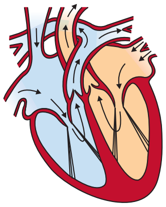

CHAPTER 5
Life Processes

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How do we tell the difference between what is alive and what is not alive? If we see a dog running, or a cow chewing cud, or a man shouting loudly on the street, we know that these are living beings. What if the dog or the cow or the man were asleep? We would still think that they were alive, but how did we know that? We see them breathing, and we know that they are alive. What about plants? How do we know that they are alive? We see them green, some of us will say. But what about plants that have leaves of colours other than green? They grow over time, so we know that they are alive, some will say. In other words, we tend to think of some sort of movement, either growth-related or not, as common evidence for being alive. But a plant that is not visibly growing is still alive, and some animals can breathe without visible movement. So using visible movement as the defining characteristic of life is not enough.

Movements over very small scales will be invisible to the naked eye – movements of molecules, for example. Is this invisible molecular movement necessary for life? If we ask this question to professional biologists, they will say yes. In fact, viruses do not show any molecular movement in them (until they infect some cell), and that is partly why there is a controversy about whether they are truly alive or not.

Why are molecular movements needed for life? We have seen in earlier classes that living organisms are well-organised structures; they can have tissues, tissues have cells, cells have smaller components in them, and so on. Because of the effects of the environment, this organised, ordered nature of living structures is very likely to keep breaking down over time. If order breaks down, the organism will no longer be alive. So living creatures must keep repairing and maintaining their structures. Since all these structures are made up of molecules, they must move molecules around all the time.

What are the maintenance processes in living organisms? Let us explore.

5.1 WHAT ARE LIFE PROCESSES?

The maintenance functions of living organisms must go on even when they are not doing anything particular. Even when we are just sitting in class, even if we are just asleep, this maintenance job has to go on. The processes which together perform this maintenance job are life processes.

Since these maintenance processes are needed to prevent damage and break-down, energy is needed for them. This energy comes from outside the body of the individual organism. So there must be a process to transfer a source of energy from outside the body of the organism, which we call food, to the inside, a process we commonly call nutrition. If the body size of the organisms is to grow, additional raw material will also be needed from outside. Since life on earth depends on carbon-based molecules, most of these food sources are also carbon-based. Depending on the complexity of these carbon sources, different organisms can then use different kinds of nutritional processes.

The outside sources of energy could be quite varied, since the environment is not under the control of the individual organism. These sources of energy, therefore, need to be broken down or built up in the body, and must be finally converted to a uniform source of energy that can be used for the various molecular movements needed for maintaining living structures, as well as to the kind of molecules the body needs to grow. For this, a series of chemical reactions in the body are necessary. Oxidising-reducing reactions are some of the most common chemical means to break-down molecules. For this, many organisms use oxygen sourced from outside the body. The process of acquiring oxygen from outside the body, and to use it in the process of break-down of food sources for cellular needs, is what we call respiration.

In the case of a single-celled organism, no specific organs for taking in food, exchange of gases or removal of wastes may be needed because the entire surface of the organism is in contact with the environment. But what happens when the body size of the organism increases and the body design becomes more complex? In multi-cellular organisms, all the cells may not be in direct contact with the surrounding environment. Thus, simple diffusion will not meet the requirements of all the cells.

We have seen previously how, in multi-cellular organisms, various body parts have specialised in the functions they perform. We are familiar with the idea of these specialised tissues, and with their organisation in the body of the organism. It is therefore not surprising that the uptake of food and of oxygen will also be the function of specialised tissues. However, this poses a problem, since the food and oxygen are now taken up at one place in the body of the organisms, while all parts of the body need them. This situation creates a need for a transportation system for carrying food and oxygen from one place to another in the body.

When chemical reactions use the carbon source and the oxygen for energy generation, they create by-products that are not only useless for the cells of the body, but could even be harmful. These waste by-products are therefore needed to be removed from the body and discarded outside by a process called excretion. Again, if the basic rules for body design in multi-cellular organisms are followed, a specialised tissue for excretion will be developed, which means that the transportation system will need to transport waste away from cells to this excretory tissue.

Let us consider these various processes, so essential to maintain life, one by one.

QUESTIONS

1. Why is diffusion insufficient to meet the oxygen requirements of multi-cellular organisms like humans?
2. What criteria do we use to decide whether something is alive?
3. What are outside raw materials used for by an organism?
4. What processes would you consider essential for maintaining life?

5.2 NUTRITION

When we walk or ride a bicycle, we are using up energy. Even when we are not doing any apparent activity, energy is needed to maintain a state of order in our body. We also need materials from outside in order to grow, develop, synthesise protein and other substances needed in the body. This source of energy and materials is the food we eat.

How do living things get their food?

The general requirement for energy and materials is common in all organisms, but it is fulfilled in different ways. Some organisms use simple food material obtained from inorganic sources in the form of carbon dioxide and water. These organisms, the autotrophs, include green plants and some bacteria. Other organisms utilise complex substances. These complex substances have to be broken down into simpler ones before they can be used for the upkeep and growth of the body. To achieve this, organisms use bio-catalysts called enzymes. Thus, the heterotrophs survival depends directly or indirectly on autotrophs. Heterotrophic organisms include animals and fungi.

5.2.1 Autotrophic Nutrition

Carbon and energy requirements of the autotrophic organism are fulfilled by photosynthesis. It is the process by which autotrophs take in substances from the outside and convert them into stored forms of energy. This material is taken in the form of carbon dioxide and water which is converted into carbohydrates in the presence of sunlight and chlorophyll. Carbohydrates are utilised for providing energy to the plant. We will study how this takes place in the next section. The carbohydrates which are not used immediately are stored in the form of starch, which serves as the internal energy reserve to be used as and when required by the plant. A somewhat similar situation is seen in us where some of the energy derived from the food we eat is stored in our body in the form of glycogen.

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} \underset{\text{(Glucose)}}{C_6H_{12}O_6} + 6O_2 + 6H_2O$$

Let us now see what actually happens during the process of photosynthesis. The following events occur during this process –

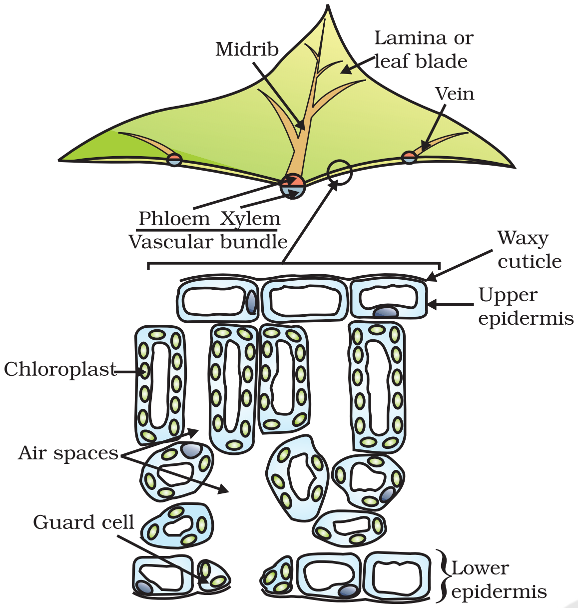

Figure 5.1
Cross-section of a leaf

(i) Absorption of light energy by chlorophyll.
(ii) Conversion of light energy to chemical energy and splitting of water molecules into hydrogen and oxygen.
(iii) Reduction of carbon dioxide to carbohydrates.

These steps need not take place one after the other immediately. For example, desert plants take up carbon dioxide at night and prepare an intermediate which is acted upon by the energy absorbed by the chlorophyll during the day.

Let us see how each of the components of the above reaction are necessary for photosynthesis.

If you carefully observe a cross-section of a leaf under the microscope (shown in Fig. 5.1), you will notice that some cells contain green dots. These green dots are cell organelles called chloroplasts which contain chlorophyll. Let us do an activity which demonstrates that chlorophyll is essential for photosynthesis.

Activity 5.1

- Take a potted plant with variegated leaves – for example, money plant or crotons.
- Keep the plant in a dark room for three days so that all the starch gets used up.
- Now keep the plant in sunlight for about six hours.
- Pluck a leaf from the plant. Mark the green areas in it and trace them on a sheet of paper.
- Dip the leaf in boiling water for a few minutes.
- After this, immerse it in a beaker containing alcohol.
- Carefully place the above beaker in a water-bath and heat till the alcohol begins to boil.
- What happens to the colour of the leaf? What is the colour of the solution?
- Now dip the leaf in a dilute solution of iodine for a few minutes.
- Take out the leaf and rinse off the iodine solution.
- Observe the colour of the leaf and compare this with the tracing of the leaf done in the beginning (Fig. 5.2).
- What can you conclude about the presence of starch in various areas of the leaf?

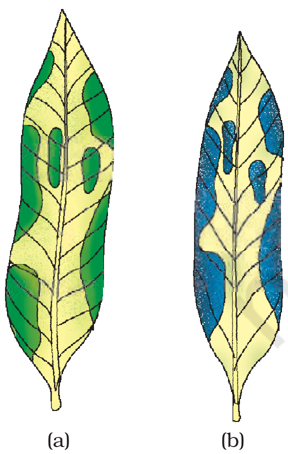

Figure 5.2
Variegated leaf (a) before and (b) after starch test

Now, let us study how the plant obtains carbon dioxide. In Class IX, we had talked about stomata (Fig. 5.3) which are tiny pores present on the surface of the leaves. Massive amounts of gaseous exchange takes place in the leaves through these pores for the purpose of photosynthesis. But it is important to note here that exchange of gases occurs across the surface of stems, roots and leaves as well. Since large amounts of water can also be lost through these stomata, the plant closes these pores when it does not need carbon dioxide for photosynthesis. The opening and closing of the pore is a function of the guard cells. The guard cells swell when water flows into them, causing the stomatal pore to open. Similarly the pore closes if the guard cells shrink.

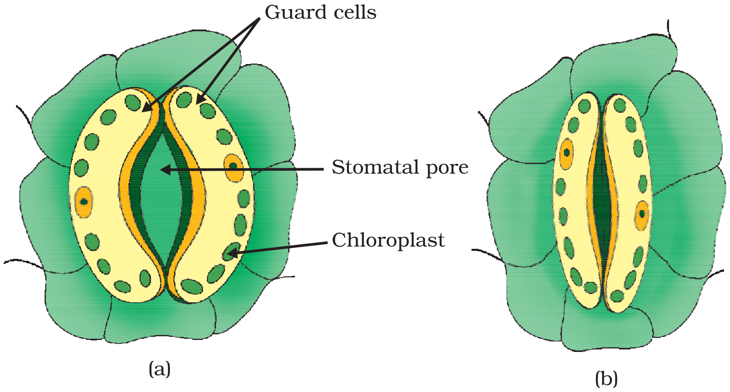

Figure 5.3 *(a) Open and (b) closed stomatal pore*

Activity 5.2

- Take two healthy potted plants which are nearly the same size.
- Keep them in a dark room for three days.
- Now place each plant on separate glass plates. Place a watch-glass containing potassium hydroxide by the side of one of the plants. The potassium hydroxide is used to absorb carbon dioxide.
- Cover both plants with separate bell-jars as shown in Fig. 5.4.
- Use vaseline to seal the bottom of the jars to the glass plates so that the set-up is air-tight.
- Keep the plants in sunlight for about two hours.
- Pluck a leaf from each plant and check for the presence of starch as in the above activity.
- Do both the leaves show the presence of the same amount of starch?
- What can you conclude from this activity?

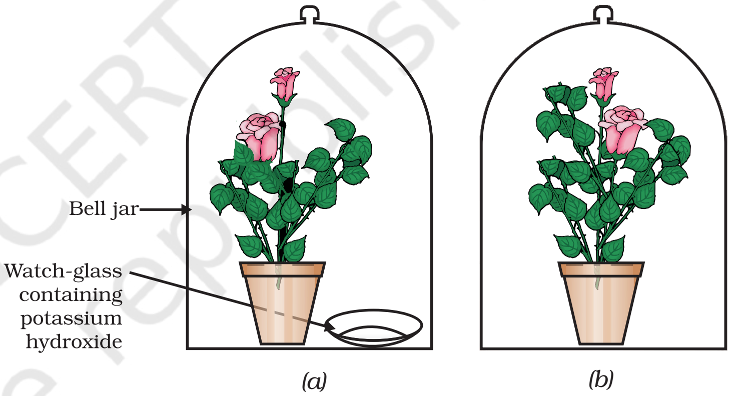

Figure 5.4 *Experimental set-up (a) with potassium hydroxide (b) without potassium hydroxide*

Based on the two activities performed above, can we design an experiment to demonstrate that sunlight is essential for photosynthesis?

So far, we have talked about how autotrophs meet their energy requirements. But they also need other raw materials for building their body. Water used in photosynthesis is taken up from the soil by the roots in terrestrial plants. Other materials like nitrogen, phosphorus, iron and magnesium are taken up from the soil. Nitrogen is an essential element used in the synthesis of proteins and other compounds. This is taken up in the form of inorganic nitrates or nitrites. Or it is taken up as organic compounds which have been prepared by bacteria from atmospheric nitrogen.

5.2.2 Heterotrophic Nutrition

Each organism is adapted to its environment. The form of nutrition differs depending on the type and availability of food material as well as how it is obtained by the organism. For example, whether the food source is stationary (such as grass) or mobile (such as a deer), would allow for differences in how the food is accessed and what is the nutritive apparatus used by a cow and a lion. There is a range of strategies by which the food is taken in and used by the organism. Some organisms break-down the food material outside the body and then absorb it. Examples are fungi like bread moulds, yeast and mushrooms. Others take in whole material and break it down inside their bodies. What can be taken in and broken down depends on the body design and functioning. Some other organisms derive nutrition from plants or animals without killing them. This parasitic nutritive strategy is used by a wide variety of organisms like cuscuta (amar-bel), ticks, lice, leeches and tape-worms.

5.2.3 How do Organisms obtain their Nutrition?

Since the food and the way it is obtained differ, the digestive system is different in various organisms. In single-celled organisms, the food may be taken in by the entire surface. But as the complexity of the organism increases, different parts become specialised to perform different functions. For example, *Amoeba* takes in food using temporary finger-like extensions of the cell surface which fuse over the food particle forming a food-vacuole (Fig. 5.5). Inside the food-vacuole, complex substances are broken down into simpler ones which then diffuse into the cytoplasm. The remaining undigested material is moved to the surface of the cell and thrown out. In *Paramoecium*, which is also a unicellular organism, the cell has a definite shape and food is taken in at a specific spot. Food is moved to this spot by the movement of cilia which cover the entire surface of the cell.

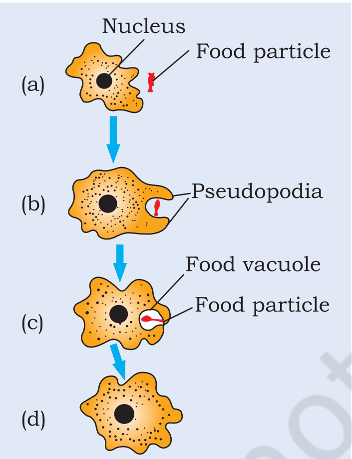

Figure 5.5
Nutrition in Amoeba

5.2.4 Nutrition in Human Beings

The alimentary canal is basically a long tube extending from the mouth to the anus. In Fig. 5.6, we can see that the tube has different parts. Various regions are specialised to perform different functions. What happens to the food once it enters our body? We shall discuss this process here.

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Activity 5.3

- Take 1 mL starch solution (1%) in two test tubes (A and B).
- Add 1 mL saliva to test tube A and leave both test tubes undisturbed for 20-30 minutes.
- Now add a few drops of dilute iodine solution to the test tubes.
- In which test tube do you observe a colour change?
- What does this indicate about the presence or absence of starch in the two test tubes?
- What does this tell us about the action of saliva on starch?

We eat various types of food which has to pass through the same digestive tract. Naturally the food has to be processed to generate particles which are small and of the same texture. This is achieved by crushing the food with our teeth. Since the lining of the canal is soft, the food is also wetted to make its passage smooth. When we eat something we like, our mouth 'waters'. This is actually not only water, but a fluid called saliva secreted by the salivary glands. Another aspect of the food we ingest is its complex nature. If it is to be absorbed from the alimentary canal, it has to be broken into smaller molecules. This is done with the help of biological catalysts called enzymes. The saliva contains an enzyme called salivary amylase that breaks down starch which is a complex molecule to give simple sugar. The food is mixed thoroughly with saliva and moved around the mouth while chewing by the muscular tongue.

It is necessary to move the food in a regulated manner along the digestive tube so that it can be processed properly in each part. The lining of canal has muscles that contract rhythmically in order to push the food forward. These peristaltic movements occur all along the gut.

From the mouth, the food is taken to the stomach through the food-pipe or oesophagus. The stomach is a large organ which expands when food enters it. The muscular walls of the stomach help in mixing the food thoroughly with more digestive juices.

