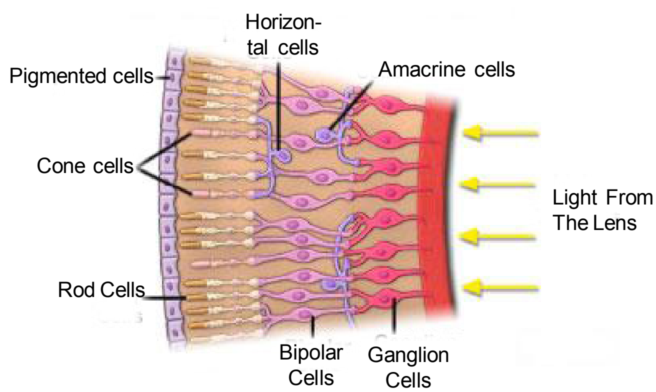


Fig. 15.19: Structure of the retina

The another common cause of nyctalopia is retinitis pigmentosa, a disorder in which the rod cells in the retina gradually lose their ability to respond to the light. Patients suffering from this genetic condition have progressive nyctalopia and eventually their daytime vision may also be affected. In X chromosome-linked congenital stationary night blindness, from birth the rods either do not work at all, or work very little, but the condition doesn't get worse.

The outer area of the retina is made up of more rods than cones. The rod cells are the cells that enable us to see in poor illumination. This is the reason why loss of side vision often results in night blindness. Individuals suffering from night blindness not only see poorly at night, but also require some time for their eyes to adjust from brightly lit areas to dim ones. Contrast vision may also be greatly reduced. Unless vitamin A intake is increased, the condition may get worse, especially when children also suffer from diarrhoea and other infections.

Historically, nyctalopia, also known as **moonblink**, was a temporary night blindness believed to be caused by sleeping in moonlight in the tropics.

Other causes of night blindness are-

i). Cataracts, which are cloudy areas in the lens of the eye,

ii). Certain medications, and

iii). Birth defects

Night blindness may result due to certain disorders that affect the ability of the body to absorb vitamin A, e. g.

i.). Liver disorders,

ii). Surgery on the pancreas or liver, and

iii). Intestinal conditions

15.15.2 What are the signs and symptoms of night blindness?

The main symptom of night blindness is difficulty or inability to see in low light or darkness. While driving, this may also occur a few seconds after the bright headlights of an oncoming vehicle have passed. Other associated symptoms include dry eyes, blurred vision, etc.

Eating a diet with adequate amounts of Vitamin A may help prevent night blindness. Foods sources or vitamin A are liver, fish-liver orl, butter, fortified margarine, etc. B-carotene or provitamin A is present in yellow, yellowish-red and green vegetables and fruits.

15.16 Rickets

Ricket is a softening of the bones in children potentially leading to fractures and deformity. Rickets is among the most frequent childhood diseases in many developing countries. The predominant cause is **vitamin D deficiency**, but lack of adequate **calcium** in the diet may also lead to rickets. Although it can occur in adults, the majority of cases occur in children suffering from severe malnutrition, usually resulting from famine or starvation during the early stages of childhood.

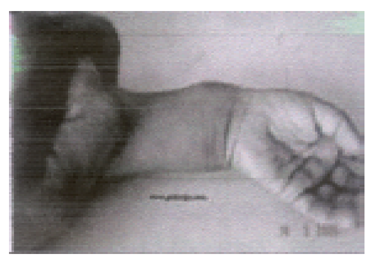


Fig.15.20:"rachitis" or "wrist widening" of rickets

Osteomalacia is the term used to describe a similar condition occurring in adults, generally due to deficiency of vitamin D. The word "rickets" comes from the word "rachitis," meaning wrist (and also spine), as wrist deformities are common in rickets.

Those at higher risk for developing rickets include:

- Breast-fed infants whose mothers are not exposed to sunlight
- Breast-fed infants who are not exposed to sunlight
- Individuals not consuming fortified milk,

Individuals with red hair have a decreased risk for rickets due to their greater production of vitamin D in sunlight.

Vitamin D is required for proper calcium absorption from the gut. In the absence of vitamin D, dietary calcium is not properly absorbed, resulting in hypocalcemia (low calcium level in blood), leading to skeletal and dental deformities, etc.

15.16.1 Signs and symptoms

Signs and symptoms of rickets include:

i). Bone pain or tenderness,
ii). dental problems,
iii). muscle weakness,
iv). bones with increased tendency for fractures,
v). Skeletal deformity, e.g. bowed legs in toddlers;
vi). cranial, spinal, and pelvic deformities;
vii). Growth disturbance;
viii). Hypocalcemia (low calcium level in the blood),
ix). Tetany or uncontrolled muscle spasms, and
x). Craniotabes (soft skull).

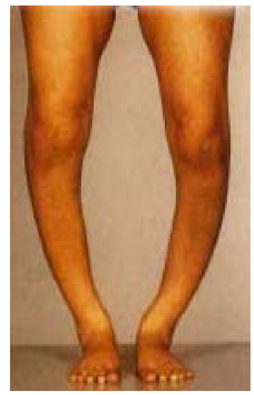


Fig.15.21: Rickets

15.16.2 Prevention

A sufficient amount of ultraviolet in sunlight each day and adequate supplies of calcium and phosphorus in the diet can prevent rickets. Darker-skinned babies need to be exposed longer to the ultraviolet rays. The replacement of vitamin D has been proven to correct rickets using these methods of ultraviolet light therapy and medicine.

Sufficient vitamin D levels can also be achieved through dietary supplementation. Vitamin D3 (cholecalciferol) is the preferred form since it is more readily absorbed than vitamin D2. Recommendations are for 200 international units (IU) of vitamin D a day for infants and children. Most dermatologists recommend vitamin D supplementation as an alternative to unprotected ultraviolet exposure due to the increased risk of skin cancer associated with sun exposure.

An infant child should be breast fed up to the 9th month. However, the breast-fed infants may not get enough vitamin D from breast milk alone. For this reason, it is recommended that infants who are exclusively breast-fed receive daily supplements of vitamin D from age of 2 months until they can start drinking vitamin D-fortified milk or formula a day. The foods of nursing mother also must have adequate vitamins. The food must contain a plenty of fresh milk from a cow fed on green grass, also butter, cream and yolk of egg but not any excess of carbohydrate. Plenty of sunlight, fresh air and muscular exercise are essential.

Points to remember

* Health is a state of complete physical, mental and social well-being.
* The biological term for health is homeostasis, which is an organism's ability to efficiently respond to destablising effects of various internal as well as external factors.
* Mental health is a concept that refers to a human individual's emotional and psychological well-being.
* Health of a person may become degraded due to lack of adequate nutritious food, lack of physical exercise, unfavorable environmental conditions, diseases, etc.
* A disease is an abnormal condition of an organism that impairs bodily functions.
* A symptom is a sensation or change in body functions experienced by a patient.
* A sign is the evidence of the presence of a disease or disorder.
* An infectious disease is a disease resulting from the presence of pathogenic microbial agents, including virus, bacteria, fungi, protozoa, etc.
* Infectious diseases are usually known as contagious diseases (also called communicable diseases) due to their potentiality of transmission from one person or species to another.
* Contagious diseases are transmitted by aerosols produced by coughs and sneezes, by bites of insects or other carries of the disease and from contaminated water or food (possibly by faeces or urine in the sewage), etc.
* Diarrhoea is a common disease characterized by an increase in the frequency of bowel movements with a decrease in the form of stool (greater looseness of stool).
* The looseness of stool in diarrhoea is causd by increased water in the stool.
* Acute diarrhoea lasts a few days or up to a week, whereas chronic diarrhoea always lasts more than three weeks.
* Viral gastroenteritis or viral infection of the stomach and the small intestine is caused by calcivituses.
* Pathogenic strains of *E. coli* cause diarrhoea either by producing toxins or by invading and inflaming the lining of the small intestine and the colon, thus causing enterocolitis.
* Dehydration occurs when there is excessive loss of fluids and minerals (electrolytes) from the body due to Diarrhoea, with or without vomiting.
* Oral rehydration solutions (ORS) are liquids that contain a carbohydrare (glucose or rice syrup) and electrolytes.
* Typhoid, or enteric fever is a disease caused by infection with *Salmonella typhi*.
* Typhoid fever is characterized by continuous fever as high as (104°F), profuse sweating, rosy spots on the lower chest and abdomen, etc.

* Typhoid infection may be prevented by using water that has been boiled or chemically disinfected.
* The most serious forms of malaria ar caused by *Plasmodium falciparum* and *Plasmodium vivax*.
* Symptoms of malaria include fever, shivering, arthralgia (joint pain), vomiting, amaemia caused by haemolysis (destructing of blood cells), haemoglobinuria, and convulsions.
* Tuberculosis is a common and infections disease caused by a bacteria known as *Mycobacterium tuberculosis*.
* Symptoms of tuberculosis include chest paint, coughing up blood, and a productive, prolonged cough for more than three weeks.
* Hepatitis A or infectious jaundice is caused by a picomavirus, which is transmitted through consumption of contaminated food and water.
* Hepatitis B is caused by a hepadnavirus, which can cause both acute and chronic hepatitis.
* Hepatitis C is caused by a Flavivirus transmitted through contact with blood (including through sexual contact).
* AIDS (acquired immune deficiency syndrome) is a condition in humans in which the immune system begins to fail, leaving the body prone to life-threatening opportunistic infections.
* Rabies is a viral *zoonotic* disease (transmitted from animals) that causes acute encenphalitis or inflammation of the brain in mammals.
* Hydrophobia is a characteristic symptom of rabies disease.
* Nutrition is the way our body takes in and uses food.
* Balanced diet is a combination of the various essential nutrients in the proper proportion.
* Malnutrition is the term used for a condition caused by improper or insufficient diet.
* Kwashiorkor and marasmus are the two main diseases of protein energy mal nutrition.
* Scurvy is a deficiency disease resulting from insufficient intake of vitamin C.
* Goitre is disease characterised by a enlargement of the thyroid gland in the neck due to insufficient intake of iodine.
* Night blindness is a condition making dificult or impossible to see in relatively low light. It is caused by deficiency of vitamin A.
* Ricket is a vitamin D deficiency disease found in children.

EXERCISES

1. *What is health?*
2. *What is a disease? What are its causes?*
3. *Define a symptom. Give two points of difference between symptom and sign of a disease.*
4. *Define diarrhoea. What are the signs of diarrhoea?*
5. *What is viral gastroenteritis? What are its symptoms?*
6. *Name the organisms which cause the following diseases: (a) Traveler's diarrhoea; (b) Food poisoning. (c) Enterocolitis.*
7. *What is dehydration? When does it occurs?*
8. *What are the conditions when a doctor should be consulted to treat a diarrhoea patient?*
9. *Which organism causes typhoid or enteric fever? What are its symptoms?*
10. *What are the preventive measures for typhoid or Enteric fever?*
11. *What is malaria? What are its symptoms? Give the name of organisms causing malaria? Which organism spreads the disease?*
12. *Which malarial parasites cause severe and chronic malaria?*
13. *What is tuberculosis? Which organism causes the disease? What are symptoms of tuberculosis?*
14. *How is tuberculosis transmitted from one person to another? How can we protect ourselves against infection with tuberculosis?*
15. *What is Hepatitis? What are the common causes of Hepatitis? What are the symptoms of acute hepatitis?*
16. *Write briefly on (i) Hepatitis A, (ii) Hepatitis B, and (iii) Hepatitis C*
17. *Write what you know about Alcoholic Hepatitis.*
18. *Write what you know about HIV/AIDS?*
19. *What are the ways through which a person can become infected with HIV?*
20. *What are the initial temporary symptoms of HIV infection?*
21. *What are the common symptoms that may appear in an HIV/AIDS infected person with weakened immune system?*
22. *What s Rabies? Name the organism that causes Rabies. How can we protect ourselves against Rabies infection?*
23. *Define nutrition.*
24. *What are nutrients? What are the different types of nutrients?*
25. *What is meant by a balanced diet? Write down the approximate proportions of various nutrients in a balanced died?*
26. *What is malnutrition? Distinguish between undernutrition and overnutrition.*
27. *Define Protein Energy Malnutrition and Micronutrient malnutrition.*
28. *Differentiate between Kwashiorkor and Marasmus.*
29. *What is Scurvy? What are its symptoms.*
30. *What is goitre? Write down its causes and symptoms.*
31. *Write the causes of night blindness. How can we prevent night blindness ?*
32. *Define Rickets. What are its causes and symptoms? Mention one preventive measure for Rickets.*

CHAPTER – 16

Transportation of substances inside the body

If we put a few drops of blue ink into water in a glass tumbler and leave it undisturbed, we will see that all the water in the glass has become blue after a few minutes. Also if we put a spoonful of common salt in a glass of water and leave it undisturbed, we will notice that the salts crystals have dissolved and the water in the whole glass has become salty. Further, we will notice that when a tea bag is placed in a cup of hot water, the reddish-brown tea in solution will automatically pass out through the material of the tea bag, and we will get a cup of tea after a few minutes even without touching the bag. Another interesting day to day observation is that the smell of a tasty curry being prepared in the neighbour's kitchen reaches us.

16.1 What is diffusion?

All the above observations are possible only because the particles, or molecules, of the different substances have a tendency to distribute themselves throughout the medium or available space. This tendency of molecules of solids, liquids and gases to get distributed throughout the available space is known as **diffusion**. It is due to the fact that the molecules are in a state of perpetual motion due to the kinetic energy present in them. This perpetual motion, also known as **Brownian movement**, results in the net movement of the substances from a place of their higher concentration of the place where they are in a lower concentration. The movement of particles continues even at the point of equilibrium, when they have occupied all available space in the medium. So, the particles still have the tendency to occupy more available space. Therefore, diffusion or observable movement of particles from one place to another can take place only when there is a difference in the concentration of a substance in the different parts of the system.

The term diffusion is derived from the Latin verb *diffundere* which means "to spread apart" but can also mean "to pour away" or "give vent to". According to **Fick's laws of diffusion**, derived by Adolf Fick in the year 1855, there are two usages of the term diffusion. Fick's first law deals with the passage of a gas through a membrane or porous material, while Fick's second law is concerned with the dispersion of particles that occur when there are different concentrations within a container.

Activity 16.1 Experiment to demonstrate diffusion

Take a wide glass tube, two corks, some cotton wool soaked in ammonia solution and some red litmus paper. Close one end of the wide glass tube with a cork. The litmus paper can be hung with a thread within the tube. Plug the other end of the tube using the wet cotton wool and the other cork. Note down what you observe.

It will be observed that the red litmus papers turn blue.

This is because the ammonia molecules travel by diffusion from the higher concentration in the cotton wool to the lower concentration in the rest of the glass tube. As the ammonia , which is alkaline, reaches the other end of the tube by diffusion, the red litmus papers turn blue.

By changing the concentration of ammonia, the rate of colour change of the litmus papers can also be changed.

