- Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus.
- Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model.
- Neils Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.
- J. Chadwick discovered presence of neutrons in the nucleus of an atom. So, the three sub-atomic particles of an atom are: (i) electrons, (ii) protons and (iii) neutrons. Electrons are negatively charged, protons are positively charged and neutrons have no charges. The mass of an electron is about $\frac{1}{2000}$ times the mass of an hydrogen atom. The mass of a proton and a neutron is taken as one unit each.
- Shells of an atom are designated as K,L,M,N,....
- Valency is the combining capacity of an atom.
- The atomic number of an element is the same as the number of protons in the nucleus of its atom.
- The mass number of an atom is equal to the number of nucleons in its nucleus.
- Isotopes are atoms of the same element, which have different mass numbers.
- Isobars are atoms having the same mass number but different atomic numbers.
- Elements are defined by the number of protons they possess.

Exercises

1. Compare the properties of electrons, protons and neutrons.
2. What are the limitations of J.J. Thomson's model of the atom?
3. What are the limitations of Rutherford's model of the atom?
4. Describe Bohr's model of the atom.
5. Compare all the proposed models of an atom given in this chapter.
6. Summarise the rules for writing of distribution of electrons in various shells for the first eighteen elements.
7. Define valency by taking examples of silicon and oxygen.

8. Explain with examples (i) Atomic number, (ii) Mass number, (iii) Isotopes and iv) Isobars. Give any two uses of isotopes.
9. Na^+ has completely filled K and L shells. Explain.
10. If bromine atom is available in the form of, say, two isotopes $^{79}_{35}Br$ (49.7%) and $^{81}_{35}Br$ (50.3%), calculate the average atomic mass of bromine atom.
11. The average atomic mass of a sample of an element X is 16.2 u. What are the percentages of isotopes $^{16}_{8}X$ and $^{18}_{8}X$ in the sample?
12. If Z = 3, what would be the valency of the element? Also, name the element.
13. Composition of the nuclei of two atomic species X and Y are given as under

		X	Y
Protons	=	6	6
Neutrons	=	6	8

Give the mass numbers of X and Y. What is the relation between the two species?
14. For the following statements, write T for True and F for False.
    (a) J.J. Thomson proposed that the nucleus of an atom contains only nucleons.
    (b) A neutron is formed by an electron and a proton combining together. Therefore, it is neutral.
    (c) The mass of an electron is about $\frac{1}{2000}$ times that of proton.
    (d) An isotope of iodine is used for making tincture iodine, which is used as a medicine.

    Put tick (✓) against correct choice and cross (×) against wrong choice in questions 15, 16 and 17
15. Rutherford's alpha-particle scattering experiment was responsible for the discovery of
    (a) Atomic Nucleus (b) Electron
    (c) Proton (d) Neutron
16. Isotopes of an element have
    (a) the same physical properties
    (b) different chemical properties
    (c) different number of neutrons
    (d) different atomic numbers.
17. Number of valence electrons in Cl^- ion are:
    (a) 16 (b) 8 (c) 17 (d) 18

18. Which one of the following is a correct electronic configuration of sodium?

(a) 2,8 (b) 8,2,1 (c) 2,1,8 (d) 2,8,1.

19. Complete the following table.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	-	10	-	-	-
16	32	-	-	-	Sulphur
-	24	-	12	-	-
-	2	-	1	-	-
-	1	0	1	0	-

Chapter 5

The Fundamental Unit of Life

While examining a thin slice of cork, Robert Hooke saw that the cork resembled the structure of a honeycomb consisting of many little compartments. Cork is a substance which comes from the bark of a tree. This was in the year 1665 when Hooke made this chance observation through a self-designed microscope. Robert Hooke called these boxes cells. Cell is a Latin word for 'a little room'.

This may seem to be a very small and insignificant incident but it is very important in the history of science. This was the very first time that someone had observed that living things appear to consist of separate units. The use of the word 'cell' to describe these units is being used till this day in biology.

Let us find out about cells.

5.1 What are Living Organisms Made Up of?

Activity _______________ 5.1

- Let us take a small piece from 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. This layer can be put immediately in a watch-glass containing water. This will prevent the peel from getting folded or getting dry. What do we do with this peel?
- Let us take a glass slide, put a drop of 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 paintbrush might be necessary to help transfer the peel. Now we put a drop of safranin solution on this piece followed by a cover slip. Take care to avoid air bubbles while putting the cover slip with the help of a mounting needle. Ask your teacher for help. We have prepared a temporary mount of onion peel. We can observe this slide under low power followed by high powers of a compound microscope.

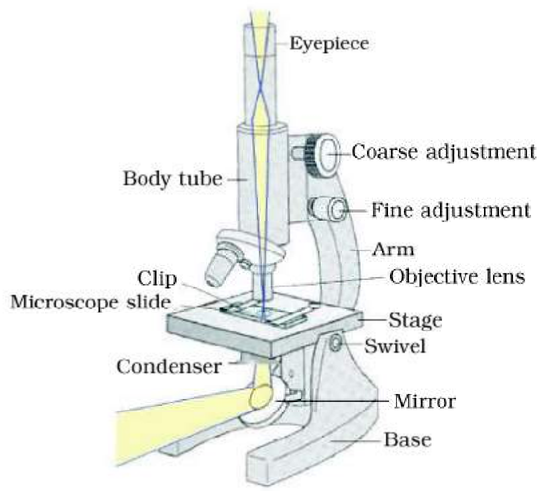


Fig. 5.1: *Compound microscope*

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 Fig. 5.2?

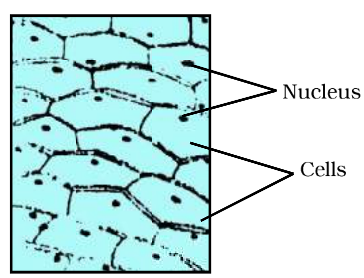


Fig. 5.2: *Cells of an onion peel*

We can try preparing temporary mounts of peels of onions of different sizes. What do we observe? Do we see similar structures or different structures?

What are these structures?

These structures look similar to each other. Together they form a big structure like an onion bulb! We find from this activity that onion bulbs of different sizes have similar small structures visible under a microscope. The cells of the onion peel will all look the same, regardless of the size of the onion they came from.

These small structures that we see are the basic building units of the onion bulb. These structures are called cells. Not only onions, but all organisms that we observe around are made up of cells. However, there are also single cells that live on their own.

More to know

Cells were first discovered by Robert Hooke in 1665. He observed the cells in a cork slice with the help of a primitive microscope. Leeuwenhoek (1674), with the improved microscope, discovered the free living cells in pond water for the first time. It was Robert Brown in 1831 who discovered the nucleus in the cell. Purkinje in 1839 coined the term 'protoplasm' for the fluid substance of the cell. The cell theory, that all the plants and animals are composed of cells and that the cell is the basic unit of life, was presented by two biologists, Schleiden (1838) and Schwann (1839). The cell theory was further expanded by Virchow (1855) by suggesting that all cells arise from pre-existing cells. With the discovery of the electron microscope in 1940, it was possible to observe and understand the complex structure of the cell and its various organelles.

The invention of magnifying lenses led to the discovery of the microscopic world. It is now known that a single cell may constitute a whole organism as in *Amoeba*, *Chlamydomonas*, *Paramoecium* and bacteria. These organisms are called unicellular organisms (uni = single). On the other hand, many cells group together in a single body and assume different functions in it to form various body parts in multicellular organisms (multi = many) such as some fungi, plants and animals. Can we find out names of some more unicellular organisms?

Every multi-cellular organism has come from a single cell. How? Cells divide to produce cells of their own kind. All cells thus come from pre-existing cells.

Activity 5.2

- We can try preparing temporary mounts of leaf peels, tip of roots of onion or even peels of onions of different sizes.
- After performing the above activity, let us see what the answers to the following questions would be:
  - (a) Do all cells look alike in terms of shape and size?
  - (b) Do all cells look alike in structure?
  - (c) Could we find differences among cells from different parts of a plant body?
  - (d) What similarities could we find?

Some organisms can also have cells of different kinds. Look at the following picture. It depicts some cells from the human body.

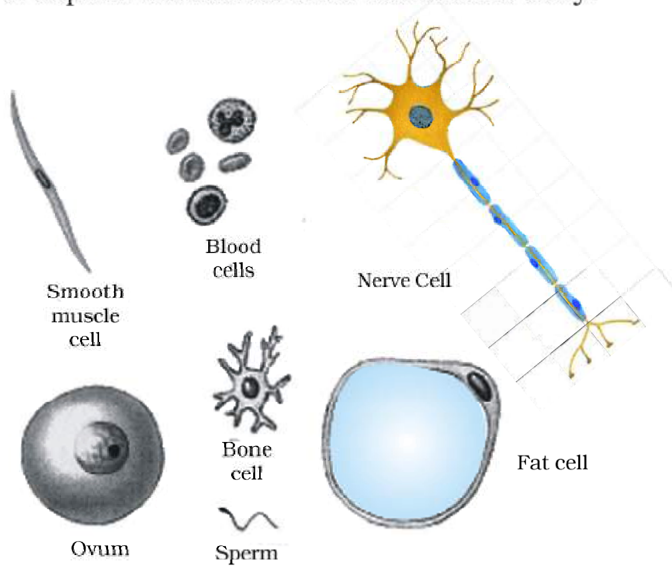


Fig. 5.3: *Various cells from the human body*

The shape and size of cells are related to the specific function they perform. Some cells like *Amoeba* have changing shapes. In some cases the cell shape could be more or less fixed and 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. How does a living cell perform these basic functions? We know that there is a division of labour in multicellular organisms such as human beings. This means that different parts of the human body perform different functions. The human body has a heart to pump blood, a stomach to digest food and so on. Similarly, division of labour is also seen within a single cell. In fact, each such cell has got certain specific components within it known as cell organelles. Each kind of cell organelle performs a special function, such as making new material in the cell, clearing up the waste material from the cell and so on. A cell is able to live and perform all its functions because of these organelles. 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.

Questions

1. *Who discovered cells, and how?*
2. *Why is the cell called the structural and functional unit of life?*

5.2 What is a Cell Made Up of? What is the Structural Organisation of a Cell?

We saw above that the cell has special components called organelles. How is a cell organised?

If we study a cell under a microscope, we would come across three features in almost every cell; plasma membrane, nucleus and cytoplasm. All activities inside the cell and interactions of the cell with its environment are possible due to these features. Let us see how.

5.2.1 Plasma membrane or cell membrane

This is the outermost covering of the cell that separates the contents of the cell from its external environment. The plasma membrane allows or permits the entry and exit 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.

How does the movement of substances take place into the cell? How do substances move out of the cell?

Some substances like carbon dioxide or oxygen can move across the cell membrane by a process called diffusion. We have studied the process of diffusion in earlier chapters. We saw that there is spontaneous movement of a substance from a region of high concentration to a region where its concentration is low.

Something similar to this happens in cells when, for example, some substance like CO_2 (which is cellular waste and requires to be excreted out by the cell) accumulates in high concentrations inside the cell. In the cell's external environment, the concentration of CO_2 is low as compared to that inside the cell. As soon as there is a difference of concentration of CO_2 inside and outside a cell, CO_2 moves out of the cell, from a region of high concentration, to a region of low concentration outside the cell by the process of diffusion. Similarly, O_2 enters the cell by the process of diffusion when the level or concentration of O_2 inside the cell decreases. Thus, diffusion plays an important role in gaseous exchange between the cells as well as the cell and its external environment.

Water also obeys the law of diffusion. The movement of water molecules through such a selectively permeable membrane is called osmosis. The movement of water across the plasma membrane is also affected by the amount of substance dissolved in water. Thus, osmosis is the passage of water from a region of high water concentration through a selectively permeable membrane to a region of low water concentration till equilibrium is reached.

What will happen if we put an animal cell or a plant cell into a solution of sugar or salt in water?

One of the following three things could happen:

1. If the medium surrounding the cell has a higher water concentration than the cell, meaning that the outside solution is very dilute, the cell will gain water by osmosis. Such a solution is known as a hypotonic solution.

   Water molecules are free to pass across the cell membrane in both directions, but more water will come into the cell than will leave. The net (overall) result is that water enters the cell. The cell is likely to swell up.
2. If the medium has exactly the same water concentration as the cell, there will be no net movement of water across the cell membrane. Such a solution is known as an isotonic solution.

   Water crosses the cell membrane in both directions, but the amount going in is the same as the amount going out, so there is no overall movement of water. The cell will stay the same size.
3. If the medium has a lower concentration of water than the cell, meaning that it is a very concentrated solution, the cell will lose water by osmosis. Such a solution is known as a hypertonic solution.

   Again, water crosses the cell membrane in both directions, but this time more water leaves the cell than enters it. Therefore the cell will shrink.

Thus, osmosis is a special case of diffusion through a selectively permeable membrane. Now let us try out the following activity:

Activity _______________ *5.3*

Osmosis with an egg

(a) Remove the shell of an egg by dissolving it in dilute hydrochloric acid. The shell is mostly calcium carbonate. A thin outer skin now encloses the egg. Put the egg in pure water and observe after 5 minutes. What do we observe?
The egg swells because water passes into it by osmosis.

(b) Place a similar de-shelled egg in a concentrated salt solution and observe for 5 minutes. The egg shrinks. Why?
Water passes out of the egg solution into the salt solution because the salt solution is more concentrated.

We can also try a similar activity with dried raisins or apricots.

Activity _______________ *5.4*

- Put dried raisins or apricots in plain water and leave them for some time. Then place them into a concentrated solution of sugar or salt. You will observe the following:
  (a) Each gains water and swells when placed in water.
  (b) However, when placed in the concentrated solution it loses water, and consequently shrinks.

Unicellular freshwater organisms and most plant cells tend to gain water through osmosis. Absorption of water by plant roots is also an example of osmosis.

Thus, diffusion is important in exhange of gases and water in the life of a cell. In additions to this, the cell also obtains nutrition from its environment. Different molecules move in and out of the cell through a type of transport requiring use of energy.

The plasma membrane is flexible and is made up of organic molecules called lipids and proteins. However, we can observe the structure of the plasma membrane only through an electron microscope.

The flexibility of the cell membrane also enables the cell to engulf in food and other material from its external environment. Such processes are known as endocytosis. *Amoeba* acquires its food through such processes.

Activity 5.5

- Find out about electron microscopes from resources in the school library or through the internet. Discuss it with your teacher.

Questions

1. *How do substances like CO_2 and water move in and out of the cell? Discuss.*
2. *Why is the plasma membrane called a selectively permeable membrane?*

5.2.2 Cell wall

Plant cells, in addition to the plasma membrane, have another rigid outer covering called the cell wall. The cell wall lies outside the plasma membrane. The plant cell wall is mainly composed of cellulose. Cellulose 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 5.6

- Mount the peel of a Rhoeo leaf in water on a slide and examine cells 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. What do we see?
- Now place some Rhoeo 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. What do we find? Did plasmolysis occur now?

What do we infer from this activity? It appears that only living cells, and not dead cells, are able to absorb water by osmosis.

Cell walls permit the cells of plants, fungi and bacteria to withstand very dilute (hypotonic) external media without bursting. In such media the cells tend to take up water by osmosis. The cell swells, building up pressure against the cell wall. The wall 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.

5.2.3 Nucleus

Remember the temporary mount of onion peel we prepared? We had put iodine solution on the peel. Why? What would we see if we tried observing the peel without putting the iodine solution? Try it and see what the difference is. Further, when we put iodine solution on the peel, did each cell get evenly coloured?

According to their chemical composition different regions of cells get coloured differentially. Some regions appear darker than other regions. Apart from iodine solution we could also use safranin solution or methylene blue solution to stain the cells.

We have observed cells from an onion; let us now observe cells from our own body.

Activity 5.7

- Let us take a glass slide with a drop of water on it. Using an ice-cream spoon gently scrape the inside surface of the cheek. Does any material get stuck on the spoon? 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!
- What do we observe? What is the shape of the cells we see? Draw it on the observation sheet.

- Was there a darkly coloured, spherical or oval, dot-like structure near the centre of each cell? This structure is called nucleus. Were there similar structures in onion peel cells?

The nucleus has a double layered covering called nuclear membrane. The nuclear membrane has pores which allow the transfer of material from inside the nucleus to its outside, that is, to the cytoplasm (which we will talk about in section 5.2.4).

The nucleus contains chromosomes, which are visible as rod-shaped structures only when the cell is about to divide. Chromosomes contain information for inheritance of characters from parents to next generation in the form of DNA (Deoxyribo Nucleic Acid) molecules. Chromosomes are composed of DNA and protein. DNA molecules contain the information necessary for constructing and organising cells. Functional segments of DNA are called genes. 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 structures. Whenever the cell is about to divide, the chromatin material gets organised into chromosomes.

The nucleus plays a central role in cellular reproduction, the process by which a single cell divides and forms two new cells. It also plays a crucial part, along with the environment, in determining the way the cell will develop and what form it will exhibit at maturity, by directing the chemical activities of the cell.

In some organisms like bacteria, the nuclear region of the cell may be poorly defined due to the absence of a nuclear membrane. Such an undefined nuclear region containing only nucleic acids is called a nucleoid. Such organisms, whose cells lack a nuclear membrane, are called prokaryotes (Pro = primitive or primary; karyote ≈ karyon = nucleus). Organisms with cells having a nuclear membrane are called eukaryotes.

Prokaryotic cells (see Fig. 5.4) also lack most of the other cytoplasmic organelles present in eukaryotic cells. Many of the functions of such organelles are also performed by poorly organised parts of the cytoplasm (see section 5.2.4). The chlorophyll in photosynthetic prokaryotic bacteria is associated with membranous vesicles (bag like structures) but not with plastids as in eukaryotic cells (see section 5.2.5).

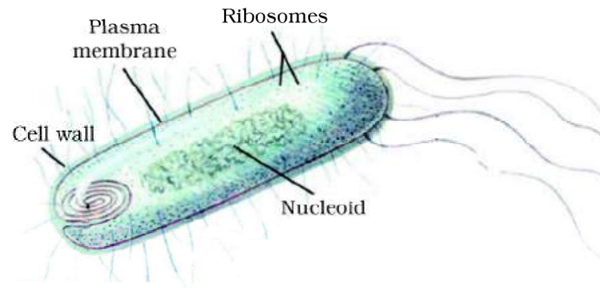


Fig. 5.4: *Prokaryotic cell*

5.2.4 Cytoplasm

When we look at the temporary mounts of onion peel as well as human cheek cells, we can see a large region of each cell enclosed by the cell membrane. This region takes up very little stain. It is called the cytoplasm. The cytoplasm is the fluid content inside the plasma membrane. It also contains many specialised cell organelles. Each of these organelles performs a specific function for the cell.

Cell organelles are enclosed by membranes. In prokaryotes, beside the absence of a defined nuclear region, the membrane-bound cell organelles are also absent. On the other hand, the eukaryotic cells have nuclear membrane as well as membrane-enclosed organelles.

The significance of membranes can be illustrated with the example of viruses. Viruses lack any membranes and hence do not show characteristics of life until they enter a living body and use its cell machinery to multiply.

uestion

1. Fill in the gaps in the following table illustrating differences between prokaryotic and eukaryotic cells.

Prokaryotic Cell	Eukaryotic Cell
1. Size : generally small (1-10 μm) 1 μm = 10^{-6} m	1. Size: generally large (5-100 μm)
2. Nuclear region: ______________ ______________ and known as__	2. Nuclear region: well defined and surrounded by a nuclear membrane
3. Chromosome: single	3. More than one chromosome
4. Membrane-bound cell organelles absent	4. ______________ ______________ ______________

5.2.5 CELL ORGANELLES

Every cell has a membrane around it to keep its own contents separate from the external environment. Large and complex cells, including cells from multicellular organisms, need a lot of chemical activities to support their complicated structure and function. To keep these activities of different kinds separate from each other, these cells use membrane-bound little structures (or 'organelles') within themselves. This is one of the features of the eukaryotic cells that distinguish them from prokaryotic cells. Some of these organelles are visible only with an electron microscope.

We have talked about the nucleus in a previous section. Some important examples of cell organelles which we will discuss now are: endoplasmic reticulum, Golgi apparatus, lysosomes, mitochondria and plastids. They are important because they carry out some very crucial functions in cells.