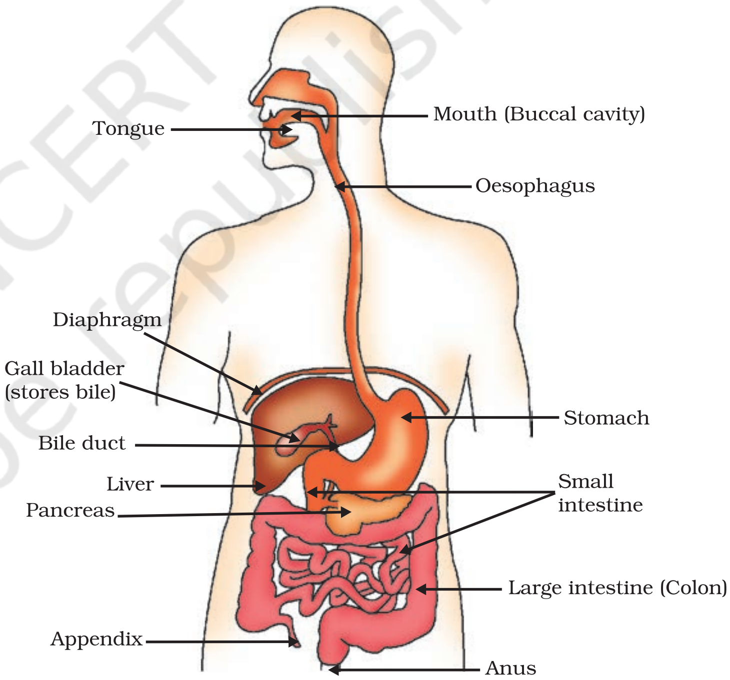

Figure 5.6 *Human alimentary canal*

The digestion in stomach is taken care of by the gastric glands present in the wall of the stomach. These release hydrochloric acid, a protein digesting enzyme called pepsin, and mucus. The hydrochloric acid creates an acidic medium which facilitates the action of the enzyme pepsin. What other function do you think is served by the acid? The mucus protects the inner lining of the stomach from the action of the acid under normal conditions. We have often heard adults complaining about 'acidity'. Can this be related to what has been discussed above?

The exit of food from the stomach is regulated by a sphincter muscle which releases it in small amounts into the small intestine. From the stomach, the food now enters the small intestine. This is the longest part of the alimentary canal which is fitted into a compact space because of extensive coiling. The length of the small intestine differs in various animals depending on the food they eat. Herbivores eating grass need a longer small intestine to allow the cellulose to be digested. Meat is easier to digest, hence carnivores like tigers have a shorter small intestine.

The small intestine is the site of the complete digestion of carbohydrates, proteins and fats. It receives the secretions of the liver and pancreas for this purpose. The food coming from the stomach is acidic and has to be made alkaline for the pancreatic enzymes to act. Bile juice from the liver accomplishes this in addition to acting on fats. Fats are present in the intestine in the form of large globules which makes it difficult for enzymes to act on them. Bile salts break them down into smaller globules increasing the efficiency of enzyme action. This is similar to the emulsifying action of soaps on dirt that we have learnt about in Chapter 4. The pancreas secretes pancreatic juice which contains enzymes like trypsin for digesting proteins and lipase for breaking down emulsified fats. The walls of the small intestine contain glands which secrete intestinal juice. The enzymes present in it finally convert the proteins to amino acids, complex carbohydrates into glucose and fats into fatty acids and glycerol.

Digested food is taken up by the walls of the intestine. The inner lining of the small intestine has numerous finger-like projections called villi which increase the surface area for absorption. The villi are richly supplied with blood vessels which take the absorbed food to each and every cell of the body, where it is utilised for obtaining energy, building up new tissues and the repair of old tissues.

The unabsorbed food is sent into the large intestine where its wall absorb more water from this material. The rest of the material is removed from the body via the anus. The exit of this waste material is regulated by the anal sphincter.

More to Know!

Dental caries

Dental caries or tooth decay causes gradual softening of enamel and dentine. It begins when bacteria acting on sugars produce acids that softens or demineralises the enamel. Masses of bacterial cells together with food particles stick to the teeth to form dental plaque. Saliva cannot reach the tooth surface to neutralise the acid as plaque covers the teeth. Brushing the teeth after eating removes the plaque before the bacteria produce acids. If untreated, microorganisms may invade the pulp, causing inflammation and infection.

QUESTIONS

1. What are the differences between autotrophic nutrition and heterotrophic nutrition?
2. Where do plants get each of the raw materials required for photosynthesis?
3. What is the role of the acid in our stomach?
4. What is the function of digestive enzymes?
5. How is the small intestine designed to absorb digested food?

5.3 RESPIRATION

Activity 5.4

- Take some freshly prepared lime water in a test tube.
- Blow air through this lime water.
- Note how long it takes for the lime water to turn milky.
- Use a syringe or *pichkari* to pass air through some fresh lime water taken in another test tube (Fig. 5.7).
- Note how long it takes for this lime water to turn milky.
- What does this tell us about the amount of carbon dioxide in the air that we breathe out?

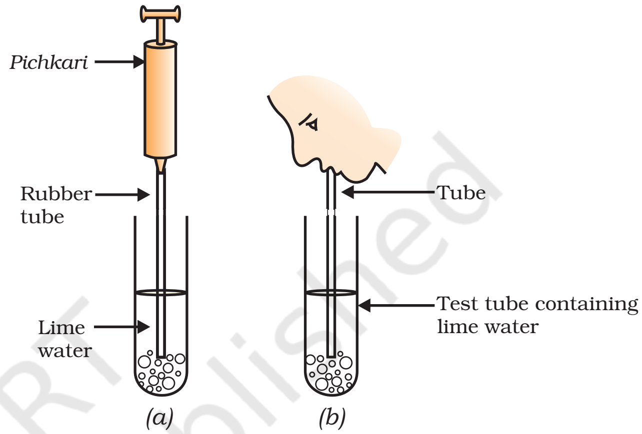

Figure 5.7
(a) Air being passed into lime water with a pichkari/ syringe, (b) air being exhaled into lime water

Activity 5.5

- Take some fruit juice or sugar solution and add some yeast to this. Take this mixture in a test tube fitted with a one-holed cork.
- Fit the cork with a bent glass tube. Dip the free end of the glass tube into a test tube containing freshly prepared lime water.
- What change is observed in the lime water and how long does it take for this change to occur?
- What does this tell us about the products of fermentation?

We have discussed nutrition in organisms in the last section. The food material taken in during the process of nutrition is used in cells to provide energy for various life processes. Diverse organisms do this in different ways – some use oxygen to break-down glucose completely into carbon dioxide and water, some use other pathways that do not involve oxygen (Fig. 5.8). In all cases, the first step is the break-down of glucose, a six-carbon molecule, into a three-carbon molecule called pyruvate. This process takes place in the cytoplasm. Further, the pyruvate may be converted into ethanol and carbon dioxide. This process takes place in yeast during fermentation. Since this process takes place in the absence of air (oxygen), it is called anaerobic respiration. Break-down of pyruvate using oxygen takes place in the mitochondria. This process breaks up the three-carbon pyruvate molecule to give three molecules of carbon dioxide. The other product is water. Since this process takes place in the presence of air (oxygen), it is called aerobic respiration. The release of energy in this aerobic process is a lot greater than in the anaerobic process. Sometimes, when there is a lack of oxygen in our muscle cells, another pathway for the break-down of pyruvate is taken. Here the pyruvate is converted into lactic acid which is also a three-carbon molecule. This build-up of lactic acid in our muscles during sudden activity causes cramps.

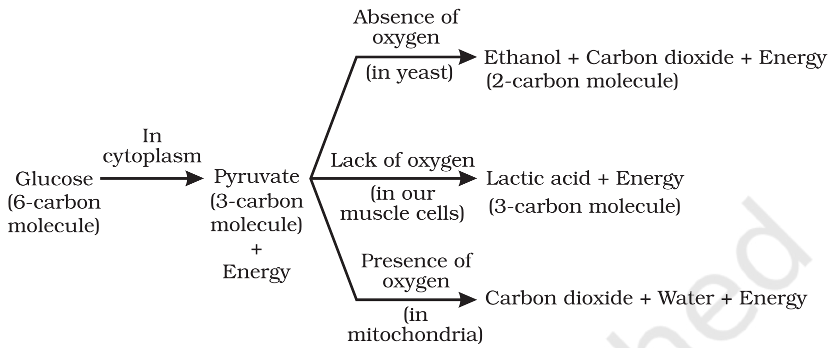

Figure 5.8 *Break-down of glucose by various pathways*

The energy released during cellular respiration is immediately used to synthesise a molecule called ATP which is used to fuel all other activities in the cell. In these processes, ATP is broken down giving rise to a fixed amount of energy which can drive the endothermic reactions taking place in the cell.

More to Know!

ATP

ATP is the energy currency for most cellular processes. The energy released during the process of respiration is used to make an ATP molecule from ADP and inorganic phosphate.

$$ADP + \textcircled{P} \xrightarrow{Energy} ADP \sim \textcircled{P} = ATP$$

$\textcircled{P}$: Phosphate

Endothermic processes in the cell then use this ATP to drive the reactions. When the terminal phosphate linkage in ATP is broken using water, the energy equivalent to 30.5 kJ/mol is released.

Think of how a battery can provide energy for many different kinds of uses. It can be used to obtain mechanical energy, light energy, electrical energy and so on. Similarly, ATP can be used in the cells for the contraction of muscles, protein synthesis, conduction of nervous impulses and many other activities.

Since the aerobic respiration pathway depends on oxygen, aerobic organisms need to ensure that there is sufficient intake of oxygen. We have seen that plants exchange gases through stomata, and the large inter-cellular spaces ensure that all cells are in contact with air. Carbon dioxide and oxygen are exchanged by diffusion here. They can go into cells, or away from them and out into the air. The direction of diffusion depends upon the environmental conditions and the requirements of the plant. At night, when there is no photosynthesis occurring, CO_2 elimination is the major exchange activity going on. During the day, CO_2 generated during respiration is used up for photosynthesis, hence there is no CO_2 release. Instead, oxygen release is the major event at this time.

Animals have evolved different organs for the uptake of oxygen from the environment and for getting rid of the carbon dioxide produced. Terrestrial animals can breathe the oxygen in the atmosphere, but animals that live in water need to use the oxygen dissolved in water.

Activity 5.6

- Observe fish in an aquarium. They open and close their mouths and the gill-slits (or the operculum which covers the gill-slits) behind their eyes also open and close. Are the timings of the opening and closing of the mouth and gill-slits coordinated in some manner?
- Count the number of times the fish opens and closes its mouth in a minute.
- Compare this to the number of times you breathe in and out in a minute.

Since the amount of dissolved oxygen is fairly low compared to the amount of oxygen in the air, the rate of breathing in aquatic organisms is much faster than that seen in terrestrial organisms. Fishes take in water through their mouths and force it past the gills where the dissolved oxygen is taken up by blood.

Terrestrial organisms use the oxygen in the atmosphere for respiration. This oxygen is absorbed by different organs in different animals. All these organs have a structure that increases the surface area which is in contact with the oxygen-rich atmosphere. Since the exchange of oxygen and carbon dioxide has to take place across this surface, this surface is very fine and delicate. In order to protect this surface, it is usually placed within the body, so there have to be passages that will take air to this area. In addition, there is a mechanism for moving the air in and out of this area where the oxygen is absorbed.

In human beings (Fig. 5.9), air is taken into the body through the nostrils. The air passing through the nostrils is filtered by fine hairs that line the passage. The passage is also lined with mucus which helps in this process. From here, the air passes through the throat and into the lungs. Rings of cartilage are present in the throat. These ensure that the air-passage does not collapse.

More to Know!

Using tobacco directly or any product of tobacco in the form of cigar, cigarettes, *bidis*, *hookah*, *gutkha*, etc., is harmful. Use of tobacco most commonly affects the tongue, lungs, heart and liver. Smokeless tobacco is also a major risk factor for heart attacks, strokes, pulmonary diseases and several forms of cancers. There is a high incidence of oral cancer in India due to the chewing of tobacco in the form of *gutkha*. Stay healthy; just say NO to tobacco and its products!

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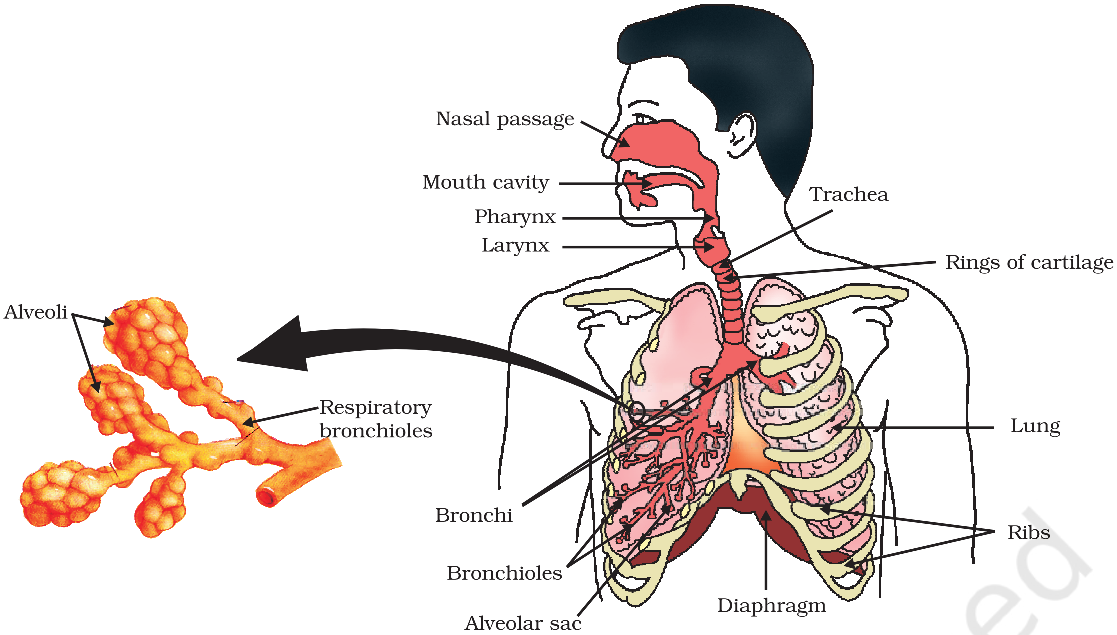


Figure 5.9 *Human respiratory system*

Do You Know?

Smoking is injurious to health.

Lung cancer is one of common causes of deaths in the world. The upper part of respiratory tract is provided with small hair-like structures called cilia. These cilia help to remove germs, dust and other harmful particles from inhaled air. Smoking destroys these hair due to which germs, dust, smoke and other harmful chemicals enter lungs and cause infection, cough and even lung cancer.

Within the lungs, the passage divides into smaller and smaller tubes which finally terminate in balloon-like structures which are called alveoli (singular–alveolus). The alveoli provide a surface where the exchange of gases can take place. The walls of the alveoli contain an extensive network of blood-vessels. As we have seen in earlier years, when we breathe in, we lift our ribs and flatten our diaphragm, and the chest cavity becomes larger as a result. Because of this, air is sucked into the lungs and fills the expanded alveoli. The blood brings carbon dioxide from the rest of the body for release into the alveoli, and the oxygen in the alveolar air is taken up by blood in the alveolar blood vessels to be transported to all the cells in the body. During the breathing cycle, when air is taken in and let out, the lungs always contain a residual volume of air so that there is sufficient time for oxygen to be absorbed and for the carbon dioxide to be released.

When the body size of animals is large, the diffusion pressure alone cannot take care of oxygen delivery to all parts of the body. Instead, respiratory pigments take up oxygen from the air in the lungs and carry it to tissues which are deficient in oxygen before releasing it. In human beings, the respiratory pigment is haemoglobin which has a very high affinity for oxygen. This pigment is present in the red blood corpuscles. Carbon dioxide is more soluble in water than oxygen is and hence is mostly transported in the dissolved form in our blood.

Do You Know?

- If the alveolar surface were spread out, it would cover about 80 m^2. How much do you think the surface area of your body is? Consider how efficient exchange of gases becomes because of the large surface available for the exchange to take place.
- If diffusion were to move oxygen in our body, it is estimated that it would take 3 years for a molecule of oxygen to get to our toes from our lungs. Aren't you glad that we have haemoglobin?

QUESTIONS

1. What advantage over an aquatic organism does a terrestrial organism have with regard to obtaining oxygen for respiration?
2. What are the different ways in which glucose is oxidised to provide energy in various organisms?
3. How is oxygen and carbon dioxide transported in human beings?
4. How are the lungs designed in human beings to maximise the area for exchange of gases?

5.4 TRANSPORTATION

5.4.1 Transportation in Human Beings

Activity 5.7

- Visit a health centre in your locality and find out what is the normal range of haemoglobin content in human beings.
- Is it the same for children and adults?
- Is there any difference in the haemoglobin levels for men and women?
- Visit a veterinary clinic in your locality. Find out what is the normal range of haemoglobin content in an animal like the buffalo or cow.
- Is this content different in calves, male and female animals?
- Compare the difference seen in male and female human beings and animals.
- How would the difference, if any, be explained?

We have seen in previous sections that blood transports food, oxygen and waste materials in our bodies. In Class IX, we learnt about blood being a fluid connective tissue. Blood consists of a fluid medium called plasma in which the cells are suspended. Plasma transports food, carbon dioxide and nitrogenous wastes in dissolved form. Oxygen is carried by the red blood corpuscles. Many other substances like salts, are also transported by the blood. We thus need a pumping organ to push blood around the body, a network of tubes to reach all the tissues and a system in place to ensure that this network can be repaired if damaged.

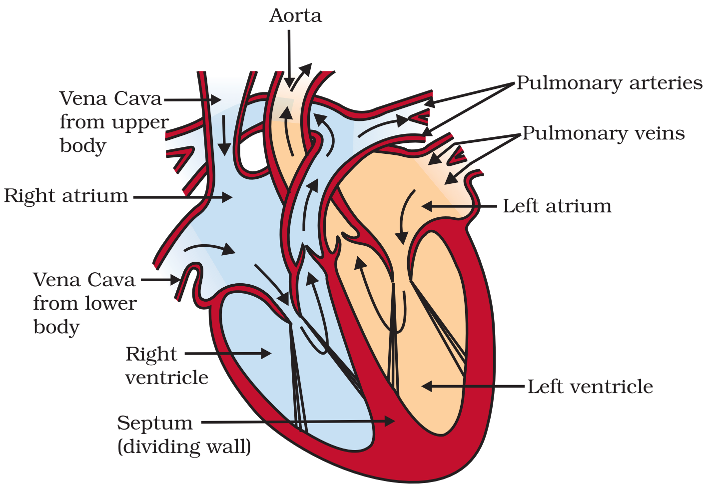


Figure 5.10
Schematic sectional view of the human heart

Our pump — the heart

The heart is a muscular organ which is as big as our fist (Fig. 5.10). Because both oxygen and carbon dioxide have to be transported by the blood, the heart has different chambers to prevent the oxygen-rich blood from mixing with the blood containing carbon dioxide. The carbon dioxide-rich blood has to reach the lungs for the carbon dioxide to be removed, and the oxygenated blood from the lungs has to be brought back to the heart. This oxygen-rich blood is then pumped to the rest of the body.