16.2 Diffusion across Membranes

In the **living systems**, diffusion is a main form of transport within cells and across cell membranes. Metabolism and respiration rely in part upon diffusion in addition to bulk or active processes. For example, in the alveoli of mammalian lungs, due to differences in partial pressures across the alveolar-capillary membrane, oxygen diffuses into the blood and carbon dioxide diffuses out. Lungs contain a large surface area to facilitate this gas exchange process.

Diffusion in the living system occurs in the following ways, viz. i) Simple diffusion, ii) Osmosis, and iii) Active transport.

16.2.1 Simple diffusion

The term simple diffusion refers to a process whereby a substance passes through a membrane without the aid of an intermediary such as an integral membrane protein. The force that drives the substance from one side of the membrane to the other is the force of diffusion. In order for substances to pass through a cell membrane by simple diffusion it must penetrate the hydrophobic core of the phospholipid bilayer. The types of molecules that can do this are themselves substantially hydrophobic in nature such as carbon dioxide, oxygen or ethanol. Simple diffusion of molecules does not require expenditure of energy. Hence, it is also known as **passive transport**.

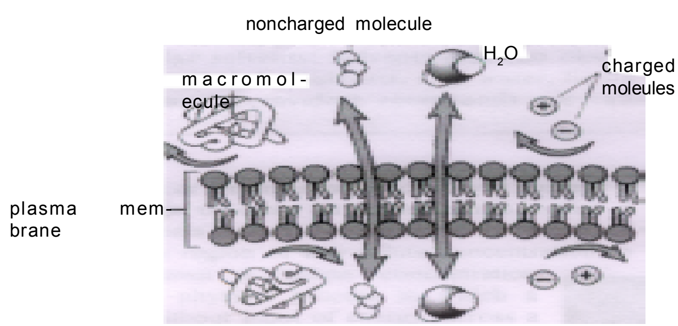


Fig. 16.1: Simple diffusion through the cell membrane

Water, oxygen, carbon dioxide, ethanol and urea are example of molecules that readily cross cell membranes by simple diffusion. They pass either directly through the lipid bilayer or through pores created by certain integral membrane proteins. The relative rate of diffusion is roughly proportional to the concentration gradient across the membrane. For example, oxygen concentrations are always higher outside than inside the cell and oxygen therefore diffuses down its concentration gradient into the cell; the opposite is true for carbon dioxide.

Rate of transport for a particular molecule by simple diffusion across a cell membrane is also proportional to the lipid solubility or hydrophobicity of that molecule. Oxygen, carbon dioxide and ethanol are highly lipid soluble and therefore diffuse across the bilayer almost as if it were not there.

So what about water? We know that water crosses cell membranes very readily – the amount of water that diffuses back and forth across the membrane of the red blood cell every second is roughly equivalent to 100 times the volume of the whole cell. Water, however, is not at all lipid soluble. However, it seems that the water molecule is small enough and has sufficient kinetic energy that it can diffuse through the lipid bilayer with minimal interference. Certain other small, uncharged, hydrophilic molecules, urea, for example, diffuse across lipid bilayers with relative ease.

Ions and charged molecules diffuse cross the lipid bilayer of cell membranes very, very poorly. Their charge, either positive or negative, causes them to be repelled from like charges in the cell membrane. Additionally, their charge causes them to electrically bond water molecules, causing them to be hydrated and effectively quite large.

To summarize, many small and uncharged molecules diffuse across the plasma membrane by virtue of their kinetic energy of motion. In most cases, such molecules are hydrophobic, nonpolar and can dissolve in and out of membrane lipid. Charged molecules are not easily transported across the plasma membranes by simple diffusion. There are other means to facilitate their transport.

Polar and nonpolar solvents: Solvents that can dissolve and split solute molecules into charged ions are polar solvents, e.g. water, liquid ammonia. Solvents that can dissolve only nonpolar covalent compounds are called non-polar solvents, e.g. Benzene.

16.2.2 Osmosis

A partition or a membrane which allows passage of certain small molecules while preventing passage of other larger molecules across it is called a **semi-permeable membrane**. **Osmosis** is the spontaneous movement of watermolecules across a semi-permeable membrane from a region of low solute concentration to a solution with a high solute concentration, down a solvent concentration gradient. It is a physical process in which a solvent moves, without input of energy, across a semi permeable membrane (permeable to the solvent, but not the solute) separating two solutions of different concentrations. Osmosis releases energy, and can be made to do work, as when a growing tree-root splits a stone.

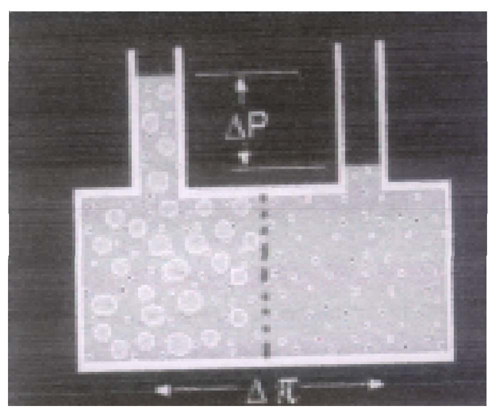


Fig.16.2: Osmosis

Net movement of solvent is from the less-concentrated (hypotonic) to the more-concentrated (hypertonic) solution, which tends to reduce the difference in concentrations.

This effect can be countered by increasing the pressure of the hypertonic solution, with respect to the hypotonic. The osmotic pressure is defined to be the pressure required to maintain equilibrium, with no net movement of solvent. Osmotic pressure depends on the molar concentration of the solute but not on its identity. Osmosis is thus the result of diffusion across a semi-permeable membrane(Fig.16.3).

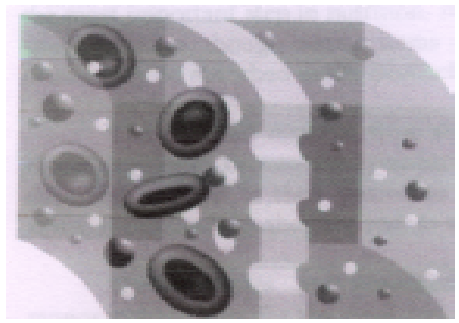


Fig.16.3: Semi-permeable membrane

Now let us try the following activities

Activity 16.2

Osmosis with an egg

Let us take an egg and remove the egg shell by placing it in dilute hydrochloric acid (HCl). The egg shell is made up mainly of calcium carbonate. A thin outer skin now encloses the egg. Put the egg in pure water and observe after 5 minutes. You will observe that the egg shrinks because water passes out of the egg solution in the salt solution because the salt solution is more concentrated.

Activity 16.3

Osmosis with Raisins and Apricots

Put dried raisins or apricots in pure water and leave them for some time. Then place them into a concentrated solution of sugar or salt. Each gains water and swells when placed in pure water. but, when they are placed in the concentrated solution it loses water, and consequently shrinks.

Osmosis is important in biological systems as many biological membranes are semipermeable. In general, these membranes are impermeable to organic solutes with large molecules, such as polysaccharides, while permeable to water and small, uncharged solutes. Permeability may depend on solubility properties, charge, solute size, etc. Water molecules travel through the plasma cell membrane tonoplast (vacuole) or protoplast in two ways, either by diffusing across the phospholipid bilayer directly, or via aquaporins (small transmembrane proteins). Osmosis provides the primary means by which water is transported into and out of cells. The turgor pressure of a cell is largely maintained by osmosis, across the cell membrane, between the cell interior and its relatively hypotonic environment.

16.2.3 Active Transport

When molecules move across a membrane regardless of the concentration gradient, it is known as active transport. During active transport, the molecules move against the concentration gradient, i.e. they move from the region of their higher concentration of the region of their lower concentration. Such movement requires energy (hence the term "active"), which is provided by ATP Adenosine triphosphate molecules. A good example of active transport mechanism is the sodium-potassium pump, which pumps potassium ions into the cell while pumping sodium ions out.

16.3 Facilitated Diffusion: Carrier Proteins and Ion Channels

Glucose, sodium ions and chloride ions are just a few examples of molecules and ions that must efficiently get across the plasma membrane but to which the lipid bilayer of the membrane is virtually impermeable. Their transport must therefore be "facilitated" by proteins that span the membrane and provide an alternative route or bypass. Facilitated diffusion is the name given to this process. It is similar to simple diffusion in the sense that it does not require expenditure of metabolic energy and transport is again down an electrochemical gradient.

16.4 Role of diffusion in metabolism

Diffusion plays the main role in nutrition, particularly in transport of water and food materials into every cell in the body. The exchange of gases during respiration and excretion in living organisms also occur by diffusion.

16.4.1 Diffusion in nutrition

Nutrition is the way our body takes in and uses food. Digestion is the process during which complex food particles are broken down into smallest possible units so that they can be absorbed or taken inside the cell. Digestion in animals occurs inside the alimentary canal or gut, which includes the mouth, pharynx, eosophagus, stomach, small intestine, large intestine, rectum and anus. Along with the associated digestive glands, viz. liver, pancreas, etc. they constitute the digestive system.

In vertebrate animals, the process of digestion of food may begin in the mouth, and is normally completed within the small intestine. Absorption of the digested food is the most important step in nutrition. It mainly occurs by diffusion through the wall of the small intestine, though certain items such as pepper, mustard, condiments and alcoholic drinks may be absorbed in the stomach.

The digested material from the intestine is absorbed by diffusion either into the blood capillaries or into the lymphatics, both of which occur in the intestinal **villi**. The absorbed material is then carried to the liver through the mesenteric veins and portal veins. From the liver they are sent to the general circulation.

Carbohydrates are absorbed through the intestinal villi in the form of monosacchararides, for the most part, by active transport. Proteins enter blood only in the form of amino acids. Their transport system across the cell membrane requires the presence of high concentration of Na^+ in the lumen of the intestine. It occurs not by simple diffusion, but by a rapid and active process.

Fats are absorbed in the form of small molecules and free fatty acids along with glycerol. They are said to be taken onto the cell by **pinocytosis**. However, short chain fatty acids are directly absorbed by simple diffusion. Nucleic acids diffuse into the capillaries in the form of small nucleoside molecules. Most of the water-soluble vitamins are absorbed by simple diffusion along with water. They are believed to enter the cells by pinocytosis. Ca^{+} is absorbed by active transport against the concentration gradient.

16.4.2 Diffusion in excretion

Excretion involves both passive diffusion and active transport of molecules across the cell membrane. In the Bowman's capsule of kidneys, a watery filtrate containing molecules that can pass through the semi-permeable membrane is formed. This filtrate, however, contains some useful materials like glucose, amino acids, fatty acids, salts, etc. Water, sodium chloride, glucose and amino acids first enter the cells of the nephrone by passive diffusion. Sodium, glucose and amino acids are then actively transported into the intercellular space, while chloride moves out by passive diffusion. These materials are again reabsorbed by the blood capillaries by the same process. Reabsorption of water from the filtrate occurs mostly through osmosis.

16.5 Diffusion in gaseous exchange

Gaseous exchange between the organism and its environment occurs during respiration. During the process, oxygen is absorbed from the surrounding medium by osmosis. This osmosis occurs when the oxygen-containing medium (water or atmosphere) comes in contact with the semi-permeable cell membrane of the respiratory surface (plasma membrane, gills, lungs, skin, etc). As the medium contains a higher concentration of oxygen compared to that inside the cells, the gas diffuses by osmosis through the plasma membrane into the cytoplasm or circulatory fluid (blood, haemolymph, etc). At the same time, carbon dioxide diffuses out due to differences in osmotic concentration (higher concentration inside and lower outside). When the circulatory fluid reaches the tissues, oxygen is offloaded and carbon dioxide is picked up, again due to differences in their osmotic concentrations.

POINTS TO REMEMBER

* The tendency of molecules of solids, liquids and gases to get evenly distributed throught the available space is known as diffusion.
* The perpetual motion of molecules due to the kinetic energy present in them is known as Brownion movement.
* Diffusion is the main form or transport within cells and across cell membranes.

* Diffusion occurs in three ways, viz.
  (i) Simple diffusion,
  (ii) Osmosis and
  (iii) Active transport.
* Simple diffusion occurs without expenditure of energy.
* Simple diffusion is also known as passive transport.
* Water, oxygen, carbon dioxide, ethanol and urea molecules are transported by simple diffusion.
* A semi permeable membrane allows movement of certain small molecules and prevents movement of larger molecules across it.
* During osmosis, water moves from a region with low solute concentration to a region with higher solute concentration across a semi permeable membrane.

EXERCISES

1. *Define diffusion. Explain it citing some common examples.*
2. *What is the importance of diffusion in the living system ?*
3. *What are the different ways in which diffusion recury in the living system ?*
4. *Explain how diffusion occurs in the following ways :*
   (i) Simple diffusion
   (ii) Osmosis
5. *What are polar and non-polar solvents? Give example.*
6. *What is a semi-permeable membrane ? Explain the process or osmosis across a semi-permeable membrane.*
7. *Write on the importance of osmosis in the living systems.*
8. *Write on the role of diffusion in nutrition.*
9. *Write on the role of diffusion in excretion.*
10. *Write on the role of diffusion is respiratour gaseous inchange.*

CHAPTER – 17

Food – Higher yields

Since the advent of agriculture, man had been growing plants and rearing animals to meet his requirements. However, the original varieties of plants and animals that man cultivated or reared did not completely fulfill his requirements, either in quality or in quantity. This is when man started to learn how to influence the process of natural evolution of plants/animals so as to produce better varieties of plants and animals.

17.1 PLANT BREEDING

Gradually, the process of developing new varieties, particularly in plants, through selection and cultivation, acquired the form of a routine endeavor—what we today call '**plant breeding**'. In plant breeding, heredity, (transfer of characters from parents to progency) plays an important role.

Various methods have evolved in plant breeding. One of the most important methods is that of **selection**.

The ability to choose gave birth to the idea of **selection**. This is the most primitive and by and large the most successful method of plant breeding. Selection as a part of plant breeding started with the domestication of plants by early man. **Domestication** refers to the process of bringing wild species under human management. Not all selection over the years have been human influenced—many of the important crop species have resulted from the **natural selection** process, which is an integral part of evolution. As human knowledge of agriculture grew, man started shuffling crop species from one geographical region to another, thus making new introductions.

Fig. 17.1: New fruit varieties

The first prerequisite of selection is the availability of **variability**, i.e. different types of forms. After a variable population is recognized, individuals that are the best performers for the desired feature, say fruit size in the case of tomatoes, are chosen and the rest of the population is discarded or rejected. The progeny of the selected individuals is grown further and again screened for the desired feature. This process is repeated until a uniform plant population is attained which has the best-desired characters. Eventually, a desired uniform crop variety is produced by this successive selection followed by multiplication of the selected individuals.

Selecting higher yielding plant varieties is not easy. Various techniques have been devised for effective plant selection. One such technique is application of mathematical computations. This technique, known as **biometrics** is now an important branch of genetics. **Biometrics** is defined as the application of statistics in biology. There are three common methods by which plant selection is carried out, namely

1. Selection for uniform plants, known as pure line selection;
2. Selection from field-grown plants, known as bulk selection or mass selection, and
3. Selection from a well-documented list of parentage, commonly known as the **pedigree system**.