5.2.5 (i) *ENDOPLASMIC RETICULUM (ER)*

The endoplasmic reticulum (ER) is a large network of membrane-bound tubes and sheets. It looks like long tubules or round or oblong bags (vesicles). The ER membrane is similar in structure to the plasma membrane. There are two types of ER– rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). RER looks rough under a microscope because it has particles called ribosomes attached to its surface. The ribosomes, which are present in all active cells, are the sites of protein manufacture. The manufactured proteins are then sent to various places in the cell depending on need, using the ER. The SER helps in the manufacture of fat molecules, or lipids, important for cell function. Some of these proteins and lipids help in building the cell membrane. This process is known as membrane biogenesis. Some other proteins and lipids function as enzymes and hormones. Although the ER varies greatly in appearance in different cells, it always forms a network system.

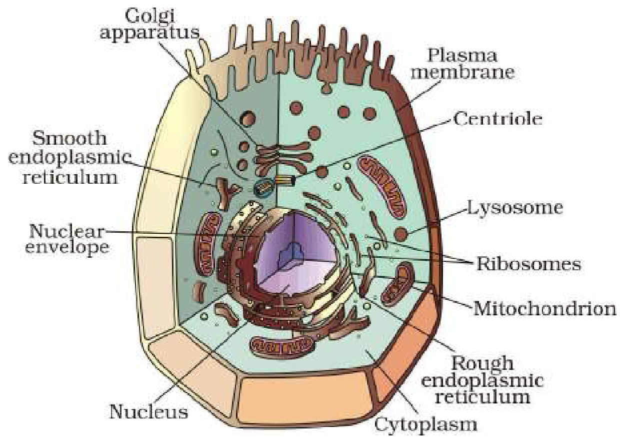


Fig. 5.5: *Animal cell*

Thus, one function of the ER is to serve as channels for the transport of materials (especially proteins) between various regions of the cytoplasm or between the cytoplasm and the nucleus. The ER also functions as a cytoplasmic framework providing a surface for some of the biochemical activities of the cell. In the liver cells of the group of animals called vertebrates (see Chapter 7), SER plays a crucial role in detoxifying many poisons and drugs.

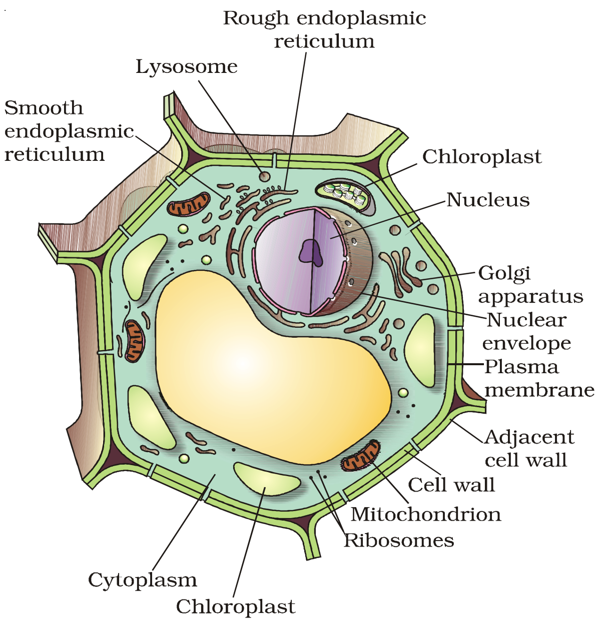
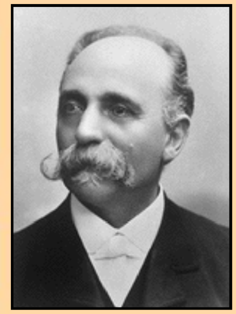


Fig. 5.6: *Plant cell*

5.2.5 (ii) *GOLGI APPARATUS*

The Golgi apparatus, first described by Camillo Golgi, consists of a system of membrane-bound vesicles (flattened sacs) arranged approximately parallel to each other in stacks called cisterns. These membranes often have connections with the membranes of ER and therefore constitute another portion of a complex cellular membrane system.

The material synthesised near the ER is packaged and dispatched to various targets inside and outside the cell through the Golgi apparatus. Its functions 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 formation of lysosomes [see 5.2.5 (iii)].



Camillo Golgi was born at Corteno near Brescia in 1843. He studied medicine at the University of Pavia. After graduating in 1865, he continued to work in Pavia at the Hospital of St. Matteo. At that time most of his investigations were concerned with the nervous system. In 1872 he accepted the post of Chief Medical Officer at the Hospital for the Chronically Sick at Abbiategrasso. He first started his investigations into the nervous system in a little kitchen of this hospital, which he had converted into a laboratory. However, the work of greatest importance, which Golgi carried out was a revolutionary method of staining individual nerve and cell structures. This method is referred to as the 'black reaction'. This method uses a weak solution of silver nitrate and is particularly valuable in tracing the processes and most delicate ramifications of cells. All through his life, he continued to work on these lines, modifying and improving this technique. Golgi received the highest honours and awards in recognition of his work. He shared the Nobel prize in 1906 with Santiago Ramony Cajal for their work on the structure of the nervous system.

5.2.5 (iii) *LYSOSOMES*

Structurally, lysosomes are membrane-bound sacs filled with digestive enzymes. These enzymes are made by RER. Lysosomes are a kind of waste disposal system of the cell. These help to keep the cell clean by digesting any foreign material as well as worn-out cell organelles. Foreign materials entering the cell, such as bacteria or food, as well as old organelles end up in the lysosomes, which break complex substances into simpler substances. Lysosomes are able to do this because they contain powerful digestive enzymes capable of breaking down all organic material. 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.

5.2.5 (iv) *Mitochondria*

Mitochondria are known as the powerhouses of the cell. Mitochondria have two membrane coverings. The outer membrane is porous while the inner membrane is deeply folded. These folds increase surface area for ATP-generating chemical reactions. The energy required for various chemical activities needed for life is released by mitochondria in the form of ATP (Adenosine triphopshate) molecules. ATP is known as the energy currency of the cell. The body uses energy stored in ATP for making new chemical compounds and for mechanical work.

Mitochondria are strange organelles in the sense that they have their own DNA and ribosomes. Therefore, mitochondria are able to make some of their own proteins.

5.2.5 (v) *Plastids*

Plastids are present only in plant cells. There are two types of plastids – chromoplasts (coloured plastids) and leucoplasts (white or colourless plastids). Chromoplasts containing the pigment chlorophyll are known as chloroplasts. Chloroplasts are important for photosynthesis in plants. Chloroplasts also contain various yellow or orange pigments in addition to chlorophyll. Leucoplasts are primarily organelles in which materials such as starch, oils and protein granules are stored.

The internal organisation of the Chloroplast consists of numerous membrane layers embedded in a material called the stroma. These are similar to mitochondria in external structure. Like the mitochondria, plastids also have their own DNA and ribosomes.

5.2.5 (vi) *Vacuoles*

Vacuoles are storage sacs for solid or liquid contents. Vacuoles are small sized in animal cells while plant cells have very large vacuoles. The central vacuole of some plant cells may occupy 50-90% of the cell volume.

In plant cells vacuoles are full of cell sap and provide turgidity and rigidity to the cell. Many substances of importance in the 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 the *Amoeba* has consumed. In some unicellular organisms, specialised vacuoles also play important roles in expelling excess water and some wastes from the cell.

Questions

1. *Can you name the two organelles we have studied that contain their own genetic material?*
2. *If the organisation of a cell is destroyed due to some physical or chemical influence, what will happen?*
3. *Why are lysosomes known as suicide bags?*
4. *Where are proteins synthesised inside the cell?*

Each cell thus acquires its structure and ability to function because of the organisation of its membrane and organelles in specific ways. The cell thus has a basic structural organisation. 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.

Cell Division

New cells formed in organisms in order to grow, to replace old, dead and injured cells, and to form gametes required for reproduction. The process by which new cells are made is called cell division. There are two main types of cell division: mitosis and meiosis.

The process of cell division by which most of the cells divide for growth is called mitosis. In this process, each cell called mother cell

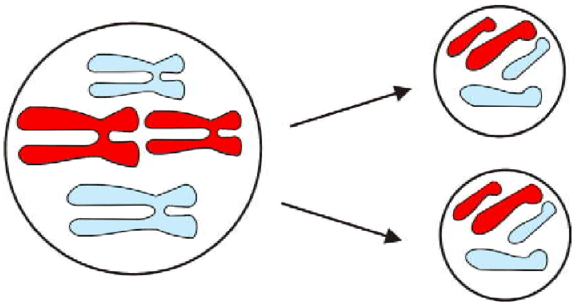


Fig. 5.7: *Mitosis*

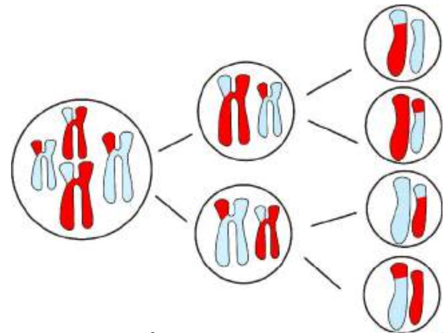


Fig. 5.8: *Meiosis*

divides to form two identical daughter cells (Fig. 5.7). The daughter cells have the same number of chromosomes as mother cell. It helps in growth and repair of tissues in organisms.

Specific cells of reproductive organs or tissues in animals and plants divide to form gametes, which after fertilisation give rise to offspring. They divide by a different process called meiosis which involves two consecutive divisions. When a cell divides by meiosis it produces four new cells instead of just two (Fig. 5.8). The new cells only have half the number of chromosomes than that of the mother cells. Can you think as to why the chromosome number has reduced to half in daughter cells?

What you have learnt

- The fundamental organisational unit of life is the cell.
- 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 ordered interior of the cell and the outer environment.
- In plant cells, a cell wall composed mainly of cellulose is located outside the cell membrane.
- 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 two types – chromoplasts and leucoplasts.

- Chromoplasts that contain chlorophyll are called chloroplasts and they perform photosynthesis.
- The primary function of leucoplasts is storage.
- Most mature plant cells have a large central vacuole that helps to maintain the turgidity of the cell and stores important substances including wastes.
- Prokaryotic cells have no membrane-bound organelles, their chromosomes are composed of only nucleic acid, and they have only very small ribosomes as organelles.
- Cells in organisms divide for growth of body, for repalcing dead cells, and for forming gametes for reproduction.

Exercises

1. Make a comparison and write down ways in which plant cells are different from animal cells.
2. How is a prokaryotic cell different from a eukaryotic cell?
3. What would happen if the plasma membrane ruptures or breaks down?
4. What would happen to the life of a cell if there was no Golgi apparatus?
5. Which organelle is known as the powerhouse of the cell? Why?
6. Where do the lipids and proteins constituting the cell membrane get synthesised?
7. How does an *Amoeba* obtain its food?
8. What is osmosis?
9. Carry out the following osmosis experiment:

   Take four peeled potato halves and scoos each one out to make potato cups. One of these potato cups should be made from a boiled potato. Put each potato cup in a trough containing water. Now,

   (a) Keep cup A empty
   (b) Put one teaspoon sugar in cup B
   (c) Put one teaspoon salt in cup C
   (d) Put one teaspoon sugar in the boiled potato cup D.

   Keep these for two hours. Then observe the four potato cups and answer the following:

   (i) Explain why water gathers in the hollowed portion of B and C.
   (ii) Why is potato A necessary for this experiment?
   (iii) Explain why water does not gather in the hollowed out portions of A and D.
10. Which type of cell division is required for growth and repair of body and which type is involved in formation of gametes?

Chapter 6

TISSUES

From the last chapter, we recall that all living organisms are made of cells. In unicellular organisms, a single cell performs all basic functions. For example, in *Amoeba*, a single cell carries out movement, intake of food and gaseous exchange and excretion. But in multi-cellular organisms there are millions of cells. Most of these cells are specialised to carry out specific functions. Each specialised function is taken up by a different group of cells. Since these cells carry out only a particular function, they do it very efficiently. 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 and so on. In plants, vascular tissues conduct food and water from one part of the plant to other parts. So, multi-cellular organisms show division of labour. Cells specialising in one function are often grouped together in the body. This means that a particular function is carried out by a cluster of cells at a definite place in the body. This cluster of cells, called a tissue, is arranged and designed so as to give the highest possible efficiency of function. Blood, phloem and muscle are all examples of tissues.

A group of cells that are similar in structure and/or work together to achieve a particular function forms a tissue.

6.1 Are Plants and Animals Made of Same Types of Tissues?

Let us compare their structure and functions. Do plants and animals have the same structure? Do they both perform similar functions?

There are noticeable differences between the two. Plants are stationary or fixed – they don't move. Since they have to be upright, they have a large quantity of supportive tissue. The supportive tissue generally has dead cells.

Animals on the other hand move around in search of food, mates and shelter. They consume more energy as compared to plants. Most of the tissues they contain are living.

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 localised 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. Cell growth in animals is more uniform. So, there is no such demarcation of dividing and non-dividing regions in animals.

The structural organisation of organs and organ systems is far more specialised and localised in complex animals than even in very complex plants. This fundamental difference reflects the different modes of life pursued by these two major groups of organisms, particularly in their different feeding methods. Also, they are differently adapted for a sedentary existence on one hand (plants) and active locomotion on the other (animals), contributing to this difference in organ system design.

It is with reference to these complex animal and plant bodies that we will now talk about the concept of tissues in some detail.

Questions

1. *What is a tissue?*
2. *What is the utility of tissues in multi-cellular organisms?*

6.2 Plant Tissues

6.2.1 Meristematic tissue

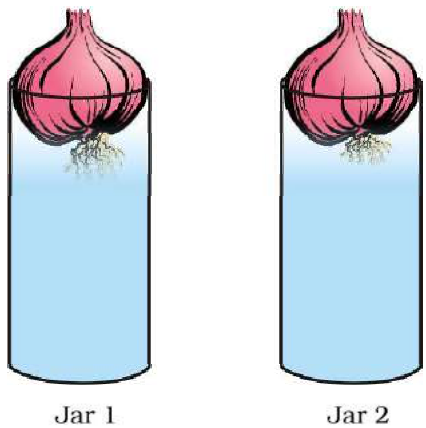


Fig. 6.1: *Growth of roots in onion bulbs*

Activity _______________ 6.1

- Take two glass jars and fill them with water.
- Now, take two onion bulbs and place one on each jar, as shown in Fig. 6.1.
- 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
Jar 1					
Jar 2					

- From the above observations, answer the following questions:
  1. Which of the two onions has longer roots? Why?
  2. Do the roots continue growing even after we have removed their tips?
  3. Why would the tips stop growing in jar 2 after we cut them?

The growth of plants occurs only in certain specific regions. This is because the dividing tissue, also known as meristematic tissue, is located only at these points. Depending on the region where they are present, meristematic tissues are classified as apical, lateral and intercalary (Fig. 6.2). New cells produced by meristem are initially like those of meristem itself, but as they grow and mature, their characteristics slowly change and they become differentiated as components of other tissues.

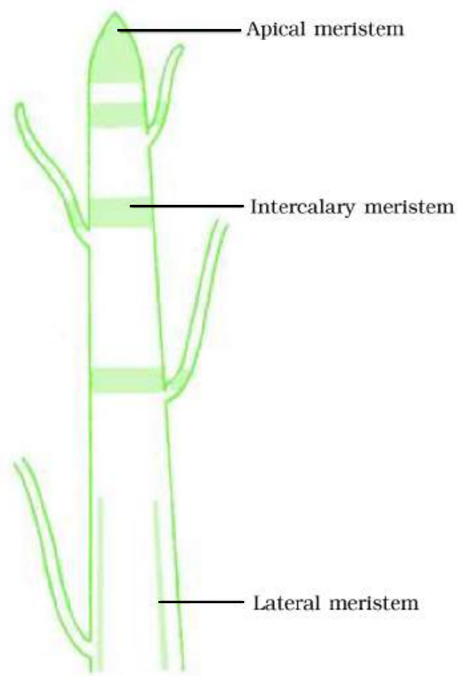


Fig. 6.2: *Location of meristematic tissue in plant body*

Apical meristem is present at the growing tips of stems and roots and increases the length of the stem and the root. The girth of the stem or root increases due to lateral meristem (cambium). Intercalary meristem seen in some plants is located near the node.

Cells of meristematic tissue are very active, they have dense cytoplasm, thin cellulose walls and prominent nuclei. They lack vacuoles. Can we think why they would lack vacuoles? (You might want to refer to the functions of vacuoles in the chapter on cells.)

6.2.2 Permanent tissue

What happens to the cells formed by meristematic tissue? They take up a specific role and lose the ability to divide. As a result, they form a permanent tissue. This process of taking up a permanent shape, size, and a function is called differentiation. Differentiation leads to the development of various types of permanent tissues.

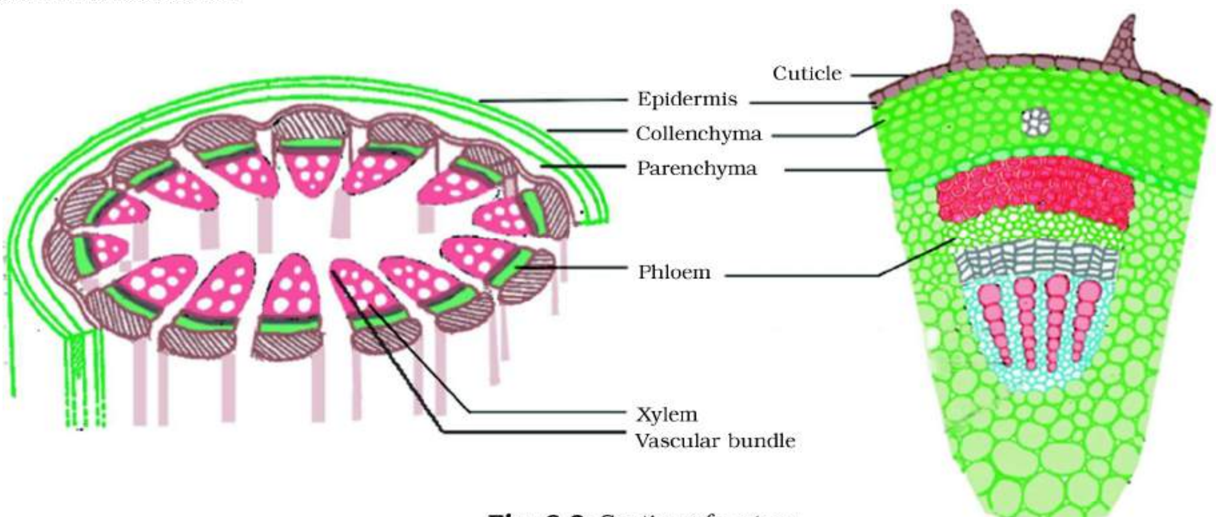


Fig. 6.3: *Section of a stem*

Activity _______________ 6.2

- Take a plant stem and with the help of your teacher cut into very thin slices or sections.
- Now, stain the slices with safranin. Place one neatly cut section on a slide, and put a drop of glycerine.
- Cover with a cover-slip and observe under a microscope. Observe the various types of cells and their arrangement. Compare it with Fig. 6.3.
- 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 we think of reasons why there would be so many types of cells?
- We can also try to cut sections of plant roots. We can even try cutting sections of root and stem of different plants.

6.2.2 (i) *Simple permanent tissue*

A few layers of cells beneath the epidermis are generally simple permanent tissue. Parenchyma is the most common simple permanent tissue. It consists of relatively unspecialised cells with thin cell walls. They are living cells. They are usually loosely arranged, thus large spaces between cells (intercellular spaces) are found in this tissue (Fig. 6.4 a). This tissue generally stores food. In some situations, it contains chlorophyll and performs photosynthesis, and then it is called chlorenchyma. In aquatic plants, large air cavities are present in parenchyma to help them float. Such a parenchyma type is called aerenchyma.

The flexibility in plants is due to another permanent tissue, collenchyma. It allows bending of various parts of a plant like tendrils and stems of climbers without breaking. It also provides mechanical support. We can find this tissue in leaf stalks below the epidermis. The cells of this tissue are living, elongated and irregularly thickened at the corners. There is very little intercellular space (Fig. 6.4 b).