We can follow this process step by step (Fig. 5.11). Oxygen-rich blood from the lungs comes to the thin-walled upper chamber of the heart on the left, the left atrium. The left atrium relaxes when it is collecting this blood. It then contracts, while the next chamber, the left ventricle, relaxes, so that the blood is transferred to it. When the muscular left ventricle contracts in its turn, the blood is pumped out to the body. De-oxygenated blood comes from the body to the upper chamber on the right, the right atrium, as it relaxes. As the right atrium contracts, the corresponding lower chamber, the right ventricle, dilates. This transfers blood to the right ventricle, which in turn pumps it to the lungs for oxygenation. Since ventricles have to pump blood into various organs, they have thicker muscular walls than the atria do. Valves ensure that blood does not flow backwards when the atria or ventricles contract.

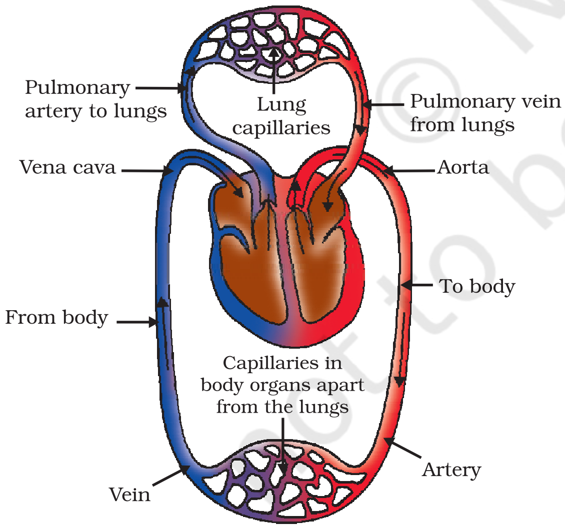


Figure 5.11
Schematic representation of transport and exchange of oxygen and carbon dioxide

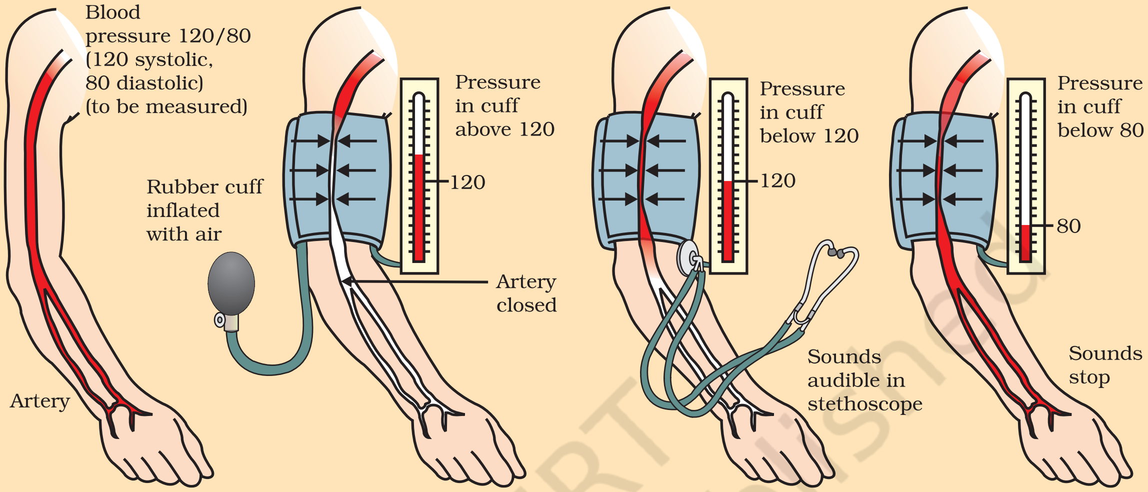
Oxygen enters the blood in the lungs

The separation of the right side and the left side of the heart is useful to keep oxygenated and de-oxygenated blood from mixing. Such separation allows a highly efficient supply of oxygen to the body. This is useful in animals that have high energy needs, such as birds and mammals, which constantly use energy to maintain their body temperature. In animals that do not use energy for this purpose, the body temperature depends on the temperature in the environment. Such animals, like amphibians or many reptiles have three-chambered hearts, and tolerate some mixing of the oxygenated and de-oxygenated blood streams. Fishes, on the other hand, have only two chambers to their hearts, and the blood is pumped to the gills, is oxygenated there, and passes directly to the rest of the body. Thus, blood goes only once through the heart in the fish during one cycle of passage through the body. On the other hand, it goes through the heart twice during each cycle in other vertebrates. This is known as double circulation.

More to Know!

Blood pressure

The force that blood exerts against the wall of a vessel is called blood pressure. This pressure is much greater in arteries than in veins. The pressure of blood inside the artery during ventricular systole (contraction) is called systolic pressure and pressure in artery during ventricular diastole (relaxation) is called diastolic pressure. The normal systolic pressure is about 120 mm of Hg and diastolic pressure is 80 mm of Hg.



Blood pressure is measured with an instrument called sphygmomanometer. High blood pressure is also called hypertension and is caused by the constriction of arterioles, which results in increased resistance to blood flow. It can lead to the rupture of an artery and internal bleeding.

The tubes – blood vessels

Arteries are the vessels which carry blood away from the heart to various organs of the body. Since the blood emerges from the heart under high pressure, the arteries have thick, elastic walls. Veins collect the blood from different organs and bring it back to the heart. They do not need thick walls because the blood is no longer under pressure, instead they have valves that ensure that the blood flows only in one direction.

On reaching an organ or tissue, the artery divides into smaller and smaller vessels to bring the blood in contact with all the individual cells. The smallest vessels have walls which are one-cell thick and are called capillaries. Exchange of material between the blood and surrounding cells takes place across this thin wall. The capillaries then join together to form veins that convey the blood away from the organ or tissue.

Maintenance by platelets

What happens if this system of tubes develops a leak? Think about situations when we are injured and start bleeding. Naturally the loss of blood from the system has to be minimised. In addition, leakage would lead to a loss of pressure which would reduce the efficiency of the

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pumping system. To avoid this, the blood has platelet cells which circulate around the body and plug these leaks by helping to clot the blood at these points of injury.

Lymph

There is another type of fluid also involved in transportation. This is called lymph or tissue fluid. Through the pores present in the walls of capillaries some amount of plasma, proteins and blood cells escape into intercellular spaces in the tissues to form the tissue fluid or lymph. It is similar to the plasma of blood but colourless and contains less protein. Lymph drains into lymphatic capillaries from the intercellular spaces, which join to form large lymph vessels that finally open into larger veins. Lymph carries digested and absorbed fat from intestine and drains excess fluid from extra cellular space back into the blood.

5.4.2 Transportation in Plants

We have discussed earlier how plants take in simple compounds such as CO_2 and photosynthesise energy stored in their chlorophyll-containing organs, namely leaves. The other kinds of raw materials needed for building plant bodies will also have to be taken up separately. For plants, the soil is the nearest and richest source of raw materials like nitrogen, phosphorus and other minerals. The absorption of these substances therefore occurs through the part in contact with the soil, namely roots. If the distances between soil-contacting organs and chlorophyll-containing organs are small, energy and raw materials can easily diffuse to all parts of the plant body. But if these distances become large because of changes in plant body design, diffusion processes will not be sufficient to provide raw material in leaves and energy in roots. A proper system of transportation is therefore essential in such situations.

Energy needs differ between different body designs. Plants do not move, and plant bodies have a large proportion of dead cells in many tissues. As a result, plants have low energy needs, and can use relatively slow transport systems. The distances over which transport systems have to operate, however, can be very large in plants such as very tall trees.

Plant transport systems will move energy stores from leaves and raw materials from roots. These two pathways are constructed as independently organised conducting tubes. One, the xylem moves water and minerals obtained from the soil. The other, phloem transports products of photosynthesis from the leaves where they are synthesised to other parts of the plant. We have studied the structure of these tissues in detail in Class IX.

Transport of water

In xylem tissue, vessels and tracheids of the roots, stems and leaves are interconnected to form a continuous system of water-conducting channels reaching all parts of the plant. At the roots, cells in contact with the soil actively take up ions. This creates a difference in the concentration of these ions between the root and the soil. Water, therefore, moves into the root from the soil to eliminate this difference. This means that there is steady movement of water into root xylem, creating a column of water that is steadily pushed upwards.

However, this pressure by itself is unlikely to be enough to move water over the heights that we commonly see in plants. Plants use another strategy to move water in the xylem upwards to the highest points of the plant body.

Activity 5.8

- Take two small pots of approximately the same size and having the same amount of soil. One should have a plant in it. Place a stick of the same height as the plant in the other pot.
- Cover the soil in both pots with a plastic sheet so that moisture cannot escape by evaporation.
- Cover both sets, one with the plant and the other with the stick, with plastic sheets and place in bright sunlight for half an hour.
- Do you observe any difference in the two cases?

Provided that the plant has an adequate supply of water, the water which is lost through the stomata is replaced by water from the xylem vessels in the leaf. In fact, evaporation of water molecules from the cells of a leaf creates a suction which pulls water from the xylem cells of roots. The loss of water in the form of vapour from the aerial parts of the plant is known as transpiration.

Thus, transpiration helps in the absorption and upward movement of water and minerals dissolved in it from roots to the leaves. It also helps in temperature regulation. The effect of root pressure in transport of water is more important at night. During the day when the stomata are open, the transpiration pull becomes the major driving force in the movement of water in the xylem.

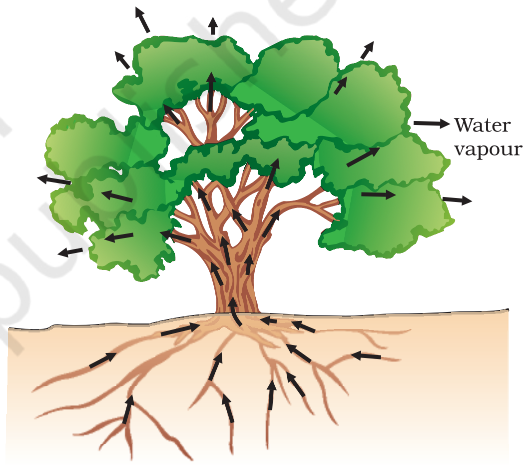


Figure 5.12
Movement of water during transpiration in a tree

Transport of food and other substances

So far we have discussed the transport of water and minerals in plants. Now let us consider how the products of metabolic processes, particularly photosynthesis, are moved from leaves, where they are formed, to other parts of the plant. This transport of soluble products of photosynthesis is called translocation and it occurs in the part of the vascular tissue known as phloem. Besides the products of photosynthesis, the phloem transports amino acids and other substances. These substances are especially delivered to the storage organs of roots, fruits and seeds and to growing organs. The translocation of food and other substances takes place in the sieve tubes with the help of adjacent companion cells both in upward and downward directions.

Unlike transport in xylem which can be largely explained by simple physical forces, the translocation in phloem is achieved by utilising energy. Material like sucrose is transferred into phloem tissue using energy from ATP. This increases the osmotic pressure of the tissue causing water to move into it. This pressure moves the material in the phloem to tissues which have less pressure. This allows the phloem to move material according to the plant's needs. For example, in the spring, sugar stored in root or stem tissue would be transported to the buds which need energy to grow.

QUESTIONS

1. What are the components of the transport system in human beings? What are the functions of these components?
2. Why is it necessary to separate oxygenated and deoxygenated blood in mammals and birds?
3. What are the components of the transport system in highly organised plants?
4. How are water and minerals transported in plants?
5. How is food transported in plants?

5.5 EXCRETION

We have already discussed how organisms get rid of gaseous wastes generated during photosynthesis or respiration. Other metabolic activities generate nitrogenous materials which need to be removed. The biological process involved in the removal of these harmful metabolic wastes from the body is called excretion. Different organisms use varied strategies to do this. Many unicellular organisms remove these wastes by simple diffusion from the body surface into the surrounding water. As we have seen in other processes, complex multi-cellular organisms use specialised organs to perform the same function.

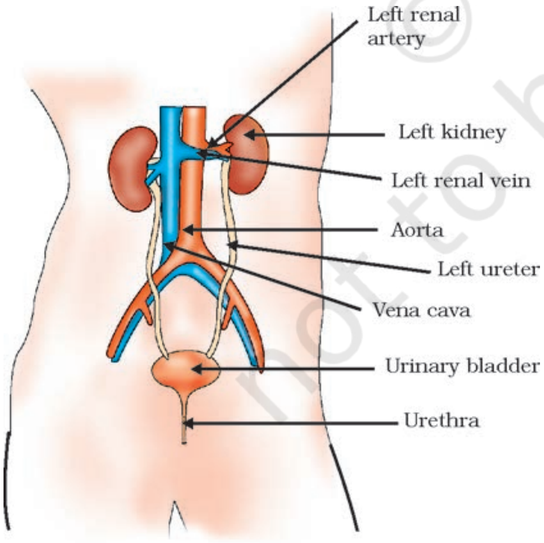


Figure 5.13
Excretory system in human beings

5.5.1 Excretion in Human Beings

The excretory system of human beings (Fig. 5.13) includes a pair of kidneys, a pair of ureters, a urinary bladder and a urethra. Kidneys are located in the abdomen, one on either side of the backbone. Urine produced in the kidneys passes through the ureters into the urinary bladder where it is stored until it is released through the urethra.

How is urine produced? The purpose of making urine is to filter out waste products from the blood. Just as CO_2 is removed from the blood in the lungs, nitrogenous waste such as urea or uric acid are removed from blood in the kidneys. It is then no surprise that the basic filtration unit in the kidneys, like in the lungs, is a cluster of very thin-walled blood capillaries. Each capillary cluster in the kidney is associated with the cup-shaped end of a coiled tube called Bowman's capsule that collects the filtrate (Fig. 5.14). Each kidney has large numbers of these filtration units called nephrons packed close together. Some substances in the initial filtrate, such as glucose, amino acids, salts and a major amount of water, are selectively re-absorbed as the urine flows along the tube. The amount of water re-absorbed depends on how much excess water there is in the body, and on how much of dissolved waste there is to be excreted. The urine forming in each kidney eventually enters a long tube, the ureter, which connects the kidneys with the urinary bladder. Urine is stored in the urinary bladder until the pressure of the expanded bladder leads to the urge to pass it out through the urethra. The bladder is muscular, so it is under nervous control, as we have discussed elsewhere. As a result, we can usually control the urge to urinate.

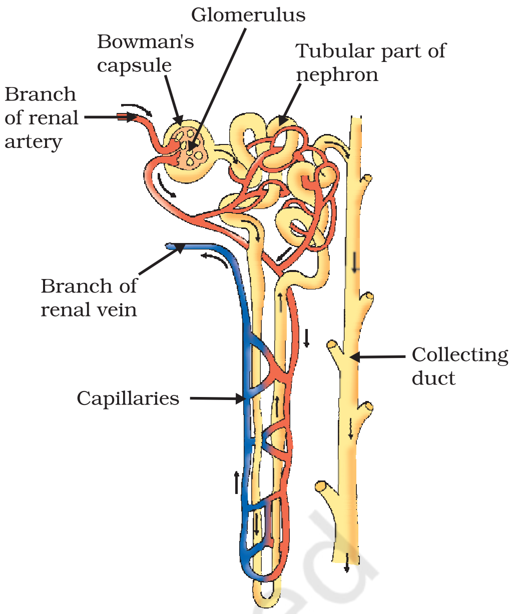


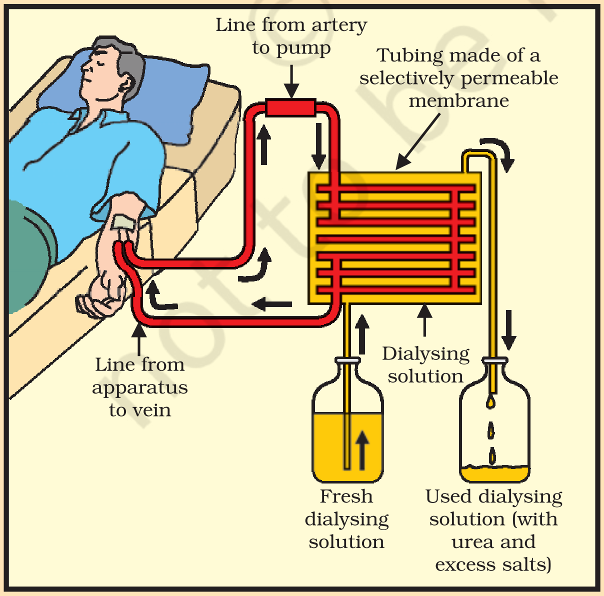
Figure 5.14
Structure of a nephron

More to Know!