17.1.1 Hybridization

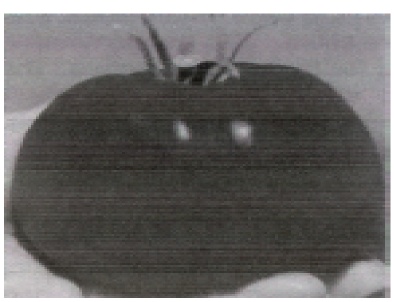
In traditional terms, hybridization refers to the union of the male gamete from a particular species with the female gamete belonging to another species to produce a zygote. In plant science, hybridization also refers to the crossing or mating of two different plants. The story of scientific hybridization of crop plants started with **J G Kolreuter**, who in 1761 published his work on the scientific bases of hybridization. Since then, hybridization followed by selection, has been the major tool of plant breeding.

Ways in which hybridization is used

Some of the ways in which hybridization has been exploited in breeding crop plants are given below.

17.1.2 Combination breeding

The main aim of combination breeding is to transfer one or more desired characters from many varieties into a single variety or plant type. The most commonly used method to achieve this goal is known as the **backcross method**. The plant type in which the character or the trait is being transferred is known as the **recipient parent** and the other as the **donor parent**. For this, the two plants are mated or crossed and the progeny is screened for the desired trait. The progeny plants possessing the desired trait are then selected and crossed back to the recipient parent. This process is repeated until the desired plant type having all the characteristics of the recipient in addition to the trait being transferred is finally obtained. This exercise is known as backcrossing. Backcrossing involves both hybridization and selection.



Hybrid tomato

Hybrid cabage

Fig.17.2:Some hybrid varities of vegetables

17.1.3 Hybrid varieties

Plant scientists exploit the characteristic feature of better yielding 'hybrids' in plants. Hybrid vigour, or **heterosis** as it is scientifically known, exploits the fact that some offspring from the progeny of a cross between two known parents would be better than the parents themselves. Many hybrid varieties of several crop species are being grown all over the world today. An example of this is the hybrid tomatoes that we eat commonly. The philosophy of hybridization has been extended from 'within the same species or genera (the same type of plants)' to 'different species or genera (totally different plants)'. This is known as wide or **distant hybridization**. Wide hybridization has helped breeders to break what is known as the species or genera barrier for gene transfer, i.e. it has helped breeders to transfer beneficial characteristics from wild and weedy plants to the cultivated crop species.

17.2 CROP PRODUCTION MANAGEMENT

Food is one of the most important basic needs of all organisms. Food provides energy and materials required by the living body. Adequate amount of nutritious food is necessary for proper development and growth of all living organisms including human beings. Thus, procurement of food enough to sustain the individual has become a basic duty of one and all.

As food obtained from natural sources is never enough to feed everyone, production of food has to be done. Increasing the production of food crops requires scientific knowledge and systematic management. In this chapter, we shall study the different management practices for increasing food production.

17.2.1 Use of fertilizers

Fertilizers are naturally occurring or synthetic chemicals containing plant nutrients. Some commonly used fertilizers are **ammonium sulphate, potassium chloride, super phosphate** and **potassium sulphate**. They provide specific nutrients like nitrogen, phosphorus and potassium to deficient soil. The use of fertilizer has increased productivity but only when appropriate amounts are applied. Improper application of fertilizers may cause serious pollution problems. Excessive addition of fertilizer damages the soil by reducing natural recomposting ability. Chemical fertilizers leached from the agricultural fields pollute ground and surface waters and create many health problems. To avoid such problems, it is better to adopt natural measures like use of organic manures.

The soil nutrients can also be replenished by growing one crop alternately with another. This type of cultivation is called **crop rotation**. It helps in increasing nutrient content of the soil. When leguminous crops are cultivated in one year and cereals the in next year, nitrogen content of the soil become increased. Farmers are encouraged to adopt such type of cultivation.

Leaving the soil uncultivated for long time may replenish the soil with plant nutrients. The process of leaving the field uncultivated is called **fallowing**. When the field is abandoned, many plants invade the area. Organic materials derived from these plants the enrich the soil with nutrients. It is a traditional method used in the hilly regions of Manipur for rejuvenating the soils in abandoned jhumlands.

17.2.2 Manuring

We have learnt that plants obtain nutrients from the soil. However, continuous cultivation of the same crop year after year in the same place depletes the soil nutrients. To replenish soil with the lost nutrients, farmers add manure or artificial fertilizer to the soil. Organic materials, derived from animal, human and plant residues that contain plant nutrients are called **manures**. The addition of these materials to the soil is called **manuring**.

17.2.3 Compost

Compost is an organic manure artificially prepared from plant residues and animal waste products. The process of making compost is known as **composting**. It is largely a biological process in which aerobic and anaerobic micro-organisms decompose organic matter and lower the carbon-nitrogen ratio of the refuse.

Compost is prepared from waste vegetables and other refuse mixed with cow-dung and urine and also from town waste and night-soil. The compost becomes ready in about three to four months without any further attention. Composts are of two types and they differ in nature and composition.

(i) Rural/Village Compost

This type of compost is prepared from farm waste products, e.g. straws, crop stubbles, crop residues such as sugarcane trash, groundnut husks and leaves, cotton stalks, etc. Weeds, waste fodder, urine soaked earth, litter from cowshed and hedge clippings may also be used. This type of compost contain 0.4-0.8 per cent Nitrogen (N), 0.3-0.6 per cent phosphorus (P_2O_5) and 0.7-1.0 per cent potash (K_2O).

(ii) Urban Compost or Town Compost

This type of compost is prepared from town waste and night soil. It contains 1.0-2.0 per cent nitrogen,1.0 per cent phosphorus (P_2O_5) and 1.5 per cent potash (K_2O).

17.2.4 Farm Yard Manure (FYM)

Farm yard manure is a mixture of the solid and liquid excreta of farm animals along with litter (i.e., the materials used for bedding purposes of cattle) and left over material from roughages or fodder fed to the cattle. The chemical composition of FYM is nitrogen—0.5%, phosphate – 0.2 %, potassium – 0.5 % and water 76 %.

17.2.5 Oil Cakes

Oil cakes are the by-products of oil seeds. Oil cakes are the important and quick acting organic nitrogenous manure. It also contain small amounts of phosphorus and potassium.

(i) Edible Oil Cakes

This type of oil cake is used for feeding cattle in the form of concentrates, e.g. mustard oil cakes, groundnut cake, sesame or til cake, linseed cake, coconut cake, etc.

(ii) Non-edible oil cakes

This type of oil cake is not suitable for feeding to cattle and mainly used for manuring crops, e.g., castor cake, neem cake, etc. The non-edible oil cakes contain a harmful toxic substance, which make them unsuitable for feeding to cattle. But these are a good sources of nitrogenous manure. The amount of nitrogen varies with the type of oil cake. It ranges from 2.5 per cent in mahua cake to 7.9 per cent in decorticate safflower cake. In addition to nitrogen, all oil cakes contain small quantities of phosphoric acid (0.8 to 2.9 per cent) and potash (1.1 to 2.2 per cent). Oil cakes are insoluble in water. But their nitrogen becomes quickly available in about a week or ten days after application to crops.

17.2.6 Green Manure

The practice of ploughing or turning into soil under-composed green plant tissue for the purpose of improving physical condition as well as fertility of the soil is referred to as **green manuring** and the manure obtained by this method is known as **green manure**.

The green manure crops should

- have profuse leaves and rapid growth early in its life cycle.
- have abundante and succulent tops
- be capable of making a good stand on poor and exhausted soils.
- have a deep root system.
- be a legume with good nodular growth habit.

Use of leguminous green manure crop is more useful in comparison to non-legumes, as more nitrogen is added by legumes. This will be advantageous for the soils and crops grown after green manuring.

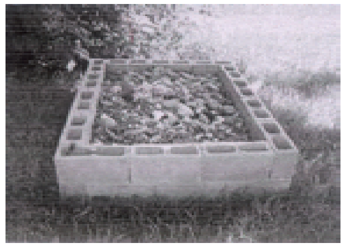
17.2.7 Vermicomposting

Vermicompost (also called **worm compost** or worm manure) is the end-product of the breakdown of organic matter by some species of earthworm. Vermicompost is a nutrient-rich, natural fertilizer and soil conditioner. The process of producing vermicompost is called **vermicomposting**.

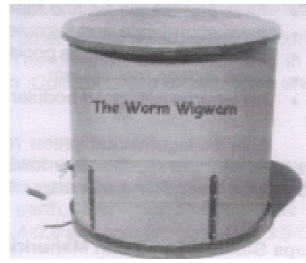
The earthworm species or **composting worms** most often used are **Red Wigglers** (*Eisenia foetida*) or Red Earthworms (*Lumbricus rubellus*). These species are commonly found in organic rich soils and especially prefer the conditions in rotting vegetation, compost and manure piles. Small-scale vermicomposting is well suited to turn kitchen waste into high-quality soil, where space is limited.

Together with bacteria, earthworms are the major catalyst for decomposition in a healthy vermiposting system although other soil (such as insects, mold), etc. also play a contributing role.

Vermicomposting bins*:* Vermicomposting bins vary depending on the desired size of the system. Garden-scale containers can be made out of bricks arranged in the shape of a box. Bins for an apartment or similar dwelling can be anything from reused plastic buckets to purpose-built commercial containers.



Garden bin



Circular bin

Fig. 17.3: Different models of vermicomposting

Vermicompost benefits soil by

- improving its physical structure;
- enriching soil micro-organisms, adding plant hormones such as auxins and gibberellic acid, and adding enzymes such as phosphates and cellulase;
- attracting deep-burrowing earthworms already present in the soil;
- improving water holding capacity;
- enhancing germination, plant growth, and crop yield; and
- improving root growth and structure.

Vermicompost can be used to make **compost tea** (worm tea), by mixing some vermicompost in water and steeping for a number of hours or days. The resulting liquid is used as a fertilizer. Vermicompost fed to poultry stimulates their immune system

17.2.8 Irrigation

The artificial application of water for the purpose of supplying moisture essential to plant growth is called **irrigation**. The most ancient and common type of irrigation is **surface irrigation**. It is the introduction of a stream of water at the field and allowing the water to flow throughout the field over the soil surface. In many advanced countries, **sprinkler** or **overhead irrigation** is used where water is supplied in the form of spray created by expelled water under pressure from an orifice. In areas where water is scarce, **trickle** or **drip irrigation** is practiced. Water is directly applied to individual plants in the form of discrete, continuous drops through mechanical devices called **emitters** located at selected points.

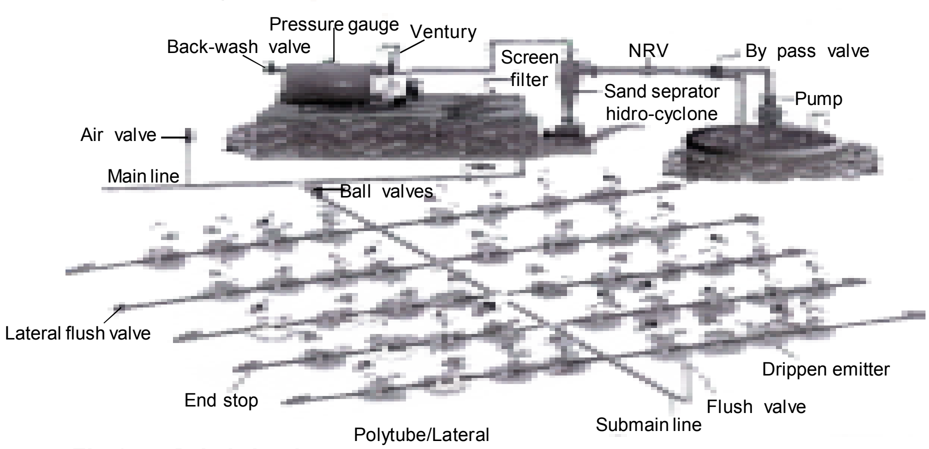


Fig.17.4: Drip irrigation

Whenever there is proper irrigation facility, the farmers are benefited in the following manners:

(a) Improvement in crop quality

(b) Significant increase in crop yields, particularly on soils having low moisture content

(c) Increased opportunity for double cropping

Though water is essential for plant growth, excessive presence of water in the soil is also harmful. **Water logging** is the condition where water is present in excess amount in the soil. It reduces air in the soil restricting respiration by underground parts of the plant. At the same time, many nutrients are lost through leaching. Crop plants could not grow properly in such condition. To prevent harmful effects of water logging, excess water should be drained out from the field.

17.3 Cropping pattern

Cropping activities go on all the year-round in India, provided water is available for crops. In northern India, there are two distinct seasons, ***kharif*** (July to October), and ***rabi*** (October to March). Crops grown between March and June are known as ***zaid.*** In some parts of the country, there are no such distinct seasons, but there they have their own classification of seasons. The village revenue officials keep plot-wise record of crops grown in each season. These are annually compiled district-wise, state-wise and on all-India basis. From these records one could calculate the relative abundance of a crop or a group of crops in a region. These crops are grown alone or mixed (mixed-cropping). **Mixed cropping** is a system of sowing two or three crops together on the same land, one being the main crop and the others the subsidiaries. When cropping is done in a definite sequence, it is called **rotational cropping**. The land may be occupied by one crop during one season, i. e. **mono-cropping**, or by two crops which may be grown in a year in sequence i. e. **double-cropping**. Of late, the trend is even more than two crops (**multiple-cropping**) in a year. These intensive croppings may be done either in sequence or even there may be relay-cropping (one crop sown under a standing crop). With wide-rowed slow growing cropping patterns, companion crops may be grown. There are various ways of utilizing the land intensively.

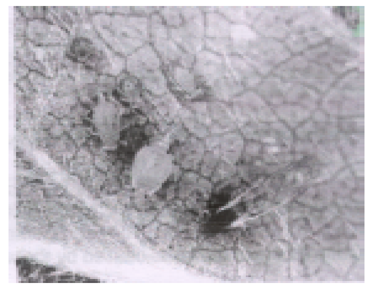
Fig. 17.5: Mixed cropping

17.4 Crop Protection from pests and diseases

Many organisms damage the crop plants that we grow for consumption as food. These organisms are called **pests.** Plant pests include insects, annelids, nematods, fungi, bacteria and virus. They cause various diseases in plants and destroy them.

Using chemical pesticides had been the only way of eradicating the plant pests. However, people have realized the lasting harm caused by chemical pesticides which pollute the environment. Residues of these chemicals enter our body through the food chain and cause a number of ailments. Hence, methods and ways to replace their use for pest eradication have been developed. Presently, the best biological pest control method is the use of **biopesticides**.

Cabbage looper



Aphids and their predator fly

Fig.17.6: Some examples of pests

Biopesticides are a class of environmen a friendly pesticides that are used to control pests like (fungi, insects, weeds and diseases). Biopesticides include naturally occurring substances that control pests (biochemical pesticides), microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants).

17.4.1 Fungi to Control Insects

Many fungi are capable of infecting and killing insects. The application of fungal insecticides is usually done using fungal spores. However, fungal mycelia are also used as inoculant to control insect pathogens.