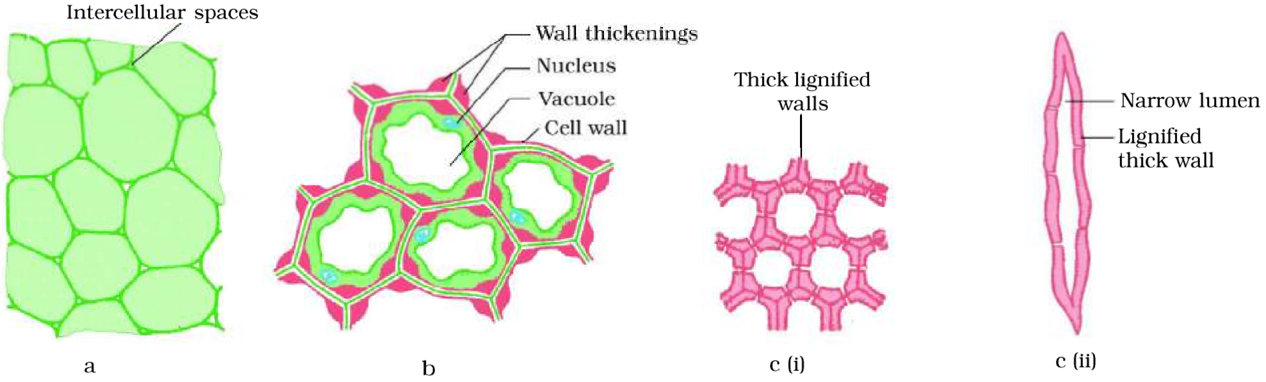


Fig. 6.4: *Various types of simple tissues: (a) Parenchyma (b) Collenchyma (c) Sclerenchyma (i) transverse section, (ii) longitudinal section.*

Yet another type of permanent tissue is sclerenchyma. It is the tissue which makes the plant hard and stiff. We have seen the husk of a coconut. It is made of sclerenchymatous tissue. The cells of this tissue are dead. They are long and narrow as the walls are thickened due to lignin. Often these walls are so thick that there is no internal space inside the cell (Fig. 6.4 c). This tissue is present in stems, around vascular bundles, in the veins of leaves and in the hard covering of seeds and nuts. It provides strength to the plant parts.

Activity ________________ 6.3

- Take a freshly plucked leaf of Rhoeo.
- Stretch and break it by applying pressure.
- While breaking it, keep it stretched gently so that some peel or skin projects out from the cut.
- Remove this peel and put it in a petri dish filled with water.
- Add a few drops of safranin.
- Wait for a couple of minutes and then transfer it onto a slide. Gently place a cover slip over it.
- Observe under microscope.

What you observe is the outermost layer of cells, called epidermis. The epidermis is usually made of a single layer of cells. In some plants living in very dry habitats, the epidermis may be thicker since protection against water loss is critical. The entire surface of a plant has an outer covering epidermis. It protects all the parts of the plant. Epidermal cells on the aerial parts of the plant often secrete a waxy, water-resistant layer on their outer surface. This aids in protection against loss of water, mechanical injury and invasion by parasitic fungi. Since it has a protective role to play, cells of epidermal tissue form a continuous layer without intercellular spaces. Most epidermal cells are relatively flat. Often their outer and side walls are thicker than the inner wall.

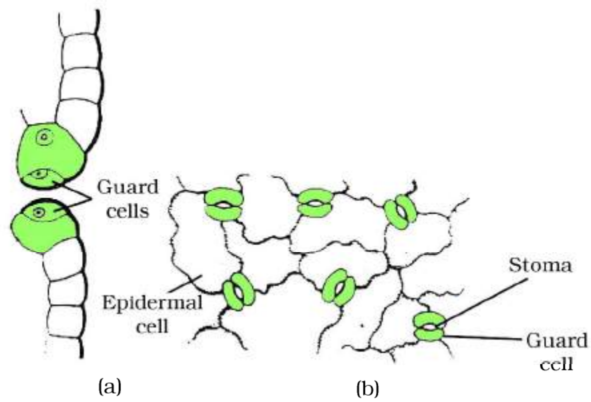


Fig. 6.5: *Guard cells and epidermal cells: (a) lateral view, (b) surface view*

We can observe small pores here and there in the epidermis of the leaf. These pores are called stomata (Fig. 6.5). Stomata are enclosed by two kidney-shaped cells called guard cells. They are necessary for exchanging gases with the atmosphere. Transpiration (loss of water in the form of water vapour) also takes place through stomata.

Recall which gas is required for photosynthesis.
Find out the role of transpiration in plants.

Epidermal cells of the roots, whose function is water absorption, commonly bear long hair-like parts that greatly increase the total absorptive surface area.

In some plants like desert plants, epidermis has a thick waxy coating of cutin (chemical substance with waterproof quality) on its outer surface. Can we think of a reason for this?

Is the outer layer of a branch of a tree different from the outer layer of a young stem?

As plants grow older, the outer protective tissue undergoes certain changes. A strip of secondary meristem located in the cortex forms layers of cells which constitute the cork. Cells of cork are dead and compactly arranged without intercellular spaces (Fig. 6.6). They also have a substance called suberin in their walls that makes them impervious to gases and water.

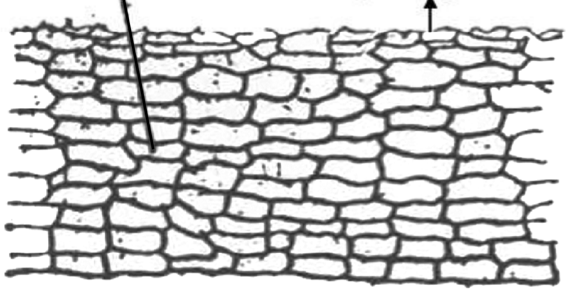


Fig. 6.6: *Protective tissue*

6.2.2 (ii) *Complex permanent tissue*

The different types of tissues we have discussed until now are all made of one type of cells, which look like each other. Such tissues are called simple permanent tissue. Yet another type of permanent tissue is complex tissue. Complex tissues are made of more than one type of cells. All these cells coordinate to perform a common function. Xylem and phloem are examples of such complex tissues. They are both conducting tissues and constitute a vascular bundle. Vascular tissue is a distinctive feature of the complex plants, one that has made possible their survival in the terrestrial environment. In Fig. 6.3 showing a section of stem, can you see different types of cells in the vascular bundle?

Xylem consists of tracheids, vessels, xylem parenchyma (Fig. 6.7 a,b,c) and xylem fibres. Tracheids and vessels have thick walls, and many are dead cells when mature. Tracheids and vessels are tubular structures. This allows them to transport water and minerals vertically. The parenchyma stores food. Xylem fibres are mainly supportive in function.

Phloem is made up of five types of cells: sieve cells, sieve tubes, companion cells, phloem fibres and the phloem parenchyma [Fig. 6.7 (d)]. Sieve tubes are tubular cells with perforated walls. Phloem transports food from leaves to other parts of the plant. Except phloem fibres, other phloem cells are living cells.

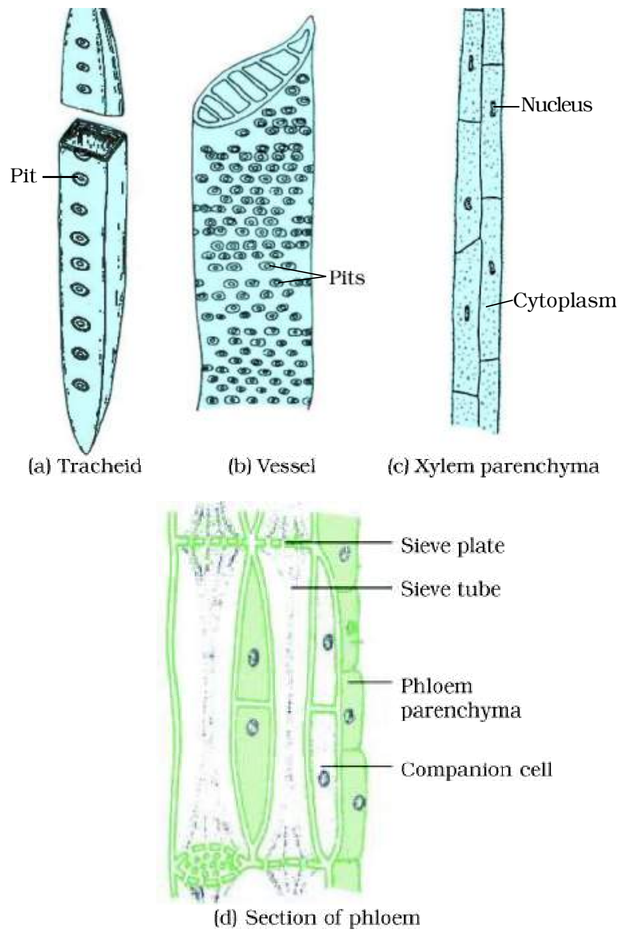


Fig. 6.7: *Types of complex tissue*

Questions

1. *Name types of simple tissues.*
2. *Where is apical meristem found?*
3. *Which tissue makes up the husk of coconut?*
4. *What are the constituents of phloem?*

6.3 Animal Tissues

When we breathe we can actually feel the movement of our chest. How do these body parts move? For this we have specialised cells called muscle cells (Fig. 6.8). The contraction and relaxation of these cells result in movement.

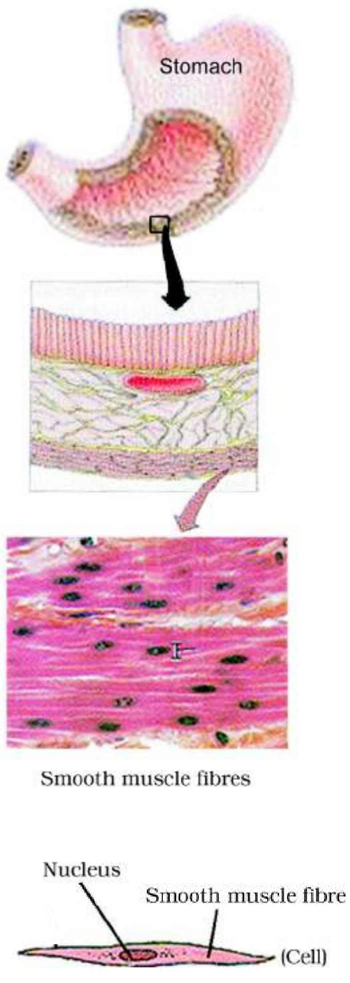


Fig. 6.8: *Location of muscle fibres*

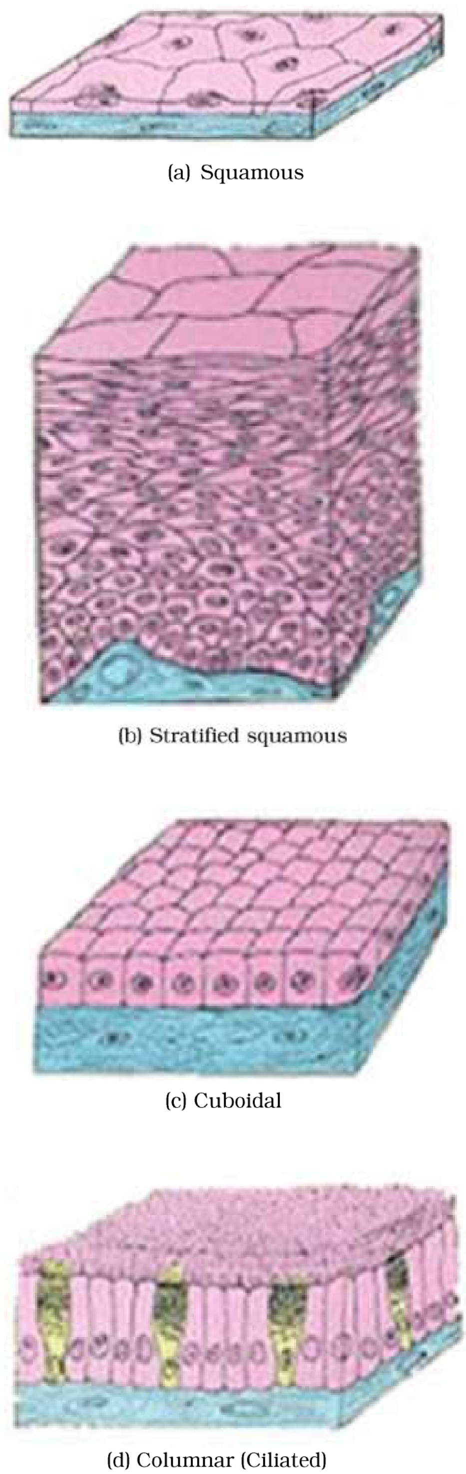
During breathing we inhale oxygen. Where does this oxygen go? It is absorbed in the lungs and then is transported to all the body cells through blood. Why would cells need oxygen? The functions of mitochondria we studied earlier provide a clue to this question. Blood flows and carries various substances from one part of the body to the other. For example, it carries oxygen and food to all cells. It also collects wastes from all parts of the body and carries them to the liver and kidney for disposal.

Blood and muscles are both examples of tissues found in our body. On the basis of the functions they perform we can think of different types of animal tissues, such as epithelial tissue, connective tissue, muscular tissue and nervous tissue. Blood is a type of connective tissue, and muscle forms muscular tissue.

6.3.1 Epithelial tissue

The covering or protective tissues in the animal body are epithelial tissues. Epithelium covers most organs and cavities within the body. It also forms a barrier to keep different body systems separate. The skin, the lining of the mouth, the lining of blood vessels, lung alveoli and kidney tubules are all made of epithelial tissue. Epithelial tissue cells are tightly packed and form a continuous sheet. They have only a small amount of cementing material between them and almost no intercellular spaces. Obviously, anything entering or leaving the body must cross at least one layer of epithelium. As a result, the permeability of the cells of various epithelia 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. Regardless of the type, all epithelium is usually separated from the underlying tissue by an extracellular fibrous basement membrane.

Different epithelia (Fig. 6.9) show differing structures that correlate with their unique functions. For example, in cells lining blood vessels or lung alveoli, where transportation of substances occurs through a selectively permeable surface, there is a simple flat kind of epithelium. This is called the simple squamous epithelium (squama means scale of skin). Simple squamous epithelial cells are extremely thin and flat and form a delicate lining. The oesophagus and the lining of the mouth are also covered with squamous epithelium. The skin, which protects the body, is also made of squamous epithelium. Skin epithelial cells are arranged in many layers to prevent wear and tear. Since they are arranged in a pattern of layers, the epithelium is called stratified squamous epithelium.



(a) Squamous

(b) Stratified squamous

(c) Cuboidal

(d) Columnar (Ciliated)

Fig. 6.9: *Different types of epithelial tissues*

Where absorption and secretion occur, as in the inner lining of the intestine, tall epithelial cells are present. This columnar (meaning 'pillar-like') epithelium facilitates movement across the epithelial barrier. In the respiratory tract, the columnar epithelial tissue also has cilia, which are hair-like projections on the outer surfaces of epithelial cells. These cilia can move, and their movement pushes the mucus forward to clear it. This type of epithelium is thus ciliated columnar epithelium.

Cuboidal epithelium (with cube-shaped cells) forms the lining of kidney tubules and ducts of salivary glands, where it provides mechanical support. Epithelial cells often acquire additional specialisation as gland cells, which can secrete substances at the epithelial surface. Sometimes a portion of the epithelial tissue folds inward, and a multicellular gland is formed. This is glandular epithelium.

6.3.2 Connective tissue

Blood is a type of connective tissue. Why would it be called 'connective' tissue? A clue is provided in the introduction of this chapter! Now, let us look at this type of tissue in some more detail. The cells of connective tissue are loosely spaced and embedded in an intercellular matrix (Fig. 6.10). The matrix may be jelly like, fluid, dense or rigid. The nature of matrix differs in concordance with the function of the particular connective tissue.

Activity 6.4

Take a drop of blood on a slide and observe different cells present in it under a microscope.

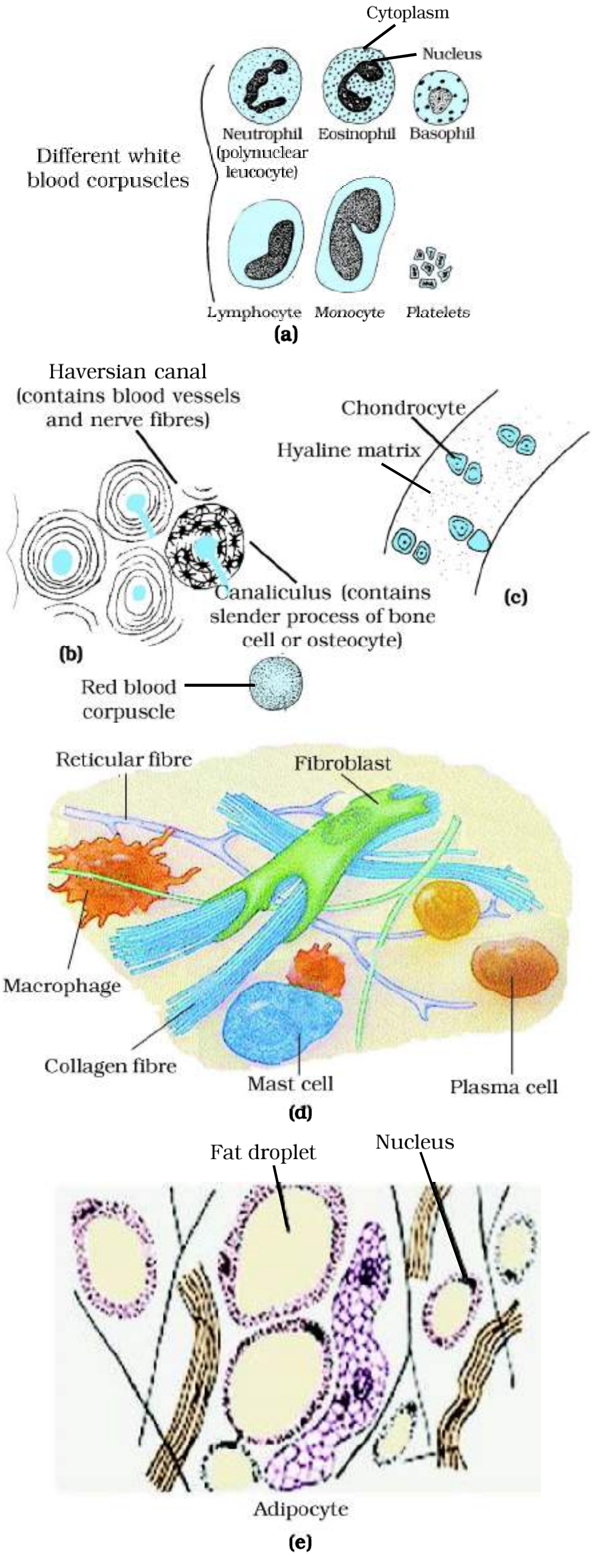


***Fig. 6.10:** Types of connective tissues: (a) types of blood cells, (b) compact bone, (c) hyaline cartilage, (d) areolar tissue, (e) adipose tissue*

Blood has a fluid (liquid) matrix called plasma, in which red blood corpuscles (RBCs), white blood corpuscles (WBCs) and platelets are suspended. The plasma contains proteins, salts and hormones. Blood flows and transports gases, digested food, hormones and waste materials to different parts of the body.

Bone is another example of a connective tissue. It forms the framework that supports the body. It also anchors the muscles and supports the main organs of the body. It is a strong and nonflexible tissue (what would be the advantage of these properties for bone functions?). Bone cells are embedded in a hard matrix that is composed of calcium and phosphorus compounds.

Two bones can be connected to each other by another type of connective tissue called the ligament. This tissue is very elastic. It has considerable strength. Ligaments contain very little matrix and connect bones with bones. Tendons connect muscles to bones and are another type of connective tissue. Tendons are fibrous tissue with great strength but limited flexibility.

Another type of connective tissue, cartilage, has widely spaced cells. The solid matrix is composed of proteins and sugars. Cartilage smoothens bone surfaces at joints and is also present in the nose, ear, trachea and larynx. We can fold the cartilage of the ears, but we cannot bend the bones in our arms. Think of how the two tissues are different!

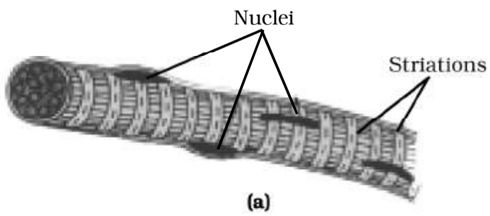
Areolar connective tissue is found between the skin and muscles, around blood vessels and nerves and in the bone marrow. It fills the space inside the organs, supports internal organs and helps in repair of tissues.

