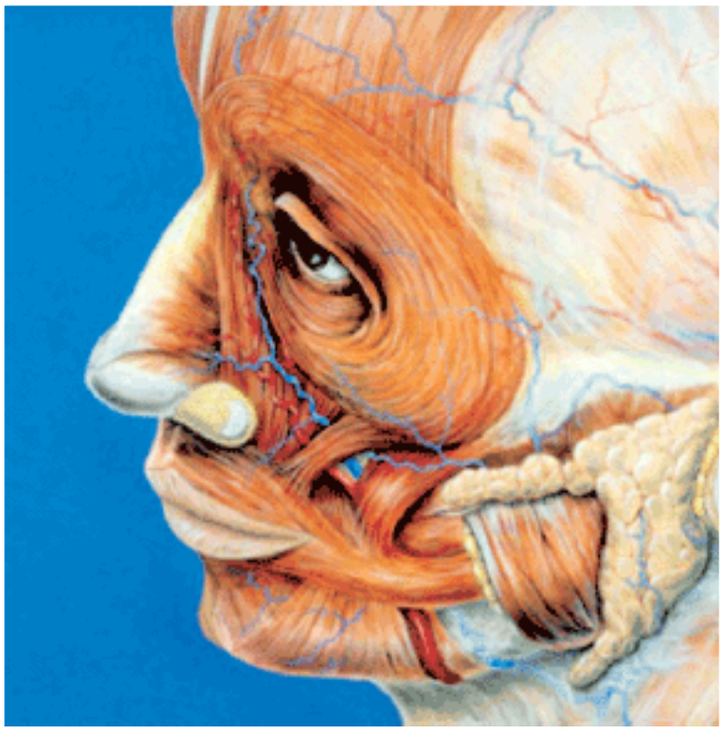
CHAPTER

10

Gaseous Exchange

Animation 10 : Gaseous Exchange
Source & Credit: Wikispaces



In Grade IX, we have studied how cells generate ATPs from food. Cellular respiration is the process in which the C-H bonds in food are broken by oxidationreduction reactions and thenergy is transformed into ATP. In aerobic respiration, oxygen is used and there is complete oxidation of the food material. Carbon dioxide and water are also producedinthisprocess.Organismsgetthe oxygen, needed for **cellular respiration,** from their environment and provide it to their cells. The carbon dioxide produced during cellular respiration is taken out of the cells and ultimately from the body.

Taking inoxygen and giving out of carbon dioxide is termed as **gaseous exchange.** The term **breathing** is used for the process through which animals take air in their bodies to get oxygen from it and then give out the air for getting rid of carbon dioxide. Thus breathing and respiration are not synonymous. Respiration involves the mechanical and the bio-chemical processes whereas breathing is only the mechanical or physical process of exchange of gases.

In this chapter we will go through the mechanisms of gaseous exchange in plants and in humans.

10.1 Gaseous Exchange In Plants

Plants have no organs or systems for the exchange of gases with the environment. Every cell of the plant body exchanges gases with the environment by its own.

The leaves and young stems have **stomata** in their epidermis. The gaseous exchange occurs through these stomata. The inner cells of leaves (mesophyll) and stems also have air spaces among them, which help in the exchange of gases (Fig:10.1).

Recalling

Organisms need energy in the form of ATP for their activities.

In young stems and leaves, some gaseous exchange also occurs through the cuticle which is present over their epidermis.

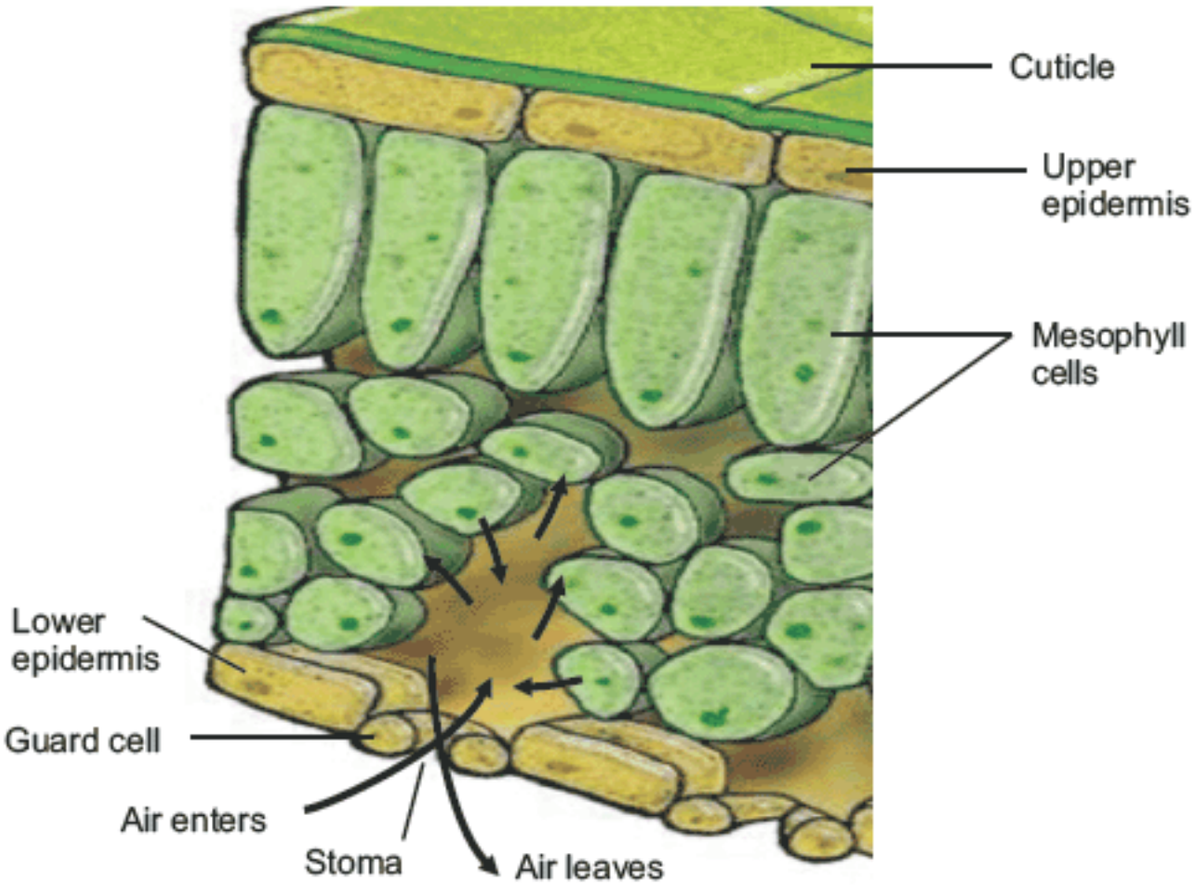


Figure 10.1: Gaseous exchange in a leaf

Leaf cells face two situations. During the daytime when the mesophyll cells of leaves are carrying out photosynthesis and respiration side by side, the oxygen produced in photosynthesis is utilized in cellular respiration. Similarly the carbon dioxide produced during cellular respiration is utilized in photosynthesis. However, during night when there is no photosynthesis occurring, the leaf cells get oxygen from the environment and release carbon dioxide through stomata.

Analyzing and Interpreting

Draw diagram of stomata of a leaf indicating the movement of gases.

In woody stems and mature roots, the entire surface is covered by bark which is impervious to gases or water. However, there are certain pores in the layer of bark. These are called the **lenticels** (Fig: 10.2). The lenticels allow air to pass through them. Gases diffuse in and out of the general surface of the young roots. The gases are found in the soil surrounding the roots.
The aquatic plants get the oxygen dissolved in water and release carbon dioxide in the water.

The lenticels are slightly more raised than the general surface of the stem

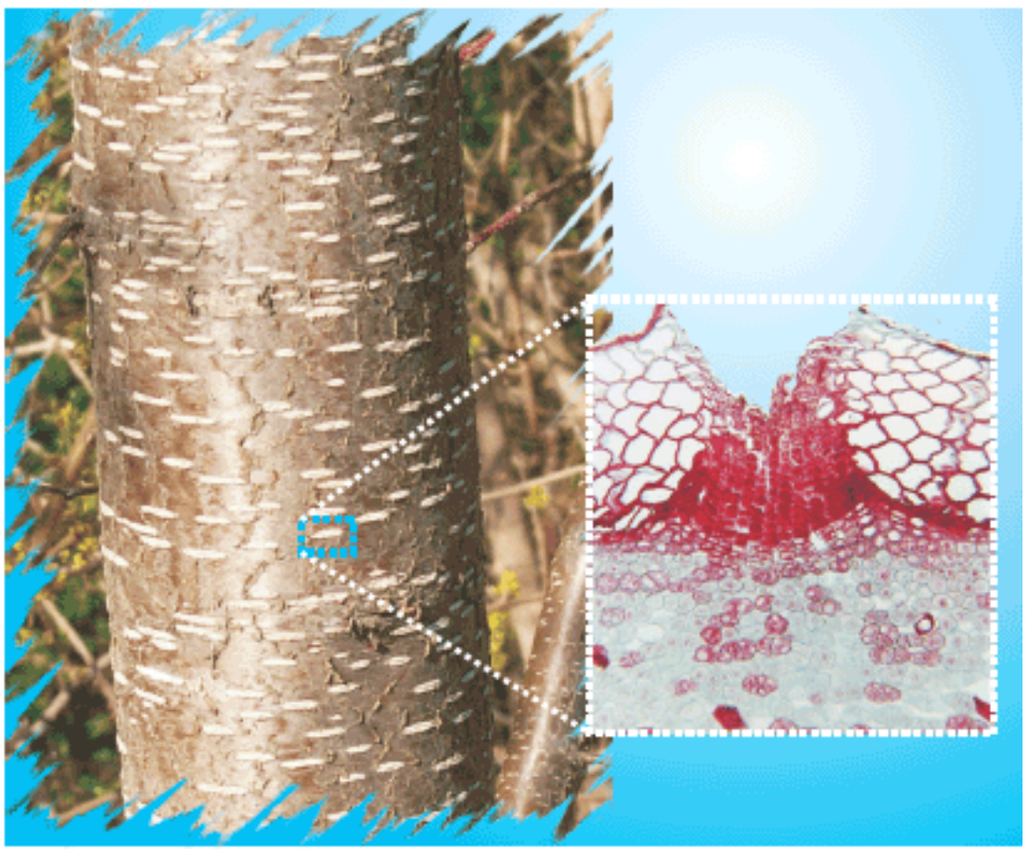


Figure 10.2: Lenticels on a stem and the internal view of a lenticel

Practical Work:

Investigate the effect of light on the net gaseous exchange from leaf

Stomata are the microscopic pores in the epidermis of leaves. They are the passageways for gases and water vapours. Opening and closing of stomata controls the gaseous exchange.

Problem: What is the net gaseous exchange from leaves during day and night times?

Apparatus required: Petri dish, water, glass slides and cover slips, methylene blue, light microscope

Background information:

- A stoma is an opening through which leaves exchange gases.
- The cells of leaves carry out photosynthesis during daytime only.
- The cells of leaves carry out respiration all the times.

Procedure:

1. Take a thick leaf and peel off a thin layer (epidermis) from its surface.
2. Place the thin layer in water in a Petri dish.
3. Cut a piece of the peeled off epidermis and place it in a drop of water on a glass slide.
4. Pour a drop of methylene blue and place a cover slip on the material.
5. Observe under the low and high powers of the microscope.
6. Perform the same steps by taking the epidermis of leaf at night time.

Observation: Observe both epidermis (upper and lower) and point out the stomata. Count the number of open stomata in both and compare their numbers. Draw your observation on the notebook.

Evaluation:

1. How many stomata did you observe?
2. What is the structure of guard cells and how does it helps in the opening and closing of stomata?

10.2 Gaseous Exchange In Humans

In humans and other higher animals the exchange of gases is carried out by the respiratory system. We can divide the respiratory system in two parts i.e. the air passageway and the lungs.

Analyzing and Interpreting

Identify the structure of human air passageway in charts and models

10.2.1 The Air Passageway

The air passageway consists of the parts through which the outside air comes in the lungs and after the exchange of gases it goes out. This passage of air consists of the following parts.

The nose encloses the **nasal cavity.** It opens to the outside through the openings called the **nostrils.** The nasal cavity is divided into two portions by a wall. Each portion is lined by fine hairs and mucous which filter the dust particles from the air. The mucous also moistens and warms the incoming air and keeps its temperature nearly equal to that of the body.

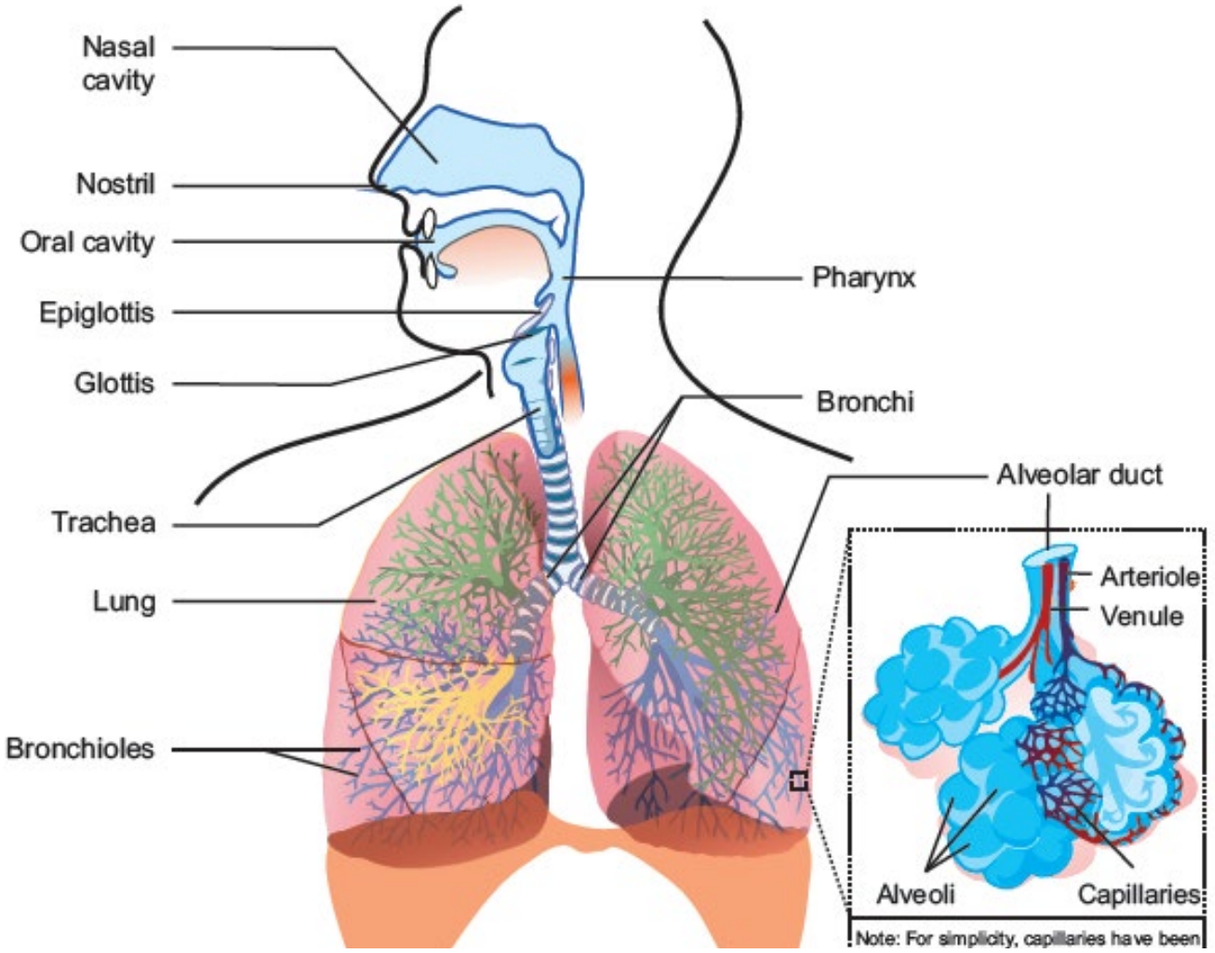


Figure 10.3: The air passageway and the lungs

Recalling

The glottis is guarded by a flap of tissue called the epiglottis.

The nasal cavity opens into the **pharynx** by means of two small openings called internal nostrils. Pharynx is a muscular passage and is common to both food and air.

It extends to the opening of the oesophagus and the larynx. The air goes from the pharynx into the larynx. We know that **glottis** is a narrow opening at the floor of pharynx which leads into larynx.

The larynx is a box, made of cartilage. It is present between pharynx and trachea. It is also called the **voice box**. Two pairs of fibrous bands called vocal cords are stretched across the larynx. The vocal cords vibrate when the air passes through them. This vibration produces sounds.

Larynx continues to the trachea, which is also called the windpipe. It is about 12 cm long tube which lies in front of the oesophagus. There are C-shaped cartilagenous rings in the wall of **trachea.** The cartilages keep the trachea from collapsing even when there is no air in it.

On entering the chest cavity, the trachea divides into two smaller tubes called **bronchi** (Singular: bronchus). The bronchi also have cartilagenous plates in their walls. Each bronchus enters into the lung of its side and then divides into smaller branches.
The bronchi continue dividing in the lungs until they make several fine tubes called **bronchioles.** The bronchioles progressively lose the cartilages as they become narrower. The bronchioles end as fine tubules called the **alveolar ducts.** Each alveolar duct opens into a cluster of pouches called **alveoli**. The alveoli form the respiratory surface in human body. Each alveolus is a sac-like structure lined by a single layer of epithelial cells. It is bound on the outside by a network of capillaries (Fig: 10.3).
The pulmonary artery from the heart containing deoxygenated blood enters the lungs and branches into arterioles and then into capillaries which surround the alveoli. These then join together to form the venules which form pulmonary vein. The pulmonary vein carries the oxygenated blood back to the heart.

The vibrations in vocal cords and the movements of lips, cheeks, tongue and jaws produce specific sounds which result in speech. Speech is an ability that only humans are gifted with and this is one of the characteristics which has put human beings superior to all.

The trachea and the bronchi are also lined with ciliated and glandular cells. The glandular cells secrete mucus which moistens the air and also traps any fine particles of dust or bacteria that have escaped from the nasal cavity. The cilia beat with an upward motion so that the foreign particles along the mucus are sent to the oral cavity from where it may be either swallowed or coughed out.

10.2.2 The Lungs

All the alveoli on one side constitute a lung. There is a pair of lungs in the thoracic cavity. The chest wall is made up of 12 pairs of **ribs** and the rib muscles called **intercoastal muscles**. A thick muscular structure, called **diaphragm,** is present below the lungs.

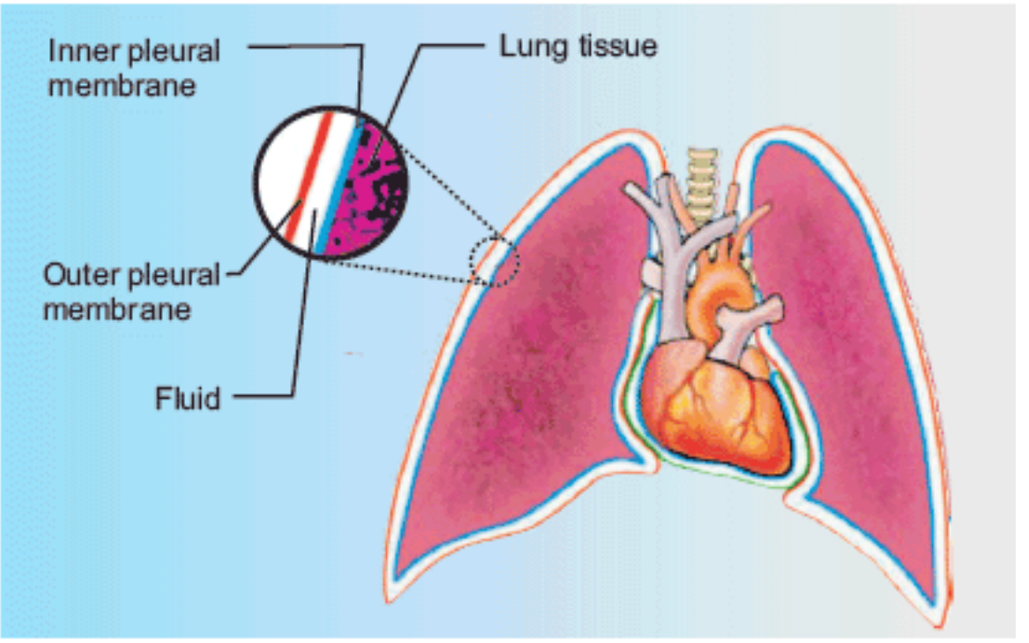


Figure 10.4: Lungs and Pleural membranes

The left lung is slightly smaller and has two lobes and the right lung is bigger with three lobes. They are spongy and elastic organs. The lungs also have blood vessels that are the branches of the pulmonary arteries and veins. Each lung is enclosed by two membranes called the outer pleural membrane and the inner pleural membrane. The membranes enclose a fluid which provides lubrication for the free expanding and contracting of the lungs.

10.2.3 The Mechanism of Breathing

The physical movements associated with the gaseous exchange are called breathing. There are two phases of breathing i.e. inhalation and exhalation.

1. Inspiration or Inhalation

During inspiration, the rib muscles contract and ribs are raised. At the same time the dome-shaped diaphragm contracts and is lowered. These movements increase the area of the thoracic cavity, which reduces the pressure on lungs. As a result, the lungs expand and the air pressure within them also decreases. The air from outside rushes into the lungs to equalize the pressure on both sides.

The breathing movements are involuntary to a large extent. However, we can control the rate of breathing but not for a long time.

2. Expiration or Exhalation

After the gaseous exchange in the lungs, the impure air is expelled out in exhalation. The rib muscles relax bringing the ribs back to the original position. The diaphragm muscles also relax and it gets its raised dome shape. This reduces the space in the chest cavity and increases the pressure on lungs. The lungs contract and the air is expelled out of them.

Humans breathe 16 -20 times per minute in normal circumstances i.e. at rest. The rate of breathing is controlled by the respiratory centre in the brain. The respiratory centre is sensitive to the concentration of carbon dioxide in the blood.

When we do exercise or some hard job our muscle cells carry out cellular respiration at a greater rate. It results in the production of more carbon dioxide which is released in the blood. This greater than normal concentration of carbon dioxide stimulates the respiratory centre of brain. The respiratory centre sends messages to the rib muscles and diaphragm to increase the rate of breathing so that the excess carbon dioxide present in blood can be removed out of body. During exercise or other hard physical works the breathing rate may increase up to 30-40 times per minute.

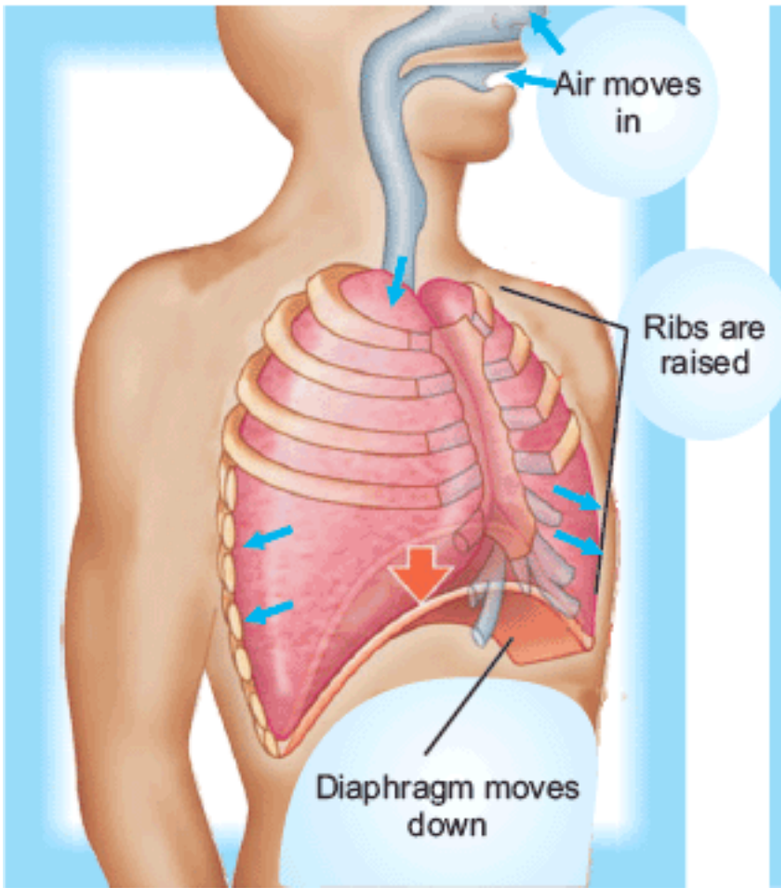


Figure 10.5: Steps of Inhalation

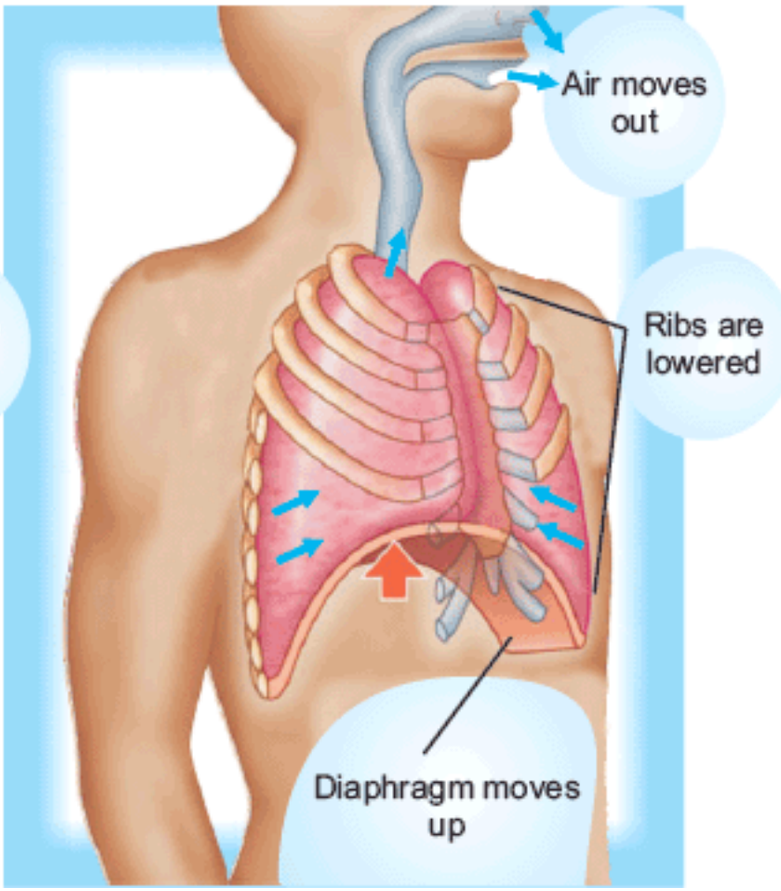


Figure 10.6: Steps of Exhalation

Table 10.1 Comparison between the inspired and expired air

Feature	Inspired Air	Expired Air
Amount of oxygen	21%	16%
Amount of carbon dioxide	0.04%	4%
Amount of nitrogen	79%	79%
Amount of water vapours	Variable	Saturated
Amount of dust particles	Variable	Almost none
Temperature	Variable	Almost equal to body temperature

A model to show the action of diaphragm

Apparatus: a bell jar, 'Y' shaped glass tube, two balloons, rubber sheet

Procedure:

- Take a bell jar. Fix a 'Y' shaped glass tube towards its rounded end, as shown in the figure. Tie a balloon on the open ends of the two branches of glass tube.
- Tie a thin rubber sheet on the open end of the jar. The cavity of the bell jar acts as the thoracic cavity, the "Y" shaped tube as the trachea that branches into bronchi. The rubber sheet acts as the diaphragm and the balloon act as the lungs.
- To demonstrate inspiration, pull the rubber sheet down. The balloons get inflated. This shows how the lungs are filled with air when the diaphragm moves down.
- To demonstrate expiration, the rubber sheet is allowed to go back to its original position. The balloons get deflated. This shows how the lungs are deflated when the diaphragm comes back to its original position.

Practical Work:

Investigate the breathing rate at rest and after exercise

The activity involves students exerting themselves in light exercise and monitoring their breathing rate for a period afterwards.

Problem: What is the effect of exercise on the breathing rate?

Apparatus required: Stopwatch or wristwatch

Background information:

- The autonomic nervous system is specialized for controlling our automatic responses, for example breathing rate, heart rate and digestion. These are the processes that we do without conscious thought.
- The respiratory centre in the brain is sensitive for the blood carbon dioxide concentration.

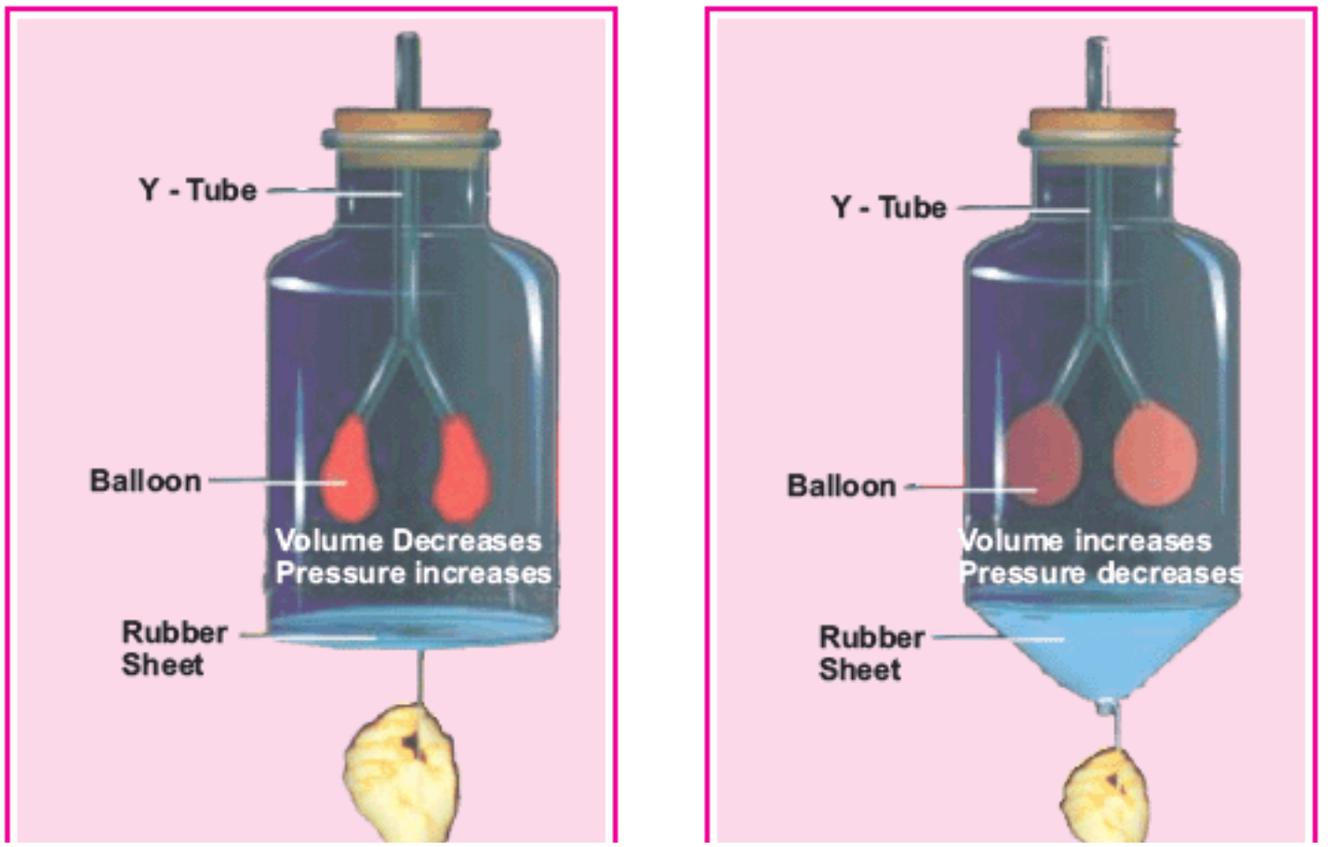


Figure 10.7: Model of the Action of Diaphragm

- When we do exercise, our muscle cells increase the rate of cellular respiration so that the concentration of carbon dioxide increases in blood.
- To remove excess of carbon dioxide and to get more oxygen, respiratory centre sends messages to the respiratory system to increase the breathing rate.

Procedure:

SAFETY: Supervision of activity by teachers will ensure that the activity does not become competitive. The activity should be appropriate to footwear and clothing worn by students, for example, walking briskly up/ down stairs or steps up onto a low bench in the lab. Students with identified physical/ health problems should not be involved. Asthmatics may be able to take part if they use their inhalers prior to starting the exercise.

- The activity will be performed in groups (each consisting of 3 students).
- Each group will note down the readings in the form of table.

1. Each group will take the breathing rate, at rest, of its members and will get the average.
2. The group members will do some light exercise (e.g; running for 5 minutes).
3. The group will take the breathing rate of its members after exercise and will get the average.

4. The members will do more hard exercise (running for 10 minutes).
5. The group will take the breathing rate of its members after hard exercise and will get the average.

Evaluation:

- What was the average breathing rate at rest?
- What was the average breathing rate after light exercise?
- After which exercise, the breathing rate showed more increase?
- Why did the breathing rate increase during exercise?

Practical Work:

Find out how much air a person can take into his / her lungs

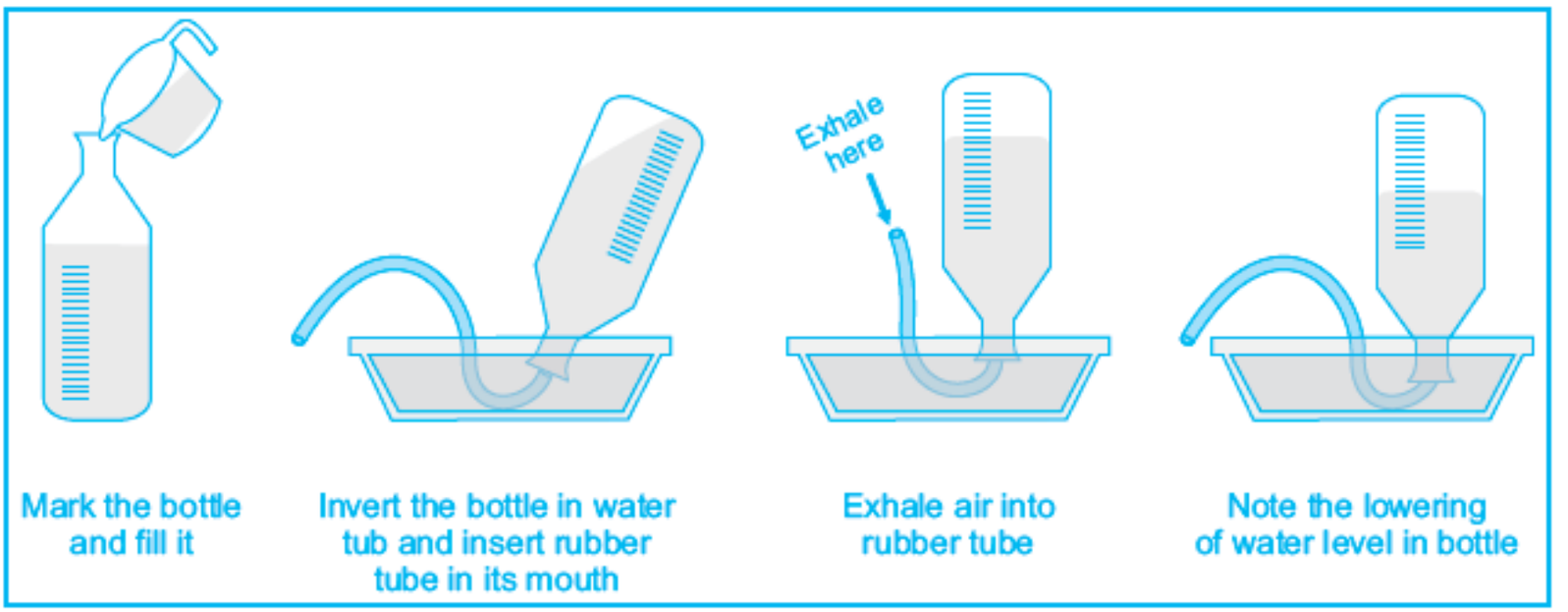
Apparatus required: Water tub, plastic bottle (5 litres), rubber tube (0.5 metre long), plastic cover

Background Information:

- Lungs have a limited capacity for taking and keeping air inside them.

Procedure:

1. Take a 5 litre plastic bottle and graduate it externally with 100 ml distance.
2. Fill the bottle with water and cover it.
3. Fill 1/3 portion of the water tub and invert the plastic bottle in the tub in such a way that mouth of the bottle is dipped in water.
4. Remove the cover from the mouth of the bottle and insert one end of the rubber tube into the bottle.
5. Take a deep breath and exhale the air into the bottle through the rubber tube.



Observation:

- Note the lowering of the water level in the bottle.

Result:

- The water level lowers when the exhaled air goes in the bottle. The volume of water that leaves the bottle is equal to the volume of the air exhaled from the lungs.

Evaluation:

- What does the lowering of water level in the bottle indicate?

Practical Work:

Demonstrate through experiment that the exhaled air contains carbon dioxide

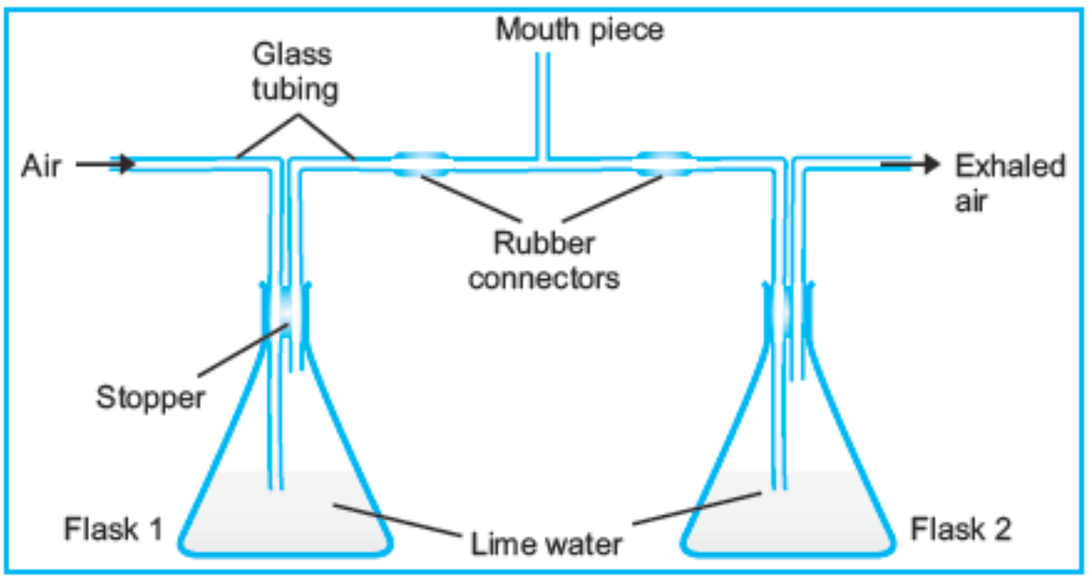
Apparatus required: Conical flasks, glass tubing, double-hole stoppers, limewater

Background Information:

- The exhaled air contains more carbon dioxide as compared to the inhaled air.

Procedure:

1. Take two conical flasks (with limewater in each). Enclose the mouths of the flasks with double-hole stoppers.
2. Adjust the glass tubing as given in the picture.
3. Breathe in and out through the mouthpiece for 10 times.



Observation:

- Observe the colour of the limewater after a few minutes.
- Look for differences in the cloudiness of the limewater in the two flasks.

Results:

- Conclude why the limewater in flask 2 turned more cloudy than in flask 1.

? What part of the blood transports oxygen from lungs to the cells of the body?

Haemoglobin in Red Blood Cells

10.3 Respiratory Disorders

There are a number of respiratory disorders which affect people. The percentage of such disorders is particularly high in Pakistan. It is due to the more concentration of air pollutants not only in the urban but also in the rural atmosphere. Some of the important respiratory disorders are described next.

1. Bronchitis

Bronchitis is the inflammation of the bronchi or bronchioles. It results in excessive secretions of mucus into the tubes, leading to the swelling of tubular walls and narrowing of tubes (Fig. 10.8). It is caused by viruses, bacteria or exposure to chemical irritants (e.g. tobacco smoke).

There are two major types of bronchitis i.e. acute and chronic. The acute bronchitis usually lasts about two weeks and patients recover with no permanent damage to the bronchi or bronchioles. In **chronic bronchitis**, the bronchi develop chronic inflammation. It usually lasts for three months to two years.

Symptoms of bronchitis include a cough, mild wheezing, fever, chills and shortness of breath (especially when doing hard job).

2. Emphysema

Emphysema is the destruction of the walls of the alveoli. It results in larger sacs but with less surface area for gaseous exchange (Fig. 10.9). As lung tissue breaks down, the lungs do not come back to their original shape after exhalation. So air cannot be pushed out and is trapped in the lungs.

The majority of people diagnosed with chronic bronchitis are 45 years of age or older.

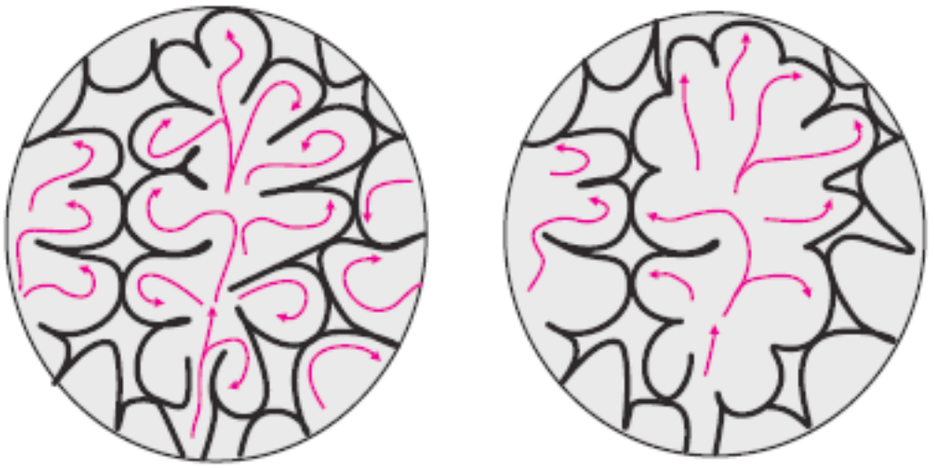


Figure 10.9: The Alveoli; normal (left) and emphysema (right)

The symptoms of emphysema include shortness of breadth, fatigue, recurrent respiratory infections and weight loss. By the time the symptoms of emphys appear, the patient has usually lost 50% to 70% of his / her lung tissue. The level of oxygen in blood may get so low that it causes serious complications.

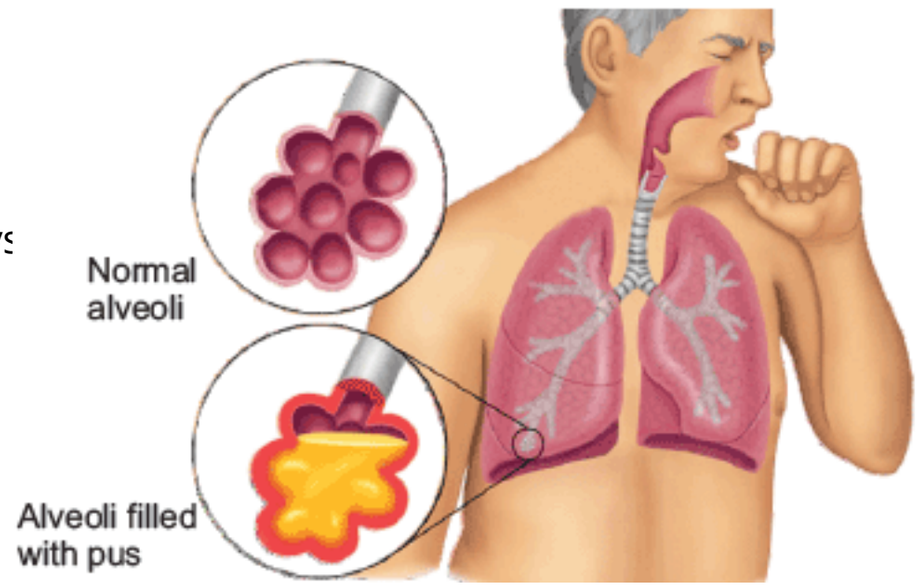


Figure 10.10: Pneumonia

3. Pneumonia

Pneumonia is an infection of lungs. If this infection affects both lungs then, it is called double pneumonia. The most common cause of pneumonia is a bacterium, Streptococcus pneumoniae.

Some viral (influenza virus) and fungal infections may also lead to pneumonia. When the causative organisms enter the alveoli, they settle there and grow in number. They break the lung tissues and the area becomes filled with fluid and pus. The symptoms of pneumonia include a cold that is followed by a high fever, shivering, and a cough with sputum production. Patient may become short of breath. The patient's skin colour may change and become dusky or purplish. It is due to poor oxygenation of blood. Vaccines are available to prevent pneumonia caused by *S. pneumoniae*. Antibiotics are used in the treatment of this type of pneumonia.

Prior to the discovery of antibiotics, one-third of pneumonia patients died from the infection.

4. Asthma

Asthma is a form of allergy, in which there is inflammation of the bronchi, more mucous production and narrowing of the airways (Fig. 10.11). In asthma patients, the bronchi and bronchioles become sensitive to different allergens (allergy causing factors) e.g. dust, smoke, perfumes, pollens etc. When exposed to any of such allergens, the sensitive airways show immediate and excessive response of constriction. In this condition, the patient feels difficulty in breathing.

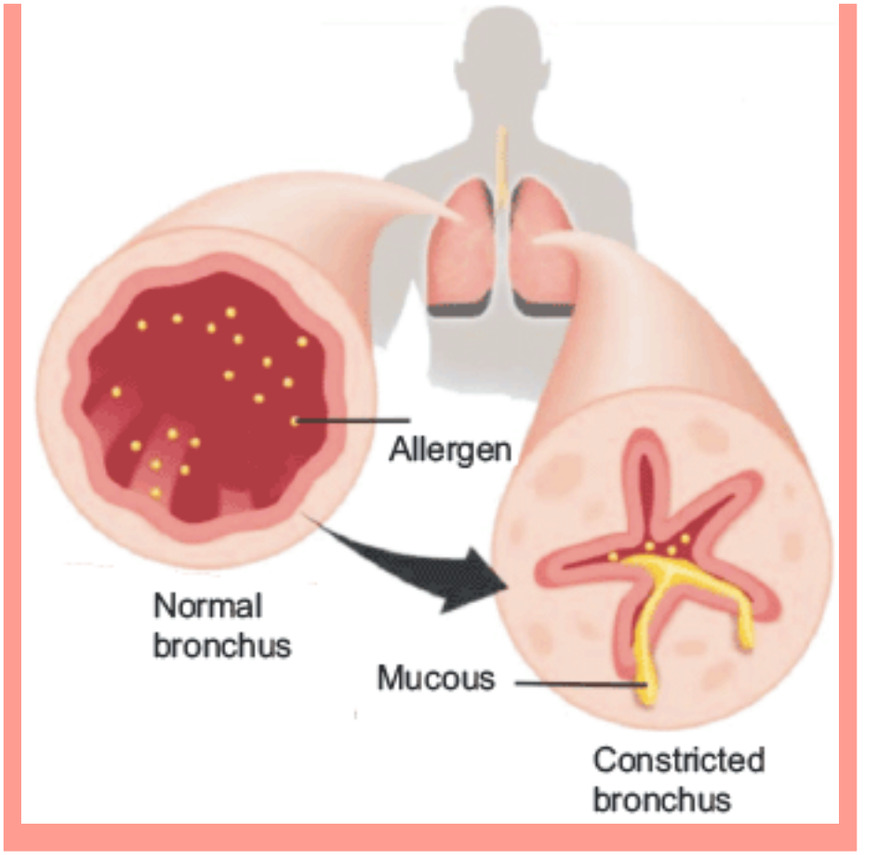


Figure 10.11: Asthma

The symptoms of asthma vary from person to person. The major symptoms include shortness of breath (especially with exertion or at night), wheezing (whistling sound when breathing out), cough and chest tightness.

The chemicals with ability to dilate the bronchi and bronchioles are used in the treatment of asthma. Such medicine is given in the form of inhalers.

5. Lung Cancer

Lung cancer is a disease of uncontrolled cell divisions in the tissues of the lung. The cells continue to divide without any control and form tumours. The cellular growth may also invade adjacent tissues beyond the lungs. The most common symptoms are shortness of breath, coughing (including coughing up blood) and weight loss.

Lung cancer is the most common cause of cancer-related deaths and is responsible for more than 1.3 million deaths worldwide annually

The main causes of any cancer include carcinogens (such as those in cigarette smoke), ionizing radiation and viral infection. Smoking is the main cause of lung cancer. This risk of lung cancer is significantly lower in non smokers. Cigarette smoke contains over 50 known carcinogens. Passive smoking (the inhalation of smoke from another's smoking) is also a cause of lung cancer. The smoke from the burning end of a cigarette is more dangerous than the smoke from the filter end.

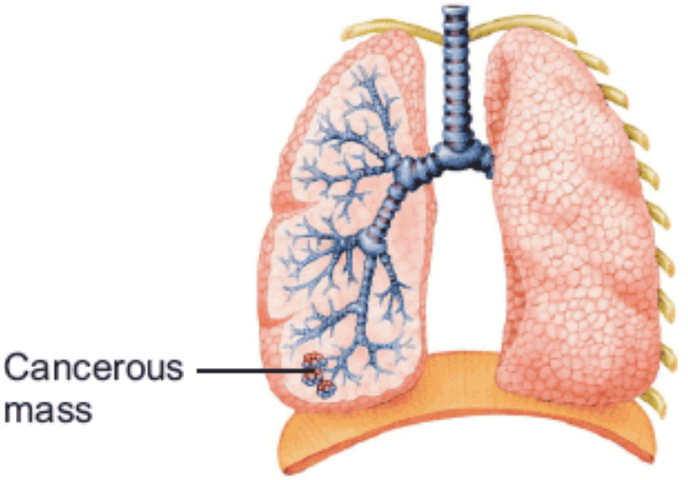


Figure 10.12: Lung Cancer

Eliminating tobacco smoking is a primary goal in the prevention of lung cancer. The World Health Organization has called for governments to stop tobacco advertising to prevent young people from taking up smoking.

10.3.1 Bad Effects of Smoking

Smoking is harmful due to the chemicals in cigarettes and smoke. Tobacco smoke contains over 4,000 different chemicals, out of which at least 50 are carcinogens and many are poisonous.
Many people think that lung cancer is the only smoking-related disease and it is the number one cause of death among smokers. But it is not right. Cigarette smoke affects the body from head to toe. Smokers have a much higher risk of developing a number of life threatening diseases.

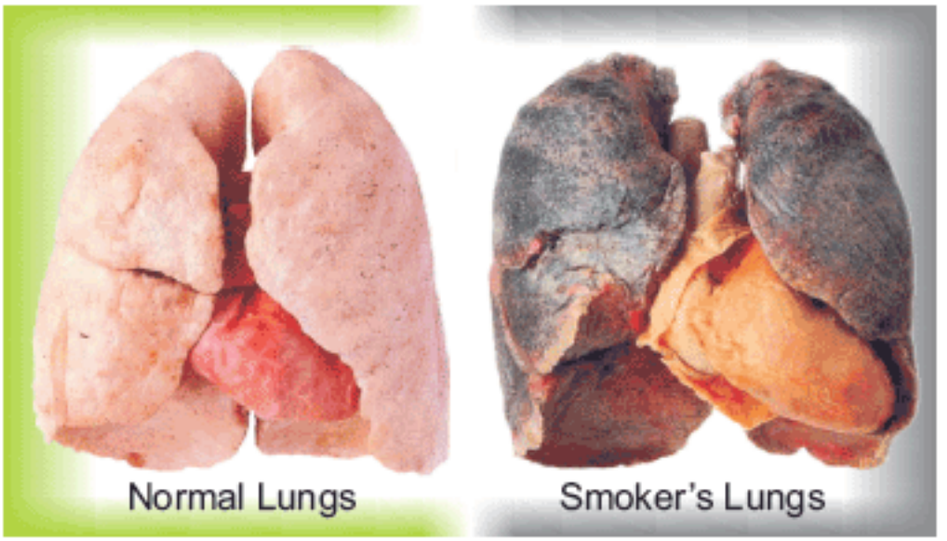
If a person stops smoking, the chance to develop cancer decreases as damage to the lungs is repaired and contaminant particles are gradually removed.

Nicotine is a powerful poison and was widely used as an insecticide in the past. When inhaled through tobacco smoking, it reaches our circulatory system and not only hardens the walls of the arteries but also damages the brain tissues.

According to the WHO, the rates of smoking have declined in the developed world. In the developing world, however, it is rising by 3.4% per year as of 2002.

Smoking may also lead to the cancers in kidneys, oral cavity, larynx, breast, bladder and pancreas etc. Many chemicals in tobacco smoke damage the air passageway, which leads to emphysema and other respiratory disorders.

The World **No** Tobacco Day is celebrated on the 31st of May every year



Smoking also has effects on the circulatory system. The carbon monoxide present in tobacco smoke lessens the oxygen-carrying capacity of haemoglobin. Many other chemicals in smoke increase the production of blood platelets. When platelets are more than the normal numbers, they make the blood viscous and it can lead to arteriosclerosis.

Smokers are at greater risk of developing infections, particularly in the lungs. For example, smoking increases the risk of tuberculosis by two to four times, and of pneumonia by four times.
Smoking is also responsible for weakening and staining the teeth. Tooth loss is 2 to 3 times higher in smokers than in non-smokers.

Non-smokers who are exposed to second-hand smoke (passive smoke) at home or work increase their heart disease risk by 25-30% and their lung cancer risk by 20-30%

Smoking also affects the social life of a person. Smokers may face social un-acceptance because other people may not want to be exposed to other's smoke.

UNDERSTANDING THE CONCEPT

1. How do the different parts of the plant body exchange gases with the environment?
2. Write down the steps of inhalation and exhalation.
3. State the signs and symptoms, causes and treatments of bronchitis, emphysema and pneumonia.
4. How does the tobacco smoke damage the respiratory system?

SHORT QUESTIONS

1. Differentiate between breathing and cellular respiration.
2. Trace the path of air from the nasal cavity to the alveoli.
3. How will you differentiate between a stoma and a lenticel?

THE TERMS TO KNOW

Alveolar duct	Diaphragm	Nasal cavity
Alveolus	Emphysema	Nostril
Asthma	Exhalation	Pneumonia
Breathing	Gaseous exchange	Trachea
Bronchioles	Inhalation	Vocal cords
Bronchus	Larynx	
Bronchitis	Lenticels	

ACTIVITIES

1. Investigate the effect of light on the net gaseous exchange from leaf, by using bicarbonate as the indicator.
2. Investigate the breathing rate at rest and after exercise.
3. Find out how much air a person can take into his lungs.
4. Demonstrate through experiment that carbon dioxide is exhaled during respiration.

SCIENCE, TECHNOLOGY AND SOCIETY

1. Evaluate the effects of tilling on roots for better exchange of gases with the soil air.
2. Outline the concept of Artificial Ventilator for artificial breathing in patients.
3. Interpret the dangers of breathing in exhausts of fossil fuels (Petrol and others)
4. Rationalize the importance of cross ventilation in homes.
5. Assess the adverse effects associated with smoking on health.
6. Point out bad social aspects of smoking.

ON-LINE LEARNING

1. en.wikipedia.org/wiki/Respiratory_system
2. www.biotopics.co.uk/humans/resyst.html
3. www.who.int/respiratory/
4. www.tutorvista.com › Science › Science II › Respiration

CHAPTER

11 Homeostasis

Animation 11.1: Homeostasis
Source & Credit: Lionden

Homeostasis may be defined as the maintenance of the internal conditions of body at equilibrium, despite changes in the external environment. For example, the core temperature of human body remains at about 37°C despite fluctuations in the surrounding air temperature. Similarly, the blood glucose level remains about 1g per litre despite eating a meal rich in carbohydrates. Body cells need the internal environment in which conditions do not change much. Stable internal conditions are important for the efficient functioning of enzymes. The following are some process of homeostasis.

Osmoregulation: It is maintenance of the amounts of water and salts in body fluids (i.e. blood and tissue fluids). We know that the relative amounts of water and salts in body fluids and inside cells control by the processes of diffusion and osmosis, which are essential for the functioning of cells (Recall "the concept of tonicity" from Grade IX Biology).

Thermoregulation: The maintenance of internal body temperature is called thermoregulation. The enzymes of body work best at particular temperatures (optimum temperature). Any change in body temperature may affect the functioning of enzymes.

Excretion is also a process of homeostasis. In this process, the metabolic wastes are eliminated from body to maintain the internal conditions at equilibrium.

Metabolic waste means any material that is produced during body metabolism and that may harm the body.

11.1 Homeostasis In Plants

Plants respond to environmental changes and keep their internal conditions constant i.e. homeostasis. They apply different mechanisms for the homeostasis of water and other chemicals (oxygen, carbon dioxide, nitrogenous materials etc).

11.1.1 Removal of Extra Carbon dioxide and Oxygen

In daytime, the carbon dioxide produced during cellular respiration is utilized in photosynthesis and hence it is not a waste product. At night, it is surplus because there is no utilization of carbon dioxide. It is removed from the tissue cells by diffusion. In leaves and young stems, carbon dioxide escapes out through stomata.
In young roots, carbon dioxide diffuses through the general root surface, especially through root hairs. Oxygen is produced in mesophyll cells only during daytime, as a by-product of photosynthesis. After its utilization in cellular respiration, the leaf cells remove the extra amount of oxygen through stomata.

11.1.2 Removal of Extra Water

We know that plants obtain water from soil and it is also produced in the body during cellular respiration. Plants store large amount of water in their cells for turgidity. Extra water is removed from plant body by transpiration.
At night, transpiration usually does not occur because most plants have their stomata closed. If there is a high water content in soil, water enters the roots and is accumulated in xylem vessels. Some plants such as grasses force this water through special pores, present at leaf tips or edges, and form drops. The appearance of drops of water on the tips or edges of leaves is called **guttation** (Fig 11.2).

Figure 11.1: Guttation in different plants

Recalling

Transpiration is the loss of water from plant surface in the form of vapours.

Guttation is not to be confused with dew, which condenses from the atmosphere onto the plant surface.

11.1.3 Removal of Other Metabolic Wastes

Plants deposit many metabolic wastes in their bodies as harmless insoluble materials. For example, calcium oxalate is deposited in the form of crystals in the leaves and stems of many plants e.g. in tomato (Fig. 11.2).

Figure 11.2: Calcium oxalate needles in a leaf cell

The removal of excretory products is a secondary function of leaf fall. If the leaves are not shed, the calcium oxalate just remains as harmless crystals in the leaves

In trees which shed their leaves yearly, the excretory products are removed from body during leaf fall.
Other waste materials that are removed by some plants are resins (by coniferous trees), gums (by keekar), latex (by rubber plant) and mucilage (by carnivorous plants and ladyfinger) etc. (Fig. 11.3).

Resin drops from a cut tree | *Latex being extracted from a tree* | *Mucilage drops on a carnivorous plant*

Figure 11.3: Removal of some wastes in plants

11.1.4 Osmotic Adjustments in Plants

On the basis of the available amount of water and salts, plants are divided into three groups.

- **Hydrophytes** are the plants which live completely or partially submerged in freshwater. Such plants do not face the problem of water shortage. They have developed mechanisms for the removal of extra water from their cells. Hydrophytes have broad leaves with a large number of stomata on their upper surfaces. This characteristic helps them to remove the extra amount of water. The most common example of such plants is water lily.
-
-
- **Xerophytes** live in dry environments. They possess thick, waxy cuticle over their epidermis to reduce water loss from internal tissues. They have less number of stomata to reduce the rate of transpiration. Such plants have deep roots to absorb maximum water from soil. Some xerophytes have special parenchyma cells in stems or roots in which they store large quantities of water. This makes their stems or roots wet and juicy, called **succulent organs.** Cacti (Singular Cactus) are the common examples of such plants.

- **Halophytes** live in sea waters and are adapted to salty environments. Salts enter in the bodies of such plants due to their higher concentration in sea water. On the other hand, water tends to move out of their cells into the hypertonic sea water. When salts enter into cells, plants carry out active transport to move and hold large amount of salts in vacuoles. Salts are not allowed to move out through the semi- permeable membranes of vacuoles. So the sap of vacuoles remains even more hypertonic than sea water. In this way, water does not move out of cells. Many sea grasses are included in this group of plants.

Animation11.2: Osmosis
Source & Credit: Leavingbio

Recalling

Osmosis is the movement of water from hypotonic solutions (less solute concentration) to hypertonic solutions (higher solute concentration), through semipermeable membrane.

Hydrophytes

Halophytes

Xerophytes

Figure 11.4: Three groups of plants

11.2 Homeostasis In Humans

Like other complex animals, humans have highly developed systems for homeostasis.
The following are the main organs which work for homeostasis:

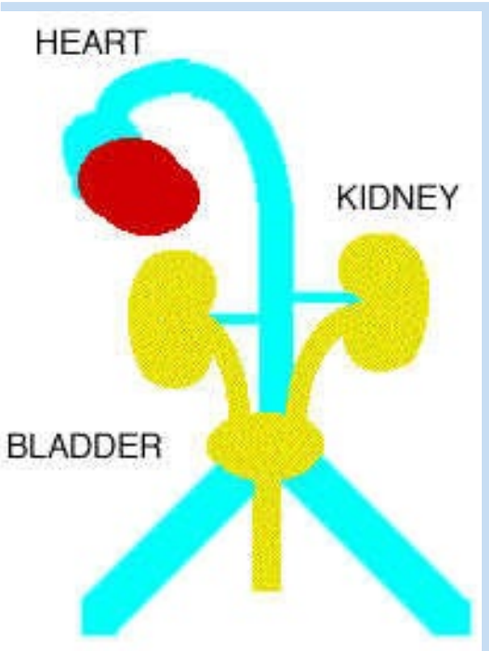
- Lungs remove excess carbon dioxide and keep it in balance.
- Skin performs role in the maintenance of body temperature and also removes excess water and salts.
- The kidney filters excess water, salts, urea, uric acid etc. from the blood and forms urine.

11.2.1 Skin

We know that our skin consists of two layers. Epidermis is the outer protective layer without blood vessels while dermis is the inner layer containing blood vessels, sensory nerve endings, sweat and oil glands, hairs and fat cells.
Skin performs important role in the regulation of body temperature. The thin layer of fat cells in the dermis insulates the body. Contraction of small muscles attached to hairs forms 'Goosebumps'. It creates an insulating blanket of warm air (Fig. 11.5).

Initiating and Planning

Hypothesize why the dogs hang their tongues out and pant



Animation11.3: The Skin,
Source & Credit: Leavingbio

Figure 11.5: Goose bumps

Similarly, skin helps in providing cooling effect when sweat is produced by sweat glands and excess body heat escapes through evaporation. Metabolic wastes such as excess water, salts, urea and uric acid are also removed in sweat.

11.2.2 Lungs

In the previous chapter we have learned how lungs maintain the concentration of carbon dioxide in the blood. Our cells produce carbon dioxide when they perform cellular respiration. From cells, carbon dioxide diffuses into tissue fluid and from there into blood. Blood carries carbon dioxide to lungs from where it is removed in air.

11.3 The Urinary System Of Humans

The excretory system of humans is also called the urinary system. It is formed of one pair of kidneys, a pair of ureters, a urinary bladder and a urethra.

Kidneys filter blood to produce urine and the ureters carry urine from kidneys to urinary bladder. The bladder temporarily stores urine until it is released from body. Urethra is the tube that carries urine from urinary bladder to the outside of body.