Artificial kidney (Hemodialysis)

Kidneys are vital organs for survival. Several factors like infections, injury or restricted blood flow to kidneys reduce the activity of kidneys. This leads to accumulation of poisonous wastes in the body, which can even lead to death. In case of kidney failure, an artificial kidney can be used. An artificial kidney is a device to remove nitrogenous waste products from the blood through *dialysis.*

Artificial kidneys contain a number of tubes with a semi-permeable lining, suspended in a tank filled with dialysing fluid. This fluid has the same osmotic pressure as blood, except that it is devoid of nitrogenous wastes. The patient's blood is passed through these tubes. During this passage, the waste products from the blood pass into dialysing fluid by diffusion. The purified blood is pumped back into the patient. This is similar to the function of the kidney, but it is different since there is no re-absorption involved. Normally, in a healthy adult, the initial filtrate in the kidneys is about 180 L daily. However, the volume actually excreted is only a litre or two a day, because the remaining filtrate is re-absorbed in the kidney tubules.



Think it over!

Organ donation

Organ donation is a generous act of donating an organ to a person who suffers from non-function of organ(s). Donation of an organ may be done by the consent of the donor and his/her family. Anyone regardless of age or gender can become an organ and tissue donor. Organ transplants can save or transform the life of a person. Transplantation is required because recipient's organ has been damaged or has failed by disease or injury. In organ transplantation the organ is surgically removed from one person (organ donor) and transplanted to another person (the recipient). Common transplantations include corneas, kidneys, heart, liver, pancreas, lungs, intestines and bone marrow. Most organ and tissue donations occur just after the donor has died or when the doctor declares a person brain dead. But some organs such as kidney, part of a liver, lung, etc., and tissues can be donated while the donor is alive.

5.5.2 Excretion in Plants

Plants use completely different strategies for excretion than those of animals. Oxygen itself can be thought of as a waste product generated during photosynthesis! We have discussed earlier how plants deal with oxygen as well as CO_2. They can get rid of excess water by transpiration. For other wastes, plants use the fact that many of their tissues consist of dead cells, and that they can even lose some parts such as leaves. Many plant waste products are stored in cellular vacuoles. Waste products may be stored in leaves that fall off. Other waste products are stored as resins and gums, especially in old xylem. Plants also excrete some waste substances into the soil around them.

QUESTIONS

1. Describe the structure and functioning of nephrons.
2. What are the methods used by plants to get rid of excretory products?
3. How is the amount of urine produced regulated?

What you have learnt

- Movement of various types can be taken as an indication of life.
- Maintenance of life requires processes like nutrition, respiration, transport of materials within the body and excretion of waste products.
- Autotrophic nutrition involves the intake of simple inorganic materials from the environment and using an external energy source like the Sun to synthesise complex high-energy organic material.
- Heterotrophic nutrition involves the intake of complex material prepared by other organisms.
- In human beings, the food eaten is broken down by various steps along the alimentary canal and the digested food is absorbed in the small intestine to be sent to all cells in the body.

- During the process of respiration, organic compounds such as glucose are broken down to provide energy in the form of ATP. ATP is used to provide energy for other reactions in the cell.
- Respiration may be aerobic or anaerobic. Aerobic respiration makes more energy available to the organism.
- In human beings, the transport of materials such as oxygen, carbon dioxide, food and excretory products is a function of the circulatory system. The circulatory system consists of the heart, blood and blood vessels.
- In highly differentiated plants, transport of water, minerals, food and other materials is a function of the vascular tissue which consists of xylem and phloem.
- In human beings, excretory products in the form of soluble nitrogen compounds are removed by the nephrons in the kidneys.
- Plants use a variety of techniques to get rid of waste material. For example, waste material may be stored in the cell-vacuoles or as gum and resin, removed in the falling leaves, or excreted into the surrounding soil.

EXERCISES

1. The kidneys in human beings are a part of the system for
   (a) nutrition. (c) excretion.
   (b) respiration. (d) transportation.
2. The xylem in plants are responsible for
   (a) transport of water. (c) transport of amino acids.
   (b) transport of food. (d) transport of oxygen.
3. The autotrophic mode of nutrition requires
   (a) carbon dioxide and water. (c) sunlight.
   (b) chlorophyll. (d) all of the above.
4. The breakdown of pyruvate to give carbon dioxide, water and energy takes place in
   (a) cytoplasm. (c) chloroplast.
   (b) mitochondria. (d) nucleus.
5. How are fats digested in our bodies? Where does this process take place?
6. What is the role of saliva in the digestion of food?
7. What are the necessary conditions for autotrophic nutrition and what are its by-products?
8. What are the differences between aerobic and anaerobic respiration? Name some organisms that use the anaerobic mode of respiration.
9. How are the alveoli designed to maximise the exchange of gases?
10. What would be the consequences of a deficiency of haemoglobin in our bodies?
11. Describe double circulation of blood in human beings. Why is it necessary?
12. What are the differences between the transport of materials in xylem and phloem?
13. Compare the functioning of alveoli in the lungs and nephrons in the kidneys with respect to their structure and functioning.

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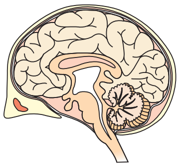


CHAPTER 6
Control and Coordination

In the previous chapter, we looked at life processes involved in the maintenance functions in living organisms. There, we had started with a notion we all have, that if we see something moving, it is alive. Some of these movements are in fact the result of growth, as in plants. A seed germinates and grows, and we can see that the seedling moves over the course of a few days, it pushes soil aside and comes out. But if its growth were to be stopped, these movements would not happen. Some movements, as in many animals and some plants, are not connected with growth. A cat running, children playing on swings, buffaloes chewing cud – these are not movements caused by growth.

Why do we associate such visible movements with life? A possible answer is that we think of movement as a response to a change in the environment of the organism. The cat may be running because it has seen a mouse. Not only that, we also think of movement as an attempt by living organisms to use changes in their environment to their advantage. Plants grow out into the sunshine. Children try to get pleasure and fun out of swinging. Buffaloes chew cud to help break up tough food so as to be able to digest it better. When bright light is focussed on our eyes or when we touch a hot object, we detect the change and respond to it with movement in order to protect ourselves.

If we think a bit more about this, it becomes apparent that all this movement, in response to the environment, is carefully controlled. Each kind of a change in the environment evokes an appropriate movement in response. When we want to talk to our friends in class, we whisper, rather than shouting loudly. Clearly, the movement to be made depends on the event that is triggering it. Therefore, such controlled movement must be connected to the recognition of various events in the environment, followed by only the correct movement in response. In other words, living organisms must use systems providing control and coordination. In keeping with the general principles of body organisation in multicellular organisms, specialised tissues are used to provide these control and coordination activities.

6.1 ANIMALS – NERVOUS SYSTEM

In animals, such control and coordination are provided by nervous and muscular tissues, which we have studied in Class IX. Touching a hot object is an urgent and dangerous situation for us. We need to detect it, and respond to it. How do we detect that we are touching a hot object? All information from our environment is detected by the specialised tips of some nerve cells. These receptors are usually located in our sense organs, such as the inner ear, the nose, the tongue, and so on. So gustatory receptors will detect taste while olfactory receptors will detect smell.

This information, acquired at the end of the dendritic tip of a nerve cell [Fig. 6.1 (a)], sets off a chemical reaction that creates an electrical impulse. This impulse travels from the dendrite to the cell body, and then along the axon to its end. At the end of the axon, the electrical impulse sets off the release of some chemicals. These chemicals cross the gap, or synapse, and start a similar electrical impulse in a dendrite of the next neuron. This is a general scheme of how nervous impulses travel in the body. A similar synapse finally allows delivery of such impulses from neurons to other cells, such as muscles cells or gland [Fig. 6.1 (b)].

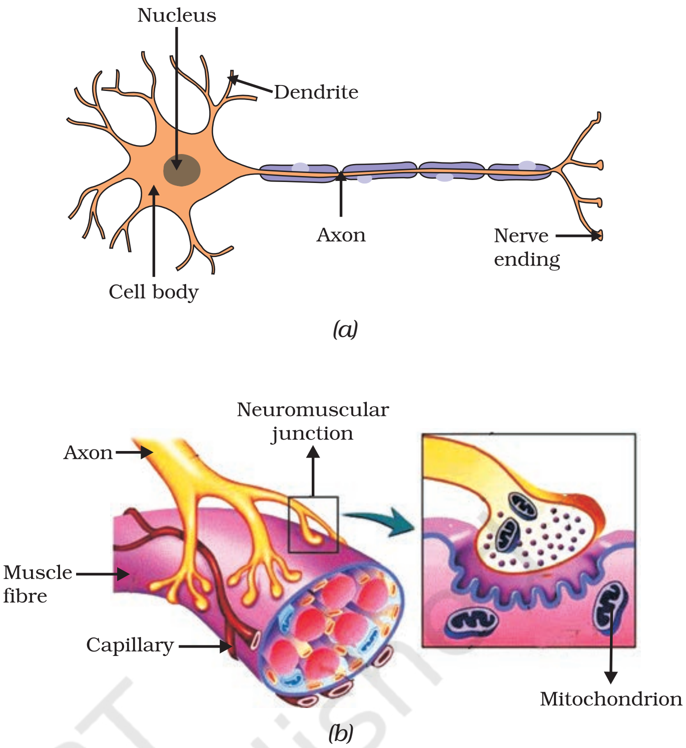


Figure 6.1 *(a) Structure of neuron, (b) Neuromuscular junction*

It is thus no surprise that nervous tissue is made up of an organised network of nerve cells or neurons, and is specialised for conducting information via electrical impulses from one part of the body to another.

Look at Fig. 6.1 (a) and identify the parts of a neuron (i) where information is acquired, (ii) through which information travels as an electrical impulse, and (iii) where this impulse must be converted into a chemical signal for onward transmission.

Activity 6.1

- Put some sugar in your mouth. How does it taste?
- Block your nose by pressing it between your thumb and index finger. Now eat sugar again. Is there any difference in its taste?
- While eating lunch, block your nose in the same way and notice if you can fully appreciate the taste of the food you are eating.

Is there a difference in how sugar and food taste if your nose is blocked? If so, why might this be happening? Read and talk about possible explanations for these kinds of differences. Do you come across a similar situation when you have a cold?

6.1.1 What happens in Reflex Actions?

'Reflex' is a word we use very commonly when we talk about some sudden action in response to something in the environment. We say 'I jumped out of the way of the bus reflexly', or 'I pulled my hand back from the flame reflexly', or 'I was so hungry my mouth started watering reflexly'. What exactly do we mean? A common idea in all such examples is that we do something without thinking about it, or without feeling in control of our reactions. Yet these are situations where we are responding with some action to changes in our environment. How is control and coordination achieved in such situations?

Let us consider this further. Take one of our examples. Touching a flame is an urgent and dangerous situation for us, or in fact, for any animal! How would we respond to this? One seemingly simple way is to think consciously about the pain and the possibility of getting burnt, and therefore move our hand. An important question then is, how long will it take us to think all this? The answer depends on how we think. If nerve impulses are sent around the way we have talked about earlier, then thinking is also likely to involve the creation of such impulses. Thinking is a complex activity, so it is bound to involve a complicated interaction of many nerve impulses from many neurons.

If this is the case, it is no surprise that the thinking tissue in our body consists of dense networks of intricately arranged neurons. It sits in the forward end of the skull, and receives signals from all over the body which it thinks about before responding to them. Obviously, in order to receive these signals, this thinking part of the brain in the skull must be connected to nerves coming from various parts of the body. Similarly, if this part of the brain is to instruct muscles to move, nerves must carry this signal back to different parts of the body. If all of this is to be done when we touch a hot object, it may take enough time for us to get burnt!

How does the design of the body solve this problem? Rather than having to think about the sensation of heat, if the nerves that detect heat were to be connected to the nerves that move muscles in a simpler way, the process of detecting the signal or the input and responding to it by an output action might be completed quickly. Such a connection is commonly called a reflex arc (Fig. 6.2). Where should such reflex arc connections be made between the input nerve and the output nerve? The best place, of course, would be at the point where they first meet each other. Nerves from all over the body meet in a bundle in the spinal cord on their way to the brain. Reflex arcs are formed in this spinal cord itself, although the information input also goes on to reach the brain.

Of course, reflex arcs have evolved in animals because the thinking process of the brain is not fast enough. In fact many animals have very little or none of the complex neuron network needed for thinking. So it is quite likely that reflex arcs have evolved as efficient ways of functioning in the absence of true thought processes. However, even after complex neuron networks have come into existence, reflex arcs continue to be more efficient for quick responses.

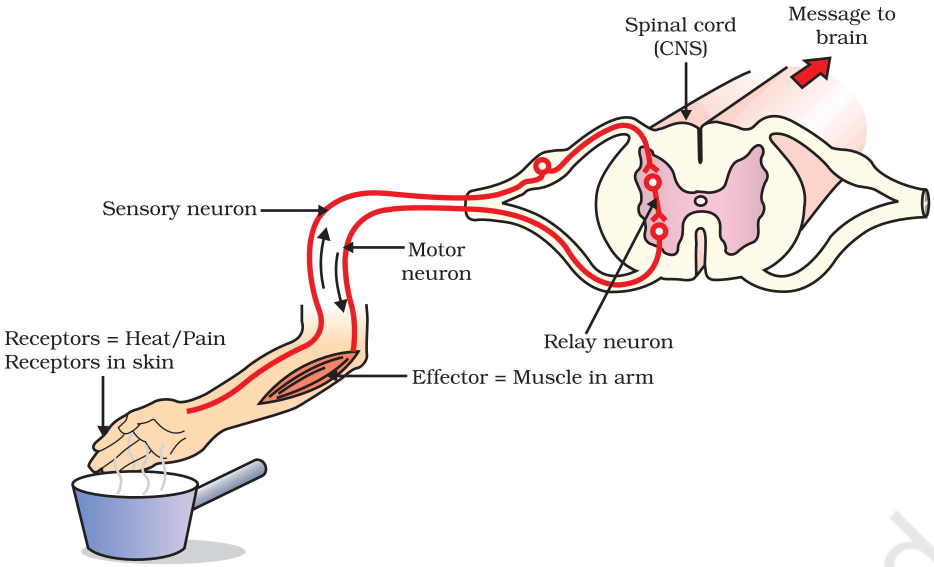


Figure 6.2 *Reflex arc*

Can you now trace the sequence of events which occur when a bright light is focussed on your eyes?

6.1.2 Human Brain

Is reflex action the only function of the spinal cord? Obviously not, since we know that we are thinking beings. Spinal cord is made up of nerves which supply information to think about. Thinking involves more complex mechanisms and neural connections. These are concentrated in the brain, which is the main coordinating centre of the body. The brain and spinal cord constitute the central nervous system (Fig. 6.3). They receive information from all parts of the body and integrate it.

We also think about our actions. Writing, talking, moving a chair, clapping at the end of a programme are examples of voluntary actions which are based on deciding what to do next. So, the brain also has to send messages to muscles. This is the second way in which the nervous system communicates with the muscles. The communication between the central nervous system and the other parts of the body is facilitated by the peripheral nervous system consisting of cranial nerves arising from the brain and spinal nerves arising from the spinal cord. The brain thus allows us to think and take actions based on that thinking. As you will expect, this is accomplished through a complex design, with different parts of the brain responsible for integrating different inputs and outputs. The brain has three such major parts or regions, namely the fore-brain, mid-brain and hind-brain.

The fore-brain is the main thinking part of the brain. It has regions which receive sensory impulses from various receptors. Separate areas of the fore-brain are specialised for hearing, smell, sight and so on. There are separate areas of association where this sensory information is interpreted by putting it together with information from other receptors as well as with information that is already stored in the brain. Based on all this, a decision is made about how to respond and the information is passed on to the motor areas which control the movement of voluntary muscles, for example, our leg muscles. However, certain sensations are distinct from seeing or hearing, for example, how do we know that we have eaten enough? The sensation of feeling full is because of a centre associated with hunger, which is in a separate part of the fore-brain.

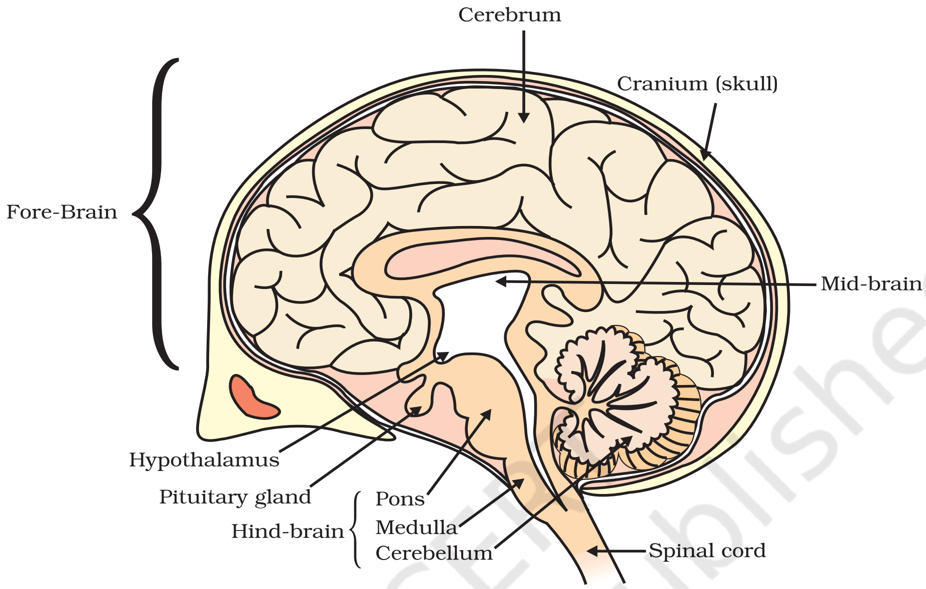


Figure 6.3 *Human brain*

Study the labelled diagram of the human brain. We have seen that the different parts have specific functions. Can we find out the function of each part?