17.4.2 Fungi to Control Weeds

The use of fungi for the control of weeds termed as mycoherbicides is certainly an environment friendly control method. This is as important alternative to control many weeds in range lands, turfs, and golf greens. Fungal herbicides are mass-produced and then applied to the area needing control. Fungal spores are used in aerosol sprayers and applied to an area needing control.

17.4.3 Fungi to Control other Fungi

Several fungi are used to control the plant fungal pathogens. One example is the damping-off disease that affects seedlings. Other plant diseases form galls and rots in plants while others infect the leaves. There are fungal organisms that actually attack these different plant pathogens and have been used to control them.

17.5 MIXED FARMING

Mixed farming is the combining of two independent agricultural enterprises on the same farm. A typical case of mixed farming is the combination of crop enterprise with dairy farming or in more general terms, crop cultivation with livestock farming. Mixed farming may be treated as a special case of diversified farming. This particular combination of enterprises, support each other and add to the farmer's profitability.

Integrated fish farming is combined culture of fish together with compatible combination(s) with poultry, duckery, pig rearing and cattle. Under this system of farming small livestock and farm yard animals, viz. pigs, poultry, ducks, etc., are integrated with composite fish culture by constructing animal housing sheds on the pond embankments in such a way that the animal wastes and washings are diverted into fish ponds. The fish not only utilize spilled animal feed but also directly feed on fresh animal excreta which is partially digested and is rich in nutrients. Surplus excreta support the rich growth of planktonic fauna. Fertilizers and supplementary feed are not used, resulting in drastic cost reduction. The salient features of the various types of livestock/carp integrated culture systems are as follows:

17.6 Integrated fish - pig farming

Pigsties are constructed either on the pond embankment or near the pond to facilitate easy drainage of waste directly into the pond which acts as pond fertilizer and supports dense growth of natural fish food organisms. Besides, fish also feed directly on the pig excreta. No other feed or fertilizer is applied to the pond. A pond is prepared by following the usual pond preparation techniques and stocked with fingerlings of all the six species of carps, column, bottom feeders and grass carp in the ratio of 40:20:30:10. Marketable size fish are sold by partial harvesting while final harvesting is done only after 12 months of farming.

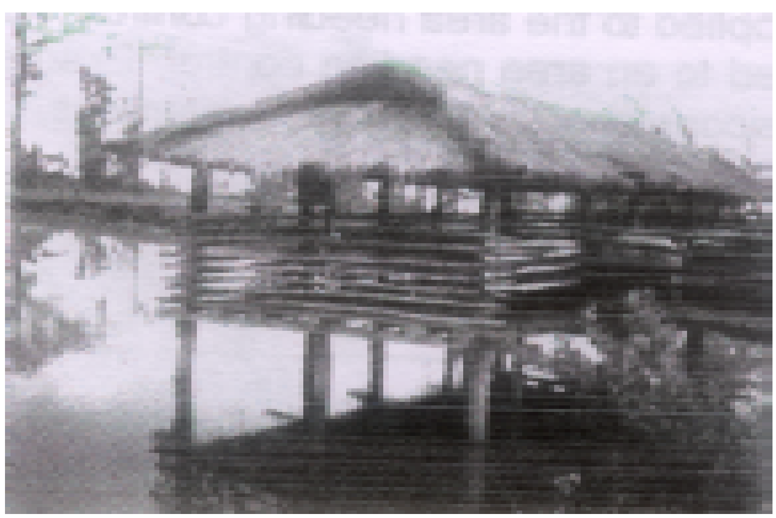


Fig.17.7: A fish-pig farming

About 2 months-old weaned piglets are fattened for six months when they attain slaughter size (60–70 kg) and similarly a second crop is raised within the next six months. About 30–40 pigs should be kept for proper fertilization of the pond. Pigs are fed on mash at an average rate of 1 kg/day. Green grasses or animal fodder is also provided. Grass with interlocked soil in root system is provided once a week to avoid mineral deficiency. Grass carp is fed with aquatic weeds or green animal fodder. Fish yields ranging from 6 000–7 000 kg/ha/yr are generally obtained.

17.7 Integrated fish - duck farming

Fig.17.8: A fish-duck farming

This is also an efficient integrated system based on the principle of waste recycling. A duck house is normally constructed on the pond embankment or on the pond water on a floating platform. When given free range, ducks feed on aquatic organisms such as insect larvae, tadpoles, molluscs, weeds, etc. The duck droppings like pig excreta act as fertilizer. Ponds are prepared and stocked with fingerlings of all the six carp species at 600 ha with surface, column, bottom feeder and grass carp in the ratio of 40:20:30:10. Fingerlings of over 10 cm are preferred for stocking. About 200–400 ducks are sufficient to adequately fertilize a I ha pond. Normally 2–3 months old ducklings are preferred. Although ducks are able to feed upon natural food from the pond, they are also provided with duck feed at the rate of 100 g/bird/day. Ducks start laying after 5–6 months and continue for 2 years. Fish yields ranging from 3 000–5 000 kg/ha/yr are generally obtained.

17.8 Organic farming

Organic farming is a form of agriculture which avoids or largely excludes the use of synthetic fertilizers and pesticides, plant growth regulators, and livestock feed additives. As far as possible, organic farmers rely on crop rotation, integrated pest management, crop residues, animal manures and mechanical cultivation to maintain soil productivity and tilth to supply plant nutrients, and to control weeds, insects and other pests.

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agricultural Movements (IFOAM), an international umbrella organization for organic organizations.

Approximately 31 million hectares (75 million acres) worldwide are now grown organically.

Organic farming can be defined as an approach to agriculture where the aim is to create integrated, humane, environmentally sustainable agricultural production systems. Maximum reliance is placed on self-regulating agro-ecosystems, locally or farm-derived renewable resources and the management of ecological and biological processes and interactions. Dependance on external inputs, whether chemical or organic, is reduced as far as possible.

The main advantages of organic farming are:

- the market price for such products are higher,
- the way in which they are produced involves less intensive use of land,
- the attainment of a better balance between supply of, and demand for, agriculture products,
- better protection of the environment.

Another advantage is that organic farms are in general, more labour intensive than conventional farms, and therefore, should contribute to rural employment and help keep in business small farms which would otherwise not be able to cope with intensification and global competition.

Fig. 17.9:Organic farm vegetables

17.9 Animal husbandry

Animal husbandry, also called animal science, is the agricultural practice of breeding and raising livestock. Livestock production is an integral part of crop farming and contributes substantially to household nutritional security and poverty alleviation through increased household income. The returns from livestock, especially dairying and mixed farming represent a sustainable income for the farmers. The progress in this sector results in more balanced development of the rural economy, and improvement in economic status of poor people associated with livestock.

India has nearly 57 per cent of the world's buffalo population and 16 per cent of the cattle population. India has now become the largest producer of milk in the world. Piggery, cattle farming, Poultry farming, etc. are common animal husbandry practices.

The economic value of livestock includes:

1. Livestock provides us meat which is a useful form of dietary protein and energy.
2. Mammalian livestock is a good source of milk, which can in turn easily be processed into other dairy products such as yoghurt, cheese, butter, ice cream, etc. Using livestock for this purpose can often yield several times the food energy of slaughtering the animal for meat.

3. Livestock produce a range of fiber/textiles. For example, sheep and goats produce wool and mohair; cows, deer, and sheep skin can be made into leather; and bones, hooves and horns of livestock can be used.
4. Cowdung can be spread on fields to increase crop yields. This is an important reason why historically, plant and animal domestication have been intimately linked. Cowdung is also used to make plaster for walls and floors and can be used as a fuel for fires. The blood and bone of animals are also used as fertilizer.
5. Animals such as horses, cows, buffaloes, donkey and yaks can be used for mechanical energy. They are still used for this purpose in many places of the world, including ploughing fields, transporting goods, and military functions.
6. The grazing of livestock is sometimes used as a way to control weeds and undergrowth in western countries. For example, in areas prone to wild fires, goats and sheep are set to graze on dry scrub which removes combustible material and reduces the risk of fires.

17.9.1 Piggery

Among the various livestock species, piggery is the most potential source of meat production and more efficient feed converters after the broiler. Apart from providing meat, it is also a source of bristles and manure. Pig farming will provide employment opportunities to seasonally employed rural farmers and supplementary income to improve their living standards. The advantages of the pig farming are:

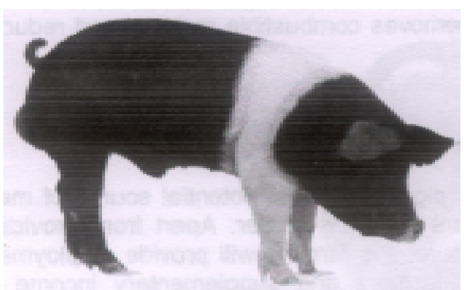
1. The pig has the highest feed conversion efficiency i.e. they produce more live weight gain from a given weight of feed than any other class of meat producing animals except broilers.
2. The pig can utilize wide variety of feed stuffs viz. grains, forages, damaged feeds and garbage and convert them into valuable nutritious meat. However, feeding of damaged grains, garbage and other unbalanced rations may result in lower feed efficiency.
3. They are prolific with shorter generation interval. A sow can be bred as early as 8-9 months of age and can farrow twice in a year. They produce 6-12 piglets in each farrowing.
4. Pig farming requires small investment on buildings and equipments
5. Pigs are known for their meat yield, which in terms of dressing percentage ranges from 65 - 80 in comparison to other livestock species whose dressing yields may not exceed 65%.
6. Pork is nutritious with high fat and low water content and has got better energy value than that of other meats. It is rich in vitamins like thiamine, Niacin and riboflavin.
7. Pigs manure is widely used as fertilizer for agriculture farms and fish ponds.
8. Pigs store fat rapidly for which there is an increasing demand from poultry feed, soap, paints and other chemical industries.
9. Pig farming provides quick returns since the marketable weight of fatteners can be achieved with in a period of 6-8 months.
10. There is good demand from domestic as well as export market for pig products such as pork, bacon, ham, sausages, lard etc.

Construction of a pigsty

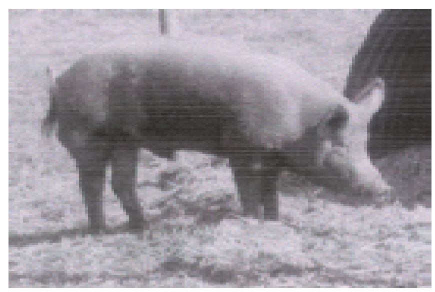
A **pigsty** should be constructed on dry and properly raised ground. Water-logged, marshy and heavy rainfall areas are to be avoided. The side walls of the sheds should be 4-5 ft. high and remaining height should be fitted with bamboo, wooden poles or GI pipes. The walls may be preferably plastered to make them damp proof. The roof of the shed should be at least 8-10 ft. high. The pigsties should be well ventilated. The floor should be hard, even, non-slippery, impervious, well sloped and properly drained to remain dry and clean. A cemented floor is preferable.

Feeding may be done using wooden feed troughs with spaces of 6-12 inches per pig. The corners of feed troughs, drains and walls should be rounded for easy cleaning. Adequate open space should be provided for each animal. Proper shade and cool drinking water must be provided in hot summer months. Excreta (dung and urine) should promptly and properly cleared. Individual pens for boars and lactating sows should be constructed, but the dry sows and fatteners can be housed in group pens.

Selection of breeding stock



Hampshire boar



Tamworth

Fig.17.10: High breed variety of pigs

For commercial pig farming upgraded or cross bred or exotic pigs in good health should be selected. While selecting a sow, a female that will produce large survivable litter and which can attain marketable weight at an age of six months or less should be considered. Exotic breeds of pigs like Largewhite Yorkshire, Hampshire, Berkshire, and Saddleback, etc. are recommended for pig farming in Manipur.

If possible animals which are ready to be bred should be obtained. The newly purchased animals are to be vaccinated against diseases. As precautionary measure, the newly procured animal must be kept under observation for a period of about two weeks before mixing them with the other animals. If any of the animals are found in bad health and grow slowly culling and replacement of animals must be done.

Feeding management

The animals are to be given the best feeds and the ration should contain adequate concentrates. Adequate vitamins and minerals should be provided. The animals should be given clean drinking water. Special care should be taken while feeding the piglets as high quality and more fortified diets are needed for feeding them. Adequate feeding of the sows during pregnancy is also of utmost importance for obtaining increased litter size.

Commercial pig farming should aim at the exploitation of non-conventional feed resources viz., waste from Kitchen/hotel/ cold storage/warehouses, in replacing the balanced rations to minimise the cost of production.

Protection against Diseases

Disease is the worst enemy for farm animals. A farmer must be on the alert for signs of illness such as reduced feed intake, fever, abnormal discharge or unusual behaviour. If any abnormality is detected a veterinary centre must be consulted.

Care should be taken to protect the animals against common diseases. In case of outbreak of contagious diseases, the sick and the healthy animals must be immediately segregated. The sick animals are to be treated immediately. The faeces of the adult animals must be regularly examined to detect eggs of internal parasites and treat the animals with suitable drugs. The animals must be washed from time to time to promote sanitation.

Breeding care

Pigs are highly prolific in nature and two farrowings in a year should be planned by adopting optimal management conditions. Breeders may be kept in the ratio of one boar for every 10 sows for maximum fertility. The animals are to be allowed to breed when it is in peak heat period (i.e. 12 to 24 hours of heat).

Care during Pregnancy

Give special attention to pregnant sows one week before farrowing by providing adequate space, feed, water etc. The sows as well as farrowing pens should be disinfected 3-4 days before the expected date of farrowing and the sows should be placed in the farrowing pen after bedding it properly.

Care of Piglets

The new born piglets should be protected with guard rails. The umbilical cord must be cut with a clean, sharp knife and disinfected. The piglets require their mothers milk for first 6-8 weeks along with creep feed. They should be protected against extreme weather conditions, particularly during the first two months after birth. Their needle teeth should be clipped shortly after birth. Vaccinate the piglets as per recommended vaccination schedule. Supplementation of Iron to prevent piglet anaemia is necessary. The piglets meant for sale as breeder stock must be reared properly. Male piglets not selected for breeding should be castrated preferably at the age of 3-4 weeks which will prevent the boar odour in the cooked meat. Additional feed requirements of lactating sow must be ensured for proper nursing of all the piglets born.

17.9.2 Cattle farming

Cattle (*Bos*) are valuable source of food (milk, cheese, butter, meat) and other items of commercial importance. These animals convert cheap, low-grade fodder into highly nutritious milk. In addition to milk, cow dung is an important organic fertilizer for crop production. Dried cow dung is also used as household fuel in rural India. In modern India, cow dung forms an important raw material for biogas production. Cattle also provide us with mechanical energy for various, farm works like transport, ploughing, etc.

In most parts of India including Manipur, cattle farming are carried out mainly for production of milk. However, for certain sections of people, it represents a good source of meat. Notwithstanding the ultimate purpose, the basics of setting up and management of a cattle farm involves the following considerations.