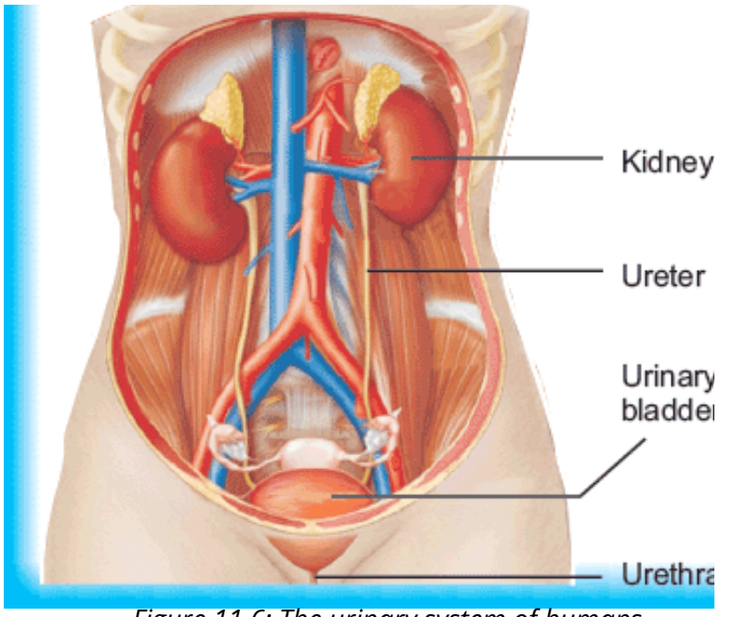


Figure 11.6: The urinary system of humans

11.3.1 Structure of Kidney

Kidneys are dark-red, bean shaped organs. Each kidney is 10 cm long, 5 cm wide and 4 cm thick and weighs about 120 grams. They are placed against the back wall of abdominal cavity just below diaphragm, one on either side of vertebral column. They are protected by the last 2 ribs. The left kidney is a little higher than the right.

The concave side of kidney faces vertebral column. There is a depression, called **hilus**, near the centre of the concave area of kidney. This is the area of kidney through which ureter leaves kidney and other structures including blood vessels, lymphatic vessels and nerves enter and leave kidney.

The longitudinal section of the kidney shows two regions (Fig 11.7). Renal cortex is the outer part of kidney and it is dark red in colour. Renal medulla is the inner part of kidney and is pale red in colour. Renal **medulla** consists of several cone shaped areas called renal **pyramids.** Renal pyramids project into a funnel-shaped cavity called renal **pelvis**, which is the base of ureter.

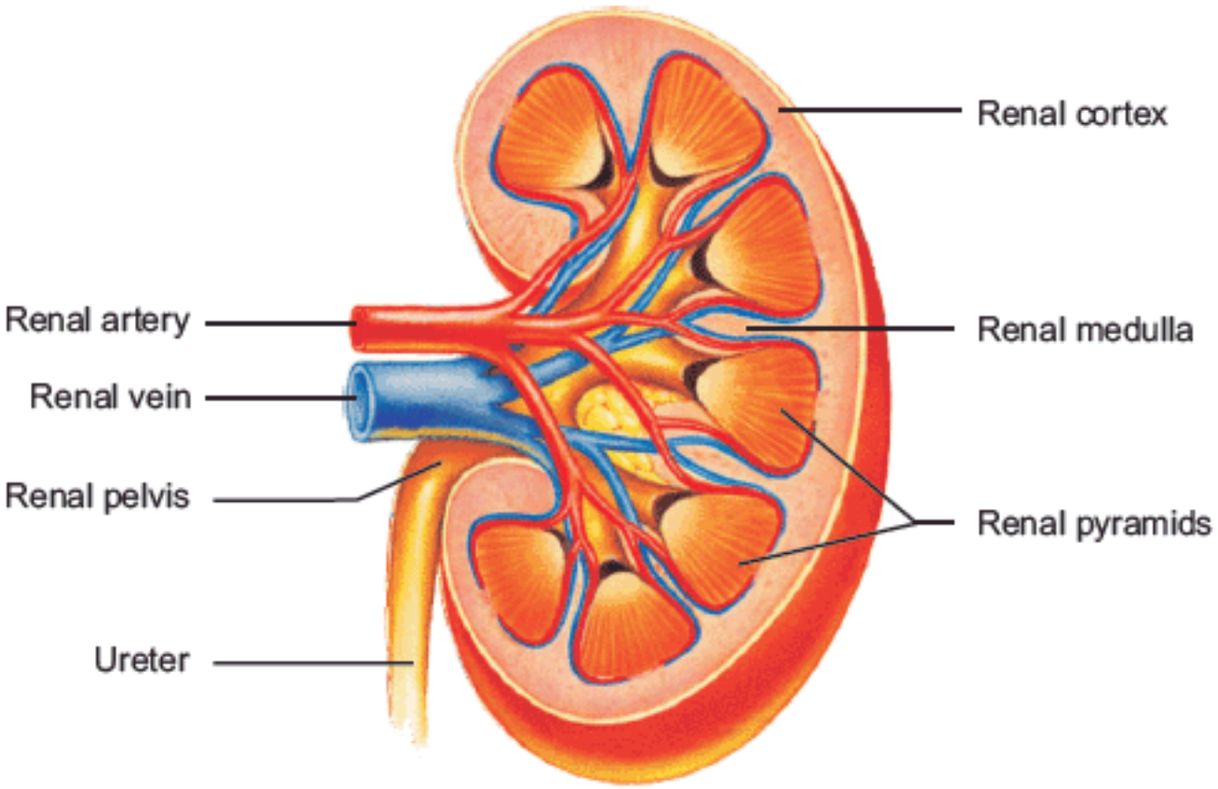


Figure 11.7: The anatomy of a kidney

The functional unit of the kidneys is called **nephron**. There are over one million nephrons in each kidney. There are two parts of a nephron i.e. renal corpuscle and renal tubule (Fig. 11.8). The renal corpuscle is not tubular and has two parts i.e. glomerulus and Bowman's capsule. Glomerulus is a network of capillaries while Bowman's capsule is a cup-shaped structure that encloses glomerulus. The **renal tubule** is the part of nephron which starts after Bowman's capsule. Its first portion is called the **proximal convoluted tubule**. Next portion is U-shaped and is called the **Loop of Henle**. The last portion of renal tubule is the **distal convoluted tubule.** The distal convoluted tubules of many nephrons open in a single collecting duct. Many **collecting ducts** join together to form several hundred **papillary ducts** which drain into renal pelvis.

The capillaries of the glomerulus arise from the afferent arteriole and join to form the efferent arteriole

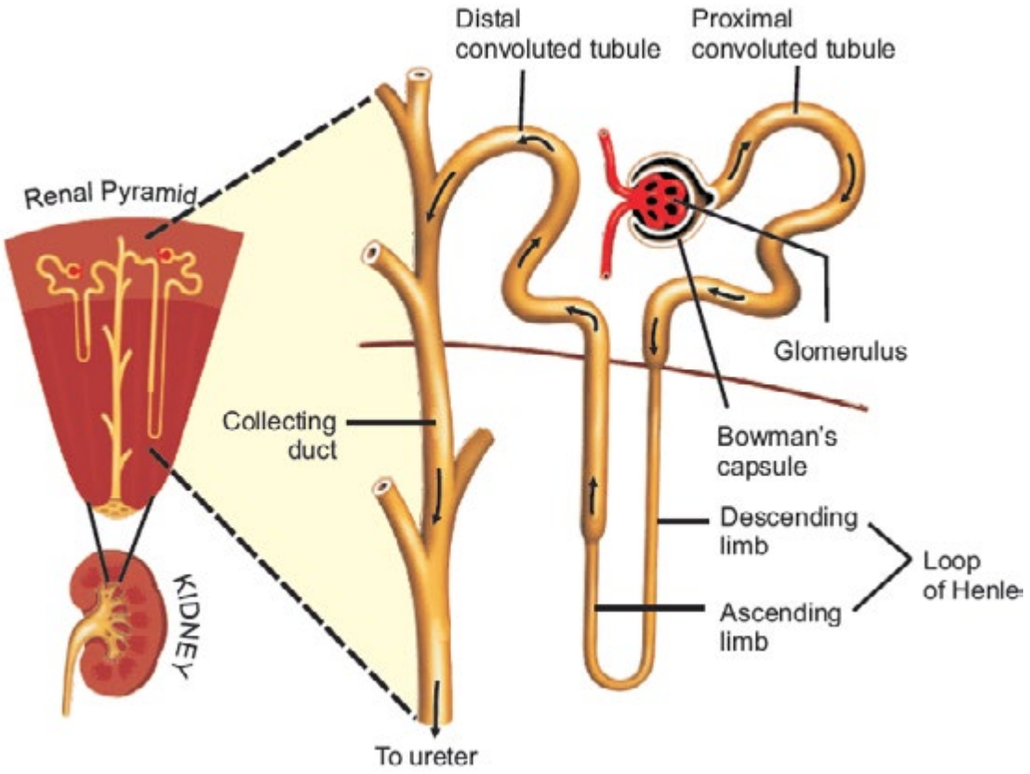


Figure 11.8: The structure of a nephron
(The capillaries surrounding the renal tubule are not shown for simplicity)

11.3.2 Functioning of Kidney

The main function of kidney is urine formation, which takes place in three steps (Fig. 11.9).The first step is **pressure filtration.** When blood enters the kidney via the renal artery, it goes to many arterioles, and then to the glomerulus. The pressure of blood is very high and so most of the water, salts, glucose and urea of blood is forced out of glomerular capillaries. This material passes into the Bowman's capsule and is now called **glomerular filtrate.**

The second step is the **selective re-absorption**. In this step about 99% of the glomerular filtrate is reabsorbed into the blood capillaries surrounding renal tubule. It occurs through osmosis, diffusion and active transport. Some water and most of the glucose is reabsorbed from the proximal convoluted tubule. Here, salts are reabsorbed by active transport and then water follows by osmosis. The descending limb of loop of Henle allows the reabsorption of water while the ascending limb of Loop of Henle allows the reabsorption of salts. The distal convoluted tubule again allows the reabsorption of water into the blood. The third step is the **tubular secretion**. Different ions, creatinine, urea etc. are secreted from blood into the filtrate in renal tubule. This is done to maintain blood at a normal pH (7.35 to 7.45).

Blood cells and proteins are not filtered through the glomerular capillaries because they are relatively larger in size.

At the final stage urine is only 1% of the originally filtered volume. The typical volume of urine produced by an average adult is around 1.4 litres per day.

Initiating and Planning

- Predict about the functioning of body without a kidney.
- Relate too much sugar intake by a diabetic with the functioning of kidney.

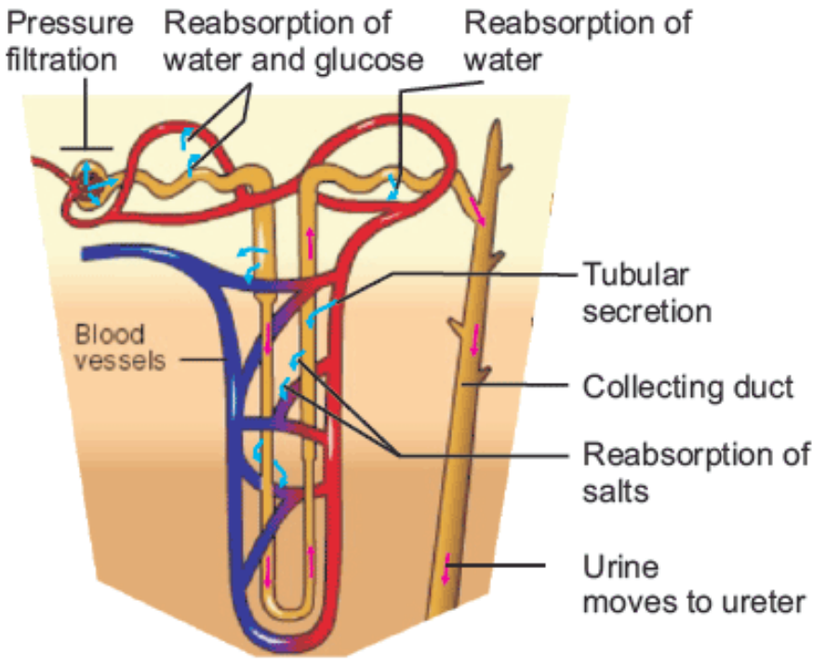


Figure 11.9: Functioning of kidney (nephron)

Table 11.1 Normal chemical composition of urine (Source: NASA Contractor Report)

Water	95%
Urea	9.3 g/l
Chloride ions	1.87 g/l
Sodium ions	1.17 g/l
Potassium ions	0.750 g/l
Other ions and compounds	Variable amounts

After the above mentioned steps, the filtrate present in renal tubules is known as **urine.** It moves into collecting ducts and then into pelvis.

11.3.3 Osmoregulatory Function of Kidney

Osmoregulation is defined as the regulation of the concentration of water and salts in blood and other body fluids. Kidneys play important role in osmoregulation by regulating the water contents of blood. It is an important process as excessive loss of water concentrates the body fluids whereas excess intake of water dilutes them.

When there is excess water in body fluids, kidneys form dilute **(hypotonic)** urine. For this purpose, kidneys filter more water from glomerular capillaries into Bowman's capsule. Similarly less water is reabsorbed and abundant dilute urine is produced. It brings down the volume of body fluids to normal.

When there is shortage of water in body fluids, kidneys filter less water from glomerular capillaries and the rate of reabsorption of water is increased. Less filtration and more reabsorption produce small amount of concentrated **(hypertonic)** urine. It increases the volume of body fluids to normal. This whole process is under hormonal control.

Practical: Examination of the longitudinal section of a mammalian kidney

- Teacher will make a kidney of a sheep or goat available in the laboratory or classroom.
- Teacher will dissect the kidney longitudinally.
- Students will observe the cut halves with the help of hand lenses and will locate the renal cortex, medulla, pyramids and pelvis.

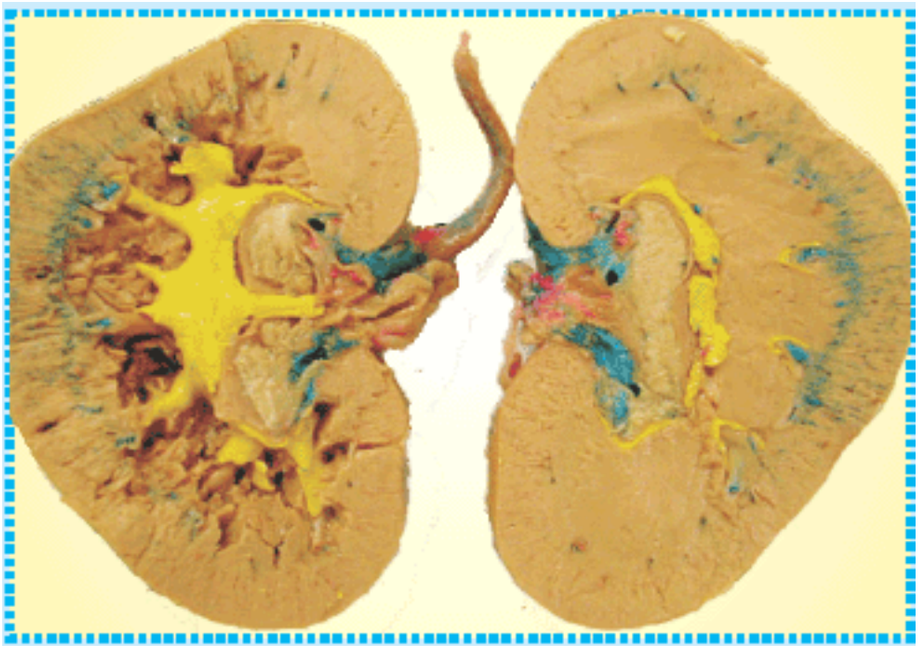
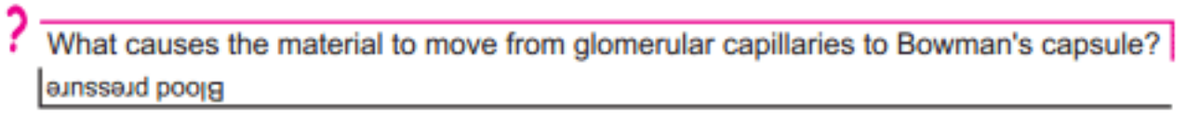


Figure 11.10: Kidneys of goat (longitudinal sections)

Students will draw the diagram of the longitudinal section of the kidney.



Activity: Trace the movement of a molecule of urea from blood to urethra using a flow chart diagram.

11.4 Disorders Of Kidney

There are many different kidney disorders.

11.4.1 Kidney Stones

When urine becomes concentrated, crystals of many salts e.g. calcium oxalate, calcium and ammonium phosphate, uric acid etc. are formed in it. Such large crystals cannot pass in urine and form hard deposits called kidney stones.

Most stones start in kidney. Some may travel to ureter or urinary bladder.

The major causes of kidney stones are age, diet (containing more green vegetables, salts, vitamins C and D), recurring urinary tract infections, less intake of water, and alcohol consumption. The symptoms of kidney stones include severe pain in kidney or in lower abdomen, vomiting, frequent urination and foul-smelling urine with blood and pus.
About 90% of all kidney stones can pass through the urinary system by drinking plenty of water. In surgical treatment, the affected area is opened and stone(s) are removed. **Lithotripsy** is another method for the removal of kidney stones. In this method, non-electrical shock waves from outside are bombarded on the stones in the urinary system. Waves hit the dense stones and break them. Stones become sand-like and are passed through urine.

Abu Nasr al-Farabi (872-951) was a prominent scientist who wrote many books that contained information about kidney diseases. The genius Abu al-Qasim Al-Zahrawi (known as Albucasis: 936-1013), is considered to be Islam's greatest surgeon who invented many surgical procedures including the surgical removal of stones from the urinary bladder. His encyclopedia, Al-Tasrif ("The Method"), contained over 200 surgical medical instruments he personally designed.

11.4.2 Kidney (Renal) failure

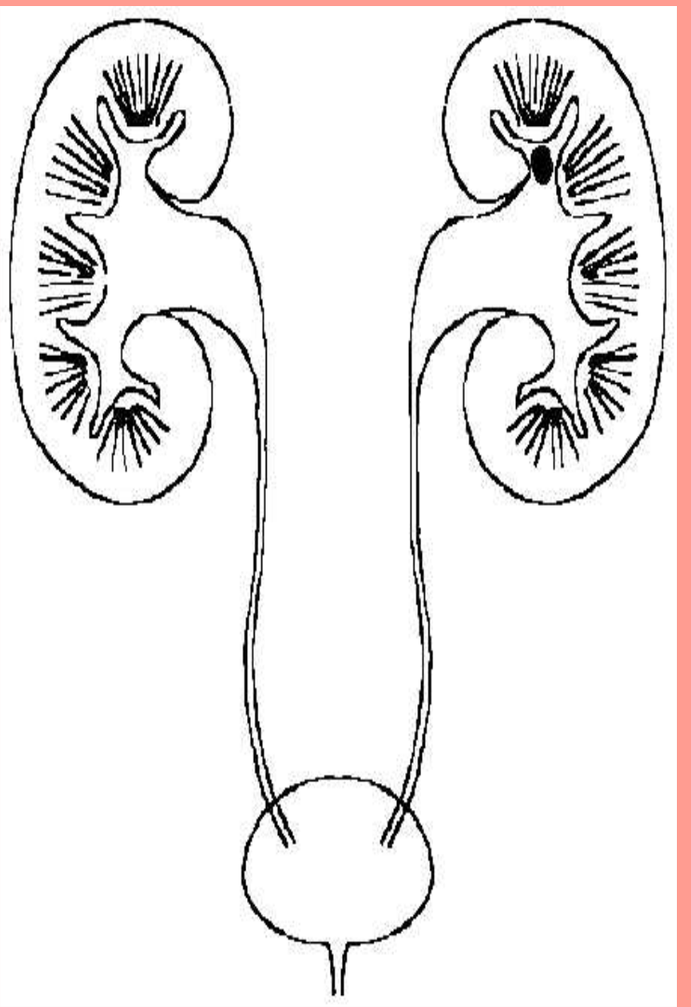
Kidney failure means a complete or partial failure of kidneys to function. Diabetes mellitus and hypertension are the leading causes of kidney failure. In certain cases, sudden interruption in the blood supply to kidney and drug overdoses may also result in kidney failure.

The main symptom of kidney failure is the high level of urea and other wastes in blood, which can result in vomiting, nausea, weight loss, frequent urination and blood in urine. Excess fluids in body may also cause swelling of legs, feet face and shortness of breath.

The kidney failure is treated with dialysis and kidney transplant.

a. Dialysis

Dialysis means the cleaning of blood by artificial ways. There are two methods of dialysis.



Animation 11.4: Stone Kidney,
Source & Credit: Renux.dmed

1. Peritoneal Dialysis

In this type of dialysis, the dialysis fluid is pumped for a time into the peritoneal cavity which is the space around gut (Fig. 11.11). This cavity is lined by peritoneum. Peritoneum contains blood vessels. When we place dialysis fluid in peritoneal cavity, waste materials from peritoneal blood vessels diffuse into the dialysis fluid, which is then drained out. This type of dialysis can be performed at home, but must be done every day.

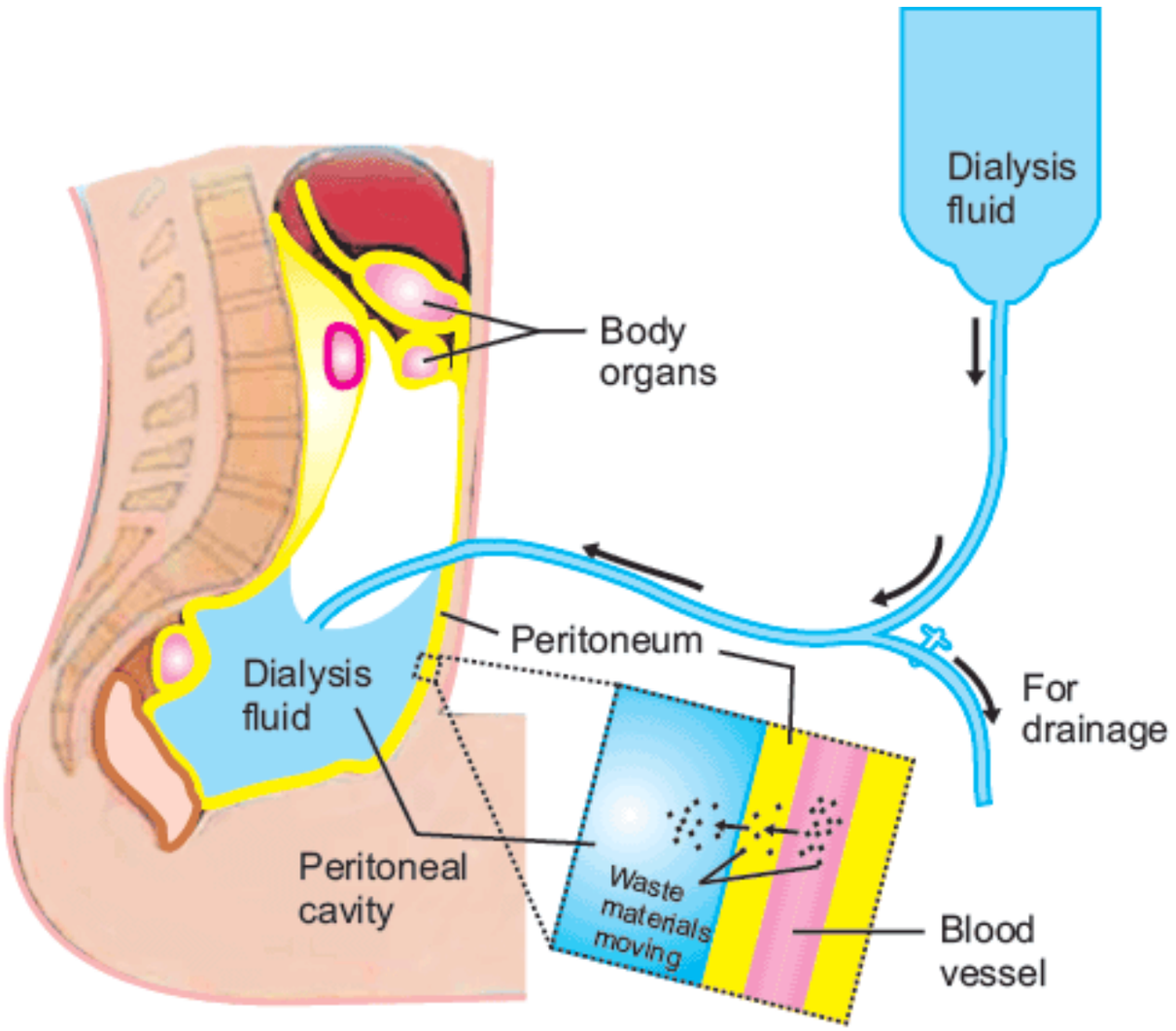


Figure 11.11: Peritoneal dialysis

2. Haemodialysis

In haemodialysis, patient's blood is pumped through an apparatus called **dialyzer.** The dialyzer contains long tubes, the walls of which act as semi-permeable membranes (Fig. 11.12). Blood flows through the tubes while the dialysis fluid flows around the tubes.
Extra water and wastes move from blood into the dialysis fluid. The cleansed blood is then returned back to body. The haemodialysis treatments are typically given in dialysis centres.

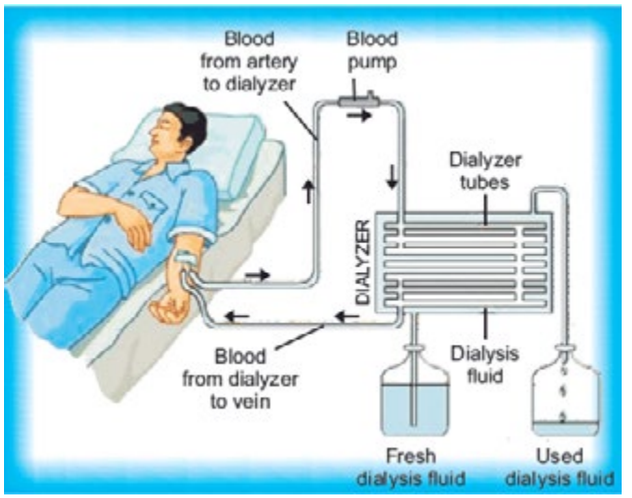


Figure 11.12: Haemodialysis

b. Kidney Transplant

We know that dialysis needs to be repeated after every few days and is unpleasant for patients and attendants. Another treatment for the end-stage kidney failure is kidney transplantation. It is the replacement of patient's damaged kidney with a donor healthy kidney.
Kidney may be donated by a deceased-donor or living-donor. The donor may or may not be a relative of the patient. Before transplant, the tissue proteins of donor and patient are matched. The donor's kidney is transplanted in patient's body and is connected to the patient's blood and urinary system. The average lifetime for a donated kidney is ten to fifteen years. When a transplant fails, the patient may be given a second kidney transplant. In this situation, the patient is treated through dialysis for some intermediary time. Problems after a transplant may include transplant rejection, infections, imbalances in body salts which can lead to bone problems and ulcers.

Analyzing and Interpreting

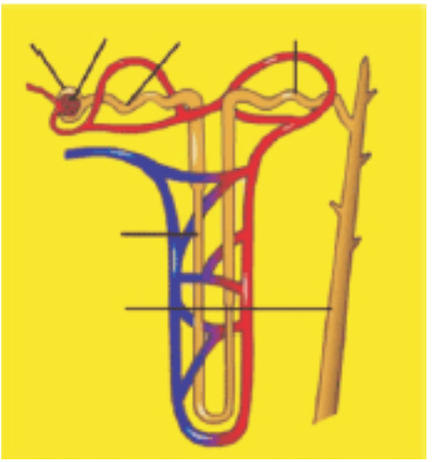
- Rationalize why dialysis machine is considered as artificial kidney.
- Design dialysis apparatus by cellophane paper and empty photographic film case.

UNDERSTANDING THE CONCEPT

1. Describe the process of selective re-absorption in the kidneys.
2. How do the plants excrete extra water and salts from their bodies?
3. What is the functional unit of the kidney? Describe its structure and draw labelled diagram.
4. What steps are involved in the formation of urine in the kidneys?
5. “Along with excretion, kidneys also play role in Osmoregulation.” Comment on this statement.

SHORT QUESTIONS

1. What are the major organs involved in homeostasis in human body? State the roles of each of these organs.
2. Identify and label the following: diagram.



THE TERMS TO KNOW		
Bowman's capsule	Homeostasis	Renal pyramid
Collecting duct	Lithotripsy	Renal tubule
Dialysis	Loop of Henle	Selective reabsorption
Dialyzer	Nephron	Tubular secretion
Distal convoluted tubule	Osmoregulation	Ureter
Excretion	Papillary ducts	Urethra
Glomerular filtrate	Peritoneal dialysis	Urinary bladder
Glomerulus	Pressure filtration	Urinary system
Guttation	Proximal convoluted tubule	
Hemodialysis	Renal corpuscle	
Hilus	Renal pelvis	

ACTIVITIES

1. Examine the structure of kidney (sheep or goat kidney / model).
2. Trace the movement of a molecule of urea from blood to urethra using a flow chart diagram.

SCIENCE, TECHNOLOGY AND SOCIETY

1. Realize the importance of drinking plentiful water daily.
2. Predict how the kidney helps to overcome the problem of dehydration.
3. Recognize the right treatments of kidney problems.

ON-LINE LEARNING

1. biology-animations.blogspot.com/.../nephron-animation.html
2. highered.mcgraw-hill.com/sites
3. leavingbio.net/EXCRETION/EXCRETION.html
4. www.tutorvista.com/.../excretion/excretory-system-animation.php

CHAPTER

12

Coordination and Control

Animation 12.1: Neuron
Source & Credit: nichd.nih

The tissues and organs in the bodies of multicellular organisms do not work independently of each other. They work together performing their many tasks as the needs of the whole body. This means that these activities are coordinated. Coordination also enables the organism to respond to happenings in the world around it.

One familiar example of coordination is the way in which muscles work together during movement. When a boy runs to catch a ball, he uses hundreds of muscles to move his arms, legs and back. His nervous system uses information from his sense organs and coordinates these muscles. Due to this coordination, the muscles contract in the correct sequence, power and length of time. But that is not all. Such activities involve many other kinds of coordination. For example breathing and heartbeat rates are increased blood pressure is adjusted, and extra heat is removed fast from the body.

How does it happen? Life activities are controlled and coordinated i.e. body works as one unit, in which its different organs and systems cooperate and work in harmony with each other.

When we are writing something, our hands and fingers work in collaboration with our muscles, eyes, thoughts etc. and then very intricate movements result.

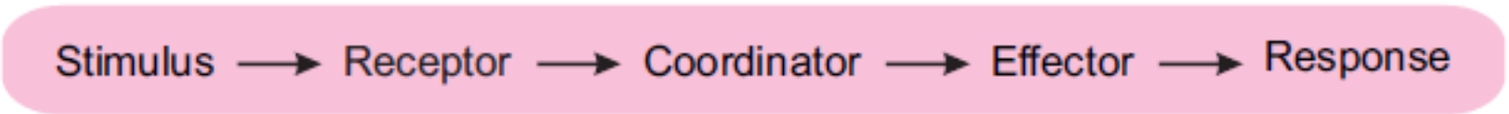
Animation 12.2: HumanAnatomy
Source & Credit: soundtells

12.1 Types Of Coordination

There are two types of coordination in organisms:
i. Nervous coordination brought about by nervous system and
ii. Chemical coordination brought about by endocrine system.
Animals have both the nervous and chemical coordination systems in their bodies while plants and other organisms have only chemical coordination.

12.1.1 Coordinated Action

A coordinated action has five components;



i- Stimuli

What happens when we touch a snail? We might have seen the flowers of sunflower plant moving towards the sun. What could be the reason for all this? Touch, light etc. are factors that can bring about certain responses in living organisms. These factors are called stimuli. We can define a stimulus as any change in environment (external and internal), which can provoke a response in organism. More examples of stimuli are heat, cold, pressure, sound waves, presence of chemicals, microbial infections etc.

Coordination also takes place in unicellular organisms. The response to stimuli is brought about through chemicals

ii- Receptors

Stimuli are detected by special organs, tissues or cells of body. For example sound waves are detected by ears, light is detected by eyes, chemicals in air are detected by nose and so on. The organs, tissues or cells which are specifically built to detect particular type of stimuli are called receptors.

iii- Coordinators

These are the organs that receive information from receptors and send messages to particular organs for proper action. In nervous coordination, brain and spinal cord are coordinators. They receive information and send messages through neurons in the form of nerve impulses. On the other hand, in chemical coordination, various endocrine glands play the role of coordinators. They receive information in the form of various chemicals and send messages by secreting particular hormones in blood.

iv- Effectors

These are the parts of body which receive messages from coordinators and produce particular responses. In nervous coordination, neurons carry messages from coordinators (brain and spinal cord) to muscles and glands, which act as effectors. In chemical coordination, particular hormones carry messages from coordinators (endocrine glands) to particular target tissues, which act as effectors. For some hormones, nephrons act as effectors. Similarly, bones and liver act as effectors for many hormones.

v- Response

On receiving the message from coordinators, the effector performs action. This action is called response. For example, pulling our hand away from something very hot and the movement of the flower of sunflower towards light are responses. Usually, nervous coordination produces immediate but short-living responses while chemical coordination produces slow but long-living responses.

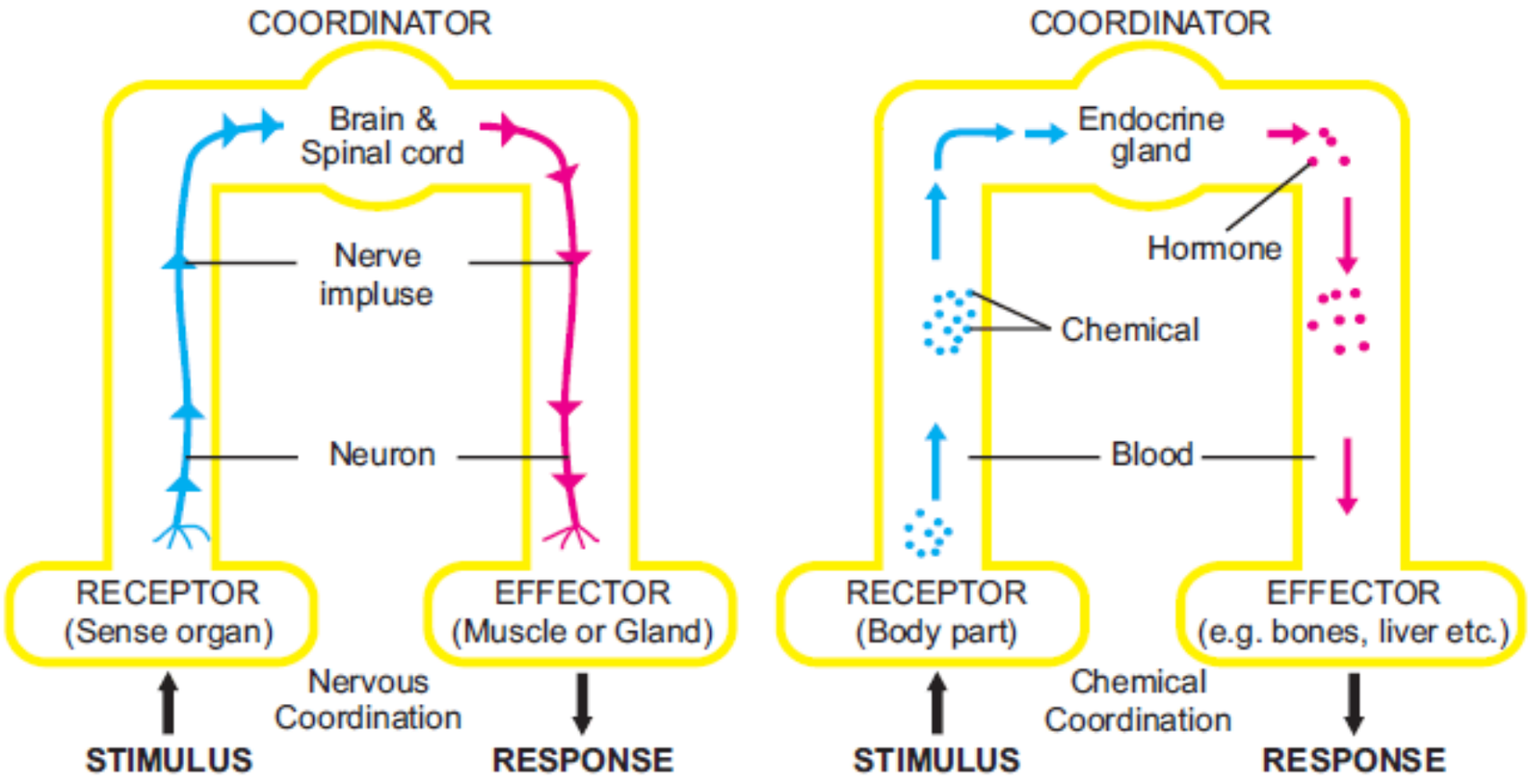


Figure 12.1: Nervous and chemical coordination

Recording Skills:

- Using the knowledge gained from the above topic, draw a table that can show the differences between the two types of coordination i.e. nervous coordination and chemical coordination.

12.2 Human Nervous System

We have understood the basic model of the working of nervous system. The nervous system in man and in other higher animals is composed of two major components i.e. central nervous system and peripheral nervous system.

Central nervous system comprises of coordinators i.e. brain and spinal cord while peripheral nervous system consists of nerves that arise from central nervous system and spread in different parts of body. All these components are made of neurons. Now we will first examine the structure and types of neuron and then we will go to the divisions of nervous system.

12.2.1 Nerve cell or Neuron

Nerve cell or neuron is the unit of the nervous system. The human nervous system consists of billions of neurons plus supporting (neuroglial) cells. Neurons are specialized cells that are able to conduct nerve impulses from receptors to coordinators and from coordinators to effectors. In this way they communicate with each other and with other types of body cells.
The nucleus and most of the cytoplasm of a neuron is located in its **cell body**. Different processes extend out from cell body. These are called **dendrites** and axons. Dendrites conduct impulses toward cell body and **axons** conduct impulses away from cell body (Fig 12.2).

Animation 12.3: Nerve impulse
Source & Credit: spiritualgarden

Unlike ordinary cells, mature neurons never divide. But a protein called nerve-growth-factor promotes the regeneration of broken nerve cells. The degenerating brain cells could be repaired, by using embryonic stem cells.

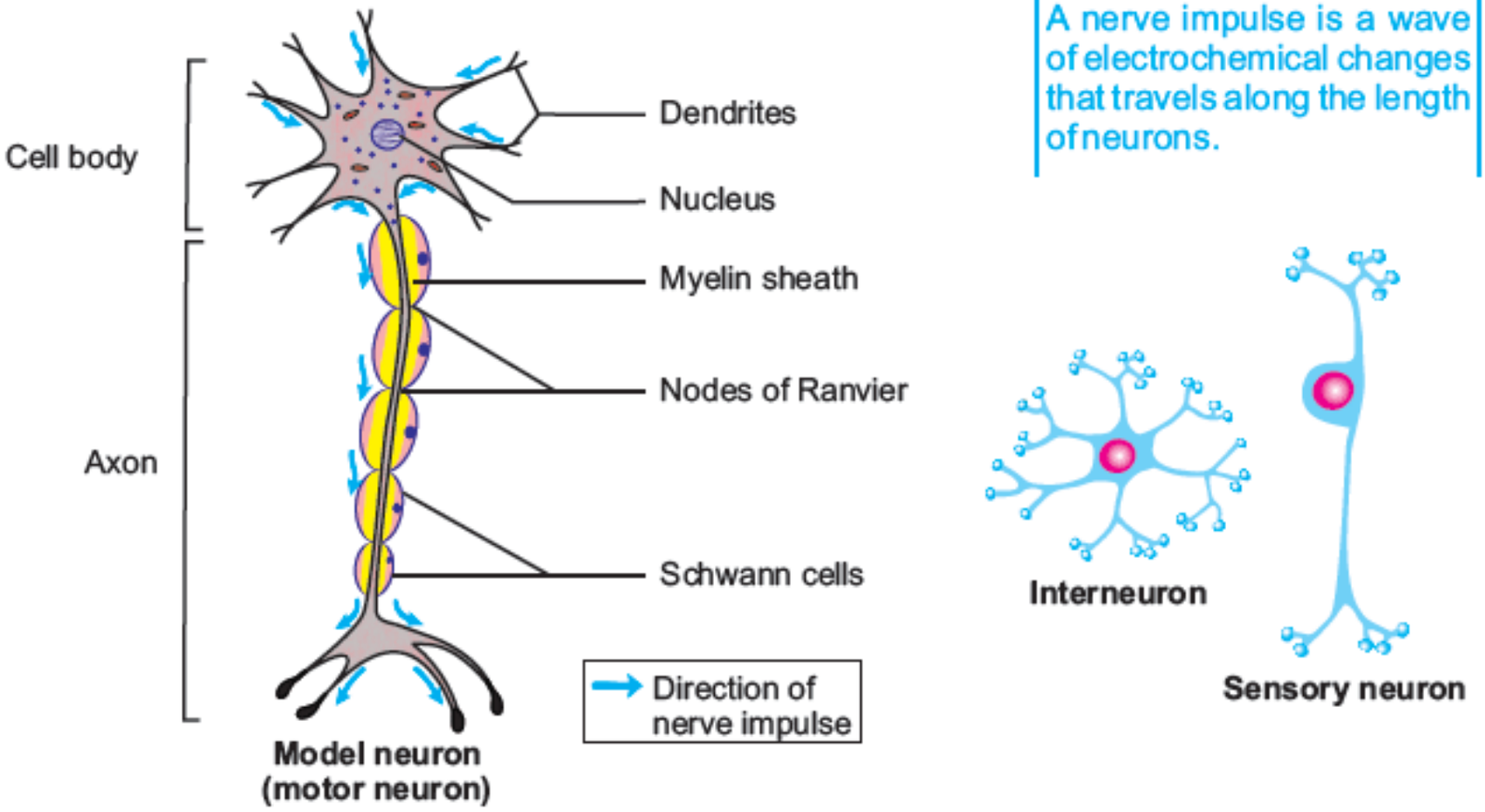


Figure 12.2: Neurons

Schwann cells are **special neuroglial** cells located at regular intervals along axons. In some neurons, Schwann cells secrete a fatty layer called **myelin sheath,** over axons. Between the areas of myelin on an axon, there are non-myelinated points, called the **nodes of Ranvier.** Myelin sheath is an insulator so the membrane coated with this sheath does not conduct nerve impulse. In such impulses are called **saltatory** ('jumping') impulses. This increases the speed of nerve impulse.

Animation 12.4: bp120
Source & Credit: clc.uc

On the basis of their functions, neurons are of three types;

1. Sensory neurons conduct sensory information (nerve impulse) from receptors towards the CNS. Sensory neurons have one dendrite and one axon.

Animation 12.5: Nerve impulse
Source & Credit: wikibooks

2. Interneurons form brain and spinal cord. They receive information, interpret them and stimulate motor neurons. They have many dendrites and axons.

3. Motor neurons carry information from interneurons to muscle or glands (effectors). They have many dendrites but only one axon.

Practical:

Observe the contraction of shin muscle of a frog, using a DC current of 12 volt.

Apparatus:

Dissected frog, Petri dish, methylene blue solution, 12 volt battery with wires.

Procedure:

- Get the shin muscle of a dissected frog (dissection would be done by teacher).
- Put the shin muscles in a Petri dish filled with methylene blue.
- Place a battery of 12 volt power near the Petri dish and touch its two wires with the opposite ends of the muscle.

Observation:

The muscle would contract when a current is applied to it.

Animation 12.8: Deporepol
Source & Credit: cybercuba

In certain parts of body, the cell bodies of many neurons form a group enveloped by a membrane. This is called ganglion.

Nerve

A nerve means the union of several axons that are enveloped by a covering made of lipid. Based on the property of axons, the nerves are classified into three types.

1. **Sensory nerves** contain the axons of sensory neurons only.
2. **Motor nerves** contain the axons of motor neurons only.
3. **Mixed nerves** contain the axons of both i.e sensory and motor neurons.

12.2.2 Divisions of the Nervous System

The details of the central and peripheral nervous systems are given below.

Central nervous system

The central nervous system consists of brain and spinal cord.

A- Brain

In animals, all life activities are under the control of brain. The structure of brain is suitable to perform this function. Brain is situated inside a bony cranium (part of skull).

Inside cranium, brain is covered by three layers called **meninges**. Meninges protect brain and also provide nutrients and oxygen to brain tissue through their capillaries.

The brain contains fluid-filled **ventricles** that are continuous with the **central canal** of spinal cord. Fluid within ventricles and central canal is called **cerebrospinal fluid** (CSF).

The Divisions of Brain

There are three major regions in the brain of human and other vertebrates. These are forebrain, midbrain and hindbrain. Important parts of each of these regions are described below:

Forebrain

Forebrain is the largest area of brain. It is most highly developed in humans. Following are the important parts of this region.

(i) Thalamus lies just below cerebrum. It serves as a relay centre between various parts of brain and spinal cord. It also receives and modifies sensory impulses (except from nose) before they travel to cerebrum. Thalamus is also involved in pain perception and consciousness (sleep and awakening).

(ii) Hypothalamus lies above midbrain and just below thalamus. In humans, it is roughly the size of an almond. One of the most important functions of hypothalamus is to link nervous system and endocrine system. It controls the secretions of pituitary gland. It also controls feelings such as rage, pain, pleasure and sorrow.

Animation 12.7: Nervous System
Source & Credit: hermes

(iii) Cerebrum is the largest part of forebrain. It controls skeletal muscles, thinking, intelligence and emotions. It is divided into two cerebral hemispheres. The anterior parts of **cerebral hemispheres** are called **olfactory bulbs** which receive impulses from olfactory nerves and create the sensation of smell. The upper layer of cerebral hemispheres i.e. cerebral cortex consists of grey matter. The grey matter of nervous system consists of cell bodies and non-myelinated axons. Beneath this layer is present the white matter. The white matter of nervous system consists of myelinated axons. Cerebral cortex has a large surface area and is folded in order to fit in skull. It is divided into four lobes.

Animation 12.8: Brainlobes
Source & Credit: people.eku

Hippocampus is a structure that is deep in the cerebrum. It functions for the formation of new memories. People with a damaged hippocampus cannot remember things that occurred after the damage but can remember things that had occurred before damage.

Lobe	Function
Frontal	Control motor functions, permits conscious control of skeletal muscles and coordinates movements involves in speech
Parietal	Contains sensory areas that receive impulses from skin.
Occipital	Receives and analyzes visual information
Temporal	Concerned with hearing and smell

Midbrain

Midbrain lies between hindbrain and forebrain and connects the two. It receives sensory information and sends it to the appropriate part of forebrain. Midbrain also controls some auditory reflexes and posture.

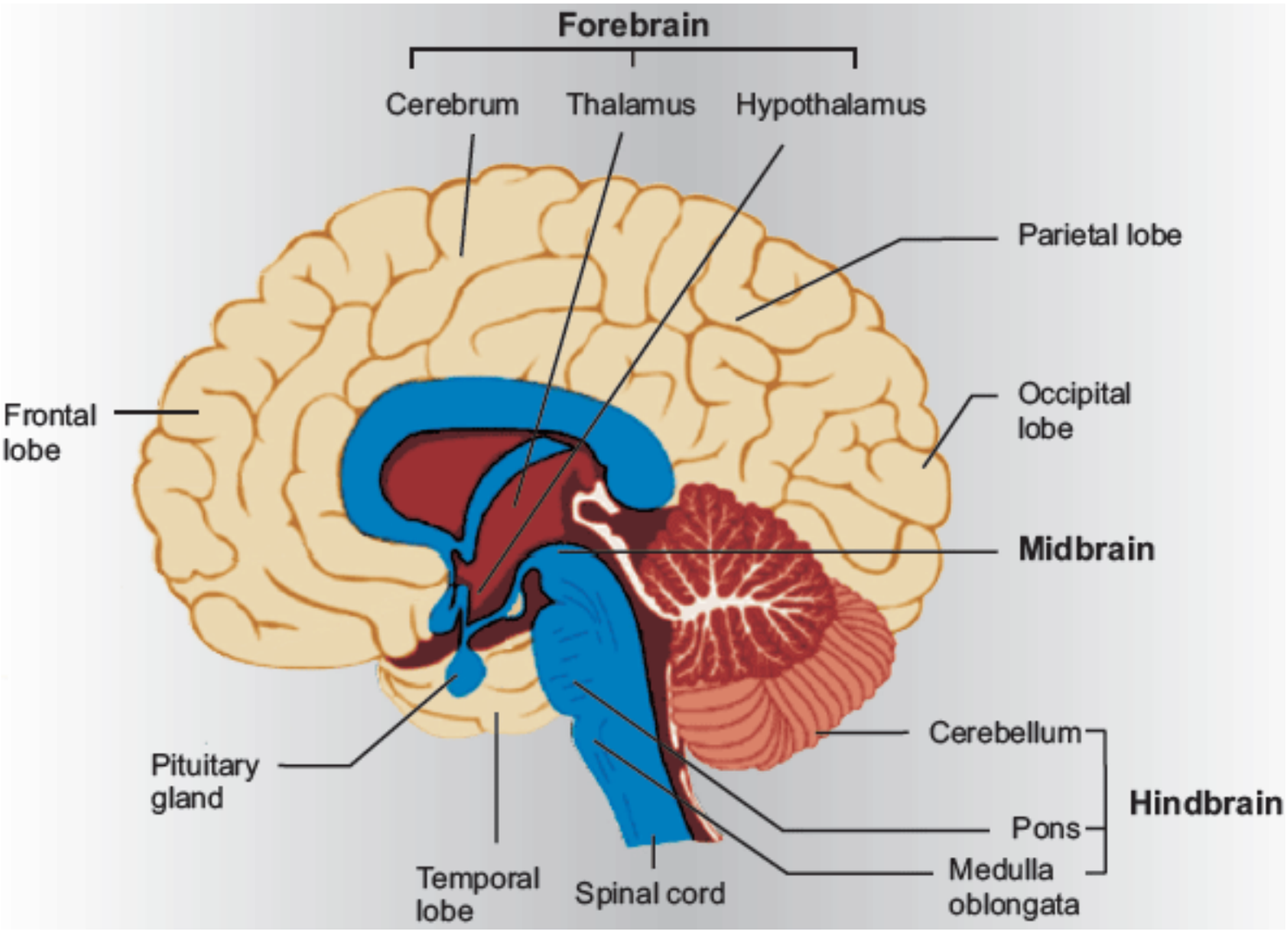


Figure 12.3: Structure of human brain

The medulla oblongata, pons, and midbrain connect the rest of brain to spinal cord. They are collectively referred to as brain stem.

Hindbrain

Hindbrain consists of three major parts.

(i) **Medulla oblongata** lies on the top of spinal cord. It controls breathing, heart rate and blood pressure. It also controls many reflexes such as vomiting, coughing, sneezing etc. Information that passes between spinal cord and the rest of brain pass through medulla.

(ii) **Cerebellum** is behind medulla. It coordinates muscle movements.

(iii) **Pons** is present on top of medulla. It assists medulla in controlling breathing. It also serves as a connection between cerebellum and spinal cord.

Animation 12.9: Rotating brain colored
Source & Credit: wikipedia

B- Spinal Cord

The spinal cord is in fact a tubular bundle of nerves. It starts from brain stem and extends to lower back. Like brain, spinal cord is also covered by meninges. The vertebral column surrounds and protects spinal cord.

The outer region of spinal cord is made of white matter (containing myelinated axons). The central region is butterfly shaped that surrounds the central canal. It is made of grey matter (containing neuron cell bodies).

31 pairs of spinal nerves arise along spinal cord. These are **"mixed"** nerves because each contains axons of both sensory and motor neurons.

At the point where a spinal nerve arises from spinal cord, there are two roots of spinal nerve. Both roots unite and form one mixed spinal nerve (Fig. 12.4).

- The dorsal root contains sensory axons and a ganglion where cell bodies are located.
- The ventral root contains axons of motor neurons.

Spinal cord is the continuation of medulla oblongata.

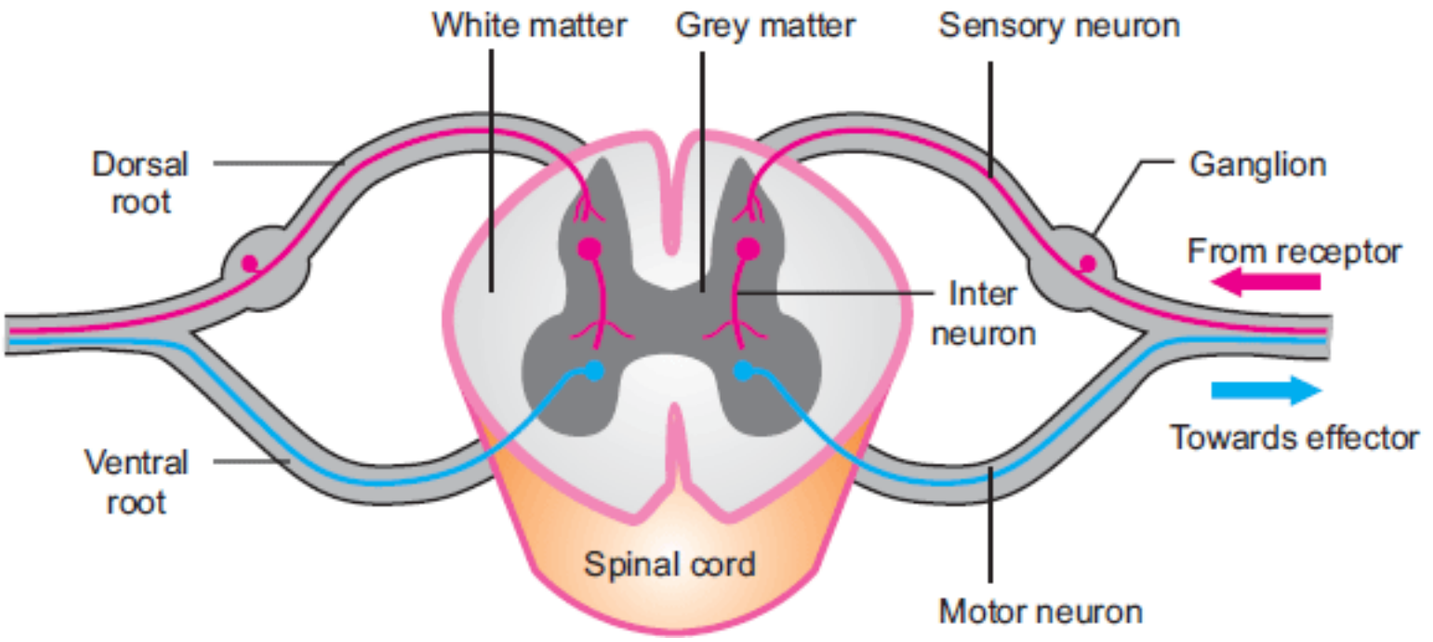


Figure 12.4: Spinal Cord and Spinal Nerves

Spinal cord performs two main functions:

1. It serves as a link between body parts and brain. Spinal cord transmits nerve impulses from body parts to brain and from brain to body parts.
2. Spinal cord also acts as a coordinator, responsible for some simple reflexes.

Peripheral Nervous System

The peripheral nervous system (PNS) is composed of nerves and ganglia. Ganglia are the clusters of neuron cell bodies outside CNS. Nerves arise or lead to brain and spinal cord. So they are named as cranial and spinal nerves.

Spinal cord is roughly 40cm long and about as wide as your thumb for most of its length.

Humans have 12 pairs of cranial nerves and 31 pairs of spinal nerves. Some cranial nerves are sensory, some are motor and some are mixed. On the other hand, all spinal nerves are mixed nerves.

The cranial and spinal nerves make two pathways i.e. sensory pathway (conducting impulses from receptors to CNS) and motor pathway (conducting impulses from CNS to effectors). Motor pathway makes two systems.

Somatic Nervous System

It is responsible for the conscious and voluntary actions. It includes all of the motor neurons that conduct impulses from CNS to skeletal muscles.

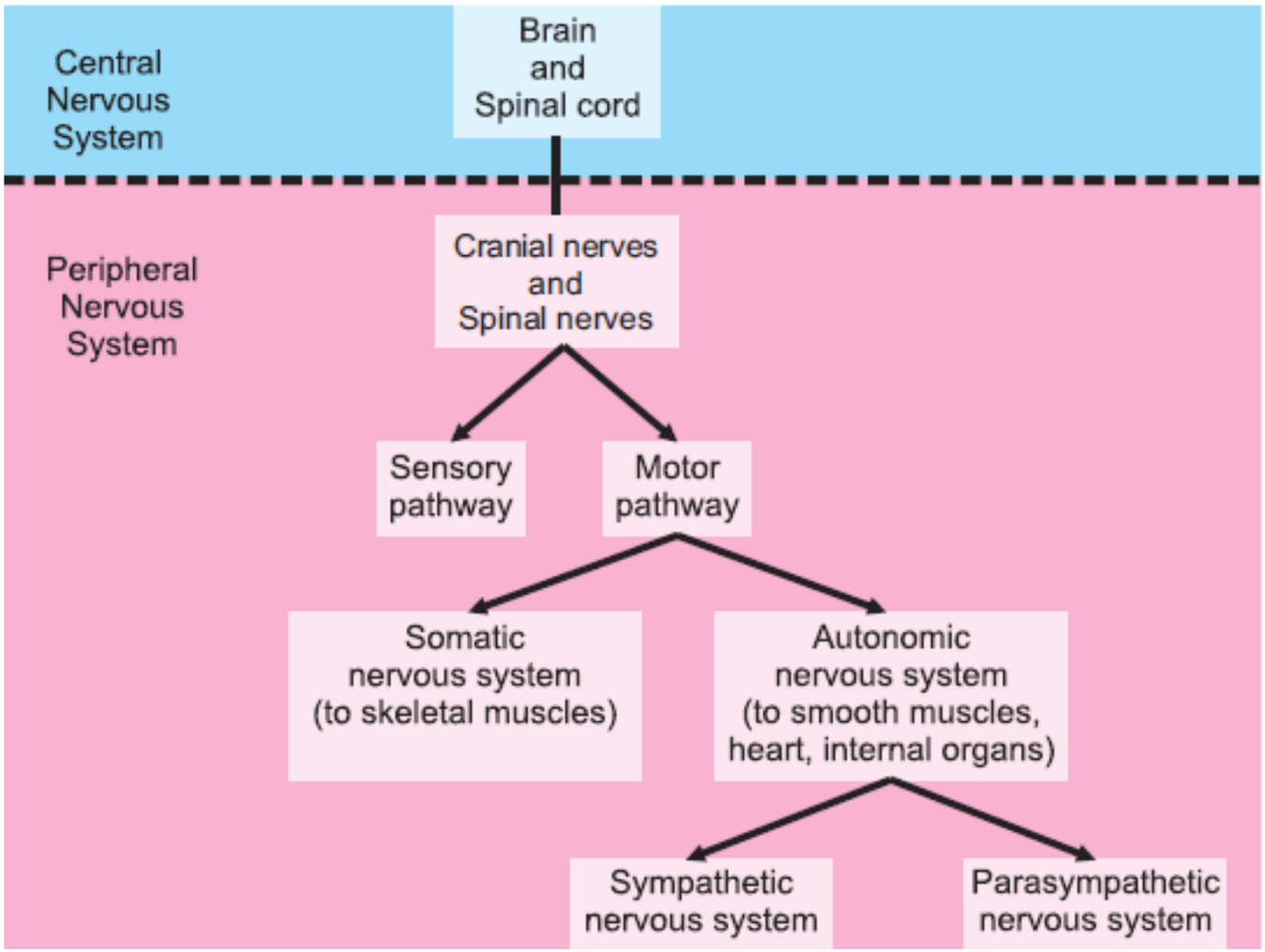


Figure 12.5: Divisions of the nervous system

Autonomic Nervous System

It is responsible for the activities, which are not under conscious control. It consists of motor neurons that send impulses to cardiac muscles, smooth muscle and glands. Autonomic nervous system comprises of sympathetic system and parasympathetic system. Sympathetic nervous system prepares body to deal with emergency situations. This is often called the “fight or flight” response. During an emergency situation, this system takes necessary actions. For example; it dilates pupils, accelerates heartbeat, increases breathing rate and inhibits digestion. When stress ends, the parasympathetic nervous system takes action and normalizes all the functions. It causes pupils to contract, promotes digestion, and slows the rate of heartbeat and breathing rate.

12.2.3 Reflex Action

When central nervous system sends impulses to muscles and glands, two types of actions (responses) result.

1. The higher centres of brain control the conscious action or voluntary actions.
2. When impulses are not passed to the higher centres of brain, it results in responses which are not under conscious control. Such responses are called involuntary actions. Sometimes, the involuntary response produced by the CNS is very quick. Such a response is called reflex action. The pathway followed by the nerve impulses for producing a reflex action, is called **reflex arc.**

The most common example of reflex action is the withdrawal of hand after touching a hot object. In this reflex action, spinal cord acts as coordinator. Heat stimulates temperature and pain receptors in skin. A nerve impulse is generated which is carried by sensory neurons to the interneurons of spinal cord.

It doesn't matter how clever we are
we will always pull our hand away
from a flame without thinking about it.

Animation 12.10: Reflexrotulien
Source & Credit: Corpshumain

From interneurons, the impulse is passed to motor neurons, which carry it to the muscles of arm. As a result, the muscles contract to withdraw hand. During it, other interneurons transmit nerve impulses up to brain so that the person becomes aware of pain and what happened.

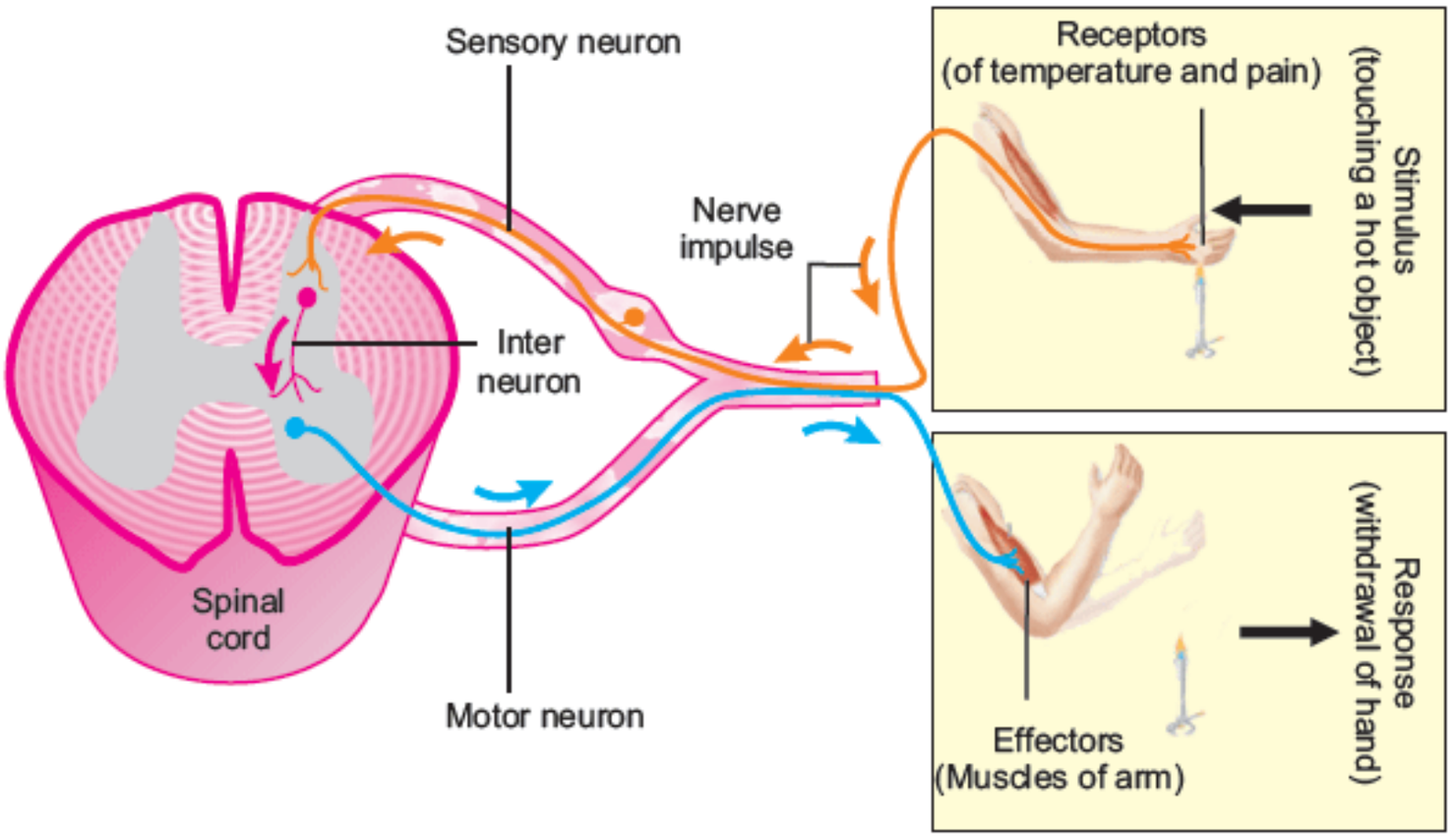


Figure 12.6: Reflex arc in a reflex action

See animation of Reflex Arc at: http://bio.rutgers.edu/~gb102/lab_5/103ar.html

12.3 Receptors In Humans

We know that the organs or parts which are specifically built to detect particular type of stimuli are called sense organs or receptors. Main receptors in man are eyes, ears, nose, taste buds, receptors of touch, heat and cold etc.