Where are fats stored in our body? Fat-storing adipose tissue 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.

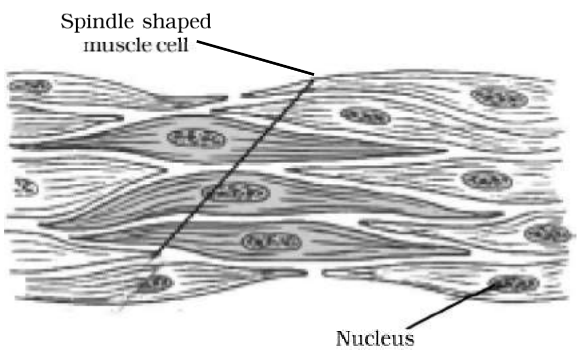
6.3.3 Muscular tissue

Muscular tissue consists of elongated cells, also called muscle fibres. This tissue is responsible for movement in our body.

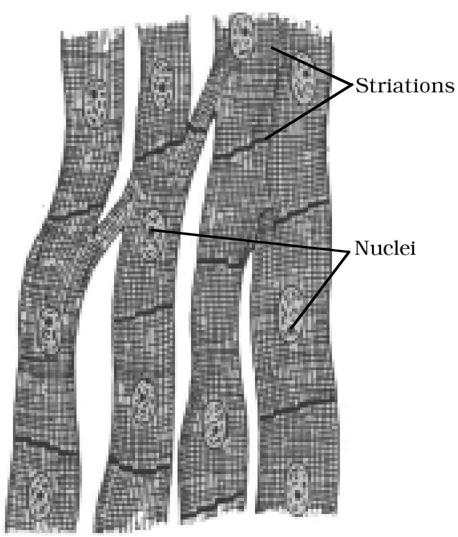
Muscles contain special proteins called contractile proteins, which contract and relax to cause movement.



(a)



(b)



(c)

Fig. 6.11: *Types of muscles fibres: (a) striated muscle, (b) smooth muscle, (c) cardiac muscle*

We can move some muscles by conscious will. Muscles present in our limbs move when we want them to, and stop when we so decide. Such muscles are called voluntary muscles [Fig. 6.11(a)]. These muscles are also called skeletal muscles as they are mostly attached to bones and help in body movement. Under the microscope, these muscles show alternate light and dark bands or striations when stained appropriately. As a result, they are also called striated muscles. The cells of this tissue are long, cylindrical, unbranched and multinucleate (having many nuclei).

The movement of food in the alimentary canal or the contraction and relaxation of blood vessels are involuntary movements. We cannot really start them or stop them simply by wanting to do so! Smooth muscles [Fig. 6.11(b)] or involuntary muscles control such movements. They are also found in the iris of the eye, in ureters and in the bronchi of the lungs. The cells are long with pointed ends (spindle-shaped) and uninucleate (having a single nucleus). They are also called unstriated muscles – why would they be called that?

The muscles of the heart show rhythmic contraction and relaxation throughout life. These involuntary muscles are called cardiac muscles [Fig. 6.11(c)]. Heart muscle cells are cylindrical, branched and uninucleate.

Activity 6.5

- Compare the structures of different types of muscular tissues. Note down their shape, number of nuclei and position of nuclei within the cell in the Table 6.1.

Table 6.1:

Features	Striated	Smooth	Cardiac
Shape			
Number of nuclei			
Position of nuclei			

6.3.4 Nervous tissue

All cells possess the ability to respond to stimuli. However, cells of the nervous tissue are highly specialised 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. The cells of this tissue are called nerve cells or neurons. A neuron consists of a cell body with a nucleus and cytoplasm, from which long thin hair-like parts arise (Fig. 6.12). Usually each neuron has a single long part (process), called the axon, and many short, branched parts (processes) called dendrites. An individual nerve cell may be up to a metre long. Many nerve fibres bound together by connective tissue make up a nerve.

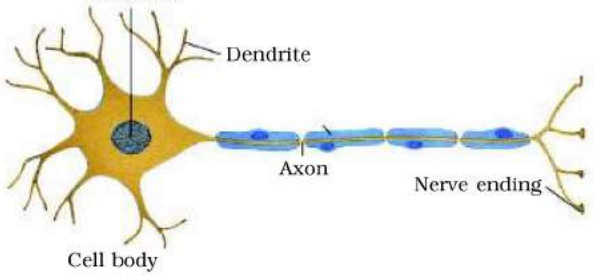


Fig. 6.12: *Neuron-unit of nervous tissue*

The signal that passes along the nerve fibre is called a nerve impulse. Nerve impulses allow us to move our muscles when we want to. The functional combination of nerve and muscle tissue is fundamental to most animals. This combination enables animals to move rapidly in response to stimuli.

Questions

1. *Name the tissue responsible for movement in our body.*
2. *What does a neuron look like?*
3. *Give three features of cardiac muscles.*
4. *What are the functions of areolar tissue?*

What you have learnt

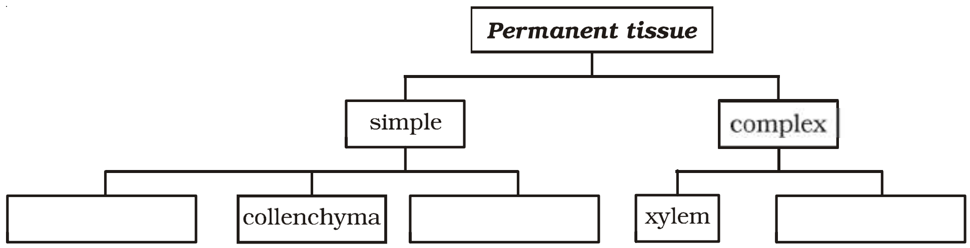
- Tissue is a group of cells similar in structure and function.
- Plant tissues are of two main types – meristematic and permanent.
- Meristematic tissue is the dividing tissue present in the growing regions of the plant.
- Permanent tissues are derived from meristematic tissue once they lose the ability to divide. They are classified as simple and complex tissues.
- Parenchyma, collenchyma and sclerenchyma are three types of simple tissues. Xylem and phloem are types of complex tissues.
- Animal tissues can be epithelial, connective, muscular and nervous tissue.
- Depending on shape and function, epithelial tissue is classified as squamous, cuboidal, columnar, ciliated and glandular.

- The different types of connective tissues in our body include areolar tissue, adipose tissue, bone, tendon, ligament, cartilage and blood.
- Striated, unstriated and cardiac are three types of muscle tissues.
- Nervous tissue is made of neurons that receive and conduct impulses.

Exercises

1. Define the term “tissue”.
2. How many types of elements together make up the xylem tissue? Name them.
3. How are simple tissues different from complex tissues in plants?
4. Differentiate between parenchyma, collenchyma and sclerenchyma on the basis of their cell wall.
5. What are the functions of the stomata?
6. Diagrammatically show the difference between the three types of muscle fibres.
7. What is the specific function of the cardiac muscle?
8. Differentiate between striated, unstriated and cardiac muscles on the basis of their structure and site/location in the body.
9. Draw a labelled diagram of a neuron.
10. Name the following.
    - (a) Tissue that forms the inner lining of our mouth.
    - (b) Tissue that connects muscle to bone in humans.
    - (c) Tissue that transports food in plants.
    - (d) Tissue that stores fat in our body.
    - (e) Connective tissue with a fluid matrix.
    - (f) Tissue present in the brain.
11. Identify the type of tissue in the following: skin, bark of tree, bone, lining of kidney tubule, vascular bundle.

12. Name the regions in which parenchyma tissue is present.
13. What is the role of epidermis in plants?
14. How does the cork act as a protective tissue?
15. Complete the following chart:



C hapter 7

Diversity in Living Organisms

Have you ever thought of the multitude of life-forms that surround us? Each organism is different from the other to a lesser or greater extent. For instance, consider yourself and a friend.

- Are you both of the same height?
- Does your nose look exactly like your friend's nose?
- Is your hand-span the same as your friend's?

However, if we were to compare ourselves and our friends with a monkey, what would we say? Obviously, we and our friends have a lot in common when we compare ourselves with a monkey. But suppose we were to add a cow to the comparison? We would then think that the monkey has a lot more in common with us than with the cow.

Activity 7.1

- We have heard of '*desi*' cows and Jersey cows.
- Does a *desi* cow look like a Jersey cow?
- Do all *desi* cows look alike?
- Will we be able to identify a Jersey cow in a crowd of *desi* cows that don't look like each other?
- What is the basis of our identification?

In this activity, we had to decide which characteristics were more important in forming the desired category. Hence, we were also deciding which characteristics could be ignored.

Now, think of all the different forms in which life occurs on earth. On one hand we have microscopic bacteria of a few micrometre in size. While on the other hand we have blue whale and red wood trees of California of approximate sizes of 30 metres and 100 metres respectively. Some pine trees live for thousands of years while insects like mosquitoes die within a few days. Life also ranges from colourless or even transparent worms to brightly coloured birds and flowers.

This bewildering variety of life around us has evolved on the earth over millions of years. However, we do not have more than a tiny fraction of this time to try and understand all these living organisms, so we cannot look at them one by one. Instead, we look for similarities among the organisms, which will allow us to put them into different classes and then study different classes or groups as a whole.

In order to make relevant groups to study the variety of life forms, we need to decide which characteristics decide more fundamental differences among organisms. This would create the main broad groups of organisms. Within these groups, smaller sub-groups will be decided by less important characteristics.

Questions

1. *Why do we classify organisms?*
2. *Give three examples of the range of variations that you see in life-forms around you.*

7.1 What is the Basis of Classification?

Attempts at classifying living things into groups have been made since time immemorial. Greek thinker Aristotle classified animals according to whether they lived on land, in water or in the air. This is a very simple way of looking at life, but misleading too. For example, animals that live in the sea include corals, whales, octopuses, starfish and sharks. We can immediately see that these are very different from each other in numerous ways. In fact, habitat is the only point they share in common. This is not an appropriate way of making groups of organisms to study and think about.

We therefore need to decide which characteristics to be used as the basis for making the broadest divisions. Then we will have to pick the next set of characteristics for making sub-groups within these divisions. This process of classification within each group can then continue using new characteristics each time.

Before we go on, we need to think about what is meant by 'characteristics'. When we are trying to classify a diverse group of organisms, we need to find ways in which some of them are similar enough to be thought of together. These 'ways', in fact, are details of appearance or behaviour, in other words, form and function.

What we mean by a characteristic is a particular feature or a particular function. That most of us have five fingers on each hand is thus a characteristic. That we can run, but the banyan tree cannot, is also a characteristic.

Now, to understand how some characteristics are decided as being more fundamental than others, let us consider how a stone wall is built. The stones used will have different shapes and sizes. The stones at the top of the wall would not influence the choice of stones that come below them. On the other hand, the shapes and sizes of stones in the lowermost layer will decide the shape and size of the next layer and so on.

The stones in the lowermost layer are like the characteristics that decide the broadest divisions among living organisms. They are independent of any other characteristics in their effects on the form and function of the organism. The characteristics in the next level would be dependent on the previous one and would decide the variety in the next level. In this way, we can build up a whole hierarchy of mutually related characteristics to be used for classification.

Now-a-days, we look at many inter-related characteristics starting from the nature of the cell in order to classify all living organisms. What are some concrete examples of such characteristics used for a hierarchical classification?

- A eukaryotic cell has membrane-bound organelles, including a nucleus, which allow cellular processes to be carried out efficiently in isolation from each other. Therefore, organisms which do not have a clearly demarcated nucleus and other organelles would need to have their biochemical pathways organised in very different ways. This would have an effect on every aspect of cell design. Further, nucleated cells would have the capacity to participate in making a multicellular organism because they can take up specialised functions. Therefore, nucleus can be a basic characteristic of classification.
- Do the cells occur singly or are they grouped together and do they live as an indivisible group? Cells that group together to form a single organism use the principle of division of labour. In such a body design, all cells would not be identical. Instead, groups of cells will carry out specialised functions. This makes a very basic distinction in the body designs of organisms. As a result, an Amoeba and a worm are very different in their body design.
- Do organisms produce their own food through the process of photosynthesis? Being able to produce one's own food versus having to get food from outside would make very different body designs a necessity.
- Of the organisms that perform photosynthesis (plants), what is the level of organisation of their body?
- Of the animals, how does the individual's body develop and organise its different parts, and what are the specialised organs found for different functions?

We can see that, even in these few questions that we have asked, a hierarchy is developing. The characteristics of body design used for classification of plants will be very different from those important for classifying animals. This is because the basic designs are different, based on the need to make their own food (plants), or acquire it (animals). Therefore, these design features (having a skeleton, for example) are to be used to make sub-groups, rather than making broad groups.

Questions

1. *Which do you think is a more basic characteristic for classifying organisms?*
   (a) the place where they live.
   (b) the kind of cells they are made of. Why?
2. *What is the primary characteristic on which the broad division of organisms is made?*
3. *On what bases are plants and animals put into different categories?*

7.2 Classification and Evolution

All living things are identified and categorised on the basis of their body design in form and function. Some characteristics are likely to make more wide-ranging changes in body design than others. There is a role of time in this as well. So, once a certain body design comes into existence, it will shape the effects of all other subsequent design changes, simply because it already exists. In other words, characteristics that came into existence earlier are likely to be more basic than characteristics that have come into existence later.

This means that the classification of life forms will be closely related to their evolution. What is evolution? Most life forms that we see today have arisen by an accumulation of changes in body design that allow the organism possessing them to survive better. Charles Darwin first described this idea of evolution in 1859 in his book, *The Origin of Species*.

When we connect this idea of evolution to classification, we will find some groups of organisms which have ancient body designs that have not changed very much. We will also find other groups of organisms that have acquired their particular body designs relatively recently. Those in the first group are frequently referred to as 'primitive' or 'lower' organisms, while those in the second group are called 'advanced' or 'higher' organisms. In reality, these terms are not quite correct since they do not properly relate to the differences. All that we can say is that some are 'older' organisms, while some are 'younger' organisms. Since there is a possibility that complexity in design will increase over evolutionary time, it may not be wrong to say that older organisms are simpler, while younger organisms are more complex.

More to know

Biodiversity means the diversity of life forms. It is a word commonly used to refer to the variety of life forms found in a particular region. Diverse life forms share the environment, and are affected by each other too. As a result, a stable community of different species comes into existence. Humans have played their own part in recent times in changing the balance of such communities. Of course, the diversity in such communities is affected by particular characteristics of land, water, climate and so on. Rough estimates state that there are about ten million species on the planet, although we actually know only one or two millions of them. The warm and humid tropical regions of the earth, between the tropic of Cancer and the tropic of Capricorn, are rich in diversity of plant and animal life. This is called the region of megadiversity. Of the biodiversity on the planet, more than half is concentrated in a few countries — Brazil, Colombia, Ecuador, Peru, Mexico, Zaire, Madagascar, Australia, China, India, Indonesia and Malaysia.

Questions

1. *Which organisms are called primitive and how are they different from the so-called advanced organisms?*
2. *Will advanced organisms be the same as complex organisms? Why?*

7.3 The Hierarchy of Classification-Groups

Biologists, such as Ernst Haeckel (1894), Robert Whittaker (1969) and Carl Woese (1977) have tried to classify all living organisms into broad categories, called kingdoms. The classification Whittaker proposed has five kingdoms: Monera, Protista, Fungi, Plantae and Animalia, and is widely used. These groups are formed on the basis of their cell structure, mode and source of nutrition and body organisation. The modification Woese introduced by dividing the Monera into Archaebacteria (or Archaea) and Eubacteria (or Bacteria) is also in use.

Further classification is done by naming the sub-groups at various levels as given in the following scheme:

Kingdom
Phylum (for animals) / Division (for plants)
Class
Order
Family
Genus
Species

Thus, by separating organisms on the basis of a hierarchy of characteristics into smaller and smaller groups, we arrive at the basic unit of classification, which is a 'species'. So what organisms can be said to belong to the same species? Broadly, a species includes all organisms that are similar enough to breed and perpetuate.

The important characteristics of the five kingdoms of Whittaker are as follows:

7.3.1 Monera

These organisms do not have a defined nucleus or organelles, nor do any of them show multi-cellular body designs. On the other hand, they show diversity based on many other characteristics. Some of them have cell walls while some do not. Of course, having or not having a cell wall has very different effects on body design here from having or not having a cell wall in multi-cellular organisms. The mode of nutrition of organisms in this group can be either by synthesising their own food (autotrophic) or getting it from the environment (heterotrophic). This group includes bacteria, blue-green algae or cyanobacteria, and mycoplasma. Some examples are shown in Fig. 7.1.

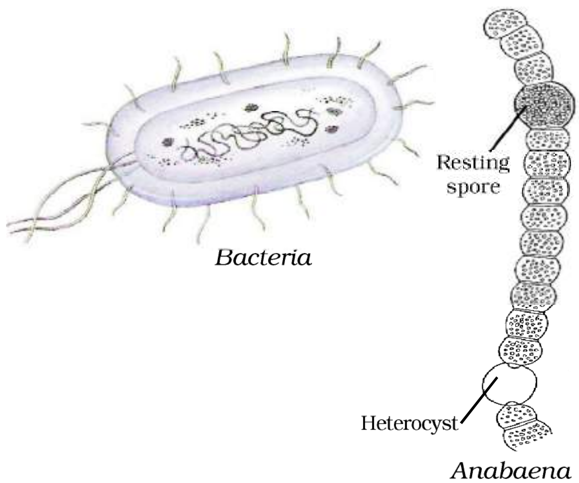
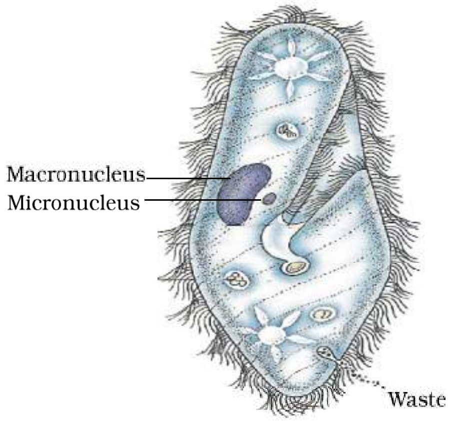


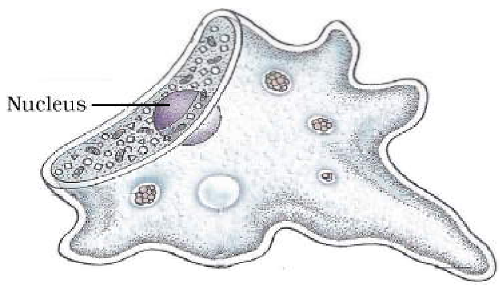
Fig. 7.1: *Monera*

7.3.2 Protista

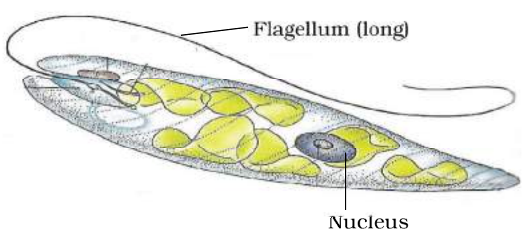
This group includes many kinds of unicellular eukaryotic organisms. Some of these organisms use appendages, such as hair-like cilia or whip-like flagella for moving around. Their mode of nutrition can be autotrophic or heterotrophic. Examples are unicellular algae, diatoms and protozoans (see Fig. 7.2 for examples).



Paramecium



Amoeba

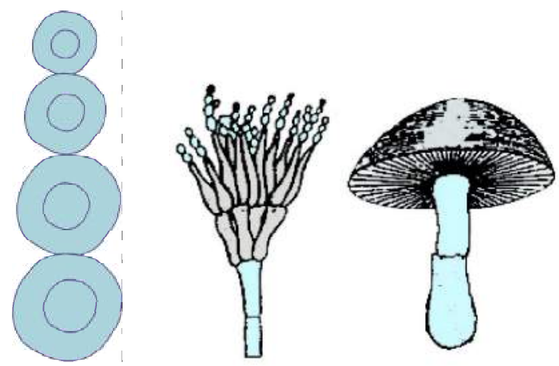


Euglena

Fig. 7.2: *Protozoa*

7.3.3 Fungi

These are heterotrophic eukaryotic organisms. Some of them use decaying organic material as food and are therefore called saprotrophs. Others require a living protoplasm of a host organism for food. They are called parasites. Many of them have the capacity to become multicellular organisms at certain stages in their lives. They have cell-walls made of a tough complex sugar called chitin. Examples are yeasts, molds and mushrooms (see Fig. 7.3 for examples).