Shelter

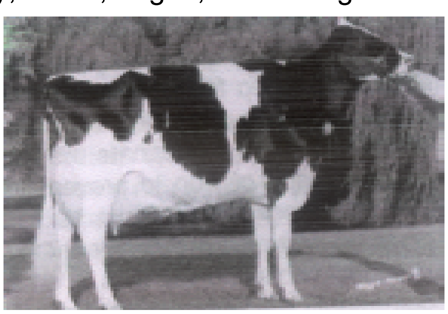
Cattle farms should be set up in a dry, airy area, where a suitably ventilated sheltering shed should be constructed. The walls of the sheds should be 1.5 to 2 metres high. The sheds should be with brick plastered walls, concrete floor and proper roofing. The floor should be hard, even, non-slippery, impervious, well sloped (3 cm per metre) and properly drained to remain dry and clean. The roof should be 3-4 metres high. A standing space of 2 x 1.05 metre for each animal is needed. A pucca drain, 0.25 metre wide must be provided at the rear of the standing space for collection of dung and urine.

Cattle sheds are to be provided with wooden or concrete feeding troughs preferably with rounded corners for easy cleaning. The sheds are to be regularly washed for maintaining cleanliness. Straw or grass may be used as dry bedding for the animals. The size of the shed depends on the number of animals to be kept. Any sharp projection is to be removed to avoid injury to animals.

Maintenance of sanitary condition around the shed is a necessity. External parasites (ticks, flies etc.) may be controlled by spraying the pens, sheds with Malathion or Copper sulphate solution. Newly purchased animals may be vaccinated against diseases. Drain urine into collection pits and then transfer it to the field through irrigation channels. Dispose of dung and urine properly. Convert the dung along with bedding material and other farm wastes into compost. Give adequate space for the animals.

Selection of breed

Selection of breed of cattle to be reared should be done with help from veterinary experts, because it is the most important step in setting up a dairy farm. The important breeds of Indian cows are Red Sindhi, Gir, Sahiwal, Kankrej, Hallikar,Ongole, Nelore, etc. all of which belong to the species *Bos indicus*. Exotic breeds such as Holstein, Friesian, Brown, Jersey, Swiss, Angus, etc. belong to the species, *Bos taurus*.



Holstein breed

Dutch friesian breed

Fig.17.11: Some foreign variety of cattle breed

High-milk yielding breeds hybrid cattle like Friesian-Sahiwal, Holstein-Friesian, etc. are also available. Important buffalo breeds are Bhadavari, Jaffarabadi, Mehsana, Murrah, Nili-Ravi, Surti, etc. belonging to the species Bubalus bubalis. Generally new breeds are also disease-resistant.

Feeding

Milk-giving animals are to be fed properly after adding adequate green fodder in the ration. The feed may be categorized into roughage and concentrates. Roughage includes grasses, dry fodder (paddy chaff), green fodder including soyabean hay and legumes like clover (*Trifolium repens*), cowpea (*Vigna sinense*), alfalfa (*Medicago sativa*), etc. Chaff the roughage before feeding. Concentrates include cereals, millets, corn, rice bran, oil cakes, etc. Oil cakes made from mustard and cottonseeds may be used to enrich the feed. Crush the grains and concentrates. The oil cakes should be flaky and crumbly. The concentrate mixture may be moistened before feeding. Urea may also be used as a protein substitute. Silage (stored fodder) prepared from succulent green fodder, if properly preserved, may be used throughout the year.

Adequate vitamins and minerals may also be added to the concentrate ration. Providing salt licks besides addition of mineral mixture to the concentrate ration enhances mineral nutrition of the animals. There should be provision for adequate, clean water.

The timing and frequency of feeding is also very important. Milch cattle are generally fed twice a day, once in the morning and once in the evening before milking are done. Water also is to be given twice a day. In rural areas, family cattle are sent out to the grazing fields in the morning and brought back in the evening.

Culling

Since milch cattle are reared for production of milk, old cattle that are not healthy and with low milk yield, are to be removed from the farm. This is known as culling. The old animals after 6-7 lactations should be culled.

Milking of Animals

The lactating animals can be milked two to three times a day. It is important to milk the animal at fixed times in a day. Milking must be done in a clean place. One milking session should not last more than eight minutes. The udder and teat are to be washed with antiseptic lotions or luke-warm water and dried before milking. As far as possible, milking should be done by the same person regularly. The milker should be free from any contagious diseases and also should wash his hands with antiseptic lotion before each milking.

Health care

Dairy animals may suffer from a number of diseases, parasitic infections and other ailments. Common diseases of cattle include foot and mouth disease, bloat, Anthrax, Mad cow disease, Foot rot, Bovine diarrhoea, etc. Foot-and-Mouth Disease is a severe, highly communicable viral disease characterized by blister-like lesions on the tongue, nose and lips, in the mouth, on the teats and between the toes, which then burst, leaving painful ulcers. **Bloat** is a form of severe indigestion marked by a collection of gas in the rumen that the animal is unable to expel. It is due to excessive green fodder and lack of dry fodder in the feed. **Anthrax**, a highly infectious and fatal disease is caused by a spore-forming bacterium called *Bacillus anthracis*. **Mad cow disease** is a fatal disease that affects the central nervous system of cattle. **Bovine Virus Diarrhea** infection can cause numerous problems, such as damage to the digestive and immune systems, pneumonia, abortions, calf deformities, etc.

Various external as well as internal parasites also cause lots of inconveniences to the animals. Flies, ticks, lice and mites are the major external parasites infesting beef cattle. Calves under one year of age are often infected by internal worm parasites. Breeding is the most important stage in rearing of cattle. The pregnant and nursing cows are to be maintained in good health all the time. They must be given nutritious feed regularly. Care should be taken to keep the newly born disease free. Precautions should be taken to prevent diseases rather than attempting to control them, as many diseases are usually difficult to control and are fatal.

Protection against Diseases

Farmers should be on the alert for signs of illness such as reduced feed intake, fever, abnormal discharge or unusual behaviour. The nearest veterinary aid centre should be consulted for help if illness is suspected. Immediate segregation of the sick animals from the healthy ones is necessary to prevent a disease from spreading. The animals may be washed from time to time to promote sanitation.

17.9.3 Poultry farming

Poultry meat and egg are good sources of important nutrients such as high quality proteins, minerals and vitamins to balance the human diet. Poultry farming, using specially developed fast growing varieties of egg layer chicken with high feed conversion efficiency, can be a main source of family income. It can provide additional income and gainful employment to farmers throughout the year. Poultry manure has high fertilizer value and can be used for increasing yield of crops.

Setting up a Poultry farm

Setting up a modern poultry farm requires the following considerations.

Poultry Housing

For construction of poultry housing, a well raised land should be selected. Land with hard rock is more suitable. Water logging and flooding areas are to be avoided. Growing chickens and mature layers are to be housed in separate sheds. The farm should have adequate facility for water, electricity, approach road, supply of chicks, feed, veterinary aid and nearness to market for sale of culled birds and eggs. A prior training or experience in poultry farming is preferable before starting a farm.

The sheds must be constructed in such a way that the end walls face East-West direction and the side walls face North-South direction. Roofing materials of the shed should be strong and hard. Raising the plinth of the shed at least one foot above the outside ground level helps to keep the floor dry and ventilated. The roof must be made to overhang the floor by at least 3 to 4 feet.

Fig.17.12: Rhode Island Red

The shed should be provided adequate light and ventilation and comfortable housing conditions during all seasons (cool in summer and warm in winter). Sheds must be constructed in such a way that predators (cats/dogs/snakes) will not enter the shed. Avoid entry of rats by constructing rat proof structures. The shed must be kept clean and free from flies and mosquitoes. The walls and floors should be kept clean, white washed with lime and disinfected with 0.5% malathion or DDT insecticide spray. A 4"deep litter layer using dry and clean litter material (sawdust, paddy husk, etc.) is to be spread on the floor.

There must be proper lighting inside the shed. One 40 watt electric bulb is sufficient for 200 sq.ft. area.

The litter material should be always kept loose and dry. Stir the litter twice a week. Any wet litter/droppings etc. should be removed and replaced with fresh/clean dry litter.

Feeding

Use high quality balanced feeds. Starter feed (up to 8 weeks of age), grower feed (9 to 16 weeks of age) and layer feed (17 to 72 weeks of age) manufactured by reputed institutions/companies should be used. The feed may be stored in clean, dry, well ventilated room. A wet feed may bring fungus infection. Wastage of feed may be avoided by using properly designed feeders and by controlling the rats. Provide adequate feeding space per bird.

Keep proper records on feed consumption per bird for each batch. About 7 kg feed is required up to 20 weeks and 38 kg feed is required from 21 to 72 weeks of age. Excess consumption may be due to feed wastage, rats, low temperature of shed or poor feed quality (low energy feed). Too low feed consumption may be due to disease condition, low quality or unpalatability of feed, high temperature in poultry shed, etc.

Water for birds

Always give fresh and clean drinking water. Water should be always available for birds. Use properly designed watering equipment. Provide adequate drinking space per bird.

Always keep water-pots clean. Avoid birds entering inside pots. Provide cool water during summer. Store the water in tanks that are not exposed to hot sun in summer.

Disease Prevention and Control

Clean sanitary conditions of poultry sheds and equipment, balanced feed, fresh clean water, healthy chicks are essential to prevent diseases. Avoid entry of visitors to farm, especially inside the sheds. Use proper vaccination schedule. Keep vaccines in cool, dry conditions away from sunlight. Any left-over vaccine should be properly disposed off. Any dead bird should be immediately removed from the shed and sent to laboratory for post-mortem examination or buried/burnt suitably away from the poultry sheds. The waste of farm should be suitably disposed off. Any bird showing advanced signs of a disease, should be removed from the shed and culled. It can be sent to laboratory for diagnosis. Birds showing advanced signs of a disease should be shown to a qualified veterinarian and suitable medication/treatment be given. Poultry manure, if infected, can spread disease, from one batch to another. Keep the litter dry, remove it after flock is sold and dispose the manure properly and quickly.

Rats are important carriers of poultry disease. They may be controlled by using suitable rat poisons/rat traps. Many poultry medicines can be given in drinking water. When medication is to be given, remove the waterers in poultry sheds on the previous evening. Next morning give medicine in measured quantity of water, so that entire medicine will be quickly consumed and there will be no wastage of medicines. Mild infection of disease may not cause mortality but it will reduce growth.

17.9.4 Fish production

Fish is the cheapest and most easily digestible animal protein food. Man used to obtain it from natural sources from time immemorial. However, due to over exploitation and pollution, the availability of fish in natural waters has declined considerably. It has necessitated adoption of various methods to increase its production.

Fish farming in controlled or under artificial conditions has become the best way of increasing the fish production and its availability for consumption. Farmers can easily take up fish culture in village ponds, tanks or any new water body and can improve their financial position substantially. It also creates gainful employment for skilled and unskilled youths.

The type of fish culture in which more than one type of compatible fishes is cultured simultaneously is the most advanced and popular fish culture technology in the country. This technology is known as **Composite Fish Culture**. This technology enables to get maximum fish production from a pond or a tank through utilization of available fish food organisms in all the natural niches, supplemented by artificial feeding. Any perennial fresh water pond or tank retaining water depth of 2 metres can be used for fish culture purpose. However, the minimum level should not fall below one metre. Even seasonal ponds can also be utilized for short duration fish culture.

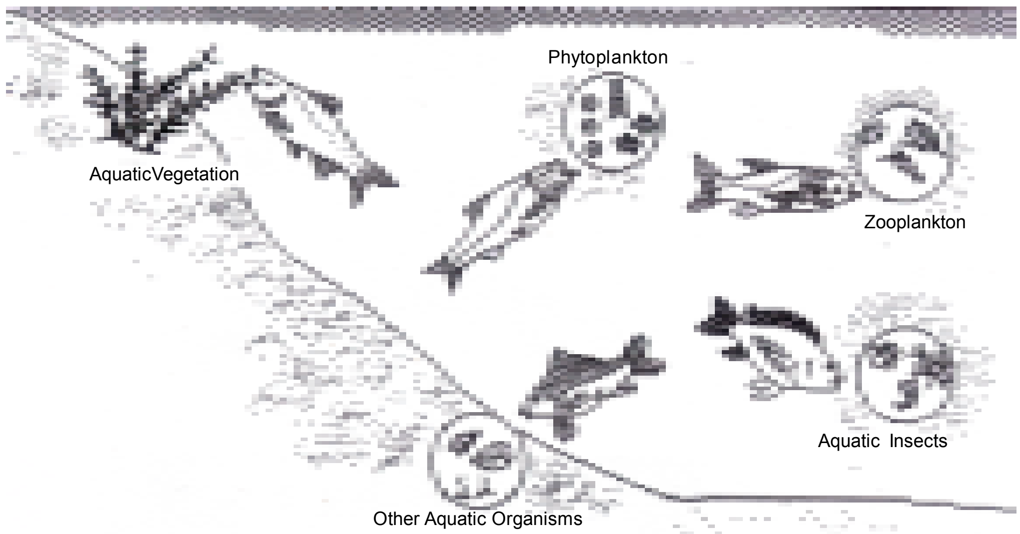


Fig.17.13: Different fishes having different feeding habits

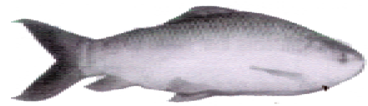
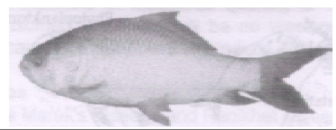
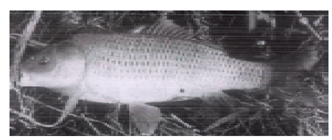
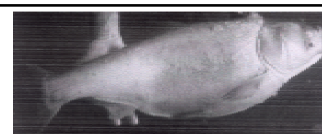
Fish species used in composite fish culture

Depending on the compatibility and type of feeding habits of the fishes, the Indian as well as Exotic varieties of fishes shown in the following table have been identified and recommended for culture in the composite fish culture technology:

Table 17.1: Feeding habit and feeding zones of fishes

Name of fish species/variety	Feeding habit	Feeding zone
Indian Major Carps		
Catla	Zooplankton feeder	Surface feeder
Rohu	Omnivorous	Column feeder
Mrigal	Detritivorous	Bottom feeder
Exotic carps		
Silver carp	Phytoplankton feeder	Surface feeder
Grass carp	Herbivorous	Surface, column and marginal areas
Common carp	Detritivorous/Omnivorous	Bottom feeder

Table 17.2: List of commonly cultured fishes

Rohu *Labeo rohita*	
Mrigal *Cirrhinus mrigala*	
Catla *Catla catla*	
Calbasu *Labeo calbasu*	
Grass carp *Ctenopharyngodon idella*	
Common carp *Cyprinus carpio*	
Silver carp *Hypothalpmicthys molitrix*	

Technical requirements

Technical requirements that need to be fulfilled for a Composite Fish Culture farm are as follows:

1. Construction of Pond

The main criteria to be kept in mind while selecting the site for pond construction is that the soil should be water retentive (non-porous), adequate supply of water is assured and that the pond is not in a flood prone area. Derelict, semi derelict or swampy ponds can be renovated for fish culture by dewatering, desilting, repair of the embankments and provisions of inlet and outlet.