12.3.1 Eye

Our eyes are located in small portions of skull known as the orbits or eye sockets. Eyelids wipe eyes and prevent dehydration. They spread tears on eyes, which contains substances for fighting bacterial infections. Eyelashes prevent fine particles from entering eye. The structure of eye can be divided into three main layers (Fig. 12.7).

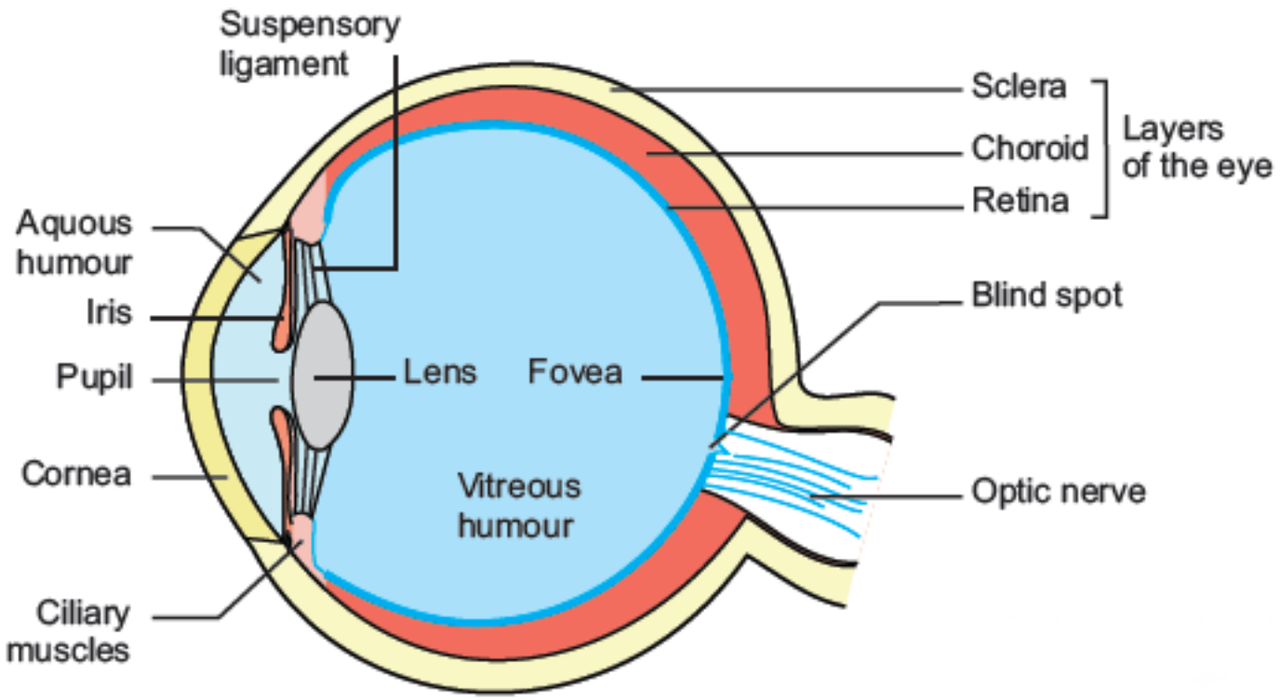


Figure 12.7: Structure of human eye

The **outer layer** of eyeball consists of **sclera** and cornea. Sclera gives eye most of its white colour. It consists of dense connective tissue and protects the inner components of eye and maintains its shape. In the front, sclera forms the transparent **cornea**. Cornea admits light to the interior of eye and bends light rays so that they can be brought to a focus.

The **middle layer** is called **choroid**. It contains blood vessels and gives the inner eye a dark colour. The dark colour prevents disruptive reflections within eye. Behind cornea, choroid bends to form a muscular ring, called iris. There is round hole, called pupil, in the centre of iris. After striking the cornea, light passes through the pupil. The size of pupil is adjusted by the muscles of iris. Pupil constricts in bright light when the circular muscles of iris contract. Similarly, pupil dilates in dim light when the radial muscles of iris contract (Fig. 12.8).

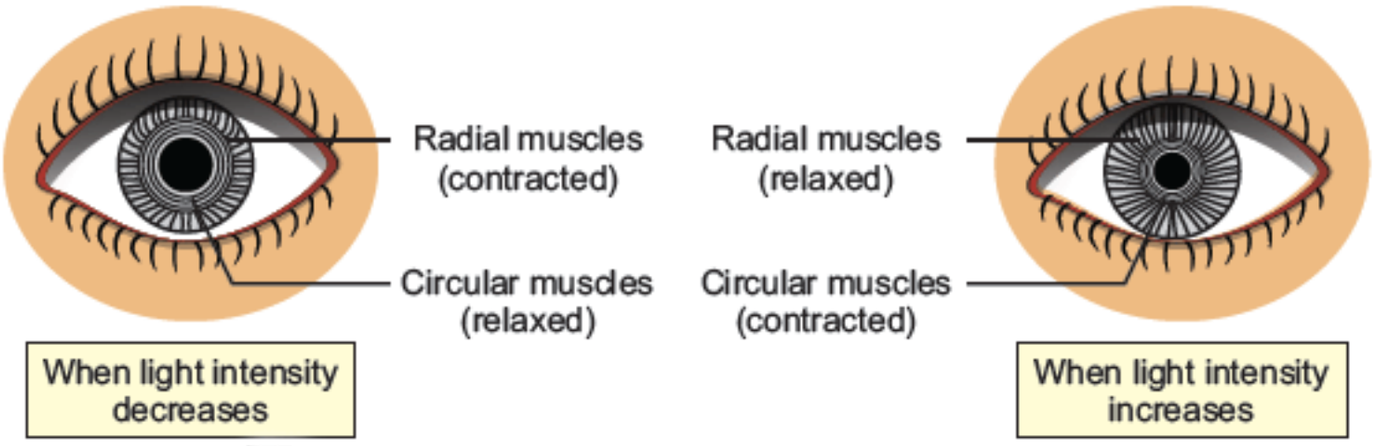


Figure 12.8: Contraction and dilation of pupil

Practical:
Perform an experiment in which a student will flash a spotlight in the eyes of another student and the third student would calculate the time taken for the eye to contract its pupil.

Behind iris, there is a convex **lens**, which focuses light on retina. Lens is attached to **ciliary muscles** of eye via a ring of **suspensory ligament**. To clearly see an object far away, ciliary muscles are relaxed and lens becomes less convex. When ciliary muscles contract, lens becomes more convex and round.

The **inner layer** is sensory and is called as **retina**. It contains the photosensitive cells called rods and cones and associated neurons.

Too much light being let in could damage the retina; too little light makes sight difficult.

Rods are sensitive to dim light while cones are sensitive to bright light and so distinguish different colours. Retina has two points i.e. fovea and optic disc. **Fovea** is a dip in retina, directly opposite to lens and is densely packed with cone cells. It is largely responsible for colour vision and sharpness. **Optic disc** is a point on retina where the optic nerve enters retina. There are no rods and cones at this point, that is why it is also referred to as the **blind spot.**

Have you seen the eyes of cat and dog shining in the night? The reason for this is the presence of tapetum behind the eye which is a layer capable of reflecting light.

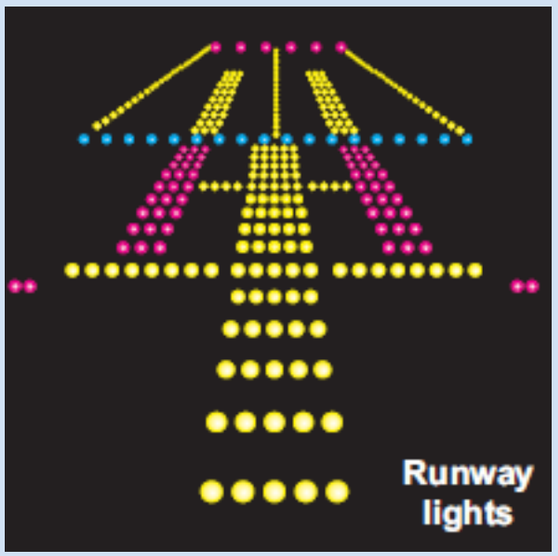
In a human eye there are about 125 lakhs rods and 7 lakhs cones.

The iris divides the cavity of eye into two chambers. The anterior chamber is in front of iris i.e. between cornea and iris; whereas the posterior chamber is between iris and retina. The anterior chamber contains a clear fluid known as **aqueous humour** while the posterior chamber contains a jelly-like fluid known as **vitreous humour**. It helps maintain the shape of eye and suspends the delicate lens.

Light from objects enters eye and is refracted when it passes through cornea, aqueous humour, lens and vitreous humour. Lens also focuses light on retina. As a result, the image falls on retina. Rods and cones generate nerve impulses in the optic nerve. These impulses are carried to the brain, which makes the sensation of vision.

Rods contain a pigment called **rhodopsin.** When light falls on rhodopsin, it breaks for generating a nerve impulse. In the absence of light, the breakdown products are again converted into rhodopsin. Body synthesizes rhodopsin from **vitamin A** and that is why the deficiency of vitamin A causes poor night vision. This problem is called **night blindness.**

Cones also contain a pigment, known as **iodopsin**. There are three main types of cones and each type has a specific iodopsin. Each type of cones recognizes one of the three primary colours i.e. blue, green and red. If any type of cones is not working well, it becomes difficult to recognize that colour. Such person is also not able to distinguish different colours. This disease is called **colour blindness** and it is a genetic problem.



For a pilot, colour vision is essential so that he/she can recognize aircraft position lights, light-gun signals, airport beacon, approach-slope indicators, and chart symbols, especially at night. A pilot must have the ability to perceive these colours necessary for the safe performance of his/her duties.

Disorders of the Eye

The working of eye is affected by the changes in the shape of eyeball.

Myopia (Short sight)

The elongation of eyeball results in myopia. Such persons are not able to see distant objects clearly. The image of a distant object is formed in front of retina (Fig. 12.9). This problem can be rectified by using concave lens.

Hypermetropia (Long sight):

It happens when eyeball shortens. Such persons are not able to see near objects clearly. The image is formed behind retina (Fig. 12.9). Convex lens is used to rectify this problem.

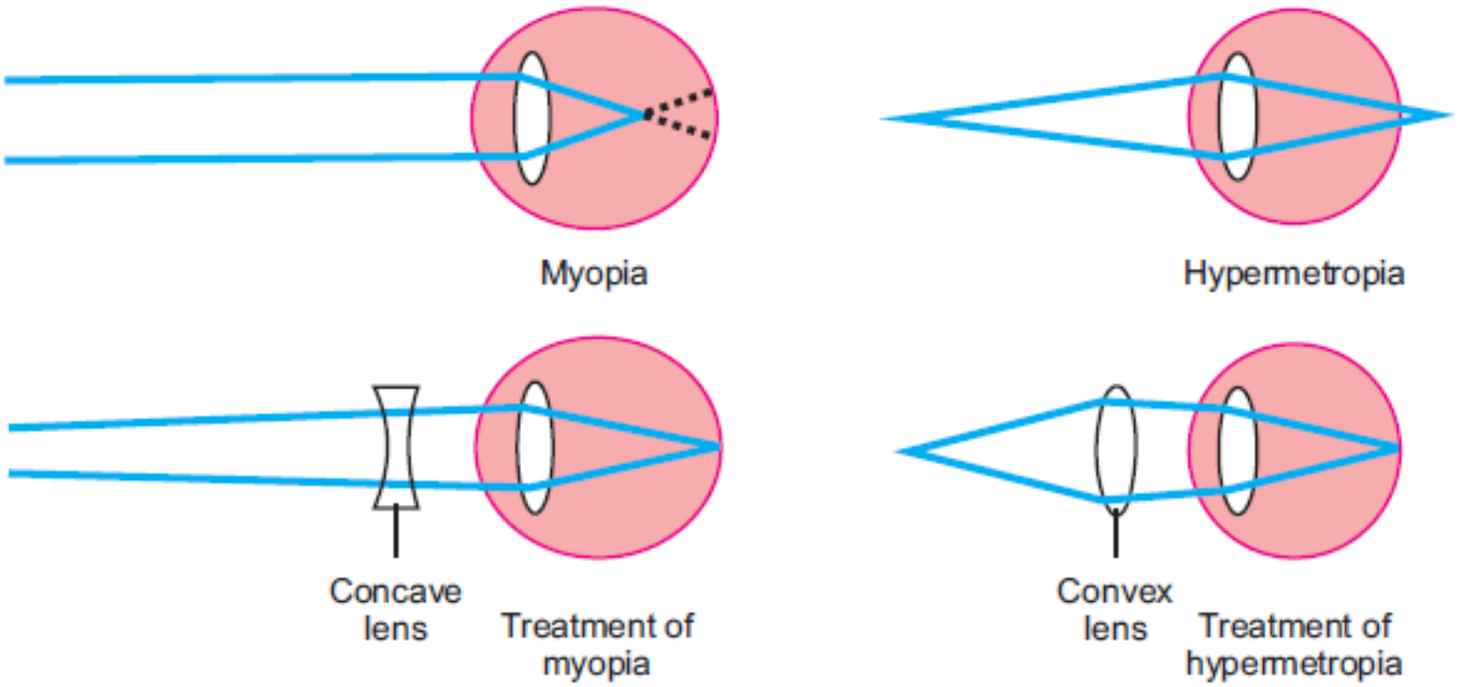


Figure 12.9: Myopia and hypermetropia

Ibn al-Haytham's "Book of Optics" has been ranked alongside a book of Isaac Newton. It is one of the most influential books ever written in the history of physics.

Contributions of Muslim Scientists

Ali ibn Isa (950 - 1012) was a famous Arab scientist. He wrote three books on ophthalmology (study of the diseases and surgery of eyes). He described 130 eye diseases and prescribed 143 drugs to treat these diseases.

Ibn al-Haytham (965 - 1039), an Arab scientist, made significant contributions to the principles of eye and vision. He is regarded as the father of optics (study of the behaviour of light). His "Book of Optics" correctly explained and proved the modern theory of vision. He discussed the topics of medicine and eye surgery in his book. He made several improvements to eye surgery and accurately described the process of sight, the structure of eye, image formation in eye and visual system. Ibn al-Haytham also described the principles of pinhole camera.

Practical: Study of the Bull Eye

- Get a real bull eye and study its longitudinal section (cut by the teacher) or study the model of bull eye.
- Identify different parts of the eye and draw a labelled diagram that would clearly show the sclera, choroid, retina, iris and lens.

Owl is not able to see during day time. The reason for this is the deficiency of cones which receive and sense the bright light. But the presence of more rods gives it greater power of vision during night. All animals that search for prey during night have this characteristic.

12.3.2 Ear

Hearing is as important as vision. Our ear helps us in hearing and also to maintain the balance or equilibrium of our body. Ear has three main parts i.e. external ear, middle ear, and internal ear.

A- External Ear

External ear consists of pinna, auditory canal and ear drum (tympanum). **Pinna** is the broad external part, made of cartilage and covered with skin. It helps to direct sound waves into **auditory canal**. There are special glands in the walls of auditory canal, which produce wax. The wax and the hairs in auditory canal protect ear from small insects, germs and dust. In additions to this, they help to maintain the temperature and dampness of auditory canal. Auditory canal ends in **ear drum.** This thin membrane separates external ear from middle ear.

Animation 12.11: Human Ear
Source & Credit: leavingbio

B- Middle Ear

Middle ear is a chamber after external ear. Three small bones, called middle ear ossicles, are present in a chain in middle ear. These movable bones include **malleus, incus** and **stapes**. **Malleus** is attached with ear drum, then comes incus and finally **stapes** that is connected with a membrane called **oval window.** Oval window separates middle ear from inner ear. Middle ear also communicates with the nasal cavity through **Eustachian tube**. This tube regulates the air pressure on both sides of ear drum.

Stapes is the smallest bone of the human body.

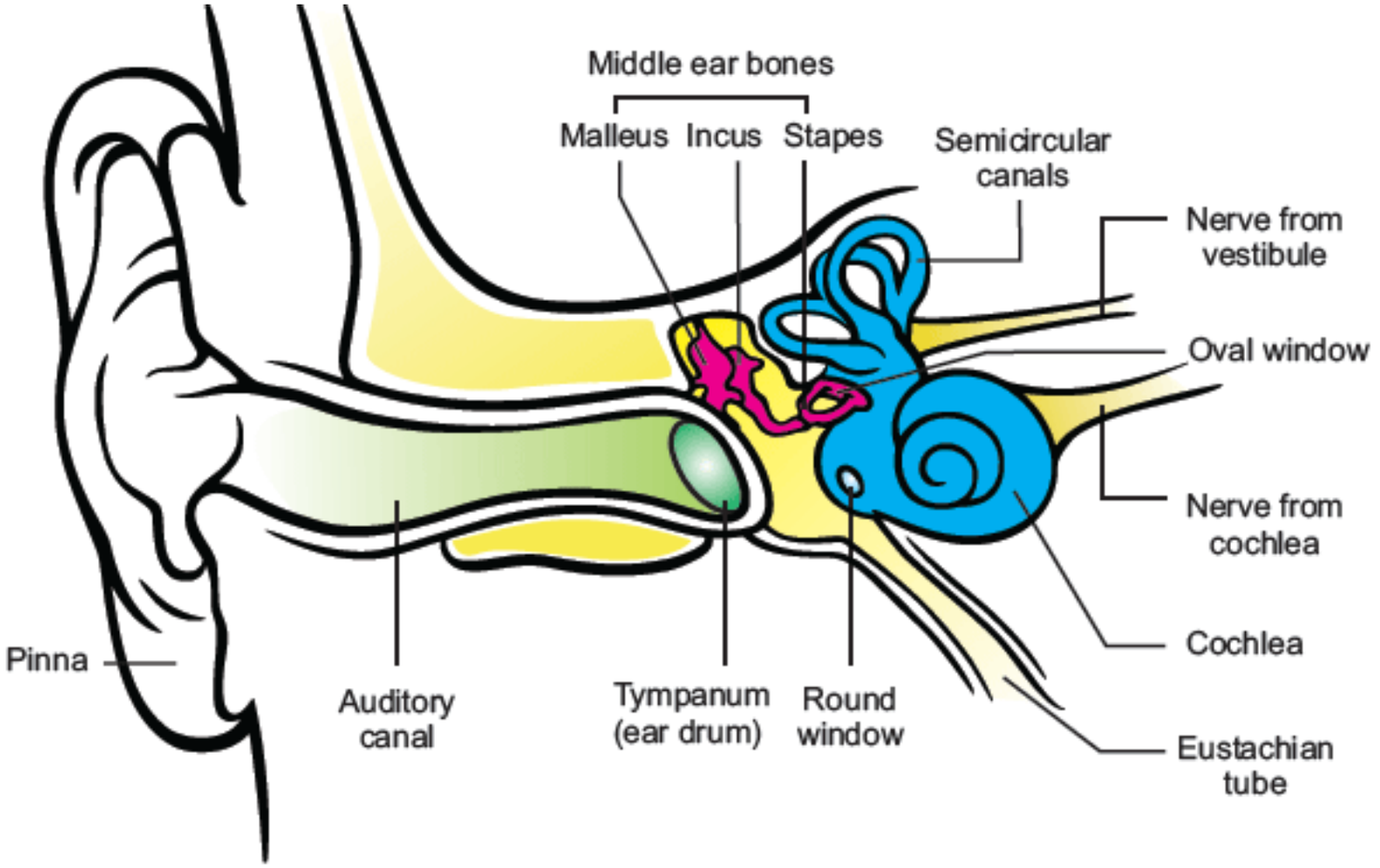


Figure 12.10: Structure of human ear

C- Inner Ear

Inner ear consists of three parts i.e. vestibule, semicircular canals and cochlea. Vestibule is present in the centre of inner ear. Three canals called semicircular canals are posterior to the vestibule. The cochlea is made of three ducts and wraps itself into a coiled tube. Sound receptor cells are present within the middle duct of cochlea.

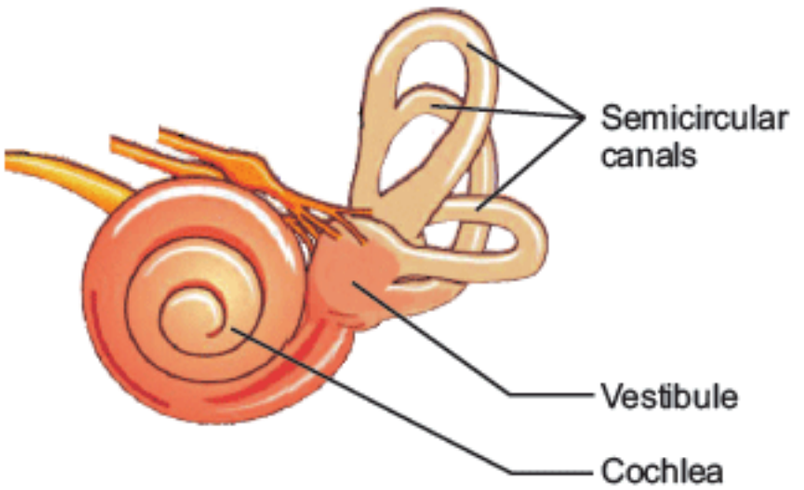


Figure 12.11: Structure of Inner ear

? To which part of ear the tympanum belongs?

External Ear

Image 12.1: Smallest bone
Source & Credit: lachicchattenoir.wordpress

Hold the fingers of your palm close to each other and place it behind the pinna. Then concentrate on a particular sound continuously having the same frequency. Remove the palm and concentrate on the same sound again.

The Process of Hearing

The pinna of the external ear focuses and directs sound waves into auditory canal. The sound waves strike ear drum and produce vibrations in it. From ear drum, the vibrations strike middle ear and produce further vibrations in malleus, incus and then stapes. From stapes, the vibrations strike the oval window and then reach the fluid-filled middle duct of cochlea. The fluid of cochlea is moved and receptor cells are stimulated. The receptor cells generate a nerve impulse, which travels to brain and is interpreted as sound.

Soundless world

Deafness is a state in which hearing is not possible. The defect of ear drum, cochlea, middle ear ossicles, or auditory nerve may cause deafness. Infection in Eustachian tube may spread to middle ear too. Ear drum may be damaged by an infection in auditory canal. Excessive noise, strong blows on cheek, pointed objects entering auditory canal and attack from insects may also affect hearing.

Ears maintain the Balance of Body

Semicircular canals and vestibule help to maintain the balance of body. Semicircular canals contain sensory nerves which can detect any movement of head. Vestibule can detect any changes in the posture of body. The neurons coming from these two receptors reach cerebellum through the auditory nerve.

A thunderstorm is characterized by the presence of lightning and a thunder. The lightning is caused by an electrical charge due to the movement of water droplets or crystals carried by the wind. The sudden increase in pressure and temperature from lightning produces rapid expansion of the air. This expansion of air produces a sound of thunder. The flash of lightening is followed after some seconds by a roar of thunder. This time difference is due to the fact that sound travels slower than light.

12.4 Endocrine System

The activities such as growth, reproduction, maintenance of glucose concentration in blood, reabsorption of water in kidneys etc. need to be regulated. Endocrine system performs this job. This system uses chemicals to "communicate" with its effectors.

These chemicals are known as hormones. A hormone is a specific messenger molecule synthesized and secreted by an endocrine gland. These glands are ductless and release their secretions (hormones) directly into bloodstream. Blood carries the hormones to target organs or tissues, upon which they act.

Many glands in our body are exocine. Such glands have ducts for releasing their secretions e.g. digestive glands, skin glands etc.

12.4.1 Important Endocrine Glands

1. Pituitary Gland

It is a pea-shaped gland attached to the hypothalamus of brain. Many hormones (trophic hormones) of pituitary gland influence the secretions of other endocrine glands. However some hormones of this gland act directly on various tissues of body. There are two lobes of pituitary gland i.e. anterior lobe and posterior lobe.

a. Anterior Lobe: It produces many hormones. One of its important hormones is somatotrophin (growth hormone). It promotes the growth of body. If the production of this hormone is diminished during growing age, the rate of growth decreases. This condition is called **dwarfism.** If this hormone is **excessively** produced during growing age, it leads to gigantism (very tall and overweight). If somatotrophin is excessively produced after growing age, internal organs and body extremities alone grow large. This condition is known as acromegaly. Such persons will have large hands, feet and jawbones.

Another important hormone secreted by the anterior lobe of pituitary gland is **thyroid-stimulating-hormone (TSH)**. It stimulates thyroid gland to secrete its hormones. The remaining hormones of anterior lobe influence reproductive organs and also control adrenal glands.

b. Posterior Lobe: The posterior lobe of pituitary gland stores and secretes two hormones i.e. oxytocin and vasopressin (antidiuretic hormone: ADH). These hormones are produced by hypothalamus (a part of brain).

Vasopressin increases the rate of reabsorption of water from nephrons. When we have low amount of water in body fluids, pituitary gland secretes vasopressin and so more reabsorption of water occurs from nephrons into blood. In this way, body retains water and less amount of urine is produced. On the other hand, when body fluids have more than normal water, there is a decline in the secretion of this hormone. If pituitary gland does not secrete this hormone in the required amount, less water is reabsorbed from nephrons and there is excessive loss of water through urine. This condition is known as **diabetes insipidus**.
The hormone, oxytocin stimulates the contraction of uterus walls in mothers for child birth. Moreover, this hormone is necessary for the ejection of milk from breast.

The stepwise process of metamorphosis in many animals is controlled by hormones. Life activities such as cell division in invertebrates are also regulated by hormones. Hormones also control activities like migration in birds. Hormones have been identified even in unicellular organisms.

2. Thyroid gland

This is the largest endocrine gland in human body. It is present in neck region, below **larynx**, and produces a hormone thyroxin. Iodine is required for the production of this hormone. If a person lacks iodine in diet, thyroid gland cannot make its hormone. In this condition, thyroid gland enlarges. This disorder is called goitre.

Have you noticed that during summer, the urine output is low? Due to increased sweating, the water level of blood is lowered. As a result, pituitary gland releases more ADH into blood.

Our government encourages salt refiners to add iodine to salt. It also encourages people to choose this iodized salt.

Thyroxin increases the break down of food (oxidation) and release of energy in body. It is also responsible for the growth of body. **Hypothyroidism** is caused by the under-production of thyroxin. It is characterized by low energy production in body and slowing down of heart-beat. **Hyperthyroidism** is caused by over-production of thyroxin. Its symptoms are increase in energy production, increased heart-beat, frequent sweating and shivering of hands.
The thyroid gland produces another hormone called calcitonin. It decreases the level of calcium ions in blood and promotes the absorption of calcium from blood into bones.

Calcitonin and parathormone complement each other and regulate the level of calcium ions in the blood.

3. Parathyroid glands

These are four glands situated on the posterior side of thyroid gland. They produce a hormone known as **parathormone**. It increases the level of calcium ions in blood.
When there is increased production of parathormone, more than normal calcium salts are absorbed from the bones and added to blood. Consequently the bones become brittle. If there is deficiency in the production of parathormone, blood calcium level falls. It leads to tetany, which affects the functioning of muscles.

Tetany is marked by sharp flexion of the wrist and ankle joints, muscle twitching, cramps and convulsions. It is due to decreased blood calcium level which makes the nerves and muscles more excitable.

4. Adrenal glands

Two adrenal glands are situated above kidneys. Each adrenal gland consists of two parts. The outer part is cortex and the inner part is medulla. Adrenal medulla secretes a hormone called **epinephrine** or **adrenaline** in response to stress. It prepares our body to overcome emergency situations. Therefore, adrenaline is also termed as 'emergency hormone'.

The adrenal cortex secretes many hormones called corticosteroids which maintain the balance of salts and water in blood.

When a person experiences fear, anger or anxiety, the rate and intensity of heartbeat increases, blood pressure increases, blood flow to the limbs increases, blood flow to the alimentary canal and skin is reduced. Such changes prepare the body to face any emergency situation.

5. Pancreas

This organ has two functions. The major part of pancreas is a ducted (exocrine) gland. This portion secretes digestive enzymes, through a duct, into the small intestine. Some portions of pancreas serve as ductless (endocrine) gland.

Activity:

Write a paper on "The changes in the body while performing an exercise like running a 100 meter race

This portion contains groups of endocrine cells referred to as **islets of Langerhans**. These islets secrete two hormones i.e. insulin and glucagon. **Glucagon** influences the liver to release glucose in blood and so the blood glucose concentration rises. **Insulin** influences the liver to take excess glucose from blood and so the blood glucose concentration falls.

The blood glucose concentration is maintained at the rate of 80 to 120 mg per 100 ml of blood.

If a person's pancreas does not make normal quantity of insulin, the blood glucose concentration rises and we say that the person has **diabetes mellitus**. Persons with diabetes have loss of body weight, weakening of muscles and tiredness. The disease can be controlled by insulin administration. Formerly, insulin extracted from animals was used for this purpose. But now human insulin produced from bacteria through genetic engineering is available.

Blood Glucose Concentration (BGC) Test:
The amount of glucose in blood is measured by this test. It is used to diagnose diabetes. Blood glucose may be measured on a fasting basis (collected after an 8 to 10 hour fast), randomly (anytime) and after a meal. The results of some BGC tests are given here

Blood Glucose After 8-10 hours Fast	
BGC	**Diagnosis**
From 70 to 99 mg/100ml	Normal
From 100 to 125 mg/100ml	Pre-diabetic
126 mg/100ml and above	Diabetic
Blood Glucose 2 hours After a 75gram Glucose Drink	
BGC	**Diagnosis**
Less than 140 mg/100ml	Normal
From 140 to 200 mg/100ml	Pre-diabetic
Over 200 mg/100ml	Diabetic

6. Gonads

Testes (Singular: testis) and ovaries are the male and female reproductive organs i.e. gonads. In addition to producing gametes, gonads also secrete hormones, called sex hormones. Testes secrete hormones e.g. **testosterone**, which is responsible for the development of male secondary sex characters such as growth of hair on face and coarseness of voice etc.

Ovaries secrete **estrogen** and **progesterone**, which are responsible for the development of female secondary characters such as the development of breast etc.

Feedback Mechanisms

Endocrine glands do not secrete their hormones at a constant rate. The rate varies with the needs of the body. Like many other functions in body, the secretion of hormones is also regulated by feedback mechanisms. Feedback mechanism means the regulation of a process by the output of the same process. Feedback mechanisms are of two types i.e. positive and negative feedbacks.

In **negative feedback**, the output of a process decreases or inhibits the process. This mechanism works to return a condition towards its normal value. For example; when the blood glucose concentration rises, pancreas secretes insulin. It decreases the blood glucose concentration. Decline in the blood glucose concentration to a normal set-point inhibits the secretion of insulin. Similarly, when blood glucose concentration drops below normal, pancreas secretes glucagon. It raises the blood glucose concentration. In this case, rise in the blood glucose concentration to a normal set-point inhibits the secretion of glucagon. In other words, the blood glucose concentration (output) controls the process i.e. the secretion of insulin and glucagon.

In **positive feedback**, the changes resulting from a process increase the rate of process. For example; suckling action of an infant stimulates the production of a hormone in mother. This hormone works for the production of milk. More suckling leads to more hormone, which in turn leads to more milk production.

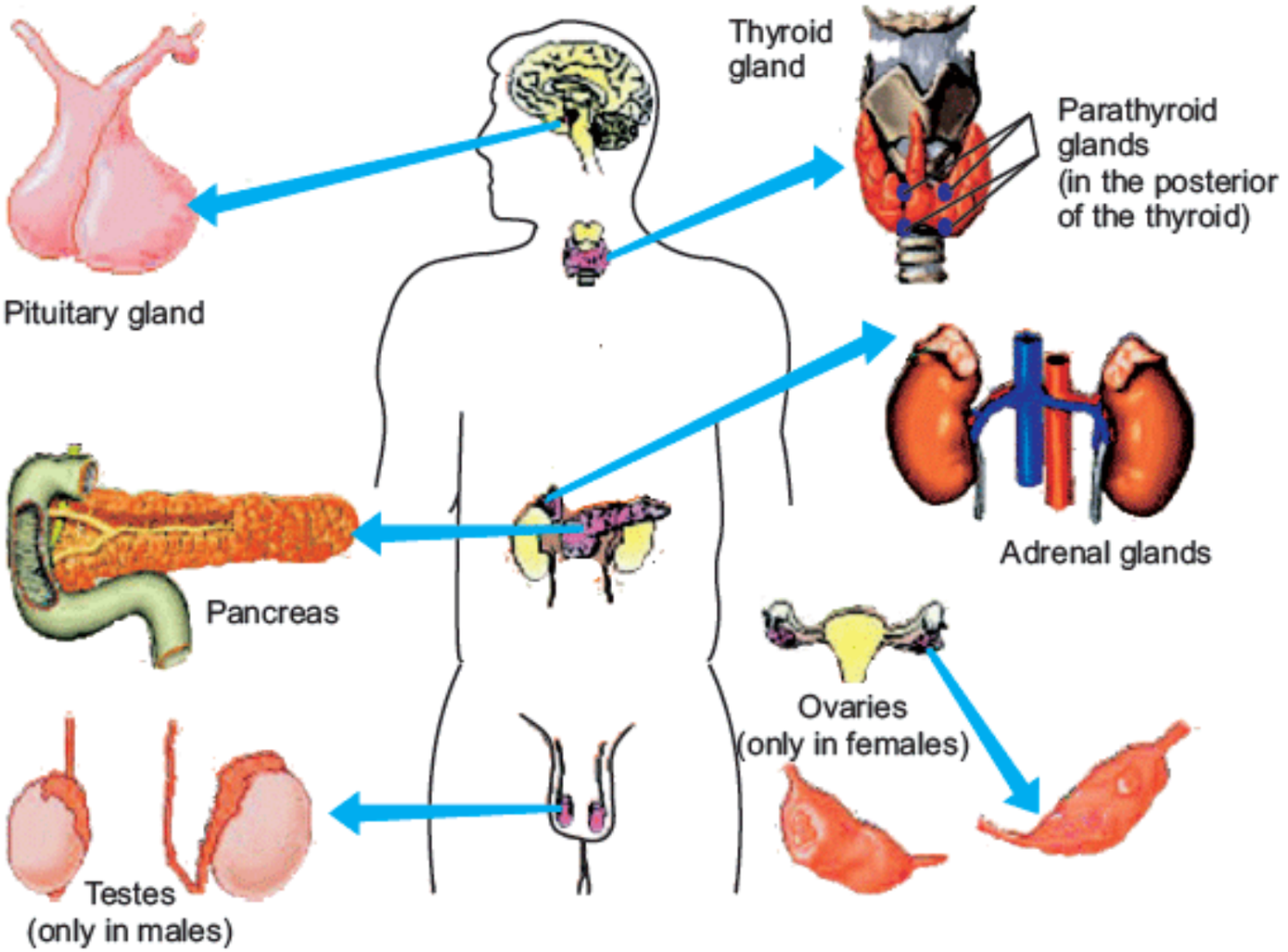


Figure 12.12: Endocrine glands in human body

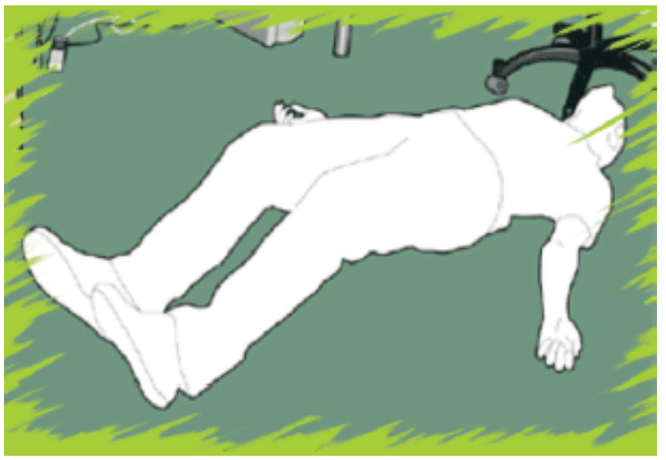
12.5 Disorders Of Nervous System

Disorders of nervous system can be categorized into two main types i.e. vascular disorders e.g. paralysis and functional disorders e.g. epilepsy. Vascular disorders are due to any disturbance in the blood supply to nervous system while functional disorders are due to disturbance in nerve impulse generation and transmission.

12.5.1 Paralysis

Paralysis is the complete loss of function by one or more muscle groups. It is most often caused by damage to the central nervous system (brain or spinal cord). The damage may be due to stroke (rupture in a blood vessel of brain or spinal cord), blood clotting in these blood vessels, or poison produced by polio viruses.

Patient may have weak paralysis throughout his / her body or have paralysis in one side of body. There may also be paralysis in the lower extremities or in all four limbs.



During a seizure attack, objects should never be placed in a patient's mouth as it can result in serious injury. It is possible that the patient will bite his/her own tongue.

12.5.2 Epilepsy

Epilepsy is a nervous disorder in which there is abnormal and excessive discharge of nerve impulses in brain. It causes unprovoked seizures in patient. A seizure of epilepsy is a temporary abnormal state of brain marked by convulsions.

In younger people, epilepsy may be due to genetic or developmental causes. In people over age 40 years, brain tumours are more likely to cause epilepsy. Head trauma and central nervous system infections may cause epilepsy at any age.

There is no known cure of epilepsy but medicines can control seizures. Patients of epilepsy have to take medicines daily for the treatment as well as prevention of seizures. These are termed "anticonvulsant" or "antiepileptic" drugs.

The knowledge of the composition and functioning of nervous system has helped man in the diagnosis and treatment of nervous disorders including paralysis and epilepsy. Man has discovered the areas of brain that receive information from different sense organs and the areas that send messages to different effectors. Such knowledge helps a lot in identifying the malfunctioning areas of brain.

UNDERSTANDING THE CONCEPT

1. Explain what can happen if there is no coordination in the activities of organisms.
2. Explain the location and function of these parts of brain; cerebrum, cerebellum, pituitary gland, thalamus, hypothalamus, medulla oblongata.
3. Define neuron and describe the structure of a general neuron.
4. Describe the structure of human eye.
5. How would you describe the structure of the external, middle and inner ear of man?
6. What are short sight and long sight problems and how these can be treated?
7. Explain the role of ear in the maintenance of balance.
8. Relate the contribution of Ibn-al-Haitham and Al-Ibn-Isa with knowledge about the structure of eye and treatment of various ophthalmic diseases.
9. Outline the major glands of the endocrine system (pituitary, thyroid, pancreas, adrenal, gonads), with name of their hormones and their functions.
10. Describe negative feedback with reference to insulin and glucagon.
11. Explain how adrenaline may be involved in exercise and emergency conditions.
12. Enlist the important symptoms and treatments of paralysis and epilepsy.

SHORT QUESTIONS

1. Identify the two types of coordination in living organisms.
2. Differentiate between the modes of nervous and chemical coordinations.
3. What are the main components of coordination?
4. Define reflex action and reflex arc.
5. Trace the path of a nerve impulse in case of a reflex action.
6. Describe the pupil reflex in dim and bright light.
7. How would you associate the role of vitamin A with vision and effects of its deficiency on retina?
8. Define the terms; hormone and endocrine system.

THE TERMS TO KNOW		
Acromegaly	Cornea	Grey matter
Antidiuretic hormone	Cranial nerve	Hormone
Aqueous humour	Dendrite	Hypermetropia
Axon	Diabetes mellitus	Hypothalamus
Calcitonin	Dwarfism	Insulin
Cell body	Ear drum	Interneuron
Cerebellum	Effector	Iodopsin
Cerebral hemisphere	Endocrine gland	Iris
Cerebrospinal fluid	Epilepsy	Islets of langerhans
Cerebrum	Epinephrine	Medulla ablongata
Choroid	Estrogen	Meninges
Cochlea	Eustachian tube	Mixed nerve
Colour blindness	Exocrine gland	Motor nerve
Cones	Ganglion	Myelin sheath
Myopia	Progesterone	Somatotrophin
Nerve	Pupil	Spinal nerve
Nerve impulse	Receptor	Suspensory ligament
Neuron	Reflex arc	Testosterone
Nodes of Ranvier	Retina	Thalamus
Optic disc	Retinine	Thyroid
Oxytocin	Rhodopsin	Thyroid-stimulating hormone
Paralysis	Rods	Thyroxin
Parathormone	Schwann cells	Tympanum
Parathyroid	Sclera	Vasopressin
Pituitary	Semicircular canals	Vestiblue
Pons	Sensory nerve	Vitreous humour

INITIATING AND PLANNING

1. Analyze why plants (like sunflower) have a very slow response to stimuli.
2. Visualize nervous and hormonal coordination by comparing electrical transmission in wires with the transmission of nerve impulse in neurons and by comparing convection currents in liquids with the hormonal transmission in blood.
3. Compare the BGC (blood glucose concentration) of healthy person with a patient suffering from Diabetes mellitus.

ACTIVITIES

1. Record the difference in quickness of response of the two types of coordination (by asking a student to say a few words in front of the class and observe the change in heartbeat).
2. Perform an experiment in which a scale held at its lower end between the thumb and index finger is allowed to fall and then recording the time taken to catch it again.
3. Identify different parts and draw a labelled diagram of the longitudinal section of the eye of sheep or bull.
4. Perform an experiment in which the shin muscle of a frog is made to contract in a Petri dish filled with methylene blue and using 12 V, DC current.
5. Check the vision of a friend to diagnose whether he/she is suffering from long or shortsightedness.
6. Perform an experiment in which one student flashes a spotlight into the eye of another and record the time taken for the eye to contract its pupil.

SCIENCE, TECHNOLOGY AND SOCIETY

1. Explain the way nervous system helps to coordinate complex and intricate movements of hand to play a piano, or write alphabets.
2. Analyze the way this knowledge has helped humans to train dogs and domesticated animals to perform specific tasks.
3. Explain the reason for salivation of mouth when a favourite food item is imagined.
4. Justify the time difference between seeing the flash of lightening and hearing the roar of a thunderstorm.
5. Explain why and how eyes are important to survival in wild animals.
6. Explain how colour blindness could be a hurdle for aircraft pilots.
7. Conceptualize how scientific advancement has helped to solve the problem of diabetes.
8. Write a paper on the changes in body while performing an exercise like running a 100m sprint race.
9. Relate how the knowledge of nervous system has helped humans to treat diseases like epilepsy, paralysis.

ON-LINE LEARNING

1. www.biology-online.org/8/1_nervous_system.htm
2. www.tutorvista.com/.../biology-nervous-system
3. www.educypedia.be/education/nervoussystem.htm
4. www.animate4.com/neuron-animation.htm
5. en.wikipedia.org/wiki/Neuron

CHAPTER

13 Support and Movement

Animation13.1: Torso
***S**ource & Credit: Usahobby*

The organisms with greater sizes need support to keep their body mass as one unit. This is particularly true for the organisms that live on land. We know that movement and locomotion are characteristics of animals. “Movement” is a general term meaning the act of changing place or position by entire body or by its parts. There are two types of movements i.e. movements of body parts and locomotion. Locomotion is the movement of an animal as a whole from one place to another.
In this chapter, we will study human skeletal system (skeleton) which is primarily responsible for support and movement.

The skeletal system of some invertebrates e.g. arthropods, is on the outside of the body, and is called exoskeleton.

13.1 Human Skeleton

Skeletal system or **skeleton** is defined as the framework of hard, articulated structures that provide physical support, attachment for skeletal muscles, and protection for the bodies of animals. Like other vertebrates, the human skeleton is on the inside of body and is called **endoskeleton**. In the living body, the skeleton is very much alive. Bones and cartilages are made of living cells and also have nerves and blood vessels in them. They grow and have the ability to repair themselves.

13.1.1 Role of Skeletal System

The big functions of skeletal system are protection, support and movements. In our body, skeleton works very closely with the muscular system to help us move. Similarly, skeleton provides protection to many internal organs e.g. skull protects brain, vertebral column protects spinal cord and ribs protect most of our other internal organs. Vertebral column also provides the main support to our body mass.

13.1.2 Bone and Cartilage

Overall, the human skeleton is made of bony framework but in certain parts, this framework is supplemented by cartilage.

a. Cartilage

Cartilage is a dense, clear blue-white firm connective tissue (but less strong than bone). The cells of cartilage are called **chondrocytes.** Each chondrocyte lies in a fluid space called **lacuna** present in the **matrix** of cartilage (Fig. 13.1). The matrix of cartilage contain also **collagen** fibres. Blood vessels do not enter cartilage. There are three types of cartilage.

Recalling
Cartilage and bone are types of connective tissue in animals. Most connective tissues contain collagen fibres in a matrix.

Recalling
Tendons and ligaments are other connective tissues that contain tightly packed collagen fibres.

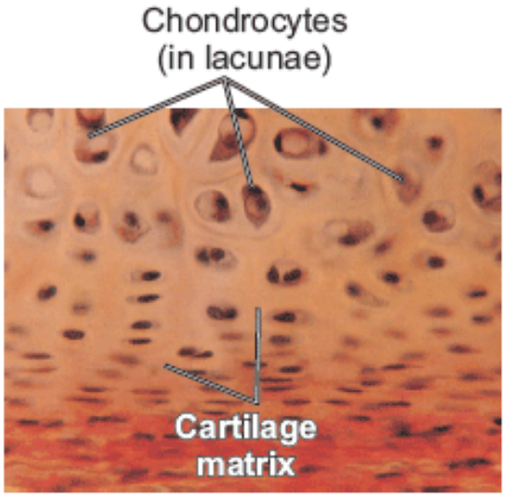


Figure 13.1: Chondrocytes in cartilage matrix

Hyaline cartilage is strong yet flexible. It is found covering the ends of the long bones, in the nose, larynx, trachea and bronchial tubes.

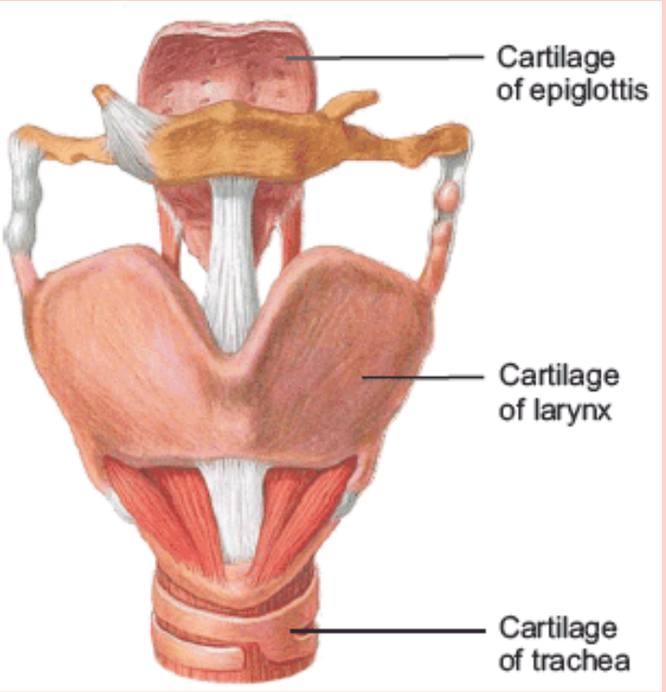
Elastic cartilage is similar in structure to hyaline cartilage. It is also quite strong but has elasticity due to a network of elastic fibres in addition to collagen fibres. It is found in epiglottis, pinna etc.

Fibrous cartilage is very tough and less flexible due to large number of thick collagen fibres present in knitted form. It is found in intervertebral discs.

b. Bone

Bone is the hardest connective tissue in body. Bones not only move, support and protect the various parts of body but also produce red and white blood cells and store minerals.

What types of cartilage these are?



Babies are born with about 300 soft bones. Some of these bones later fuse together, so that the adult skeleton has 206 hard bones.

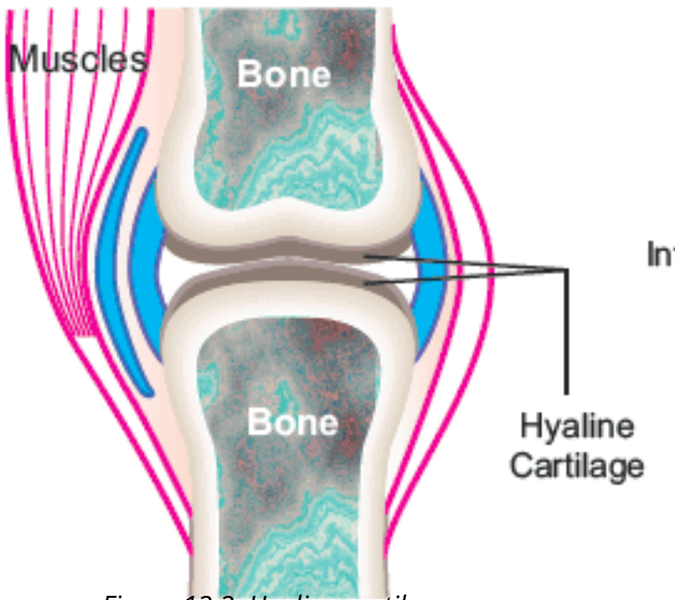


Figure 13.2: Hyaline cartilage

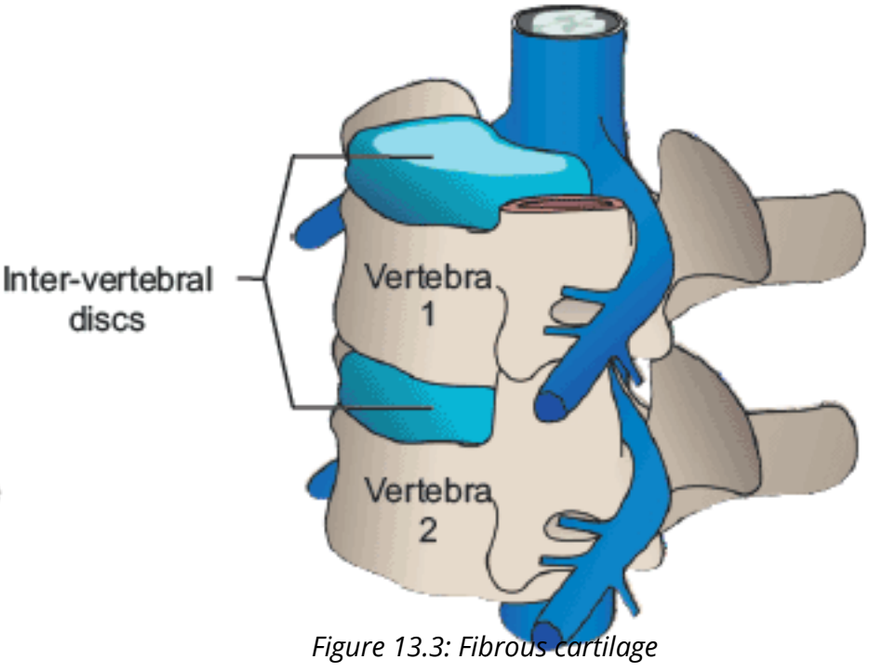


Figure 13.3: Fibrous cartilage

The hard outer layer of a bone is called compact bone while the interior of bone is soft and porous. It is called spongy bone. Spongy bone contains blood vessels and bone marrow (Fig. 13.4).

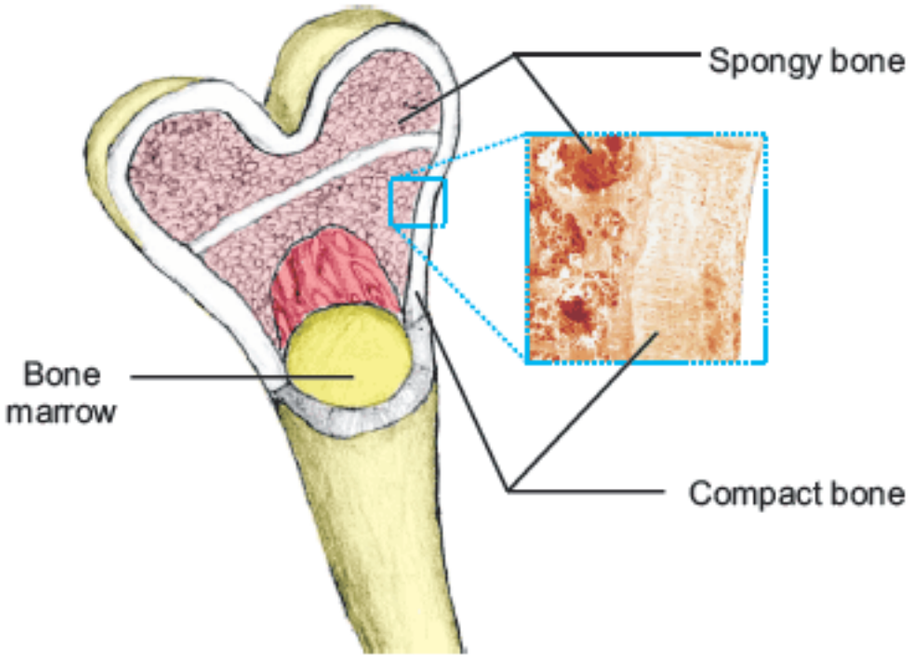


Figure 13.4: Compact and spongy bone

Animation13.3: Marvelous structure, Source & Credit: Wmt

Like cartilage, the matrix of bones also contains collagen. But it also contains minerals e.g. calcium and phosphate. We know that cartilage contains a single type of cell. On the other hand, bones contain different types of cell. The mature bone cells are called **osteocytes.**

Animation 13.4: Anatomy,
Source & Credit: Teamchiroames

Animation13.5: kneeanim2,
Source & Credit: Bicyclefitguru

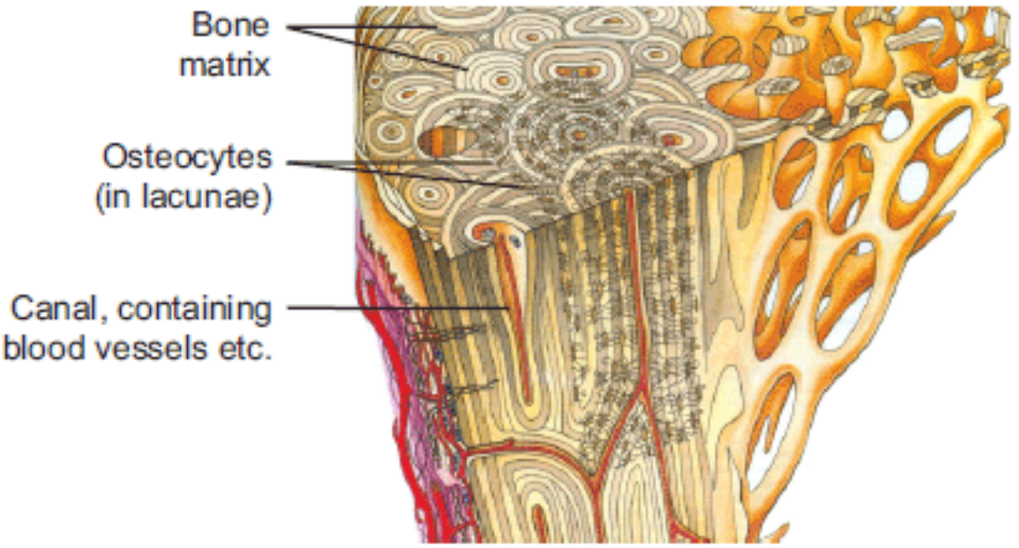
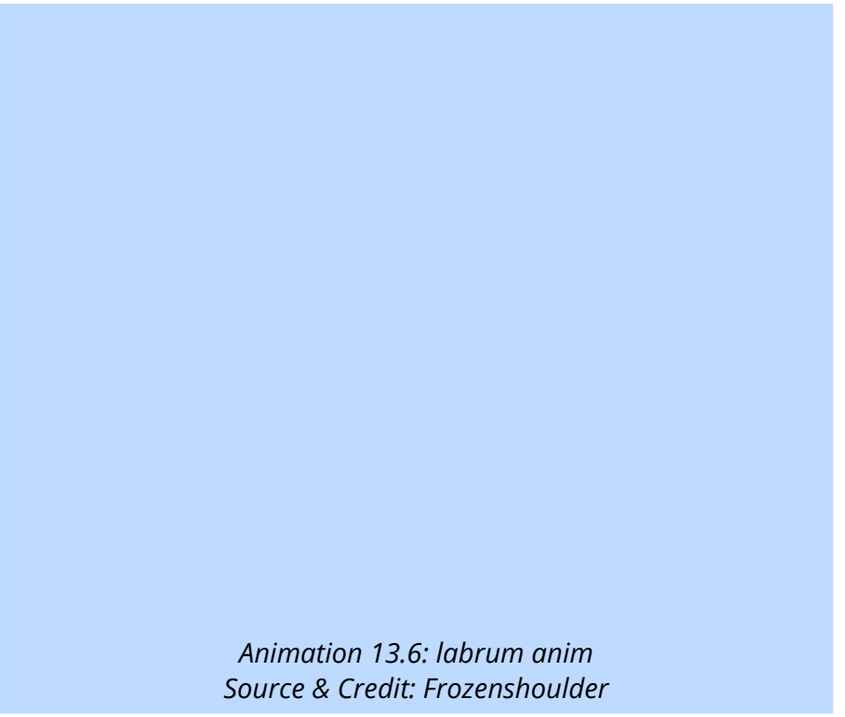


Figure 13.5: The internal structure of bone

13.1.3 Components of Human Skeleton

The 206 bones in the adult human skeleton are organized into a longitudinal axis i.e. axial skeleton, to which appendicular skeleton is attached.



Animation 13.6: labrum anim
Source & Credit: Frozenshoulder

a. Axial skeleton

Axial skeleton consists of the 80 bones in the head and trunk of body. It is composed of five parts. **Skull** contains 22 bones out of which 8 are cranial bones (enclosing the brain) and 14 are facial bones. There are 6 **middle ear ossicles** (3 in each ear). There is also a hyoid bone in neck. Vertebral column contains 26 bones (vertebrae). The **chest** is made of a chest bone called sternum and 24 (12 pairs) ribs.

b. Appendicular Skeleton

Appendicular skeleton is composed of 126 bones. Pectoral (shoulder) girdle is made of 4 bones. Arms have 6 bones. Both hands have 54 bones. Pelvic girdle (hips) has 2 bones. Legs have 6 bones. Both feet have 54 bones.

Practical:

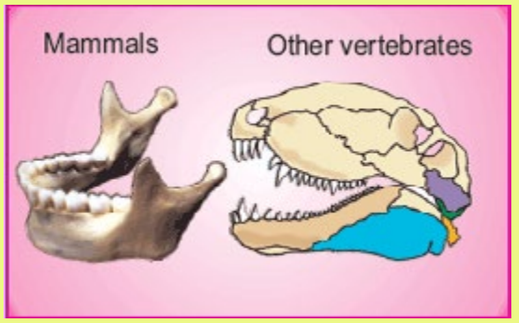
Identify and draw labelled diagrams of different bones of the human skeleton from real specimens, models or charts.

Painting from Vesalius book

Andreas Vesalius (1514-1564) is honoured for developing modern anatomical studies. Vesalius was born in Brussels, Belgium. He made many discoveries in anatomy, based on studies made by dissection of human dead bodies. His book contained the most accurate depictions of the whole skeleton and muscles of the human body.

Do you know?

The upper jaw is fixed with the skull and is composed of two bones. The lower jaw is mobile and articulates with the skull. In lower vertebrates, the lower jaw is made up of more than one bone while in mammals, it is made of single bone. During evolution, mammals modified the lower jaw bones and incorporated four of them into the middle ear (in the form of malleus and incus in both ears). This adaptation proved beneficial for mammals. Lower jaw with single bone is stronger and the malleus and incus also improve hearing.



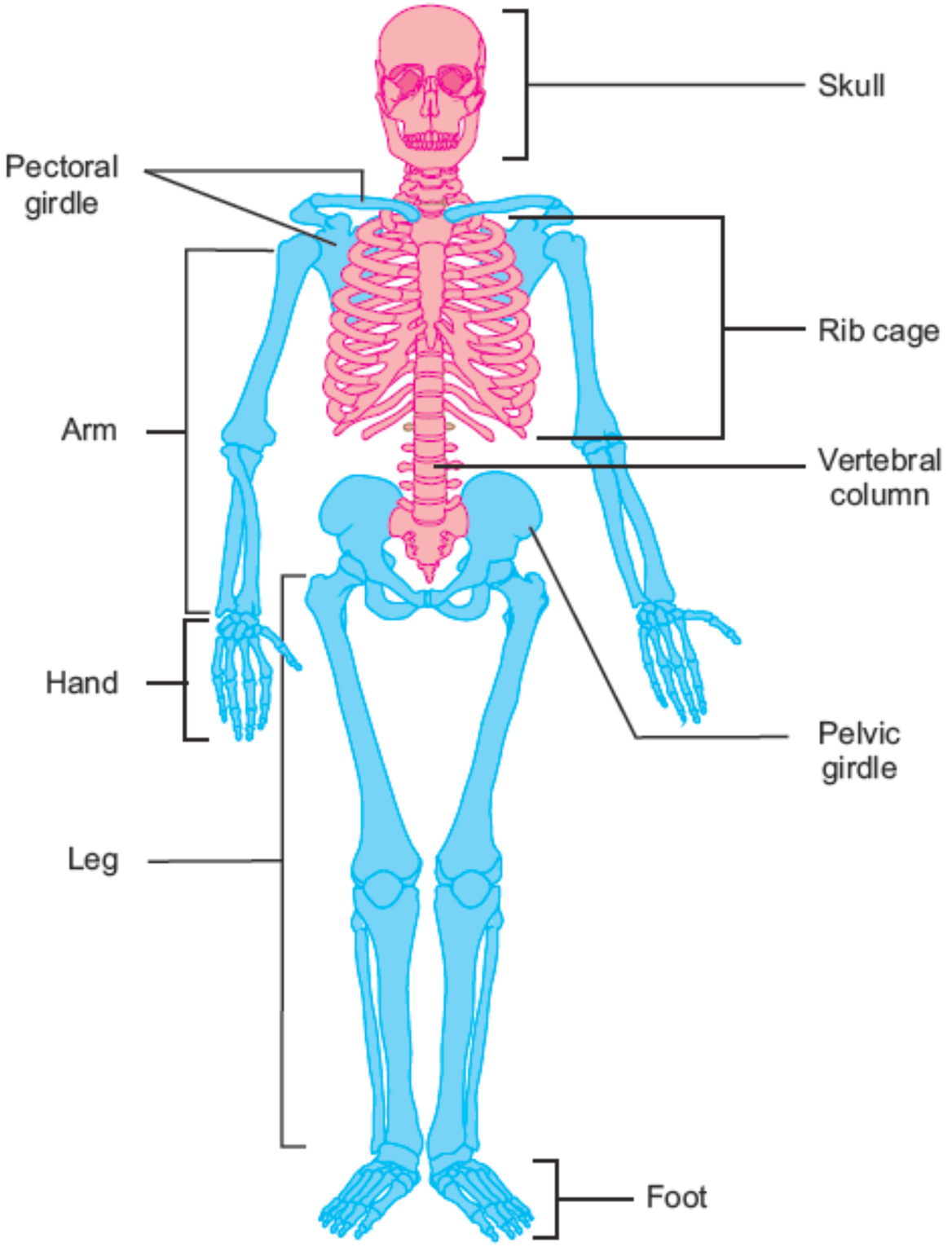


Figure 13.6: Human skeleton

You can see in the diagram. The thigh bone is the longest bone in our body. Recall your knowledge and name the smallest bone.