Let us look at the other use of the word 'reflex' that we have talked about in the introduction. Our mouth waters when we see food we like without our meaning to. Our hearts beat without our thinking about it. In fact, we cannot control these actions easily by thinking about them even if we wanted to. Do we have to think about or remember to breathe or digest food? So, in between the simple reflex actions like change in the size of the pupil, and the thought out actions such as moving a chair, there is another set of muscle movements over which we do not have any thinking control. Many of these involuntary actions are controlled by the mid-brain and hind-brain. All these involuntary actions including blood pressure, salivation and vomiting are controlled by the medulla in the hind-brain.

Think about activities like walking in a straight line, riding a bicycle, picking up a pencil. These are possible due to a part of the hind-brain called the cerebellum. It is responsible for precision of voluntary actions and maintaining the posture and balance of the body. Imagine what would happen if each of these events failed to take place if we were not thinking about it.

6.1.3 How are these Tissues protected?

A delicate organ like the brain, which is so important for a variety of activities, needs to be carefully protected. For this, the body is designed so that the brain sits inside a bony box. Inside the box, the brain is contained in a fluid-filled balloon which provides further shock absorption. If you run your hand down the middle of your back, you will feel a hard, bumpy structure. This is the vertebral column or backbone which protects the spinal cord.

6.1.4 How does the Nervous Tissue cause Action?

So far, we have been talking about nervous tissue, and how it collects information, sends it around the body, processes information, makes decisions based on information, and conveys decisions to muscles for action. In other words, when the action or movement is to be performed, muscle tissue will do the final job. How do animal muscles move? When a nerve impulse reaches the muscle, the muscle fibre must move. How does a muscle cell move? The simplest notion of movement at the cellular level is that muscle cells will move by changing their shape so that they shorten. So the next question is, how do muscle cells change their shape? The answer must lie in the chemistry of cellular components. Muscle cells have special proteins that change both their shape and their arrangement in the cell in response to nervous electrical impulses. When this happens, new arrangements of these proteins give the muscle cells a shorter form. Remember when we talked about muscle tissue in Class IX, there were different kinds of muscles, such as voluntary muscles and involuntary muscles. Based on what we have discussed so far, what do you think the differences between these would be?

QUESTIONS

1. What is the difference between a reflex action and walking?
2. What happens at the synapse between two neurons?
3. Which part of the brain maintains posture and equilibrium of the body?
4. How do we detect the smell of an *agarbatti* (incense stick)?
5. What is the role of the brain in reflex action?

6.2 COORDINATION IN PLANTS

Animals have a nervous system for controlling and coordinating the activities of the body. But plants have neither a nervous system nor muscles. So, how do they respond to stimuli? When we touch the leaves of a *chhui-mui* (the 'sensitive' or 'touch-me-not' plant of the Mimosa family), they begin to fold up and droop. When a seed germinates, the root goes down, the stem comes up into the air. What happens? Firstly, the leaves of the sensitive plant move very quickly in response to touch.

There is no growth involved in this movement. On the other hand, the directional movement of a seedling is caused by growth. If it is prevented from growing, it will not show any movement. So plants show two different types of movement – one dependent on growth and the other independent of growth.

6.2.1 Immediate Response to Stimulus

Let us think about the first kind of movement, such as that of the sensitive plant. Since no growth is involved, the plant must actually move its leaves in response to touch. But there is no nervous tissue, nor any muscle tissue. How does the plant detect the touch, and how do the leaves move in response?

Figure 6.4 *The sensitive plant*

If we think about where exactly the plant is touched, and what part of the plant actually moves, it is apparent that movement happens at a point different from the point of touch. So, information that a touch has occurred must be communicated. The plants also use electrical-chemical means to convey this information from cell to cell, but unlike in animals, there is no specialised tissue in plants for the conduction of information. Finally, again as in animals, some cells must change shape in order for movement to happen. Instead of the specialised proteins found in animal muscle cells, plant cells change shape by changing the amount of water in them, resulting in swelling or shrinking, and therefore in changing shapes (Fig. 6.4).

6.2.2 Movement Due to Growth

Some plants like the pea plant climb up other plants or fences by means of tendrils. These tendrils are sensitive to touch. When they come in contact with any support, the part of the tendril in contact with the object does not grow as rapidly as the part of the tendril away from the object. This causes the tendril to circle around the object and thus cling to it. More commonly, plants respond to stimuli slowly by growing in a particular direction. Because this growth is directional, it appears as if the plant is moving. Let us understand this type of movement with the help of an example.

Activity 6.2

- Fill a conical flask with water.
- Cover the neck of the flask with a wire mesh.
- Keep two or three freshly germinated bean seeds on the wire mesh.
- Take a cardboard box which is open from one side.
- Keep the flask in the box in such a manner that the open side of the box faces light coming from a window (Fig. 6.5).
- After two or three days, you will notice that the shoots bend towards light and roots away from light.
- Now turn the flask so that the shoots are away from light and the roots towards light. Leave it undisturbed in this condition for a few days.
- Have the old parts of the shoot and root changed direction?
- Are there differences in the direction of the new growth?
- What can we conclude from this activity?

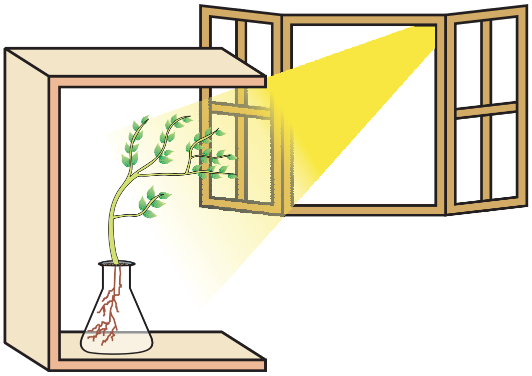


Figure 6.5
Response of the plant to the direction of light

Environmental triggers such as light, or gravity will change the directions that plant parts grow in. These directional, or tropic, movements can be either towards the stimulus, or away from it. So, in two different kinds of phototropic movement, shoots respond by bending towards light while roots respond by bending away from it. How does this help the plant?

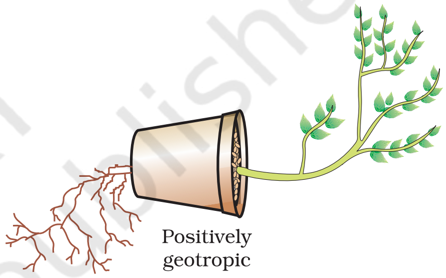


Figure 6.6 *Plant showing geotropism*

Plants show tropism in response to other stimuli as well. The roots of a plant always grow downwards while the shoots usually grow upwards and away from the earth. This upward and downward growth of shoots and roots, respectively, in response to the pull of earth or gravity is, obviously, geotropism (Fig. 6.6). If 'hydro' means water and 'chemo' refers to chemicals, what would 'hydrotropism' and 'chemotropism' mean? Can we think of examples of these kinds of directional growth movements? One example of chemotropism is the growth of pollen tubes towards ovules, about which we will learn more when we examine the reproductive processes of living organisms.

Let us now once again think about how information is communicated in the bodies of multicellular organisms. The movement of the sensitive plant in response to touch is very quick. The movement of sunflowers in response to day or night, on the other hand, is quite slow. Growth-related movement of plants will be even slower.

Even in animal bodies, there are carefully controlled directions to growth. Our arms and fingers grow in certain directions, not haphazardly. So controlled movements can be either slow or fast. If fast responses to stimuli are to be made, information transfer must happen very quickly. For this, the medium of transmission must be able to move rapidly.

Electrical impulses are an excellent means for this. But there are limitations to the use of electrical impulses. Firstly, they will reach only those cells that are connected by nervous tissue, not each and every cell in the animal body. Secondly, once an electrical impulse is generated in a cell and transmitted, the cell will take some time to reset its mechanisms before it can generate and transmit a new impulse. In other words, cells cannot continually create and transmit electrical impulses. It is thus no wonder that most multicellular organisms use another means of communication between cells, namely, chemical communication.

If, instead of generating an electrical impulse, stimulated cells release a chemical compound, this compound would diffuse all around the original cell. If other cells around have the means to detect this compound using special molecules on their surfaces, then they would be able to recognise information, and even transmit it. This will be slower, of course, but it can potentially reach all cells of the body, regardless of nervous connections, and it can be done steadily and persistently. These compounds, or hormones used by multicellular organisms for control and coordination show a great deal of diversity, as we would expect. Different plant hormones help to coordinate growth, development and responses to the environment. They are synthesised at places away from where they act and simply diffuse to the area of action.

Let us take an example that we have worked with earlier [Activity 6.2]. When growing plants detect light, a hormone called auxin, synthesised at the shoot tip, helps the cells to grow longer. When light is coming from one side of the plant, auxin diffuses towards the shady side of the shoot. This concentration of auxin stimulates the cells to grow longer on the side of the shoot which is away from light. Thus, the plant appears to bend towards light.

Another example of plant hormones are gibberellins which, like auxins, help in the growth of the stem. Cytokinins promote cell division, and it is natural then that they are present in greater concentration in areas of rapid cell division, such as in fruits and seeds. These are examples of plant hormones that help in promoting growth. But plants also need signals to stop growing. Abscisic acid is one example of a hormone which inhibits growth. Its effects include wilting of leaves.

QUESTIONS

1. What are plant hormones?
2. How is the movement of leaves of the sensitive plant different from the movement of a shoot towards light?
3. Give an example of a plant hormone that promotes growth.
4. How do auxins promote the growth of a tendril around a support?
5. Design an experiment to demonstrate hydrotropism.

6.3 HORMONES IN ANIMALS

How are such chemical, or hormonal, means of information transmission used in animals? What do some animals, for instance squirrels, experience when they are in a scary situation? Their bodies have to prepare for either fighting or running away. Both are very complicated activities that will use a great deal of energy in controlled ways. Many different tissue types will be used and their activities integrated together in these actions. However, the two alternate activities, fighting or running, are also quite different! So here is a situation in which some common preparations can be usefully made in the body. These preparations should ideally make it easier to do either activity in the near future. How would this be achieved?

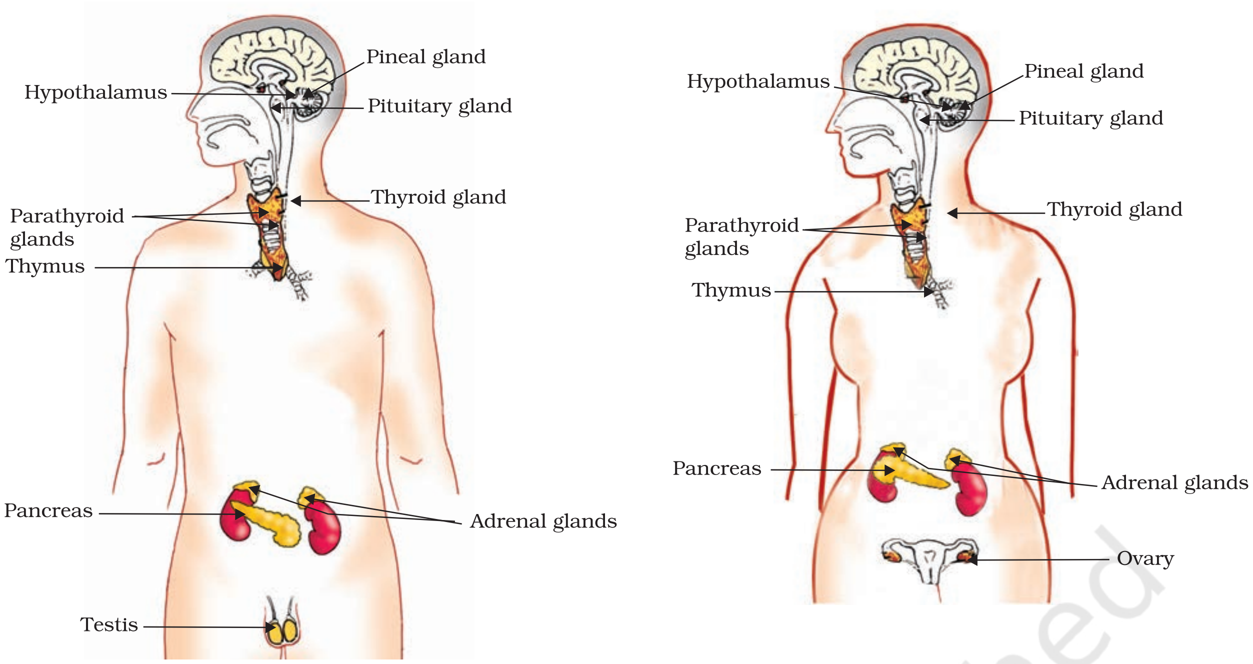
If the body design in the squirrel relied only on electrical impulses via nerve cells, the range of tissues instructed to prepare for the coming activity would be limited. On the other hand, if a chemical signal were to be sent as well, it would reach all cells of the body and provide the wide-ranging changes needed. This is done in many animals, including human beings, using a hormone called adrenaline that is secreted from the adrenal glands. Look at Fig. 6.7 to locate these glands.

Adrenaline is secreted directly into the blood and carried to different parts of the body. The target organs or the specific tissues on which it acts include the heart. As a result, the heart beats faster, resulting in supply of more oxygen to our muscles. The blood to the digestive system and skin is reduced due to contraction of muscles around small arteries in these organs. This diverts the blood to our skeletal muscles. The breathing rate also increases because of the contractions of the diaphragm and the rib muscles. All these responses together enable the animal body to be ready to deal with the situation. Such animal hormones are part of the endocrine system which constitutes a second way of control and coordination in our body.

Activity 6.3

- Look at Fig. 6.7.
- Identify the endocrine glands mentioned in the figure.
- Some of these glands have been listed in Table 6.1 and discussed in the text. Consult books in the library and discuss with your teachers to find out about other glands.

Remember that plants have hormones that control their directional growth. What functions do animal hormones perform? On the face of it, we cannot imagine their role in directional growth. We have never seen an animal growing more in one direction or the other, depending on light or gravity! But if we think about it a bit more, it will become evident that, even in animal bodies, growth happens in carefully controlled places. Plants will grow leaves in many places on the plant body, for example. But we do not grow fingers on our faces. The design of the body is carefully maintained even during the growth of children.



(a) *(b)*

Figure 6.7 *Endocrine glands in human beings (a) male, (b) female*

Let us examine some examples to understand how hormones help in coordinated growth. We have all seen salt packets which say 'iodised salt' or 'enriched with iodine'. Why is it important for us to have iodised salt in our diet? Iodine is necessary for the thyroid gland to make thyroxin hormone. Thyroxin regulates carbohydrate, protein and fat metabolism in the body so as to provide the best balance for growth. Iodine is essential for the synthesis of thyroxin. In case iodine is deficient in our diet, there is a possibility that we might suffer from goitre. One of the symptoms in this disease is a swollen neck. Can you correlate this with the position of the thyroid gland in Fig. 6.7?

Sometimes we come across people who are either very short (dwarfs) or extremely tall (giants). Have you ever wondered how this happens? Growth hormone is one of the hormones secreted by the pituitary. As its name indicates, growth hormone regulates growth and development of the body. If there is a deficiency of this hormone in childhood, it leads to dwarfism.

You must have noticed many dramatic changes in your appearance as well as that of your friends as you approached 10–12 years of age. These changes associated with puberty are because of the secretion of testosterone in males and oestrogen in females.

Do you know anyone in your family or friends who has been advised by the doctor to take less sugar in their diet because they are suffering from diabetes? As a treatment, they might be taking injections of insulin. This is a hormone which is produced by the pancreas and helps in regulating blood sugar levels. If it is not secreted in proper amounts, the sugar level in the blood rises causing many harmful effects.

Do You Know?

Hypothalamus plays an important role in the release of many hormones. For example, when the level of growth hormone is low, the hypothalamus releases growth hormone releasing factor which stimulates the pituitary gland to release growth hormone.

If it is so important that hormones should be secreted in precise quantities, we need a mechanism through which this is done. The timing and amount of hormone released are regulated by feedback mechanisms. For example, if the sugar levels in blood rise, they are detected by the cells of the pancreas which respond by producing more insulin. As the blood sugar level falls, insulin secretion is reduced.

Activity 6.4

- Hormones are secreted by endocrine glands and have specific functions. Complete Table 6.1 based on the hormone, the endocrine gland or the functions provided.

Table 6.1 : Some important hormones and their functions

S.No.	Hormone	Endocrine Gland	Functions
1.	Growth hormone	Pituitary gland	Stimulates growth in all organs
2.		Thyroid gland	Regulates metabolism for body growth
3.	Insulin		Regulates blood sugar level
4.	Testosterone	Testes	
5.		Ovaries	Development of female sex organs, regulates menstrual cycle, etc.
6.	Adrenaline	Adrenal gland	
7.	Releasing hormones		Stimulates pituitary gland to release hormones

QUESTIONS

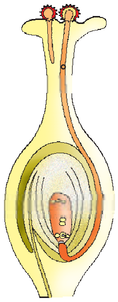
1. How does chemical coordination take place in animals?
2. Why is the use of iodised salt advisable?
3. How does our body respond when adrenaline is secreted into the blood?
4. Why are some patients of diabetes treated by giving injections of insulin?

What you have learnt

- Control and coordination are the functions of the nervous system and hormones in our bodies.
- The responses of the nervous system can be classified as reflex action, voluntary action or involuntary action.
- The nervous system uses electrical impulses to transmit messages.
- The nervous system gets information from our sense organs and acts through our muscles.
- Chemical coordination is seen in both plants and animals.
- Hormones produced in one part of an organism move to another part to achieve the desired effect.
- A feedback mechanism regulates the action of the hormones.