Saccharomyces (Yeast) *Penicillium (Mold)* *Agaricus (Mushroom)*

Fig. 7.3: *Fungi*

Some fungal species live in permanent mutually dependent relationships with blue-green algae (or cyanobacteria). Such relationships are called symbiotic. These symbiobic life forms are called lichens. We have all seen lichens as the slow-growing large coloured patches on the bark of trees.

7.3.4 Plantae

These are multicellular eukaryotes with cell walls. They are autotrophs and use chlorophyll for photosynthesis. Thus, all plants are included in this group. Since plants and animals are most visible forms of the diversity of life around us, we will look at the subgroups in this category later (section 7.4).

7.3.5 Animalia

These include all organisms which are multicellular eukaryotes without cell walls. They are heterotrophs. Again, we will look at their subgroups a little later in section 7.5.

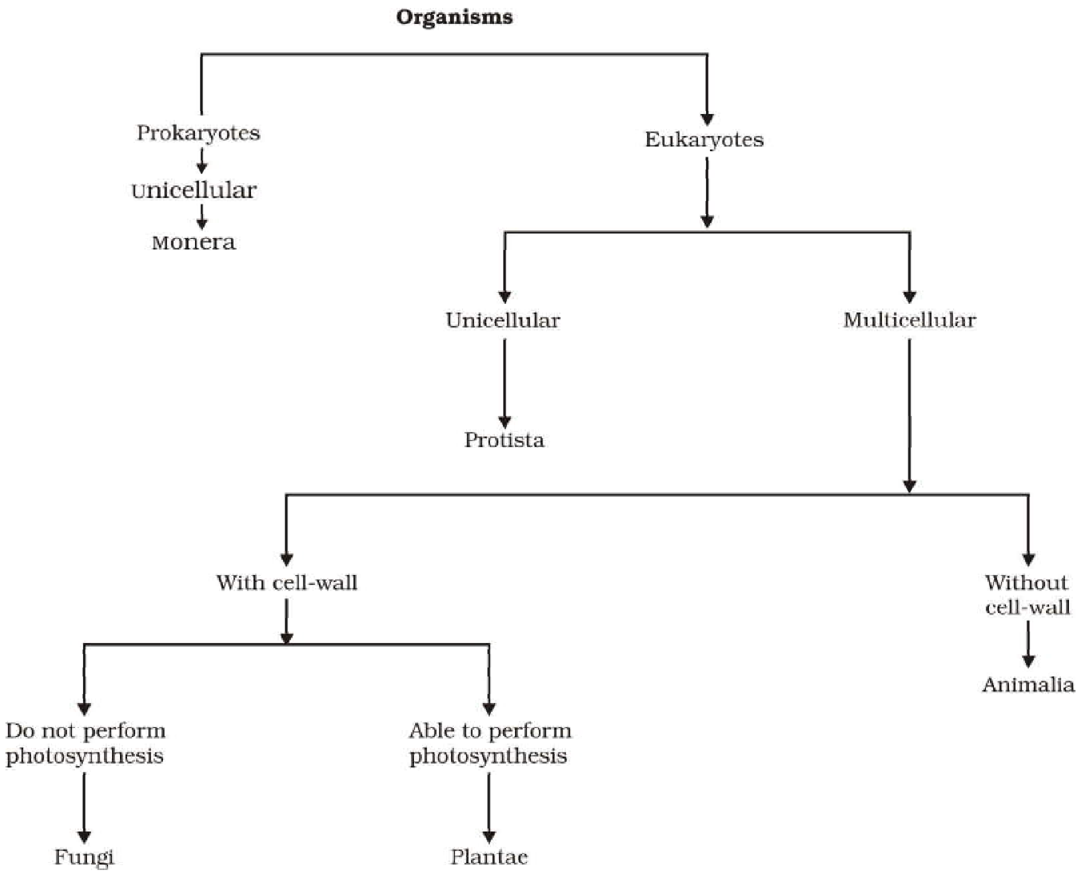


Fig. 7.4: *The Five Kingdom classification*

Questions

1. *What is the criterion for classification of organisms as belonging to kingdom Monera or Protista?*
2. *In which kingdom will you place an organism which is single-celled, eukaryotic and photosynthetic?*
3. *In the hierarchy of classification, which grouping will have the smallest number of organisms with maximum common characteristics and which will have the largest number of organisms?*

7.4 Plantae

The first level of classification among plants depends on whether the plant body has well-differentiated, distinct parts. The next level of classification is based on whether the differentiated plant body has special tissues for the transport of water and other substances. Further classification looks at the ability to bear seeds and whether the seeds are enclosed within fruits.

7.4.1 Thallophyta

Plants that do not have well-differentiated body design fall in this group. The plants in this group are commonly called algae. These plants are predominantly aquatic. Examples are *Spirogyra*, *Ulothrix*, *Cladophora*, *Ulva* and *Chara* (see Fig. 7.5).

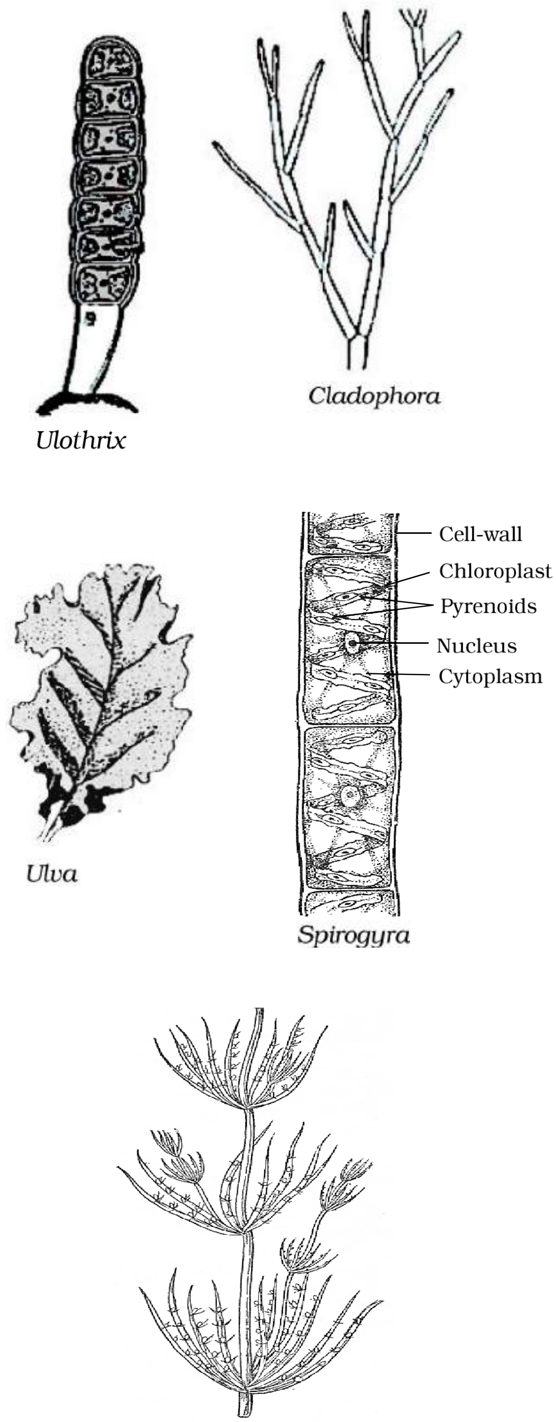


Fig. 7.5: *Thallophyta – Algae*

7.4.2 Bryophyta

These are called the amphibians of the plant kingdom. The plant body is commonly differentiated to form stem and leaf-like structures. However, there is no specialised tissue for the conduction of water and other substances from one part of the plant body to another. Examples are moss (*Funaria*) and *Marchantia* (see Fig. 7.6).

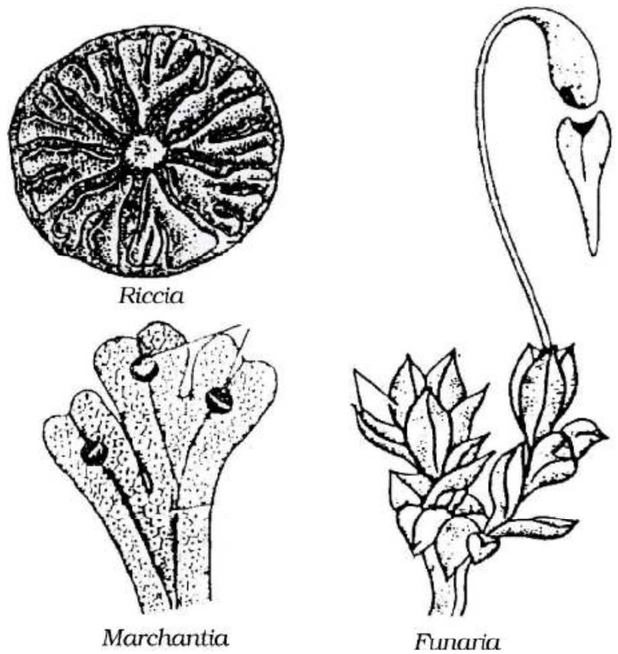


Fig. 7.6: *Some common bryophytes*

7.4.3 Pteridophyta

In this group, the plant body is differentiated into roots, stem and leaves and has specialised tissue for the conduction of water and other substances from one part of the plant body to another. Some examples are *Marsilea*, ferns and horse-tails (see Fig. 7.7).

The reproductive organs of plants in all these three groups are very inconspicuous, and they are therefore called 'cryptogams', or 'those with hidden reproductive organs'.

On the other hand, plants with well-differentiated reproductive parts that ultimately make seeds are called

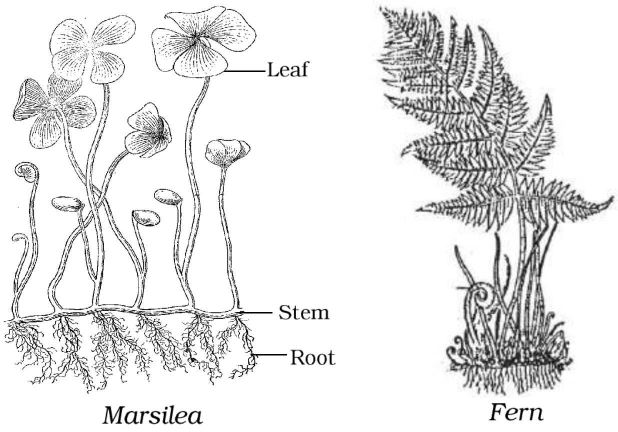


Fig. 7.7: *Pteridophyta*

phanerogams. Seeds are the result of sexual reproduction process. They consist of the embryo along with stored food, which assists for the initial growth of the embryo during germination. This group is further classified, based on whether the seeds are naked or enclosed in fruits, giving us two groups: gymnosperms and angiosperms.

7.4.4 Gymnosperms

This term is derived from two Greek words: *gymno*– means naked and *sperma*– means seed. The plants of this group bear naked seeds and are usually perennial, evergreen and woody. Examples are pines and deodar (see Fig. 7.8 for examples).

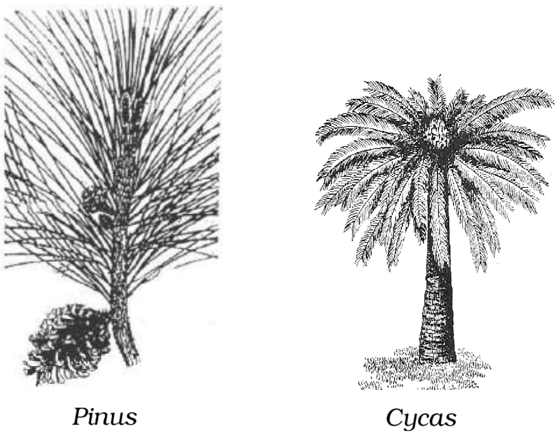


Fig. 7.8: *Gymnosperms*

7.4.5 Angiosperms

This word is made from two Greek words: *angio* means covered and *sperma*– means seed. These are also called flowering plants. The seeds develop inside an ovary which is modified to become a fruit. Plant embryos in seeds have structures called cotyledons. Cotyledons are called 'seed leaves' because in many instances they emerge and become green when the seed germinates. The angiosperms are divided into two groups on the basis of the number of cotyledons present in the seed. Plants with seeds having a single cotyledon are called monocotyledonous or monocots. Plants with seeds having two cotyledons are called dicots (see Figs. 7.9 and 7.10).

Fig. 7.9: *Monocot*

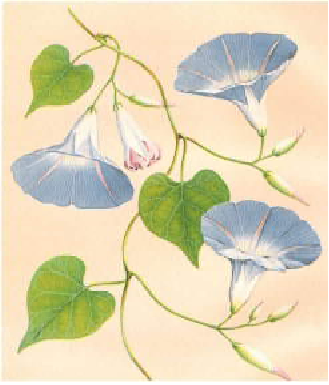


Fig. 7.10: *Dicot*

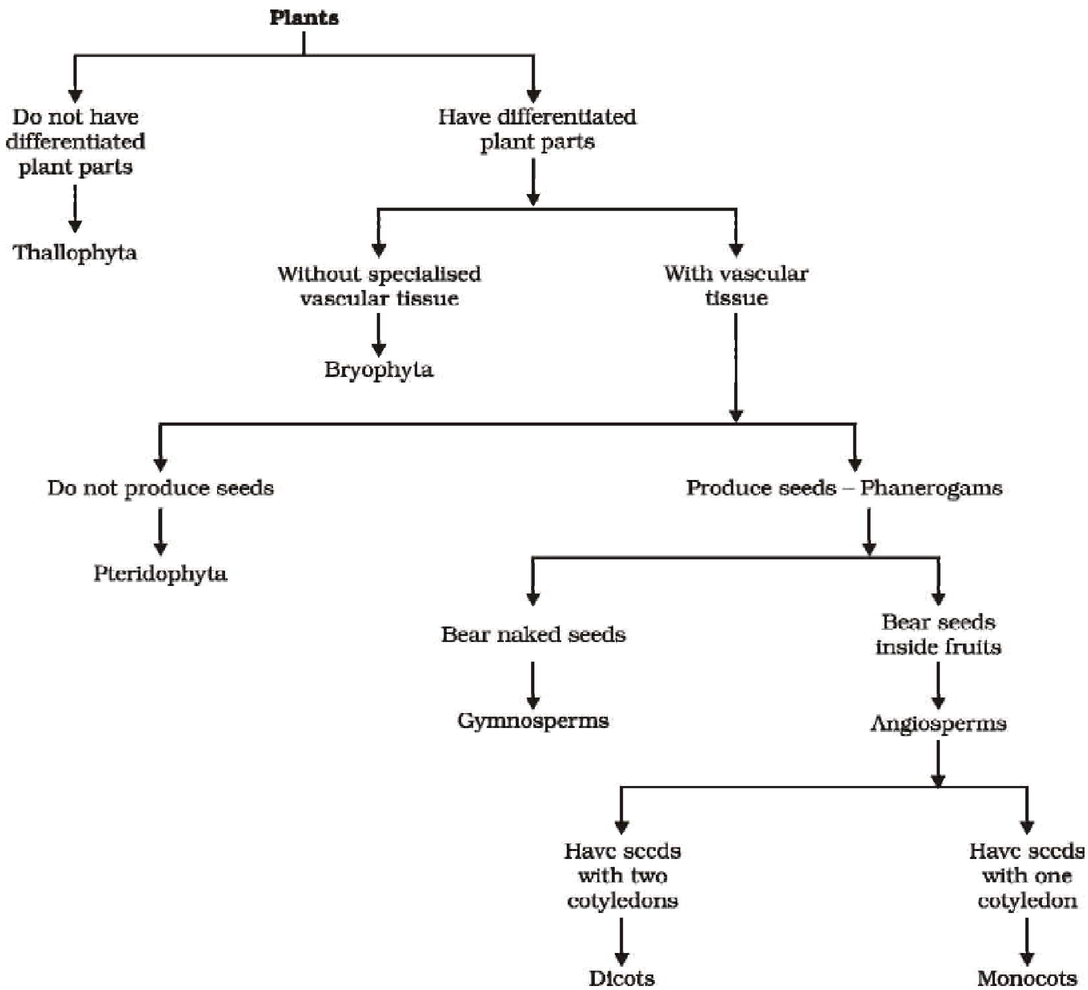


Fig. 7.11: *Classification of plants*

Activity _______________ *7.2*

- Soak seeds of green gram, wheat, maize, peas and tamarind. Once they become tender, try to split the seed. Do all the seeds break into two nearly equal halves?
- The seeds that do are the dicot seeds and the seeds that don't are the monocot seeds.
- Now take a look at the roots, leaves and flowers of these plants.
- Are the roots tap-roots or fibrous?
- Do the leaves have parallel or reticulate venation?
- How many petals are found in the flower of these plants?
- Can you write down further characteristics of monocots and dicots on the basis of these observations?

Questions

1. *Which division among plants has the simplest organisms?*
2. *How are pteridophytes different from the phanerogams?*
3. *How do gymnosperms and angiosperms differ from each other?*

7.5 Animalia

These are organisms which are eukaryotic, multicellular and heterotrophic. Their cells do not have cell-walls. Most animals are mobile.

They are further classified based on the extent and type of the body design differentiation found.

7.5.1 Porifera

The word Porifera means organisms with holes. These are non-motile animals attached to some solid support. There are holes or 'pores', all over the body. These lead to a canal system that helps in circulating water throughout the body to bring in food and oxygen. These animals are covered with a hard outside layer or skeleton. The body design involves very minimal differentiation and division into tissues. They are commonly called sponges, and are mainly found in marine habitats. Some examples are shown in Fig. 7.12.

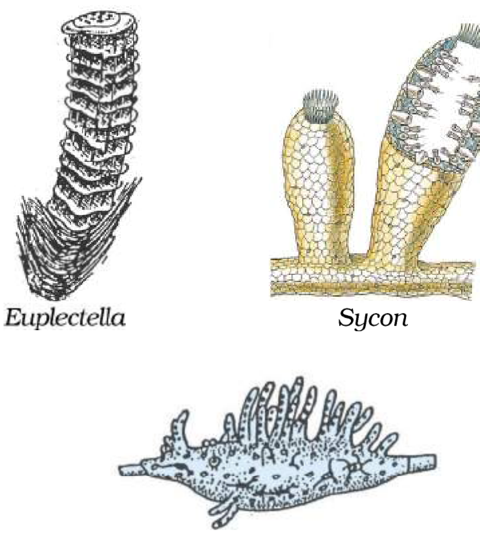


Fig. 7.12: *Porifera*

7.5.2 Coelenterata (Cnidaria)

These are animals living in water. They show more body design differentiation. There is a cavity in the body. The body is made of two layers of cells: one makes up cells on the outside of the body, and the other makes the inner lining of the body. Some of these species live in colonies (corals), while others have a solitary like–span (*Hydra*). Jellyfish and sea anemones are common examples (see Fig. 7.13).

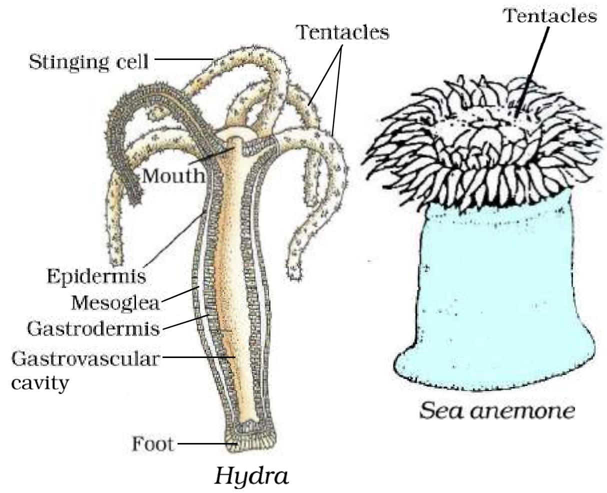


Fig. 7.13: *Coelenterata*

7.5.3 Platyhelminthes

The body of animals in this group is far more complexly designed than in the two other groups we have considered so far. The body is bilaterally symmetrical, meaning that the left and the right halves of the body have the same design. There are three layers of cells from which differentiated tissues can be made, which is why such animals are called triploblastic. This allows outside and inside body linings as well as some organs to be made. There is thus some degree of tissue formation. However, there is no true internal body cavity or coelom, in which well-developed organs can be accommodated. The body is flattened dorsoventrally (meaning from top to bottom), which is why these animals are called flatworms. They are either free-living or parasitic. Some examples are free-living animals like planarians, or parasitic animals like liverflukes (see Fig. 7.14 for examples).