13.2 Types Of Joints

A joint is the location at which two or more bones make contact. They allow movement and provide mechanical support. Joints can be classified on the basis of the degree of movement they allow.
Immoveable (Fixed) joints: Such joints allow no movement e.g. the joints between the skull bones.
Slightly moveable joints: Such joints allow slight movements e.g. joints between the vertebrae.

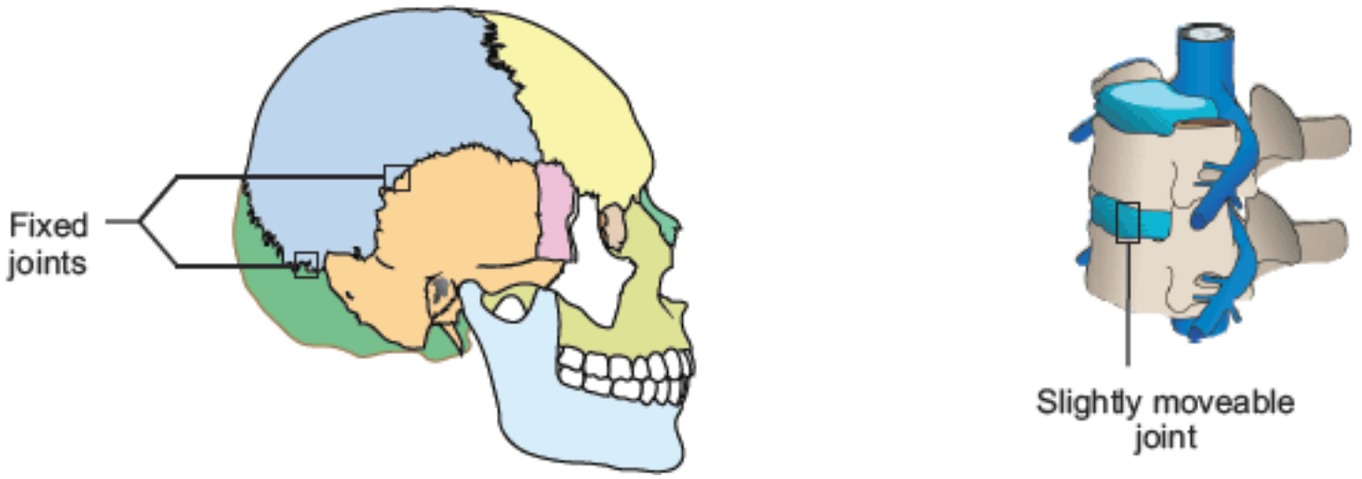


Figure 13.7: Fixed and slightly moveable joints

Moveable joints: They allow a variety of movements e.g. shoulder joint, hip joint, elbow joint, knee joint etc. There are many types of moveable joints in body. The main types are hinge joints and ball-and-socket joints. **Hinge joints** move back and forth like the hinge on a door and allow movements in one plane only. The knee and elbow are hinge joints.

Ball-and-socket joints allow movement in all directions. The hip and shoulder joints are ball-and-socket joints (Fig. 13.8).

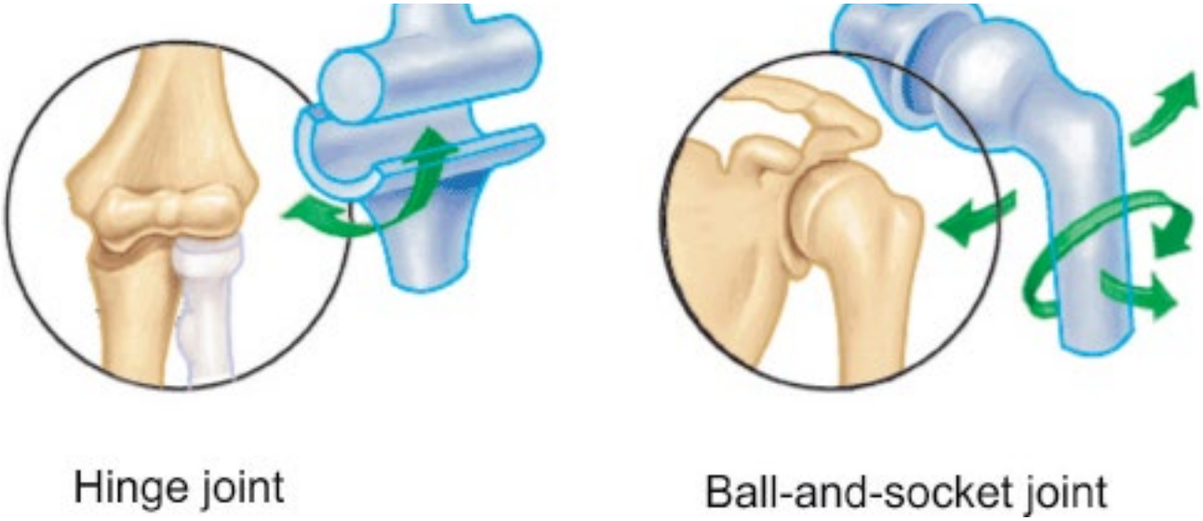


Figure 13.8: Two types of moveable joints

Practical:
Observe models for the movements at joints and describe how joints allow various movements.

The neck joint between vertebral column and head allows movements side to side. Can you think what would have happened if it were a ball-and-socket joint?

13.2.1 Roles of Tendons and Ligaments

Tendons and ligaments are bands of connective tissue (made of collagen). Tendons are tough bands and attach muscles to bones. When a muscle contracts tendon exerts a pulling force on the attached bone, which moves as a result. Ligaments are strong but flexible bands and join one bone to another at joints. They prevent dislocation of bones at joints.

Animation 13.8: Knee
Source & Credit: Wikipedia

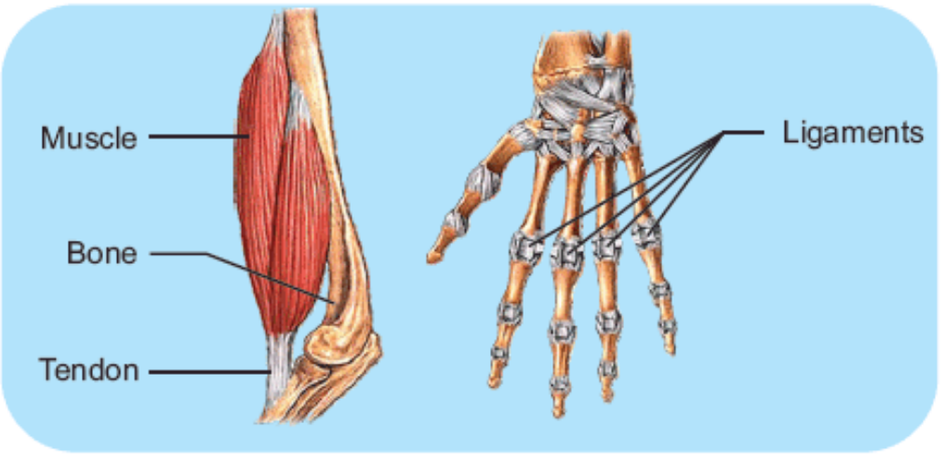


Figure 13.9: Tendons and ligaments

It is important to remember that muscles can only pull or contract, not push.

Most activities in our body like standing, walking, running, playing etc.require combined action of several muscles.

13.3 Muscles And Movement

We know that when bones move at joints, they produce movements. The movements in bones are brought about by the contractions of skeletal muscles, which are attached with them by tendons. The role of skeletal muscles is as follows.

One end of a skeletal muscle is always attached with some immoveable bone. This end of muscle is called the origin. Other end of muscle is attached with a moveable bone and is called the insertion. When a muscle is stimulated by a nerve impulse, it contracts to become shorter and thicker. Due to this contraction, it pulls the moveable bone (at insertion).

Skeletal muscles are usually in pairs of **antagonists**. In an antagonistic pair, both muscles do opposite jobs. When one muscle contracts the other relaxes and this phenomenon is known as antagonism (antagonistic action). When a muscle contracts and bends the joint, it is known as flexor muscle and the movement is called **flexion**. When a muscle contracts and straightens the joint, it is known as extensor muscle and the movement is called **extension**. Following is an example of the antagonistic action of a pair of skeletal muscles.

Biceps is a flexor muscle on the front of the upper arm bone while Triceps is an extensor muscle on the back of arm.

Both these muscle have their origin at pectoral girdle and insertion at one of the two bones of forearm. When biceps contracts, the forearm (insertion end) is pulled upward. It is the flexion of elbow joint. During this flexion, triceps muscle relaxes. When triceps muscle contracts, forearm is pulled down. It is the extension at elbow joint. During it, biceps muscle relaxes (Fig. 13.10).
In this way, biceps and triceps make up an antagonistic pair of muscles. Similar pairs, working antagonistically across other joints, provide for almost all the movements of skeleton.

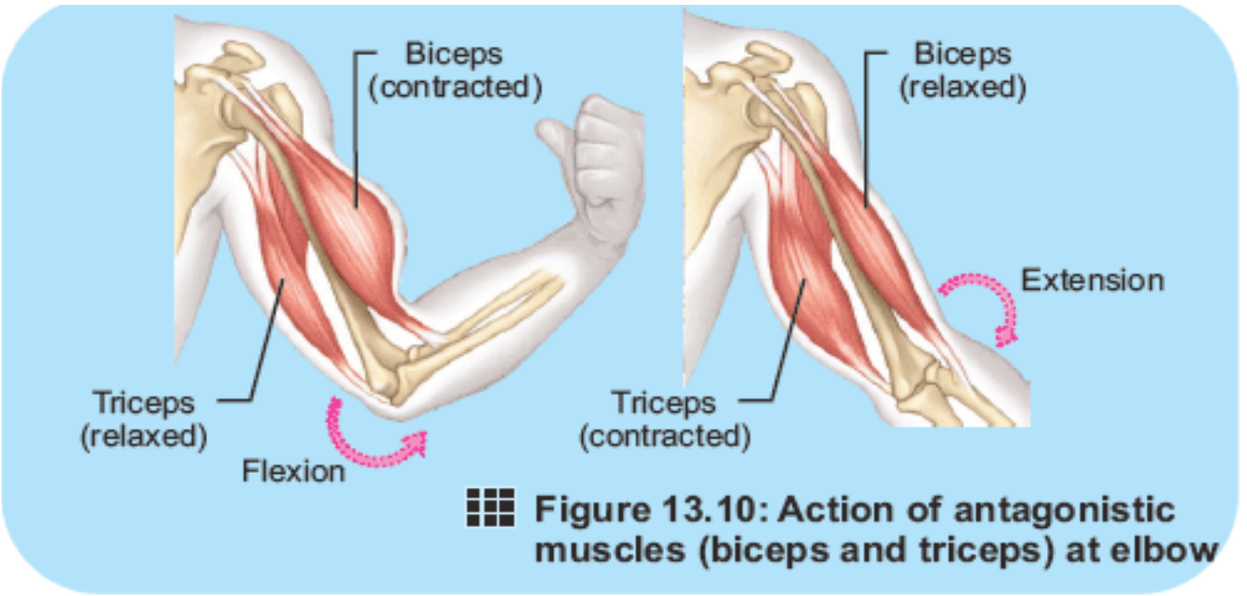


Figure 13.10: Action of antagonistic muscles (biceps and triceps) at elbow

Figure 13.10: Action of antagonistic muscles (biceps and triceps) at elbow

? Which point of attachment is pulled when a muscle contracts?
What point of attachment is pulled when a muscle contracts?
Insertion

Practical:

Describe the movement of biceps and triceps through presentation of the movement of your elbow joint.

Can you do it?

Aquatic animals need less skeletal support than land animals of similar size. Propose an explanation for this fact.

13.4 Disorders Of Skeletal System

The following disorders of skeletal system are important.

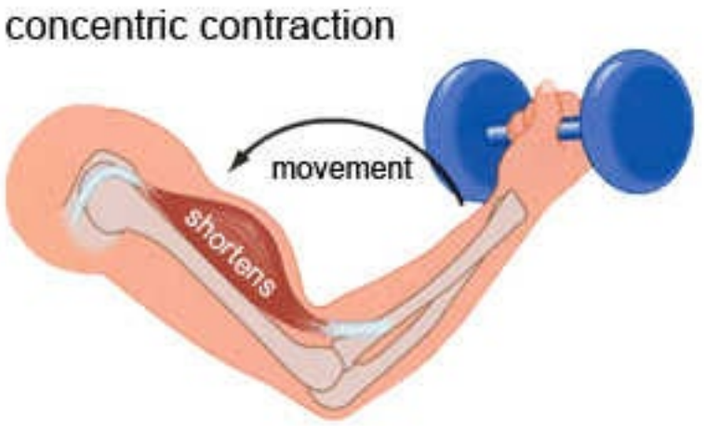
13.4.1 Osteoporosis

Osteoporosis is a bone disease in adults, especially in old people. It is more common in old women. In osteoporosis, there is a decrease in the density of bones due to loss of calcium and phosphorus. It may be due to malnutrition (lack of proteins and Vitamin C), lack of physical activities or deficiency of estrogen hormone.

It is one of the functions of esterogen to deposit minerals in bones. When the reproductive cycle stops in females, not enough esterogen is secreted.

In old age, there is decreased secretion of growth hormones and it also leads to decreased deposition of minerals in bone matrix.

Animation 13.12: Muscles and Movement
Source & Credit: Jeron



Animation 13.13: Contraction, Source & Credit: Letsmakerobots

13.4.2 Arthritis

Arthritis means "inflammation in joints". It is also very common in old age and in women. It is characterised by pain and stiffness in joints (particularly in the weight bearing joints e.g. hip joint, ankle joint etc.). The treatment of arthritis includes pain killer and anti inflammatory medicines. There are many types of arthritis, for example:

1. Osteo-arthritis: It is due to degeneration in the cartilage present at joints or due to decreased lubricant production at joints. In this arthritis, fusion of the bones at joint may occur and joints may become totally immoveable.

2. Rheumatoid arthritis: It involves the inflammation of the membranes at joints. Its symptoms include fatigue, low-grade fever, pain and stiffness in joints.

3. Gout: It is characterised by the accumulation of uric acid crystals in moveable joints. It generally attacks the toe joints.

Practical:

Investigate the chemical nature of bone

The bone matrix carries most of its mass. It contains large amounts of calcium.

***Hypothesis*:** The bone matrix contains calcium.

***Deduction*:** If a bone is placed in acidic solution, its calcium will get dissolved and bone will become porous.

***Apparatus*:** Three rib bones of goat, Petri dish, beaker, 20% HCl, 20% NaOH, distilled water

***Procedure*:**

- Take three Petri dishes and mark them 'A', 'B' and 'C'.
- Place one rib bone in each of the dishes.
- Add distilled water in dish 'A', HCl in dish 'B' and NaOH in dish 'C'.
- Keep the apparatus as such for 2 hours.

***Observation*:**

Observe the bones in the three Petri dishes.

- The bones in Petri dishes 'A' and 'C' do not show any change while the bone in dish 'B' becomes much weaker and porous.

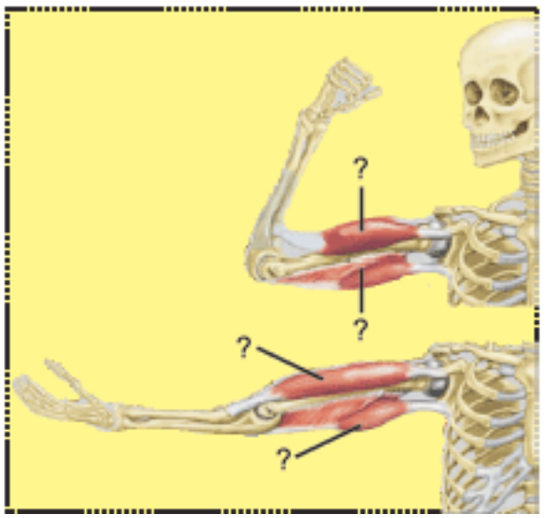
***Results*:** The observation indicates that bone is made of calcium (in the form of $CaCO_3$). HCl reacts with $CaCO_3$ and dissolves it.

UNDERSTANDING THE CONCEPT

What are the main components of the axial skeleton and the appendicular skeleton of human?
2. Describe the types of joints and give examples.
3. What are ligaments and tendons? What function do they perform?
4. Explain antagonism in muscle action selecting biceps and triceps as example

SHORT QUESTIONS

1. Differentiate between cartilage and bone.
2. What is the role of skeleton in support and movement?
3. How would you differentiate between osteoporosis and arthritis?
4. Label the biceps and triceps in the following diagrams and also mention their contracted or relaxed states.



THE TERMS TO KNOW

Antagonism	Flexor	Rheumatoid arthritis
Appendicular skeleton	Gout	skeleton
Arthritis	Hinge joint	spongy bone
Axial skeleton	Hyaline cartilage	Sternum
Ball-and-socket joint	Insertion	Tendon
Biceps	joint	Triceps
Bone	Lacuna	
Cartilage	Ligament	
Chondrocyte	Origin	
Compact bone	Osteoarthritis	
Cranial bones	Osteocyte	
Extensor	Osteoporosis	
Fibrous cartilage		

ACTIVITIES

1. Identify and draw labelled diagrams of different bones of the axial and appendicular skeleton from real specimen models or charts.
2. Describe the movement of various human joints through observation of models.
3. Describe the movement of biceps and triceps through presentation of the movement of your elbow.
4. Investigate the chemical nature of bone (by putting three pieces of rib bone of lamb or goat in water, NaOH and dilute HCl).

SCIENCE, TECHNOLOGY AND SOCIETY

1. Relate your skeleton with its functioning in daily life.
2. Relate the principle of leverage to the action of elbow joint.
3. State the principles of arthroplasty for the replacement of joints.

CHAPTER

14

Reproduction

Animation14.1:Geotropism,
Source & Credit: Leaving Bio.net

In this chapter we shall explore the various ways in which organisms reproduce.

14.1 Reproduction

Reproduction is defined as the production of individuals of the same species i.e. the next generation of species. While it is one of the fundamental characteristics of living things, it is not an essential life process.

Reproduction is thus essential for the continuation of species. It ensures that the genetic material of one generation is transmitted to the next. Each generation produces more offsprings for the next generation. Many individuals die due to various reasons like diseases, competition, genetic factors etc. before reaching the reproductive age. Only the fittest and the best survive can reach the reproductive age. This ensures that the advantageous characteristics are transmitted to the next generation.

In previous classes we have learnt the two basic types of reproduction. Asexual reproduction means simple cell division that produces an exact duplicate of an organism. There are many types of asexual reproduction which we shall discuss on the following pages. Sexual reproduction involves the joining (fusion) of male and female sex cells i.e. gametes.

14.2 Methods Of Asexual Reproduction

Asexual reproduction does not involve the fusion of gametes. There are many types of asexual reproduction, all producing individuals that are genetically identical to each other and to the parent.

14.2.1 Binary Fission

Binary fission means “division into two”. It is the simplest and most common method of asexual reproduction. It occurs in prokaryotes (bacteria), many unicellular eukaryotes e.g. protozoa (Fig. 14.1) and some invertebrates. During binary fission in bacteria, the DNA is duplicated and so two copies of DNA are formed. The two copies move towards the opposite poles of cell. The cell membrane invaginates in centre and divides the cytoplasm into two. New cell wall is deposited between two cross membranes. It results in the formation of two daughter bacteria, which grow in size and divide again.

An individual can live without reproducing, but a species cannot survive without reproduction.

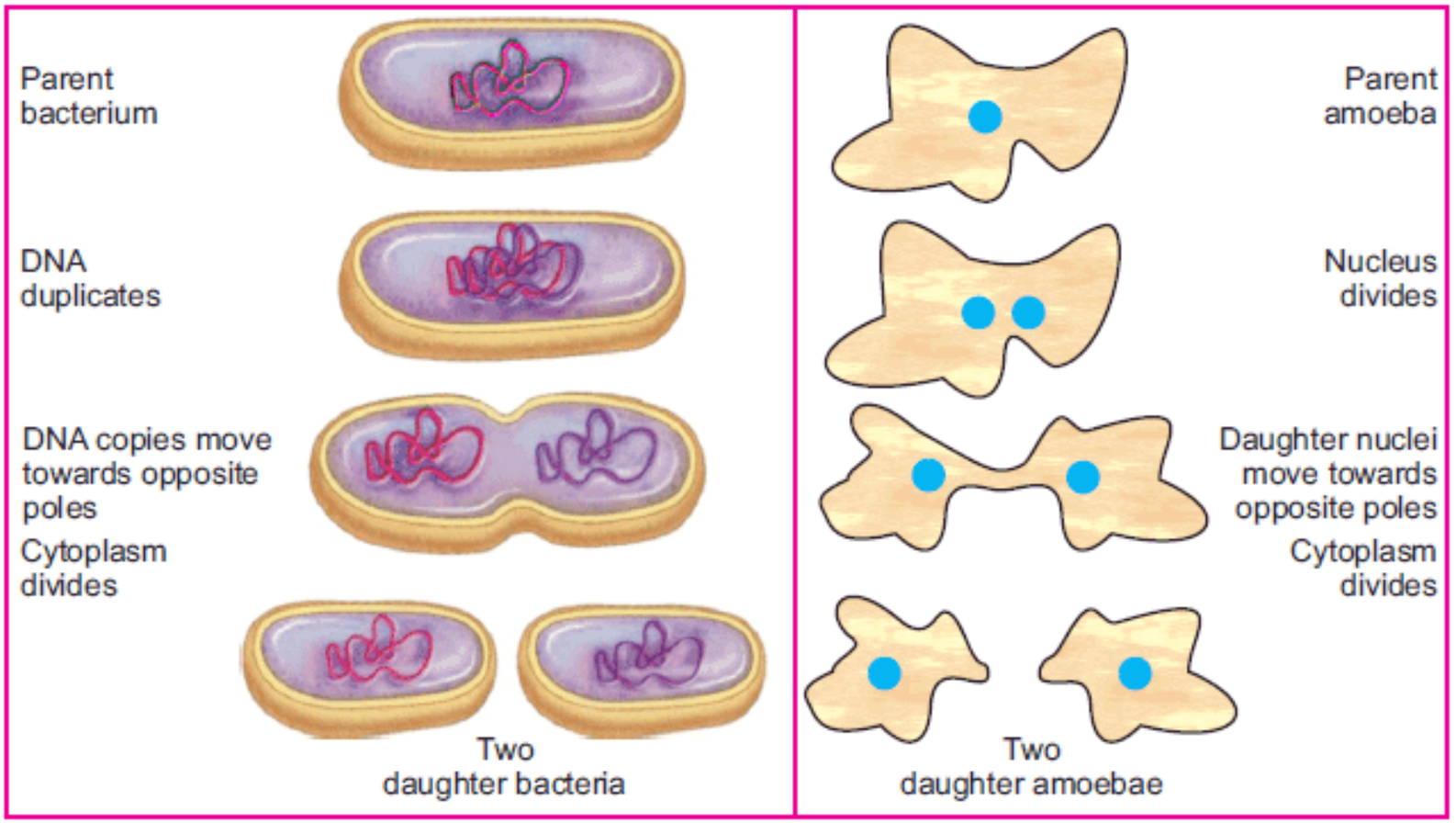


Figure 14.1: Binary fission in a bacterium (left) and in an Amoeba (right)

Animation14.3:Reproduction in plants
Source & Credit:washingtonch

During binary fission in unicellular eukaryotes, the nucleus of parent organism divides into two (by mitosis). It is followed by the division of cytoplasm. So two daughter cells of almost equal size are formed. Daughter cells grow in size and then divide again.

Practical:
Draw different stages of binary fission in Amoeba after observing them in slides or charts.

Some invertebrates also reproduce asexually through binary fission. During this reproduction, body is cut into two halves (fission) and the missing body parts are regenerated in both halves. This type of asexual reproduction is common in planaria (Fig. 14.2) and many echinoderms.

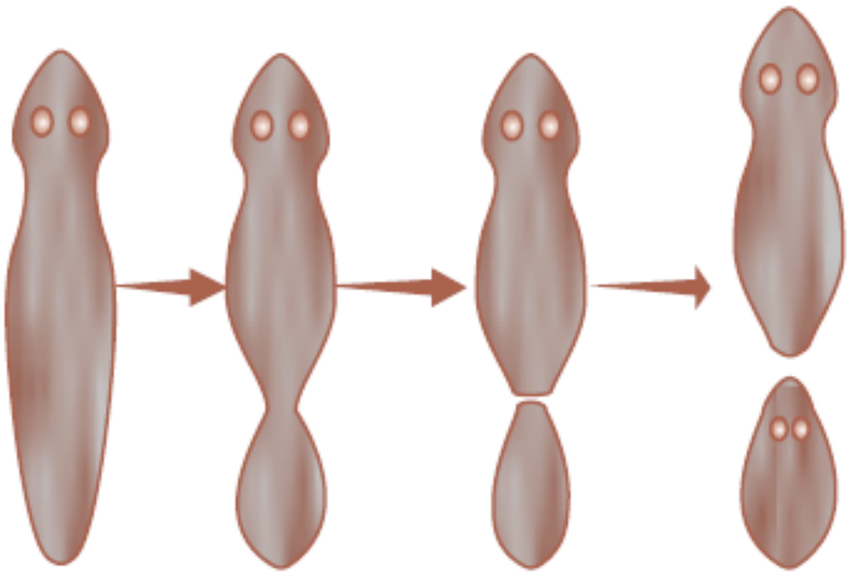
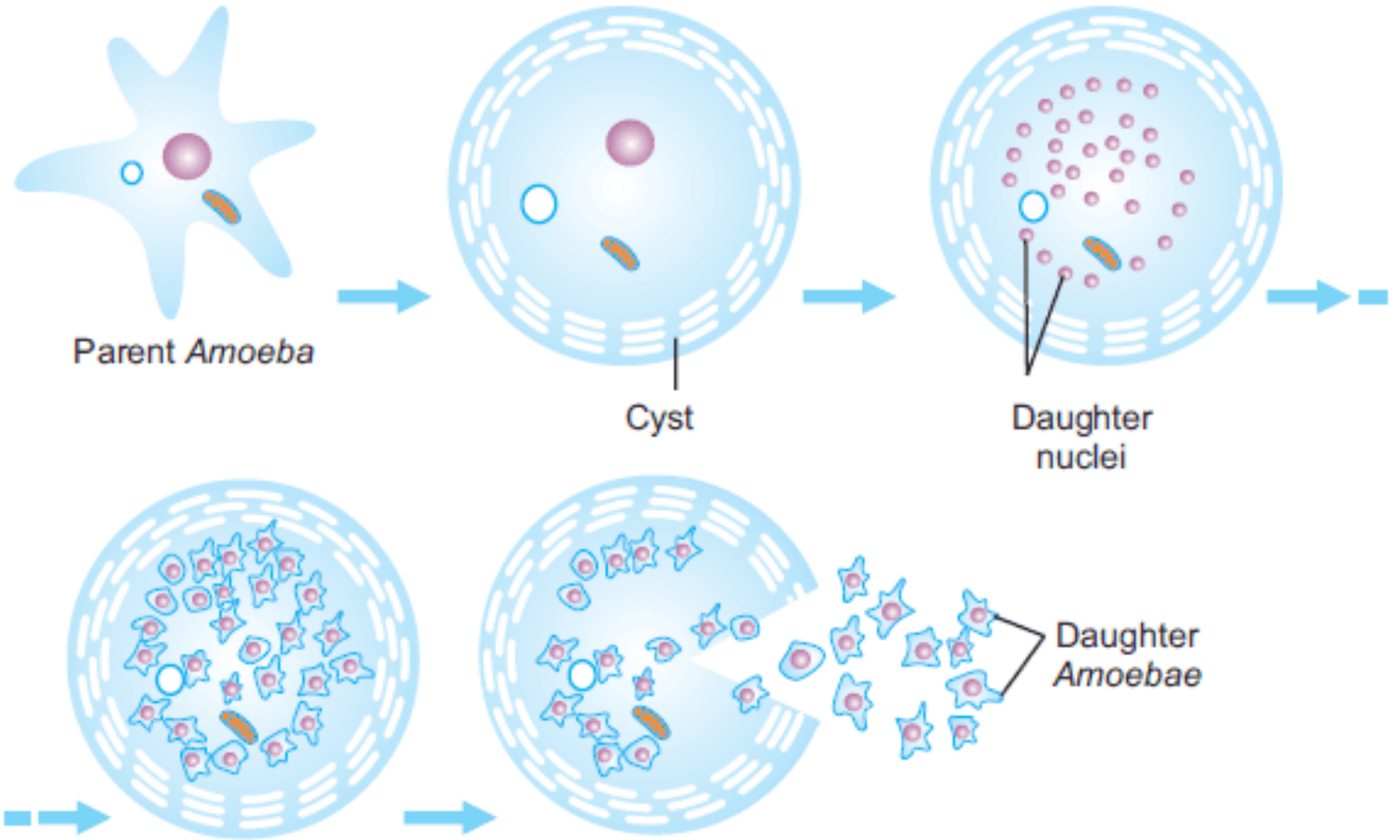


Figure 14.2: Binary fission in a planarian



Some unicellular organisms (e.g. Amoebae) form hard walls called cysts around them, under unfavourable conditions. When favourable conditions return, the nucleus of parent divides into many daughter nuclei by repeated divisions. This is followed by the division of cytoplasm into several parts. Each new part of cytoplasm encloses one nucleus. So a number of daughter cells are formed from a single parent at the same time. This kind of fission is known as multiple fission.

14.2.2 Fragmentation

As certain worms grow to full size, they spontaneously break up into 8 or 9 pieces. Each piece (fragment) develops into a mature worm, and the process is repeated. If a planarian breaks into many pieces instead of two, it will also be called as fragmentation.

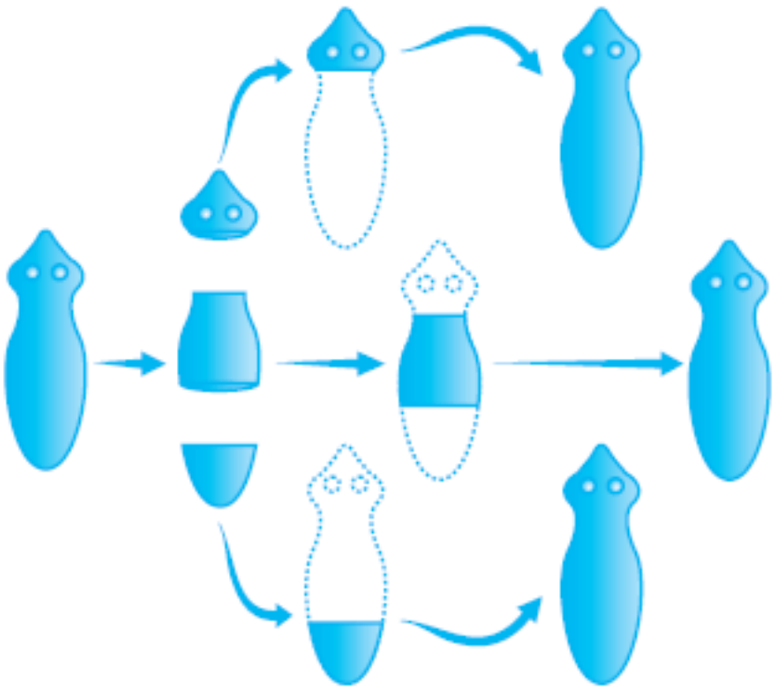


Figure 14.3: Fragmentation in a planarian

14.2.3 Budding

In this type of asexual reproduction, a bud develops as a small outgrowth on parent's body. In case of yeast (a unicellular fungus) a small bud is formed on one side of cell. The nucleus of cell divides and one of the daughter nuclei is passed into the bud. Parent cell may form more than one bud at a time. Each bud enlarges and develops the characteristics of parent organism (Fig. 14.4). The bud may separate from parent body. In some cases, the buds never separate and as a result, colonies of individuals are formed.

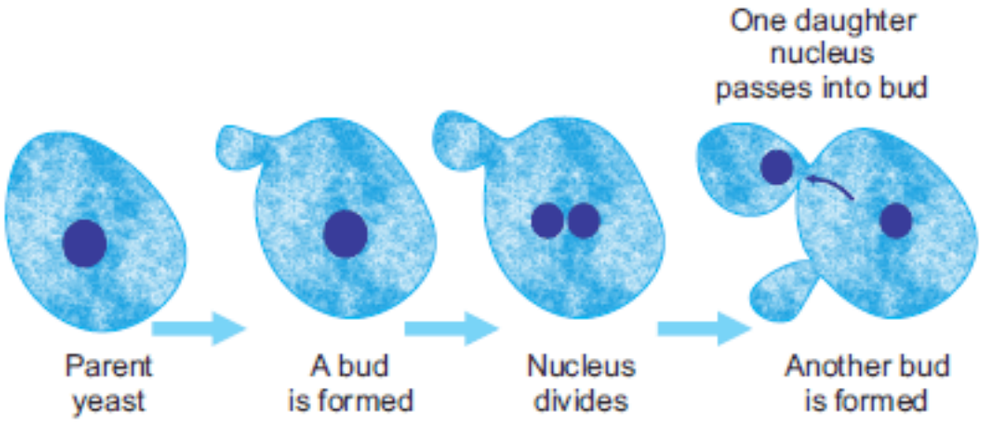


Figure 14.4: Budding in yeast

Animals such as sponges, Hydra and corals also reproduce by means of budding. In them, a small bud is formed on the side of body, by mitosis. This bud enlarges by the formation of more cells. It then detaches from the parent body and grows into new organism.

In corals, the buds do not detach from the parent body. Corals form big colonies, because the buds grow into new organisms by remaining attached to the parent body.

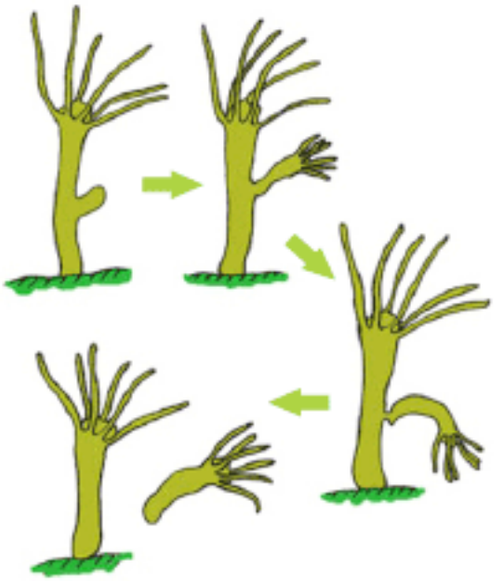


Figure 14.5: Budding in Hydra

14.2.4 Spore Formation

It is generally seen in most fungi (e.g. Rhizopus). When *Rhizopus* reaches reproductive age, its body cells form thick walled spore sacs called sporangia (sing. sporangium).

Inside each sporangium, a cell divides many times and forms many daughter cells called spores. Each spore is covered with a thick wall called cyst and it can survive unfavourable conditions. When sporangia are mature, they burst and release spores. Under favourable conditions, the spores germinate and develop into new *Rhizopus*.

Under unfavourable conditions, some species of bacteria reproduce by forming spores, e.g. *Clostridium* and *Bacillus* species. The bacterial spores are also thick-walled. They are formed inside bacterial cells, so are called endospores (Fig. 14.7).

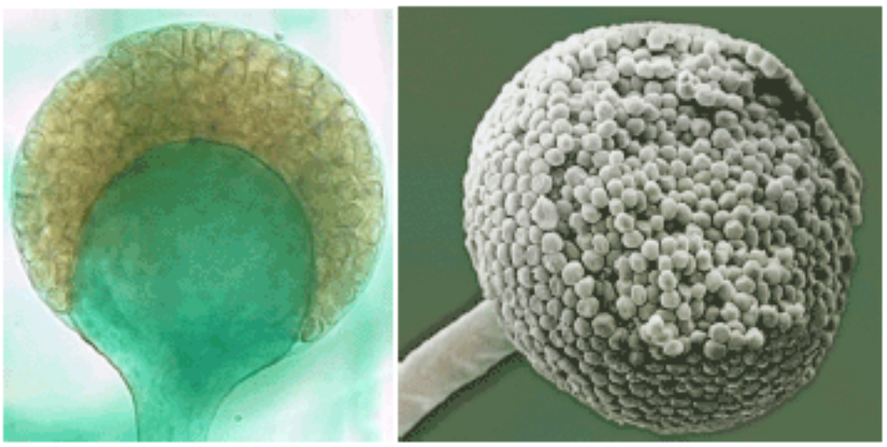


Figure 14.6: Spore formation in Rhizopus; Mature sporangium (left), sporangium bursts (right)

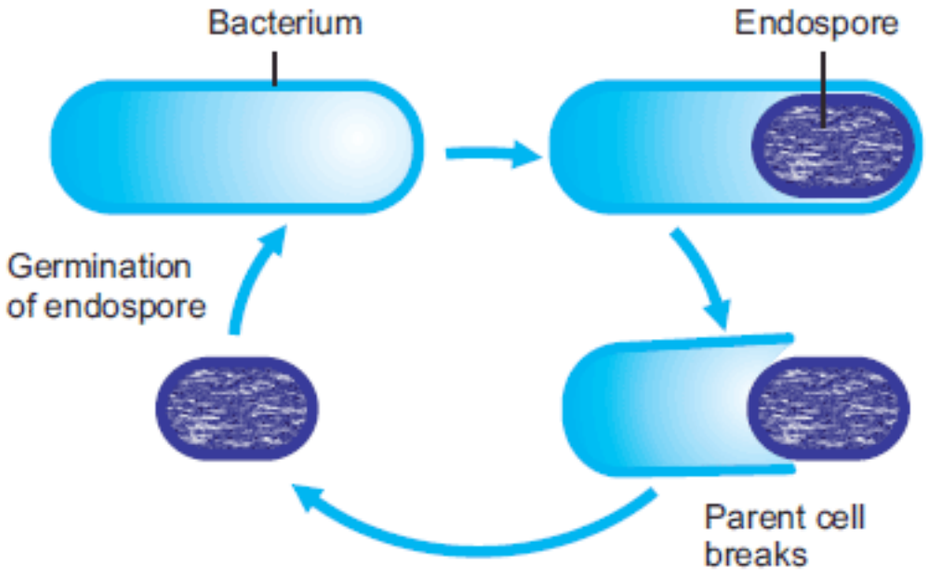


Figure 14.7: Spore formation in a bacterium

14.2.5 Parthenogenesis

Parthenogenesis is also considered as a form of asexual reproduction. In it, an unfertilized egg develops into new offspring. Some fishes, frogs and insects reproduce by means of parthenogenesis. Similarly, queen honeybee lays eggs in the cells of honeycomb. Many eggs remain unfertilised and develop into haploid males (drones) by parthenogenesis. At the same time, some eggs are fertilized by male bees and these develop into diploid females (new queen and worker bees).

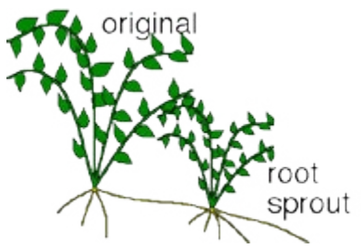
14.2.6 Vegetative Propagation

When vegetative parts of plants i.e. roots, stems or leaves give rise to new plants, the process is called vegetative reproduction or vegetative propagation. It occurs naturally, and can also be brought about artificially.

Natural Vegetative Propagation

Vegetative propagation occurs naturally in several ways.

1. Bulbs are short underground stems surrounded by thick, fleshy leaves that contain stored food. Adventitious roots emerge under the base of bulb while shoots emerge from the top of the base. Tulips, onions and lilies reproduce by bulbs.



Natural Vegetative Propagation

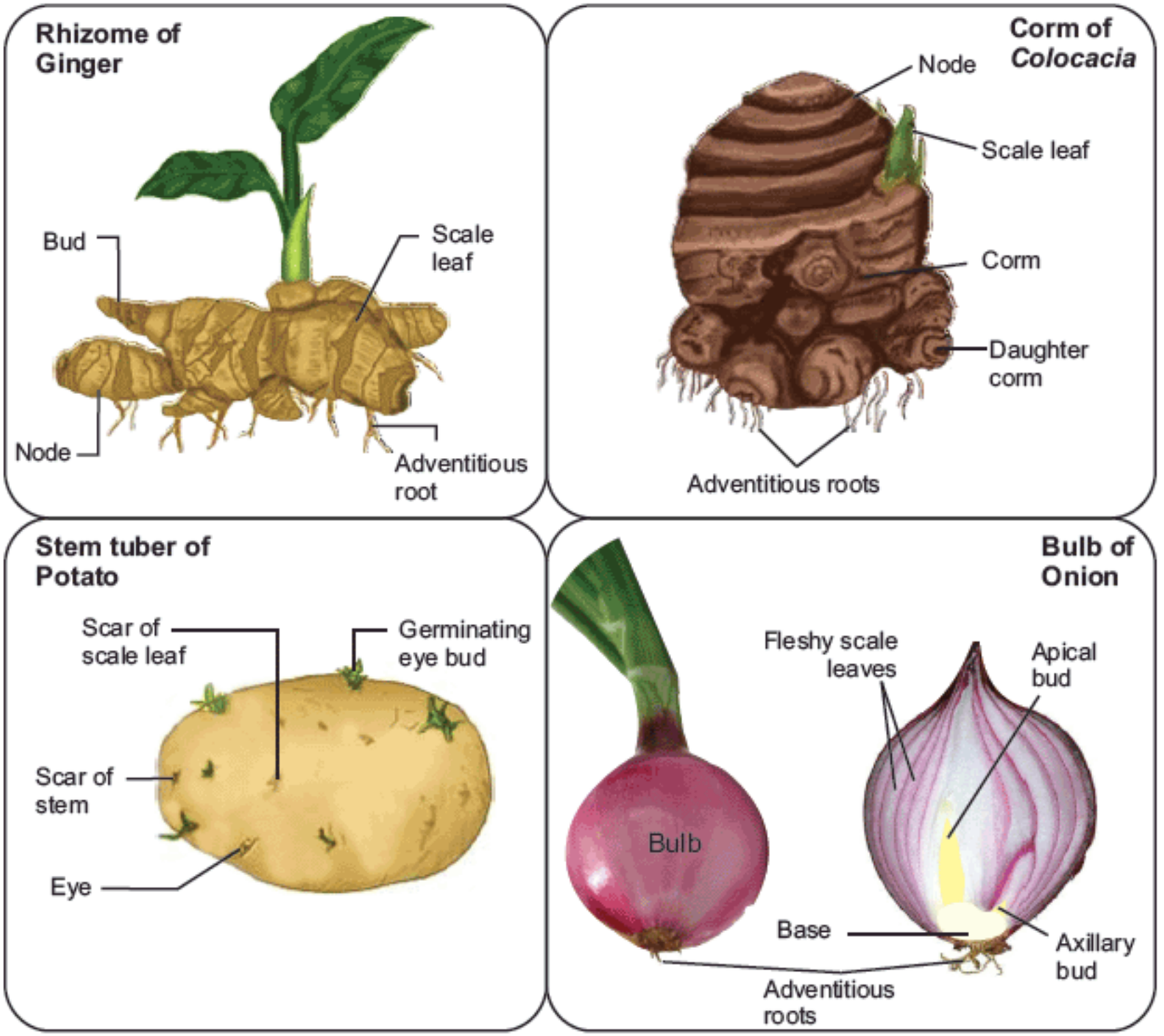


Figure 14.8: Some types of natural vegetative propagation

2. Corms are short and swollen underground stems containing stored food. Buds are present at the top of corm. From a bud, shoot grows and forms a new plant. Dasheen and garlic reproduce by corms.

3. Rhizomes are horizontal underground stems with scale leaves. There are enlarged portions called nodes on rhizome. Buds are produced at nodes. The buds present on the upper surface of rhizome give rise to shoot. The lower surface of rhizome produces adventitious roots. Ginger, ferns and water lilies reproduce by rhizomes.

4. Stem Tubers are the enlarged portions of an underground stem (rhizome). There are aggregations of tiny buds in the form of "eyes" along the surface of tuber. Each bud develops into shoot that grows upward and also produces roots. Potatoes and yams reproduce by tubers.

5. Suckers are lateral stems close to ground level. A sucker grows underground from some distance and then turns up, producing the new plant. Mint and *Chrysanthemum* reproduce in this way.

6. Vegetative propagation by **leaves** is not common and is seen in plants such as *Bryophyllum* (Pather chut). This plant has fleshy leaves and adventitious buds are present at the margins of leaves. When leaf falls on ground, the buds grow into new plants.

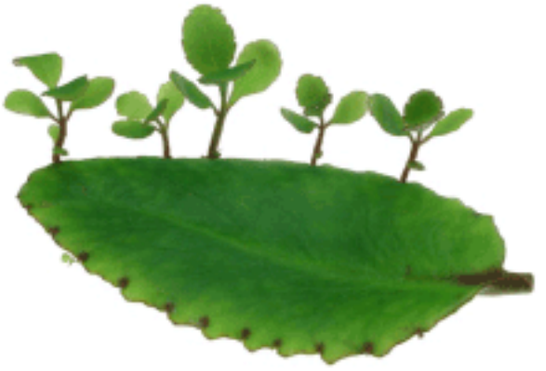


Figure 14.9: A Bryophyllum leaf with buds

Artificial Vegetative Propagation

Gardeners and farmers use artificial methods of vegetative propagation to increase the stock of a plant. The following two are the most common methods of artificial vegetative propagation (Fig. 14.10).

1. Cuttings

In this method, cuttings may be taken mainly from the stems or roots of parent plant. These cuttings must have a meristematic region from which growth can occur. When cuttings are placed in a suitable soil and under right conditions (sufficient nutrients, water and sunlight), they form roots and shoots. Roots and shoots grow and develop into a plant identical to the parent plant from which the cuttings were taken. Roses, ivy and grapevines are propagated by stem cuttings. Sweet potato is an enlarged root. Farmers place it in moist sand or soil until it produces several plantlets. Then the plantlets are removed and planted. This process is used to produce many plants from a single plant. All new plants are exactly the same. This artificial vegetative propagation has been very beneficial on sugar cane plantation.

2. Grafting

In grafting, a piece of stem is cut from the plant and is attached with another plant with established root system. After a while, the vascular bundles of the attached stem piece and the host plant are connected to each other.

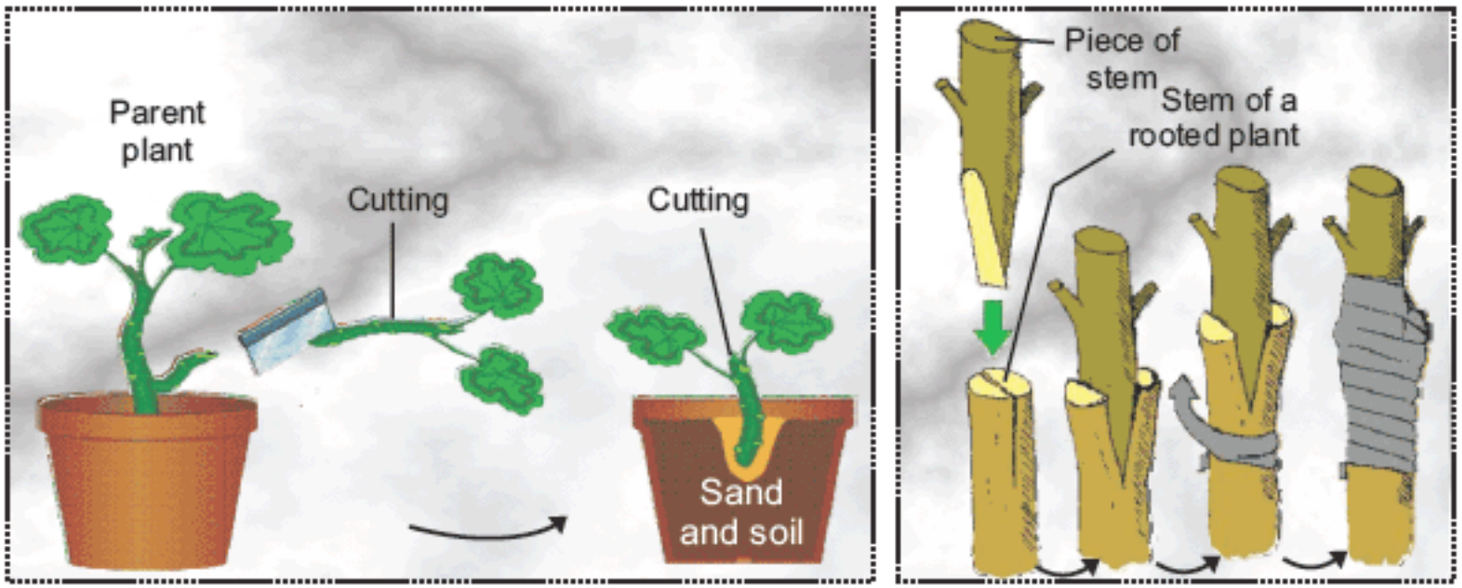


Figure 14.10: Artificial vegetative propagation: Cutting (left) and Grafting (right)

The stem piece and the plant begin to grow together. This method is used to propagate many .(roses, peach trees, plum trees and various seedless fruits (including grapes

Figure 14.11: Product of artificial vegetative propagation: Seedless oranges

Advantages and Disadvantages of Vegetative Propagation of Plants

Plants can reproduce asexually via vegetative propagation. This method of reproduction has some advantages and disadvantages as well.

Advantages

The offsprings produced through vegetative propagation are genetically identical. Therefore beneficial characteristics can be preserved. In vegetative propagation, there is no need of any mechanism of pollination. It helps to increase number of plants at a rapid rate. The organs of vegetative propagation enable many plants to pass over unfavourable conditions. Plants bearing seedless fruits can be grown only by vegetative propagation.

Disadvantages

The plants do not have genetic variations. Species specific diseases can attack and this can result in the destruction of an entire crop.

Tissue Culture and Cloning

Cloning is the latest method of vegetative propagation. In this method, identical offsprings are produced from a single parent using its vegetative tissue or cell. Tissue culture is the technique applied in this method.

This method of propagation is also called micro-propagation since it uses only a small part of plant.

Tissues are taken from any part of plant and are put in a suitable nutrient medium. The tissue cells start mitosis and produce masses of cells called calluses are transferred to other medium that contains different hormones for the formation of roots, stem and leaves. Calluses make these structures and grow into new small plants. The small plants are then planted in pots and then in fields.

Practical:

Examine the specimens of onion, corn, ginger and potato and write the modes of their reproduction.

? Write in sequence the underground stems for vegetative propagation in onion, ginger, potato and garlic.

Bulb, rhizome, stem tuber and corm

14.3 Sexual Reproduction In Plants

Sexual reproduction involves the production of gametes (sperms and egg cells) and their fusion i.e. fertilization. Gametes are produced in special structures in plant body. The major plant groups are mosses, ferns and seed plants. The seed plants include gymnosperms and angiosperms (flowering plants). Plant groups use different methods for bringing the sperm and egg cells together. In mosses and ferns sperms are motile and can swim to egg cells. Therefore, these plants require water (in the form of dew or rain) for sexual reproduction. On the other hand, gymnosperms and angiosperms have special methods for carrying their sperms to egg cells. They do not need water for reproduction.

In the life cycle of plants, two different generations alternate with each other. One generation is diploid and produces spores. It is called sporophyte generation. The other generation is haploid and produces gametes. It is called gametophyte generation. The phenomenon in which two different generations alternate with each other during life cycle is known as alternation of generations.

In most plants, sporophyte generation is dominant. It means that it is big in size and is independent. Sporophyte produces haploid spores by meiosis. The spores develop into gametophyte. It is small in size and depends upon sporophyte. It produces gametes by mitosis. The male and female gametes fuse and form diploid zygote. The zygote undergoes repeated mitosis and develops into a new diploid sporophyte (Fig. 14.12).

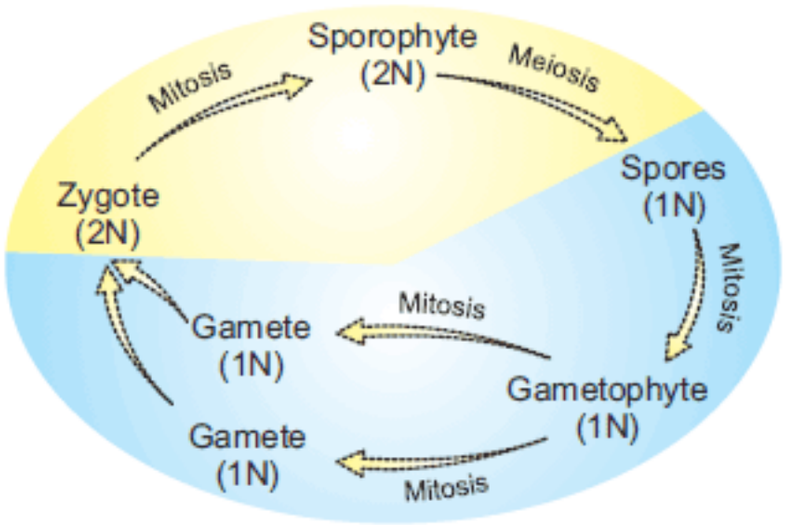


Figure 14.12: An overview of alternation of generations in plants

14.3.1 Sexual Reproduction in Flowering Plants

We know that in angiosperms, parent plant is diploid sporophyte generation. Flower is the reproductive structure in this generation. The flower components are arranged in the form of whorls. The outer two whorls in a flower are are the non-reproductive whorls while the inner two
whorls are the reproductive whorls.

The flower is actually a condensed shoot with the nodes present very close to each other. The different parts of the flower are attached to the nodes. All the structures present at one node are collectively called the whorl.

Calyx is the outermost whorl. It is usually green in colour. Its individual units (leaflets) are called sepals. Sepals protect the inner whorls at bud stage. Corolla is the next inner whorl and is often coloured brightly. Its individual units (leaflets) are called .petals. They serve to attract bees, birds, etc. which are the agents of pollination

Third whorl i.e. **androecium** is the male reproductive part of flower. Its units are called **stamens.** Each stamen has a thread-like **filament** at the free end of which **anther** is attached. Anther has **pollen-sacs** in which haploid **microspores** (pollen grains) are produced through meiosis. Each microspore germinates into the male gametophyte generation. During it, the nucleus of microspore undergoes mitosis and produces two nuclei i.e. a t**ube nucleus** and a **generative nucleus.** The generative nucleus again undergoes mitosis and produces two **sperms.** So, a germinated microspore has a tube nucleus and two sperms. All these structures are the male gametophyte generation of plant.

Animation14.5:Mitosis,
Source & Credit: tokyo-med.ac.jp

Fourth whorl i.e. **gynoecium** is the female reproductive part of flower. Its units are called **carpels** (or pistils). Each carpel is made up of the basal **ovary,** middle **style** and upper **stigma**. Inside ovary, there are one to many **ovules**. Inside each ovule, one haploid **macrospore** is produced through meiosis. Macrospore germinates into the female gametophyte generation. During it, macrospore undergoes mitosis and produces an **egg cell** and some associated structures (e.g. fusion nucleus). Egg cell and associated structures are the female gametophyte generation of plant.

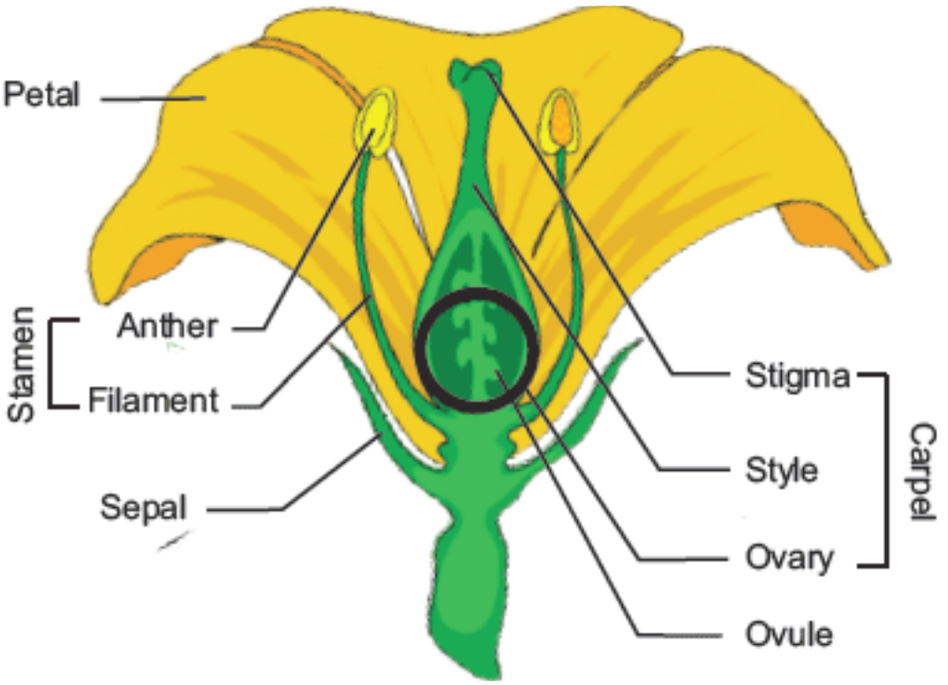


Figure 14.13: Structure of a flower

When pollen grains mature, they are transferred to stigma. It is called **pollination**. On reaching the stigma, the tube nucleus of pollen grain constructs a **pollen tube**. The pollen tube contains a tube nucleus and two sperms. The tube grows through style and ovary and enters ovule. Here, it bursts and releases the sperms. Both sperms enter the female gametophyte. One sperm fuses with egg and forms a diploid **zygote**. The other sperm fuses with diploid **fusion** nucleus and forms a triploid (3N) nucleus called **endosperm nucleus.** Since the process of fertilization involves two fusions, it is called **double fertilization.** Zygote develops into embryo and endosperm nucleus develops into endosperm tissue (food of the growing embryo). Ovule then becomes **seed** and ovary changes into **fruit.**

When seeds mature, they are dispersed (we shall discuss in the next section). If seeds get suitable conditions, their embryos develop into new plants (the diploid sporophytes of the next generation).

Animation14.6:Fertilization,
Source & Credit: urbanext.illinois

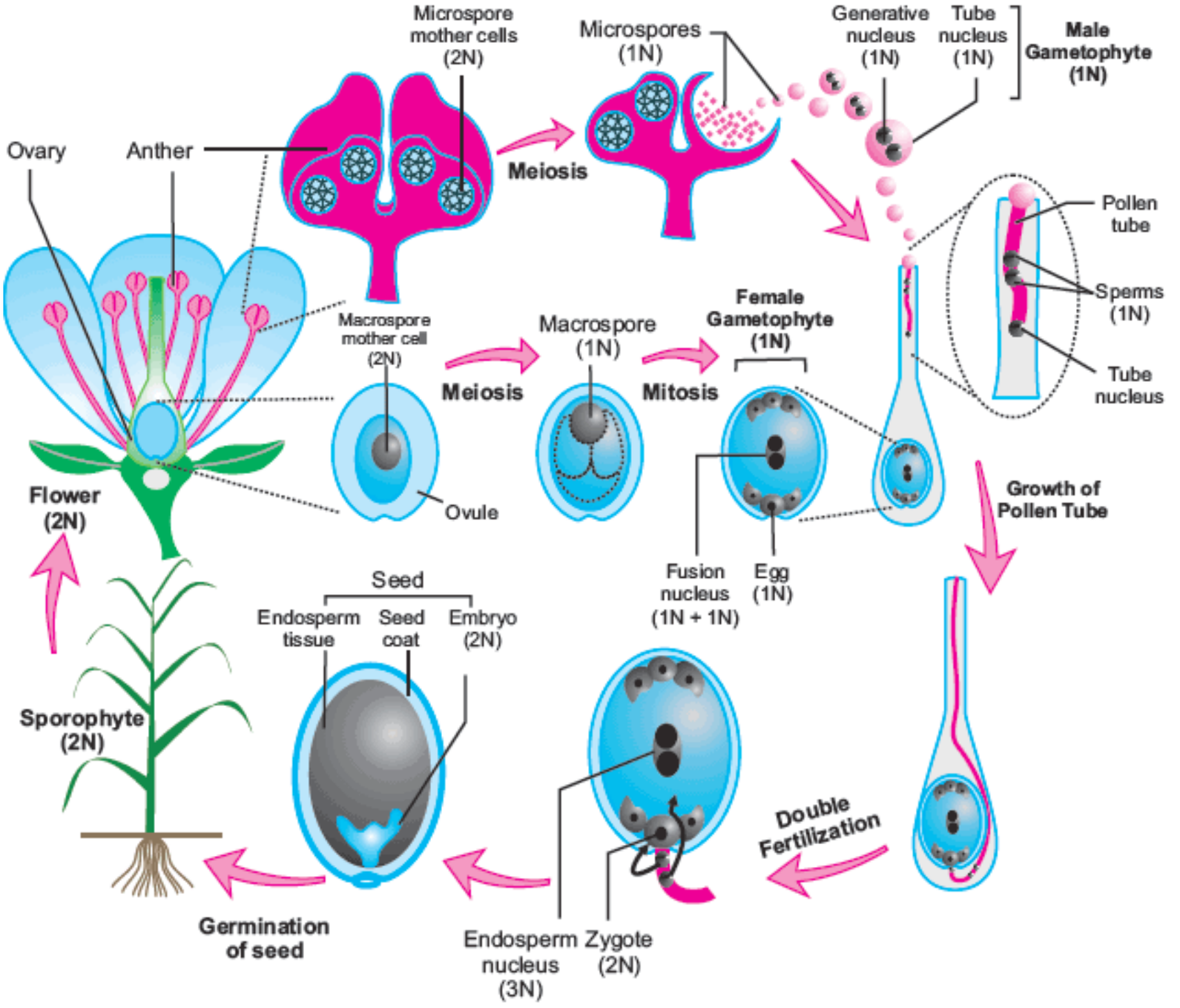


Figure 14.14: Life cycle of a flowering plant

14.3.2 Pollination

Pollination is defined as the transfer of pollen grains from flower's anther to stigma. Two types of pollination are recognised.

Self pollination is defined as the transfer of pollen grains from the anther to the stigma of the same flower or other flower of the same plant.

Cross pollination is the transfer of pollen grains from the flower on one plant to the flower on other plant of the same species. Cross pollination is brought about by various agencies like wind, water, bees, birds, bats and other animals including man.

The insect pollinated and wind pollinated flowers have structural adaptations that facilitate the transfer of pollen grains between two plants. Some of these adaptations are described in Table 14.1.