2. Pond Management

Pond Management plays a very important role in fish farming before and after the stocking of fish seed. Various measures that are required to be undertaken in pre and post stocking practices are described below:

A. Prestocking: In case of new ponds, prestocking operations include liming and filling of the pond with water. However, the first step for existing ponds requiring development include clearing the pond of unwanted weeds and fishes either by manual, mechanical or chemical means. Different methods are employed for this.

a) Removal of weeds by Manual/Mechanical or through Chemical means.

b) Removal of unwanted and predatory fishes and other animals by repeated netting or using mahua oil cake @ 2500 kg/ha metre or by sun drying the pond bed.

i) Liming: The tanks which are acidic in nature are less productive than alkaline ponds. Lime is used to bring the pH to the desired level. In addition lime also has the following effects:

a) Increases the pH.

b) Acts as buffer and avoids fluctuations of pH.

c) It increases the resistance of soil to parasites.

d) Its toxic effect kills the parasites; and

e) It hastens organic decomposition.

The normal doses of the lime required ranges from 200 to 250 Kg/ha. However, the actual dose has to be calculated based on pH of the soil and water.

The pond is required to be filled with rain water or water from other sources after liming in case it is a new pond.

ii) Pond Fertilization: Fertilization of the pond is an important means of intensifying fish culture by increasing the natural productivity of the pond. The fertilization schedule has to be prepared after studying the quality of the pond soil. A combination of both Organic and Inorganic fertilizers may be used for best results. The fertilizer programme has to be suitably modified depending on the growth of the fish, available food reserve in the pond, physico-chemical properties of the pond and climatic conditions.

B. Stocking

The pond will be ready for stocking after 15 days of application of fertilizers. Fingerlings of 10 cm size (approx) should be used for stocking @ 5000 fish per hectare. However, if fingerlings of smaller size are used, suitable increase may be made accounting for mortality. Depending on availability of seed and market condition, stocking can be of 3, 4 or 6 species combination in the following ratio.

Table 17.2: List of commonly cultured fishes

Species combination (ratio)

Species	3-species	4-species	6-species
Catla	4.0	3.0	1.5
Rohu	3.0	3.0	2.0
Mrigal	3.0	2.0	1.5
Silver Carp	-	-	1.5
Grass Carp	-	-	1.5
Common Carp	-	2.0	2.0

c) Post stocking

iii) Supplementary feeding: Fishes need much more food than what is available naturally in the pond. Fishes can be fed with a mixture of bran and oilcake in equal quantities daily. The feed should be placed on a bamboo tray and lowered to the pond bottom or it can be sprayed at the corners. After some time the fishes will get used to this type of feeding and aggregate at the same place at the particular time. The recommended feeding rate is given in the table no 17.4 .

Table 17.4: Recommended feeding rate of fishes during culture period

Culture period	Quantity of feed per day in kgs.
1st 3 months	1.5 to 3
2nd 3 months	3 to 6
3rd 3 months	6 to 9
4 th 3 months	9 to 12
Total (for the year)	1,655 to 2,700

iv) Manuring: Organic manuring may be done in monthly instalments @ 1000 kg/ha. Inorganic fertilization may be done at monthly intervals alternating with organic manuring. However, the monthly rate of fertilization will depend on pond productivity and the growth of the fishes. It should be ensured that excess fertilisation does not take place which may result in **eutrophication**.

D) Harvesting:

Harvesting is generally done at the end of 1st year, when the fishes attain average weight of 750 g to 1.25 kg. A production of 4 to 5 tons/ha can be obtained in a year. Harvesting is done by partial dewatering and repeated netting. In some cases complete dewatering of ponds may be done.

17.9.5 Bee keeping

Beekeeping, or **apiculture**, is the of honey bees for obtaining honey, wax, etc.Honey bees live in large colonies of up to 100,000 individuals. In Europe and America the species universally reared by beekeepers is the Western honey bee *Apis mellifera*. In India, beekeeping is done using the Indian honey bee (*Apis indica*), though other wild species such as *Apis dorsata* (Rock bee), *Apis florea* (Little bee), etc. are also available.

Essential bee-keeping activities

While starting bee keeping activities, the following essential steps should be considered:

1. A beginner should learn the details about the habit and behaviour of the bees.
2. The hive and other necessary tools are to be procured.
3. The hive should be placed in a locality rich in vegetation, especially flowering plants.

4. When several hives are kept in a plot, the distance between two adjacent hives should be about at least 6 feet.
5. The hive should face east. It should receive sunlight in the morning and evening, and some shade during mid-day.
6. Water should be available nearby and an open space in front of hive entrance is necessary.
7. Spring is the best season to start bee keeping as during which bees can be easily procured to be hived.

Bee hive

In each honey bee hive, there are thousands of **worker bees** (sterile females), hundreds of **drones** (male), but only a single **queen**, who is mother to them all. The queen is somewhat larger than drones and workers, especially her abdomen, in which the ovaries are full of eggs. The ovary of the worker bee is shrunken and normally cannot produce eggs. The sting queen's is smooth and she can use it repeatedly. She uses it only to kill rival queens just after she emerges out as an adult. The worker's stinger is barbed-if used against an enemy with soft skin, such as a human, it may remain in the victim's flesh. The worker bee pulls out its own entrails in trying to escape and soon dies. Drones exist solely to mate with queens other than their own.

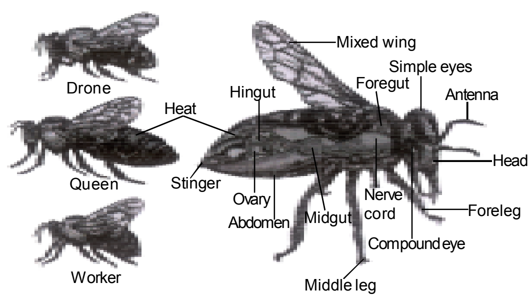


Fig. Three casts of honey bee

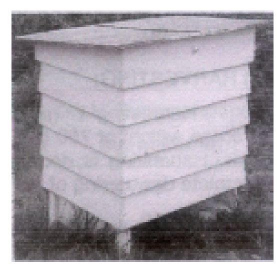


Fig. An artificial bee hive

Artificial bee hive: The modern bee hive is categorised as a **'Movable frame hive'**. The hive is made up of a wooden box with certain special features. The box may be single or double-walled. Single-walled hive is light and cheap, whereas the double-walled hive is heavy and costly. However, the double-walled hive is more durable and provides better protection to the bees. The double-walled hive with sufficient insulation keeps the hive warm in winter and cool in summer.

A modern bee hive, also known as the **Longstroth hive**, has a basal plate or bottom board on which is placed a wooden box called "**brood chamber**". A bottom pore in the brood chamber act as entrance for bees. Inside the hive the brood chamber has several frames hanging vertically from the top. These frames can be removed independently, hence the name movable frame hive. The distance between two frames is known as "**bee space**". This space serves as a passage for movement of the bees. This space should neither too narrow nor too wide.

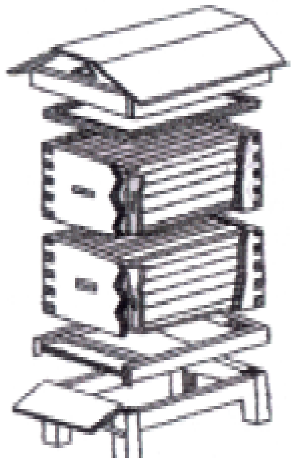


Fig. Langsthroth hive

There is another similar chamber above the brood chamber, which is known as "Super". The "**Super**" is a chamber meant for storage of honey only. The queen is never allowed to enter this chamber. To prevent the queen from entering the super, a grill, known as "**queen excluder**" is used between super and brood chambers. On top of the super there is an inner covering and then a roof.

The hive is generally painted with two coats of white, green or yellow coloured paint, which not only protects the hive from different weather conditions but also help the bees to easily recognise their hive.

Different types of hives are used in diferent countries of the world. In India, three types of hive are generally in use, namely Langstroth, Newton and Jeolikote.

Comb foundation: It is a sheet of bee wax on both sides of which exact shapes of different cells of the natural comb is made in advance. The sheet is cut to the size of the hanging frames and are fitted in it. It can be used for several years.

Bee glove: These are leather gloves used by bee keepers to protect their hands from the sting of the bees.

Bee veil: The bee veil is made of fine net, usually silken through which bees cannot pass. A bee veil is used to protect the bee keeper's face from the sting of the bees.

Smoker: It is a device used to subdue the bees if irritated during hive inspection. Smoke can be produced using anything like rotten wood chips, waste papers, etc. Carbolic acid is also sometimes used as bee quieter in place of smokers. It is a powerful antiseptic, a good repellant and can be used in dilute form.

Hive tool: It is a flat, narrow and long piece of iron used in scraping the dirty materials deposited by the bees including bee wax and superfluous pieces of comb on the inner walls of the hive.

Fig. Smoker

Uncapping knife: It is a long, broad iron piece used in removing the cap of the hive during regular inspections.

Bee brush: It is used to brush off bees from honey combs particularly at the time of honey extraction.

Queen introducing cage: It is a pipe made of wire nets through which the queen cannot pass. This tool is used in keeping the newly introduced queen arrested in the hive for about 24 hrs during which she becomes acquinted with the hive as well as the worker bees. The both ends of the pipe with the queen inside are pluged with “queen candy” made by kneading powdered sugar with some honey. In about 24 hrs a hole is eaten by both the queen and worker, thus releasing the queen. If the bees fail to eat the candy in 48 hrs, the queen is to be released directly.

Honey extractor: This is used in extracting honey from the comb. It is a metal drum having several pocket around a rotatingwheel. The frames with honey are hanged from these pockets and rotated around a central axis. Centrifugal force seperates honey from the combs. Honey is collected through a hole at the bottom. After extraction of honey, the combs can be used again.

Points to remember

* Plant breeding is the process of developing new varieties, particularly in plants, through selection and cultivation.
* Domestication refers to the process of bringing wild species under human management.
* Selection is the most primitive and the most successful method of plant breeding.
* The first prerequisite of selection is the availability of different types of forms i.e. variability.
* Biometrics is defined as the application of statistics in biology.
* There are three common methods by which plant selection is carried out
* Hybridization traditionally refers to the union of the male from a particular species with the female gamete belonging to another species to produce a zygote.
* The main aim of combination breeding is to transfer one or more desired characters from many varieties into a single variety or plant type.
* The selection of progeny plants possessing a desired trait and crossing it back to the recipient parent is known as backcrossing.
* Hybrid vigour, or hetrosis, exploits the fact that some offsprings from the progeny of a cross between two known parents would be better than the parents themselves.
* Hybridization between totally different plants belonging to different species or genera is known as wide or distant hybridization.
* Fertilizers are naturally occurring or synthetic chemicals containing plant nutrients.
* Chemical fertilizers leached from the agricultural field pollute ground and surface waters and created many health problems.
* The soil nutrients can also be replenished by growing one crop alternately with another. This type of cultivation is called crop rotation.
* Leaving the soil uncultivated for long time may replenish the soil with plant nutrients. The process of leaving the field uncultivated is called fallowing

* Organic materials, derived from animal, human and plant residues that contain plant nutrients are called manures. The addition of these materials to the soil is called manuring.
* Compost is a kind of organic manure artificially prepared from plant residues and animal waste products. The process of making compost is known as composting.
* Farm yard manure is a mixture of the solid and liquid excreta of farm animals along with litter and left-over material from roughages or fodder fed to the cattle.
* The practice of mixing under-composed green plant materials into soil for the purpose of improving physical condition and fertility of the soil is referred to as green manuring and the manure so obtained is known as green manure.
* Vermicompost is the end-product of the breakdown of organic matter by some species of earthworms. The process of producing vermicompost is called vermicomposting.
* The artificial application of water for the purpose of supplying moisture essential to plant growth is called irrigation.
* In drip irrigation, water is directly applied to individual plants in the form of discrete, continuous drops through mechanical devices called emitters located at selected points.
* Mixed cropping is a system of sowing two or three crops together on the same land, one being the main crop and the others the subsidiaries.
* Growing two crops in a year in sequence is known as double-cropping. Growing more than two crops in a year is known as multiple-cropping.
* Organisms which damage the crop plants that we grow are called crop pests.
* Biopesticides are a class of environment-friendly, naturally occurring substances or organisms that are used as pesticides to control pests.
* Mixed farming is the combining of two independent agricultural enterprises on the same farm.
* Integrated fish farming is combined culture of fish together with compatible combinations with poultry, duckery, pig rearing and cattle.
* Organic farming is a form of agriculture which avoids or largely excludes the use of synthetic fertilizers and pesticides, plant growth regulators, and livestock feed additives.
* Animal husbandry is the agricultural practice of breeding and raising livestock.
* In most parts of India including Manipur cattle farming is carried out mainly for production of milk. However, for certain sections of people, it represents a good source of meat.
* The type of fish culture in which more than one type of compatible fishes is cultured simultaneously is known as Composite Fish Culture.
* In each honey bee hive, there are thousands of worker bees, hundreds of drones, but only a single queen.

EXERCISES

1. *Define plant breeding.*
2. *Name the different methods of plant breeding.*
3. *What is biometrics?*
4. *What are the common methods of plant selection?*
5. *Define hybridization.*
6. *What is the main aim of combination breeding?*
7. *What is most common method for carrying out combination breeding?*
8. *Define hybrid vigour or heterosis.*
9. *Name some commonly used chemical fertilizers.*
10. *What are the nutrients that plants get from fertilizers?*
11. *Give two harmful effects of chemical fertilizers on the soil?*
12. *How can we replenish soil nutrients through crop rotation?*
13. *Define fallowing.*
14. *What do you mean by manures and manuring?*
15. *Define compost. How is it prepared?*
16. *Write three differences between rural compost and urban compost.*
17. *What is farmyard manure? What is its NPK composition?*
18. *Give two differences between the edible and non-edible oil cakes.*
19. *What is meant by green manuring?*
20. *What do you mean by vermicomposting?*
21. *Enumerate the benefits of using vermicompost to soil.*
22. *What is compost tea? What are its uses?*
23. *Name the different irrigation methods used in agriculture.*
24. *Enumerate the benefits of proper irrigation facilities.*
25. *Define mixed cropping.*
26. *Define crop pests with examples.*
27. *Write a short note on Biopesticides.*
28. *Write on the use of fungi as a biopesticide.*
29. *What do you mean by organic farming? What are the advantages of organic farming?*
30. *What do you mean by animal husbandry? How can animal husbandry improve rural economy?*
31. *Write down five economic values of livestock.*
32. *Define piggery. What are advantages of pig farming in Manipur?*
33. *Write what you know about Composite Fish Culture.*
34. *Name the Indian and exotic carps which can be cultured together.*

CHAPTER – 18

Natural Resources

The earth is the only planet known to have life on it. A large variety of plants and animals exist today on the earth, ranging from protozoa to humans in the animal world, and from algae to trees in the plant kingdom. Life could originate and flourish on the earth because it has the necessary resources essential for the living. The heat and light from the sun is the main source of energy that plays an important role in the maintenance of life on the earth.