EXERCISES

1. Which of the following is a plant hormone?
   (a) Insulin
   (b) Thyroxin
   (c) Oestrogen
   (d) Cytokinin.
2. The gap between two neurons is called a
   (a) dendrite.
   (b) synapse.
   (c) axon.
   (d) impulse.
3. The brain is responsible for
   (a) thinking.
   (b) regulating the heart beat.
   (c) balancing the body.
   (d) all of the above.
4. What is the function of receptors in our body? Think of situations where receptors do not work properly. What problems are likely to arise?
5. Draw the structure of a neuron and explain its function.
6. How does phototropism occur in plants?
7. Which signals will get disrupted in case of a spinal cord injury?
8. How does chemical coordination occur in plants?
9. What is the need for a system of control and coordination in an organism?
10. How are involuntary actions and reflex actions different from each other?
11. Compare and contrast nervous and hormonal mechanisms for control and coordination in animals.
12. What is the difference between the manner in which movement takes place in a sensitive plant and the movement in our legs?



CHAPTER 7

How do Organisms Reproduce?

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Before we discuss the mechanisms by which organisms reproduce, let us ask a more basic question – why do organisms reproduce? After all, reproduction is not necessary to maintain the life of an individual organism, unlike the essential life processes such as nutrition, respiration, or excretion. On the other hand, if an individual organism is going to create more individuals, a lot of its energy will be spent in the process. So why should an individual organism waste energy on a process it does not need to stay alive? It would be interesting to discuss the possible answers in the classroom!

Whatever the answer to this question, it is obvious that we notice organisms because they reproduce. If there were to be only one, non-reproducing member of a particular kind, it is doubtful that we would have noticed its existence. It is the large numbers of organisms belonging to a single species that bring them to our notice. How do we know that two different individual organisms belong to the same species? Usually, we say this because they look similar to each other. Thus, reproducing organisms create new individuals that look very much like themselves.

7.1 DO ORGANISMS CREATE EXACT COPIES OF THEMSELVES?

Organisms look similar because their body designs are similar. If body designs are to be similar, the blueprints for these designs should be similar. Thus, reproduction at its most basic level will involve making copies of the blueprints of body design. In Class IX, we learnt that the chromosomes in the nucleus of a cell contain information for inheritance of features from parents to next generation in the form of DNA (Deoxyribo Nucleic Acid) molecules. The DNA in the cell nucleus is the information source for making proteins. If the information is changed, different proteins will be made. Different proteins will eventually lead to altered body designs.

Therefore, a basic event in reproduction is the creation of a DNA copy. Cells use chemical reactions to build copies of their DNA. This creates two copies of the DNA in a reproducing cell, and they will need to be separated from each other. However, keeping one copy of DNA in the original cell and simply pushing the other one out would not work, because the copy pushed out would not have any organised cellular structure for maintaining life processes. Therefore, DNA copying is accompanied by the creation of an additional cellular apparatus, and then the DNA copies separate, each with its own cellular apparatus. Effectively, a cell divides to give rise to two cells.

These two cells are of course similar, but are they likely to be absolutely identical? The answer to this question will depend on how accurately the copying reactions involved occur. No bio-chemical reaction is absolutely reliable. Therefore, it is only to be expected that the process of copying the DNA will have some variations each time. As a result, the DNA copies generated will be similar, but may not be identical to the original. Some of these variations might be so drastic that the new DNA copy cannot work with the cellular apparatus it inherits. Such a newborn cell will simply die. On the other hand, there could still be many other variations in the DNA copies that would not lead to such a drastic outcome. Thus, the surviving cells are similar to, but subtly different from each other. This inbuilt tendency for variation during reproduction is the basis for evolution, as we will discuss in the next chapter.

7.1.1 The Importance of Variation

Populations of organisms fill well-defined places, or niches, in the ecosystem, using their ability to reproduce. The consistency of DNA copying during reproduction is important for the maintenance of body design features that allow the organism to use that particular niche. Reproduction is therefore linked to the stability of populations of species.

However, niches can change because of reasons beyond the control of the organisms. Temperatures on earth can go up or down, water levels can vary, or there could be meteorite hits, to think of a few examples. If a population of reproducing organisms were suited to a particular niche and if the niche were drastically altered, the population could be wiped out. However, if some variations were to be present in a few individuals in these populations, there would be some chance for them to survive. Thus, if there were a population of bacteria living in temperate waters, and if the water temperature were to be increased by global warming, most of these bacteria would die, but the few variants resistant to heat would survive and grow further. Variation is thus useful for the survival of species over time.

Q U E S T I O N S

1. What is the importance of DNA copying in reproduction?
2. Why is variation beneficial to the species but not necessarily for the individual?

7.2 MODES OF REPRODUCTION USED BY SINGLE ORGANISMS

Activity 7.1

- Dissolve about 10 gm of sugar in 100 mL of water.
- Take 20 mL of this solution in a test tube and add a pinch of yeast granules to it.
- Put a cotton plug on the mouth of the test tube and keep it in a warm place.
- After 1 or 2 hours, put a small drop of yeast culture from the test tube on a slide and cover it with a coverslip.
- Observe the slide under a microscope.

Activity 7.2

- Wet a slice of bread, and keep it in a cool, moist and dark place.
- Observe the surface of the slice with a magnifying glass.
- Record your observations for a week.

Compare and contrast the ways in which yeast grows in the first case, and how mould grows in the second.

Having discussed the context in which reproductive processes work, let us now examine how different organisms actually reproduce. The modes by which various organisms reproduce depend on the body design of the organisms.

7.2.1 Fission

For unicellular organisms, cell division, or fission, leads to the creation of new individuals. Many different patterns of fission have been observed. Many bacteria and protozoa simply split into two equal halves during cell division. In organisms such as *Amoeba*, the splitting of the two cells during division can take place in any plane.

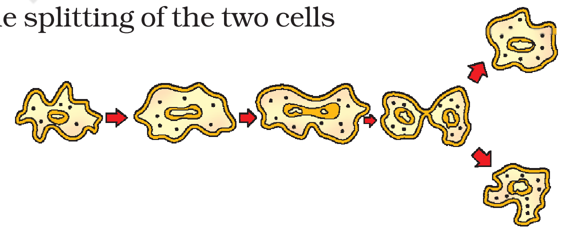


Figure 7.1(a) *Binary fission in Amoeba*

Activity 7.3

- Observe a permanent slide of *Amoeba* under a microscope.
- Similarly observe another permanent slide of *Amoeba* showing binary fission.
- Now, compare the observations of both the slides.

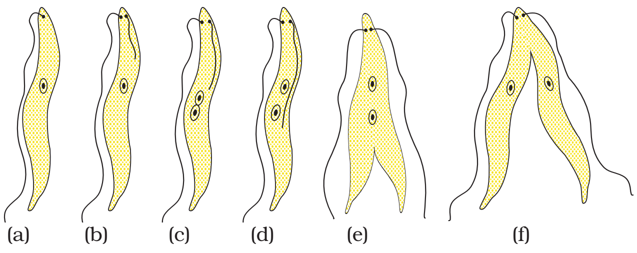


Figure 7.1(b) *Binary fission in Leishmania*

However, some unicellular organisms show somewhat more organisation of their bodies, such as is seen in *Leishmania* (which cause *kala-azar*), which have a whip-like structure at one end of the cell. In such organisms, binary fission occurs in a definite orientation in relation to these structures. Other single-celled organisms, such as the malarial parasite, *Plasmodium*, divide into many daughter cells simultaneously by multiple fission.

Yeast, on the other hand, can put out small buds that separate and grow further, as we saw in Activity 7.1.

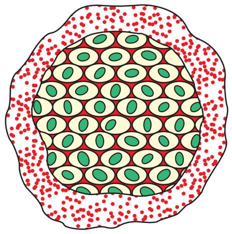


Figure 7.2
Multiple fission in Plasmodium

7.2.2 Fragmentation

Activity 7.4

- Collect water from a lake or pond that appears dark green and contains filamentous structures.
- Put one or two filaments on a slide.
- Put a drop of glycerine on these filaments and cover it with a coverslip.
- Observe the slide under a microscope.
- Can you identify different tissues in the *Spirogyra* filaments?

In multi-cellular organisms with relatively simple body organisation, simple reproductive methods can still work. *Spirogyra*, for example, simply breaks up into smaller pieces upon maturation. These pieces or fragments grow into new individuals. Can we work out the reason for this, based on what we saw in Activity 7.4?

This is not true for all multi-cellular organisms. They cannot simply divide cell-by-cell. The reason is that many multi-cellular organisms, as we have seen, are not simply a random collection of cells. Specialised cells are organised as tissues, and tissues are organised into organs, which then have to be placed at definite positions in the body. In such a carefully organised situation, cell-by-cell division would be impractical. Multi-cellular organisms, therefore, need to use more complex ways of reproduction.

A basic strategy used in multi-cellular organisms is that different cell types perform different specialised functions. Following this general pattern, reproduction in such organisms is also the function of a specific cell type. How is reproduction to be achieved from a single cell type, if the organism itself consists of many cell types? The answer is that there must be a single cell type in the organism that is capable of growing, proliferating and making other cell types under the right circumstances.

7.2.3 Regeneration

Many fully differentiated organisms have the ability to give rise to new individual organisms from their body parts. That is, if the individual is somehow cut or broken up into many pieces, many of these pieces grow into separate individuals. For example, simple animals like *Hydra* and *Planaria* can be cut into any number of pieces and each piece grows into a complete organism. This is known as regeneration (see Fig. 7.3). Regeneration is carried out by specialised cells. These cells proliferate and make large numbers of cells. From this mass of cells, different cells undergo changes to become various cell types and tissues. These changes

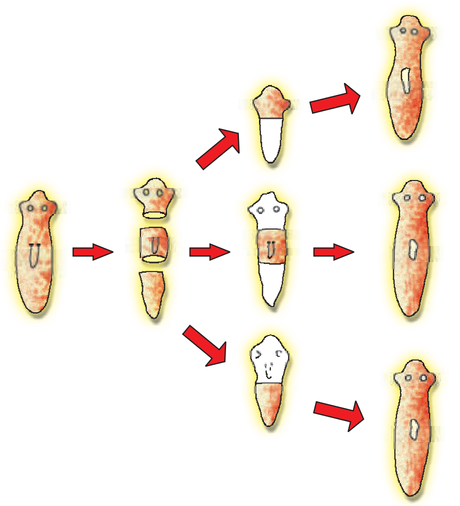


Figure 7.3 *Regeneration in Planaria*

take place in an organised sequence referred to as development. However, regeneration is not the same as reproduction, since most organisms would not normally depend on being cut up to be able to reproduce.

7.2.4 Budding

Organisms such as *Hydra* use regenerative cells for reproduction in the process of budding. In *Hydra*, a bud develops as an outgrowth due to repeated cell division at one specific site (Fig. 7.4). These buds develop into tiny individuals and when fully mature, detach from the parent body and become new independent individuals.

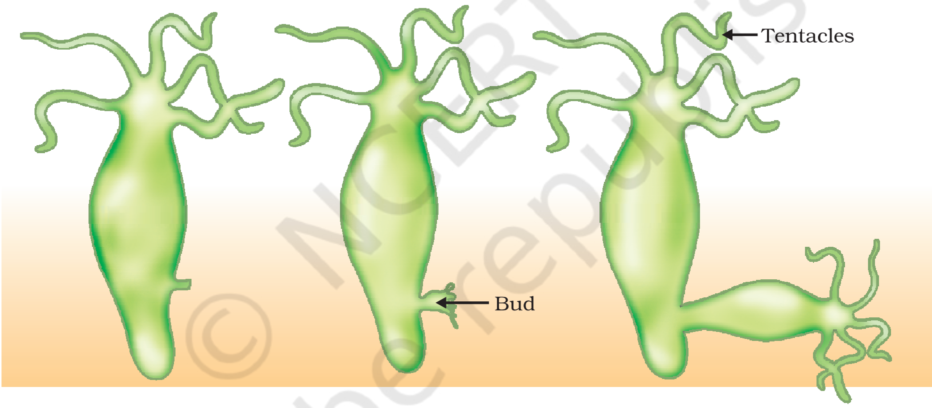


Figure 7.4 *Budding in Hydra*

7.2.5 Vegetative Propagation

There are many plants in which parts like the root, stem and leaves develop into new plants under appropriate conditions. Unlike in most animals, plants can indeed use such a mode for reproduction. This property of vegetative propagation is used in methods such as layering or grafting to grow many plants like sugarcane, roses, or grapes for agricultural purposes. Plants raised by vegetative propagation can bear flowers and fruits earlier than those produced from seeds. Such methods also make possible the propagation of plants such as banana, orange, rose and jasmine that have lost the capacity to produce seeds. Another advantage of vegetative propagation is that all plants produced are genetically similar enough to the parent plant to have all its characteristics.

Activity 7.5

- Take a potato and observe its surface. Can notches be seen?
- Cut the potato into small pieces such that some pieces contain a notch or bud and some do not.
- Spread some cotton on a tray and wet it. Place the potato pieces on this cotton. Note where the pieces with the buds are placed.
- Observe changes taking place in these potato pieces over the next few days. Make sure that the cotton is kept moistened.
- Which are the potato pieces that give rise to fresh green shoots and roots?

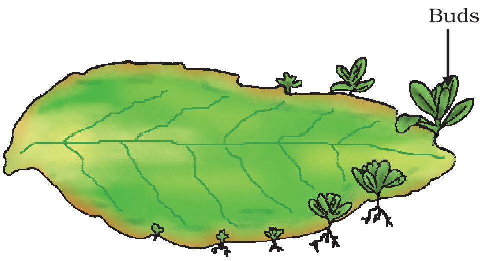


Figure 7.5
Leaf of Bryophyllum with buds

Similarly buds produced in the notches along the leaf margin of *Bryophyllum* fall on the soil and develop into new plants (Fig. 7.5).

Activity 7.6

- Select a money-plant.
- Cut some pieces such that they contain at least one leaf.
- Cut out some other portions between two leaves.
- Dip one end of all the pieces in water and observe over the next few days.
- Which ones grow and give rise to fresh leaves?
- What can you conclude from your observations?

More to Know?

Tissue culture

In tissue culture, new plants are grown by removing tissue or separating cells from the growing tip of a plant. The cells are then placed in an artificial medium where they divide rapidly to form a small group of cells or callus. The callus is transferred to another medium containing hormones for growth and differentiation. The plantlets are then placed in the soil so that they can grow into mature plants. Using tissue culture, many plants can be grown from one parent in disease-free conditions. This technique is commonly used for ornamental plants.

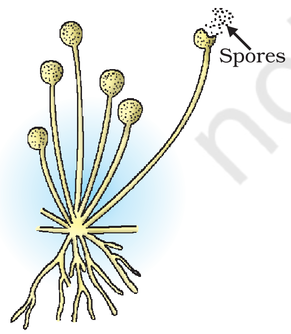


Figure 7.6
Spore formation in Rhizopus

7.2.6 Spore Formation

Even in many simple multi-cellular organisms, specific reproductive parts can be identified. The thread-like structures that developed on the bread in Activity 7.2 above are the hyphae of the bread mould (*Rhizopus*). They are not reproductive parts. On the other hand, the tiny blob-on-a-stick structures are involved in reproduction. The blobs are sporangia, which contain cells, or spores, that can eventually develop into new *Rhizopus* individuals (Fig. 7.6). The spores are covered by thick walls that protect them until they come into contact with another moist surface and can begin to grow.

All the modes of reproduction that we have discussed so far allow new generations to be created from a single individual. This is known as asexual reproduction.

QUESTIONS

1. How does binary fission differ from multiple fission?
2. How will an organism be benefited if it reproduces through spores?
3. Can you think of reasons why more complex organisms cannot give rise to new individuals through regeneration?
4. Why is vegetative propagation practised for growing some types of plants?
5. Why is DNA copying an essential part of the process of reproduction?

7.3 SEXUAL REPRODUCTION

We are also familiar with modes of reproduction that depend on the involvement of two individuals before a new generation can be created. Bulls alone cannot produce new calves, nor can hens alone produce new chicks. In such cases, both sexes, males and females, are needed to produce new generations. What is the significance of this sexual mode of reproduction? Are there any limitations of the asexual mode of reproduction, which we have been discussing above?

7.3.1 Why the Sexual Mode of Reproduction?

The creation of two new cells from one involves copying of the DNA as well as of the cellular apparatus. The DNA copying mechanism, as we have noted, cannot be absolutely accurate, and the resultant errors are a source of variations in populations of organisms. Every individual organism cannot be protected by variations, but in a population, variations are useful for ensuring the survival of the species. It would therefore make sense if organisms came up with reproductive modes that allowed more and more variation to be generated.

While DNA-copying mechanisms are not absolutely accurate, they are precise enough to make the generation of variation a fairly slow process. If the DNA copying mechanisms were to be less accurate, many of the resultant DNA copies would not be able to work with the cellular apparatus, and would die. So how can the process of making variants be speeded up? Each new variation is made in a DNA copy that already has variations accumulated from previous generations. Thus, two different individuals in a population would have quite different patterns of accumulated variations. Since all of these variations are in living individuals, it is assured that they do not have any really bad effects. Combining variations from two or more individuals would thus create new combinations of variants. Each combination would be novel, since it would involve two different individuals. The sexual mode of reproduction incorporates such a process of combining DNA from two different individuals during reproduction.

But this creates a major difficulty. If each new generation is to be the combination of the DNA copies from two pre-existing individuals, then each new generation will end up having twice the amount of DNA that the previous generation had. This is likely to mess up the control of the cellular apparatus by the DNA. How many ways can we think of for solving this difficulty?

We have seen earlier that as organisms become more complex, the specialisation of tissue increases. One solution that many multi-cellular organisms have found for the problem mentioned above is to have special lineages of cells in specialised organs in which only half the number of chromosomes and half the amount of DNA as compared to the non-reproductive body cells. This is achieved by a process of cell division called meiosis. Thus, when these germ-cells from two individuals combine during sexual reproduction to form a new individual, it results in re-establishment of the number of chromosomes and the DNA content in the new generation.