Figure 14.15: Self pollination (left) and cross pollination (right)

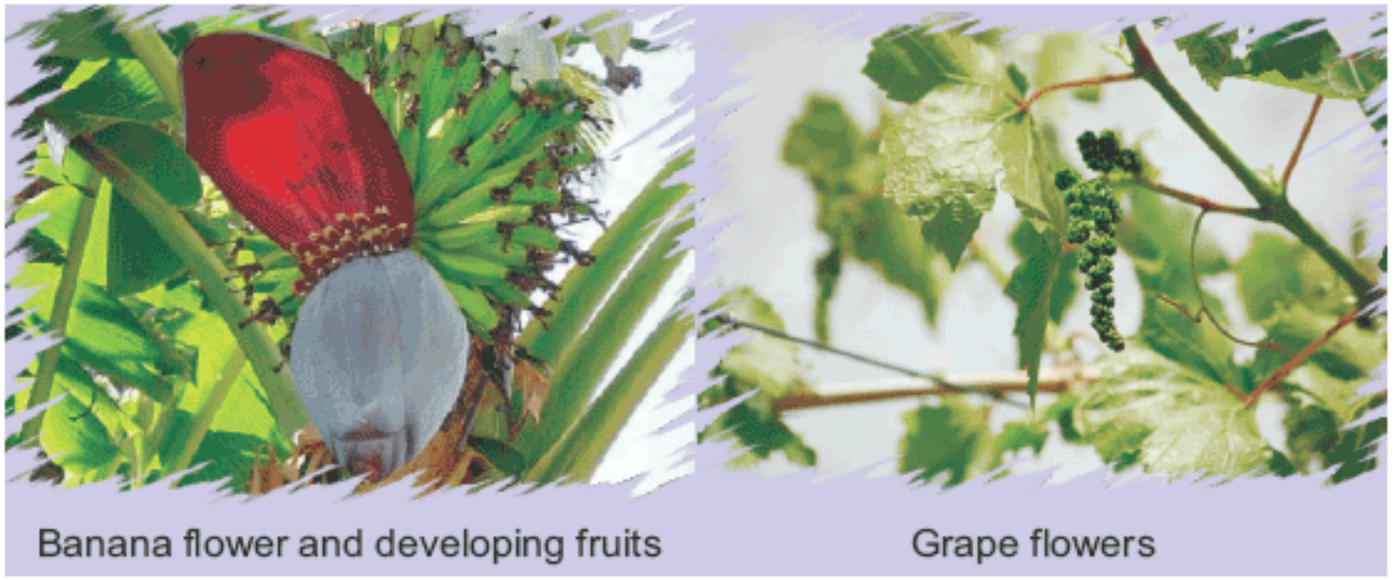
Table 14.1: Adaptations in insect-pollinated and wind-pollinated flowers

Feature	Insect Pollinated Flowers	Wind Pollinated Flowers
Size	Generally large	Generally small
Color	Petals brightly colored	Petals green or dull in color
Nectar	Produce nectar	Do not produce nectar
Floral arrangement	Flowers face upwards	Flowers hang down for easy shaking
Stamens and stigmas	Enclosed inside ring of petals	Hang out of ring of petals
Pollen grains	Small number produced/ heavy and sticky	Large number produced/light with smooth surface
Stigma	Pinhead shaped with no branches	Feathery branches for catching pollen

Figure 14.16: An insect-pollinated flower (left) and a wind-pollinated (right) flowers

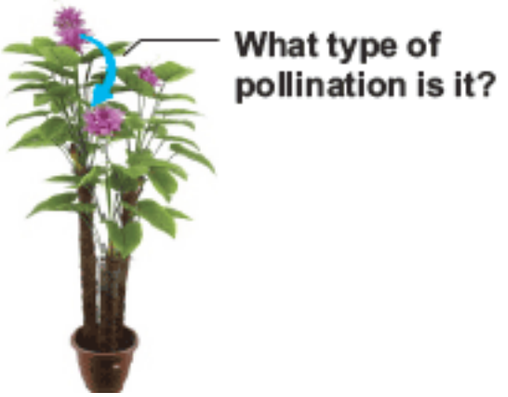
Initiating and Planning

Hypothesize why Mendel used Pea plants for his experiments.



In some plants, ovaries develop into fruit without the fertilization inside their ovules. This process is known as parthenocarpy and it results in seedless fruits e.g. bananas and seedless varieties of grapes.

Examples of insect pollinated flowers are buttercup, rose, wallflower, sunflower, orchid etc. Examples of wind pollinated flowers are grasses, hazel, willow, corn etc.



The evolution of seed has been proved as an important step in the success and spread of flowering plants, as compared to the seed-less plants like mosses and ferns.

14.3.3 Development and Structure of Seed

We know that after fertilization in the female gametophyte, zygote divides repeatedly by mitosis and develops into an embryo. At this stage (in gymnosperms and angiosperms), ovule changes into seed. The formation of seed completes the process of sexual reproduction in seed plants.

Angiosperm seeds consist of three distinct parts:
(1) the embryo formed from zygote,
(2) the endosperm tissue formed from endosperm nucleus, and
(3) the seed coat which develops from the wall of ovule (integument).

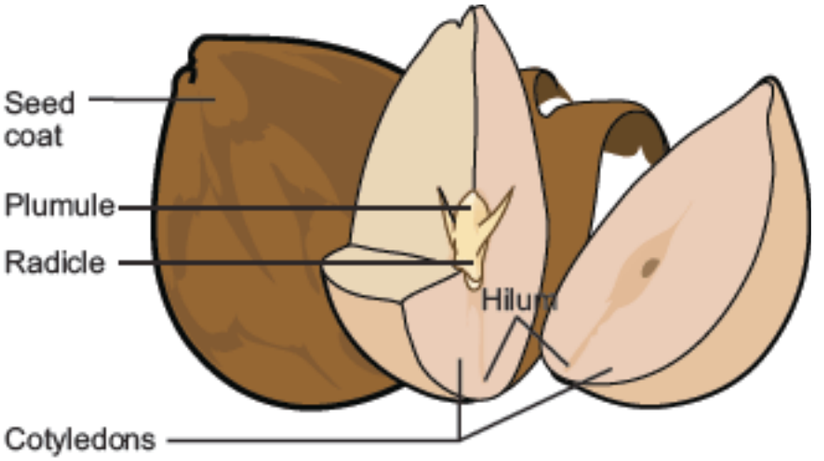


Figure 14.17: The structure of a dicot seed

Seed coat (or testa) develops from the integument, originally surrounding the ovule. It may be a paper-thin layer (e.g. peanut) or thick and hard (e.g. coconut). Seed coat protects embryo from mechanical injury and from drying out. There is a scar on seed coat, called hilum. It is where the seed is attached to ovary wall (fruit). At one end of **hilum,** there is micropyle. This is the same opening through which the pollen tube entered ovule. Seed uses it for the absorption of water.

The form of the stored nutrients in seeds varies depending on the kind of plant.

Embryo is actually an immature plant. It consists of a **radicle,** a **plumule** and one or two cotyledons (seed leaves). The radicle of embryo develops into new root while the plumule develops into new shoot. The embryonic stem above the point of attachment of cotyledon(s) is called **epicotyl.** The embryonic stem below the point of attachment is **hypocotyl.** Within seed, there is a **store of nutrients** for the seedling that will grow from embryo. In angiosperms, the stored food is derived from the endosperm tissue. This tissue is rich in oil or starch and protein. In many seeds, the food of the endosperm is absorbed and stored by cotyledons.

14.3.4 Germination of Seed

For the germination of seeds, they must arrive at a suitable location and be there at a time favourable for germination and growth.

Seed germination is a process by which a seed embryo develops into a seedling. During germination, embryo soaks up water which causes it to swell, splitting the seed coat. Root is the first structure that emerges from the radicle present in seed. It grows rapidly and absorbs water and nutrients from soil. In the next phase, plumule develops into tiny shoot which elongates and comes out of soil.

On the basis of the elongation of hypocotyl and epicotyl, there are two types of germination (Fig. 14.18). In **epigeal** germination, the hypocotyl elongates and forms a hook, pulling the cotyledons above ground. Beans, cotton and papaya are the examples of seeds that germinate this way. In **hypogeal** germination, the epicotyl elongates and forms the hook. In this type of germination, the cotyledons stay underground. Pea, maize and coconut germinate this way.

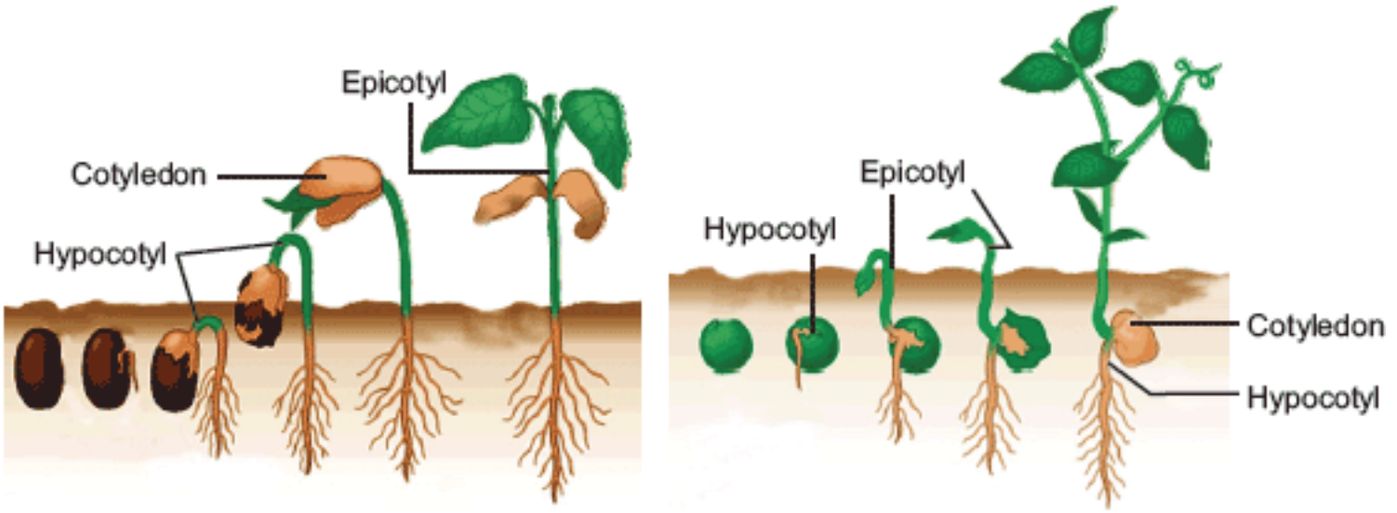


Figure 14.18: Types of seed germination; epigeal (left) and hypogeal (right)

Most seeds go through a period, during which there is no growth. This period is called the dormancy of the seed. Dormant seeds are ripe seeds but do not germinate. Under favourable conditions, the seeds break dormancy and begin to germinate

Conditions for Seed Germination

Seed germination depends on both internal and external conditions. The internal conditions include a live embryo and sufficient food storage. The most important external conditions include water, oxygen and favourable temperatures.

Water (moisture): Seeds of most plants have low water content, and germination cannot occur until seed coat or other tissues have imbibed (taken in) water. The absorbed water is used in the digestion of the stored food and it also helps in the elongation of hypocotyl and epicotyl.

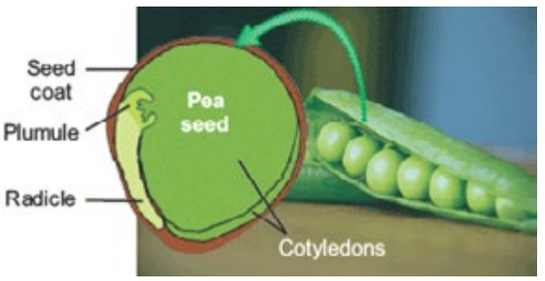
Oxygen: Oxygen is essential for the respiration in the cells of embryo.

Temperature: Seeds differ greatly in their temperature requirements for germination. The optimum temperature for the germination of the seeds of most plants ranges from 25-30^{o}C.

Germination of seeds of many plants is also favoured by light. In others, germination is retarded by light.

Practicals:

- Identify different parts of flower.
- Identify and draw the component of the seeds of pea or gram.
- List some of the ripened ovaries and ovules, which are eaten in daily life.
- Perform experiment to investigate the necessary conditions for seed germination



? What is the future of ovule and ovary after fertilization in flower?

Ovule develops into seed while ovary wall develops into fruit

14.4 Sexual Reproduction In Animals

Most animals reproduce sexually. The sexual reproduction is based on the formation and the fusion of male and female gametes.

14.4.1 Formation of Gametes (Gametogenesis)

The formation of gametes is called gametogenesis. In this process, diploid (2N) gamete mother cells undergo meiosis and form haploid (1N) gametes. The male and female gametes (sperms and egg cells or ova) are produced in specialized organs called gonads. Male gonads are called testes (Singular: testis) while female gonads are called ovaries. The production of sperms in testes is called spermatogenesis and the production of egg cells in ovaries is called oogenesis (Fig. 14.19).

Spermatogenesis

Some cells present in the walls of the seminiferous tubules of testes divide repeatedly by mitosis to form large number of diploid spermatogonia. Some spermatogonia produce primary spermatocytes. Each primary spermatocyte undergoes meiosis-I and produces two haploid daughter cells called secondary spermatocytes. These cells undergo meiosis-II. In this way four haploid spermatids are produced from each primary spermatocyte. The spermatids are non-motile and many changes occur in them to convert them into motile cells. Their nuclei shrink and some structures are formed e.g. a corner called acrosome, a tail and a mitochondrial ring. After these changes, the spermatids are called sperms.

Oogenesis

Some cells of ovary prepare structures called follicles, in which many diploid oogonia are present. Some oogonia produce diploid primary oocytes.

One of the primary oocytes completes meiosis-I and produces two haploid cells. The smaller cell is called first polar body and the larger one is called secondary oocyte. The secondary oocyte completes meiosis-II and produces two haploid cells i.e. a second polar body and an egg cell.

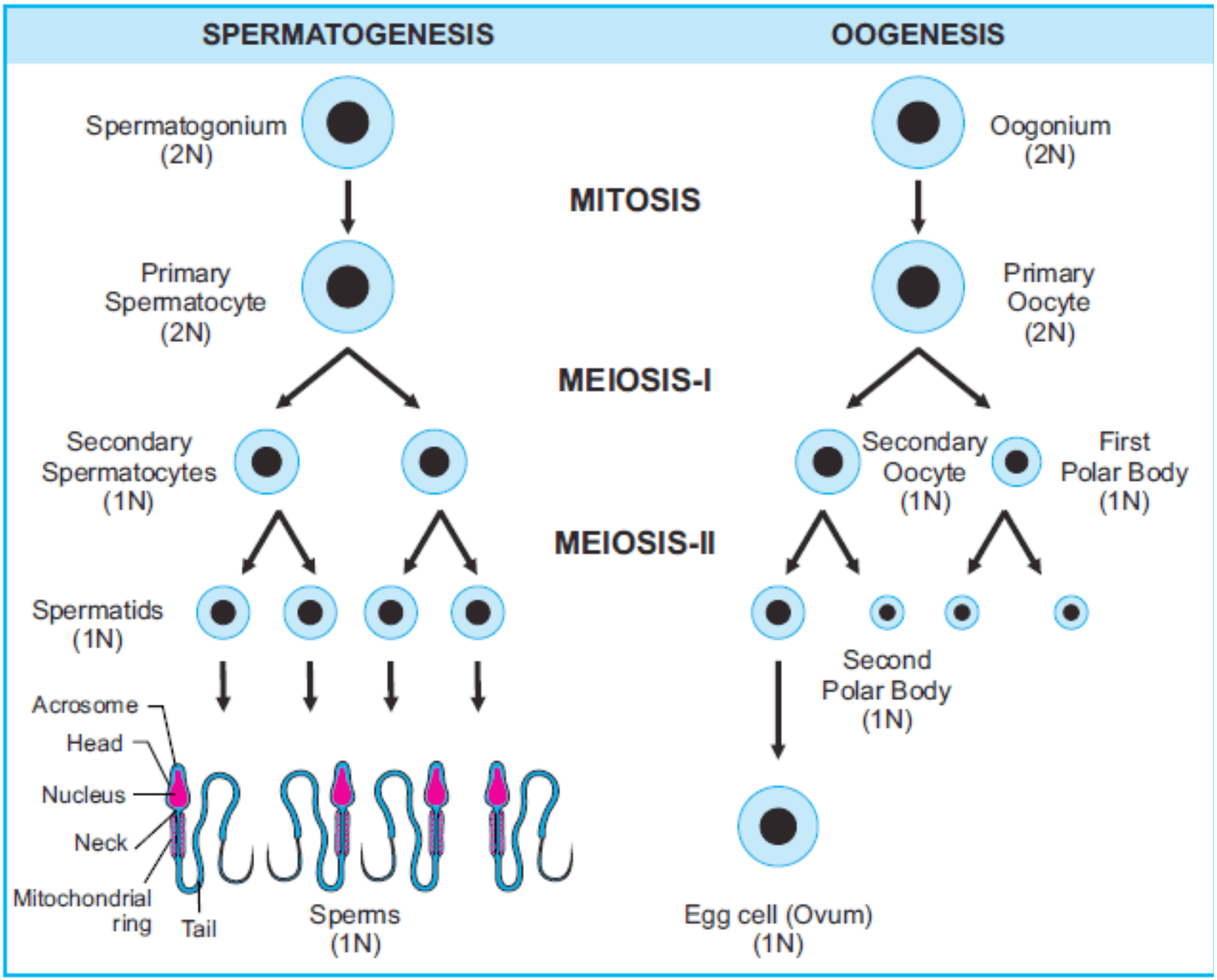


Figure 14.19: Gametogenesis in animals

14.4.2 Fertilization

After the formation of gametes, fertilization occurs. There are two mechanisms by which fertilization can take place i.e. external fertilization and internal fertilization.

In **external fertilization**, egg cells are fertilized outside of body. External fertilization occurs mostly in aquatic environment. It requires both the male and the female animals to release their gametes into their surroundings at almost the same time. For external fertilization, the animals have to release great number of gametes. In external fertilization, there is risk of loss of gametes due to environmental hazards such as predators. External fertilization occurs in many invertebrates and the first two groups of vertebrates i.e. fishes and amphibians.

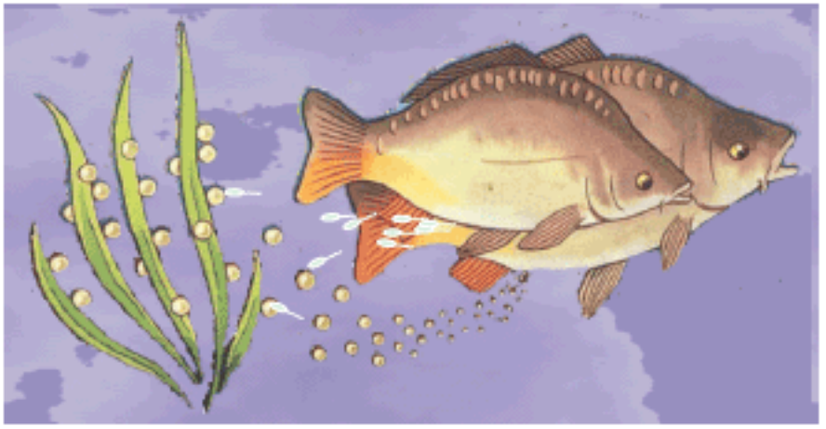


Figure 14.20: External fertilization in fish

In **internal fertilization,** egg cells are fertilized within the reproductive tract of female. It occurs in reptiles, birds and mammals. Such animals provide protection to the developing embryo. After fertilization, reptiles and birds make protective shells around their egg cells and then lay them.

The shell is resistant to water loss and damage. In mammals (with the exception of egg-laying mammals) the development of fertilized egg into new baby takes place within mother body. In this case, there is extra protection to the embryo and mother also supplies everything that embryo needs.

Figure 14.21: Reptiles and Bird's egg provides protection and food to embryo

14.4.3 Reproduction in Rabbit

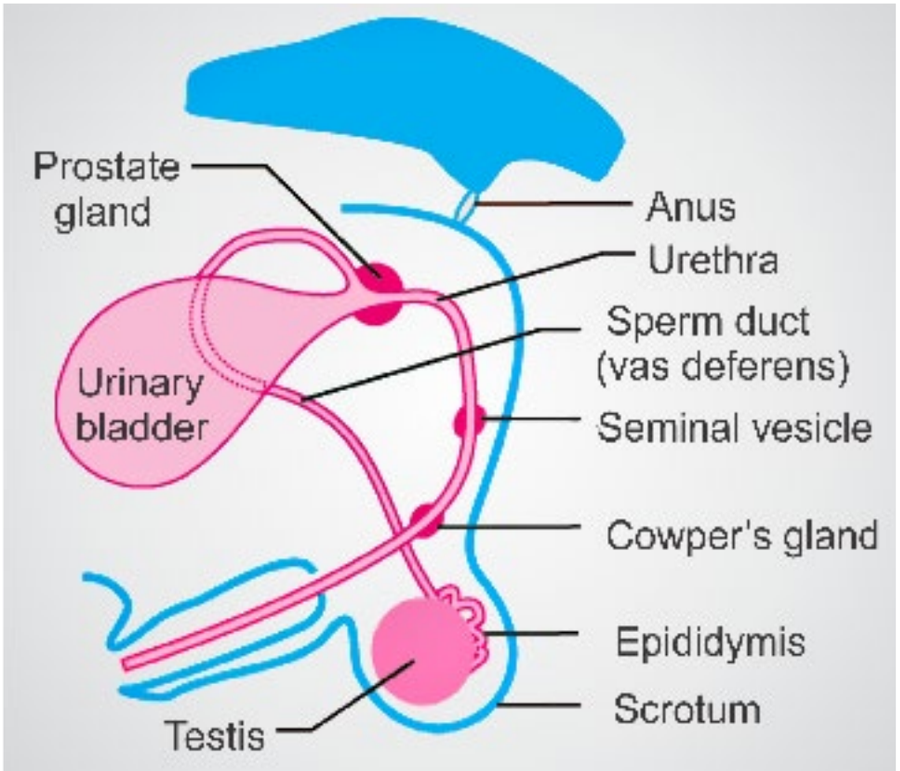
Rabbits reingest their own pellet-like faeces to digest their food further and extract sufficient nutrients.

Rabbits are small mammals found in several parts of the world. They are used in research as experimental animals.

Male Reproductive System

The male reproductive system of rabbit consists of a pair of testes that produce sperms, the associated ducts that transport sperm to external genitalia and glands that add secretions to sperms (Fig. 14.22). Testes are located in a bag of skin called the scrotum that hangs below the body. Each testis consists of a mass of coiled tubes called the seminiferous tubules. In these tubules, the sperms are formed.

When sperms are mature, they accumulate in the **collecting ducts** of testes and then pass to **epididymis.** From epididiymis, sperms move to a sperm duct called **vas deferens.** Both sperm ducts join **urethra** just below urinary bladder. The urethra transports both sperm and urine.



Semen is the material containing sperms in a fluid. It consists of 10% sperms and 90% fluid. As the sperms pass down the ducts from testes to urethra, the associated glands add various secretions. **Seminal vesicles** produce secretions that provide nutrients for sperms. **Prostate gland** produces a secretion that neutralizes the acidity of the fluid. **Cowper's glands** produce secretions that lubricate the ducts.

Female Reproductive System

The female reproductive system of rabbit consists of ovaries and associated ducts (fig.14.23). **Ovaries** are small oval organs situated in abdominal cavity just ventral to kidneys. Like most animals, female rabbits have a pair of ovaries. The outer region of ovary produces egg cells. A cluster of specialized cells called **follicle** surrounds and nourishes each egg cell. From ovaries, egg cells are released in **fallopian tubes.**

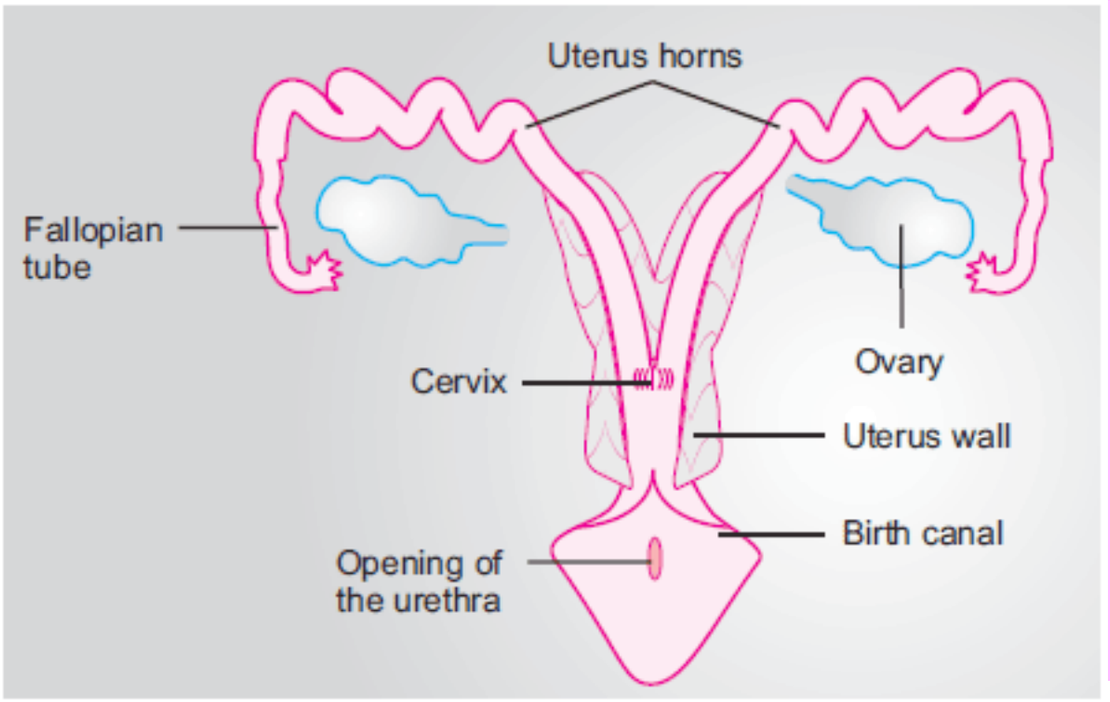


Figure 14.23: Female reproductive system of rabbit

Activity:

Locate the different organs of rabbit's male and female reproductive systems on a chart or diagram.

The opening of fallopian tube lies close to ovary. Fertilization occurs in fallopian tubes and the fertilized egg (zygote) is carried to **uterus.** The uterus of rabbit is divided into two separate parts or **horns.** The uterus horns join and open into **vagina** or **birth canal. Cervix** is the portion of uterus, which separates it from birth canal, where sperms of male are deposited.

Fertilization and Development in Rabbit

Rabbits can breed throughout the year but male rabbits are commonly sterile during the summer months. Male rabbit deposits its sperms in the vagina (birth canal) of female. Sperms swim through cervix and uterus to fallopian tubes where they fertilize the egg cells, released from ovary. After fertilization, zygote is carried to uterus. By this time, the zygote has started dividing and is now called embryo. The embryo is implanted in uterus walls. A connection, called **placenta,** is established between embryo and uterus wall. Embryo develops into new offspring (rabbit kit) in 30–32 days, after which it is born.

14.4.4 Growth in Human Population and its Consequences

Pakistan's population in the year 2007-2008 was 163,775,000. By the end of this decade, our population is expected to exceed 176 million. Pakistan's population had a relatively high growth rate in past. When population growth exceeds the carrying capacity of an area or environment, it results in overpopulation.

Logo of an organization working for awareness of overpopulation

Many problems are associated with human overpopulation. The overpopulated areas face severe shortage of fresh water and natural resources. Overpopulation results in deforestation and loss of ecosystems. It leads to more pollution and global warming. There is high infant and child mortality rate in overpopulated areas due to poverty. Overpopulation raises demands for more housing units, more hospitals, more jobs, more educational institutions, increase in food crops etc. We have to check overpopulation otherwise we will have to face huge problems because of our limited resources. People should be educated about the problems of overpopulation. Pakistan's Ministry of Population Welfare has taken a number of steps to make people aware of the hazards of overpopulation and to stabilize the population to match our resources.

Pakistan has a multicultural and multiethnic society and hosts the largest refugee population in the world.

The United Nations Population Fund
UNFPA began operations in 1969. It is the largest international organization funding for population and health programmes. The UNFPA works in over 140 countries, for awareness about the consequences of overpopulation.

14.4.5 AIDS: A Sexually Transmitted Disease

Sexually Transmitted Diseases (STDs) are defined as the diseases that are transmitted through sexual act. The most serious and challenging health problem faced by the world today is AIDS. It is also a sexually transmitted disease. AIDS stands for Acquired Immune Deficiency Syndrome. It is caused by human immunodeficiency virus (HIV). The virus destroys white blood cells, which results in loss of resistance against infections. It is a fatal disease. It spreads through transfer of body fluids such as blood and semen. Thus the main causes are unprotected sexual activities, use of infected needles or transfusion of infected blood.

According to the United nations Programme on AIDS i.e. UNAIDS estimates, some 70,000 to 80,000 persons, or 0.1 percent of the adult population in Pakistan, are infected with HIV.

Role of National AIDS Control Programme (NACP) and Non-Governmental Organizations (NGOs)

Pakistan's Federal Ministry of Health established NACP in 1987. The main objective of this programme is to help the public for the prevention of HIV transmission, safe blood transfusions and reduction of STDs.

The frequency of HIV infection in Pakistan is still low. But, the country is at risk of epidemic due to various risk factors e.g. exposure to infected blood or blood products, homo-sex, and injecting drug users. For improved prevention by the general public, the NACP started services through TV and radio channels and print media in 2005. The objectives of this activity were to:

- Change public attitude for safe sexual activities,
- Create demand for information on HIV and AIDS, and
- Improve attitudes and behaviour among healthcare workers

The number of drug addicts in Pakistan is currently estimated to be about 500,000, of whom 60,000 inject drugs.

According to the latest data by the World Bank, at least 54 NGOs are working in Pakistan for HIV/AIDS public awareness and for the care and support of persons living with HIV/AIDS. These NGOs also work on AIDS education and prevention for sex workers and other high-risk groups. NGOs serve as members of the Provincial consortium on HIV/AIDS, which has been set up in all the provinces of Pakistan

Although NGOs are very busy in HIV/AIDS prevention activities, it is believed that they are reaching less than 5 percent of the vulnerable population.

UNDERSTANDING THE CONCEPT

1. Give an introduction of Pakistan's National AIDS Control Program.
2. What are the different ways by which prokaryotes, protozoans and fungi reproduce asexually?
3. Explain the different parts of the plant that help in natural vegetative propagation.
4. Explain, how the epigeal and hypogeal germinations are different?
5. What conditions are necessary for the germination of seeds?
6. Outline the methods of asexual reproduction in animals.
7. Write a note on the male and female reproductive systems of rabbit.
8. Describe the processes of spermatogenesis and oogenesis.
9. Why do we consider that overpopulation is a global problem?

SHORT QUESTIONS

1. How are the natural and artificial vegetative propagations the methods of asexual reproduction in plants?
2. Why do gardeners use the methods of cutting and grafting?
3. "Parthenogenesis is a type of asexual reproduction". Give comments on this statement.
4. Outline the life cycle of a flowering plant.
5. What structural adaptations will you find in a wind-pollinated flower?

THE TERMS TO KNOW		
Acrosome	Cloning	Epididimys
Alternation of generations	Corm	Epigeal germination
Androecium	Corolla	Fallopian tube
Anther	Cotyledon	Follicle
Binary fission	Cowper's gland	Fragmentation
Budding	Endosperm nucleus	Fusion nucleus
Bulb	Endosperm tissue	Gametogenesis
Calyx	Endospore	Gametophyte
Carpel	Epicotyl	Grafting
Cervix		Gynoecium

Hilum
Hypocotyl
Hypogeal germination
Micropyle
Microspore
Multiple fission
Oogenesis
Oogonium
Ovary
Ovule
Parthenogenesis
Plumule
Pollen grain
Pollen tube
Prostate gland
Radicle
Rhizomes
Seed dormancy
Semen
Seminal vesicle
Seminiferous tubule
Sperm
Spermatid
Spermatogenesis
Spermatogonium
Sporophyte
Stamen
Stigma
Style
Testa
Testis
Tuber
Uterus horn
Vas deferens
Vegetative propagation

ACTIVITIES

1. Identify different stages of budding in the prepared slides of yeast and draw diagrams.
2. Examine the specimens of onion, corn, ginger and potato and write the mode of their reproduction and describe their cultivation to get new plants.
3. Identify different parts of flower.
4. Identify and draw the component of the seeds of pea or gram.
5. Perform experiment to investigate the necessary conditions for seed germination.
6. Draw different stages of binary fission in amoeba after observing them through slides or charts.

CHAPTER

15

Inheritance

Animation 15.1: Inheritance
Source and Credit: Wikipedia

For much of human history , people were unaware of the scientific details of how babies got the characteristics of their parents. People had always thought that there was some hereditary connection between parents and children, but the mechanisms were not understood. Many answers to the questions about how offspring get the characteristics from their parents came from Gregor Mendel's work. In this chapter, we will go through Mendel's work and other discoveries of inheritance.

Animation 15.2: DNA
Source and Credit: Estrellamountain

15.1 Introduction To Genetics

Genetics is the branch of biology in which we study inheritance. Inheritance means the transmission of characteristics from parents to offspring. These characteristics are called the **traits.** For example: in man height, colour of the eyes, intelligence etc. are all inheritable traits.

Parents pass characteristics to their young through gene transmission. Equal numbers of chromosomes from each parent are combined during fertilization. The chromosomes carry the units of inheritance called the genes.

15.2 Chromosomes And Genes

Genes consist of DNA. They contain specific instructions for protein synthesis. In order to know the nature and working of genes, we will have to study chromosomes in detail. The body cells have a constant number of paired **chromosomes.** The two chromosomes of a pair are known as homologous chromosomes. In human body cells, there are 23 pairs of homologous chromosomes for a total of 46 chromosomes. We may recall that during meiosis, the two members of each chromosome pair separate and each of them enters into one gamete.
Chromosome is made of chromatin material (simply as chromatin). **Chromatin** is a complex material, made of DNA and proteins (mainly histone proteins). DNA wraps around histone proteins and forms round structures, called **nucleosomes**. DNA is also present between nucleosomes. In this way, the nucleosomes and the DNA between them look like "beads on a string" (Fig. 15.1).

The fibres consisting of nucleosomes condense into compact forms and get the structure of chromosomes.

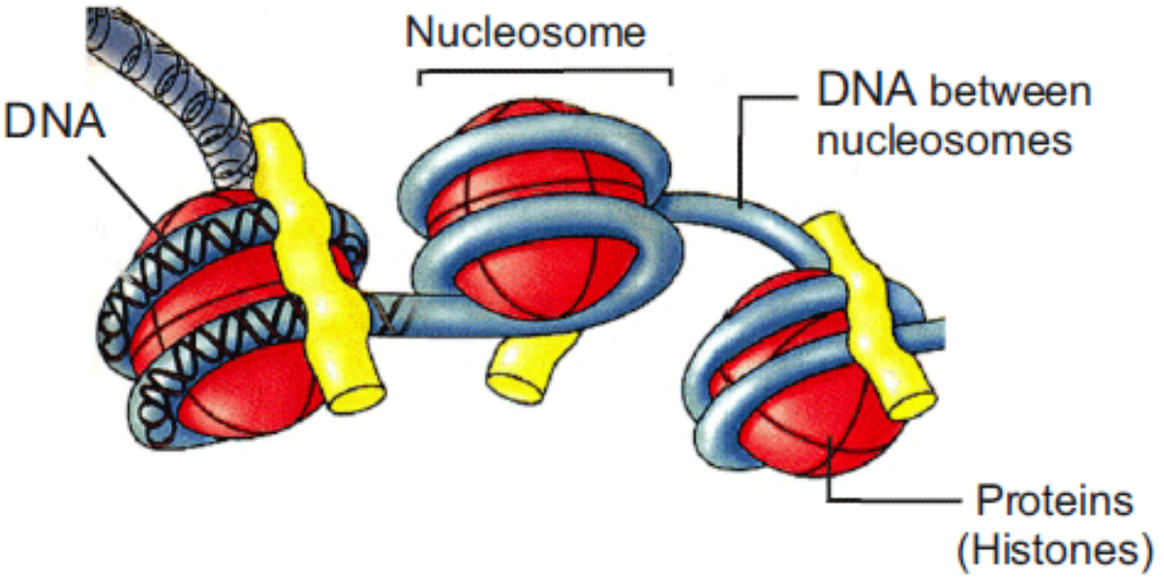


Figure 15.1: Chemical composition of chromosome

Watson-Crick Model of DNA

In 1953, **James Watson** and **Francis Crick** proposed the structure for DNA. According to the Watson-Crick model, a DNA molecule consists of two polynucleotide strands. These strands are coiled around each other in the form of a double helix. There is a phosphate-sugar backbone on the outside of double helix, and the nitrogenous bases are on the inside. In double helix, the nitrogenous bases of opposite nucleotides form pairs through hydrogen bonds. This pairing is very specific. The nitrogenous base adenine of one nucleotide forms pair with the thymine of opposing nucleotide, while cytosine forms pair with guanine. There are two hydrogen bonds between adenine and thymine while there are three hydrogen bonds between cytosine and guanine.

DNA Replication

We have studied in Grade IX (cell cycle) that before a cell divides, its DNA is replicated (duplicated). It is done to make the copies of the chromatids of chromosomes. During replication, the DNA double helix is unwound and the two strands are separated, much like the two sides of a zipper. Each strand acts as a template to produce another strand. Its N- bases make pairs with the N-bases of new nucleotides. In this way, both template strands make new polynucleotide strands in front of them. Each template and its new strand together then form a new DNA double helix, identical to the original.

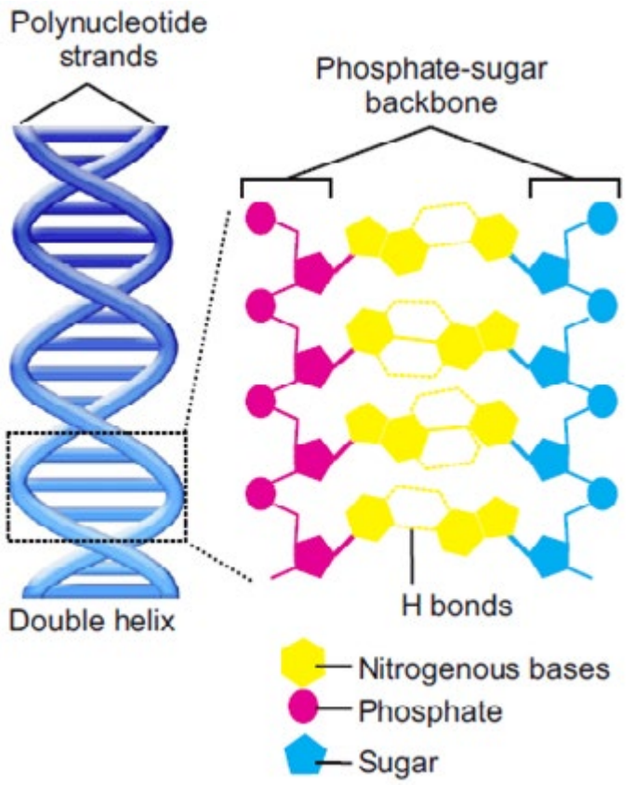


Figure 15.2: The Watson and Crick model of DNA

How Does the DNA of Chromosome work?

DNA is the genetic material i.e. it contains the instructions to direct all the functions of cells. It performs its role by giving instructions for the synthesis of specific proteins. Some proteins perform structural roles while the others act as enzymes to control all biochemical reactions of cells. In this way, whatever a cell does, is actually controlled by its DNA. In other words, DNA makes the characteristic or trait of cell or organism. Let us see how DNA is responsible for this (Fig. 15.4).

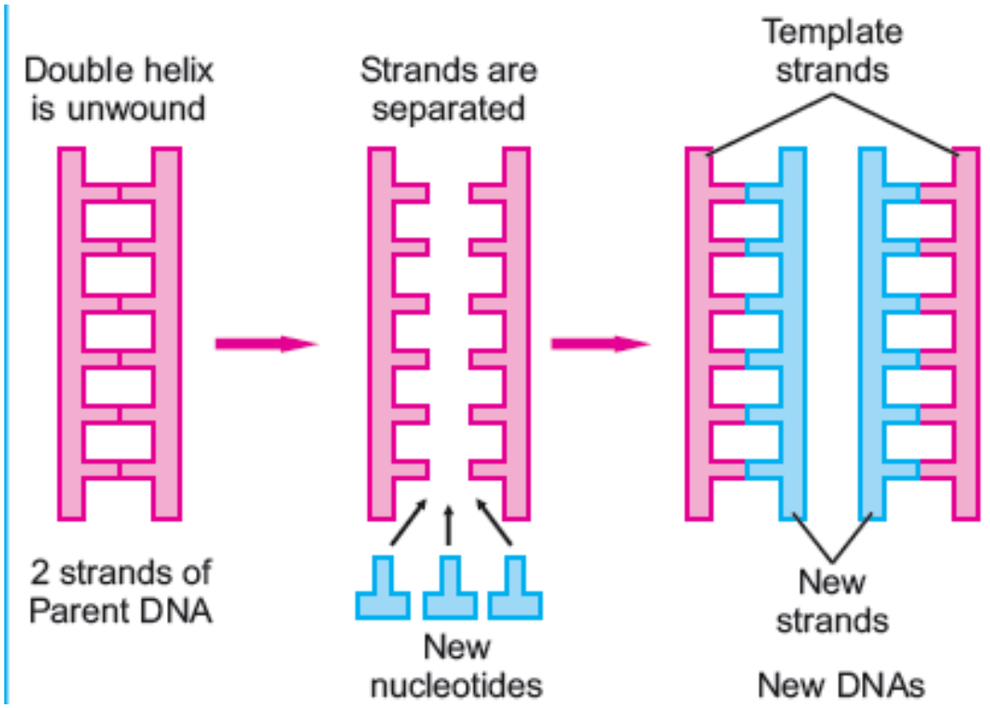


Figure 15.3: How does DNA replicate?

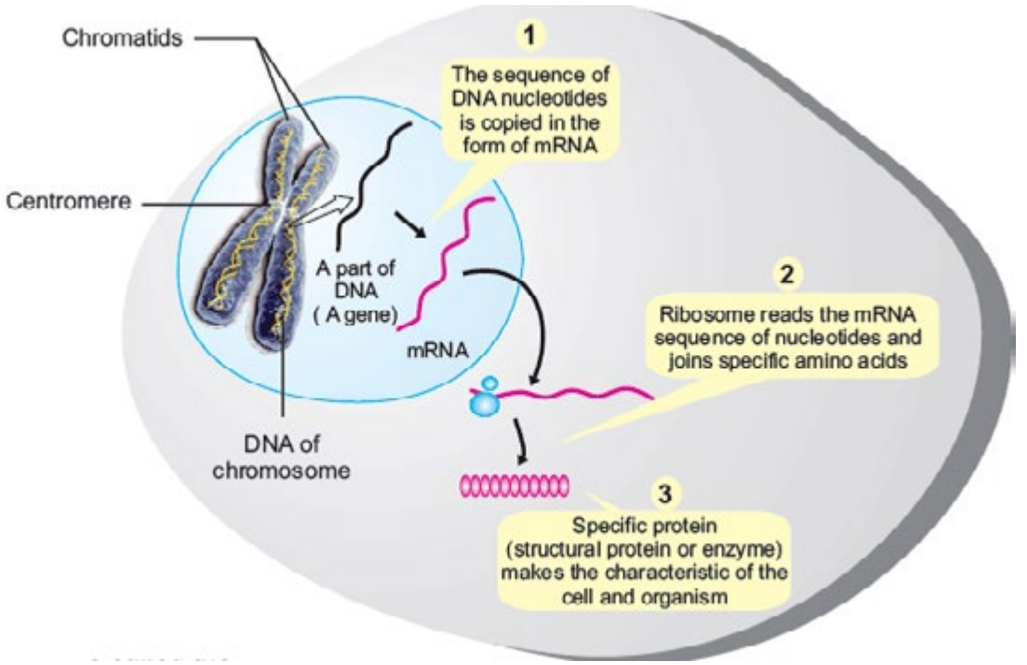
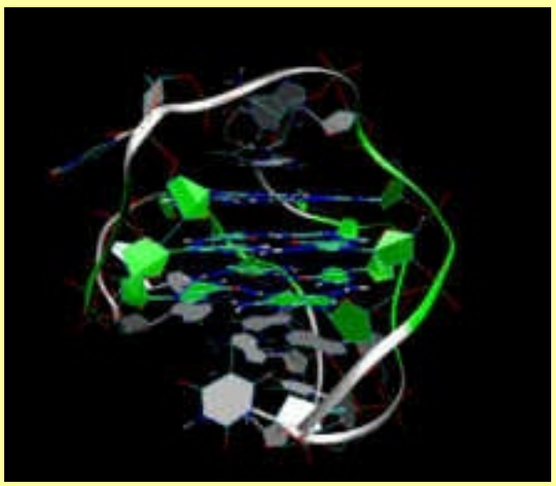
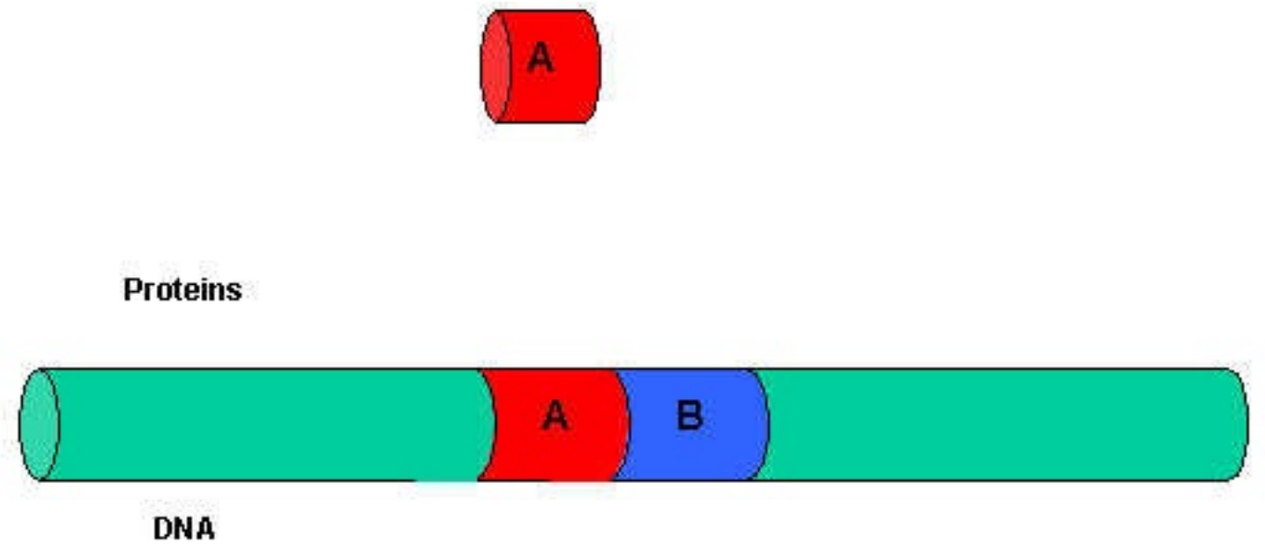


Figure 15.4: Working of DNA (also called the Central Dogma)

We studied that traits are made by specific proteins. Specific proteins have specific number and sequence of their amino acids. DNA controls this sequence of amino acids by the sequence of its nucleotides. During protein synthesis, the sequence of DNA nucleotides decides that what will be the sequence of amino acids. For this purpose, the specific sequence of DNA nucleotides is copied in the form of messenger RNA (mRNA) nucleotides. This process is called **transcription**. The mRNA carries the sequence of its nucleotides to ribosome. The ribosome reads this sequence and joins specific amino acids, according to it, to form protein. This step is known as **translation** (Fig. 15.4).The part of DNA (sequence of nucleotides) that contains the instructions for the synthesis of a particular protein is known as a gene. DNA of each chromosome contains thousands of genes. Like chromosomes, genes also occur in pairs, one on each homologous chromosome. The locations or positions of genes on chromosomes are known as loci (Singular: locus).



Animation 15.3: DNA-Barcoding
Source and Credit: Dnal



Animation 15.4: DNA-Protein
Source and Credit: Employees.csbsju

Animation 15.5: Promoter and Terminator
Source and Credit: Biology.kenyon

Each gene determines a particular trait in an organism. Each individual carries at least one pair of genes for each trait. For convenience, pairs of genes are represented by a letter or symbol. Both members of a gene pair may be the same in some individuals (a condition which we may represent as AA or aa or BB) and different in others (Aa or Bb). It means that a gene exists in more than one alternate forms. In the above example, 'A' and 'a' are the two alternate forms of a gene and 'B' and 'b' are the alternate forms of another gene. The alternate forms of a gene are called **alleles**. If an individual has Aa gene pair, 'A' and 'a' are the alleles of one another. In this individual, allele 'A' is located on one of the two homologous chromosomes and the allele 'a' is on the other chromosome as shown in Figure 15.5. When chromosomes separate during meiosis, alleles also separate and each gamete gets one of the two alleles. When gametes of both parents unite, the zygote (and the offspring also) receives one allele from each parent.

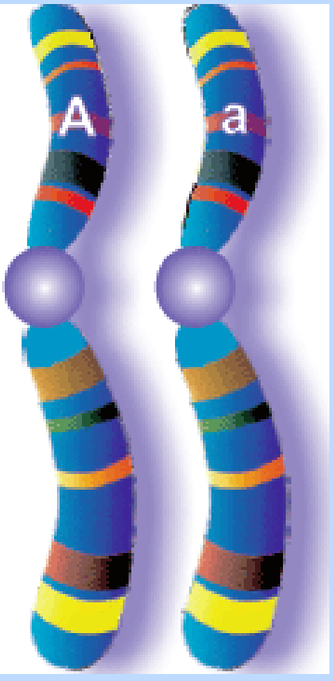
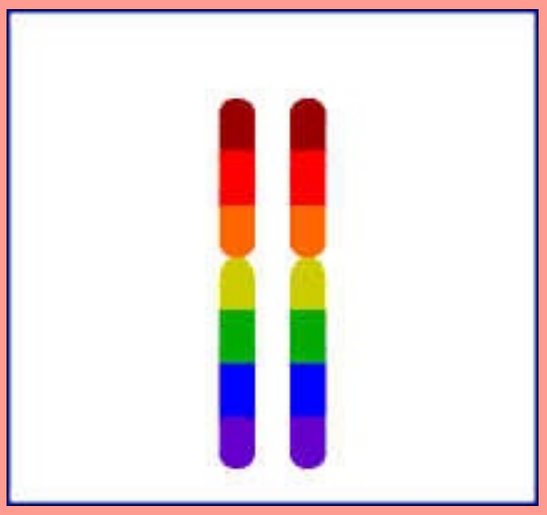


Figure 15.5: Location of alleles on chromosomes

Genotype and its Types

The specific combination of genes in an individual is known as **genotype**. It is of two types i.e. homozygous and heterozygous. In order to understand the concept of genotype, let us consider an example trait i.e. **albinism** (a condition in which normal body pigments are absent). Like other traits, it is also controlled by one pair of genes. We can represent the two alleles of the pair as 'A' and 'a'. Three combinations i.e. genotypes are possible for these two alleles i.e. AA, Aa, and aa. These genotypes can be grouped into two types. The genotype in which the gene pair contains two identical alleles (AA or aa), is called **homozygous genotype**. The genotype in which the gene pair contains two different alleles (Aa), is called **heterozygous genotype.**



Animation 15.6: Chromosomes
Source and Credit: Tokyo-med

When in the heterozygous condition one allele masks or prevents the expression of the other, it is called the **dominant** allele. The allele which is not expressed is called **recessive.**

The dominant alleles are represented by capital letters and recessive alleles by lower case letters. Albinism is a recessive trait i.e. it is produced when both alleles are recessive. In humans, allele 'A' produces normal body pigments while allele 'a' does not produce pigments. If genotype is AA or Aa, the individual will produce pigments. On the other hand, if genotype is aa, no pigments will be produced and the individual will be albino. In this example, you see that the allele 'A' dominates over 'a', because in Aa indiviual pigments are produced and the effect of 'a' is suppressed by 'A'. The expression of this genotype in the form of trait (in our example, being albino or having normal pigmentation) is known as the **phenotype.**

A dominant allele only suppresses the expression of recessive allele. It does not affect its nature.

15.3 Mendel's Laws Of Inheritance

Gregor Mendel was a monk (priest) in Austria. He developed the fundamental principles of genetics. Mendel proposed that there are "special factors" in organisms, which control the expression of traits and their transmission to next generations. These factors were eventually termed genes.

Mendel used 28,000 pea plants in his experiments. Source & Credit: Wikipedia

Mendel selected pea plant (*Pisum sativum*) to carry out a large number of experiments. In his writings, he gave reasons for this selection. He argued that an organism for genetic experiments should have the following features:

- There should be a number of different traits that can be studied (Fig. 15.6).
- The organism should have contrasting traits e.g. for the trait of height there should be only two very different phenotypes i.e. tallness and dwarfness.
- The organism (if it is a plant) should be self-fertilizing but cross fertilization should also be possible.
- The organism should have a short but fast life cycle.

All these features are present in pea plant. Normally, the flowers of pea plant allow self-pollination. Cross pollination can also be done by transferring the pollen grains from the flower on one plant to the flower on another plant. Each trait studied in pea plant had two distinct forms. Mendel succeeded in his work not only because he selected the right organisms for his experiments but also because he analyzed the results by using the principles of statistics (ratios).

15.3.1 Mendel's Law of Segregation

Mendel studied the inheritance of seed shape first. For this purpose, he crossed (reproduced) two plants having one contrasting trait i.e. seed shape. A cross in which only one trait is studied at a time, is called as a **monohybrid cross.** Mendel crossed a true-breeding round-seeded plant with a true-breeding wrinkled-seeded plant.

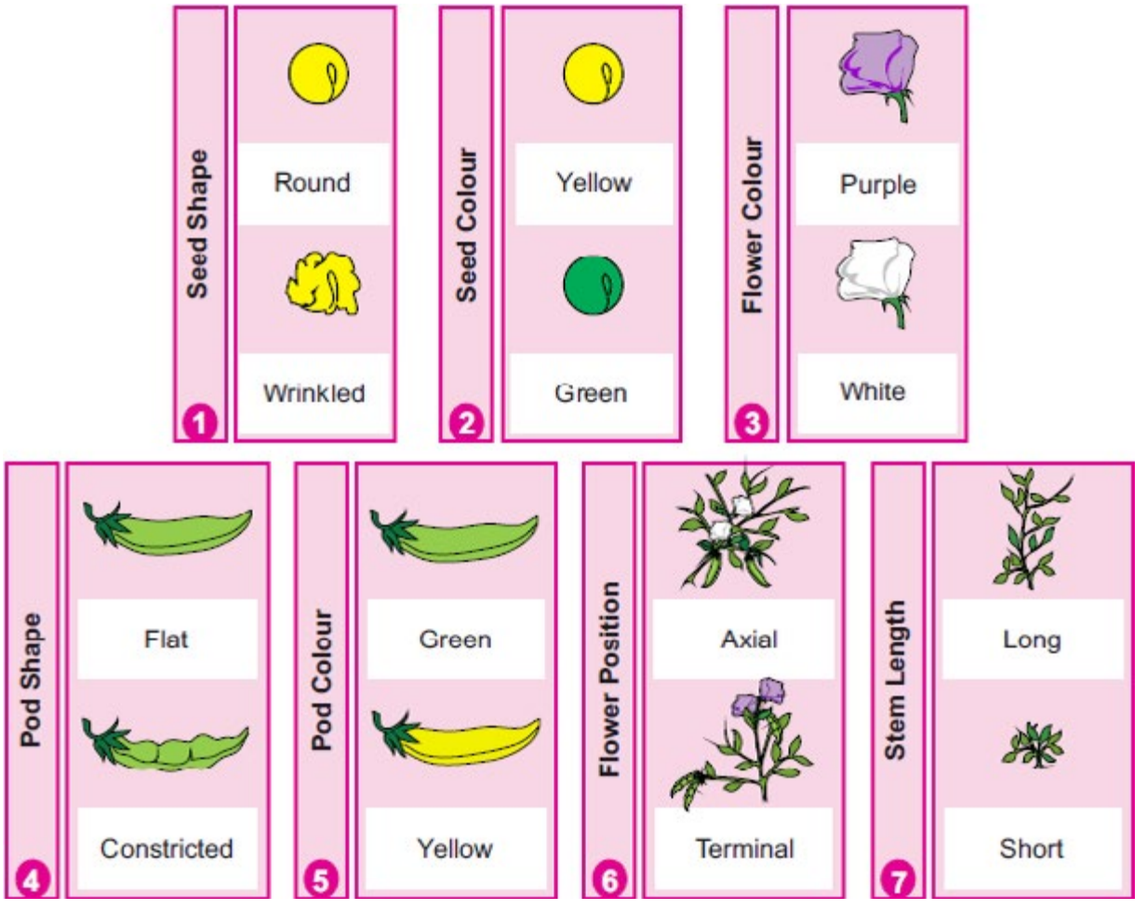
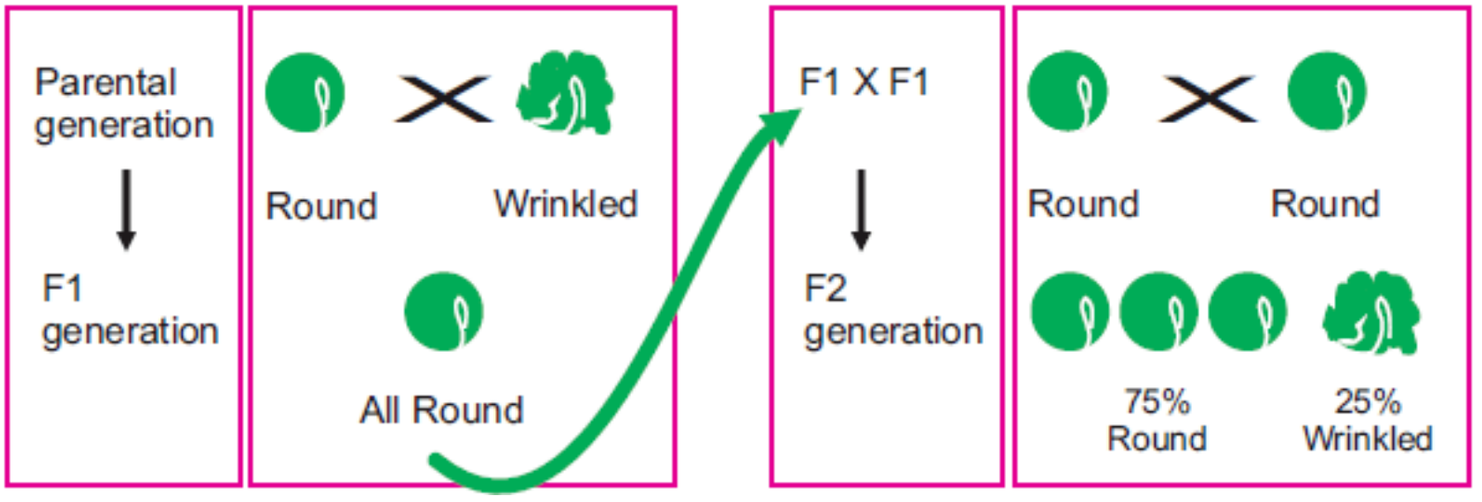
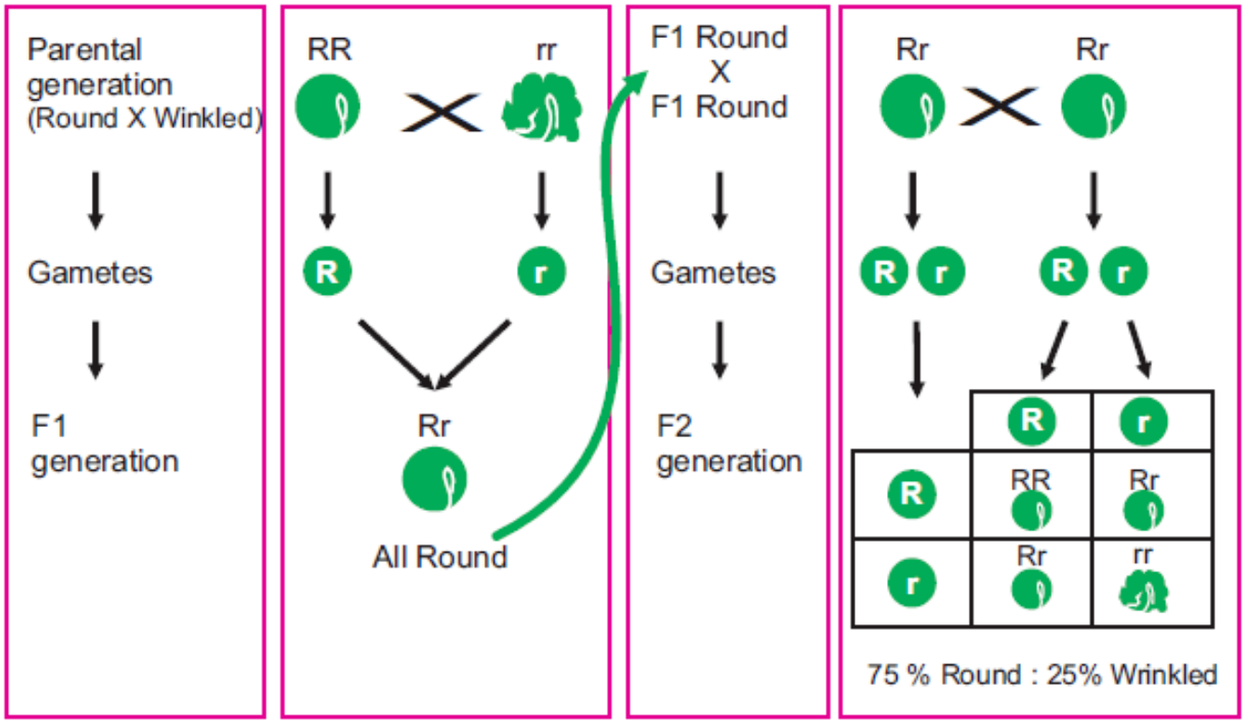


Figure 15.6: Traits in Pea Plant studied by Mendel

All resulting seeds of the next generation were round. Mendel declared the trait "round seeds" as dominant, while "wrinkled seeds" as recessive. The following year, Mendel planted these seeds and allowed the new plants to self-fertilize. As a result, he got 7324 seeds: 5474 round and 1850 wrinkled (3 round : 1wrinkled). The parental generation is denoted as P1 generation. The offspring of P1 generation are F1 generation (first filial). The cross in F1 generation produces F2 generation (second filial).



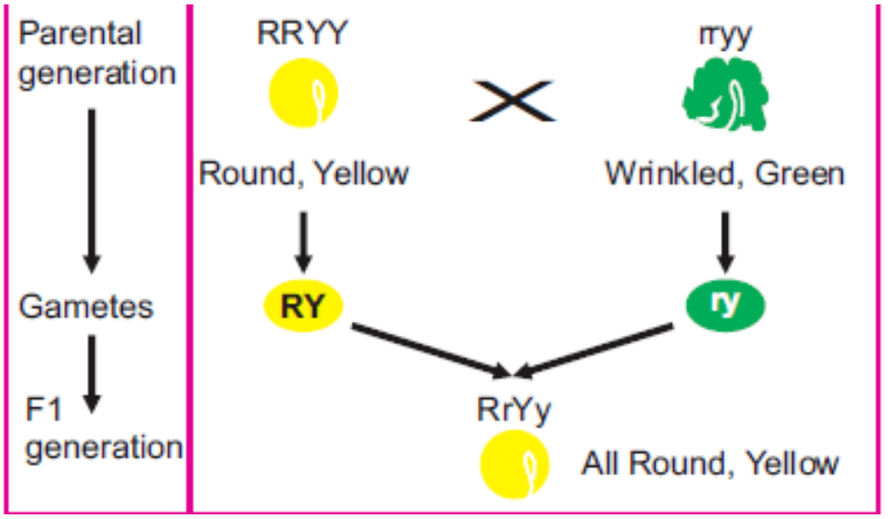
Similarly, when "true-breeding" tall plants were crossed with "true-breeding" short plants, all offspring of F1 were tall plants i.e. tallness was a dominant trait. When members of F1 generation were self-fertilized, Mendel got the ratio of tall to short plants in F2 as 3:1.