18.1 What are the resources on the earth?

We all know that it is the crust of the earth that is habitable. The thickness of the crust varies from 35 to 60 km from the deepest of the oceans to the highest mountains. The solid part of the oceans to crust is called lithosphere. The oceans, rivers and other water bodies on the surface of the earth together comprise the hydrosphere. The gaseous part is known as the atmosphere. It is the air that covers the entire earth like a blanket. The light and heat received from the sun is the main source of energy. Living things are found where these resources exist. The habitable part of the earth where the atmosphere, the hydrosphere and lithosphere interact and make life possible is known as the biosphere.

Biosphere has two types of components, biotic and abiotic. Living things constitute the biotic components. The air, the water and the soil form the non-living or abiotic components of the biosphere. Both the types of components provide resources to meet the basic requirements of life forms. However, the energy required for sustaining life is ultimately obtained from the sun. It is used in the synthesis of food. Most life forms require an ambient temperature, water and food.

The two components affect each other. For example, if it does not rain and the temperature is very high, plants dry up. Animals including us find it very difficult to live in such an environment.

In desert areas there is sand all around. It rains very little, water is hence scarce. Days are very hot while nights are cool. Because of such abiotic conditions there is very little vegetation and a few species of animals can live. Can you name one?

Thus we find that biotic components depend on abiotic components. However, abiotic components are also affected by biotic components. For example, if there are more trees in a place then air contains more moisture at the place and temperature remains low. Also dust particles are less in air. Have you ever noticed this effect? Why we encourage planting of trees on the roadside.

It is noticed that fertility of soil is destroyed by the affect of water, temperature and air in a place where there is less or no plants at all.

Thus, dependence of biotic and abiotic components of the biosphere on each other cannot be ignored as soon as it is being ignored environmental problems start.

18.2 Air, the breath of life.

Air is a mixture of gases that forms a transparent envelope or atmosphere around the earth. Air is dense below near the surface of earth. It becomes progressively rarefied with height. The height to which air or atmosphere extends is about 500 km. It does not escape into space, being held to earth by gravity.

Life and burning of things are not possible without air. We cannot see air like soil and water but we can feel it while breathing. We can see the plants moving, dust and papers being blown by the wind. These show the effects of air.

We can live without food for some days but it is impossible to remain alive without air even for some moments. Hold your breath for sometime. You will start feeling uncomfortable by not taking in air. Hence, air is called the breaths of the life as life cannot exist without it. Even the composition of air is the result of life on earth. Venus and Mars are two planets having air or atmosphere around them. There is no life on these planets. The major component of the atmosphere is found to be carbon dioxide which constitutes 95-97% of the atmosphere.

18.2.1 What is the composition of air?

The main gases present in the air are Nitrogen and oxygen. In addition to these gases carbon dioxide and some inert gases like helium, argon, krypton, Xenon etc are also present in very small quantities. Water in the form of vapour is also present in these gases.

The main composition of air is given in table below:

Gases	Total % of Air	% according to the volume in air.
Oxygen Nitrogen	99%	20.9478.04
Carbon dioxide Argon Other gases and water vapour	1%	0.030.930.05

Besides these gases some dust particles and other gases like oxides of nitrogen and sulphur, carbon monoxide etc are also found in the air the amount of which is more in the industrial areas and less in the area with more plants.

The main components of air remain largely stable as the consumption of various components is counterbalanced by their regeneration. For example, eukaryotic and many prokaryotic cells used up oxygen to break down glucose molecules during respiration for obtaining energy required for their activities. Carbon dioxide is produced in the process. Oxygen is also consumed in the combination of fuels, forest, fires and many other processes. Carbon dioxide is the common product. However, the concentration of carbon dioxide does not increase nor that of oxygen decrease. It is because carbon dioxide is fixed in two ways: (i) green plants convert carbon dioxide into glucose in the presence of sunlight (photosynthesis), giving out oxygen and (ii) many marine animals use dissolved carbon dioxide in sea water as carbonates to make their shells.

18.2.2 Role of air in moderating temperature:

The air which forms the atmosphere covering the Earth like a blanket is a bad conductor of heat. It prevents the sudden increase in temperature during the daylight hours. And during the night, it slows down the escape of heat into outer space. Because of it, the average temperature of the Earth remains fairly steady during the day and even during the course of the year. The moon, which is at nearly the same distance from the sun as that of earth, has no atmosphere. Its temperature rises very high to about 110^{0}C during the day and cools to -190^{0}C during the night.

Activity 18.1

* Take : (i) a beaker full of water,
(ii) a beaker full of sand or soil,
(iii) a corked glass bottle with a thermometer fitted through the cork.

* Measure the temperature
* Keep the three in bright sunlight for three hours.
* Again note the temperature.
* Place the three in shade for three hours and take the temperature.

Find out:

a) Is the temperature reading the same in beakers (i) and (ii)
b) Based on the above data, which would become hot faster – the land or the sea;
c) Is the temperature reading of air in shade the same as the temperature of sand or water
   in shade? What is the reason for this?
d) Is the temperature of air in the closed bottle the same as the temperature taken in open air? What is the reason for this?

Result : Sand or soil heats up quickly in sunlight. It also cools down quickly. Water is very slow to get heated. It is also very slow to cool down. Temperature of air in closed glass bottle rises slowly. It remains higher than the outside air even in shade.

18.2.3 Movement of Air: Wind

Activity 18.2

* Fix a candle in a beaker or wide-mouthed bottle and light it.
* Light an incense stick and take it to the mouth of the above bottle.
* Observe which way the smoke flows when the incense stick is kept near the edge of the mouth.
* Which way does the smoke flow when the incense stick is kept a little above the candle?
* Which way does the smoke flow the incense stick is kept in other regions:

The patterns of the smoke show us the direction in which hot and cold air move. When incense stick is kept near the edge, smoke from incense stick will move towards the flame. This also occurs when it is halfway towards the flame. However, when the incense stick is kept above the flame, the smoke rises up. In all cases smoke flows towards the area of low pressure.

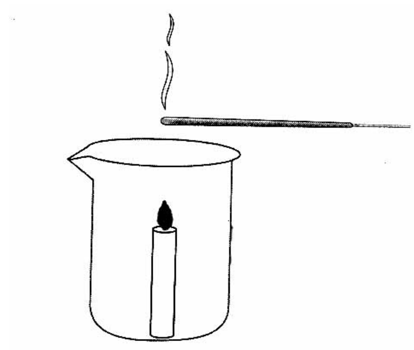


Fig. 18.1: Air currents caused by uneven heating of air

From the above activity you have just performed, you can understand that movement of winds occurs from the area of high pressure to the area of low pressure. Such movement of air resulting in diverse atmospheric phenomena is caused by the uneven heating of the atmosphere in different regions of the earth. Various other factors like the rotation of earth and the presence of mountain ranges in the paths of the winds also influence the movement of winds.

18.1.3 Rain

When water bodies are heated during the day, a great amount of water evaporates and goes into the air. Some amounts of water vapour also get into the atmosphere because of various biological activities (transpiration by plants). When air is heated, it rises up carrying the water vapour with it. As the air rises, it expands and cools, that causes the water vapour in the air to condense to form tiny droplets. Dust particles and other suspended particles in the air act on the nucleus for these drops to form around, that in turn facilitate the process of condensation of water. Once the water droplets are formed, they grow bigger due to condensation of water droplets. When the drops have grown big and heavy, they fall down in the form of rain. Sometimes, when the temperature of air is low, precipitation may occur in the form of snow or hail.

Patterns of rain fall are determined by the prevailing wind patterns. In large parts of India, rains are brought by south-west or north-east monsoons.

18.1.4 Air pollution.

An increase in the content of the harmful substances in air is called **air pollution**. Air pollution can severely affects plants and animals. In human, it can cause many health problems like respiratory problems, renal problems, high blood pressure, problems in nervous system etc.

Industrial growth in the present day has polluted air to a greater extent by releasing SO_2, CO_2, CO, oxides of nitrogen and sulphur etc. For example, the burning of coal and oil to generate electric power, run factories and fuel automobile engines creates oxides of nitrogen and sulphur. Inhalation of these gases is dangerous. SO_2 dissolve in and acidify the rain by forming sulphuric acid. This cause acid rain. Acid rain severely affects the growth of plants, Salmon reproduction and fish yield and it also eats into the surface of the buildings, eroding the stone and brick woods. The combustion of fossil fuels also increases the amount of suspended particles (unburned carbon, hydrocarbons) in air.

18.2 Water:

Water is by far the most important substance necessary for life. Water is present everywhere. The earth's surface is covered for more than 70 percent of its area by water in the form of sea, lakes and rivers. Most of the water of our utilization on the earth comes from rivers, lakes, ponds and even underground wells. Fresh water forms only 2.5 percent of water and major part of this fresh water is frozen in glacial ice. However, the availability of fresh water varies from a place to a place.

Water is one of the most unusual natural compounds found on earth and it is also one of the most important. All the physiological processes take place in the medium of water. All the reactions that take place within our body and within the cells occur between the substances dissolved in water. Substances are also transported from one part of the body to the other in the dissolved form. Hence, organisms need to maintain the level of water within their bodies to stay alive.

18.2.1 Water pollution:

Water pollution adversely changes the quality of water. It disturbs the balance of ecosystem and it causes health hazards to human and animals. Water becomes polluted by the presence or addition of inorganic, organic or biological substances.

Fertilizers and pesticides used in the farm and field get dissolved in water and some percentages of these substances are washed into the water bodies. Effluents from urban and rural sewage, factories etc. are also dumped into rivers or lakes.

Some substances dissolved in water could be poisonous that can cause many diseases like cholera. Enrichment of water by nutrients (especially phosphates and nitrate) results in eutrophication of lakes and water bodies. This results in excessive growth of harmful blue green algae and depletion of dissolved oxygen present in the lake. Such reduction in the amount of dissolved oxygen adversely affects aquatic organisms. Aquatic organisms can sustain a certain range of temperature in the water body. Their breeding processes may be adversely affected if there is any change of temperature.

18.3 Soil

Soil is derived from the Latin word solum meaning 'the floor' or the ground surface. The soil is the weathered (or broken particles) surface of the earth's crusts which is mixed with organic material and in which microorganisms live and plants grow. Thickness of the soil on the earth's crust ranges from a few millimeters to 3-4 meters. Terrestrial plants depend upon the soil for their nutrients, water supply, and anchorage.

18.3.1 Formation of Soil

Soil formation is a slow process and it may take thousands of years to form a thick soil layer. Soils are formed by the disintegration and decomposition of rocks due to weathering (action of rain-water, running streams, wind, alternate high and low temperature etc) and action of soil organisms like bacteria, fungi, protozoa, earthworm etc. and also interaction of various chemical substances present the soil. Although soils are normally formed from underlying rocks in a particular region, these may be transported to long distances by agencies like rivers, glaciers, strong winds, etc.

Physically the soil is a mixture of mineral particles of varying sizes – coarse and fine – of different degrees, some angular and rounded, with certain amount of decaying organic matter in it.

The spaces between the soil particles may be occupied by air and water. Water has minerals dissolved in it. Soil water is of different types: capillary water, hygroscopic water and gravitational water. Plants can absorb only capillary water. Soil air differs from atmospheric air as it is interrupted by the soil particles and has higher moisture content. Carbon dioxide content of the soil air is usually higher and oxygen content is lower than in the atmospheric air. The amount of air in the soil largely depends on the amount of water in the soil. Proper aeration (ventilation) of soil is necessary for plants roots and soil microorganisms and humus formation, nitrification etc.

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Humus constitutes the most important part of the soil. It consists of partially decayed organic matters. It makes the soil porous, thereby increasing the water-holding capacity. It is rich in nutrients that promote plant growth. Being black, humus absorbs heat to warm up the soil. The nutrient contents of a soil, the amount of humus present in it and depth of the soil are some of the factors that determines which plant can thrive on that soil. The quality of the topsoil is an important factor that decides biodiversity in that area.

Soils may be classified into different types depending upon size of the particles that a particular type of soil is composed of. Soils may be classified into the following types:

(1) **Sandy soil**: It contains a large proportion of sand and small amount of clay and slit. It remains dry most of the time as it is well aerated and porous. It cannot hold much water. This soil is light.

(2) **Clay Soil**: This soil contains more of clay and very small amount of slit and humus. It has a great capacity for retaining water. It is heavy and easily becomes compact and cracks when it dries up.

(3) **Loamy Soil**: It contains more of slit, a small amount of clay and sand. It is the best soil for plant growth and is most suitable for agricultural crops because all the important physical conditions are satisfied. This soil has good capacity for water holding and is porous to allow aeration of roots.

18.3.2 Soil Erosion:

The soil erosion is a process of removal of fertile surface of the soil layer by various factors. The movement of soil takes place from one place to another place in soil erosion due to flood, rainwater or winds.

Soil erosion can be understood in performing the following activity.

Activity: 18.3

Let us take two identical trays and fill them with soil. Plant mustard or green gram or paddy in one of the trays and water both the trays regularly for a few days till the first tray is covered by plant growth. Now, tilt both the trays and fix them in that position. Make sure that both the trays are tilted at the same angle. Pour equal amount of water gently on both trays such that the water flows out of the tray. And study amount of soil that is carried out of the trays. Is the amount the same in both the trays?

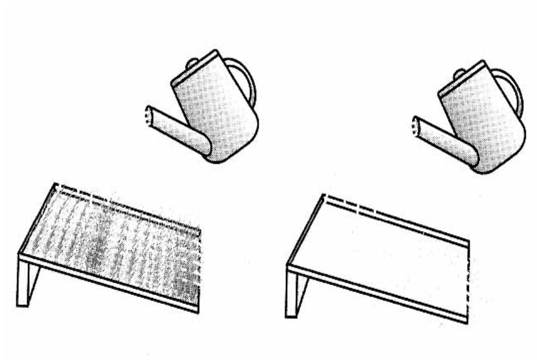

Fig.18.2: Effect of flowing water on the top soil

Now pour equal amounts of water on both thetrays from a height. Pour three or four times the amount that you poured earlier. And study the amount of soil that is carried out of the trays now. Is the amount the same in both trays? Is the amount of soil that is carried out more or less or equal to the amount washed out earlier?

The plant roots have a very important role in preventing soil erosion. The large scale deforestation not only destroys biodiversity but also cause soil erosion. If there is no vegetation on the topsoil, it is likely to remove the surface layer of the soil quickly. Such process is accelerated in hilly and mountainous regions. The process of soil erosion is very difficult to reverse. Vegetative cover on the ground facilitates percolation of water into the deeper layer.

18.3.3 Soil Pollution

Soil pollution is the removal of useful components from the soil and addition of other substances that not only can adversely affect the fertility of the soil but also kill the organisms that live in it. Soil pollution is caused by solid wastes like polythene plastics etc and chemicals like pesticides and fertilizers used in farming. Industries are also one of the major factors in soil pollution. Soil pollution can destroy the soil structure by killing soil organisms that are responsible for recycling of nutrients in the soil. It can also kill the earthworms that are instrumental in making the soil rich humus.