If the *zygote* is to grow and develop into an organism which has highly specialised tissues and organs, then it has to have sufficient stores of energy for doing this. In very simple organisms, it is seen that the two germ-cells are not very different from one another, or may even be similar. But as the body designs become more complex, the germ-cells also specialise. One germ-cell is large and contains the food-stores while the other is smaller and likely to be motile. Conventionally, the motile germ-cell is called the male gamete and the germ-cell containing the stored food is called the female gamete. We shall see in the next few sections how the need to create these two different types of gametes give rise to differences in the male and female reproductive organs and, in some cases, differences in the bodies of the male and female organisms.

7.3.2 Sexual Reproduction in Flowering Plants

The reproductive parts of angiosperms are located in the flower. You have already studied the different parts of a flower – sepals, petals, stamens and pistil. Stamens and pistil are the reproductive parts of a flower which contain the germ-cells. What possible functions could the petals and sepals serve?

The flower may be unisexual (papaya, watermelon) when it contains either stamens or pistil or bisexual (*Hibiscus*, mustard) when it contains both stamens and pistil. Stamen is the male reproductive part and it produces pollen grains that are yellowish in colour. You must have seen this yellowish powder that often sticks to our hands if we touch the stamen of a flower. Pistil is present in the centre of a flower and is the female reproductive part. It is made of three parts.

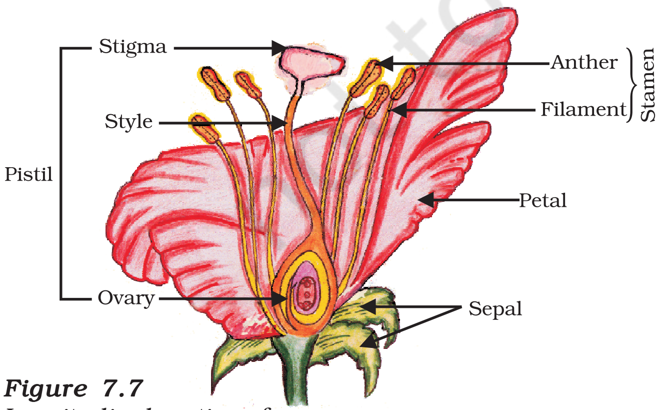


Figure 7.7
Longitudinal section of flower

The swollen bottom part is the ovary, middle elongated part is the style and the terminal part which may be sticky is the stigma. The ovary contains ovules and each ovule has an egg cell. The male germ-cell produced by pollen grain fuses with the female gamete present in the ovule. This fusion of the germ-cells or fertilisation gives us the zygote which is capable of growing into a new plant.

Thus the pollen needs to be transferred from the stamen to the stigma. If this transfer of pollen occurs in the same flower, it is referred to as self-pollination. On the other hand, if the pollen is transferred from one flower to another, it is known as cross-pollination. This transfer of pollen from one flower to another is achieved by agents like wind, water or animals.

After the pollen lands on a suitable stigma, it has to reach the female germ-cells which are in the ovary. For this, a tube grows out of the pollen grain and travels through the style to reach the ovary.

After fertilisation, the zygote divides several times to form an embryo within the ovule. The ovule develops a tough coat and is gradually converted into a seed. The ovary grows rapidly and ripens to form a fruit. Meanwhile, the petals, sepals, stamens, style and stigma may shrivel and fall off. Have you ever observed any flower part still persisting in the fruit? Try and work out the advantages of seed-formation for the plant. The seed contains the future plant or embryo which develops into a seedling under appropriate conditions. This process is known as germination.

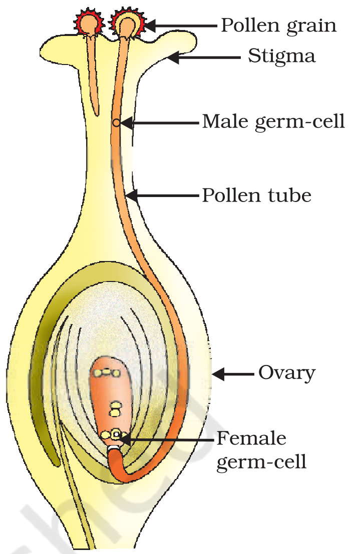


Figure 7.8
Germination of pollen on stigma

Activity 7.7

- Soak a few seeds of Bengal gram (*chana*) and keep them overnight.
- Drain the excess water and cover the seeds with a wet cloth and leave them for a day. Make sure that the seeds do not become dry.
- Cut open the seeds carefully and observe the different parts.
- Compare your observations with the Fig. 7.9 and see if you can identify all the parts.

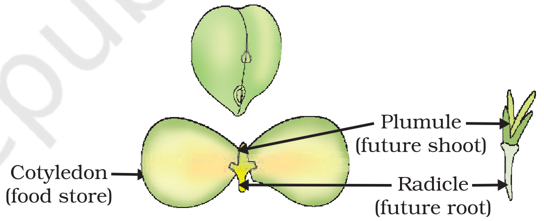


Figure 7.9
Germination

7.3.3 Reproduction in Human Beings

So far, we have been discussing the variety of modes that different species use for reproduction. Let us now look at the species that we are most interested in, namely, humans. Humans use a sexual mode of reproduction. How does this process work?

Let us begin at an apparently unrelated point. All of us know that our bodies change as we become older. You have learnt changes that take place in your body earlier in Class VIII also. We notice that our height has increased continuously from early age till now. We acquire teeth, we even lose the old, so-called milk teeth and acquire new ones.

All of these are changes that can be grouped under the general process of growth, in which the body becomes larger. But in early teenage years, a whole new set of changes occurs that cannot be explained simply as body enlargement. Instead, the appearance of the body changes. Proportions change, new features appear, and so do new sensations.

Some of these changes are common to both boys and girls. We begin to notice thick hair growing in new parts of the body such as armpits and the genital area between the thighs, which can also become darker in colour. Thinner hair can also appear on legs and arms, as well as on the face. The skin frequently becomes oily and we might begin to develop pimples. We begin to be conscious and aware of both our own bodies and those of others in new ways.

On the other hand, there are also changes taking place that are different between boys and girls. In girls, breast size begins to increase, with darkening of the skin of the nipples at the tips of the breasts. Also, girls begin to menstruate at around this time. Boys begin to have new thick hair growth on the face and their voices begin to crack. Further, the penis occasionally begins to become enlarged and erect, either in daydreams or at night.

All of these changes take place slowly, over a period of months and years. They do not happen all at the same time in one person, nor do they happen at an exact age. In some people, they happen early and quickly, while in others, they can happen slowly. Also, each change does not become complete quickly either. So, for example, thick hair on the face in boys appears as a few scattered hairs first, and only slowly does the growth begin to become uniform. Even so, all these changes show differences between people. Just as we have differently shaped noses or fingers, so also we have different patterns of hair growth, or size and shape of breast or penis. All of these changes are aspects of the sexual maturation of the body.

Why does the body show sexual maturation at this age? We have talked about the need for specialised cell types in multi-cellular bodies to carry out specialised functions. The creation of germ-cells to participate in sexual reproduction is another specialised function, and we have seen that plants develop special cell and tissue types to create them. Human beings also develop special tissues for this purpose. However, while the body of the individual organism is growing to its adult size, the resources of the body are mainly directed at achieving this growth. While that is happening, the maturation of the reproductive tissue is not likely to be a major priority. Thus, as the rate of general body growth begins to slow down, reproductive tissues begin to mature. This period during adolescence is called puberty.

So how do all the changes that we have talked about link to the reproductive process? We must remember that the sexual mode of reproduction means that germ-cells from two individuals have to join together. This can happen by the external release of germ-cells from the bodies of individuals, as happens in flowering plants. Or it can happen by two individuals joining their bodies together for internal transfer of germ-cells for fusion, as happens in many animals. If animals are to participate in this process of mating, their state of sexual maturity must be identifiable by other individuals. Many changes during puberty, such as new hair-growth patterns, are signals that sexual maturation is taking place.

On the other hand, the actual transfer of germ-cells between two people needs special organs for the sexual act, such as the penis when it is capable of becoming erect. In mammals such as humans, the baby is carried in the mother's body for a long period, and will be breast-fed later. The female reproductive organs and breasts will need to mature to accommodate these possibilities. Let us look at the systems involved in the process of sexual reproduction.

7.3.3 (a) Male Reproductive System

The male reproductive system (Fig. 7.10) consists of portions which produce the germ-cells and other portions that deliver the germ-cells to the site of fertilisation.

The formation of germ-cells or sperms takes place in the testes. These are located outside the abdominal cavity in scrotum because sperm formation requires a lower temperature than the normal body temperature. We have discussed the role of the testes in the secretion of the hormone, testosterone, in the previous chapter. In addition to regulating the formation of sperms, testosterone brings about changes in appearance seen in boys at the time of puberty.

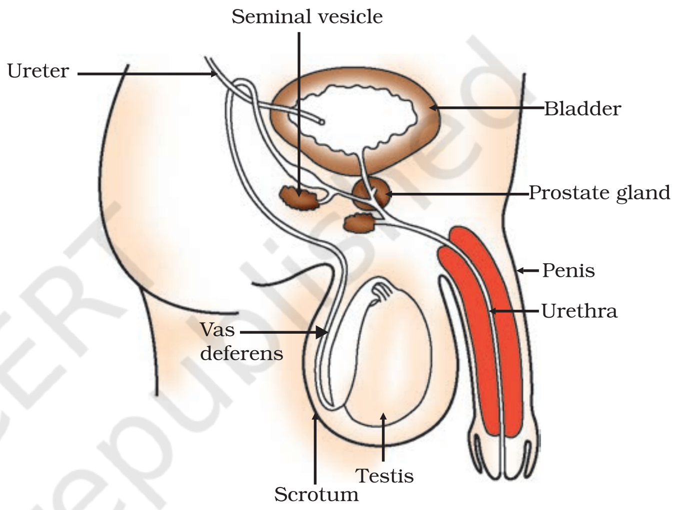


Figure 7.10 *Human–male reproductive system*

The sperms formed are delivered through the vas deferens which unites with a tube coming from the urinary bladder. The urethra thus forms a common passage for both the sperms and urine. Along the path of the vas deferens, glands like the prostate and the seminal vesicles add their secretions so that the sperms are now in a fluid which makes their transport easier and this fluid also provides nutrition. The sperms are tiny bodies that consist of mainly genetic material and a long tail that helps them to move towards the female germ-cell.

7.3.3 (b) Female Reproductive System

The female germ-cells or eggs are made in the ovaries. They are also responsible for the production of some hormones. Look at Fig. 7.11 and identify the various organs in the female reproductive system.

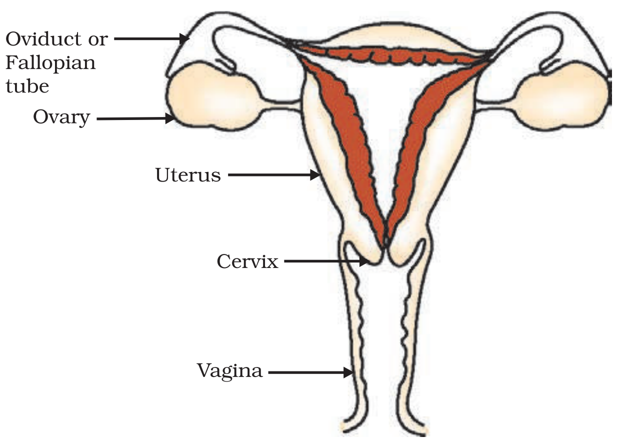


Figure 7.11 *Human–female reproductive system*

When a girl is born, the ovaries already contain thousands of immature eggs. On reaching puberty, some of these start maturing. One egg is produced every month by one of the ovaries. The egg is carried from the ovary to the womb through a thin oviduct or fallopian tube. The two oviducts unite into an elastic bag-like structure known as the uterus. The uterus opens into the vagina through the cervix.

The sperms enter through the vaginal passage during sexual intercourse. They travel upwards and reach the oviduct where they may encounter the egg. The fertilised egg (zygote) starts dividing and form a ball of cells or embryo. The embryo is implanted in the lining of the uterus where they continue to grow and develop organs to become foetus. We have seen in earlier sections that the mother's body is designed to undertake the development of the child. Hence the uterus prepares itself every month to receive and nurture the growing embryo. The lining thickens and is richly supplied with blood to nourish the growing embryo.

The embryo gets nutrition from the mother's blood with the help of a special tissue called placenta. This is a disc which is embedded in the uterine wall. It contains villi on the embryo's side of the tissue. On the mother's side are blood spaces, which surround the villi. This provides a large surface area for glucose and oxygen to pass from the mother to the embryo. The developing embryo will also generate waste substances which can be removed by transferring them into the mother's blood through the placenta. The development of the child inside the mother's body takes approximately nine months. The child is born as a result of rhythmic contractions of the muscles in the uterus.

7.3.3 (c) What happens when the Egg is not Fertilised?

If the egg is not fertilised, it lives for about one day. Since the ovary releases one egg every month, the uterus also prepares itself every month to receive a fertilised egg. Thus its lining becomes thick and spongy. This would be required for nourishing the embryo if fertilisation had taken place. Now, however, this lining is not needed any longer. So, the lining slowly breaks and comes out through the vagina as blood and mucous. This cycle takes place roughly every month and is known as menstruation. It usually lasts for about two to eight days.

7.3.3 (d) Reproductive Health

As we have seen, the process of sexual maturation is gradual, and takes place while general body growth is still going on. Therefore, some degree of sexual maturation does not necessarily mean that the body or the mind is ready for sexual acts or for having and bringing up children. How do we decide if the body or the mind is ready for this major responsibility? All of us are under many different kinds of pressures about these issues. There can be pressure from our friends for participating in many activities, whether we really want to or not. There can be pressure from families to get married and start having children. There can be pressure from government agencies to avoid having children. In this situation, making choices can become very difficult.

We must also consider the possible health consequences of having sex. We have discussed in Class IX that diseases can be transmitted from person to person in a variety of ways. Since the sexual act is a very intimate connection of bodies, it is not surprising that many diseases can be sexually transmitted. These include bacterial infections such as gonorrhoea and syphilis, and viral infections such as warts and HIV-AIDS. Is it possible to prevent the transmission of such diseases during the sexual act? Using a covering, called a condom, for the penis during sex helps to prevent transmission of many of these infections to some extent.

The sexual act always has the potential to lead to pregnancy. Pregnancy will make major demands on the body and the mind of the woman, and if she is not ready for it, her health will be adversely affected. Therefore, many ways have been devised to avoid pregnancy. These contraceptive methods fall in a number of categories. One category is the creation of a mechanical barrier so that sperm does not reach the egg. Condoms on the penis or similar coverings worn in the vagina can serve this purpose. Another category of contraceptives acts by changing the hormonal balance of the body so that eggs are not released and fertilisation cannot occur. These drugs commonly need to be taken orally as pills. However, since they change hormonal balances, they can cause side-effects too. Other contraceptive devices such as the loop or the copper-T are placed in the uterus to prevent pregnancy. Again, they can cause side effects due to irritation of the uterus. If the vas deferens in the male is blocked, sperm transfer will be prevented. If the fallopian tube in the female is blocked, the egg will not be able to reach the uterus. In both cases fertilisation will not take place. Surgical methods can be used to create such blocks. While surgical methods are safe in the long run, surgery itself can cause infections and other problems if not performed properly. Surgery can also be used for removal of unwanted pregnancies. These may be misused by people who do not want a particular child, as happens in illegal sex-selective abortion of female foetuses. For a healthy society, the female-male sex ratio must be maintained. Because of reckless female foeticides, child sex ratio is declining at an alarming rate in some sections of our society, although prenatal sex determination has been prohibited by law.

We have noted earlier that reproduction is the process by which organisms increase their populations. The rates of birth and death in a given population will determine its size. The size of the human population is a cause for concern for many people. This is because an expanding population makes it harder to improve everybody's standard of living. However, if inequality in society is the main reason for poor standards of living for many people, the size of the population is relatively unimportant. If we look around us, what can we identify as the most important reason(s) for poor living standards?

Q U E S T I O N S

1. How is the process of pollination different from fertilisation?
2. What is the role of the seminal vesicles and the prostate gland?
3. What are the changes seen in girls at the time of puberty?
4. How does the embryo get nourishment inside the mother's body?
5. If a woman is using a copper-T, will it help in protecting her from sexually transmitted diseases?

What you have learnt

- Reproduction, unlike other life processes, is not essential to maintain the life of an individual organism.
- Reproduction involves creation of a DNA copy and additional cellular apparatus by the cell involved in the process.
- Various organisms use different modes of reproduction depending on their body design.
- In fission, many bacteria and protozoa simply divide into two or more daughter cells.
- Organisms such as hydra can regenerate if they are broken into pieces. They can also give out buds which mature into new individuals.
- Roots, stems and leaves of some plants develop into new plants through vegetative propagation.
- These are examples of asexual reproduction where new generations are created from a single individual.
- Sexual reproduction involves two individuals for the creation of a new individual.
- DNA copying mechanisms creates variations which are useful for ensuring the survival of the species. Modes of sexual reproduction allow for greater variation to be generated.
- Reproduction in flowering plants involves transfer of pollen grains from the anther to the stigma which is referred to as pollination. This is followed by fertilisation.
- Changes in the body at puberty, such as increase in breast size in girls and new facial hair growth in boys, are signs of sexual maturation.
- The male reproductive system in human beings consists of testes which produce sperms, vas deferens, seminal vesicles, prostate gland, urethra and penis.
- The female reproductive system in human beings consists of ovaries, fallopian tubes, uterus and vagina.
- Sexual reproduction in human beings involves the introduction of sperm in the vagina of the female. Fertilisation occurs in the fallopian tube.
- Contraception to avoid pregnancy can be achieved by the use of condoms, oral pills, copper-T and other methods.