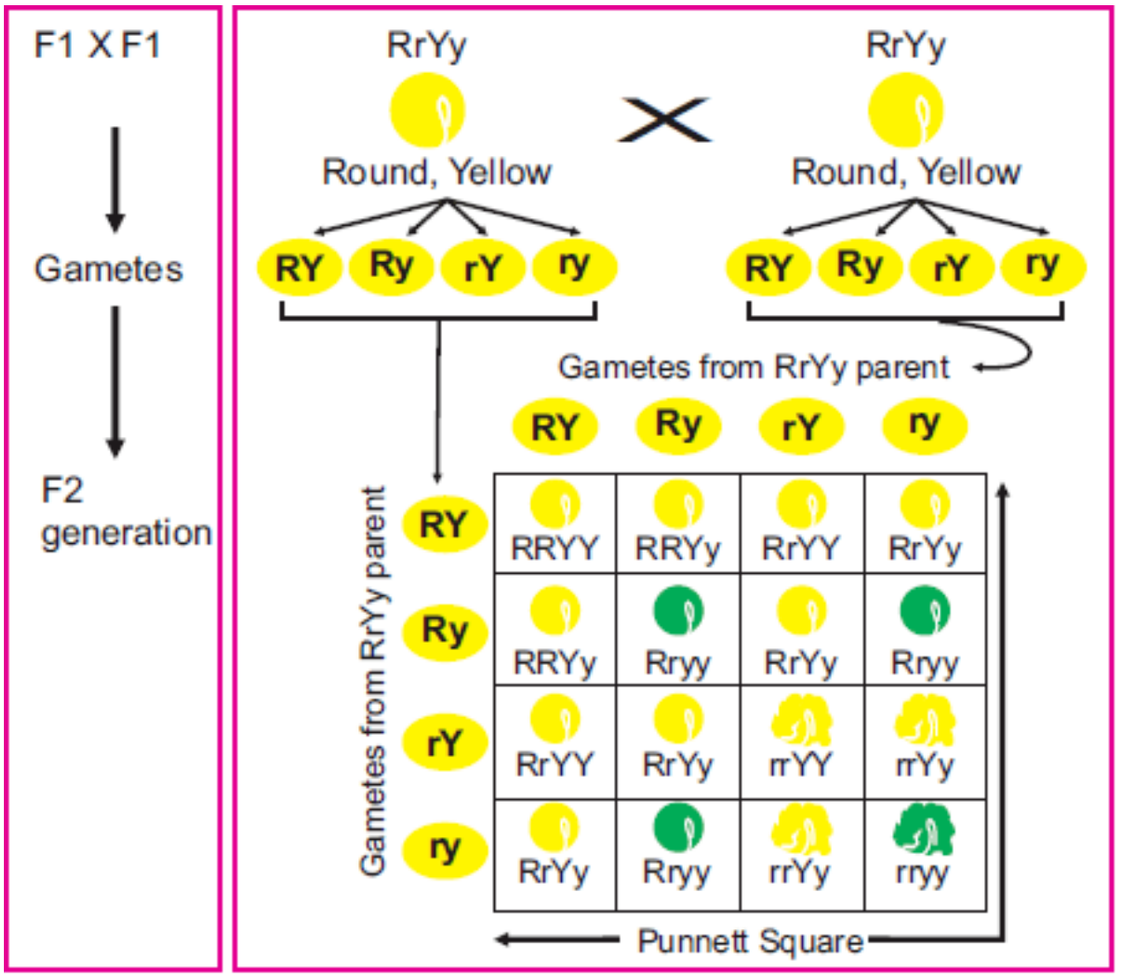
Mendel concluded that the traits under study were controlled by discrete (separable) factors or genes. In each organism, the genes are present in pairs. During gamete formation, the genes (alleles) of each pair segregate from each other and each gamete receives one gene from the pair. When the gametes of male and female parents unite, the resulting offspring agains gets the genes in pairs. These conclusions were called the **Law of Segregation.**

15.3.2 Mendel's Law of Independent Assortment

In the next crosses, Mendel studied two contrasting traits at a time. Such crosses are called **dihybrid crosses.** He performed experiments on two seed traits i.e. shape and colour. The trait of round seeds (controlled by allele R) was dominant over wrinkled (controlled by allele r) seeds. Similarly, yellow seed colour (controlled by Y) was dominant over green (controlled by y). Mendel crossed a truebreeding plant that had round yellow seeds (RRYY) with a truebreeding plant having wrinkled green seeds (rryy). All seeds in F1 generation were round yellow.



When F1 seeds grew into plants, they were self-fertilized. This cross produced seeds with four phenotypes. There were 315 round yellow seeds, 108 round green seeds, 101 wrinkled yellow seeds and 32 wrinkled green seeds. The ratio of these phenotypes was 9:3:3:1.



The Punnett square is a diagram that is used to predict an outcome of a particular cross or breeding experiment. It is named after **R. C. Punnett** (an English mathematician). The gametes of both parents having all possible genetic set-ups are determined. A checker board is used to cross all the possible gametes of one parent with all the gametes of other parent. In this way, a biologist can find all the possible genotypes of offsprings.

Mendel explained that the two traits i.e. seed shape and seed colour are not tied with each other. The segregation of 'R' and 'r' alleles happens independently of the segregation of 'Y' and 'y' alleles. From his second experiment, Mendel concluded that different traits are inherited independently of one another. This principle is known as the **law of independent assortment.** It states as: "the alleles of a gene pair segregate (get separated and distributed to gametes) independently from the alleles of other gene pairs".

15.4 Co-Dominance And Incomplete Dominance

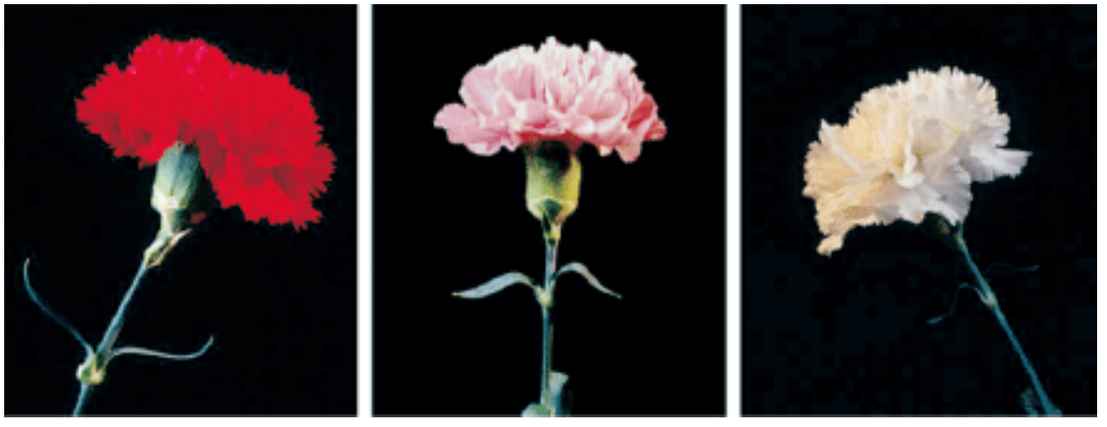
After the discovery of Mendel's work, scientists began experiments on the genetics of various organisms. These experiments proved that all the traits in organisms do not follow Mendel's laws. For example, it was found that there are many traits which are controlled by more than one pair of genes. Similarly for many traits, there are more than two alleles in a gene pair. Co-dominance and incomplete dominance are two examples of such deviations from Mendel's laws.

Co-dominance is the situation where two different alleles of a gene pair express themselves completely, instead of showing a dominant-recessive relationship. As a result, the heterozygous organism shows a phenotype that is different from both homozygous parents.

An example of co-dominance is the expression of human blood group AB. The ABO blood group system is controlled by the gene 'I'. This gene has three alleles i.e. I^A, I^B and i. The allele I^A produces antigen A in blood and the phenotype is blood group A. The allele I^B produces antigen B in blood and the phenotype is blood group B. The allele i does not produce any antigen and the phenotype is blood group O. The alleles I^A and I^B are dominant over i. When there is a heterozygous genotype of I^A I^B, each of the two alleles produces the respective antigen and neither of them dominates over the other.

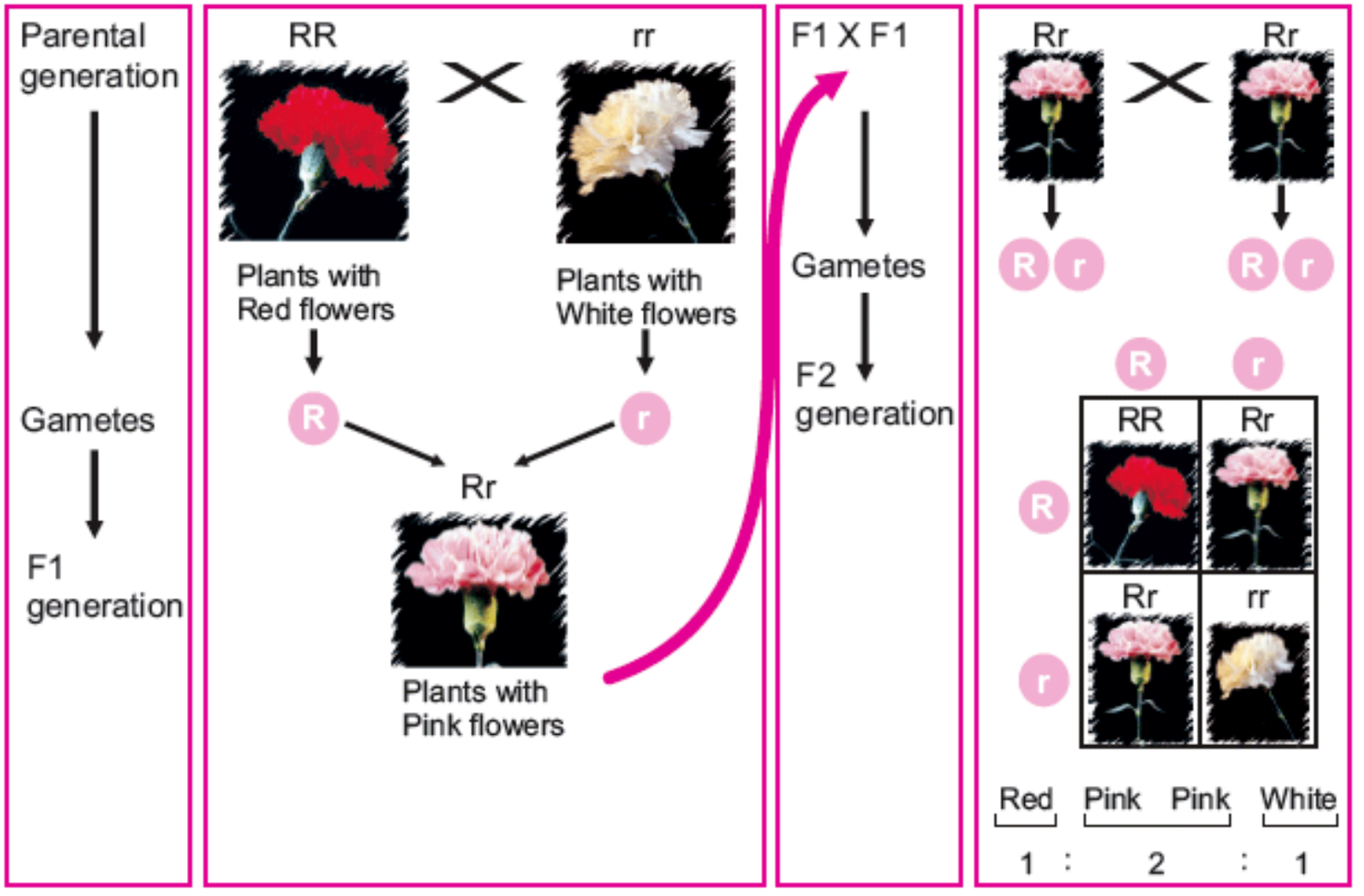
Genotype	Antigen produced	Phenotype	Relationship Between Alleles
I^AI^A or I^Ai	Antigen A	Blood Group A	Allele I^A is dominant over i
I^BI^B or I^Bi	Antigen B	Blood Group B	Allele I^B is dominant over i
ii	No Antigen	Blood Group O	Allele i is recessive
I^AI^B	Antigen A & Antigen B	Blood Group AB	Alleles I^A and I^B are co-dominant

In-complete dominance is the situation where, in heterozygous genotypes, both the alleles express as a blend (mixture) and neither allele is dominant over the other. As a result of this blending, an intermediate phenotype is expressed. Following is the familiar example of incomplete dominance.



In Four 'O' Clock plants, the 3 flower colours are red, pink and white. There is no specific gene responsible for producing pink flowers.

In Four 'O' clock plant, the trait of flower colour is controlled by two alleles (let us say them R and r). The true breeding plants RR and rr have red and white flowers, respectively. When a homozygous red flowered plant (RR) is crossed with homozygous white flowered plant (rr), the heterozygous (Rr) plants of F1 generation produce pink flowers (pink is a blend of red and white colours). This result clearly indicates that neither of the red flower allele (R) and white flower allele (r) is dominant. However, when two heterozygous plants with pink flowers (Rr) are crossed, F2 generation shows phenotypes of red, pink and white flowers in the ratio 1:2:1.



Initiating and Planning:

- Predict from pedigree charts the passage of traits from one generation to the other.
- Solve basic genetic problems involving monohybrid crosses, incomplete dominance and co-dominance, using the Punnet square.

? What is the dominance relationship between blood group alleles I^A and I^A?

Co-dominance

15.5 Variations And Evolution

In the previous chapter, we studied that sexual reproduction produces variations in the next generation. No two individuals resulting from separate fertilizations are genetically identical. The main sources of variations in sexually reproducing populations are describes next.

- The genetic recombination produced through crossing over (recall from previous studies that crossing over occurs during meiosis) results in gametes with variations.
- Mutations (changes in DNA) are important source of variations. Mutations also happen during gametes formation through meiosis.
- During fertilization, one of the millions of sperms combines with a single egg. The chance involved in this combination also act as the source of variations.
- Gene flow i.e. movement of genes from one population to another is also an important source of variations.

Practical:

- Record the heights of class fellow's to predict which kind of variation is it.
- Present the data of class fellow's heights in graphical form.

Discontinuous and Continuous Variations

The inheritable variations are of two types i.e. discontinuous and continuous variations. Discontinuous variations show distinct phenotypes. The phenotypes of such variations cannot be measured. The individuals of a population either have distinct phenotypes, which can be easily distinguished from each other. Blood groups are a good example of such variations. In a human population, an individual has one of the four distinct phenotypes (blood groups) and cannot have in between. Discontinuous variations are controlled by the alleles of a single gene pair. The environment has little effect on this type of variations. In continuous variations, the phenotypes show a complete range of measurements from one extreme to the other. Height, weight, feet size, intelligence etc. are example of continuous variations. In every human population, the individuals have a range of heights (from very small to tall). No population can show only two or three distinct heights. Continuous variations are controlled by many genes and are often affected by environmental factors.

Animation15.8: Darwin-Evolution
Source and Credit: Zebu.uoregon9

15.5.1 Variations lead to Evolution

Organic evolution (biological evolution) is the change in the characteristics of a population or species of organisms over the course of generations. The evolutionary changes are always inheritable. The changes in an individual are not considered as evolution, because evolution refers to populations and not to individuals. Organic evolution includes two major processes:

- Alteration in genetic characteristics (traits) of a type of organism over time; and
- Creation of new types of organisms from a single type.

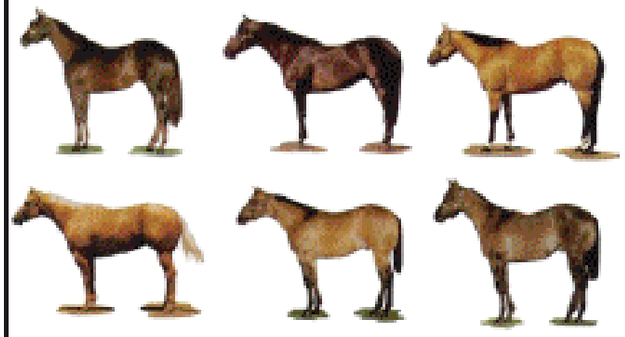
The study of evolution determines the ancestry and relationships among different kinds of organisms. The anti-evolution ideas support that all living things had been created in their current form only a few thousand years ago. It is known as the **"theory of special creation".** But the scientific work in eighteenth century led to the idea that living things might change as well.

Variations are also caused by different combinations of chromosomes in gametes and then in zygote. In the case of humans, the possible number of chromosomal combinations at fertilization is 70,368,744,177,664. In other words, a couple can produce more than 70 trillion genetically different children!

Variations
Continuous or Discontinuous?

Variations in human skin colour
Discontinuous ☐ Continuous ☐

Variations in human body weight
Discontinuous ☐ Continuous ☐



Variations in horse skin colour
Discontinuous ☐ Continuous ☐

Variations in rose flower colour
Discontinuous ☐ Continuous ☐

French biologist **C. de Buffon** (1707–1788) was the first to hint at evolution. His countryman **J. de Lamarck** (1744–1829) was the first to propose a mechanism of evolution. Lamarck's ideas were soon rejected due to the vagueness of the mechanisms he proposed.

Charles Darwin (1809–1882) proposed the mechanism of organic evolution in 1838. It was called as "The Theory of Natural Selection". Darwin proposed this theory after his 5-year voyage on the HMS (His Majesty's Ship) Beagle. He also published a book "On the Origin of Species by means of Natural Selection" in 1859. Darwin's theory of evolution was not widely accepted because of lack of sufficient evidence. Modern evolutionary theory began in the late 1920s and early 1930s. Some scientists proved that the theory of natural selection and Mendelian genetics are the same ideas just as Darwin had proposed.

C. de Buffon

J. de Lamarck

Mechanism of Evolution - Natural Selection

Almost every population contains several variations for the characteristics of its members. In other words, there are morphological and physiological variations in all populations. Natural selection is the process by which the better genetic variations become more common in successive generations of a population.

The central concept of natural selection is the evolutionary fitness of an organism. Fitness means an organism's ability to survive and reproduce. Organisms produce more offspring than can survive and these offspring vary in fitness. These conditions produce struggle for survival among the organisms of population . The organisms with favourable variations are able to reproduce and pass these variations to their next generations.

On the other hand, the rate of the transmission of unfavourable to next generations is low. We can say that the favourable variations are “selected for” their transmission to next generations, while the unfavourable variations are “selected against” their transmission to next generations. In the example mentioned next, we can see a mouse population with variations in skin colour. Cat preys upon light and medium coloured mouse. In first generation, light coloured mouse is preyed upon by cat.

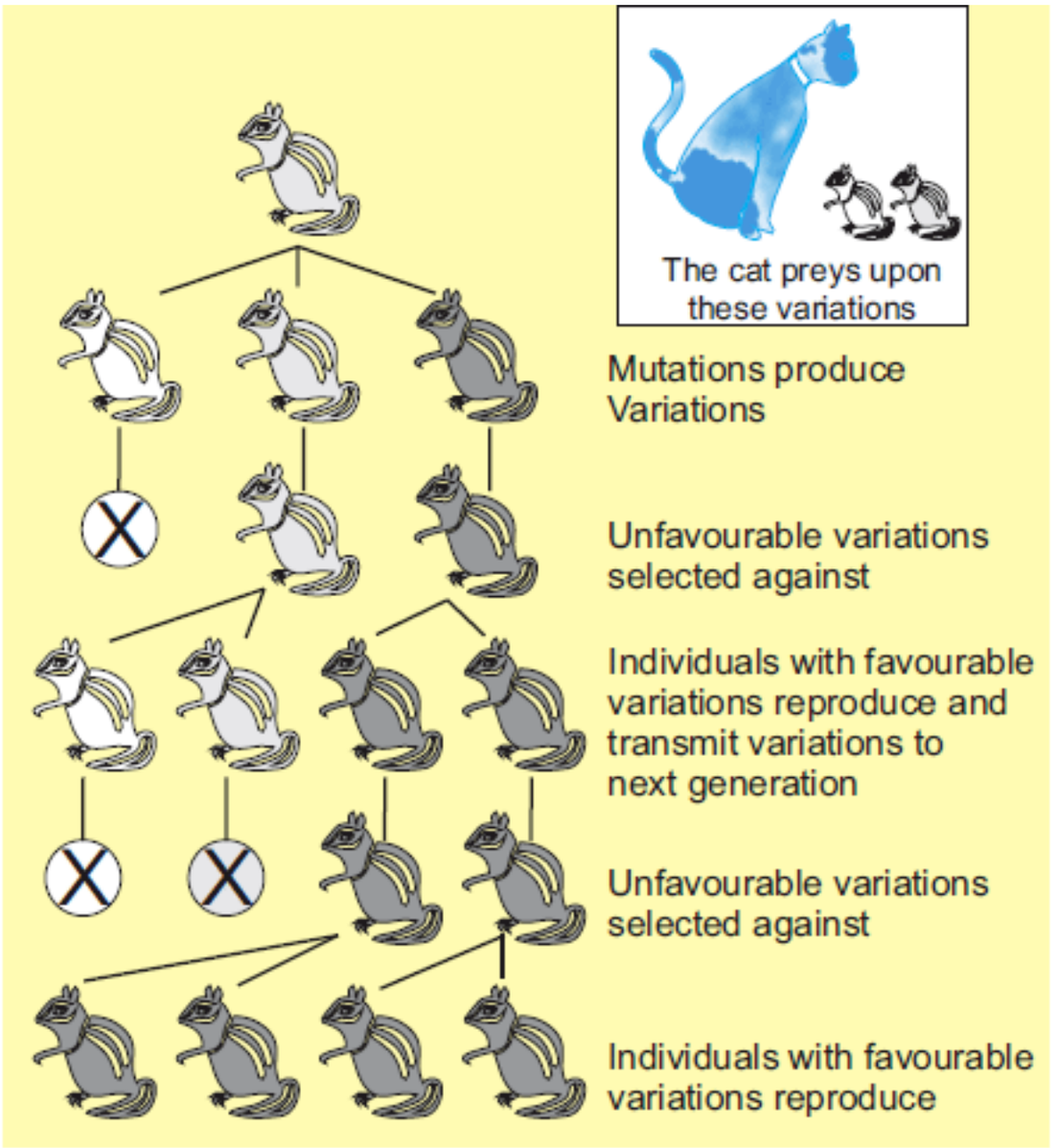


Figure 15.7: The concept of natural selection

Different populations face different environments and they have to adapt to different conditions.

Only medium and dark coloured mouse can make their next generations. In next generation, population again contains light, medium and dark coloured mouse. Cat preys upon the light and medium coloured mouse. Now only the dark coloured mouse make new generation. If this happens in many generations, we will see only the dark coloured (favourable variation) mouse in the population (Fig. 15.7).

As a result of natural selection, the allele that gives more fitness of characteristics (favourable variations) than other alleles becomes more common within population. So, the individuals with favourable variations become a major part of population while the individuals with harmful or unfavourable variations become rarer.

In England, the moths had two variations i.e. dark and white coloured moths (Fig.15.8). The moths used to rest on the light coloured tree trunks (on which white lichens had grown). In the 19th century when industries were established in England, the lichens on tree trunks died (due to polluted air) and the naked tree trunks turned dark. Now the white moth variation became harmful because a white moth resting on a dark tree trunk was easily visible to the predatory birds. The natural selection selected dark moths to reproduce. In this way dark coloured moth became more common and at last the white moths disappeared from population. In this case, the dark colour variation in moth may be considered an adaptation to environment.

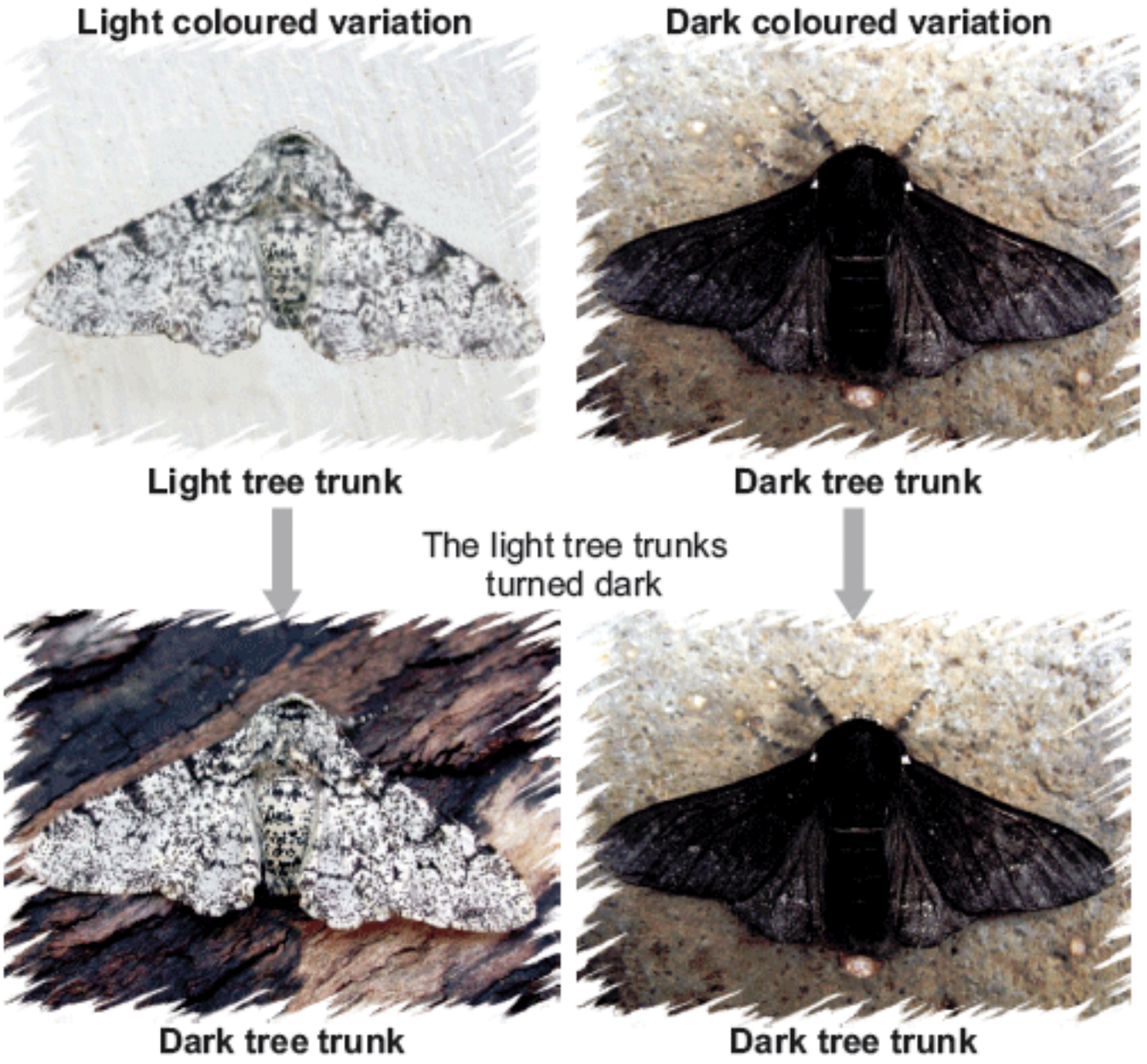


Figure 15.8: White and dark coloured moths

Initiating and Planning:

Write down the procedure of an experiment in which you can cross true-breeding tall and short plants to get tall plants and can test the natural selection of these variants.

15.5.2 Artificial Selection

The term “artificial selection” was expressed by the Persian scientist Abu Rayhan Biruni in the 11th century. Charles Darwin also used this term in his work on natural selection. He noted that many domesticated animals and plants had special properties that were developed by:

- Intentional breeding among individuals with desirable characteristics; and
- Discouraging the breeding of individuals with less desirable characteristics

Artificial selection (or selective breeding) means intentional breeding between individuals for certain traits, or combination of traits. Selective breeding has revolutionized agricultural and livestock production throughout the world. Animals or plants having desirable characteristics are selected for breeding. In this way, many new generations with desirable characteristics are produced. In artificial selection, the bred animals are known as **breeds,** while bred plants are known as **varieties** or **cultivars.** Numerous breeds of sheep, goat, cow, hen etc. have been produced by artificial selection to increase the production of wool, meat, milk, eggs etc.

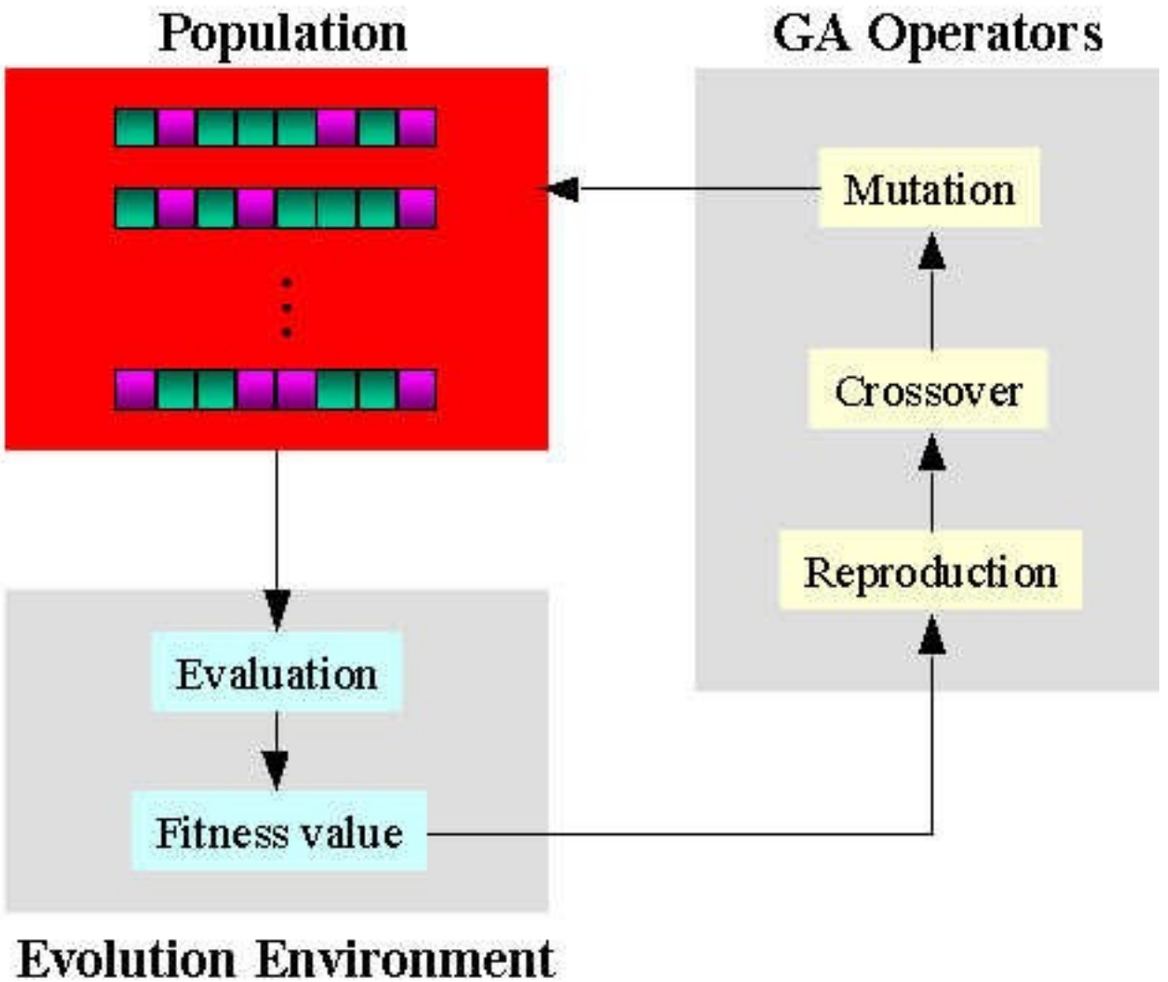
Similarly many plant varieties (cultivars) have been produced for better quantity and quality of cereals, fruits and vegetables.

Figure 15.9: Breeds of hen, produced through artificial selection

In artificial selection, humans favour specific variations for selection while in natural selection the environment selects or rejects variations.

Initiating and Planning:

- Analyze a case study of variation and selection e.g. in peppered moth.
- Analyze how artificial selection can lead to the development of crop plants with higher yields.



Genetic Algorithm Evolution Flow

Animation 15.9: Evolution
Source and Credit: Ewh.ieee

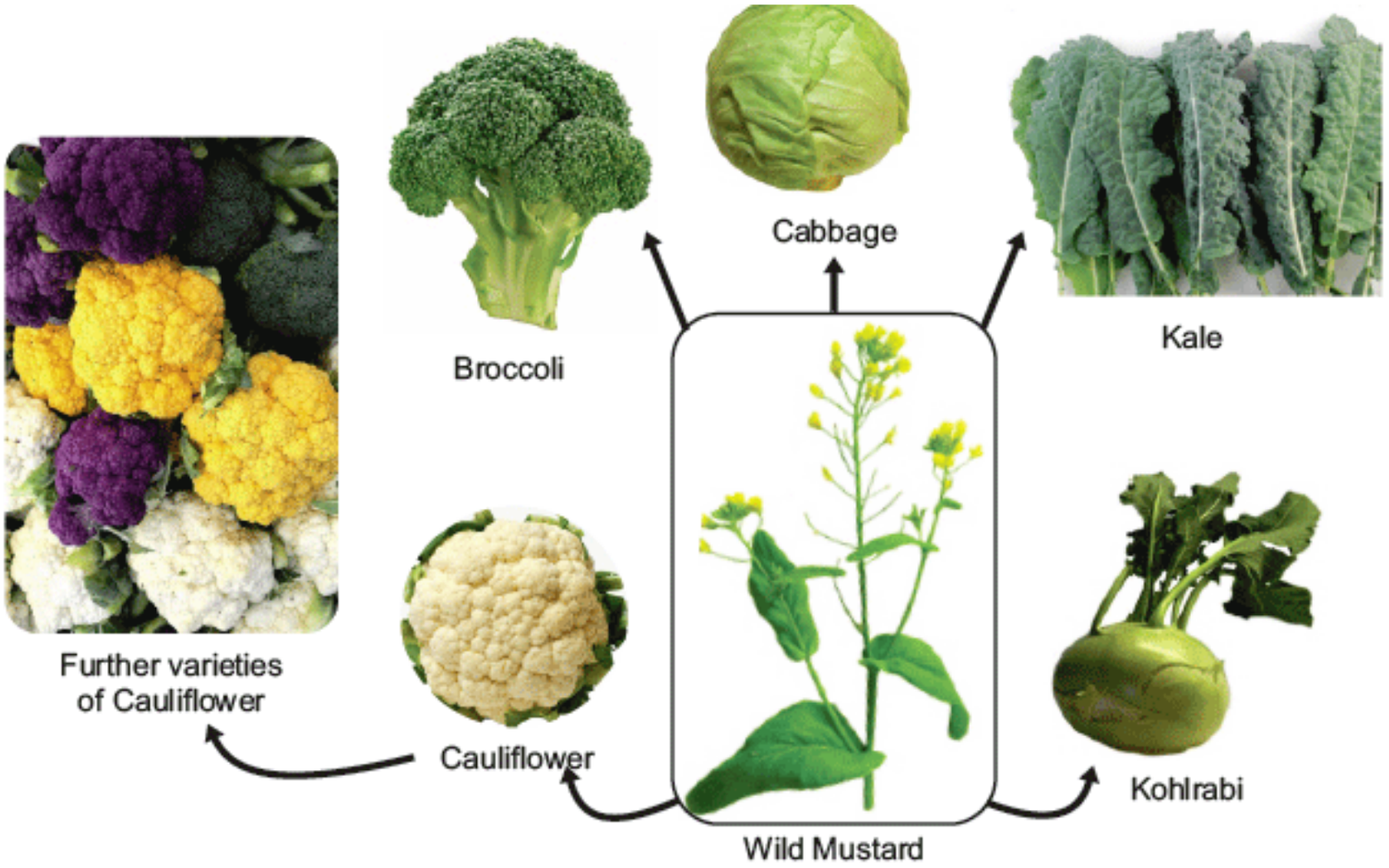


Figure 15.10: Plant varieties produced through artificial selection in wild mustard

UNDERSTANDING THE CONCEPT

1. Describe the structure of chromatin.
2. Describe Mendel's law of segregation.
3. Explain how Mendel proved the law of independent assortment.
4. How would you prove that variations lead to evolution?
5. Explain the phenomenon of incomplete dominance with the help of example.
6. What do you mean by co-dominance. Give an example.

SHORT QUESTIONS

1. Define genotype and phenotype.
2. What do you mean by dominant and recessive alleles?
3. What are the homozygous and heterozygous genotypes?
4. Differentiate between natural and artificial selection.

ACTIVITIES

1. Draw the chromosomes of a plant cell after observing in prepared slides unlabelled charts.
2. Record the heights of class fellows to predict which kind of variation is it.
3. Present the data of class fellows' heights in graphical form.

THE TERMS TO KNOW		
Allele	Genotype	Mutation
Artificial selection	Heterozygous	Natural selection
Breeds	Histone	Nucleosome
Chromatin	Homologous chromosomes	Organic evolution
Co-dominance	Homozygous	Phenotype
Cultivar	Incomplete dominance	Recessive trait
Dihybrid cross	Inheritance	Trait
Dominant	Locus	True-breeding
Gene	Monohybrid cross	Variations

SCIENCE, TECHNOLOGY AND SOCIETY

1. Describe various possibilities if humans could be able to control the functioning of genes.
2. Prepare a report using newspaper clippings on the recent advances and future possibilities in genetics.
3. Rationalize life as a product of the diversity brought about by chromosomes, genes and DNA.
4. Outline the scientific findings and some of the technological advances that led to the modern concept of gene.
5. Analyse the concept of gene to produce various proteins of the body.
6. Describe the importance of scientific investigation and mathematical know how in genetics.
7. Explain how genetics can predict the progeny of two individuals which are crossed.
8. What is the role of environment on the selection of better variations?

ON-LINE LEARNING

1. en.wikipedia.org/wiki/Punnett_square
2. www.uic.edu/classes/bios/bios101/genes1
3. www.human-nature.com/darwin/
4. en.mimi.hu › Biology

CHAPTER

16

Man and His Environment

Animation 16: Ecology- Man and his environment
Source & Credit: Wikispaces

Every organism has its specific surrounding or environment with which it continuously interacts and remains fully adapted. An organism's environment is the sum of physical (abiotic) and biological (biotic) conditions which influence that organism. The study of the interrelationship between organisms and their environment is called **ecology.**

16.1 Levels Of Biological Selection

In ecology, the levels of organization range from organism to biosphere. An organism may be unicellular or multicellular. A group of the organisms of the same species inhabiting a specific geographical area (habitat) at a particular time is called a **population**. All the populations that live in a habitat and interact in various ways with one another are collectively called a **community.**

Recalling
A species is a group of organisms which can interbreed freely in nature, to produce fertile offspring.

Living organisms cannot live isolated from the non-living part of their environment. The biotic and abiotic components of environment interact with each other to form a system. The self-sufficient unit of an environment that is formed as a result of interactions between its biotic community and the abiotic components is known as an **ecosystem**. A pond, a lake and a forest are examples of natural ecosystems. Ecosystems may also be artificial for example an aquarium.

All **ecosystems** of the world together form the biosphere. It includes all the ecosystems of the planet Earth. In other words, the biosphere consists of all organisms present on the Earth and all regions of the Earth where they live. **Biosphere** ranges from the floor of oceans to the tops of the highest mountains. It is about 20 kilometres thick.

The biosphere makes a thin layer surrounding the planet Earth. If you consider the Earth as of the size of an apple, then the biosphere will be as thick as the apple's skin.

16.1.1 Components of Ecosystem

We have studied in lower classes about the basic components of an ecosystem. We know that an ecosystem comprises of two basic parts i.e. **abiotic components** and **biotic components.** The abiotic components include the non-living factors present in ecosystem. The important non-living factors are light, air, water, soil and the basic elements and compounds. The biotic components comprise the living part (organisms) of the ecosystem. Biotic components are further classified as producers, consumers and decomposers.

Recalling
Omnivores are the consumers that eat animal flesh as well as plants and plant products. Find examples of omnivores.

The **producers** are the autotrophs present in an ecosystem. Producers include plants, algae and photosynthetic bacteria. These organisms are able to synthesize complex organic compounds (food) from inorganic raw materials. Producers form the basis of any ecosystem. In terrestrial ecosystems, plants are the main producers. In aquatic ecosystems, the main producers are the floating photosynthetic organisms (mainly algae) called phytoplankton and shallow water rooted plants.

The **consumers** are heterotrophs. They cannot synthesize their food and so depend upon producers for food. Consumers include all animals, fungi, protozoans and many of the bacteria. The animals are the major consumers of ecosystems. They are further classified as herbivores and carnivores. Herbivores e.g. cattle, deer, rabbit, grasshopper etc. feed on plants.

They are the **primary consumers**. They feed directly on plants or products of plants. Carnivores feed on other animals. Primary carnivores **(secondary consumers)** feed on herbivores. Fox, frog, predatory birds, many fishes and snakes etc. are primary carnivores. Secondary carnivores **(tertiary consumers)** feed on primary carnivores. Wolf and owl etc. are secondary carnivores. Tertiary carnivores e.g. lion, tiger etc. feed on secondary carnivores

Tertiary carnivores are not eaten by any other animals. They are also called top carnivores.

Decomposers or reducers break down the complex organic compounds of dead matter (of plants and animals) into simple compounds. They secrete digestive enzymes into dead and decaying plant and animal remains to digest the organic material. After digestion, decomposers absorb the products for their own use. The remaining substances are added to environment. Many types of bacteria and fungi are the principal decomposers of biosphere.

The minerals, which are released by decomposers, are used as nutrients by the producers.

Analyzing and Interpreting:

- Identify the producers and consumers in a pond ecosystem and describe the interactions among the biotic and abiotic factors involved here.

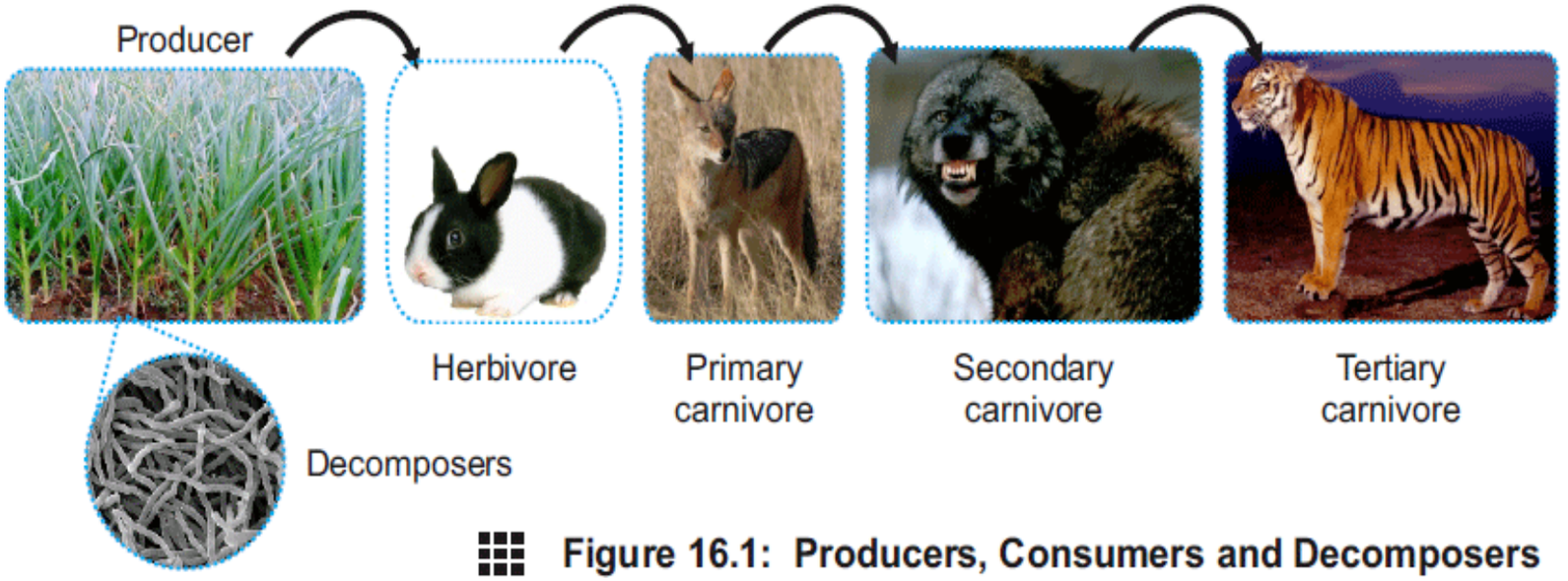


Figure 16.1: Producers, Consumers and Decomposers

16.2 Flow Of Materials And Energy In Ecosystem

In an ecosystem, energy as well as materials travel from one trophic level to the next. Trophic (food) level is the level at which an organism feeds in food chain. The first trophic level is made of producers; the second of primary consumers and so on.

16.2.1 Flow of Energy

The flow of energy in different trophic levels of ecosystem is unidirectional. The following is an overview of the flow of energy in an ecosystem (Fig. 16.2).

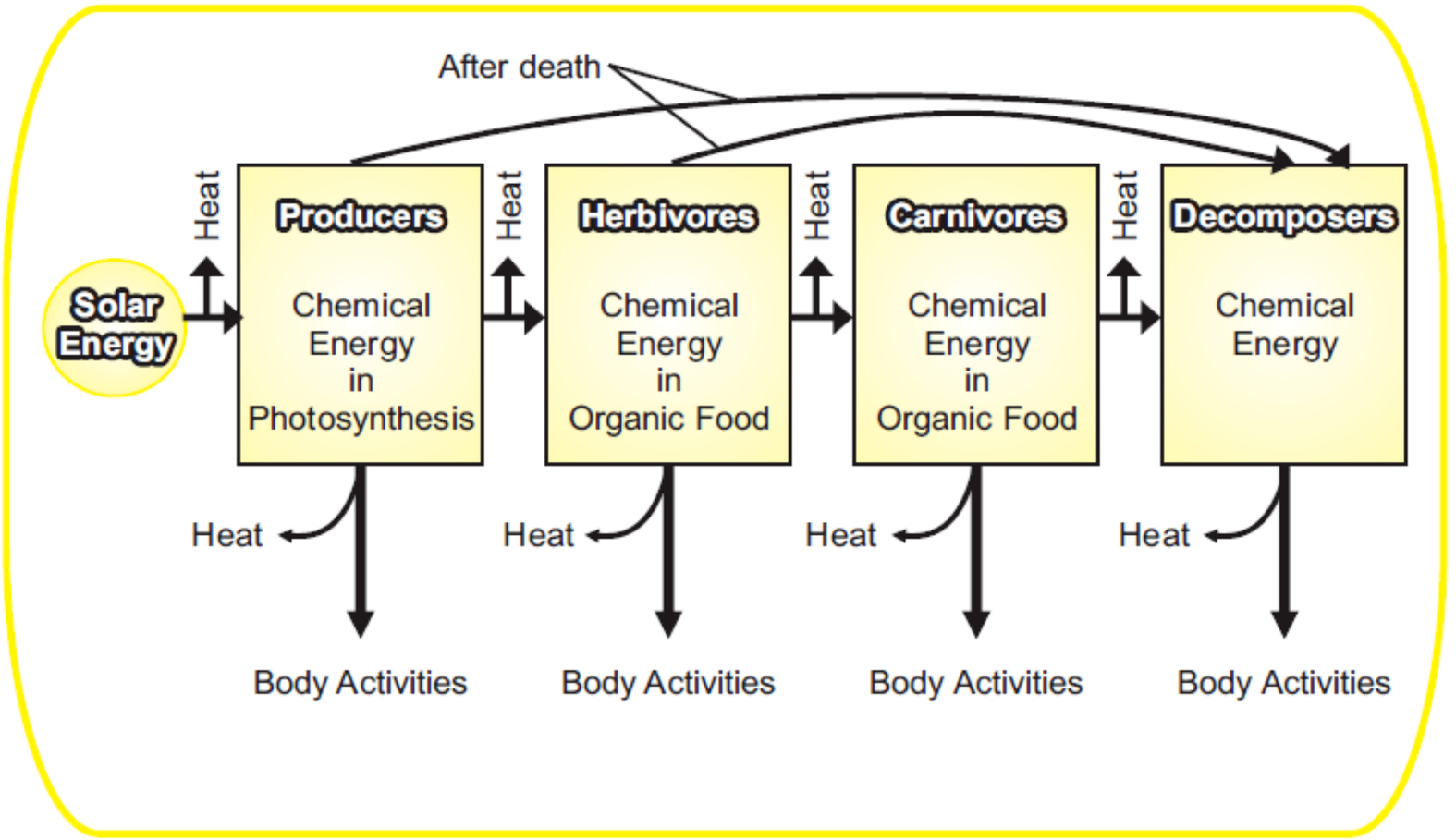


Figure 16.2: Energy flow in an ecosystem

The Sun is the primary source of energy for all ecosystems. Producers get solar energy and transform it into chemical energy by the process of photosynthesis. They store this energy in their tissues and also transform it into mechanical and heat energy during their metabolic activities.

The energy in producers' tissues flows to herbivores when producers are eaten. Herbivores transform it into mechanical and heat energy during their metabolic activities and store the rest in their tissues. Carnivores eat herbivores and get energy. They also use it for their body activities and store the rest in their tissues. After the death of producers and consumers, the energy stored in their tissues is used by decomposers.

The storage and expenditure of energy in an ecosystem is in accordance with the basic law of thermodynamics i.e. 'energy can neither be created nor destroyed but can be transformed from one form into another'.

In an ecosystem there is,

- Constant flow or transfer of energy from the Sun through producers to consumers and decomposers.
- A significant decrease in useful energy during transfer of energy at each trophic level.

16.2.2 Flow of Materials

The materials flow from one trophic level to the next by means of food chains and food webs. A food chain is a series of organisms within an ecosystem, in which each organism feeds on the one before it and is fed by the one after it. For example, following is a food chain in an ecosystem:

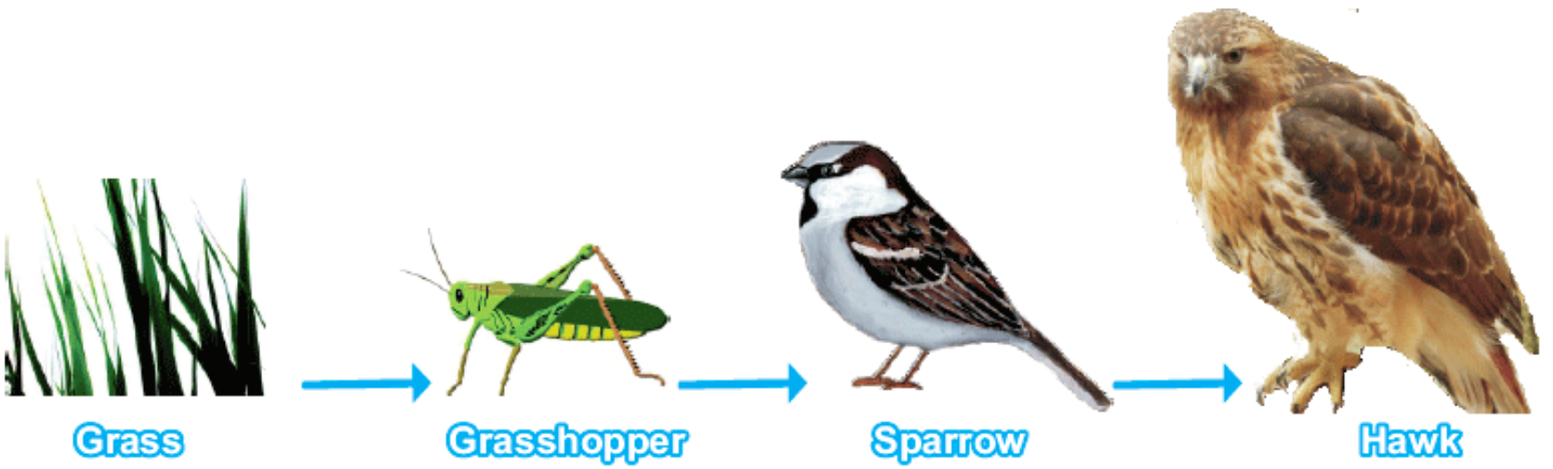


Figure 16.3: A simple food chain

The base of food chain is always formed by a plant (producer). It is eaten by a primary consumer, which is preyed upon by a secondary consumer. The secondary consumer may be eaten by a tertiary consumer. A food chain, can therefore, be represented as,

Producer →Primary Consumer → Secondary Consumer → Tertiary Consumer

A food chain involves a nutritive interaction among the biotic components of an ecosystem. Usually there are 4 or 5 trophic levels. Shorter food provide greater available energy and vice - versa.

Analyzing and Interpreting:

- Construct food chains and food webs through observation of a local pond or grassland ecosystem

In nature, food chains are very complex, as one organism may be the food source of many other organisms. Thus, instead of a simple linear food chain, there is a web-like structure formed by these interlinked food chains. Such interconnected food chains collectively make **'food web'.** Food web can be defined as, "a network of food chains which are interconnected at various trophic levels.

16.2.3 Ecological Pyramids

In 1927, Charles Elton (an English ecologist) developed the concept of ecological pyramids.

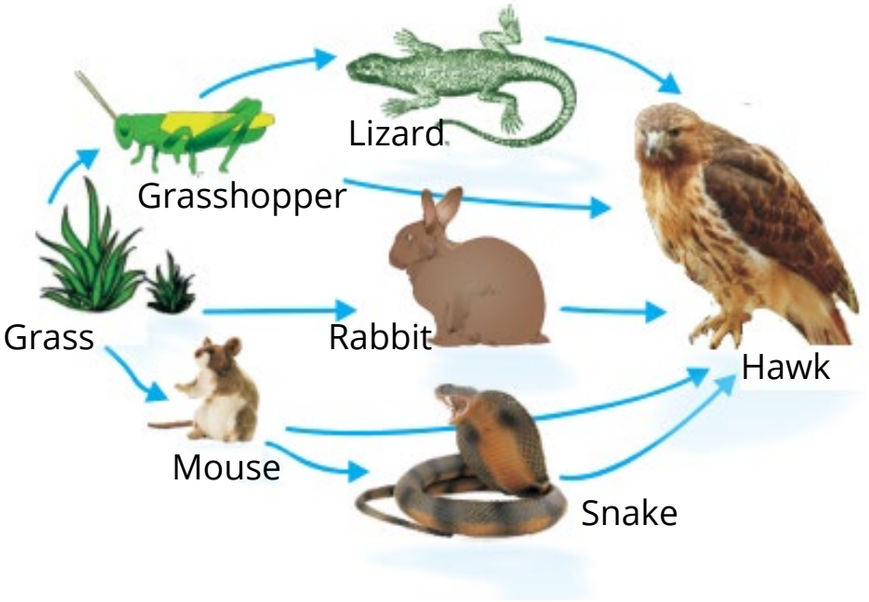


Figure 16.4: A food web in grassland ecosystem

He noted that the animals present at the beginning of food chain are abundant in number while the animals present at the end of food chain are fewer in number. Ecological pyramid can be defined as, "A representation of the number of individuals or amount of biomass or energy present in various trophic levels of a food chain". Ecological pyramids are of three types. Here, we will study two of them.

1. Pyramid of Numbers

It is the graphic representation of the number of individuals per unit area at various trophic levels. Usually, producers are present in large number, primary consumers are in lesser number, secondary consumers are fewer, and so on. So, the producers are of smallest size but maximum in number, while the tertiary consumers are larger in size but lesser in number (Fig. 16.5).

The total amount of living or organic matter in an ecosystem at any time is called "biomass".

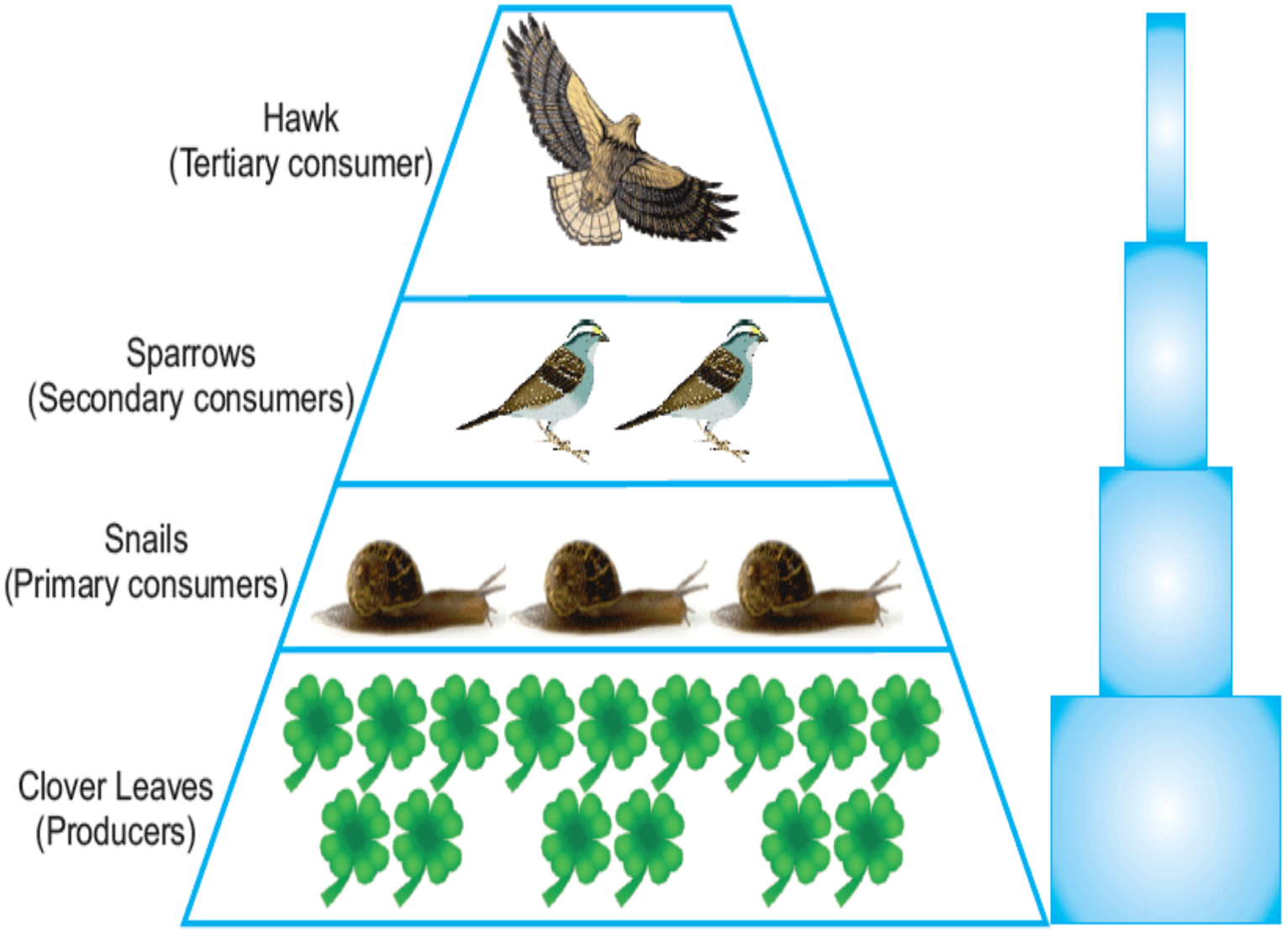


Figure 16.5: Pyramid of numbers in an ecosystem

2. Pyramid of Biomass

It is the graphic representation of biomass present per unit area at different trophic levels. In a terrestrial ecosystem, the maximum biomass occurs in producers, and there is progressive decrease in biomass from lower to higher trophic levels.

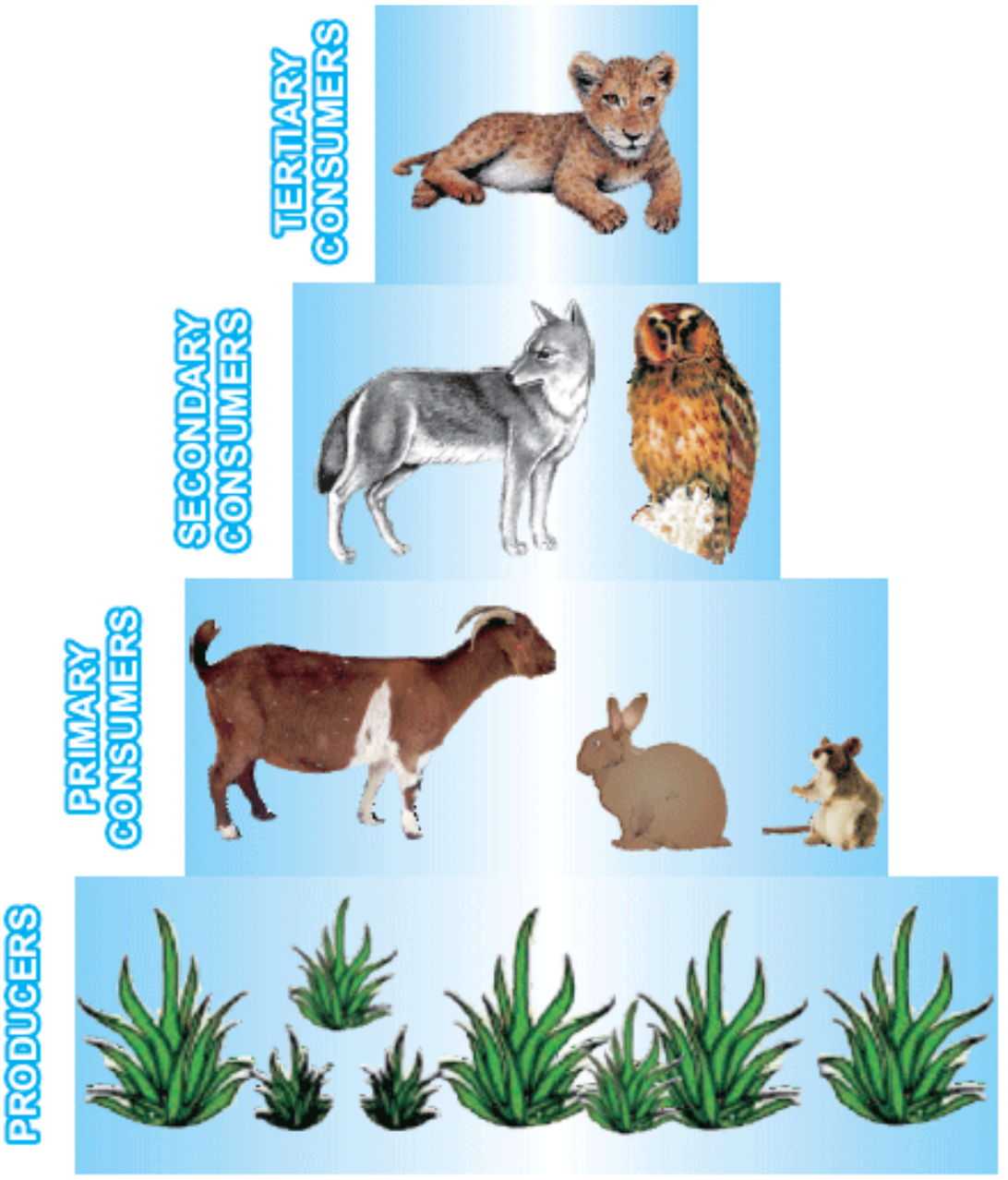


Figure 16.6: Pyramid of biomass in an ecosystem

16.2.4 Biogeochemical Cycles

We know that environment is the source of materials for all living organisms. Environment provides bioelements which are used by organisms for their bodies and metabolism. The materials are continuously recycled between organisms and environment. Biogeochemical cycles are the cyclic pathways through which materials move from environment to organisms and back to environment.

Since such movement of elements and inorganic compounds is essential for maintenance of life, they are also called “nutrient cycles”.

1. Carbon Cycle

Carbon atom is the principal building block of many kinds of biomolecules. Carbon is found as graphite and diamond in nature. It also occurs as carbon dioxide in atmosphere.

Major source of carbon for the living world is carbon dioxide present in atmosphere and water. Fossil fuels like peat, coal, natural gas and petroleum also contain carbon. Carbonates of Earth’s crust also give rise to carbon dioxide.

Carbon cycle is a perfect cycle in the sense that carbon is returned to atmosphere as soon as it is removed.