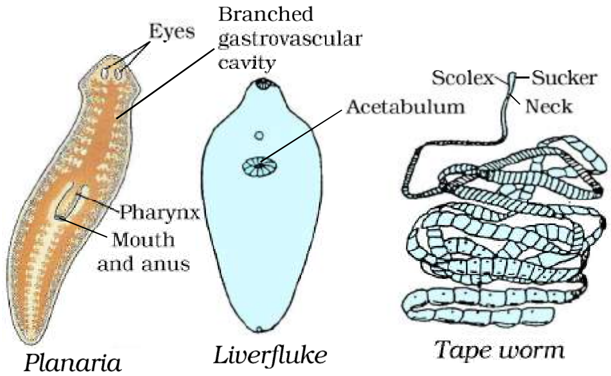


Fig. 7.14: *Platyhelminthes*

7.5.4 Nematoda

The nematode body is also bilaterally symmetrical and triploblastic. However, the body is cylindrical rather than flattened. There are tissues, but no real organs, although a sort of body cavity or a pseudo-coelom, is present. These are very familiar as parasitic worms causing diseases, such as the worms causing elephantiasis (filarial worms) or the worms in the intestines (roundworm or pinworms). Some examples are shown in Fig. 7.15.

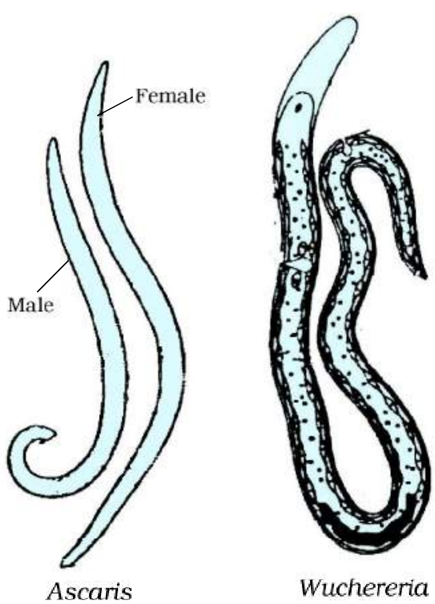


Fig. 7.15: *Nematoda (Aschelminthes)*

7.5.5 Annelida

Annelid animals are also bilaterally symmetrical and triploblastic, but in addition they have a true body cavity. This allows true organs to be packaged in the body structure. There is, thus, extensive organ differentiation. This differentiation occurs in a segmental fashion, with the segments lined up one after the other from head to tail. These animals are found in a variety of habitats– fresh water, marine water as well as land. Earthworms and leeches are familiar examples (see Fig. 7.16).

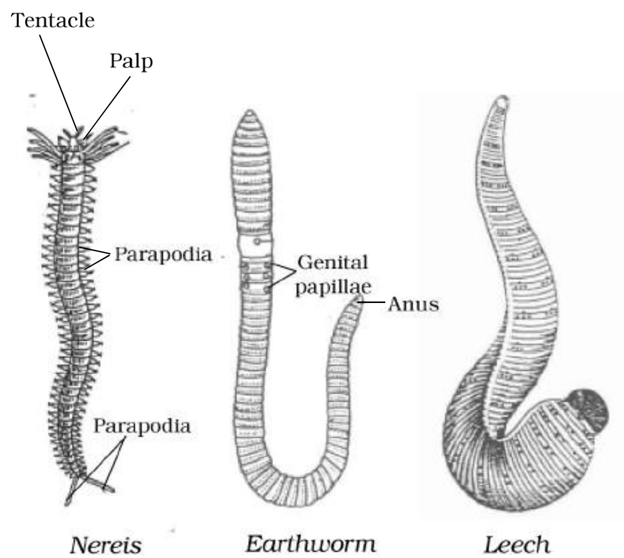


Fig. 7.16: *Annelida*

7.5.6 Arthropoda

This is probably the largest group of animals. These animals are bilaterally symmetrical and segmented. There is an open circulatory system, and so the blood does not flow in well-defined blood vessels. The coelomic cavity is blood-filled. They have jointed legs (the word 'arthropod' means 'jointed legs'). Some familiar examples are prawns, butterflies, houseflies, spiders, scorpions and crabs (see Fig. 7.17).

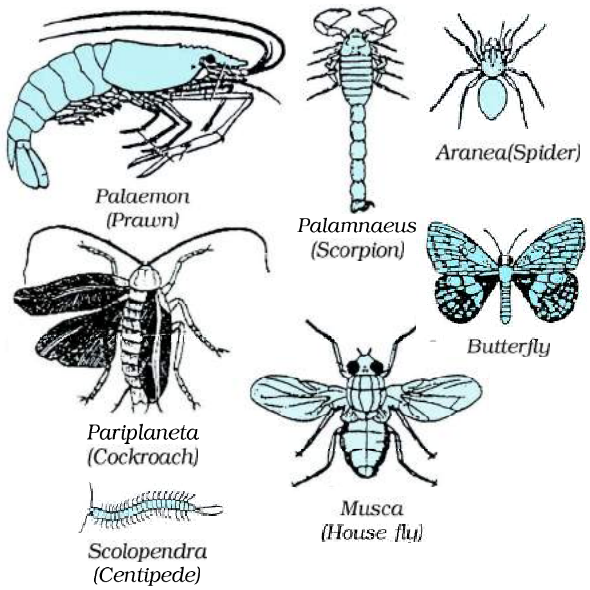


Fig. 7.17: *Arthropoda*

7.5.7 Mollusca

In the animals of this group, there is bilateral symmetry. The coelomic cavity is reduced. There is little segmentation. They have an open circulatory system and kidney-like organs for excretion. There is a foot that is used for moving around. Examples are snails and mussels (see Fig. 7.18).

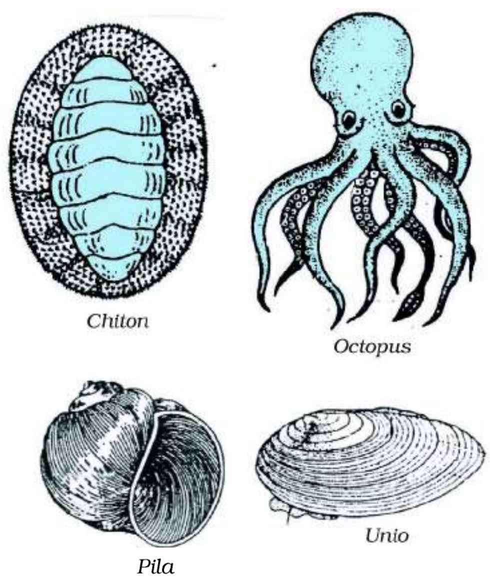


Fig. 7.18: *Mollusca*

7.5.8 Echinodermata

In Greek, *echinos* means hedgehog (spiny mammal), and *derma* means skin. Thus, these are spiny skinned organisms. These are exclusively free-living marine animals. They are triploblastic and have a coelomic cavity. They also have a peculiar water-driven tube system that they use for moving around. They have hard calcium carbonate structures that they use as a skeleton. Examples are sea-stars and sea urchins (see Fig. 7.19).

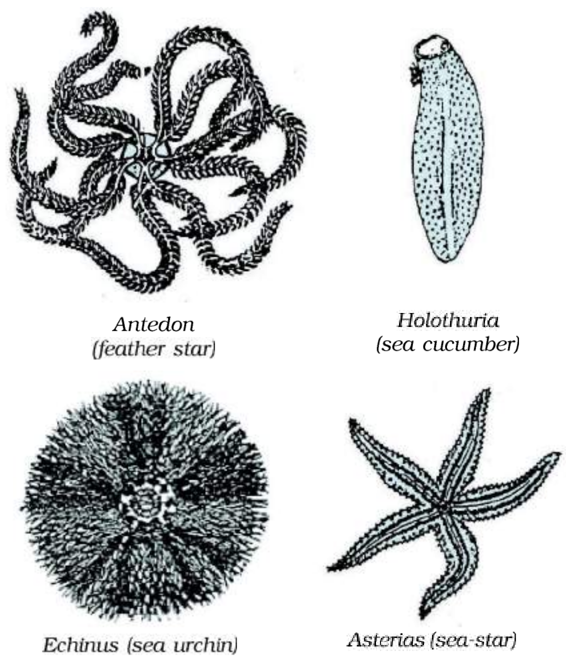


Fig. 7.19: *Echinodermata*

7.5.9 Protochordata

These animals are bilaterally symmetrical, triploblastic and have a coelom. In addition, they show a new feature of body design, namely a notochord, at least at some stages during their lives. The notochord is a long rod-like support structure (chord=string) that runs along the back of the animal separating the nervous tissue from the gut. It provides a place for muscles to attach for ease of movement. Protochordates may not have a proper notochord present at all stages in their lives or for the entire length of the animal. Protochordates are marine animals. Examples are *Balanoglossus*, *Herdmania* and *Amphioxus* (see Fig. 7.20).

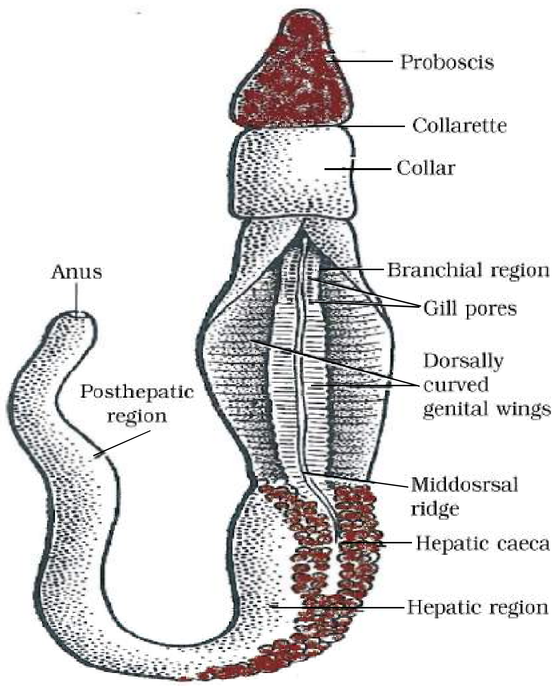


Fig. 7.20: *Protochordata: Balanoglossus*

7.5.10 Vertebrata

These animals have a true vertebral column and internal skeleton, allowing a completely different distribution of muscle attachment points to be used for movement.

Vertebrates are bilaterally symmetrical, triploblastic, coelomic and segmented, with complex differentiation of body tissues and organs. All chordates possess the following features:

(i) have a notochord
(ii) have a dorsal nerve cord
(iii) are triploblastic
(iv) have paired gill pouches
(v) are coelomate.

Vertebrates are grouped into six classes.

7.5.10 (i) *Cyclostomata*

Cyclostomes are jawless vertebrates. They are characterised by having an elongated eel-like body, circular mouth, slimy skin and are

Fig. 7.21: *A jawless vertebrate: Petromyzon*

scaleless. They are ectoparasites or borers of other vertebrates. *Petromyzon* (Lamprey) and *Myxine* (Hagfish) are examples.

7.5.10 (ii) *Pisces*

These are fish. They are exclusively aquatic animals. Their skin is covered with scales/ plates. They obtain oxygen dissolved in water by using gills. The body is streamlined, and a muscular tail is used for movement. They are cold-blooded and their hearts have only two chambers, unlike the four that humans have. They lay eggs. We can think of many kinds of fish, some with skeletons made entirely of cartilage, such as sharks, and some with a skeleton made of both bone and cartilage, such as tuna or rohu [see examples in Figs. 7.22 (a) and 7.22 (b)].

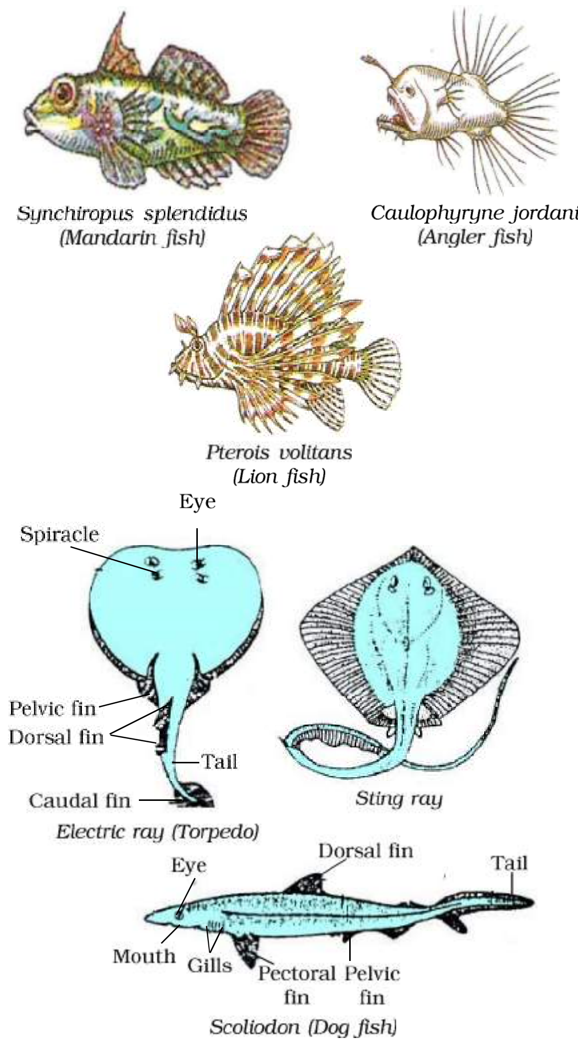


Fig. 7.22 (a): *Pisces*

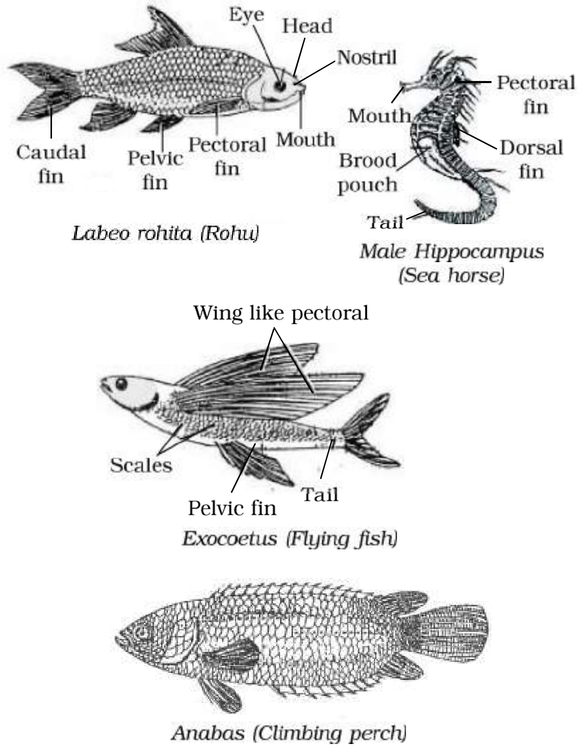


Fig. 7.22 (b): *Pisces*

7.5.10 (iii) *AMPHIBIA*

These animals differ from the fish in the lack of scales, in having mucus glands in the skin, and a three-chambered heart. Respiration is through either gills or lungs. They lay eggs. These animals are found both in water and on land. Frogs, toads and salamanders are some examples (see Fig. 7.23).

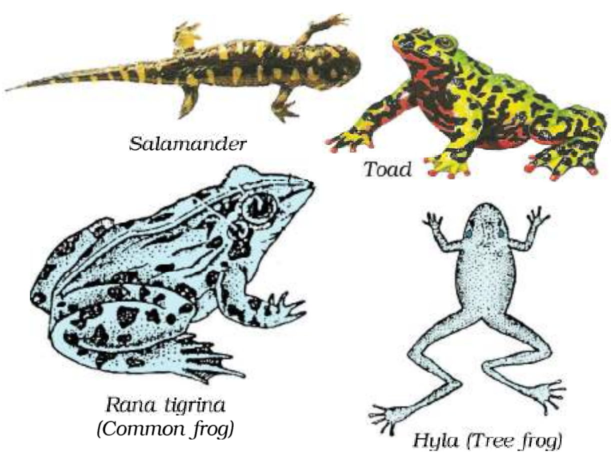


Fig. 7.23: *Amphibia*

7.5.10 (iv) *REPTILIA*

These animals are cold-blooded, have scales and breathe through lungs. While most of them have a three-chambered heart, crocodiles have four heart chambers. They lay eggs with tough coverings and do not need to lay their eggs in water, unlike amphibians. Snakes, turtles, lizards and crocodiles fall in this category (see Fig. 7.24).

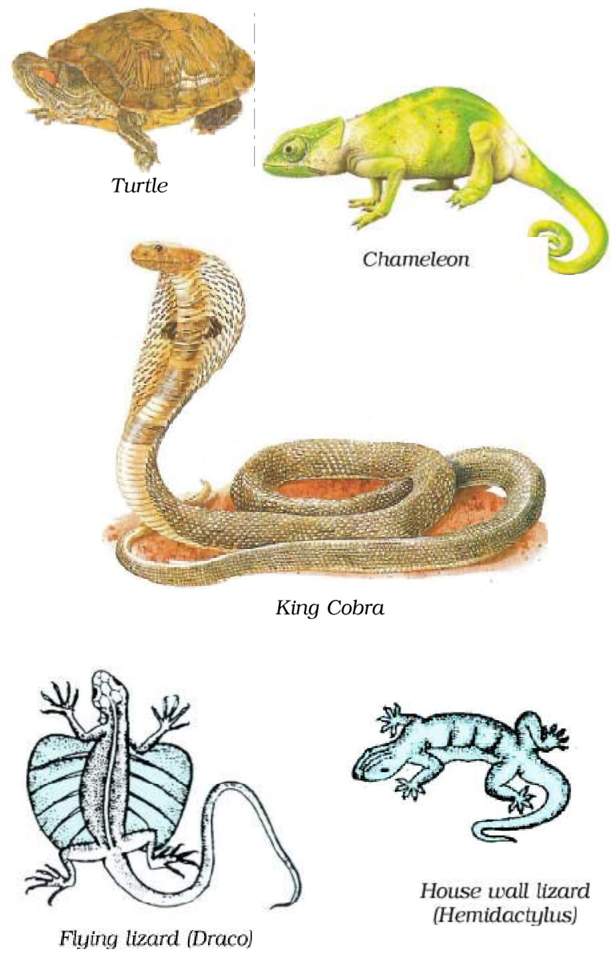


Fig. 7.24: *Reptilia*

7.5.10 (v) *AVES*

These are warm-blooded animals and have a four-chambered heart. They lay eggs. There is an outside covering of feathers, and two forelimbs are modified for flight. They breathe through lungs. All birds fall in this category (see Fig. 7.25 for examples).