18.4 Biogeochemical Cycles

The life on the earth depends upon the availability of energy and circulation of certain chemical substances such as Carbon (C), nitrogen (N), oxygen (O), potassium (K), Sulphur (S), Phosphorus (P) etc. These substances act as nutrients. There is a non-stop transfer and circulation of these nutrients through soil, water, air and living organisms. *This flow of nutrients from the non-livings to livings, back to the non-livings in a cyclic form is known as* **biogeochemical cycle**. Cycling of such nutrients is required for the working of any type of ecosystem and ecological balance on the earth.

18.4.1 Water Cycle

Water is the most abundant compound present in all living organisms. It is made up of two elements, hydrogen and oxygen. Living organisms contain about 75% of water in their body. In order to perform various life processes, living organism require water. Water from the oceans evaporates to become water vapour. These vapours get cooled and slowly condense into water droplets at the low temperatures. These droplets come down as rain and snow on the land and ultimately get collected again in the ocean passing through rivers. This circulation of water is known as water cycle.

All the water comes down as rain and snow do not go to ocean. Some water get absorbed by the soil and some of these underground water are brought to the surface of the earth through well and tube-wells.

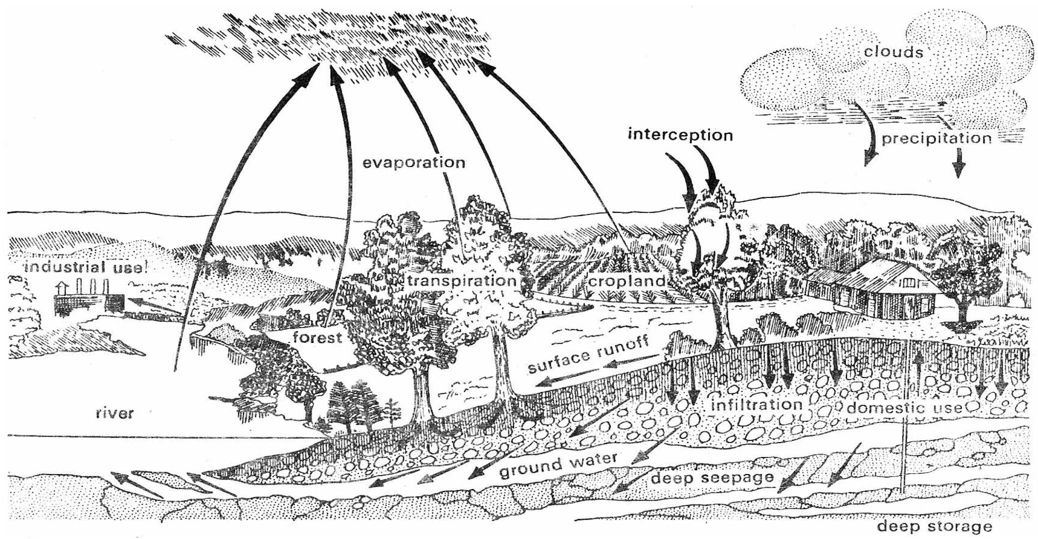

Fig. 18.3: Water Cycle in nature

18.4.2 Oxygen Cycle

Oxygen is the second most abundant element forming about 21% of the constituents of the air. It is available in free molecular form as oxygen gas (O_2) Oxygen occurs as a component of water (H_2O) and carbon dioxide (CO_2) in combined form. It remains dissolved in water and helps in the survival of animal and plants living in under water (aquatic).

Oxygen is taken from air for respiration by all living beings. Then convert it into carbon dioxide and water during respiration and release the products into atmosphere. Micro organisms like decomposers also require oxygen during decomposition. Oxygen is also used up during burning of fossil fuels like wood, coal etc, releasing carbon dioxide and water. These carbon dioxide and water released during the above processes are used by plants during the process of photosynthesis to form carbohydrates releasing oxygen gas into the atmosphere. Thus, oxygen cycle is completed in nature. Oxygen cycle maintains the oxygen contents of the atmosphere at a constant level.

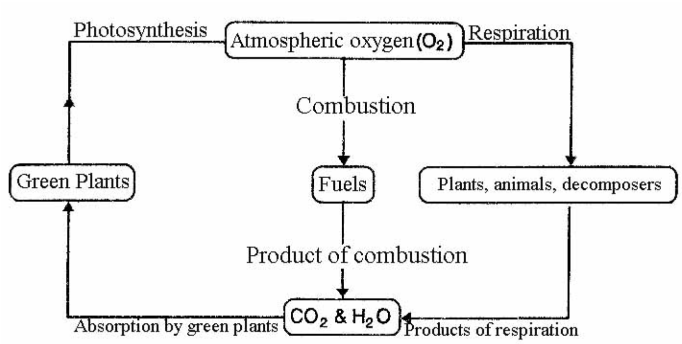

Fig. 18.5: Oxygen Cycle

18.4.2.1 Depletion of ozone layer: Ozone hole:

Ozone (O_3) is an isotope of oxygen containing three atoms of oxygen. It is poisonous and we are lucky that it is not stable nearer to the surface of the earth. It is found in the stratosphere. The presence of this layer containing ozone is essential necessity for life on the earth. It absorbs harmful ultraviolet rays of the sun, preventing it from reaching earth surface. These ultraviolet rays can damage many forms of life if they reach the earth's surface.

Over the past few decades, it is discovered that this ozone layer is getting depleted. It is because of man made pollutants which react with ozone molecules and resulting in the reduction of ozone layer. Some major pollutants responsible for depletion of ozone are Chlorofloro carbons (CFCs), nitrogen oxides, hydrocarbons and oxides of chlorine and bromine. Recently, a hole in the ozone layer is found above the Antarctica. Consequences may be very serious if it is not checked now. Many countries have started working on it to stop further depletion in ozone layer.

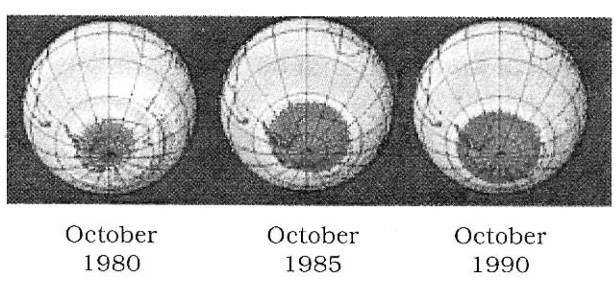

Fig. 18.6: Satellite picture showing the hole (black colour) in the ozone layer over Antarctica

18.4.3 Carbon Cycle:

Carbon is a basic component of all organic compounds. It is also a building material of all living organisms. It can exist in different forms as carbohydrates, nucleic acids, proteins, fats. It is transferred from organisms to organisms through food chain systems. Gaseous carbon is mainly occurring in the atmosphere (the concentration of carbon is about 0.03 – 0.04) and they are mostly dissolved in the ocean. Movement of carbon takes place in cycle from reservoir i.e. atmosphere to producers and then to consumers.

Carbon cycle involves a constant supply of carbon dioxide into the air. This is accomplished by the plants and animals, as they release carbon in the form of carbon dioxide during respiration. Carbon is also released by bacteria, fungi and decomposers, acting on the animal wastes. The burning of coal, wood etc. also releases carbon to the air. Limestones also release carbon due to weathering. Hydrochloric acid (HCl) reacts with marble (calcium carbonate), washing soda (sodium carbonate) etc to produce carbon dioxide.

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

(Marble) (Hydrochloric acid)

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2 \uparrow$

(Washing soda) (Hydrochloric acid)

Further, there is continual exchange of CO_2 between the atmosphere and water. If there is any deficit in concentration of CO_2 either in air or in sea, the movement of it takes place towards the air or sea. Carbon cycle occurs in the following way.

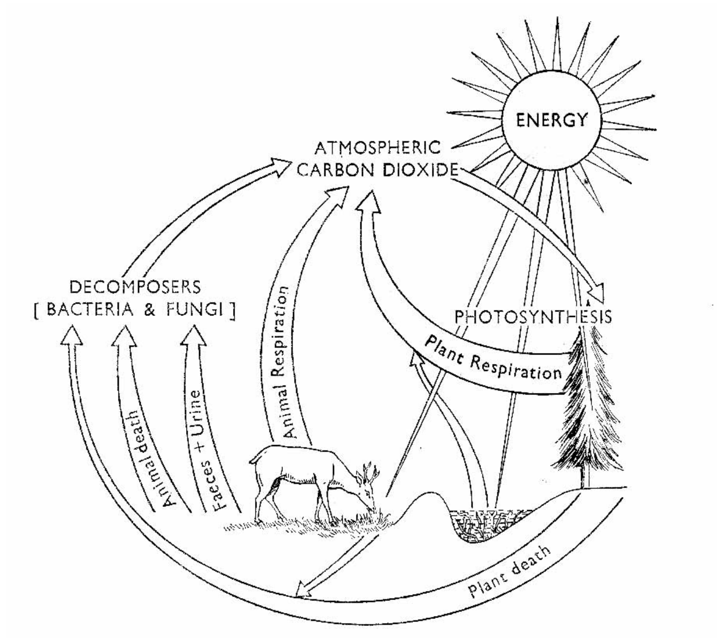

Fig. 18.7: Carbon Cycle

18.4.3.1 Greenhouse effect:

The carbon dioxide of the atmosphere keeps the earth warm. Such warming of earth is known as green house effect. Without it, the earth would be a frozen wasteland. Earth absorbs some short wavelengths or ultraviolet radiation coming from sun penetrating the atmosphere. This absorbedenergy is also radiated back to space. The atmosphere has some gases that trap the outgoing radiation, resulting in warming the earth. Such gases are known as greenhouse gases. Some prominent

examples of green house gases are water vapour, carbon dioxide, methane, ozone, nitrous oxide, CFC(Chloroflouro carbons) and halons.

The increase in the quantity of the greenhouse gases in the atmosphere can reinforce the greenhouse effect and leads to the global warming, which is rise in average global temperature to a level which affects the life-forms on the earth surface. Global warming can give a dangerous impact on the earth. It may lead to melting of polar ice caps and ultimately rise in the sea level. The sea water will inundate the coastal area and massive human and economic dislocation in low-lying areas around the world.

18.4.4 Nitrogen cycle

Nitrogen is the most abundant component of the atmosphere. Nitrogen gas makes up 78%of the atmosphere. It is present in all organisms. It is also a part of many molecules essential to life like nucleic acids (DNA and RNA), proteins and some vitamins.

There is a regular cycle of nitrogen through the air, soil, plants and animals. Soil nitrogen is not exhaustible. Free nitrogen of the air is brought down into the soil as products of nitrates and nitrites of some salts through fixation and assimilation by bacteria of particular kind. These are known as 'nitrogen fixing' bacteria which are may be free living or commonly found in the roots of legumes plants in a special structure known as root nodules. Physical processes like lightning also convert this nitrogen into nitrites and nitrates. During lightning, high temperature and pressure are created in the air and convert nitrogen to its oxides. These oxides dissolve in water to give nitric and nitrous acid and fall on land along with rain. These are then utilized by various life-forms. Plants absorbed these nitrates and convert into ammonia and then into amino-acids. Plant proteins are subsequently consumed by herbivorous animals. Proteins and other nitrogenous compounds go to the soil after the death and decay of animals and plants. These compounds are again converted into nitrates by ammonification (process of formation of ammonia) and nitrification (process of conversion of ammonia into nitrates). Nitrates are absorbed by plants again. Finally there are some other bacteria like decomposers which reduce nitrates back into nitrogen or to ammonia or to some other oxides. This process is known as denitrification. Free nitrogen returns to atmosphere and oxides are absorbed by plants again. Thus, there is a nitrogen cycle.

Some organisms involved in nitrogen cycles are

1. *Rhizobium,* found in root nodules, *Azotobactor* in soil, blue green algae are responsible for nitrogen fixation.

2. Putrefying bacteria and fungi are responsible for ammonification.
3. Nitrifying bacteria like *Nitrosomonas* and *Nitrobacter* for nitrification.
4. *Pseudomonas*, denitrifying bacteria, responsible for denitrification.

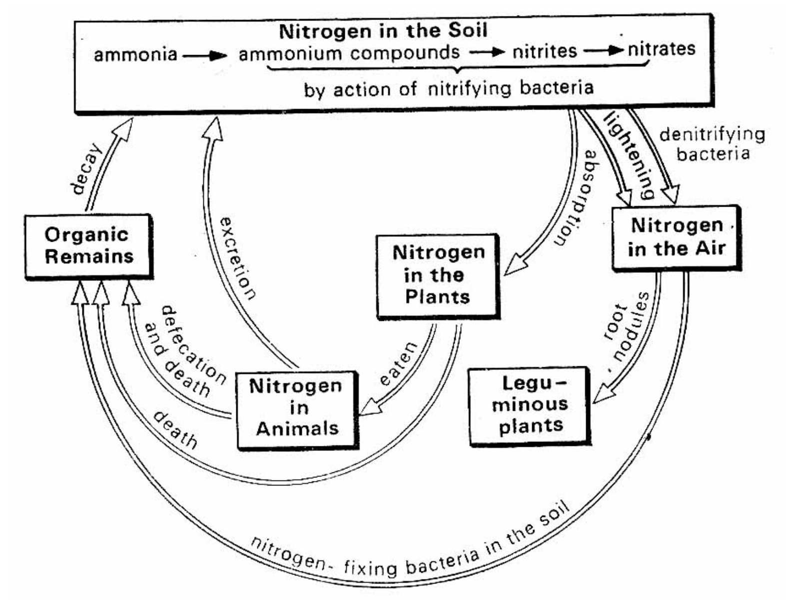

Fig.18.4: Nitrogen Cycle

POINTS TO REMEMBER

- * Life on earth depends on natural resources like water, air, soil and sun energy.
- * Winds are caused by uneven heating of air over the land and water-bodies.
- * Evaporation of water from water bodies and subsequent condensation gives us rain.
- * Biogeochemical cycle is the flow of nutrients from the non-livings to livings and back to the non-livings in a cyclic form.

  Biogeochemical cycle maintain the balance between the various components of the biosphere.
- * Pollution of water, air and soil affect the quality of life and harm the biodiversity.
- * Some greenhouse gases like water vapour, carbon dioxide, CFCs etc. causes greenhouse effect resulting in global warming.
- * We need to conserve our natural resources and use them in a sustainable manner.

EXERCISES

(1) *Why is the atmosphere essential for life?*
(2) *Why is water essential for life?*
(3) *What are biogeochemical cycles? Explain the pathway of any one.*
(4) *Define nitrogen fixation? Name some bacteria involved in it.*
(5) *What is green house effect?*
(6) *What is global warming? How is it caused?*
(7) *How is depletion in ozone layer caused?*
(8) *Give diagrammatical representation of nitrogen cycle.*
(9) *Give diagrammatical representation of carbon cycle.*
(10) *How does oxygen content of the atmosphere maintained?*
(11) *Write on the importance of water cycle in the environment.*