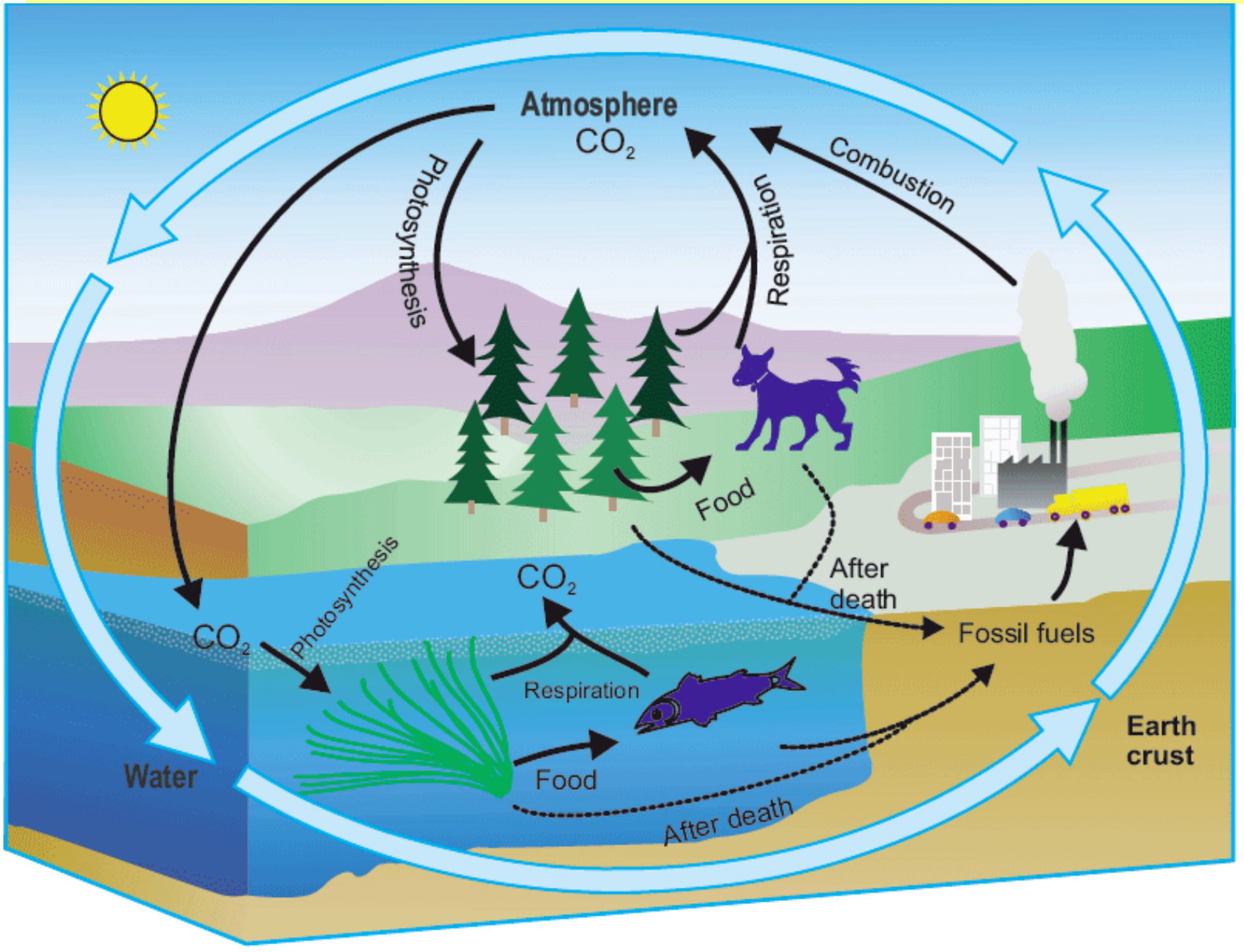


Figure 16.7: Carbon cycle

The major process that brings carbon from atmosphere or water into living world is photosynthesis. Producers take in carbon dioxide from atmosphere and convert it into organic compounds. In this way, carbon becomes a part of the body of producers. This carbon enters food chains and is passed to herbivores, carnivores and decomposers.

Carbon dioxide is released back to environment by respiration of producers and consumers. It is also released by the decomposition of organic wastes and dead bodies by decomposers. Burning of wood and fossil fuels also adds large amount of carbon dioxide into atmosphere.

The balance of carbon cycle has been upset by human activities such as deforestation and excessive burning of fossil fuels. As a result, the amount of carbon dioxide in atmosphere is increasing, causing the green house effect and global warming.

2. Nitrogen Cycle

Nitrogen is an important component of many biomolecules, like proteins and nucleicacids (DNA and RNA). Atmosphere is the reservoir of free gaseous nitrogen. Living organisms cannot pickup this gaseous nitrogen directly from atmosphere (except for nitrogen fixing bacteria). It has to be converted into nitrates to be utilised by plants. Nitrogen cycling involves several stages:

a- Formation of Nitrates

It is done by the following ways:

i. Nitrogen Fixation

Conversion of nitrogen gas into nitrates is called nitrogen fixation. It occurs in the following ways.

- Thunderstorms and lightning convert atmospheric gaseous nitrogen to oxides of nitrogen. These oxides dissolve in water and form nitrous acid and nitric acid. The acids in turn combine with other salts to produce 'nitrates'. It is called as **atmospheric nitrogen fixation.**
- Some bacteria also have the ability to transform gaseous nitrogen into nitrates. It is called **biological nitrogen fixation.** Some of these nitrogen fixing bacteria live as symbionts and many are free-living.

Nitrogen fixation is also done in industries. In **industrial nitrogen fixation,** hydrogen is combined with atmospheric nitrogen under high pressure and temperature. It produces ammonia which is further converted into ammonium nitrate.

ii. Ammonification and Nitrification

Ammonification is the breakdown of the proteins of dead organisms and nitrogenous wastes (urea, uric acid etc.) to ammonia. It is done by ammonifying bacteria. After the formation of ammonia, it is converted into nitrites and nitrates. It is called nitrification and is done by nitrifying bacteria. First, ammonia is converted into nitrites by bacteria (e.g. Nitrosomonas). The nitrites are then converted into nitrates by other bacteria (e.g. Nitrobacter).

b- Assimilation

The nitrates formed by the above processes, are absorbed by plants and are utilized for making proteins etc. Animals take nitrogenous compounds from plants. The utilization of nitrates by organisms is called assimilation.

c- Denitrification

It is a biological process in which nitrates and nitrites are reduced to nitrogen gas by denitrifying bacteria. By this process, nitrogen is returned to atmosphere

Excessive denitrification reduces soil fertility and is stimulated by water logging, lack of aeration and accumulation of organic matter in the soil.

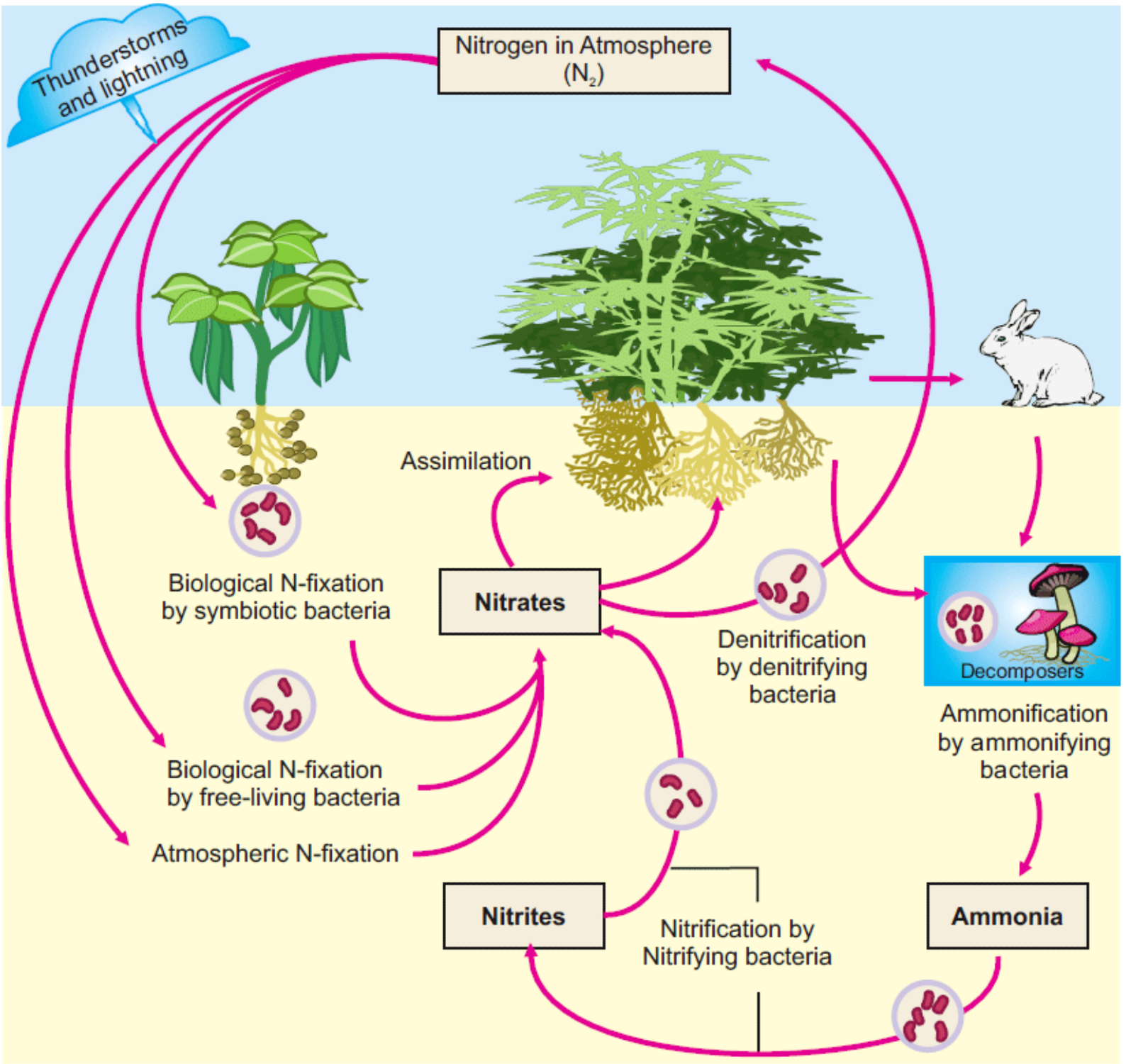


Figure 16.8: Nitrogen cycle

16.3 Interactions In Ecosystems

In all ecosystems, there are many kinds of interactions among living organisms. The **interactions** between the members of the same species are called **intraspecific interactions** while the interactions between the members of different species are called **interspecific interactions**. Some important interactions among living organisms in ecosystems are given below.

16.3.1 Competition

In ecosystems, the natural resources e.g. nutrients, space etc. are usually in short supply. So there is a competition among the organisms of ecosystem for the utilization of resources. The competition may be intraspecific or interspecific.
Intraspecific competition is always stronger and more severe than the interspecific competition. Competition helps in maintaining a balance between the available resources and the number of individuals of a species.

16.3.2 Predation

It is an interaction between two animals of different species or between a plant and an animal. In predation, one organism (the predator) attacks, kills and feeds on other organism (the prey). Some examples of predation are given below.
All carnivore animals are predators (Fig. 16.9). For example, frog preys upon mosquito and fox preys upon rabbit. There are some examples where a predator is preyed upon by a second predator and then the second one is preyed upon by a third predator. For example, frog (predator 1) is preyed upon by a snake (predator 2) and the snake is preyed upon by an eagle (predator 3).

Plants also show competition for space, light, water and minerals.

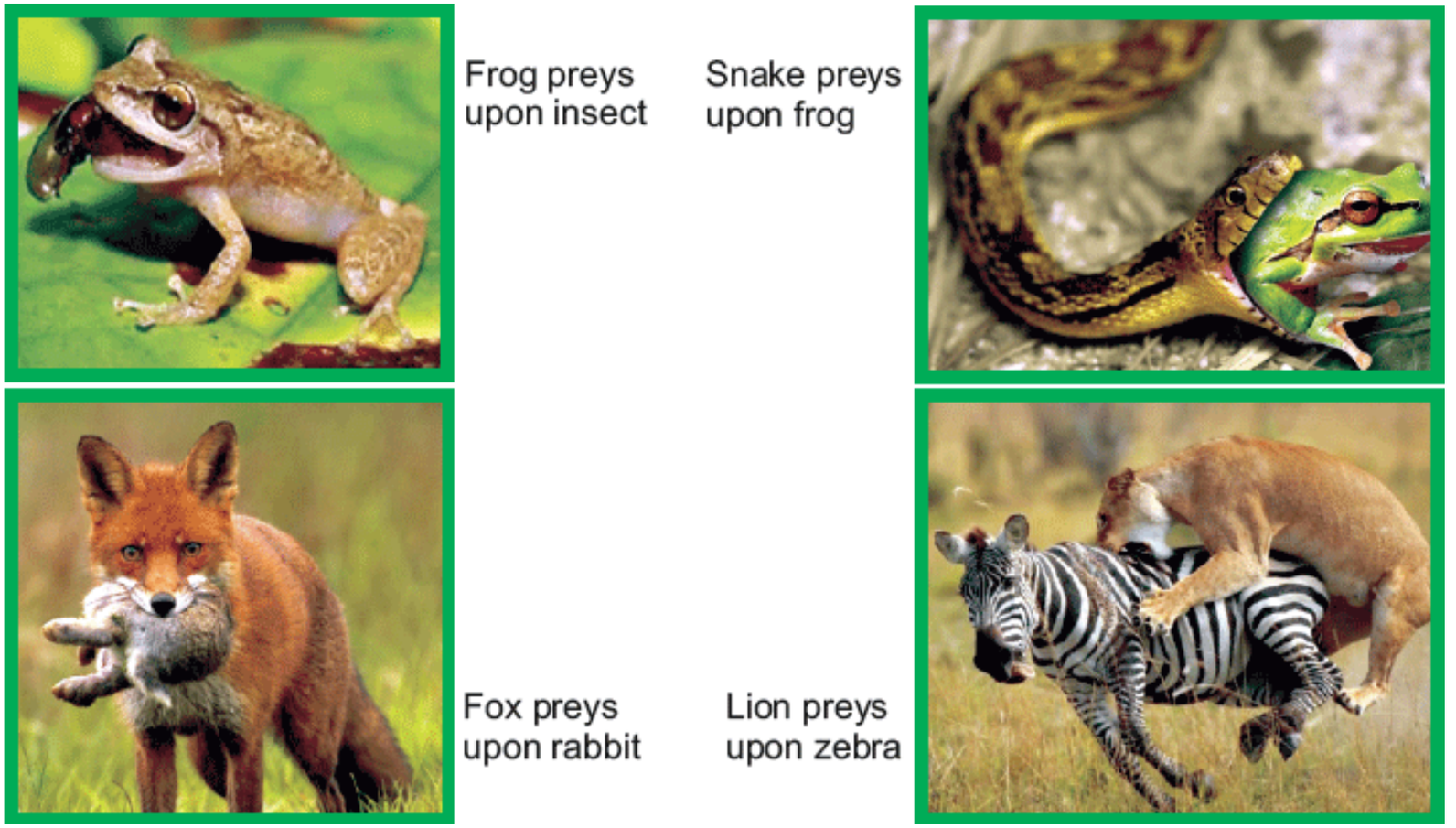


Figure 16.9: Examples of predators and their preys

- Certain plants (Pitcher plant, sundew, Venus fly trap etc.) are carnivorous and live as predators (Fig. 16.10). Such plants live in the areas where minerals and other nutrients are lacking. They feed on insects to fulfill their nitrogen requirements. These plants have mechanism to attract insects. For example, they secrete sweet nectar that attracts the insects searching for food. Their leaves are also modified to capture the prey.

Host can survive without parasite, but parasite cannot survive without host.

Figure 16.10: Predator Plants

Predation keeps the prey population under check, so as to maintain an ecological balance. Humans benefit from this interaction in the biological control of weeds and pests. In order to control pests in an area, their predators are released there.

16.3.3 Symbiosis

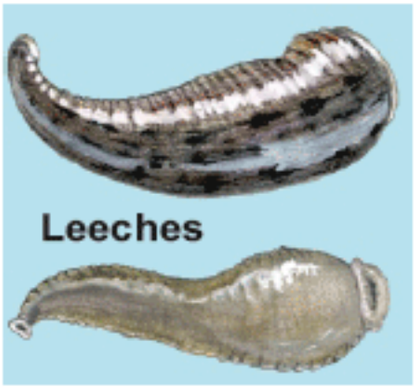
It is a relationship between members of different species, in which they live together for longer or shorter periods of time. Symbiosis is of three types.

a. Parasitism

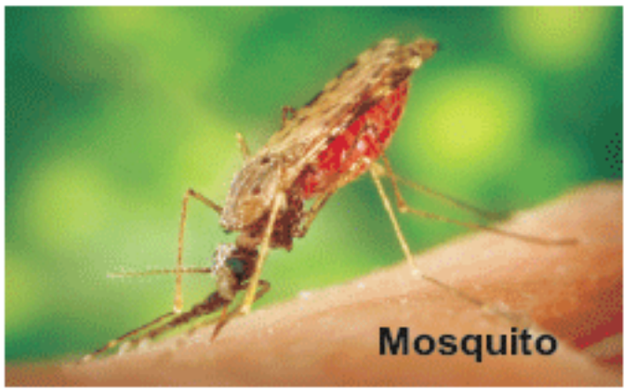
It is a type of symbiosis (between members of different species), in which smaller partner (parasite) derives food and shelter from the body of larger partner (host) and, in turn, harms it.

In temporary parasitism, the parasite spends most of its life cycle as independent free-living organisms. Only a part of its life cycle is spent as a parasite.

Leech, bed bug, mosquito are common temporary parasites of humans. In permanent parasitism, the parasites spend their whole life cycle as parasites. Many disease causing bacteria and all viruses are permanent parasites. Parasites may also be classified as ectoparasites and endoparasites. Ectoparasites live outside i.e. on the surface of host's body and get food from there. Mosquitoes, leeches, lice etc. are the examples of ectoparasites.



Leeches



Mosquito

Endoparasites live inside the body of host and get food and shelter. Bacteria, viruses, tapeworm, Ascaris, Entamoeba, Plasmodium etc. are the examples of endoparasites.

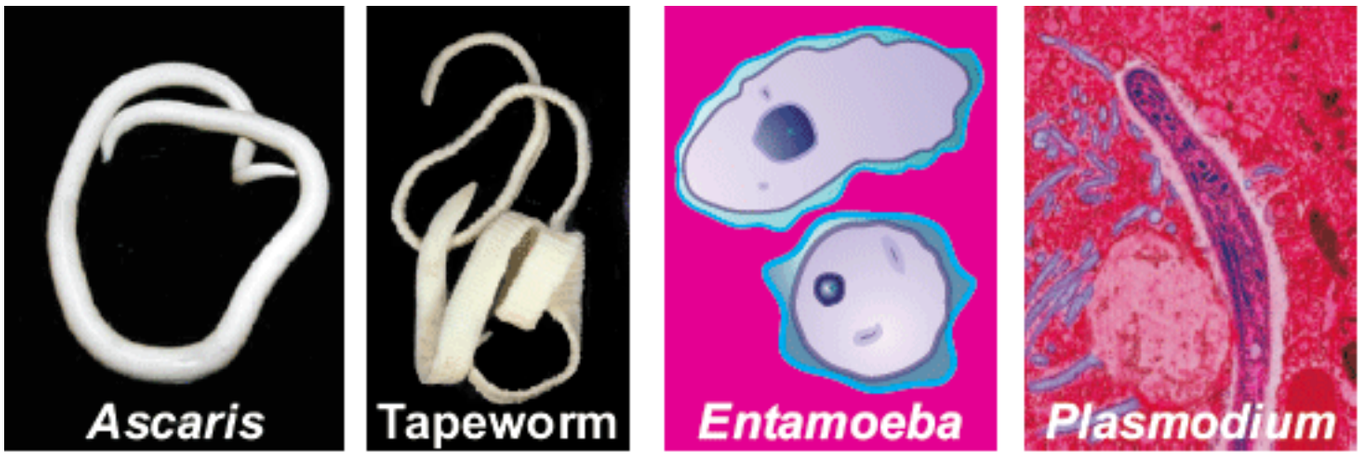


Figure 16.12: Some endoparasites

Some plants (e.g. Cuscuta, also called dodder) are parasites on other plants.
Parasitic plants grow special types of roots (haustoria) into host body and suck the required nutrients from the vascular tissues of host.

b. Mutualism

In this type of symbiotic interaction, both partners (of different species) get benefit and neither is harmed. For example, Termites eat wood but are not able to digest it. A protozoan lives in its intestine. It secretes 'cellulase' enzyme to digest the cellulose of wood. In return, the termite provides food and shelter to the protozoan (Fig. 16.14). The nitrogen fixer bacteria Rhizobium live in the root nodules of leguminous plants like pea, gram etc. The bacteria obtain food and shelter from plants while in return they fix gaseous nitrogen into nitrates for the plant which is required for their growth.

Figure 16.13: A parasitic plant and its host tree trunk

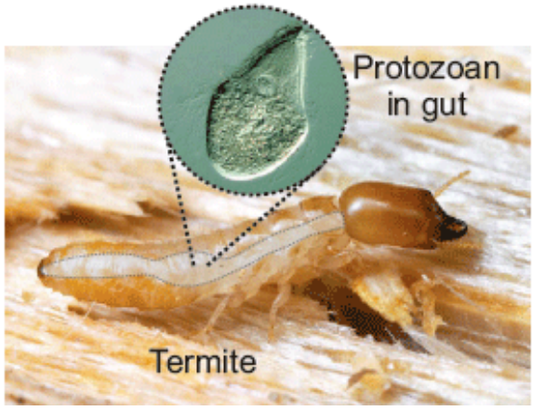


Figure 16.14: Termite, with a protozoan in its gut

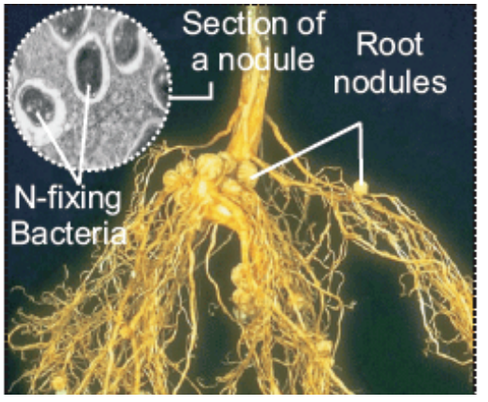


Figure 16.15: Bacteria in root nodules

c. Commensalism

It is a type of symbiosis in which one partner is benefited while the other is neither benefited nor harmed. For example:

- Epiphytes are small plants found growing on other larger plants for space only (Fig. 16.16-a). They absorb water and minerals from atmosphere and prepare their own food. The larger plants are neither benefited nor harmed in any way.
- Sucker fish attaches to the surface of sharks by its sucker (Fig. 16.6-b). In this way, the shark provides easy transport to the sucker fish to new feeding grounds.

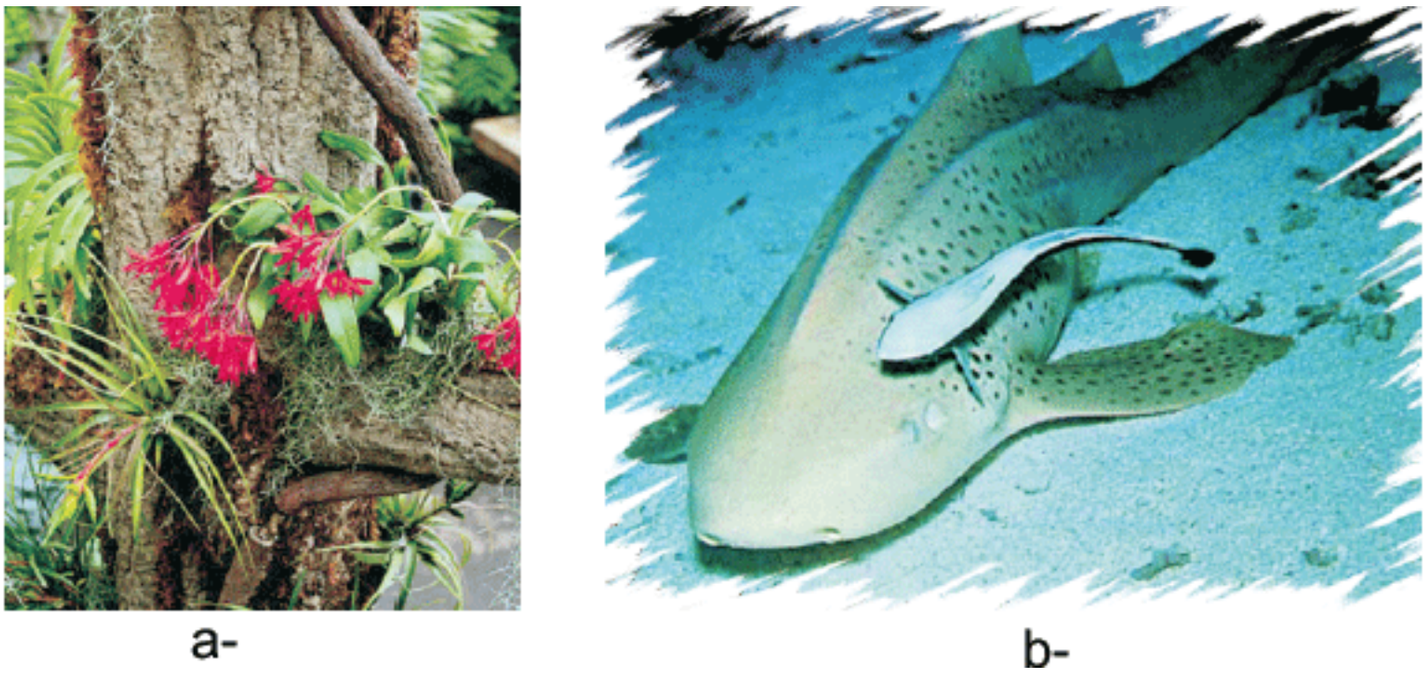


Figure 16.16: a- An epiphyte orchid plant growing on a tree trunk; b- A sucker fish attached with shark

What type of symbiosis is it?

The honeyguide bird feeds on wax and the larvae present in honeycombs. It flies around looking for honeycombs, but it is not strong enough to open the comb. Badgers are large mammals that feed on honey. When a honeyguide bird goes to find honeycombs, the badger follows it. When the bird finds a honeycomb, it calls the badger. Sometimes the bird has to stop and wait for the slow-moving badger. After reaching there, the badger opens the honeycomb and both of them eat their foods together. Traditionally, humans have also used these birds to find honeybee colonies.

16.4 Ecosystem Balance And Human Impact

The interactions among organisms and between organisms and the abiotic components of their environment produce steady and balanced ecosystems. Biogeochemical cycles also maintain the balance in ecosystems by recycling natural resources, so that they do not deplete.

Humans try to modify environment (e.g. cutting of trees) to fulfill their needs. This has upset the delicate balance in ecosystems and nature as well. Some of the human impacts on the balance of ecosystems and nature are described next.

1. Global Warming

The addition of greenhouse gases (e.g. carbon dioxide, methane, ozone) in atmosphere increases the temperature of the Earth. These gases remain in the lowest part of Earth's atmosphere and do not allow solar radiations to reflect back into space. As a result, heat remains within the Earth's atmosphere and increases its temperature. This is called global warming.

Due to global warming, polar ice-caps and glaciers are melting faster than the time taken for new ice layers to form. Sea water is also expanding causing sea levels to rise. Due to melting glaciers, rivers overflow and cause floods.

The Maldives' Survival

Scientists fear that the sea level is rising up to 0.9cm a year. Rise in sea level has worst effects on coastal countries. Most of the islands of the Maldives are less than 1 metre above sea level. It is estimated that within 100 years, the Maldives might become uninhabitable and the citizens would be forced to evacuate.

In 1990, the United Nations established Intergovernmental Panel on Climate Change (IPCC). It provides scientific advice to the world leaders on issues like the build-up of greenhouse gases and its prevention. According to IPCC, Earth's surface temperature has increased ≈0.2°C per decade in the past 30 years.

Greenhouse Effect

The term 'Greenhouse Effect' refers to the phenomenon in which certain gases (called greenhouse gases) trap heat in the atmosphere. These gases act like the glass in a greenhouse, which does not allow the inner heat to escape. When sunlight reaches the surface of the Earth, much of its energy is transformed into heat energy. The Earth surface reflects this heat energy towards space as infrared

radiation. The greenhouse gases trap infrared radiation and send it back to Earth. Carbon dioxide, methane and nitrous oxide are important greenhouse gases. Since 1800, the amount of Carbon dioxide in atmosphere has increased 30 %. The amount of methane has more than doubled and the amount of nitrous oxide has increased about 8%.

2. Acid Rain

When rain falls through polluted air, it comes across chemicals such as oxides of sulphur and nitrogen. These chemicals interact with water vapours in the presence of sunlight to form sulphuric acid and nitric acid. These acids remain as vapour at high temperatures.

As temperature falls, the acids begin to condense into liquid form and mix with rain or snow, on the way down to the Earth. This makes rain acidic with pH range of 3 to 6. Some of the significant ill effects of acid rain are:

- Acid rain destroys the necessary nutrients present in the waters of rivers and lakes etc. Its also lowers the pH of water. Most of the aquatic animals cannot survive at this pH.
- Acid rain washes nutrients out of soil, damages the bark and leaves of trees and harms root hairs. Leaf pigments (chlorophyll) are also destroyed.
- Metallic surfaces exposed to acid rain are easily corroded. Fabrics, paper and leather products lose their material strength or disintegrate easily.
- Building materials such as limestone, marble, dolomite, mortar and slate are weakened with acid rains because of the formation of soluble compounds. Thus, acid rain is dangerous for historical monuments. The building of famous Taj Mahal has been corroded at many places, due to acid rains (Fig. 16.17).

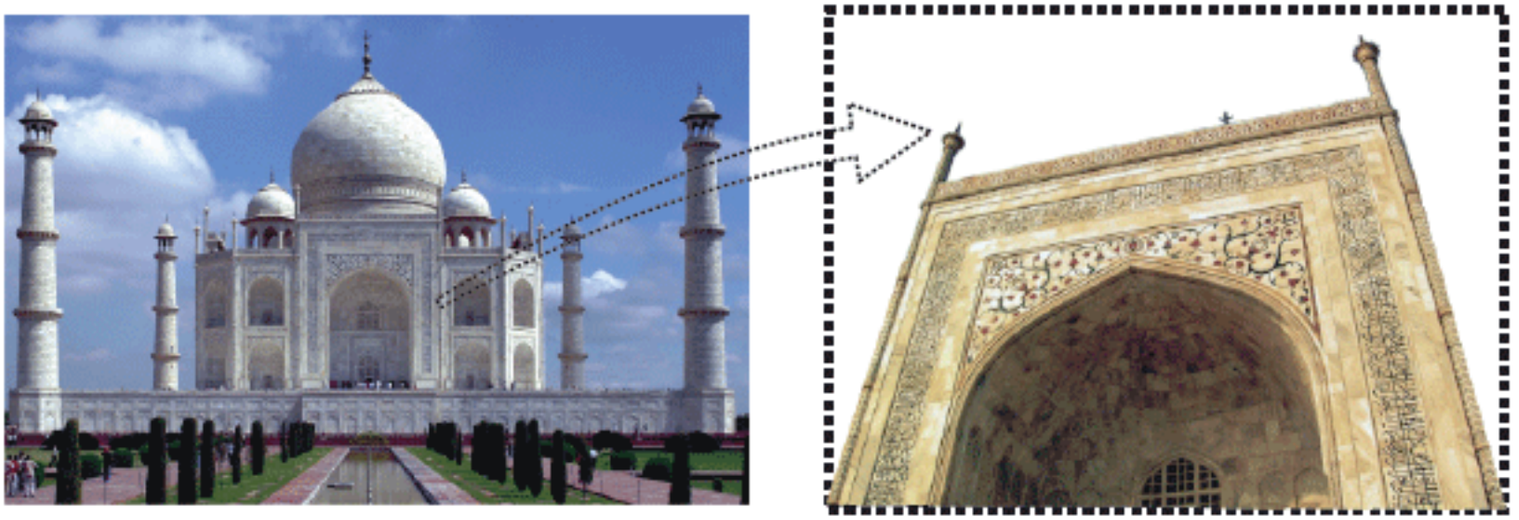


Figure 16.17: Taj Mahal and its corroded door

3. Deforestation

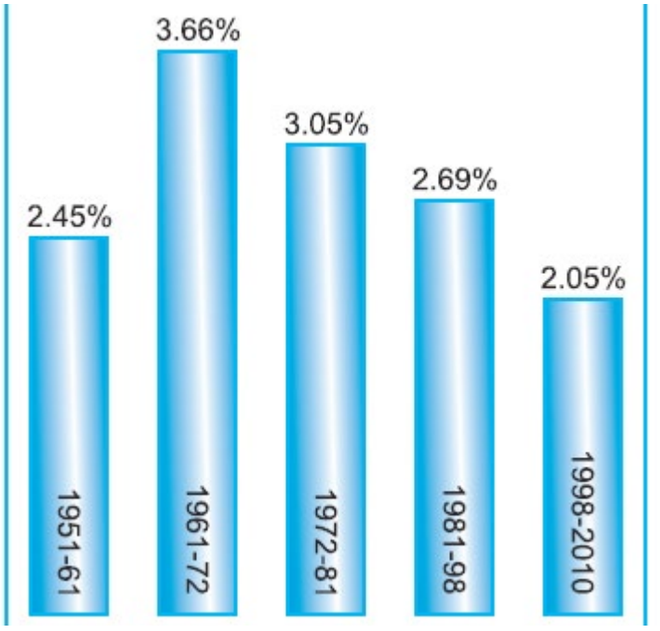
Deforestation means clearing of forests by natural causes or humans. Large areas of forests have been cleaned for agriculture, factories, roads, rail tracks and mining. Humans cut trees for getting wood (lumber), which is then used for making structures and for heat production. Human preys upon forest animals, which are the predators of many insect pests. In this way,
insect pests destroy forests by eating the shoots and spreading diseases. The effects of deforestation include floods, droughts, landslides and soil erosions, global warming and loss of habitat of many species.

Figure 16.18: Forests are cut for making roads

4. Overpopulation

When the industrial revolution started some 250 years ago, the world population was at 600 million - that seems like a lot of people but now the world population is almost ten times at 6 billion and will grow to 8 billion by 2025. Better health facilities and lowered mortality rates have contributed in population growth.

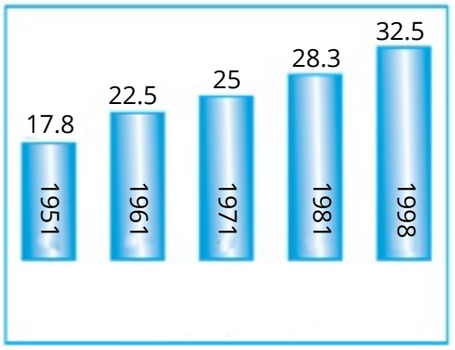
Year	Population
1981	85,096,000
1984	92,284,301
1987	99,953,232
1990	107,975,060
1993	116,444,165
1996	125,409,851
1999	134,790,000
2002	144,902,409
2005	155,772,000
2008	166,111,487
2009	169,708,303
2010	173,510,000



Pakistan Population Growth Rates
Source: Pakistan Economy survey
Ministry of Population Welfare
Government of Pakistan

5. Urbanization

Urbanization means growing of cities. People move from rural areas to cities in search of better jobs, education opportunities and higher standards of living. If there is rapid urban growth, the governments find it difficult to provide even the basic facilities like health, education, shelter, water, electricity etc. Most of the migrants in cities do not find good jobs and become the part of urban poor. There is overcrowding in schools, hospitals etc. The slum areas increase in number and people living there are at greater risk of diseases.



Pakistan Urban population in %age
Source: The world Bank

Urbanization is a global problem and cannot be stopped but it can be managed. The current level of urbanization in Pakistan is about 32% which is not high by global standards. A planned urbanization can solve many problems. The cities should have thick green belts in their surroundings to control pollution. The open spaces in cities should be reserved through zoning and land plans. The urban spread-out should also be controlled. Utilization of public transport instead of individual transports also proves effective way to manage urbanization.

16.5 Pollution; Consequenses And Control

For better life, human society is becoming more and more dependent on technology and industries. Technology and industry are making life easier and convenient for humans but are also contributing towards the pollution of
environment. Pollution is defined as any undesirable change in the physical, chemical or biological characteristics of air, water and land that may harmfully affect living organisms and natural resources.

1. Air Pollution

Air pollution is one of the major environmental issues of today. It is defined as the change of composition of air by the addition of harmful substances (e.g. industrial and automobile gases and particulate matter). All sources of air pollution are related to human activities. Burning of coal produces a lot of smoke and dust whereas burning of petroleum produces sulphur dioxide. In addition to these, air pollutants include carbon monoxide, carbon dioxide, nitrogen oxides, hydrocarbons, particulate matter and traces of metals. Different industries produce air pollution in the following way.

The substances that actually cause pollution are called the pollutants. They may be the industrial effluents, domestic wastes, medical wastes etc. Pollutants are of two types i.e. biodegradable and non-biodegradable.

Fertilizer industries release oxides of sulphur and nitrogen, hydrocarbons, particulate matter and fluorine. Thermal industries are coal based and their pollutants are fly ash, soot and sulphur dioxide. Textile industries release cotton dust, nitrogen oxides, chlorine, smoke and sulphur dioxide. Steel industries release carbon monoxide, carbon dioxide, sulphur dioxide, phenol, fluorine, cyanide, particulate matter etc.

Effects of Air Pollution

We have studied that global warming is one of the consequences of air pollution. Other effects of air pollution are as follows.

Smog formation:

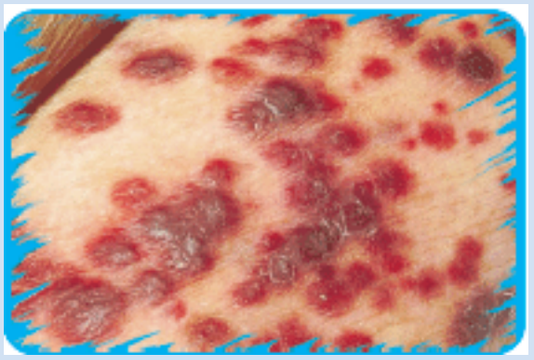
When pollutants like hydrocarbons and nitrogen oxides combine in the presence of sunlight, smog is formed. This is a mixture of gases. It forms a yellowish brown haze especially during winter and hampers visibility. It also causes many respiratory disorders and allergies as it contains polluting gases.

Acid rains:

The air pollutants like sulphur dioxide and nitrogen oxides react with water in the atmosphere producing acid rains.

According to estimates, at the current rate of increase, the average global temperature will go up by 3^{o}C to 8^{o}C in the next 100 years.

Ozone depletion: The upper layer (stratosphere) of the atmosphere has ozone (O_3) which absorbs ultraviolet (UV) rays present in the sun's radiation. However, the air pollutants like chlorofluorocarbons (CFCs) destroy the ozone molecules and so break the ozone layer. Ozone holes are created which permit UV rays to reach the Earth's surface. The UV rays increase the temperature and also cause skin cancers.



The harmful effects of the UV rays are visible in the countries such as Australia and New Zealand where the rate of skin cancer is higher than the other regions of the world.

Control of Air Pollution

For effective control of air pollution, it is important to create public awareness about the ill-effects of air pollution. Air pollution can be controlled by the following ways:

Afforestation: It means the establishment of new forests by planting on non-forest areas. Forests are effective means to control air pollution because plants can filter and absorb air pollutants

Modification of industrial effluents: The air pollutants coming from industries should be passed through filters and other devices, so that the particulate matter is removed before the waste gases are released out. The smoke producing units should have long chimneys to take the polluting gases far above and then disperse over a larger area. Industries should also invest for solar cookers or for producing bio gas.

Environment friendly fuels: Lead-free fuels should be used in automobiles. Similarly, sulphur-free fuel should be used in coal-based industry to reduce pollution by sulphur dioxide.

2. Water Pollution

It is the change in the composition of water by the addition of harmful substances. Water pollution severely affects the health of people. Sewage is one of the major pollutants of water. It contains organic matter and the excreta of human and other animals. Organic matter encourages the growth of microorganisms which spread diseases. The wastes of industries (acids, alkalis, dyes and other chemicals) are disposed in nearby water bodies. These wastes change the pH of water and are harmful or even fatal to aquatic organisms. Certain industries release a lot of hot water from their cooling plants. It results in heating up of water bodies and kills aquatic life. Fertilizers and pesticides enter into water bodies with the rain water flow and the ground water by seepage. These chemicals remain in water for a long time and can enter food chains. They cause a number of diseases in animals. Oil tankers and offshore petroleum refineries cause oil leakage into water.

Oil floats on the water surface and prevents atmospheric oxygen from mixing in water. So, aquatic animals begin to die due to oxygen shortage.
Some heavy metals e.g. lead, mercury, arsenic and cadmium also make the water polluted. Such metals can be present in the water, released from industrial and urban areas.

If water with such heavy metals is given to plants, the metals enter the vegetables that grow on these plants. Such contaminated vegetables are harmful for human health. Heavy metals reduce growth and development, and cause cancer and nervous system damage. Mercury and lead can cause joint diseases such as rheumatoid arthritis, and diseases of kidneys, circulatory system and nervous system.

There are more than 200 tanneries (industry where raw skin is treated to make leather) operating in Kasur city. The industry discharges 9000 cubic metres of waste water daily into the nearby water bodies. This water contains heavy metals and becomes a part of the underground water. In 2003, a survey showed that two-thirds of residents and 72 percent of tannery workers suffered cancer, infections of the kidney, or loss of eyesight. Tests showed that the drinking water was contaminated with lead, mercury and chromium. The Pakistan government and the United Nations Development Programme (UNDP) launched the Kasur Tannery Pollution Control Project. The project has established an effluent treatment plant, chromium plant and a solid waste disposal site.

Effects of Water Pollution

The following are major effects of water pollution.

Eutrophication: Enrichment of water with inorganic nutrients (nitrates and phosphates) is called **eutrophication.** The sewage and fertilizers contain large amount of inorganic material (nutrients). When sewage and fertilizers reach water bodies, the nutrients present in them promote algal blooms (excessive growth) there (Fig. 16.19). Rich algal growth leads to increase in the number of the decomposers. Decomposers use the oxygen present in water and it results in the depletion of oxygen. Algal bloom also reduces the light reaching the lower layers in water.

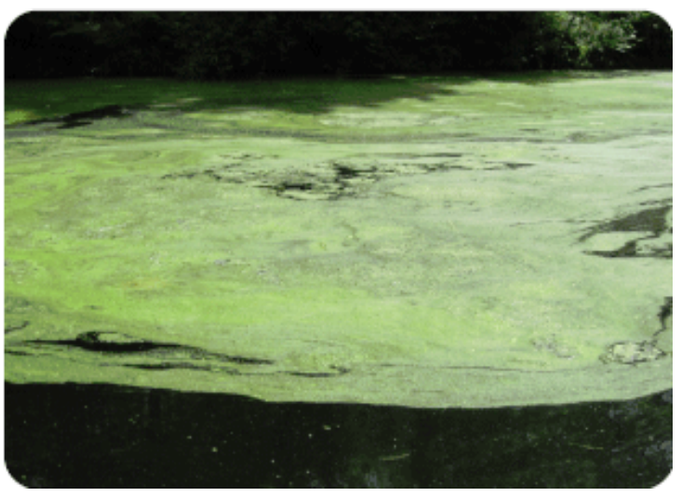


Figure 16.19: Eutrophication in a lake

Food chain contamination: The non-biodegradable water pollutants may stay in water for long times. From water, they enter into small organisms, which are fed upon by fish. The fish in turn are fed upon by land animals including human.

Epidemics: Organic pollutants in water facilitate the growth of germs. Such polluted water causes epidemics like cholera, gastroenteritis etc.

Control of Water Pollution

Public should be made aware of the dangers of water pollution. Before releasing the sewage into water bodies, it must be purified through sewage treatment techniques. Industrial wastes should also be treated before they are released into water bodies.

Analyzing and Interpreting

- Interpret the data about local environmental problems (through survey search).
- Plan and carry out simple investigation to determine the nature and effects of pollutants

3. Land Pollution

Land (soil) is an important resource as it is the basis for the growth of producers. In the recent times, soil has been subjected to pollution.

The pesticides used in agriculture have chemicals that stay in soil for long times. The acid rains change the pH of soil making it unsuitable for cultivation. The household and other city garbage lies scattered in soil in the absence of a proper disposal system. Materials like polythene block the passage of water into soil and so decrease the waterholding capacity of soil.

Many industries produce harmful chemicals which are disposed of without being treated. Improper disposal of nuclear wastes also causes radioactive substances to remain in soil for a long time. Open latrines in villages and some parts of cities are also the source of land pollution.

Control of Land Pollution

There should be suitable and safe disposal of wastes including nuclear wastes. Nonbiodegradable materials like plastic, glass, metals etc. should be recovered and recycled. Inorganic pesticides should be replaced by organic pesticides.

Figure 16.20: Can we control land pollution?

16.6 Conservation Of Nature

Conservation of nature means the conservation of natural resources. Everything that we use or consume e.g. food, petrol etc. is obtained from natural resources. The renewable natural resources e.g. air are reproduced easily but the non-renewable resources (e.g. minerals and fossil fuels) are not replenished once they get depleted. We have to conserve the non-renewable resources because their reserves are limited and humans are heavily dependent on them for daily needs. The renewable resources too have to be judiciously used. To ensure sustainable use of resources in our environment, we should act upon the principle of 'The 3R' i.e. Reduce, Reuse, and Recycle.

The R1: Reduce: We should use the natural resources less and should not waste them. We should use this principle at different places, in our daily lives. We should not waste water, electricity, fuel etc.

We should turn off the tap when not in use. We should bathe with a bucket instead of shower. The lights and fans should be off, when we are not in room. We should take public transport (like buses) or walk short distances instead of using motor fuel. We should not waste food and should give unused food to poor people.

A recycling of one tone paper can save 17 trees

A recycling of one tonne of paper can save 17 trees.

Clean water, air, fuels, agricultural land and forests appeared to be plentiful earlier, but now these are becoming scarce. If we continue depleting them like this, we will be creating untold misery for ourselves and for our future generations.

The R2: Reuse: We should use things again and again. We should not throw away materials such as glass containers, plastic bags, paper, cloth etc. These should be reused at domestic levels rather than being thrown. It also reduces solid waste pollution.

The R3: Recycle: Materials such as paper, plastic, glass etc. can be recycled. This decreases the volume of refuse and helps in the conservation of natural resources.

We can add the R4 i.e. Reforest. Trees should be planted during the rains. Trees make our environment more cool, shady and green.

Plans for the Conservation of Nature

In Grade IX, we have studied the projects and plans of Pakistan for the conservation of wildlife, which is an important natural resource. The following are the projects and plans of our government for the conservation of other resources.

In 1992, Pakistan developed and the National Conservation Strategy. The main objectives of the strategy are conservation of natural resources and improved efficiency in the use of resources. It also covers the policies for promoting efficiency and conservation of energy resources.

The Federal Ministry of Environment has launched the National Drinking Water and Sanitation Policy. It focuses on the provision of clean drinking water to entire population and the conservation of water resources. Water purification plants are being installed all over the country.

In 2006, the UNDP launched the project "Mass Awareness for Water Conservation and Management". The objective of the project was to launch a comprehensive awareness campaign for the conservation and management of water resources in Pakistan.

The organization SCOPE (Society for Conservation and Protection of Environment) works with government for mass awareness and research for the conservation of natural resources in Pakistan.

The WWF (old name is World Wildlife Fund but now it is called World Wide Fund for Nature) is working on many projects related to the conservation of nature. The following are some important programmes of WWF-Pakistan (in collaboration with the government of Pakistan):

- Improving sub-watershed management and environmental awareness around Ayubia National Park
- Plantation of the trees of Jatropha and Mangroves at District Thatta, Sindh
- District-wise forest cover assessment of Pakistan
- Saving Wetlands Sky High Programme (for the conservation and management of high altitude wetlands)
- Indus Basin Water Security Project (to protect the water-flow needed for the maintenance of river ecosystem and for the benefit of nearby areas)
- Regional Climate Risk Reduction in Himalayas

Analyzing and Interpreting

Collect data from internet and state the names of endangered and threatened animals species in Pakistan.

Basic Information about Dengue Fever

Dengue fever is a viral infection transmitted through a mosquito Aedes aegypti. It has become a major health problem in tropical and sub-tropical countries, including Pakistan. There are four types of dengue virus. Recovery from infection by one provides lifelong immunity against that virus but provides no protection against infection by the other three viruses. According to the World Health Organization, there are 50 million dengue infections worldwide every year. Now, there are 2.5 billion people at risk from dengue.

The female Aedes mosquito gets the virus when it bites an infected person. When an infected mosquito bites another person, viruses enter his / her blood and attack white blood cells. Inside WBCs, viruses reproduce and destroy them. In severe cases, the virus affects liver and bone marrow. As a result there is a decrease in the production of blood platelets and patient suffers from bleeding. Other symptoms of dengue include high fever, severe headache, pain behind the eyes, muscle and joint pains and rash.




Adult Aedes ⇨ Eggs of Aedes ⇨ Larva of Aedes ⇨ Pupa of Aedes

Sometimes, dengue fever converts into dengue haemorrhagic fever (DHF) or into dengue shock syndrome (DSS). DHF results in bleeding, low levels of blood platelets and blood plasma leakage. In DSS the blood pressure falls dangerously low. There is no vaccine or treatment for dengue fever. At present, the only method of controlling dengue virus transmission is to check the spread of Aedes mosquitoes. Aedes aegypti breeds primarily in the containers used for water storage, discarded plastic containers, used automobile tyres and other items that collect rainwater. The mosquitoes can be controlled through proper solid waste disposal and improved water storage practices. Small fish and crustaceans have also been used for killing the larvae of the mosquito. Insecticide sprays have not proved efficient in killing the mosquitoes, because spray does not penetrate all habitats of adult mosquitoes.

UNDERSTANDING THE CONCEPT

1. Explain what do you mean by the pyramids of number and biomass.
2. Write a note on Carbon cycle.
3. What are the different stages of Nitrogen cycle?
4. Write notes on competition, predation and symbiosis.
5. Explain how human activities have contributed to the loss of balance in nature.
6. Write note on the causes and effects of the air and water pollutions.

SHORT QUESTIONS

1. What are the different levels of ecological organization?
2. Define ecosystem and its components.
3. How the flow of energy is different from that of materials?
4. Define food chain and food web.
5. What do you mean by the concept of 3Rs with reference to the conservation of natural resources?

THE TERMS TO KNOW

Abiotic
Acid Rain
Ammonification
Atmospheric nitrogen fixation
Biogeochemical Cycle
Biological nitrogen fixation
Biosphere
Biotic
Carbon cycle
Carnivore
Commensalism
Competition
Consumer
Decomposer
Deforestation
Denitrification
Ecological pyramid
Environment
Eutrophication
Food chain
Food web
Global Warming
Interspecific interactions
Intraspecific interactions
Mutualism
Natural resources
Nitrification
Nitrogen cycle
Nitrogen fixation
Non-renewable resources
Overpopulation
Ozone
Parasitism
Phytoplankton
Pollutant
Pollution
Predation
Producer
Pyramid of biomass
Pyramid of numbers
Renewable resources
Symbiosis

ACTIVITIES

1. Make a visit to a pond and compare the abiotic and biotic factors of a pond with that of an aquarium.

SCIENCE, TECHNOLOGY AND SOCIETY

1. State how your city or village is an ecosystem and describe your position and role in that ecosystem.
2. Describe the possible consequences of competition (due to limited resources and overpopulation) in human society.
3. Use data from internet and literature search on Pakistan population growth from 1990 to 2000 and interpret this population growth and the possible consequences on our society.
4. Identify environmental problems in your community. What are the causes and what should be done to solve these problems?
5. Actively participate in the community efforts for the conservation of nature.
6. Organize a poster or picture exhibition at school on some environmental topic.

ON-LINE LEARNING

1. http://www.environment.gov.pk/
2. www.sciencedaily.com/news/earth.../environmental_science/
3. www.globalchange.umich.edu/.../ecosystem/ecosystem.html
4. www.biology.ualberta.ca/facilities/multimedia/.../Ecosystem.swf
5. 3dnature.com/anims.html

CHAPTER

17 Biotechnology

Animation 17.1: Biotechnology
Source & Credit: dailykos

Humans have been making use of biotechnology since they discovered farming. This use extended from the planting of seeds to the control of plant growth and crop production. Animal breeding is also a form of biotechnology. Cross-pollination of plants and cross-breeding of animals were major techniques in biotechnology. These techniques were used to enhance product quality and to meet specific requirements. In this chapter we will get basic knowledge about the techniques being used in biotechnology.

17.1 Introduction Of Biotechnology

Biotechnology is defined as the use of living organisms in processes for the manufacture of useful products or for services. Although the term biotechnology is new, the discipline itself is very old. Fermentation and other such processes, which are based on the natural capabilities of organisms, are commonly considered as old biotechnology.

In Scotland, in 1997, an embryologist Ian Wilmut produced a sheep (Dolly) from the body cell of an adult sheep.

Genetic engineering i.e. the artificial synthesis, modification, removal, addition and repair of the genetic material (DNA) is considered as modern biotechnology. It is done to alter the characteristics of organisms. The work on genetic engineering started in 1944 when it was proved that DNA carries the genetic information. Scientists isolated the enzymes of DNA synthesis and then prepared DNA outside cells. In 1970s, they were able to cut and paste the DNA of organisms. In 1978, scientists prepared human insulin by inserting the insulin gene in bacteria. Human growth hormone was also synthesized in bacteria. In 1990, the **Human Genome Project** was launched to map all the genes in human cell. The complete map of human genome was published in 2002.

Human began using microorganisms as early as 4000 BC for making wine, vinegar, cheese, yogurt etc. Some of these processes have become a part of every home that we may even hesitate to refer them as biotechnology.

17.1.1 Scope And Importance Of Biotechnology

In recent years, biotechnology is growing as a separate science. It has attracted the attention of many intellectuals from diverse fields like agriculture, medicine, microbiology and organic chemistry. The scope for biotechnology is so wide that it is difficult to recognize the limits. The following are some areas of the application of biotechnology.

Biotechnology in the Field of Medicine

In the field of medicine, biotechnologists synthesized insulin and interferon (antiviral proteins) from bacteria and released for sale. A large number of vaccines and antibodies; human growth hormone and other medicines have also been produced. Various enzymes are being synthesized for medicinal as well as industrial use. Gene therapy (treatment through genes) has become important in recent years. Biotechnology also proved much beneficial in forensic medicine. The study of DNA helps in the identification of criminals.

Biotechnology in the Field of Food and Agriculture

Fermented foods (e.g. pickles, yogurt), malted foods (e.g. powdered milk: a mixture of barley, wheat flour and whole milk), various vitamins and dairy products are produced by using microorganisms. Wine and beer are produced in beverage industry. Biotechnology has also revolutionized research activities in the area of agriculture. Transgenic (organisms with modified genetic set-up) plants are being developed, in which desirable characteristics are present e.g. more yields and resistance against diseases, insects and herbicides. Transgenic goats, chickens, cows give more food and milk etc. Many animals like mice, goats, cows etc. have been made transgenic to get medicines through their milk, blood or urine.

Biotechnology and Environment

Biotechnology is also being used for dealing with environmental issues, like pollution control, development of renewable sources for energy, restoration of degraded lands and biodiversity conservation. Bacterial enzymes are used to treat sewage water to purify. Microbes are being developed to be used as biopesticides, biofertilizers, biosensors etc. Such transgenic microorganisms are also used for the recovery of metals, cleaning of spilled oils and for many other purposes.

Fears are also being expressed about the advances in biotechnology in terms of release of harmful organisms developed through recombinant DNA technology.

17.2 Fermentation

We know that in cellular respiration, glucose molecule goes through oxidation-reduction reactions to release energy in the form of ATP. Fermentation is the process in which there is incomplete oxidation-reduction of glucose. Fermentation has been in the knowledge of man since centuries, but it was believed that it is purely a chemical process.

In 1857, Pasteur convinced the scientific community that all fermentations are the results of microbial activity. He showed that fermentation is always accompanied by the development of microorganisms. There are many kinds of fermentation and each kind is a characteristic of particular microbial group.

Fermentations are classified in terms of the products formed. The initial steps of **carbohydrate fermentation** are identical to those of respiration. The process begins with glycolysis, in which the glucose, molecule is broken into two molecules of pyruvic acid. Different microorganisms proceed the further reactions in different ways. It results in the formation of various products from pyruvic acid.

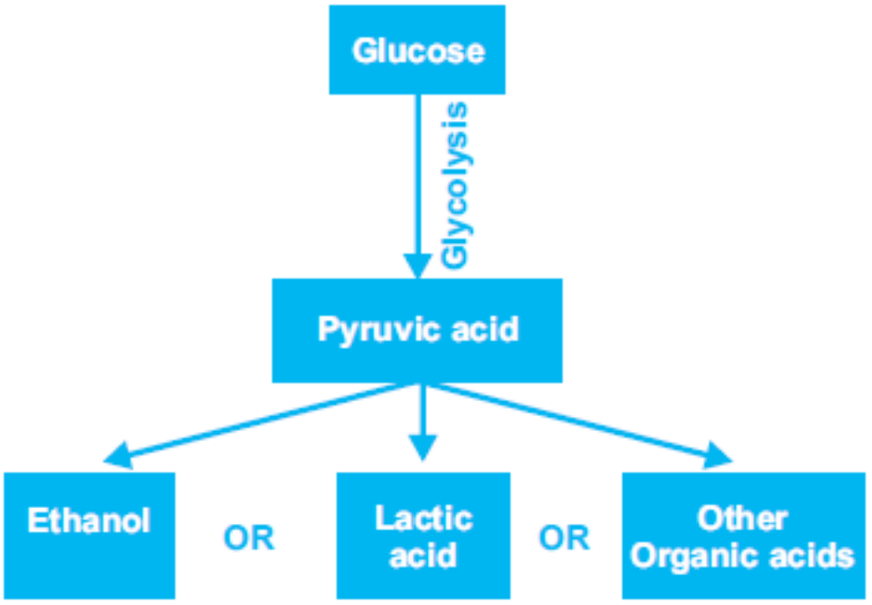
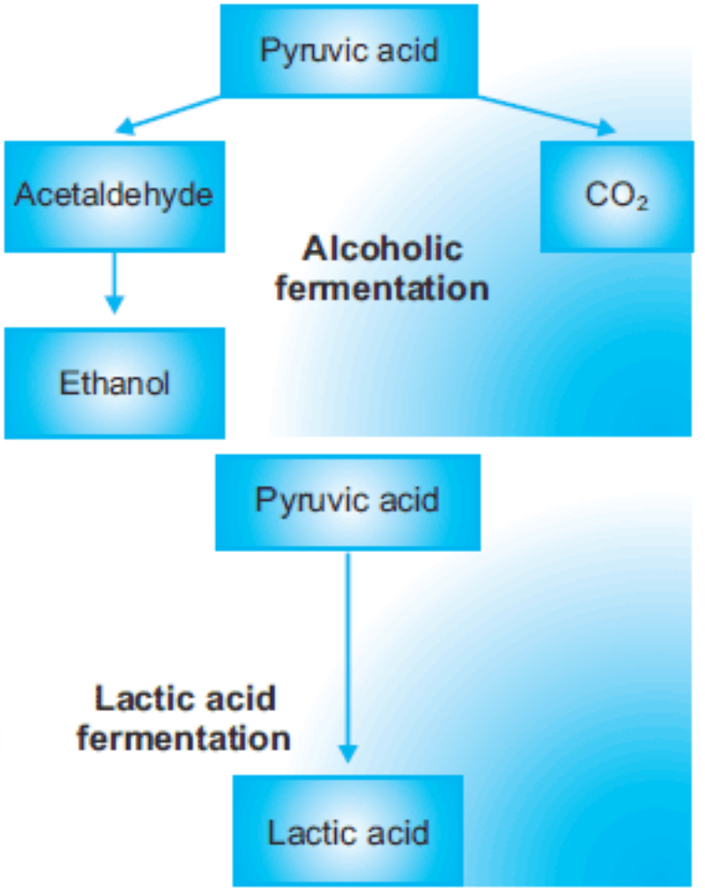


Figure 17.1: Carbohydrate fermentation and its products

The two basic types of carbohydrate fermentation are described next.

1. Alcoholic Fermentation (by yeast)

This fermentation is carried out by many types of yeast such as Saccharomyces cerevisiae. This process is quite important and is used to produce bread, beer, wine and distilled spirits. In this process, carbon dioxide is removed from pyruvic acid. The product i.e. acetaldehyde is then reduced to ethanol. The carbon dioxide produced during this fermentation causes the rise of the bread.



2. Lactic Acid Fermentation (by bacteria)

In this process, pyruvic acid is reduced to lactic acid. It is carried out by many bacteria e.g. *Streptococcus* and many Lactobacillus species. It is quite important in dairy industry where it is used for souring milk and also for production of various types of cheese.

17.2.1 Fermentation In Biotechnology

In beginning, the meaning of fermentation process was the use of microorganisms for the production of foods (cheese, yogurt, fermented pickles and sausages, soy sauce), beverages (beers, wines) and spirits. However, in biotechnology the term "fermentation" means the production of any product by the mass culture of microorganisms.

Applications of Fermentation

In fermentation, maximum growth of an organism is obtained for the production of desired products of commercial value. Traditionally, only food and beverage products were produced by using fermentation. Now many other products e.g. industrial chemicals are also being produced.

a- Fermented Foods

Fermentation often makes the food more nutritious, more digestible and tastier. It also tends to preserve the food, lowering the need for refrigeration. The following groups are included in the fermented foods.

Cereal products: Bread is the commonest type of fermented cereal product. Wheat dough is fermented by *S. cerevisiae* along with some lactic acid bacteria.

Dairy products: Cheese and yogurt are important fermentation products. Cheese is formed when a milk protein is coagulated. This happens when the acid produced by lactic acid bacteria reacts with milk protein. Yogurt is made from milk by different lactic acid bacteria.

Fruit and vegetable products: Fermentation is usually used, along with salt and acid, to preserve pickle, fruits and vegetables.

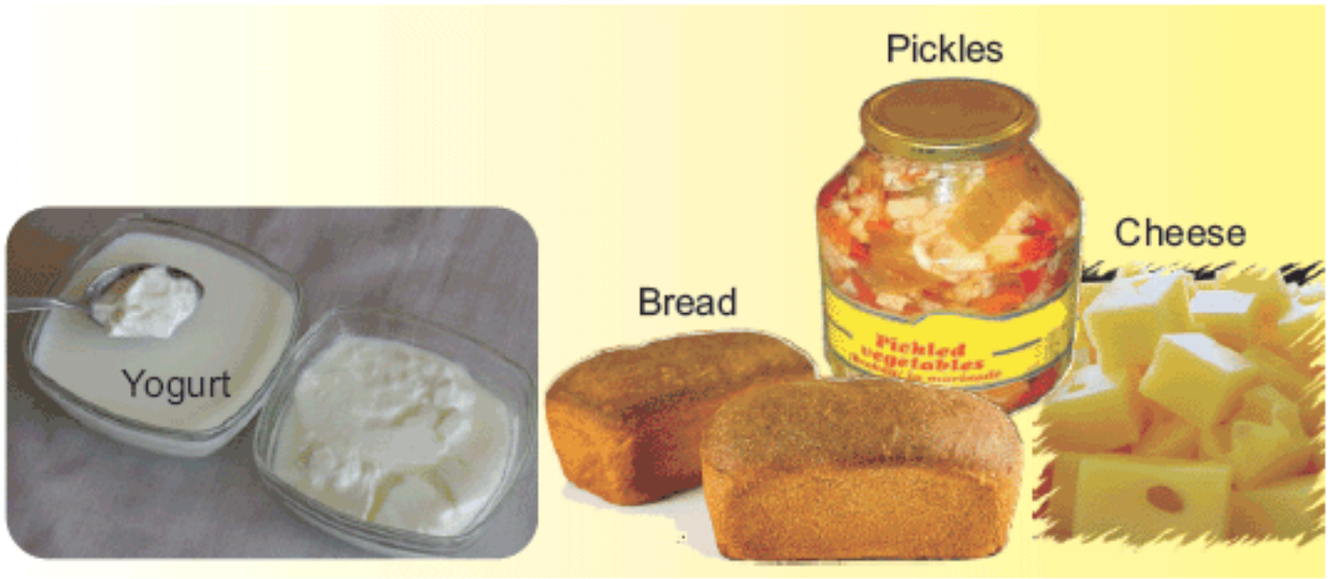


Figure 17.2: Fermented foods

Beverage Products:

Beer is produced from cereal grains which have been malted, dried and ground into fine powder. Fermentation of the powder is done by yeast. This process breaks the glucose present in powder into pyruvic acid and then into ethanol. Grapes can be directly fermented by yeasts to wine.

b- Industrial Products

The following are the important industrial products produced through the process of fermentation.