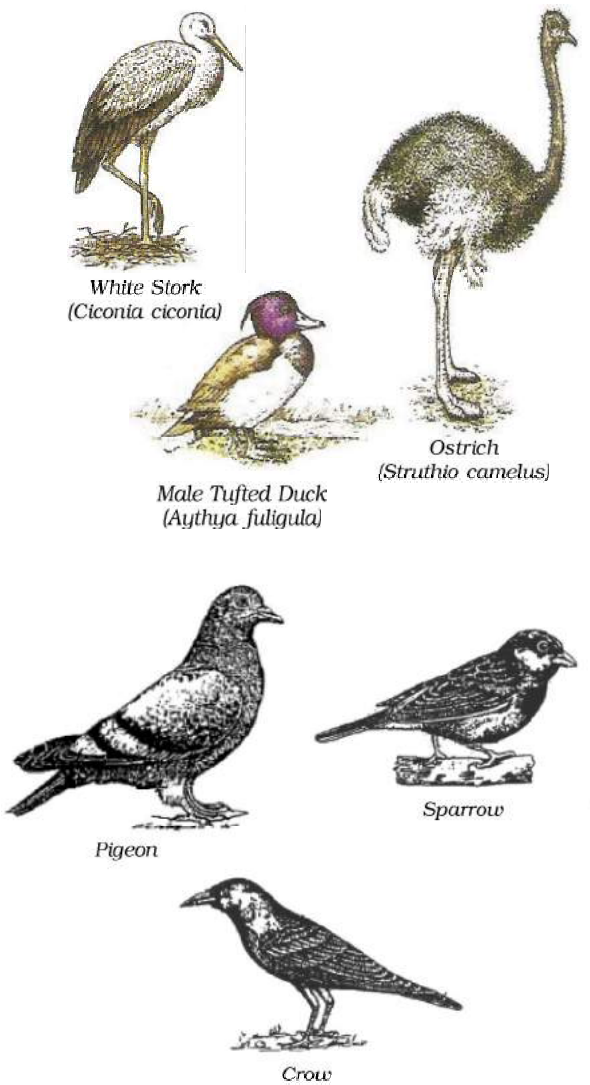


Fig. 7.25: Aves (birds)

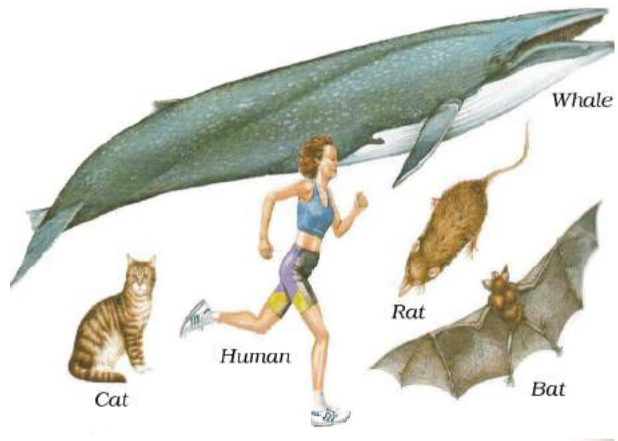


Fig. 7.26: Mammalia

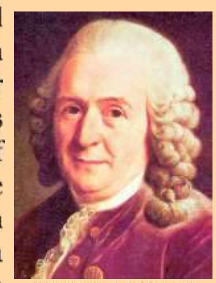
7.5.10 (vi) *Mammalia*

Mammals are warm-blooded animals with four-chambered hearts. They have mammary glands for the production of milk to nourish their young. Their skin has hairs as well as sweat and oil glands. Most mammals familiar to us produce live young ones. However, a few of them, like the platypus and the echidna lay eggs, and some, like kangaroos give birth to very poorly developed young ones. Some examples are shown in Fig. 7.26.

The scheme of classification of animals is shown in Fig. 7.27.

Questions

1. *How do poriferan animals differ from coelenterate animals?*
2. *How do annelid animals differ from arthropods?*
3. *What are the differences between amphibians and reptiles?*
4. *What are the differences between animals belonging to the Aves group and those in the mammalia group?*



Carolus Linnaeus (1707-1778)

Carolus Linnaeus (Karl von Linne) was born in Sweden and was a doctor by professsion. He was interested in the study of plants. At the age of 22, he published his first paper on plants. While serving as a personal physician of a wealthy government official, he studied the diversity of plants in his employer's garden. Later, he published 14 papers and also brought out the famous book *Systema Naturae* from which all fundamental taxonomical researches have taken off. His system of classification was a simple scheme for arranging plants so as to be able to identify them again.

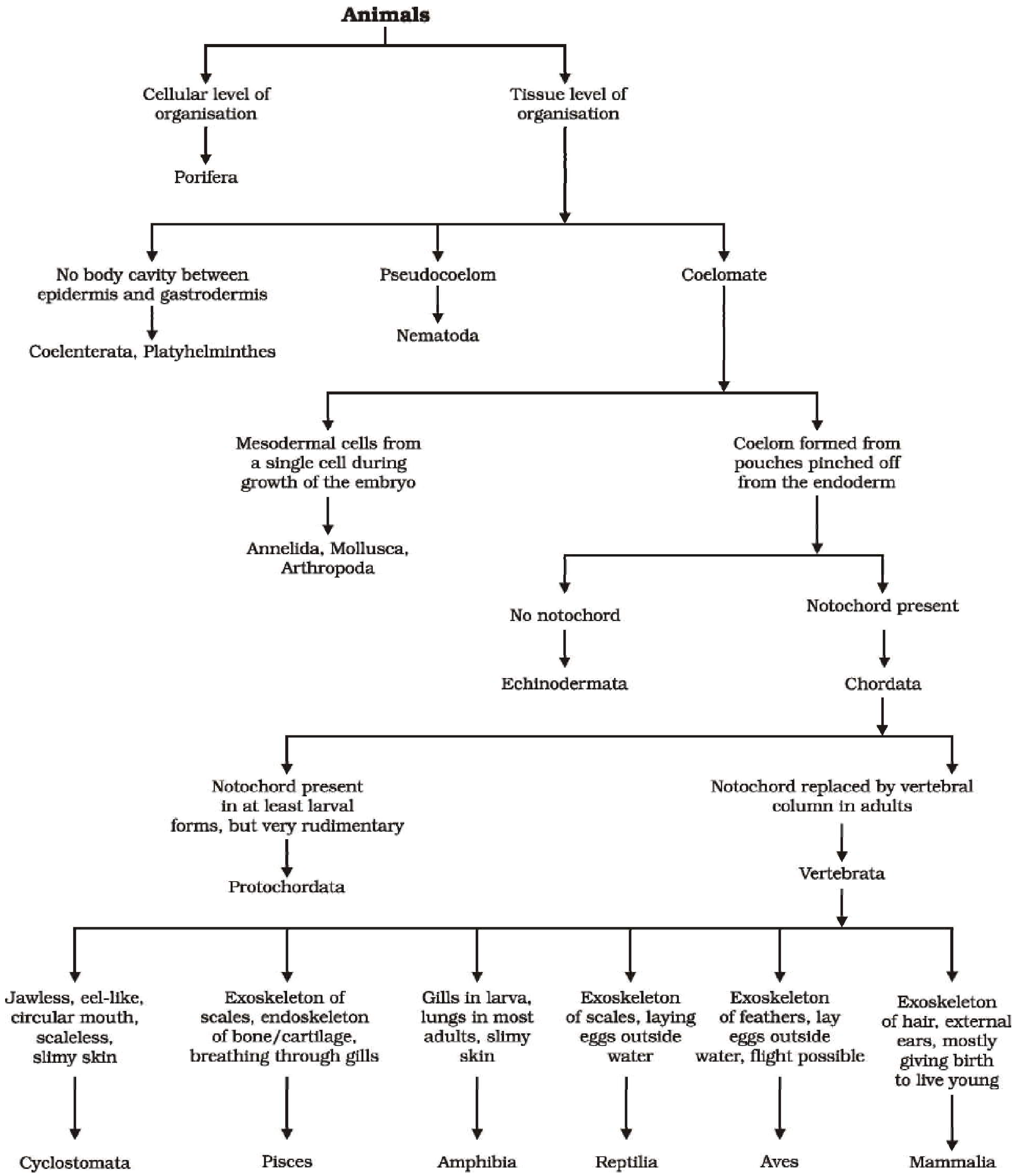


Fig. 7.27: *Classification of animals*

7.6 Nomenclature

Why is there a need for systematic naming of living organisms?

Activity ______________ 7.3

- Find out the names of the following animals and plants in as many languages as you can:
  1. Tiger 2. Peacock 3. Ant
  4. Neem 5. Lotus 6. Potato

As you might be able to appreciate, it would be difficult for people speaking or writing in different languages to know when they are talking about the same organism. This problem was resolved by agreeing upon a 'scientific' name for organisms in the same manner that chemical symbols and formulae for various substances are used the world over. The scientific name for an organism is thus unique and can be used to identify it anywhere in the world.

The system of scientific naming or nomenclature we use today was introduced by Carolus Linnaeus in the eighteenth century. The scientific name of an organism is the result of the process of classification which puts it along with the organisms it is most related to. But when we actually name the species, we do not list out the whole hierarchy of groups it belongs to. Instead, we limit ourselves to writing the name of the genus and species of that particular organism. World over, it has been agreed that both these names will be used in Latin forms.

Certain conventions are followed while writing the scientific names:

1. The name of the genus begins with a capital letter.
2. The name of the species begins with a small letter.
3. When printed, the scientific name is given in italics.
4. When written by hand, the genus name and the species name have to be underlined separately.

Activity ______________ 7.4

- Find out the scientific names of any five common animals and plants. Do these names have anything in common with the names you normally use to identify them?

What you have learnt

- Classification helps us in exploring the diversity of life forms.
- The major characteristics considered for classifying all organisms into five major kingdoms are:
  (a) whether they are made of prokaryotic or eukaryotic cells
  (b) whether the cells are living singly or organised into multi-cellular and thus complex organisms
  (c) whether the cells have a cell-wall and whether they prepare their own food.
- All living organisms are divided on the above bases into five kingdoms, namely Monera, Protista, Fungi, Plantae and Animalia.
- The classification of life forms is related to their evolution.

- Plantae and Animalia are further divided into subdivisions on the basis of increasing complexity of body organisation.
- Plants are divided into five groups: Thallophytes, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms.
- Animals are divided into ten groups: Porifera, Coelenterata, Platyhelminthes, Nematoda, Annelida, Arthropoda, Mollusca, Echinodermata, Protochordata and Vertebrata.
- The binomial nomenclature makes for a uniform way of identification of the vast diversity of life around us.
- The binomial nomenclature is made up of two words – a generic name and a specific name.

Exercises

1. What are the advantages of classifying organisms?
2. How would you choose between two characteristics to be used for developing a hierarchy in classification?
3. Explain the basis for grouping organisms into five kingdoms.
4. What are the major divisions in the Plantae? What is the basis for these divisions?
5. How are the criteria for deciding divisions in plants different from the criteria for deciding the subgroups among animals?
6. Explain how animals in Vertebrata are classified into further subgroups.

Chapter 8

MOTION

In everyday life, we see some objects at rest and others in motion. Birds fly, fish swim, blood flows through veins and arteries, and cars move. Atoms, molecules, planets, stars and galaxies are all in motion. We often perceive an object to be in motion when its position changes with time. However, there are situations where the motion is inferred through indirect evidences. For example, we infer the motion of air by observing the movement of dust and the movement of leaves and branches of trees. What causes the phenomena of sunrise, sunset and changing of seasons? Is it due to the motion of the earth? If it is true, why don't we directly perceive the motion of the earth?

An object may appear to be moving for one person and stationary for some other. For the passengers in a moving bus, the roadside trees appear to be moving backwards. A person standing on the road–side perceives the bus alongwith the passengers as moving. However, a passenger inside the bus sees his fellow passengers to be at rest. What do these observations indicate?

Most motions are complex. Some objects may move in a straight line, others may take a circular path. Some may rotate and a few others may vibrate. There may be situations involving a combination of these. In this chapter, we shall first learn to describe the motion of objects along a straight line. We shall also learn to express such motions through simple equations and graphs. Later, we shall discuss ways of describing circular motion.

Activity _______________ 8.1

- Discuss whether the walls of your classroom are at rest or in motion.

Activity _______________ 8.2

- Have you ever experienced that the train in which you are sitting appears to move while it is at rest?
- Discuss and share your experience.

Think and Act

We sometimes are endangered by the motion of objects around us, especially if that motion is erratic and uncontrolled as observed in a flooded river, a hurricane or a tsunami. On the other hand, controlled motion can be a service to human beings such as in the generation of hydro-electric power. Do you feel the necessity to study the erratic motion of some objects and learn to control them?

8.1 Describing Motion

We describe the location of an object by specifying a reference point. Let us understand this by an example. Let us assume that a school in a village is 2 km north of the railway station. We have specified the position of the school with respect to the railway station. In this example, the railway station is the reference point. We could have also chosen other reference points according to our convenience. Therefore, to describe the position of an object we need to specify a reference point called the origin.

8.1.1 Motion along a straight line

The simplest type of motion is the motion along a straight line. We shall first learn to describe this by an example. Consider the motion of an object moving along a straight path. The object starts its journey from O which is treated as its reference point (Fig. 8.1). Let A, B and C represent the position of the object at different instants. At first, the object moves through C and B and reaches A. Then it moves back along the same path and reaches C through B.

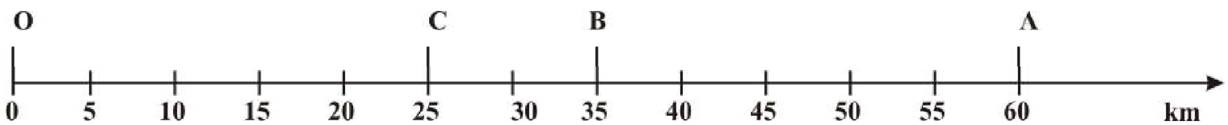


Fig. 8.1: *Positions of an object on a straight line path*

The total path length covered by the object is OA + AC, that is 60 km + 35 km = 95 km. This is the distance covered by the object. To describe distance we need to specify only the numerical value and not the direction of motion. There are certain quantities which are described by specifying only their numerical values. The numerical value of a physical quantity is its magnitude. From this example, can you find out the distance of the final position C of the object from the initial position O? This difference will give you the numerical value of the displacement of the object from O to C through A. The shortest distance measured from the initial to the final position of an object is known as the displacement.

Can the magnitude of the displacement be equal to the distance travelled by an object? Consider the example given in (Fig. 8.1). For motion of the object from O to A, the distance covered is 60 km and the magnitude of displacement is also 60 km. During its motion from O to A and back to B, the distance covered = 60 km + 25 km = 85 km while the magnitude of displacement = 35 km. Thus, the magnitude of displacement (35 km) is not equal to the path length (85 km). Further, we will notice that the magnitude of the displacement for a course of motion may be zero but the corresponding distance covered is not zero. If we consider the object to travel back to O, the final position concides with the initial position, and therefore, the displacement is zero. However, the distance covered in this journey is OA + AO = 60 km + 60 km = 120 km. Thus, two different physical quantities — the distance and the displacement, are used to describe the overall motion of an object and to locate its final position with reference to its initial position at a given time.

Activity ______________ 8.3

- Take a metre scale and a long rope.
- Walk from one corner of a basket-ball court to its oppposite corner along its sides.
- Measure the distance covered by you and magnitude of the displacement.
- What difference would you notice between the two in this case?

Activity ______________ 8.4

- Automobiles are fitted with a device that shows the distance travelled. Such a device is known as an odometer. A car is driven from Bhubaneshwar to New Delhi. The difference between the final reading and the initial reading of the odometer is 1850 km.
- Find the magnitude of the displacement between Bhubaneshwar and New Delhi by using the Road Map of India.

Questions

1. *An object has moved through a distance. Can it have zero displacement? If yes, support your answer with an example.*
2. *A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds from his initial position?*
3. *Which of the following is true for displacement?*
   (a) *It cannot be zero.*
   (b) *Its magnitude is greater than the distance travelled by the object.*

8.1.2 Uniform motion and non-uniform motion

Consider an object moving along a straight line. Let it travel 5 m in the first second, 5 m more in the next second, 5 m in the third second and 5 m in the fourth second. In this case, the object covers 5 m in each second. As the object covers equal distances in equal intervals of time, it is said to be in uniform motion. The time interval in this motion should be small. In our day-to-day life, we come across motions where objects cover unequal distances in equal intervals of time, for example, when a car is moving on a crowded street or a person is jogging in a park. These are some instances of non-uniform motion.

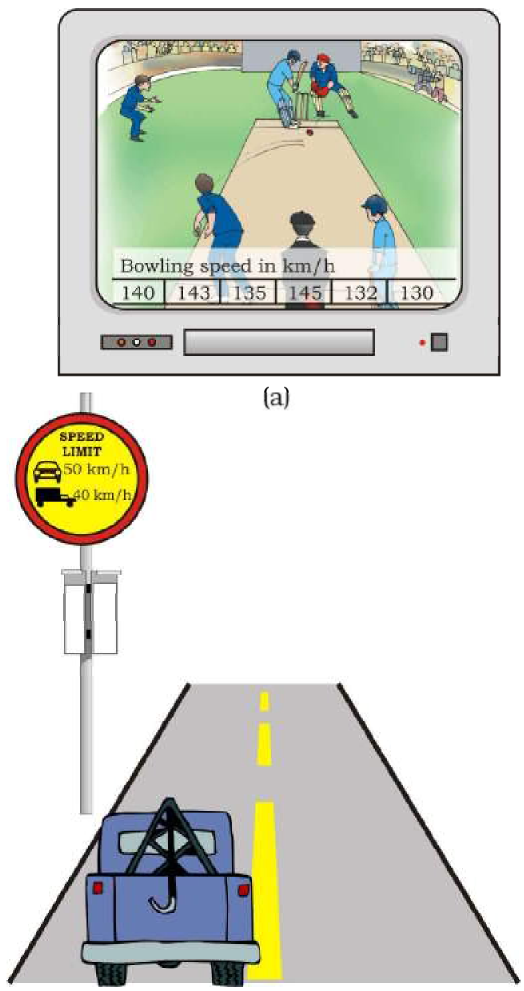
Activity 8.5

- The data regarding the motion of two different objects A and B are given in Table 8.1.
- Examine them carefully and state whether the motion of the objects is uniform or non-uniform.

Table 8.1

Time	Distance travelled by object A in m	Distance travelled by object B in m
9:30 am	10	12
9:45 am	20	19
10:00 am	30	23
10:15 am	40	35
10:30 am	50	37
10:45 am	60	41
11:00 am	70	44

8.2 Measuring the Rate of Motion



(a)
(b)
Fig. 8.2

Look at the situations given in Fig. 8.2. If the bowling speed is 143 km h^{-1} in Fig. 8.2(a) what does it mean? What do you understand from the signboard in Fig. 8.2(b)?

Different objects may take different amounts of time to cover a given distance. Some of them move fast and some move slowly. The rate at which objects move can be different. Also, different objects can move at the same rate. One of the ways of measuring the rate of motion of an object is to find out the distance travelled by the object in unit time. This quantity is referred to as speed. The SI unit of speed is metre per second. This is represented by the symbol m s^{-1} or m/s. The other units of speed include centimetre per second (cm s^{-1}) and kilometre per hour (km h^{-1}). To specify the speed of an object, we require only its magnitude. The speed of an object need not be constant. In most cases, objects will be in non-uniform motion. Therefore, we describe the rate of motion of such objects in terms of their average speed. The average speed of an object is obtained by dividing the total distance travelled by the total time taken. That is,

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

If an object travels a distance s in time t then its speed v is,

$$v = \frac{s}{t} \qquad (8.1)$$

Let us understand this by an example. A car travels a distance of 100 km in 2 h. Its average speed is 50 km h^{-1}. The car might not have travelled at 50 km h^{-1} all the time. Sometimes it might have travelled faster and sometimes slower than this.

Example 8.1 An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?

Solution:

Total distance travelled by the object = 16 m + 16 m = 32 m
Total time taken = 4 s + 2 s = 6 s

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

$$= \frac{32 \text{ m}}{6 \text{ s}} = 5.33 \text{ m s}^{-1}$$

Therefore, the average speed of the object is 5.33 m s^{-1}.

8.2.1 Speed with direction

The rate of motion of an object can be more comprehensive if we specify its direction of motion along with its speed. The quantity that specifies both these aspects is called velocity. Velocity is the speed of an object moving in a definite direction. The velocity of an object can be uniform or variable. It can be changed by changing the object's speed, direction of motion or both. When an object is moving along a straight line at a variable speed, we can express the magnitude of its rate of motion in terms of average velocity. It is calculated in the same way as we calculate average speed.

In case the velocity of the object is changing at a uniform rate, then average velocity is given by the arithmetic mean of initial velocity and final velocity for a given period of time. That is,

$$\text{average velocity} = \frac{\text{initial velocity} + \text{final velocity}}{2}$$

$$\text{Mathematically, } v_{av} = \frac{u + v}{2} \qquad (8.2)$$

where v_{av} is the average velocity, u is the initial velocity and v is the final velocity of the object.

Speed and velocity have the same units, that is, m s^{-1} or m/s.

Activity 8.6

- Measure the time it takes you to walk from your house to your bus stop or the school. If you consider that your average walking speed is 4 km h^{-1}, estimate the distance of the bus stop or school from your house.

Activity 8.7

- At a time when it is cloudy, there may be frequent thunder and lightning. The sound of thunder takes some time to reach you after you see the lightning.
- Can you answer why this happens?
- Measure this time interval using a digital wrist watch or a stop watch.
- Calculate the distance of the nearest point of lightning. (Speed of sound in air = 346 m s^{-1}.)