EXERCISES

1. Asexual reproduction takes place through budding in
   (a) *Amoeba.*
   (b) Yeast.
   (c) *Plasmodium.*
   (d) *Leishmania.*
2. Which of the following is not a part of the female reproductive system in human beings?
   (a) Ovary
   (b) Uterus
   (c) Vas deferens
   (d) Fallopian tube
3. The anther contains
   (a) sepals.
   (b) ovules.
   (c) pistil.
   (d) pollen grains.
4. What are the advantages of sexual reproduction over asexual reproduction?
5. What are the functions performed by the testis in human beings?
6. Why does menstruation occur?
7. Draw a labelled diagram of the longitudinal section of a flower.
8. What are the different methods of contraception?
9. How are the modes for reproduction different in unicellular and multicellular organisms?
10. How does reproduction help in providing stability to populations of species?
11. What could be the reasons for adopting contraceptive methods?

CHAPTER 8

Heredity

We have seen that reproductive processes give rise to new individuals that are similar, but subtly different. We have discussed how some amount of variation is produced even during asexual reproduction. And the number of successful variations are maximised by the process of sexual reproduction. If we observe a field of sugarcane we find very little variations among the individual plants. But in a number of animals including human beings, which reproduce sexually, quite distinct variations are visible among different individuals. In this chapter, we shall be studying the mechanism by which variations are created and inherited.

8.1 ACCUMULATION OF VARIATION DURING REPRODUCTION

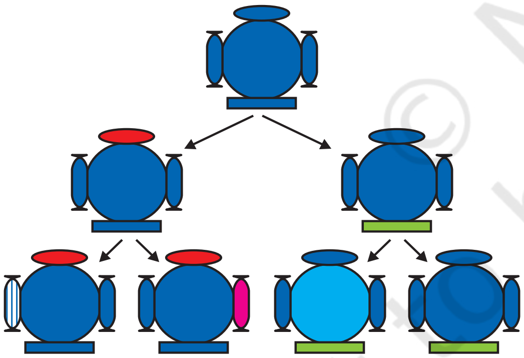


Figure 8.1
Creation of diversity over succeeding generations. The original organism at the top will give rise to, say, two individuals, similar in body design, but with subtle differences. Each of them, in turn, will give rise to two individuals in the next generation. Each of the four individuals in the bottom row will be different from each other. While some of these differences will be unique, others will be inherited from their respective parents, who were different from each other.

Inheritance from the previous generation provides both a common basic body design, and subtle changes in it, for the next generation. Now think about what would happen when this new generation, in its turn, reproduces. The second generation will have differences that they inherit from the first generation, as well as newly created differences (Fig. 8.1).

Figure 8.1 would represent the situation if a single individual reproduces, as happens in asexual reproduction. If one bacterium divides, and then the resultant two bacteria divide again, the four individual bacteria generated would be very similar. There would be only very minor differences between them, generated due to small inaccuracies in DNA copying. However, if sexual reproduction is involved, even greater diversity will be generated, as we will see when we discuss the rules of inheritance.

Do all these variations in a species have equal chances of surviving in the environment in which they find themselves? Obviously not. Depending on the nature of variations, different individuals would have different kinds of advantages. Bacteria that can withstand heat will survive better in a heat wave, as we have discussed earlier. Selection of variants by environmental factors forms the basis for evolutionary processes, as we will discuss in later sections.

QUESTIONS

1. If a trait A exists in 10% of a population of an asexually reproducing species and a trait B exists in 60% of the same population, which trait is likely to have arisen earlier?
2. How does the creation of variations in a species promote survival?

8.2 HEREDITY

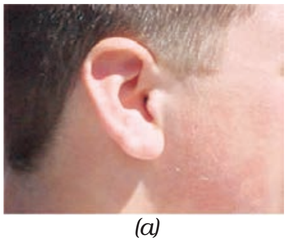
The most obvious outcome of the reproductive process still remains the generation of individuals of similar design. The rules of heredity determine the process by which traits and characteristics are reliably inherited. Let us take a closer look at these rules.

8.2.1 Inherited Traits

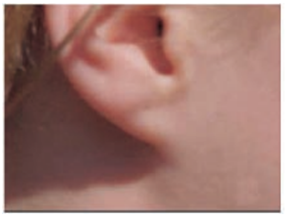
What exactly do we mean by similarities and differences? We know that a child bears all the basic features of a human being. However, it does not look exactly like its parents, and human populations show a great deal of variation.

Activity 8.1

- Observe the ears of all the students in the class. Prepare a list of students having free or attached earlobes and calculate the percentage of students having each (Fig. 8.2). Find out about the earlobes of the parents of each student in the class. Correlate the earlobe type of each student with that of their parents. Based on this evidence, suggest a possible rule for the inheritance of earlobe types.



(a)



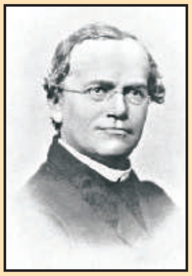
(b)

Figure 8.2
(a) Free and (b) attached earlobes. The lowest part of the ear, called the earlobe, is closely attached to the side of the head in some of us, and not in others. Free and attached earlobes are two variants found in human populations.

8.2.2 Rules for the Inheritance of Traits – Mendel's Contributions

The rules for inheritance of such traits in human beings are related to the fact that both the father and the mother contribute practically equal amounts of genetic material to the child. This means that each trait can be influenced by both paternal and maternal DNA. Thus, for each trait there will be two versions in each child. What will, then, the trait seen in the child be? Mendel (see box) worked out the main rules of such inheritance, and it is interesting to look at some of his experiments from more than a century ago.

Gregor Johann Mendel (1822–1884)



Mendel was educated in a monastery and went on to study science and mathematics at the University of Vienna. Failure in the examinations for a teaching certificate did not suppress his zeal for scientific quest. He went back to his monastery and started growing peas. Many others had studied the inheritance of traits in peas and other organisms earlier, but Mendel blended his knowledge of science and mathematics and was the first one to keep count of individuals exhibiting a particular trait in each generation. This helped him to arrive at the laws of inheritance.

Mendel used a number of contrasting visible characters of garden peas – round/wrinkled seeds, tall/short plants, white/violet flowers and so on. He took pea plants with different characteristics – a tall plant and a short plant, produced progeny by crossing them, and calculated the percentages of tall or short progeny.

In the first place, there were no halfway characteristics in this first-generation, or F1 progeny – no 'medium-height' plants. All plants were tall. This meant that only one of the parental traits was seen, not some mixture of the two. So the next question was, were the tall plants in the F1 generation exactly the same as the tall plants of the parent generation? Mendelian experiments test this by getting both the parental plants and these F1 tall plants to reproduce by self-pollination. The progeny of the parental plants are, of course, all tall. However, the second-generation, or F2, progeny of the F1 tall plants are not all tall. Instead, one quarter of them are short. This indicates that both the tallness and shortness traits were inherited in the F1 plants, but only the tallness trait was expressed. This led Mendel to propose that two copies of factor (now called genes) controlling traits are present in sexually reproducing organism. These two may be identical, or may be different, depending on the parentage. A pattern of inheritance can be worked out with this assumption, as shown in Fig. 8.3.

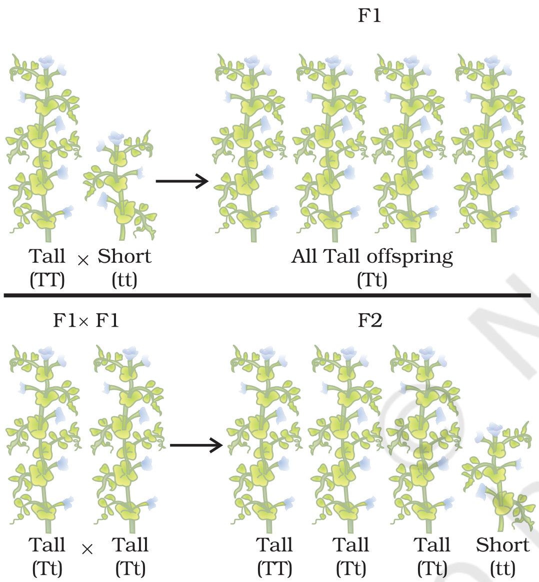


Figure 8.3
Inheritance of traits over two generations

Activity 8.2

- In Fig. 8.3, what experiment would we do to confirm that the F2 generation did in fact have a 1:2:1 ratio of TT, Tt and tt trait combinations?

In this explanation, both TT and Tt are tall plants, while only tt is a short plant. In other words, a single copy of 'T' is enough to make the plant tall, while both copies have to be 't' for the plant to be short. Traits like 'T' are called dominant traits, while those that behave like 't' are called recessive traits. Work out which trait would be considered dominant and which one recessive in Fig. 8.4.

What happens when pea plants showing two different characteristics, rather than just one, are bred with each other? What do the progeny of a tall plant with round seeds and a short plant with wrinkled-seeds look like? They are all tall and have round seeds. Tallness and round seeds are thus dominant traits. But what happens when these F1 progeny are used to generate F2 progeny by self-pollination? A Mendelian experiment will find that some F2 progeny are tall plants with round seeds, and some were short plants with wrinkled seeds. However, there would also be some F2 progeny that showed new combinations. Some of them would be tall, but have wrinkled seeds, while others would be short, but have round seeds. You can see as to how new combinations of traits are formed in F2 offspring when factors controlling for seed shape and seed colour recombine to form zygote leading to form F2 offspring (Fig. 8.5). Thus, the tall/short trait and the round seed/wrinkled seed trait are independently inherited.

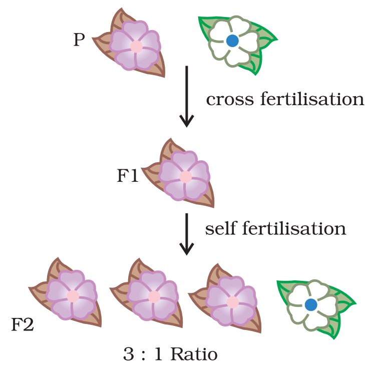


Figure 8.4

8.2.3 How do these Traits get Expressed?

How does the mechanism of heredity work? Cellular DNA is the information source for making proteins in the cell. A section of DNA that provides information for one protein is called the gene for that protein. How do proteins control the characteristics that we are discussing here? Let us take the example of tallness as a characteristic. We know that plants have hormones that can trigger growth. Plant height can thus depend on the amount of a particular plant hormone. The amount of the plant hormone made will depend on the efficiency of the process for making it. Consider now an enzyme that is important for this process. If this enzyme works efficiently, a lot of hormone will be made, and the plant will be tall. If the gene for that enzyme has an alteration that makes the enzyme less efficient, the amount of hormone will be less, and the plant will be short. Thus, genes control characteristics, or traits.

If the interpretations of Mendelian experiments we have been discussing are correct, then both parents must be contributing equally to the DNA of the progeny during sexual reproduction. We have disscussed this issue in the previous Chapter. If both parents can help determine the trait in the progeny, both parents must be contributing a copy of the same gene. This means that each pea plant must have two sets of all genes, one inherited from each parent. For this mechanism to work, each germ cell must have only one gene set.

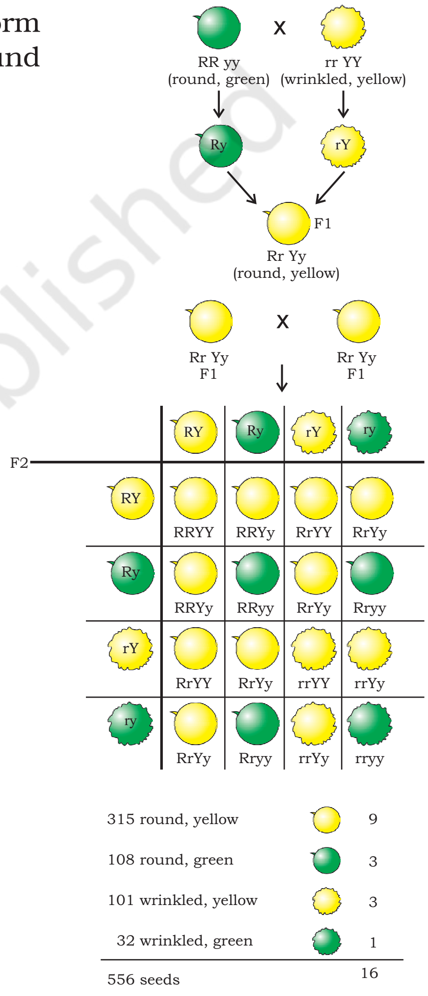


Figure 8.5
Independent inheritance of two separate traits, shape and colour of seeds

How do germ-cells make a single set of genes from the normal two copies that all other cells in the body have? If progeny plants inherited a single whole gene set from each parent, then the experiment explained in Fig. 8.5 cannot work. This is because the two characteristics 'R' and 'y' would then be linked to each other and cannot be independently inherited. This is explained by the fact that each gene set is present, not as a single long thread of DNA, but as separate independent pieces, each called a chromosome. Thus, each cell will have two copies of each chromosome, one each from the male and female parents. Every germ-cell will take one chromosome from each pair and these may be of either maternal or paternal origin. When two germ cells combine, they will restore the normal number of chromosomes in the progeny, ensuring the stability of the DNA of the species. Such a mechanism of inheritance explains the results of the Mendel experiments, and is used by all sexually reproducing organisms. But asexually reproducing organisms also follow similar rules of inheritance. Can we work out how their inheritance might work?

8.2.4 Sex Determination

We have discussed the idea that the two sexes participating in sexual reproduction must be somewhat different from each other for a number of reasons. How is the sex of a newborn individual determined? Different species use very different strategies for this. Some rely entirely on environmental cues. Thus, in some animals like a few reptiles, the temperature at which fertilised eggs are kept determines whether the animals developing in the eggs will be male or female. In other animals, such as snails, individuals can change sex, indicating that sex is not genetically determined. However, in human beings, the sex of the individual is largely genetically determined. In other words, the genes inherited from our parents decide whether we will be boys or girls. But so far, we have assumed that similar gene sets are inherited from both parents. If that is the case, how can genetic inheritance determine sex?

The explanation lies in the fact that all human chromosomes are not paired. Most human chromosomes have a maternal and a paternal copy, and we have 22 such pairs. But one pair, called the sex chromosomes, is odd in not always being a perfect pair. Women have a perfect pair of sex chromosomes, both called X. But men have a mismatched pair in which one is a normal-sized X while the other is a short one called Y. So women are XX, while men are XY. Now, can we work out what the inheritance pattern of X and Y will be?

As Fig. 8.6 shows, half the children will be boys and half will be girls. All children will inherit an X chromosome from their mother regardless of whether they are boys or girls. Thus, the sex of the children will be determined by what they inherit from their father. A child who inherits an X chromosome from her father will be a girl, and one who inherits a Y chromosome from him will be a boy.

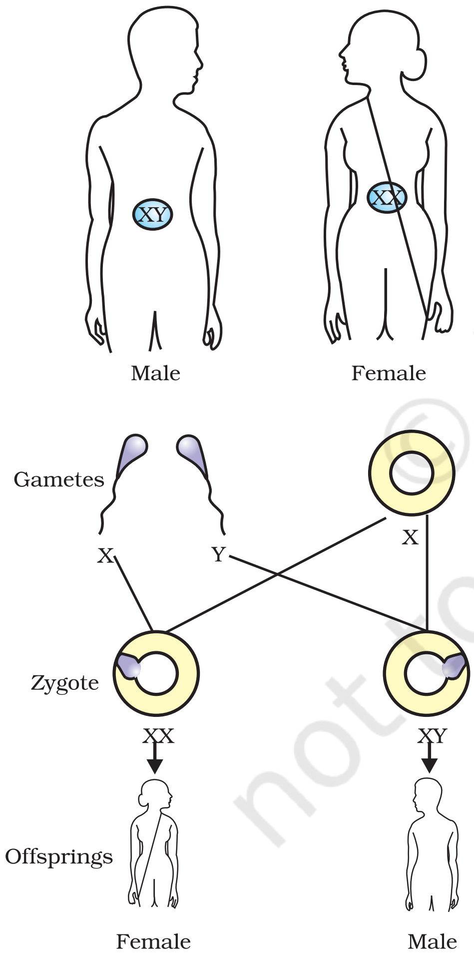


Figure 8.6
Sex determination in human beings

QUESTIONS

1. How do Mendel's experiments show that traits may be dominant or recessive?
2. How do Mendel's experiments show that traits are inherited independently?
3. A man with blood group A marries a woman with blood group O and their daughter has blood group O. Is this information enough to tell you which of the traits – blood group A or O – is dominant? Why or why not?
4. How is the sex of the child determined in human beings?

What you have learnt

- Variations arising during the process of reproduction can be inherited.
- These variations may lead to increased survival of the individuals.
- Sexually reproducing individuals have two copies of genes for the same trait. If the copies are not identical, the trait that gets expressed is called the dominant trait and the other is called the recessive trait.
- Traits in one individual may be inherited separately, giving rise to new combinations of traits in the offspring of sexual reproduction.
- Sex is determined by different factors in various species. In human beings, the sex of the child depends on whether the paternal chromosome is X (for girls) or Y (for boys).

EXERCISES

1. A Mendelian experiment consisted of breeding tall pea plants bearing violet flowers with short pea plants bearing white flowers. The progeny all bore violet flowers, but almost half of them were short. This suggests that the genetic make-up of the tall parent can be depicted as
   (a) TTWW
   (b) TTww
   (c) TtWW
   (d) TtWw
2. A study found that children with light-coloured eyes are likely to have parents with light-coloured eyes. On this basis, can we say anything about whether the light eye colour trait is dominant or recessive? Why or why not?
3. Outline a project which aims to find the dominant coat colour in dogs.
4. How is the equal genetic contribution of male and female parents ensured in the progeny?