Questions

1. *Distinguish between speed and velocity.*
2. *Under what condition(s) is the magnitude of average velocity of an object equal to its average speed?*
3. *What does the odometer of an automobile measure?*
4. *What does the path of an object look like when it is in uniform motion?*
5. *During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, that is, 3×10^8 m s^{-1}.*

Example 8.2 The odometer of a car reads 2000 km at the start of a trip and 2400 km at the end of the trip. If the trip took 8 h, calculate the average speed of the car in km h^{-1} and m s^{-1}.

Solution:

Distance covered by the car,
s = 2400 km – 2000 km = 400 km
Time elapsed, t = 8 h
Average speed of the car is,

$$v_{av} = \frac{s}{t} = \frac{400\text{ km}}{8\text{ h}}$$

$$= 50\text{ km h}^{-1}$$

$$= 50 \frac{\text{km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{3600\text{ s}}$$

$$= 13.9\text{ m s}^{-1}$$

The average speed of the car is 50 km h^{-1} or 13.9 m s^{-1}.

Example 8.3 Usha swims in a 90 m long pool. She covers 180 m in one minute by swimming from one end to the other and back along the same straight path. Find the average speed and average velocity of Usha.

Solution:

Total distance covered by Usha in 1 min is 180 m.
Displacement of Usha in 1 min = 0 m

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

$$= \frac{180\text{ m}}{1\text{ min}} = \frac{180\text{ m}}{1\text{ min}} \times \frac{1\text{ min}}{60\text{ s}}$$

$$= 3\text{ m s}^{-1}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Total time taken}}$$

$$= \frac{0\text{ m}}{60\text{ s}}$$

$$= 0\text{ m s}^{-1}$$

The average speed of Usha is 3 m s^{-1} and her average velocity is 0 m s^{-1}.

8.3 Rate of Change of Velocity

During uniform motion of an object along a straight line, the velocity remains constant with time. In this case, the change in velocity of the object for any time interval is zero. However, in non-uniform motion, velocity varies with time. It has different values at different instants and at different points of the path. Thus, the change in velocity of the object during any time interval is not zero. Can we now express the change in velocity of an object?

To answer such a question, we have to introduce another physical quantity called acceleration, which is a measure of the change in the velocity of an object per unit time. That is,

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

If the velocity of an object changes from an initial value u to the final value v in time t, the acceleration a is,

$$a = \frac{v - u}{t} \qquad (8.3)$$

This kind of motion is known as accelerated motion. The 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 is m s^{-2} .

If an object travels in a straight line and its velocity 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 body is an example of uniformly accelerated motion. On the other hand, an object can travel with non-uniform acceleration if its velocity changes at a non-uniform rate. For example, if a car travelling along a straight road increases its speed by unequal amounts in equal intervals of time, then the car is said to be moving with non-uniform acceleration.

Activity 8.8

- In your everyday life you come across a range of motions in which
  - (a) acceleration is in the direction of motion,
  - (b) acceleration is against the direction of motion,
  - (c) acceleration is uniform,
  - (d) acceleration is non-uniform.
- Can you identify one example each for the above type of motion?

Example 8.4 Starting from a stationary position, Rahul paddles his bicycle to attain a velocity of 6 m s^{-1} in 30 s. Then he applies brakes such that the velocity of the bicycle comes down to 4 m s^{-1} in the next 5 s. Calculate the acceleration of the bicycle in both the cases.

Solution:

In the first case:
initial velocity, $u = 0$;
final velocity, $v = 6$ m s^{-1} ;
time, $t = 30$ s .
From Eq. (8.3), we have

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

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

$$a = \frac{(6\,\text{m s}^{-1} - 0\,\text{m s}^{-1})}{30\,\text{s}}$$

$$= 0.2\ \text{m s}^{-2}$$

In the second case:
initial velocity, $u = 6$ m s^{-1};
final velocity, $v = 4$ m s^{-1};
time, $t = 5$ s.

$$\text{Then, } a = \frac{(4\,\text{m s}^{-1} - 6\,\text{m s}^{-1})}{5\,\text{s}}$$

$$= -0.4\ \text{m s}^{-2}.$$

The acceleration of the bicycle in the first case is 0.2 m s^{-2} and in the second case, it is –0.4 m s^{-2}.

Questions

1. *When will you say a body is in (i) uniform acceleration? (ii) non-uniform acceleration?*
2. *A bus decreases its speed from 80* km h^{-1} *to 60* km h^{-1} *in 5* s. *Find the acceleration of the bus.*
3. *A train starting from a railway station and moving with uniform acceleration attains a speed 40* km h^{-1} *in 10 minutes. Find its acceleration.*

8.4 Graphical Representation of Motion

Graphs provide a convenient method to present basic information about a variety of events. For example, in the telecast of a one-day cricket match, vertical bar graphs show the run rate of a team in each over. As you have studied in mathematics, a straight line graph helps in solving a linear equation having two variables.

To describe the motion of an object, we can use line graphs. In this case, line graphs show dependence of one physical quantity, such as distance or velocity, on another quantity, such as time.

8.4.1 Distance–time graphs

The change in the position of an object with time can be represented on the distance-time graph adopting a convenient scale of choice. In this graph, time is taken along the *x*–axis and distance is taken along the *y*-axis. Distance-time graphs can be employed under various conditions where objects move with uniform speed, non-uniform speed, remain at rest etc.

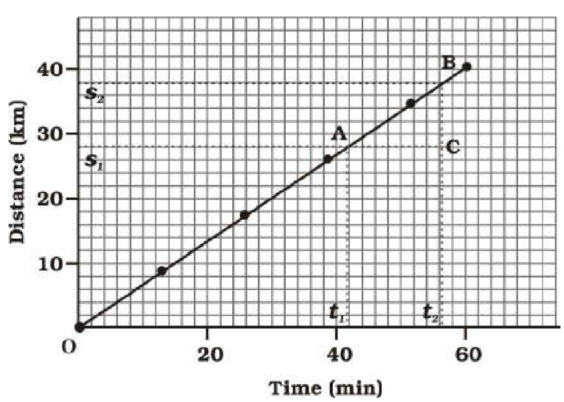


Fig. 8.3: *Distance-time graph of an object moving with uniform speed*

We know that when an object travels equal distances in equal intervals of time, it moves with uniform speed. This shows that the distance travelled by the object is directly proportional to time taken. Thus, for uniform speed, a graph of distance travelled against time is a straight line, as shown in Fig. 8.3. The portion OB of the graph shows that the distance is increasing at a uniform rate. Note that, you can also use the term uniform velocity in place of uniform speed if you take the magnitude of displacement equal to the distance travelled by the object along the *y*-axis.

We can use the distance-time graph to determine the speed of an object. To do so, consider a small part AB of the distance-time graph shown in Fig 8.3. Draw a line parallel to the *x*-axis from point A and another line parallel to the *y*-axis from point B. These two lines meet each other at point C to form a triangle ABC. Now, on the graph, AC denotes the time interval $(t_2 - t_1)$ while BC corresponds to the distance $(s_2 - s_1)$. We can see from the graph that as the object moves from the point A to B, it covers a distance $(s_2 - s_1)$ in time $(t_2 - t_1)$. The speed, v of the object, therefore can be represented as

$$v = \frac{s_2 - s_1}{t_2 - t_1} \qquad (8.4)$$

We can also plot the distance-time graph for accelerated motion. Table 8.2 shows the distance travelled by a car in a time interval of two seconds.

Table 8.2: Distance travelled by a car at regular time intervals

Time in seconds	Distance in metres
0	0
2	1
4	4
6	9
8	16
10	25
12	36

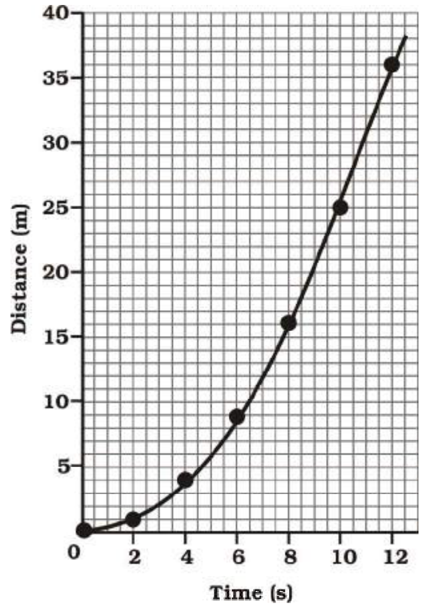


Fig. 8.4: *Distance-time graph for a car moving with non-uniform speed*

The distance-time graph for the motion of the car is shown in Fig. 8.4. Note that the shape of this graph is different from the earlier distance-time graph (Fig. 8.3) for uniform motion. The nature of this graph shows non-linear variation of the distance travelled by the car with time. Thus, the graph shown in Fig 8.4 represents motion with non-uniform speed.

8.4.2 Velocity-time graphs

The variation in velocity with time for an object moving in a straight line can be represented by a velocity-time graph. In this graph, time is represented along the *x*-axis

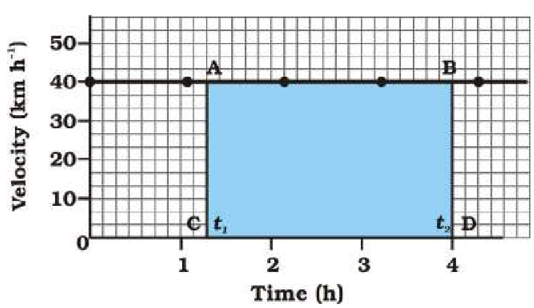


Fig. 8.5: *Velocity-time graph for uniform motion of a car*

and the velocity is represented along the *y*-axis. If the object moves at uniform velocity, the height of its velocity-time graph will not change with time (Fig. 8.5). It will be a straight line parallel to the *x*-axis. Fig. 8.5 shows the velocity-time graph for a car moving with uniform velocity of 40 km h^{-1}.

We know that the product of velocity and time give displacement of an object moving with uniform velocity. The area enclosed by velocity-time graph and the time axis will be equal to the magnitude of the displacement.

To know the distance moved by the car between time t_1 and t_2 using Fig. 8.5, draw perpendiculars from the points corresponding to the time t_1 and t_2 on the graph. The velocity of 40 km h^{-1} is represented by the height AC or BD and the time $(t_2 - t_1)$ is represented by the length AB.

So, the distance *s* moved by the car in time $(t_2 - t_1)$ can be expressed as

s = AC × CD

= [(40 km h^{-1}) × $(t_2 - t_1)$ h]

= 40 $(t_2 - t_1)$ km

= area of the rectangle ABDC (shaded in Fig. 8.5).

We can also study about uniformly accelerated motion by plotting its velocity–time graph. Consider a car being driven along a straight road for testing its engine. Suppose a person sitting next to the driver records its velocity after every 5 seconds by noting the reading of the speedometer of the car. The velocity of the car, in km h^{-1} as well as in m s^{-1}, at different instants of time is shown in table 8.3.

Table 8.3: Velocity of a car at regular instants of time

Time (s)	Velocity of the car (m s^{-1})	(km h^{-1})
0	0	0
5	2.5	9
10	5.0	18
15	7.5	27
20	10.0	36
25	12.5	45
30	15.0	54

In this case, the velocity-time graph for the motion of the car is shown in Fig. 8.6. The nature of the graph shows that velocity changes by equal amounts in equal intervals of time. Thus, for all uniformly accelerated motion, the velocity-time graph is a straight line.

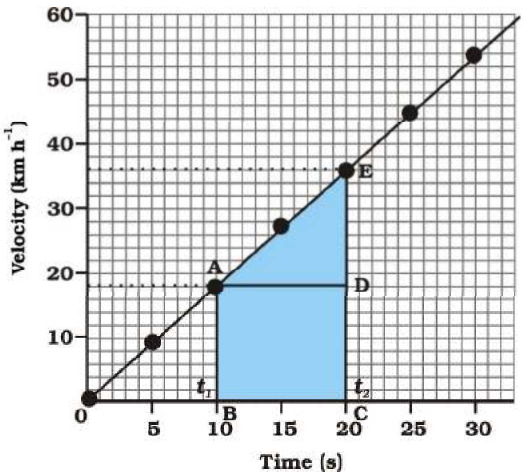


Fig. 8.6: Velocity-time graph for a car moving with uniform accelerations.

You can also determine the distance moved by the car from its velocity-time graph. The area under the velocity-time graph gives the distance (magnitude of displacement) moved by the car in a given interval of time. If the car would have been moving with uniform velocity, the distance travelled by it would be represented by the area ABCD under the graph (Fig. 8.6). Since the magnitude of the velocity of the car is changing due to acceleration, the distance s travelled by the car will be given by the area ABCDE under the velocity-time graph (Fig. 8.6).

That is,

s = area ABCDE

= area of the rectangle ABCD + area of the triangle ADE

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

In the case of non-uniformly accelerated motion, velocity-time graphs can have any shape.

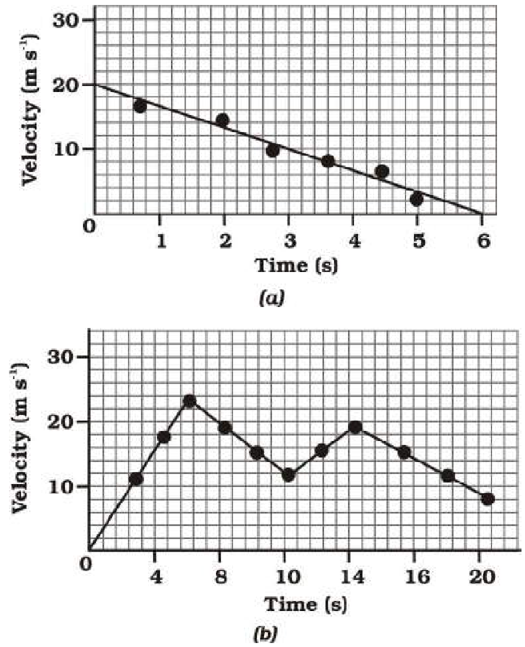


Fig. 8.7: Velocity-time graphs of an object in non-uniformly accelerated motion.

Fig. 8.7(a) shows a velocity-time graph that represents the motion of an object whose velocity is decreasing with time while Fig. 8.7 (b) shows the velocity-time graph representing the non-uniform variation of velocity of the object with time. Try to interpret these graphs.

Activity ______________ 8.9

- The times of arrival and departure of a train at three stations A, B and C and the distance of stations B and C from station A are given in table 8.4.

Table 8.4: Distances of stations B and C from A and times of arrival and departure of the train

Station	Distance from A (km)	Time of arrival (hours)	Time of departure (hours)
A	0	08:00	08:15
B	120	11:15	11:30
C	180	13:00	13:15

- Plot and interpret the distance-time graph for the train assuming that its motion between any two stations is uniform.

Activity _____________ 8.10

- Feroz and his sister Sania go to school on their bicycles. Both of them start at the same time from their home but take different times to reach the school although they follow the same route. Table 8.5 shows the distance travelled by them in different times

Table 8.5: Distance covered by Feroz and Sania at different times on their bicycles

Time	Distance travelled by Feroz (km)	Distance travelled by Sania (km)
8:00 am	0	0
8:05 am	1.0	0.8
8:10 am	1.9	1.6
8:15 am	2.8	2.3
8:20 am	3.6	3.0
8:25 am	–	3.6

- Plot the distance-time graph for their motions on the same scale and interpret.

Questions

1. *What is the nature of the distance-time graphs for uniform and non-uniform motion of an object?*
2. *What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis?*
3. *What can you say about the motion of an object if its speed-time graph is a straight line parallel to the time axis?*
4. *What is the quantity which is measured by the area occupied below the velocity-time graph?*

8.5 Equations of Motion by Graphical Method

When an object moves along a straight line with uniform acceleration, it is possible to relate its velocity, acceleration during motion and the distance covered by it in a certain time interval by a set of equations known as the equations of motion. For convenience, a set of three such equations are given below:

$$v = u + at \qquad (8.5)$$

$$s = ut + \tfrac{1}{2} at^2 \qquad (8.6)$$

$$2as = v^2 - u^2 \qquad (8.7)$$

where u is the initial velocity of the object which moves with uniform acceleration a for time t, v is the final velocity, and s is the distance travelled by the object in time t. Eq. (8.5) describes the velocity-time relation and Eq. (8.6) represents the position-time relation. Eq. (8.7), which represents the relation between the position and the velocity, can be obtained from Eqs. (8.5) and (8.6) by eliminating t. These three equations can be derived by graphical method.

8.5.1 Equation for velocity-time relation

Consider the velocity-time graph of an object that moves under uniform acceleration as

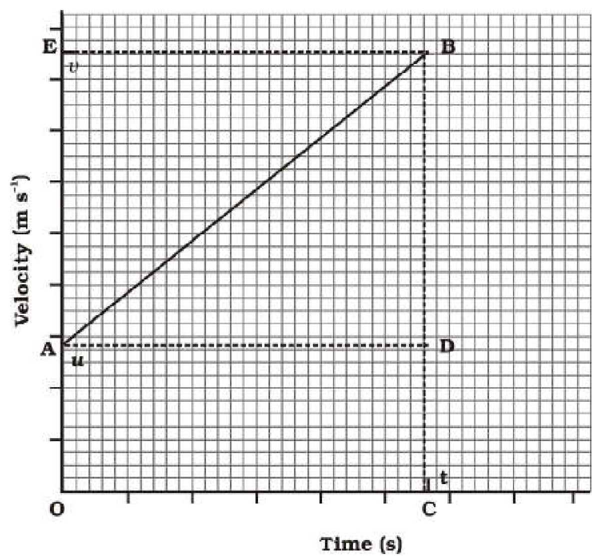


Fig. 8.8: *Velocity-time graph to obtain the equations of motion*

shown in Fig. 8.8 (similar to Fig. 8.6, but now with $u \neq 0$). From this graph, you can see that initial velocity of the object is u (at point A) and then it increases to v (at point B) in time t. The velocity changes at a uniform rate a. In Fig. 8.8, the perpendicular lines BC and BE are drawn from point B on the time and the velocity axes respectively, so that the initial velocity is represented by OA, the final velocity is represented by BC and the time interval t is represented by OC. BD = BC – CD, represents the change in velocity in time interval t.

Let us draw AD parallel to OC. From the graph, we observe that

BC = BD + DC = BD + OA

Substituting BC $= v$ and OA $= u$,

we get v = BD + u

or BD $= v - u$ (8.8)

From the velocity-time graph (Fig. 8.8), the acceleration of the object is given by

$$a = \frac{\text{Change in velocity}}{\text{time taken}}$$

$$= \frac{BD}{AD} = \frac{BD}{OC}$$

Substituting OC = t, we get

$$a = \frac{BD}{t}$$

or BD $= at$ (8.9)

Using Eqs. (8.8) and (8.9) we get

$$v = u + at$$

8.5.2 Equation for Position-Time Relation

Let us consider that the object has travelled a distance s in time t under uniform acceleration a. In Fig. 8.8, the distance travelled by the object is obtained by the area enclosed within OABC under the velocity-time graph AB.

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

s = area OABC (which is a trapezium)

= area of the rectangle OADC + area of the triangle ABD

$$= OA \times OC + \frac{1}{2}(AD \times BD) \qquad (8.10)$$

Substituting OA $= u$, OC = AD $= t$ and BD $= at$, we get

$$s = u \times t + \frac{1}{2}(t \times at)$$

or $$s = ut + \frac{1}{2}at^2$$

8.5.3 Equation for Position–Velocity Relation

From the velocity-time graph shown in Fig. 8.8, the distance s travelled by the object in time t, moving under uniform acceleration a is given by the area enclosed within the trapezium OABC under the graph. That is,

s = area of the trapezium OABC

$$= \frac{(OA + BC) \times OC}{2}$$

Substituting OA $= u$, BC $= v$ and OC $= t$, we get

$$s = \frac{(u + v)t}{2} \qquad (8.11)$$

From the velocity-time relation (Eq. 8.6), we get

$$t = \frac{(v - u)}{a} \qquad (8.12)$$

Using Eqs. (8.11) and (8.12) we have

$$s = \frac{(v + u) \times (v - u)}{2a}$$

or $$2as = v^2 - u^2$$

Example 8.5 A train starting from rest attains a velocity of 72 km h^{-1} in 5 minutes. Assuming that the acceleration is uniform, find (i) the acceleration and (ii) the distance travelled by the train for attaining this velocity.