Products	Microorganisms used	Some uses
Formic acid	Aspergillus	Used in textile dyeing, leather treatment, electroplating, rubber manufacture
Ethanol	Saccharomyces	Used as solvent; used in the production of vinegar and beverages
Glycerol	Saccharomyces	Used as solvent; used in the production of plastics, cosmetics and soaps; used in printing; used as sweetener
Acrylic acid	Bacillus	Used in the production of plastics

17.2.2 Fermenter

Fermenter is a device that provides optimum environment to microorganisms to grow into a biomass, so that they can interact with a substrate, forming the product. Fermentation is carried out in fermenters, in the following two ways.

Batch Fermentation

In this process, the tank of fermenter is filled with the raw materials to be fermented. The temperature and pH for microbial fermentation is properly adjusted, and nutritive supplements are added.

In fact, the fermenter constitutes the heart of any industrial fermentation process.

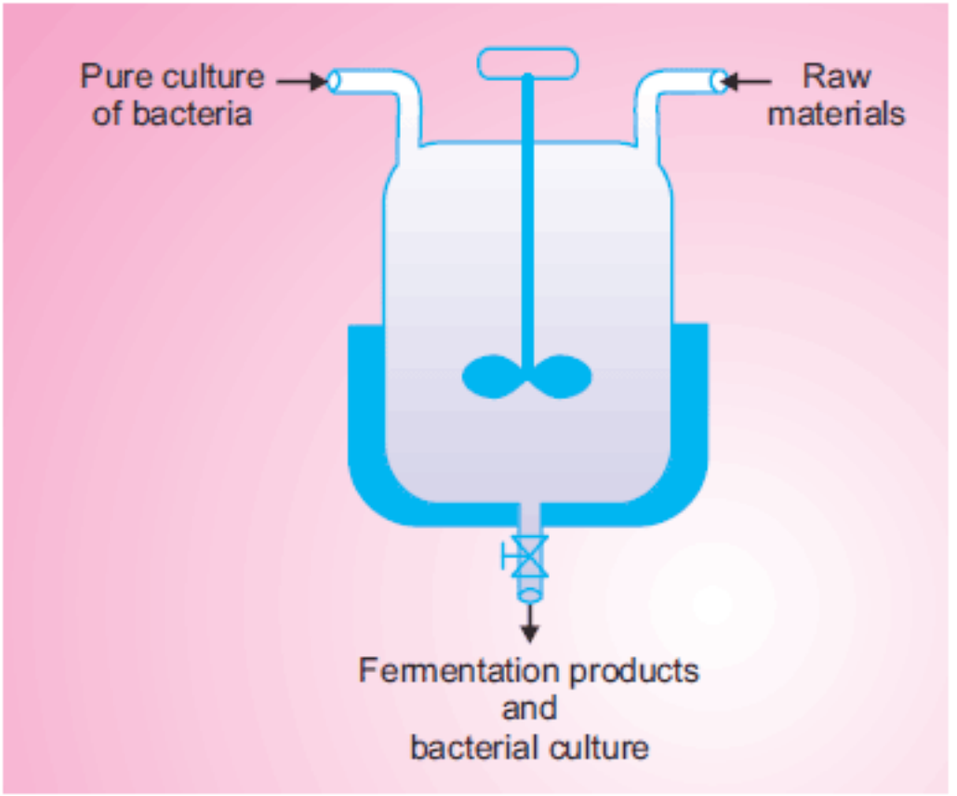


Figure 17.3: A batch fermenter

All the material is steam sterilized. The pure culture of microorganisms is added to fermenter from a separate vessel (Fig. 17.3). Fermentation proceeds and after the proper time the contents of fermenter are taken out. Fermenter is cleaned and the process is repeated. Thus, fermentation is a discontinuous process divided into batches.

Continuous Fermentation

In this process, the substrate is added to fermenter continuously at a fixed rate. This maintains the microorganisms in growth phase. Fermentation products are taken out continuously (Fig. 17.4).

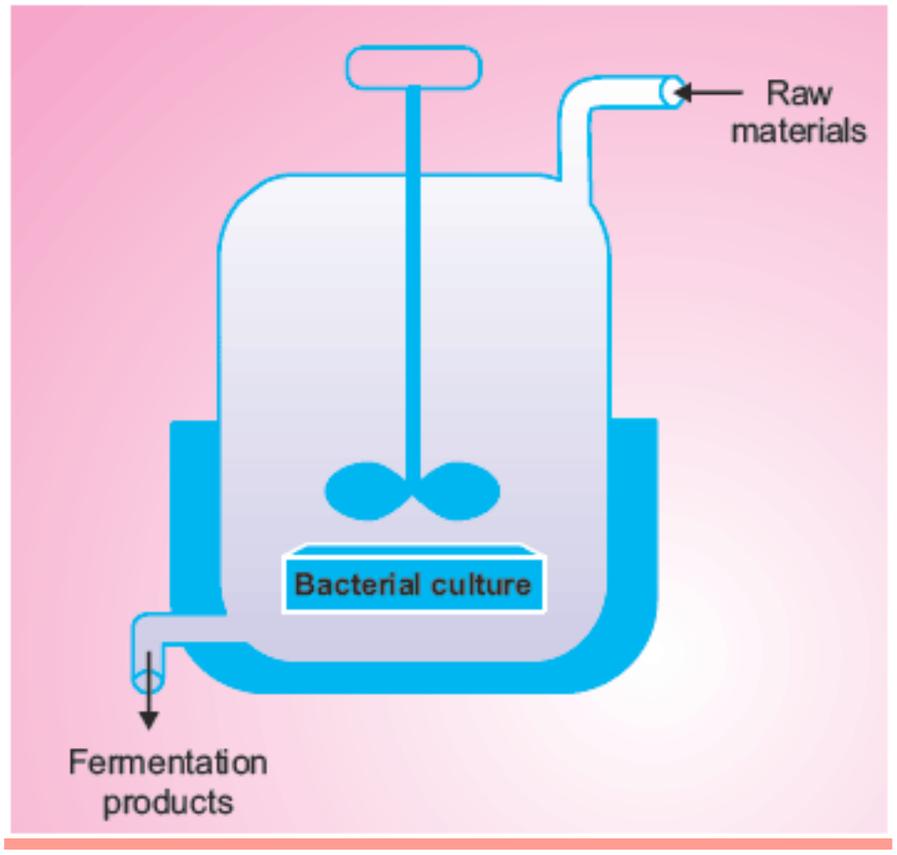


Fig 17.4 A continuous fermenter

Advantages of using Fermenters

For each biotechnological process, the environment provided to the organisms must be monitored and controlled. Such a controlled environment is provided by fermenters. A fermenter optimizes the growth of the organisms by controlling many factors like nutrients, oxygen, growth inhibitors, pH and temperature. A fermenter may hold several thousand litres of the growth medium. So, fermenters allow the production of materials in bulk quantities. Massive amounts of medicines, insulin, human growth hormone and other proteins are being produced in fermenters and this production proves much inexpensive.

Figure 17.5: Fermenters used in food and pharmaceutical industry

Practicals:

- Investigate the role of yeast in the fermentation of flour.
- Investigate the role of bacteria in the fermentation of milk.

17.3 Genetic Engineering

Genetic engineering or recombinant DNA technology involves the artificial synthesis, modification, removal, addition and repair of the genetic material (DNA). Genetic engineering developed in the mid-1970s when it became possible to cut DNA and to transfer particular pieces of DNA from one type of organism into another. As a result, the characteristics of the host organism could be changed. If host organism is a microorganism, such as a bacterium, the transferred DNA is multiplied many times as the microorganism multiplies. Consequently, it is possible to obtain millions of copies of a specific DNA inside a bacterial cell.

17.3.1 Objectives of Genetic Engineering

The important objectives of genetic engineering are as follows.

- Isolation of a particular gene or part of a gene for various purposes such as gene therapy
- Production of particular RNA and protein molecules
- Improvement in the production of enzymes, drugs and commercially important organic chemicals
- Production of varieties of plants having particular desirable characteristics
- Treatment of genetic defects in higher organisms

17.3.2 Basic Steps in Genetic Engineering

All the above mentioned objectives can be obtained by some basic methodologies, such as:

1. Isolation of the gene of interest

In the first step, the genetic engineer identifies the gene of interest in a donor organism. Special enzymes, called restriction endonucleases, are used to cut the identified gene from the total DNA of donor organism.

2. Insertion of the gene into a vector

A vector is selected for the transfer of the isolated gene of interest to the host cell. The vector may be a plasmid (the extra-chromosomal DNA present in many bacteria) or a bacteriophage. The gene of interest is attached with the vector DNA by using endonuclease (breaking enzymes) and ligase (joining enzymes). The vector DNA and the attached gene of interest are collectively called **recombinant DNA.**

3. Transfer of recombinant DNA into host organism

Recombinant DNA is transferred to the target host. In this way, host organism is transformed into a genetically modified organism (GMO).

4. Growth of the GMO

The GMO are provided suitable culture medium for growth to give as much copies of the gene of interest as needed.

5. Expression of the gene

The GMO contains the gene of interest and manufactures the desired product, which is isolated from culture medium.

17.3.3 Achievements of Genetic Engineering

Various achievements of genetic engineering are as follows.

- Human **insulin** gene was transferred into bacteria. The genetically modified bacteria became able to synthesize insulin. Diabetics are now receiving this insulin. The steps of genetic engineering for the production of insulin are shown in figure 17.7.
- In 1977 an E. coli bacterium was created that was capable of synthesizing the **human growth hormone.**
- The hormone **thymosin** which may prove effective against brain and lung cancer has been produced by genetically modified microorganisms.
- **Beta-endorphin**, a pain killer produced by the brain, has also been produced by genetic engineering techniques.
- Genetic engineers produced a safe **vaccine** against the foot and mouth disease (a viral disease in cattle, goats and deer). Similarly many vaccines have been produced against human diseases such as hepatitis B.

Before genetic engineering, 500,000 sheep brains were required to produce 5 mg human growth hormone.

Figure 17.6: Some medicines produced by genetic engineers

- **Interferons** are anti-viral proteins produced by cells infected with viruses. In 1980, interferon was produced in the genetically modified microorganisms, for the first time.
- The enzyme **urokinase,** which is used to dissolve blood clots, has been produced by genetically modified microorganisms.
- Now it has become possible to modify the genes in the human egg cell. This can lead to the elimination of inherited diseases like **haemophilia.**
- Genetic engineering techniques can also be used to cure **blood diseases** like thalassemia and sickle-cell anaemia, which result from defects in single genes.
- Normal genes could be transferred into the bone marrow.
- Genetic engineers have developed plants that can **fix nitrogen** directly from the atmosphere. Such plants need less fertilizers.

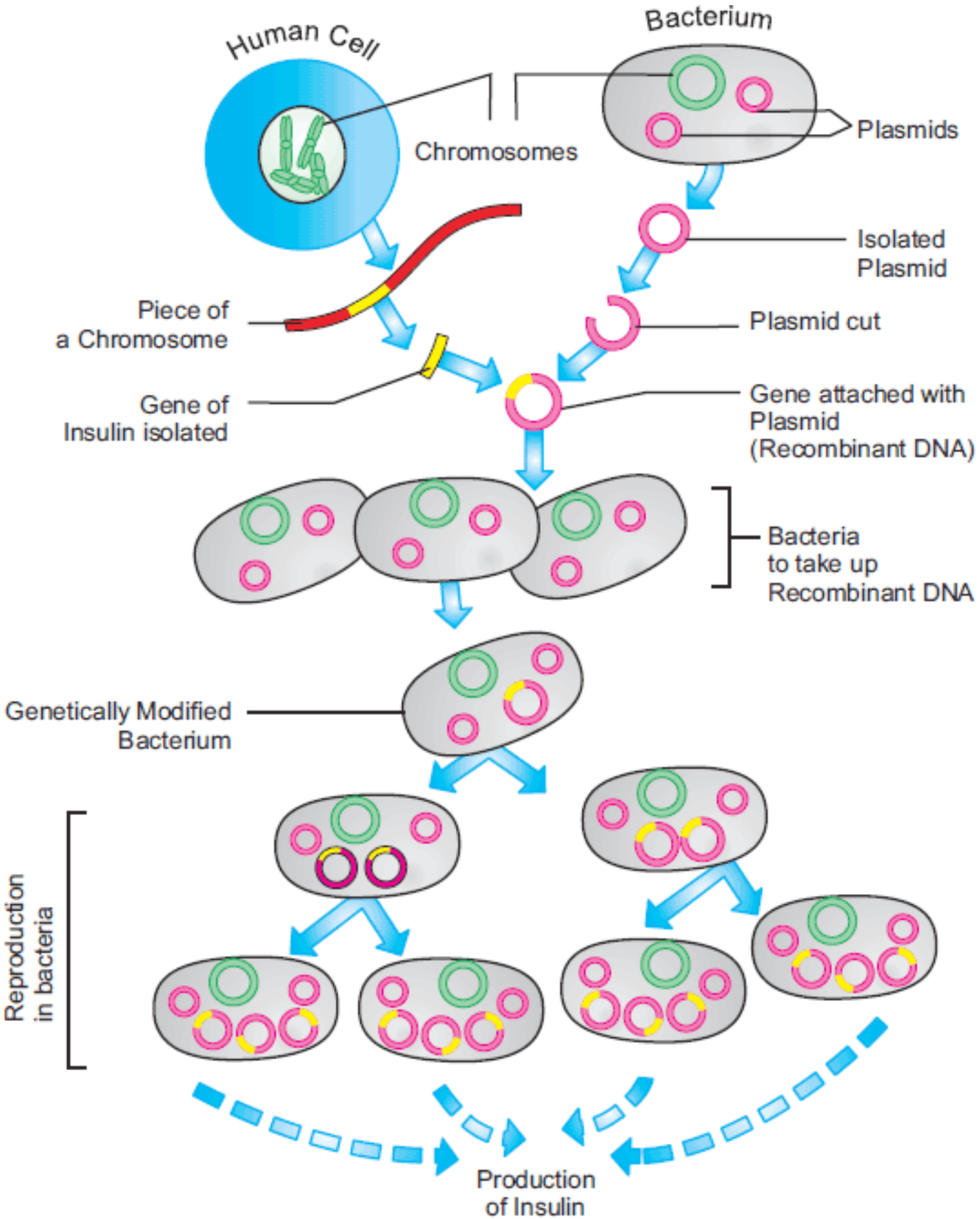


Figure 17.7: Production of insulin through genetic engineering
See animation at:
http://www.youtube.com/watch?v=x2jUMG2E-ic

17.4 Single-Cell Protein

In genetic engineering, we have studied about the transformation of microorganisms by the introduction of genes of beneficial proteins e.g. insulin. Single-Cell Protein (SCP) refers to the protein content extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria. For the production of single-cell proteins, the microorganisms are grown in fermenters. These microorganisms utilize a variety of substrate like agricultural wastes, industrial wastes, natural gas like methane etc. Microorganisms grow very vigorously and produce a high yield of protein. The protein content produced by microorganisms is also known as novel protein or minifood.

We know that due to over-population, the world is facing the problem of food shortage. In future, the conventional agricultural methods might not be able to provide a sufficient supply of food (especially proteins). For a better management of food shortage problems (in humans and domestic animals), the use of microbes as the producers of single-cell proteins has been successful on experimental basis. This technique was introduced by Prof. Scrimshow of Massachusetts Institute of Technology. Scientist and food technologists believe that single-cell proteins will substitute the other protein-rich foods in human and animal feeds.

All scientists recognize the significance of the production of single-cell proteins. The microorganisms grow very vigorously and produce a high yield. It has been calculated that 50 kilogram of yeast produces about 250 tons of protein within 24 hours. Algae grown in ponds produce 20 tons (dry weight) of protein per acre/year. This yield of protein is 10-15 times higher than soybeans and 20-50 times higher than corn. When single-cell proteins are produced by using yeasts, the products also contain high vitamin content. In the production of single cell proteins, industrial wastes are used as raw materials for microorganisms. It helps in controlling pollution. The use of single-cell proteins has good prospects in future because they contain all essential amino acids. Moreover, the production of single-cell proteins is independent of seasonal variations.

It is known as single cell protein because the microorganisms used as producers are unicellular or filamentous individuals.

SCP is gaining popularity day by day because it requires limited land area for production.

UNDERSTANDING THE CONCEPT

1. Define biotechnology and describe its importance.
2. What is a fermenter? What are the two types of fermentation carried out in fermenters?
3. Describe the achievements of genetic engineering in medicine, agriculture and environment.
4. What basic steps a genetic engineer adopts during the manipulation of genes?
5. What are single cell proteins? Describe their importance.

SHORT QUESTIONS

1. How would you define fermentation with reference to biotechnology?
2. Name any two industrial products made by fermentation. Also describe their uses in the industry.
3. What are the products of the two types of carbohydrate fermentation?
4. Give an example how biotechnology is helping for better environment.
5. In biotechnology, what is meant by Genetically Modified Organism (GMO)? How is it made?

THE TERMS TO KNOW

Batch fermentation	Genetically modified organism	Transgenic
Biotechnology	Recombinant DNA	Vector
Continuous fermentation	Restriction endonucleases	
Fermentation	Single-cell protein	
Fermenter		

ACTIVITIES

1. Investigate the role of yeast in the fermentation of flour.
2. Investigate the role of bacteria in the fermentation of milk.

SCIENCE, TECHNOLOGY AND SOCIETY

1. Apply knowledge to identify different products of animal and human food having single cell proteins.
2. Develop awareness among the students of other classes about important social and ethical issues of genetic engineering.
3. Describe the ways in which our society can benefit from the knowledge of genetic engineering.
4. Interpret the data collected from internet on virus resistant, insect resistant and high yielding varieties of agricultural crops in Pakistan.

ON-LINE LEARNING

1. www.sciencedaily.com/news/plants_animals/biotechnology/
2. http://www.youtube.com/watch?v=x2jUMG2E-ic
3. www.pakissan.com/biotech/institutes.biotech.engineering.shtm

CHAPTER

18 Pharmacology

Animation 18.1: 3D-Animation
Source & Credit: rikkyo.ac

Pharmacology is the study of drug composition, properties and medical applications. The sources of drugs are also studied in pharmacology.

Clinical pharmacology was present in the Middle Ages. Early pharmacologists focused on natural substances, mainly plant extracts. Pharmacology developed in the 19th century as a biomedical science.

Any substance that, when absorbed into the body of a living organism, alters normal body function is known as a **drug**. Drugs are broadly classified into two types.

Pharmacology is not synonymous with pharmacy, which is the name used for a profession, though in common usage the two terms are confused.

A **pharmaceutical drug** or medicinal drug is defined as any chemical substance used in the diagnosis, cure, treatment, or prevention of disease.

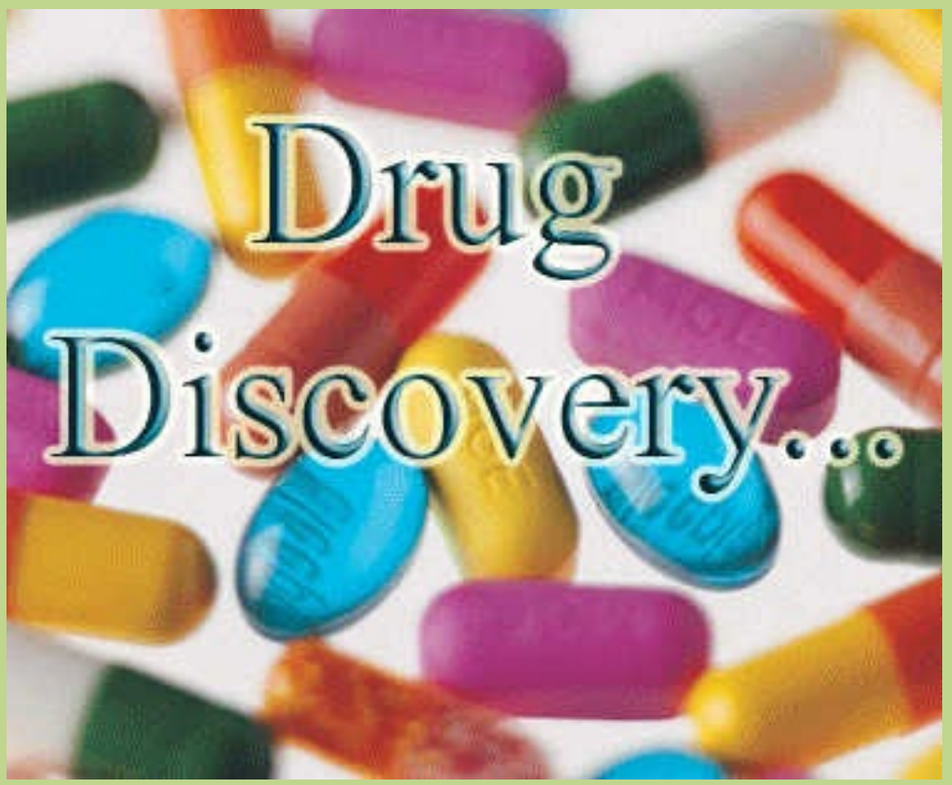
Some drugs often make person dependent on them, or addicted. These may be called as **addictive drugs**. By using such drug, the person's body becomes familiar to it and the user cannot function well without it.

In this chapter, we will learn about the functions of pharmaceutical drugs and the dangers of the addictive drugs.

A page from the book of Materia Medica

Until 1890, the subject of pharmacology was known as Materia Medica.

Prescription drugs are sold only on physician's prescription. These include barbiturates, tranquillizers, antibiotics etc. Non-prescription drugs are sold over the counter because these are considered safe enough. These include aspirin and some cough medicines.



Animation 18.2: Insilicon
Source & Credit: Pharmainfo

18.1 Medicinal Drugs

Various diseases have been made easier to treat in recent years by the production of medicinal drugs. Drugs are obtained from the following sources.

1. Synthetic Drugs

Such drugs do not occur naturally but are synthesized in laboratory. Pharmaceutical companies produce these drugs e.g. aspirin.

2. Drugs from Plants and Fungi

Many important medicines are obtained from plants and fungi. These medicines include antibiotics, cardiotonics and certain analgesics. The antibiotic penicillin comes from a fungus. The cardiotonic, known as digitalis, is used to stimulate the heart. It is made from the leaves of purple flowered plant, foxglove.

Figure 18.1: Digitalis (foxglove)

Animation 18.3: plantsani
Source & Credit: thyroidmiracles

Many addictive illegal drugs e.g. marijuana are also obtained from plants.

Researchers of a pharmaceutical company spent two years testing soil from all parts of the world to find new antibiotics. The project resulted in the development of one antibiotic, Terramycin, which is used to treat many infections.

The pain reliever morphine is made from opium, which comes from the juice of opium poppy plant.

3. Drugs from Animals

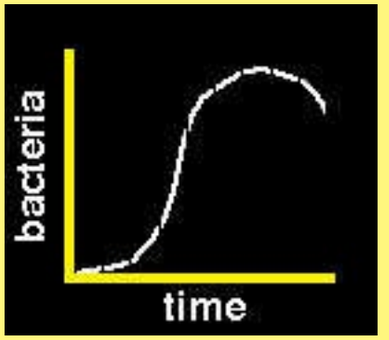
Drugs obtained from animals are usually their glandular products. Fish liver oils, musk, bees' wax, certain hormones and antitoxins are obtained from animal sources.

4. Drugs from Minerals

Several common drugs are produced from minerals. The mineral iodine is used in making tincture of iodine, a liquid that helps prevent infection when applied to cuts and bruises. The powder form of silver nitrate is applied on wounds to stop bleeding and prevent infection.

5. Drugs from Bacteria

Many antibiotics e.g. streptomycin are obtained from bacteria.



Animation 18.4: Drugs from Bacteria
Source & Credit : leavingbio

18.1.1 Principle Usage Of Important Medicinal Drugs

Drugs are classified on the basis of their chemical properties and modes of action.

- **Analgesics** (painkillers) reduce pain e.g. aspirin, paracetamol etc.
- **Antibiotics** inhibit or kill bacteria and treat bacterial infections e.g. tetracycline, cephalosporin etc.
- **Sedatives** induce sedation by reducing irritability or excitement e.g. diazepam.
- **Vaccines** are used to develop immunity against viral and bacterial infections e.g. vaccines against small pox, whooping cough, hepatitis B etc.

Antiseptics reduce the possibility of infections on skin
Antibiotics inhibit or kill bacteria within or on the body
Disinfectants destroy microorganisms found on non-living objects.

Joseph Lister (1827 – 1912) was an English surgeon. He promoted the idea of sterile surgery for the first time. He introduced carbolic acid to sterilise surgical instruments and to clean wounds.

Sir Alexander Flemming (1881 – 1955) was a Scottish biologist. He discovered the antibiotic penicillin from the fungus Penicillium notatum, for which he was awarded the Nobel Prize in 1945.

Things to remember !

Medicines can help you feel better. But if medicines are taken incorrectly, they can actually make you feel worse. It is important to:

- Always check the instructions on doctor's prescription slip and make sure you take the doses of medicine strictly as your doctor prescribed.
- Always check the expiry date printed on the medicine pack. The expired medicines may prove poisonous.
- Never take medicines prescribed for someone else, even if you think you have the same medical problem.
- Some medicines – such as antibiotics - must be taken for a specific number of days. Make sure you take the medicine for the stated time. Otherwise the problem may come back again.
- Always check with your doctor before you stop taking a medicine or consider a new treatment.
- Some medicines are not suitable for children, and there are special children's dosages for many medicines.
- Do not take medicine in the dark.
- If your prescription medicines are crucial for your health and life, carry medicines and dosage instructions with you, whenever you are out of home.
- Always keep healthcare products out of the reach of children.
- Do not use the medicine if there are signs of tampering. Inform the pharmacist and the manufacturer of the medicine, about it.

18.2 Addictive Drugs

The following are major categories of addictive drugs:

1. Sedatives

These drugs interact with central nervous system to depress its activities. Sedative drugs induce dizziness, lethargy, slow brain function and depression. Long-term use of sedative induce suicidal thoughts.

2. Narcotics

Narcotics are strong painkillers. These drugs are often prescribed in conjunction with other less potent painkillers (paracetamol or aspirin). These are used to relieve pain for patients with chronic diseases such as cancer. These are also used to relieve acute pain after operations. But some people may abuse narcotics for ecstatic effects.

Morphine and **codeine** are the narcotics, derived from opium (poppy). Morphine acts directly on central nervous system to relieve pain. Morphine has a high potential for addiction. The most commonly abused narcotic i.e. heroin is a semi-synthetic drug from morphine. It affects on central nervous system and causes drowsiness.

Figure 18.2: The fruits of the opium poppy plant

Animation 18.5: Drug addiction
Source & Credit: teensandhealth

In many western countries, heroin is prescribed as a strong analgesic under the name diamorphine. Its use includes treatment for acute pain, such as in severe physical trauma, myocardial infarction, post-surgical pain etc.

3. Hallucinogens

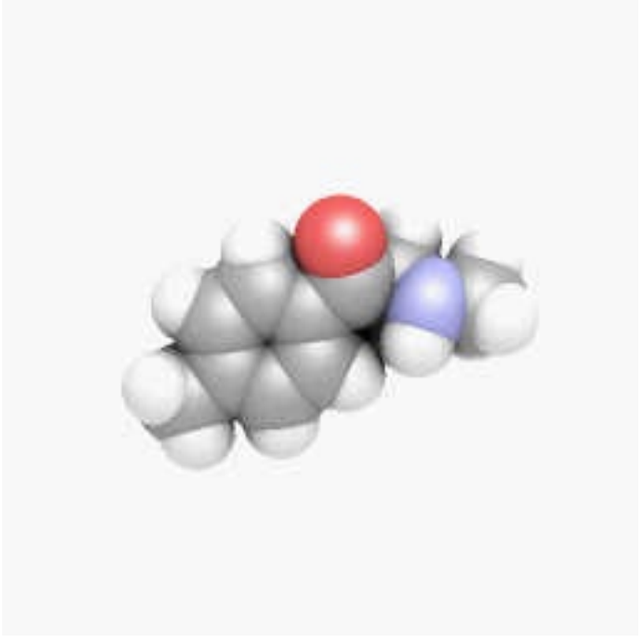
Hallucinogens are the drugs that cause changes in perception, thought, emotion and consciousness. The group includes **mescaline**, which comes from a cactus and **psilocin**, which comes from a mushroom. Physiologically, hallucinogens affect on the sympathetic nervous system, causing dilation of pupils, constriction of some arteries and rise in blood pressure.

Hallucinations are perceptions that have no basis in reality, but that appear entirely realistic.

4. Marijuana (Hashish)

Marijuana is a hallucinogen, which is smoked. It is obtained from the flowers, stems, and leaves of the marijuana plant (Cannabis sativa and C. indica). Small doses of marijuana result in a feeling of well-being that lasts two to three hours. High doses increase heart rate. It also affects the production of sperms in men and also weakens the short-term memory.

Marijuana is one of the most commonly used drugs in the world, following only caffeine, nicotine, and alcoholic beverages in popularity.



Animation 18.6: 3D Structure of Marijuana
Source & Credit: disinfo

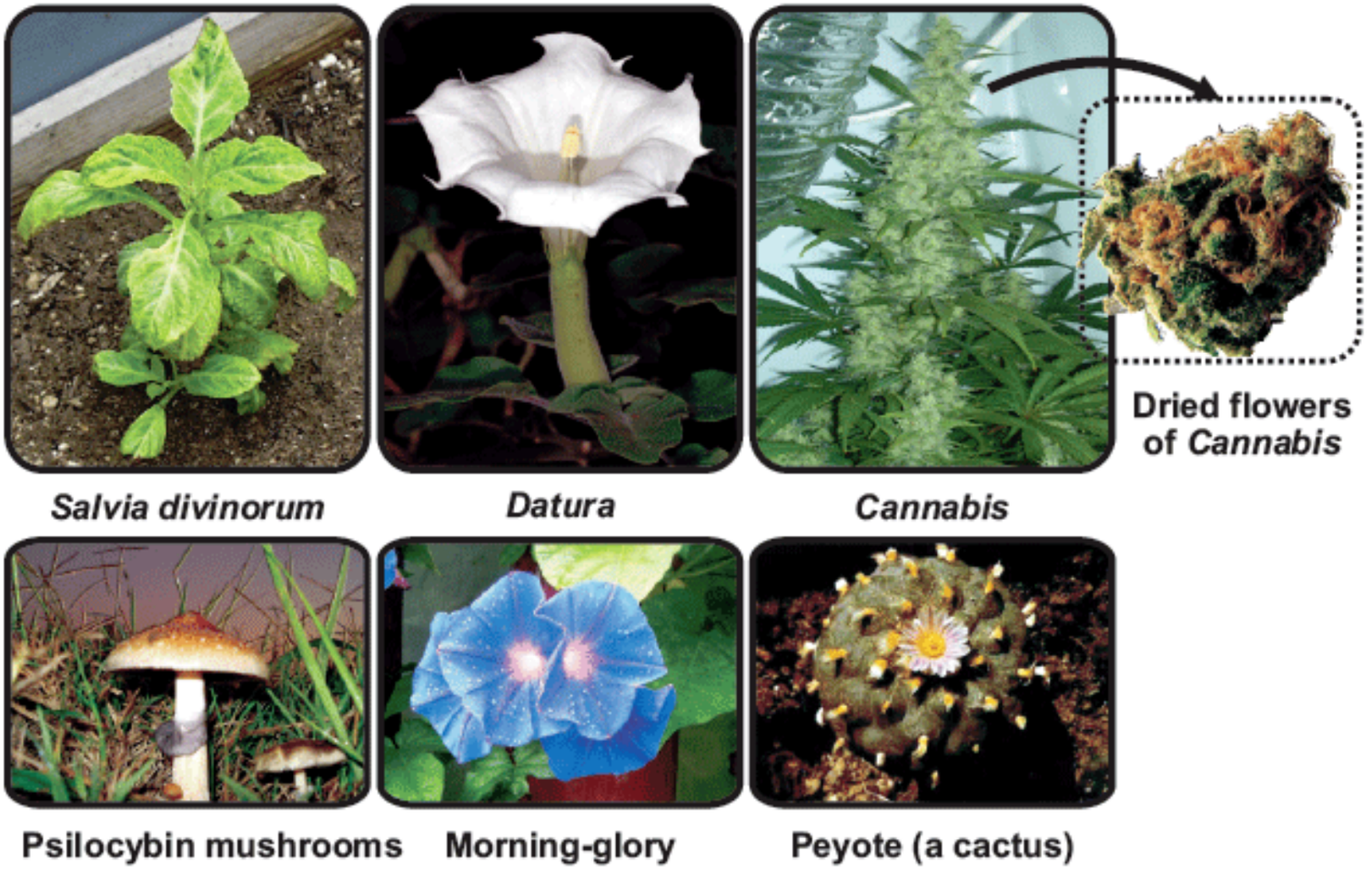


Figure 18.3: Plants from where hallucinogens are obtained

18.2.1 Drug Addiction And Associated Problems

The jails and prisons of our country are full of such people who have committed no other crime than the illegal possession of narcotics.

Drug abusers go through withdrawal of social contact or communication. Many studies by the experts of social sciences prove that there exists a close relationship between drug addiction and crime. The compulsion for narcotic drug makes every drug addict a law violator and a criminal. Mere possession of a narcotic drug is a violation of the law. Thus, every drug addict is subject to arrest by the police.

Most narcotic addicts get involved in various types of crime e.g. robbery, shoplifting, burglary, embezzlement etc.

Drug addicts may commit violent crimes since so many become psychic patients. The addicts are very weak in their social behaviour. They face social stigma i.e. the society dislikes them because of their unpredictable behaviours.

18.3 Antibiotics And Vaccines

Two important medicinal drugs are antibiotics and vaccines.

18.3.1 Antibiotics

An antibiotic is a drug that kills or retards the growth (reproduction) of bacteria. They are the chemicals produced by or derived from microorganisms (bacteria and fungi).

Bactericidal and Bacteriostatic antibiotics

Antibiotics are used to treat many different bacterial infections. Some antibiotics are 'bactericidal', meaning that they kill bacteria. Others are 'bacteriostatic', meaning that they work by stopping bacterial growth.

Three major groups of antibiotics are described below.

Antibiotics are among the most frequently prescribed medications in modren medicine.

Animation 18.8: Narcotics
Source & Credit: whyquit

1. Cephalosporins

Cephalosporins interfere with synthesis of bacterial cell wall and so are bactericidal. Cephalosporins are used to treat pneumonia, sore throat, tonsillitis, bronchitis etc.

Some antibiotics can be used to treat a wide range of infections and are known as 'broad-spectrum' antibiotics. Others are only effective against a few types of bacteria and are called 'narrowspectrum' antibiotics.

2. Tetracyclines

These are broad-spectrum bacteriostatic antibiotics and inhibit bacterial protein synthesis. Tetracyclines are used in the treatment of infections of respiratory tract, urinary tract, intestine etc. Tetracyclines are not used in children under the age of 8, and specifically during periods of tooth development.

3. Sulpha Drugs - Sulfonamides

Sulpha drugs are synthetic antibiotics that contain sulfonamide group. Sulfonamides are broad spectrum bacteriostatic antibiotics. They inhibit the folic acid synthesis in bacteria. They are used to treat pneumonia and urinary tract infections.

Antibiotic Resistance

Antibiotics are extremely important in medicine, but unfortunately bacteria are capable of developing resistance to them. Such bacteria are not affected by commonly used antibiotics.

Bacteria have number of ways of developing resistance. Sometimes, their internal mechanism stops the working of antibiotic. Bacteria can also transfer the genes responsible for antibiotic resistance between them. So such resistant bacteria make it possible for other bacteria to acquire resistance

Expired drugs can cause damage to kidneys.

Image 18.6: Metabolism
Source & Credit: microgene

The sulfonamide group is also present in other medications that are not antibiotics e.g. thiazide diuretics (medicines for lowering blood pressure).

When bacteria are exposed to the same antibiotics over and over, they can change and are no longer affected by the drug.

Another reason for increasing antibiotic resistance in bacteria is their use in diseases in which they have no efficacy (e.g. antibiotics are not effective against infections caused by viruses).
Resistance to antibiotics poses a serious and growing problem, because some infectious diseases are becoming more difficult to treat. Some of the resistant bacteria can be treated with more powerful antibiotics, but there are some infections that do not eliminate even with new antibiotics.

18.3.2 Vaccines

A vaccine is a material containing weakened or killed pathogens and is used to produce immunity to a disease by stimulating the production of antibodies.
In 1796, a British physician, Edward Jenner, infected a young boy with cowpox, by injecting pus cells. After the boy had recovered from cowpox, Jenner injected the pus cells from a smallpox patient into him. The boy did not get smallpox.
So it became clear that intentional infection with cowpox protected people from smallpox. This method was named "vaccination" and the substance used to vaccinate was called a "vaccine".

A painting showing Edward Jenner, injecting the boy. It was the world's first vaccination.

The Mode of Action of Vaccines

Pathogens contain special proteins called **"antigens".** When pathogens enter the body (blood) of host, these proteins stimulate the immune response in host i.e. synthesis of **"antibodies"**. Antibodies bind to pathogens and destroy them. In addition, "memory cells" are produced, which remain in blood and provide protection against future infections with the same pathogen.
When a vaccine i.e. weakened or dead pathogen is introduced into bloodstream, the white blood cells are stimulated. **B-lymphocytes** recognize the weakened or dead pathogens as enemies and start producing antibodies against them. These antibodies remain in blood and provide protection against pathogens. If real pathogens enter blood, the already present antibodies kill them.

The most common method of administering vaccines is by injection, but some vaccines are given by mouth or nasal spray.

Children are required to be vaccinated before attending school. The vaccination of children has resulted in marked decrease of many once-common diseases including whooping cough, polio, smallpox and others.

Some vaccines do not provide lifetime immunity. For example, tetanus vaccines are only effective for a limited period of time. In such cases, booster shots are necessary to maintain continuous protection.

UNDERSTANDING THE CONCEPT

1. What are the sources of drugs? Give examples.
2. Write a note on sedatives, narcotics and hallucinogens.
3. Describe the main groups of antibiotics.
4. Write a note on resistance against antibiotics.
5. Describe the mode of action of vaccines.

SHORT QUESTIONS

1. Define pharmacology and distinguish it from pharmacy.
2. Differentiate between medicinal drug and addictive drug.
3. Differentiate between analgesic and antibiotic.
4. What is marijuana? To which category of addictive drugs, it belongs?
5. Differentiate between narcotics and hallucinogens.

THE TERMS TO KNOW

Addictive drug
Analgesic
Antibiotic
Aspirin
Bactericidal
Bacteriostatic
Cardiotonic
Cephalosporin
Hallucinogen
Heroin
Marijuana
Medicinal drug
Morphine
Narcotics
Pharmacology
Sedatives
Sulfonamide
Gout
Vaccine

•

SCIENCE, TECHNOLOGY AND SOCIETY

1. Compile a list of various painkillers, antibiotics and sedatives being used in our Pakistan.
2. Summarize the antisocial effects of the usage of hallucinogens and narcotics.
3. Justify the effects of possible over-dosage, under-dosage and drug interactions when using antibiotics without doctor's consultation.

CREDITS AND SUPPLEMENTARY READING BOOKS FOR DATA

- William D. Schraer, Herbert J. Stoltze: Biology - The Study of Life (Allyn and Bacon Inc., 1987)
- P. H. Raven, George B. Johnson: Biology: (Mosby-Year Book Inc. 1992)
- Stephen A. Miller, John P. Harley: Zoology Edition: 6 (The McGraw Hill Companies Inc, 2005)
- Lauralee Sherwood: Human Physiology: From Cells to Systems (Cengage Learning, 2008)
- R. I. Mateles, Steven R. Tannenbaum: Single-Cell Protein (Massachusetts Institute of Technology)
- G. R. Hanson, P. J. Venturelli: Drugs and Society (Jones & Bartlett Learning, 2006)
- Elaine N. Marieb, Katja Hoehn: Human Anatomy and Physiology: Edition 8 (Benjamin-Cummings Publishing Company, 2009)

ON-LINE LEARNING:

1. http://www.drugabuse.gov/Infofacts/hallucinogens.html
2. http://en.wikipedia.org/wiki/Psychedelics,_dissociatives_and_deliriants
3. http://www.well.com/user/woa/fshallu.htm

GLOSSARY

Abiotic: The non-living components of the environment like water, sunlight, soil, heat etc.
Acid rain: The rain containing sulphuric acid and nitric acid; with pH range of 3 to 6
Acromegaly: Abnormal growth due to excessive production of growth hormone after growing age; the internal organs and body extremities alone grow large and affected persons have large hands, feet and jawbones.
Acrosome: Cap-like head of sperm cell which helps it in penetrating the egg cell.
Addictive drug: The drug which makes a person dependent on it, or addicted
Adrenal cortex: The outer portion of adrenal gland; secretes corticosteroids
Adrenal medulla: The inner portion of adrenal gland; secrets epinephrine or adrenaline
Adrenaline: Epinephrine; a hormone that prepares body to overcome emergency situations; a neurotransmitter produced by some nerve cells
Allele: The alternative form of a gene
Alternation of generations: In plants, the phenomenon in which the sporophyte and gametophyte generations alternate with each other
Alveolar duct: Fine tubules at the end of bronchioles; open into alveoli
Alveolus: A sac-like structure present next to the alveolar duct in lungs
Ammonification: The decomposition of protein of dead plants and animals, and nitrogenous wastes to ammonia by ammonifying bacteria
Analgesic: The medicines that reduce pain
Androecium: The male reproductive whorl of the flower; consists of stamens
Anther: The sac-like structure of a stamen in which pollen grains are produced
Antibiotics: The medicines which inhibit or kill bacteria
Antidiuretic hormone: The hormone of the posterior pituitary; promotes the reabsorption of water in renal tubules
Appendicular Skeleton: The division of the skeleton that includes arms, hands, legs, feet pectoral girdle and pelvic girdle
Aqueous humour: The fluid present in the anterior chamber of the eye i.e. between the cornea and the iris
Arthritis: Terms used for the inflammation in joints
Artificial selection: Selective breeding; intentional breeding between individuals for certain traits, or combination of traits
Aspirin: Acetaminophen; A pain-killer medicine
Asthma: An inflammation of the bronchi that causes swelling and narrowing of the airways
Atmospheric nitrogen fixation: The conversion of atmospheric gaseous nitrogen to nitrates by thunderstorms and lightning

Auditory canal: The part of the external ear; ends at ear drum
Autonomic Nervous System: Part of the peripheral nervous system; consists of motor neurons that send signals to the cardiac muscles, smooth muscle and glands; generally without conscious control
Axial skeleton: The division of the skeleton that includes the skull, vertebral column, ribs and breastbone
Axon: A long, thin fibre that carries nerve impulse away from the cell body of a neuron
Bactericidal: The antibiotics that work by killing bacteria
Bacteriophages: The viruses that attack bacteria
Bacteriostatic: The antibiotics that work by stopping bacteria multiplying
Ball-and-socket joint: The joint that allows movement in all directions e.g. hip and shoulder joints
Batch fermentation process: The discontinuous fermentation process, divided into batches
Biceps: A flexor muscle on the front of the upper arm bone
Binary fission: Division into two; the simplest method of asexual reproduction in prokaryotes and many unicellular eukaryotes
Biogeochemical Cycle: The cyclic pathway through which chemical elements move from environment to organisms and back to the environment
Biological nitrogen fixation: The conversion of gaseous nitrogen into nitrates by living organisms
Biosphere: The last level of ecological organization; all the ecosystems of the world together form the biosphere
Biotechnology: The use of living organisms in systems or processes for the manufacture of useful products or for services for humankind
Biotic: The living components of the environment; include producers, consumers and decomposers
Bone: Hard connective tissue; moves, supports and protects the various organs of the body
Bowman's capsule: Part of nephron: cup-shaped structure enclosing the glomerulus
Breathing: The process through which animals take air in their bodies to get oxygen and then give out the air for getting rid of carbon dioxide
Breeds: The animals which are bred through artificial selection
Bronchioles: Fine tubules formed by the division of the bronchi
Bronchitis: Inflammation in the bronchi or bronchioles
Bronchus: The part of air passageway; formed by the division of the trachea
Budding: A type of asexual reproduction in which a bud develops as a small outgrowth on parent's body and forms the new individual

Bulbs: Underground vertical shoots which have modified leaves
Calyx: The outer whorl of flowers; consists of sepals
Carbon cycle: The biogeochemical cycle in which carbon flows between organisms and the environment
Cardiotonic: Medicines for giving strength to heart muscles
Carnivores: The consumers which eat only animal flesh
Carpel: Part of the gynoecium of the flower; consists of stigma, style and ovary
Cartilage: The connective tissue that makes part of the human skeleton
Cell body: The part of the nerve cell that contains nucleus
Central nervous system: The part of the nervous system consisting of brain and spinal cord
Cephalosporin: A group of antibiotics; interfere with synthesis of the bacterial cell wall
Cerebellum: The part of the hindbrain; controls muscle movements
Cerebral cortex: The outer layer of the cerebral hemispheres
Cerebral hemispheres: The divisions of the cerebrum of the brain
Cerebrospinal fluid: The fluid in the ventricles of the brain and in the central canal of the spinal cord
Cerebrum: The largest part of the forebrain; controls many sensory and motor functions
Cervix: In female reproductive system, the part which separates uterus from the vagina
Chondrocyte: The cells present in the cartilage
Chromatin: The chemical material that make the structure of the chromosome
Cloning: Method of asexual reproduction in which identical offsprings are produced from a vegetative tissue or cell of the parent
Cochlea: The part of the inner ear; consists of three ducts wrapped in the form of a coiled tube; contains sound receptors
Co-dominance: The situation where two allele of a gene pair express their traits independently instead of showing a dominant-recessive relationship
Collecting duct: The tubes into which the renal tubules of nephrons open
Colour blindness: Genetic disorders in which person fails to recognize the basic colours
Commensalism: A type of symbiosis in which one of the partners gets benefit while the other is neither benefited nor harmed
Compact bone: The hard outer layer of bones
Cones: The photosensitive cells in the retina of the eye; sensitive to bright light and so distinguish different colours
Consumer: The part of the biotic components of the ecosystem that consists of animals
Continuous fermentation process: The fermentation in which substrate is added to the fermenter continuously, at a fixed rate

Corm: Short, swollen underground stem; has bud(s) at the top; gives rise to new plants by vegetative propagation
Cornea: The transparent part of sclera that forms in the front of the eye through which light enters
Corolla: The second whorl of flower, consisting of petals
Cotyledon: A modified leaf present in seeds; often gives nourishment to the developing seedling
Cowper's gland: An accessory gland in rabbits male reproductive system; provides lubrication to the ducts
Cranial bones: The bone of the cranium
Cranial nerves: Nerves that arise from or lead to the brain
Cranium: The part of the skull that encloses the brain
Cultivars: The plants which are bred through artificial selection
Cutting: Artificial vegetative propagation in which cuttings are taken from stem or root of parent and are placed in soil
Decomposer: An organism which decomposes the dead bodies and dead matter
Deforestation: Clearing of forests by natural causes or by humans
Dendrites: Short, branched projections of neuron's cell body; transmits nerve impulse towards cell body
Denitrification: The conversion of nitrites and nitrates into nitrogen gas
Diabetes mellitus: More than normal level of glucose in blood; a condition caused by insufficient concentration of insulin in blood
Dialysis: The cleaning of blood (removing nitrogenous wastes and extra water) by artificial ways
Dialyzer: The apparatus used for haemodialysis
Diaphragm: The muscular structure that forms the floor of the chest cavity; present below lungs
Dihybrid cross: A genetic cross in which two pairs of contrasting traits are studied
Distal convoluted tubule: The last part of the nephron
Dominant trait: The trait that appears in the offspring of a cross between two homozygous individuals showing contrasting forms of the trait
Drug: Any substance that, when absorbed into the body of a living organism, alters normal body function
Dwarfism: Less than normal body growth; a condition caused when growth hormone is insufficient during the growing age
Ear drum: Tympanic membrane; A membrane stretched across the inner end of the auditory canal of the ear
Ecological pyramid: A representation of the number of individuals or amount of biomass or energy present in various trophic levels of a food chain

Effectors: The parts of the coordination system that respond when stimulated by nerve impulses or hormones

Emphysema: A disease in which the walls of the alveoli are destroyed

Endocrine gland: A ductless gland; produces and secretes hormones

Endosperm nucleus: In the female gametophyte, the triploid nucleus formed by the fusion of sperm and the fusion nucleus

Endosperm tissue: The tissues that develops from endosperm nucleus; often serves as a food supply for developing embryo

Endospore: The spore formed inside the bacterial cell

Environment: The sum total of physical (abiotic) and biotic conditions which influence the organism

Epicotyl: The embryonic stem above the point of attachment of the cotyledon(s)

Epididimys: A storage area for sperms on the upper part of the testes

Epigeal germination: A type of seed germination in which the hypocotyl elongates and forms a hook, pulling the cotyledons above the ground

Epilepsy: A nervous disorder characterized by recurrent unprovoked seizures (convulsions)

Epinephrine: See Adrenaline

Estrogen: A hormone secreted by the ovaries; promotes development of female secondary sex characteristics and regulates the reproductive cycle

Eustachian tube: The tube between middle ear and the nasal cavity that equalizes the pressure on both sides of the ear drum

Eutrophication: The enrichment of water with inorganic nutrients; the nutrients promote the growth of algae and it leads to increase in the number of the decomposers and depletion of oxygen

Excretion: The process by which the metabolic wastes are removed from the body

Exhalation: The phase of breathing in which air is expelled from the lungs

Exocrine gland: A gland that discharges its secretion into a duct

Extensor: A muscle that extends a joint

Fallopian tube: a part of the female reproductive system; receives egg cell discharged from the ovary

Feedback mechanisms: The mechanisms to control certain functions; one of the products of a pathway are used, usually the end product, to control the activity of the pathway

Fermentation: The process in which there is incomplete oxidation-reduction of the organic substrate (glucose)

Fermenter: A device that provides optimum environment in which organisms can grow to produce biomass and to form the product.

Fertilization: The fusion of male and female gametes to form a zygote
Fibrous cartilage: The cartilage that has large number of fibres in the matrix e.g. the cartilage in intervertebral disc
Flexor: A muscle that bends a joint
Follicle: A structure in the ovary in which the mature egg develops
Food chain: The series of organisms in an ecosystem, in which an organism eats the preceding one and is eaten by the next one
Food web: A network of interconnected food chains; has a number of feeding connections amongst different organisms of a community
Forebrain: The part of the brain; includes cerebrum, thalamus and hypothalamus
Fragmentation: A type of asexual reproduction in which the animal breaks up into many pieces and each piece develops into a mature animal
Fusion nucleus: A part of the female gametophyte in plants; formed by the fusion of two nuclei; gives rise to endosperm nucleus when fertilized by a sperm
Gametogenesis: The process of the formation of gametes
Gametophyte: The haploid generation in plant life cycle; produces gametes
Ganglion: The aggregation of the cell bodies of neurons
Gaseous exchange: Taking in and giving out of gas (oxygen and carbon dioxide) by organism
Gene*:* Unit of inheritance; consists of the length of DNA that contains specific instructions for the synthesis of a protein molecule
Genetically Modified Organism: The organism in which DNA (gene) from some other organism has been transferred
Genotype: The specific combination of genes in an individual; may be homozygous or heterozygous
Germination: The process by which a seed embryo develops into a seedling
Gigantism: The condition due to excessively production of growth hormone during the growing age; leads to very tall and overweight persons
Global Warming: Increase in the temperature of the Earth; due to the addition of greenhouse gases in atmosphere, which do not allow solar radiations to reflect back into the space
Glomerular filtrate: The material that passes from glomerulus into the Bowman's capsule
Glomerulus: The network of capillaries in the nephron of kidney
Glucagon: The hormone secreted by the islets of Langerhan; increases the blood glucose level
Gout: A type of arthritis; characterised by the accumulation of uric acid crystals in the moveable joints
Grafting: A type of artificial vegetative propagation in which a piece of stem is cut from the plant and is inserted into another plant with established root system

Grey matter: The nervous tissue containing cell bodies and non-myelinated processes of the neurons

Guttation: Appearance of drops of xylem sap on the tips or edges of leaves

Gynoecium: The central whorl in the flower; consists of carpels

Hallucinogen: Drug that causes changes in perception, thought, emotion and consciousness

Haemodialysis: The dialysis in which patient's blood is pumped through the apparatus called dialyzer for cleaning

Heroin: A commonly abused narcotic; derived from morphine; affects the central nervous system and causes drowsiness, disorientation, hypotension etc.

Heterozygous: The genotype that has two different alleles of a trait

Hilum: A scar on the seed coat; the point where the seed is attached to the ovary wall

Hilus: A depression near the centre of the concave area of the kidney; the area through which the ureter, blood and lymphatic vessels and nerves enter/leave the kidney

Hindbrain: The part of the brain consisting of cerebellum, medulla oblongata and pons

Hinge joint: A joint that permits movement of bones in one plane e.g. elbow and knee joints

Histone: The protein present in the structure of chromosome

Homeostasis: The maintenance of a constant internal environment in response to environmental changes

Homologous chromosomes: A pair of chromosomes having the same size and shape and carrying alleles for the same traits

Homozygous: Having two identical alleles of a trait

Hormone: A substance that is secreted by an endocrine gland directly into blood and that produces a specific effect on a particular tissue

Hyaline cartilage: The cartilage that has collagen fibres in its matrix; found covering the ends of the long bones, in the nose, larynx, trachea and bronchial tubes

Hyoid bone: The bone present in neck

Hypermetropia: The condition in which a person is not able to see near objects clearly; happens when the eyeball shortens and image is formed behind the retina

Hyperthyroidism: The over-production
of thyroxin; result in increase in energy production, increased heart-beat, frequent sweating and shivering of hands

Hypocotyl: The embryonic stem below the point of attachment of cotyledon

Hypogeal germination: A type of seed germination in which the epicotyl elongates and forms the hook while the cotyledons stay underground

Hypothalamus: The part of the forebrain below the thalamus; controls body temperature, blood pressure and emotion

Hypothyroidism: The under-production of thyroxin; results in low energy production and slowing down of heart-beat

Incomplete dominance: A type of inheritance in which neither of the pair of contrasting alleles is dominant over the other and the heterozygous individual is intermediate in phenotype
Inhalation: The phase of breathing in which air is drawn into the lungs
Inheritance: The transmission of characteristics from parents to offspring
Insertion: The end of the muscle that is attached with a moveable bone
Insulin: The hormone produced by the Islets of Langerhans; lowers the blood glucose level
Interneurons: The neurons present in the brain and spinal cord
Interspecific interactions: Interactions between the members of the different species
Intraspecific interactions: Interactions between the members of the same species
Iodopsin: A pigment present in the cones of the retina
Islets of Langerhans: Groups of endocrine cells present in pancreas; secrete hormones insulin and glucagon
Iris: A muscular ring formed by the bending of the choroid behind the cornea of the eye
Joint: The location at which two or more bones make contact
Kidney failure: A complete or near complete failure of the kidneys to excrete wastes and to regulate water and salts
Kidney stone: The deposits of large chemicals such as calcium oxalate, calcium and ammonium phosphate, uric acid, cystine etc. present in kidneys, ureter or bladder; cannot pass in the urine
Lacuna: The fluid filled space in bone and cartilage, where their cells are present
Larynx: The part of the air passageway between pharynx and the trachea
Lenticels: Pores in the bark of wooding stems and mature roots
Ligament: Strong but flexible connective tissue that joins one bone to bone at the joints
Lithotripsy: Treatment for removing kidney stones; non-electrical shock waves are bombarded on the stones to break them
Locus: Plural Loci; The locations or positions of genes on chromosomes
Loop of Henle: The U-shaped portion of the renal tubule of nephron
Macrospore: Haploid cell produced in the ovule; divides mitotically and produces the female gametophyte
Marijuana: A hallucinogen and addictive drug; obtained from the flowers, stems, and leaves of the marijuana plant
Medicinal drug: Any chemical substance intended for use in the medical diagnosis, cure, treatment, or prevention of disease
Medulla oblongata: Part of the hindbrain; on the top of the spinal cord; controls breathing, heart rate, blood of the retina

Narcotics: Strong painkiller drugs; also used as addictive drugs; commonly abused narcotics include heroin, morphine, methadone etc

Nasal cavity: Hollow space in the nose; opens to the outside through nostrils; divided into two portions by a wall

Natural resources: The resources on Earth, which provide everything that humans use or consume

Natural selection: The process in which organisms with favourable variations survive and produce more offspring than less well-adapted organisms

Nephron: The functional unit of kidneys

Nerve: The union of several axons that are enveloped by a covering made of lipid

Neuron: Nerve cell; the unit of the nervous system; able to conduct nerve impulses

Nitrification: The oxidation of ammonia to nitrites and nitrates by the nitrifying bacteria

Nitrogen cycle: The flow of nitrogen between environment and the organisms

Nitrogen fixation: Conversion of nitrogen into nitrates

Nodes of Ranvier: The non-myelinated points between the areas of myelin on the axons of neurons

Non-renewable resource: A resource that is formed over very long periods; the rate of formation is extremely slow so cannot be replaced; e.g. minerals and fossil fuels

Nostril: The openings of the nasal cavity

Nucleosome: The structure formed by the wrapping of DNA around histone proteins

Olfactory bulbs: The anterior parts of the cerebral hemispheres; receive impulses from the olfactory nerves and create the sensation of smell

Oogenesis: The formation of ovum (egg cell)

Oogonium: (Plural Oogonia): The diplod cells in the follicles of the ovary; produce diploid primary oocytes during oogenesis

Optic disc: Blind spot; a point on the retina of the eye where the optic nerve enters the retina; no photosensitive cells exist at this point

Organic evolution: Biological evolution: The modification of characteristics in the species or populations of organisms during their descent, generation by generation

Origin: The end of the muscle that is attached with a immoveable bone

Osmoregulation: The regulation of water content in body fluids

Osteoarthritis: Inflammation in joints due to degeneration in the cartilage present at the joints or due to decreased lubricant production at the joints

Osteocyte: The mature bone cells

Osteoporosis: A bone disease in adults, especially in old age; there is a decrease in the density of bones due to loss of calcium and phosphorus

Oval window: The membrane which separates the middle ear from the inner ear
Ovary: The female gonad; produces egg cells and female sex hormones
Overpopulation: Increase in population beyond the carrying capacity of an area or environment
Ozone: The O_3 gas; also present in the upper layer of the atmosphere where it absorbs the ultraviolet rays present in the sun's radiation
Ovule: In seed plants, a structure present in the ovary; contains macrospore that develops into female gametophyte; ovule develops into seed after fertilization
Oxytocin: The hormone secreted by the posterior pituitary; stimulates the contraction of uterus walls in females for child birth; necessary for ejection of milk from the breasts
Papillary ducts: The ducts formed by the joining of many collecting ducts; open into renal pelvis
Paralysis: Complete loss of function by one or more muscle groups due to damage in the nervous system
Parasitism: A type of interspecific interaction in which smaller partner (parasite) derives food and shelter from the body of larger partner (host) and harms the host
Parasympathetic nervous system: Part of the autonomic nervous system; works when there is little or no stress and slows down the overall activity of the body
Parathormone: Hormone of the parathyroid glands; increases the level of calcium ions in the blood
Parathyroid: The endocrine glands located on the posterior sides of the thyroid gland; secrete parathormone
Parthenocarpy: The process in which ovaries develop into fruit without the fertilization in the ovules present in them; results in seedless fruits e.g. bananas
Parthenogenesis: A form of asexual reproduction in which an unfertilized egg develops into new offspring
Peripheral nervous system: A division of the nervous system that consists of nerves and ganglia
Peritoneal dialysis: The dialysis in which the dialysis fluid is pumped into the abdominal peritoneal cavity; the wastes from the blood vessels of the peritoneum diffuse into the dialysis fluid which is then drained out
Pharmaceutical drug: See medicinal drug
Pharmacology: The study of drug composition and properties and medical applications
Phenotype: The expression of the genotype in the form of trait
Phytoplankton: Photosynthetic organisms that float on the surface of water
Pituitary: The endocrine gland attached to the hypothalamus that controls many other endocrine glands in the body

Plumule: The part of the plant embryo that develops into new shoot
Pneumonia: The infection of one or both lungs; caused by specific bacteria, viruses or fungi; the infected part of the lung becomes filled with fluid and pus
Pollen grain: See Microspore
Pollen tube: A tube formed by the tube nucleus of the pollen grain; carries sperms to the ovule
Pollen-sac: The part of the anther where microspore (pollen grains) are produced
Pollination: The transfer of pollen grains from flower's anther to stigma
Pollutant: The substance that causes pollution
Pollution: Undesirable change in the physical, chemical or biological characteristics of air, water and land that may harmfully affect living organisms and other resources
Pons: Part of the hindbrain; present on top of the medulla; assists the medulla in controlling breathing and serves as a connection between the cerebellum and the spinal cord
Predation: An interaction between animals of two species or any plant and an animal, in which the predator attacks, kills and feeds on the smaller animal called prey
Pressure filtration: The first step in urine formation; the process in which most of the water, salts, glucose and urea of the blood is forced out of the glomerulus and passed into Bowman's capsule
Producer: An organism that produces organic compounds from inorganic compounds; an autotroph
Progesterone: A hormone secreted by the ovaries that maintains the uterus during pregnancy
Prostate gland: An accessory gland in the male reproductive system; produces a secretion that neutralizes the acidity
Proximal convoluted tubule: The part of the nephron between Bowman's capsule and the loop of Henle
Pupil: The opening in the centre of the iris of the eye
Pyramid of Biomass: The graphic representation of biomass present per unit area at different trophic levels in an ecosystem
Pyramid of Numbers: The graphic representation of the number of individuals per unit area at various trophic levels in an ecosystem
Radicle: The part of the plant embryo that develops into new root
Receptors: The organs, tissues or cells which detect particular type of stimuli
Recessive trait: The trait which is masked in the offspring of a cross between two homozygous individuals showing contrasting forms of the trait
Recombinant DNA: The vector DNA and the attached gene of interest
Reflex Action: The involuntary and immediate response to a stimulus

Reflex arc: The nerve pathway over which the nerve impulses travel in a reflex action
Renal corpuscle: The collective name for the glomerulus and Bowman's capsule of the nephron
Renal pelvis: The funnel-shaped cavity into which the renal pyramids of kidney project
Renal pyramids: Cone-shaped areas in the renal medulla
Renal tubule: The part of the nephron after the Bowman's capsule; consists of proximal convoluted tubule, loop of Henle and distal convoluted tubule
Renewable resources: The resources which are replenished or reproduced easily e.g. sunlight, air, wind etc.
Reproduction: The process by which organisms produce new organisms of their own kind
Restriction endonucleases: Enzymes used to cut the gene from the total DNA of the organism
Retina: The innermost and the sensitive layer in the eye
Rheumatoid arthritis: Painful inflammation of the membranes at the joints
Rhizomes: Horizontal underground stems; have scale leaves with buds; shoots of the new plant develop and grow form buds (vegetative propagation)
Rhodopsin: A pigment present in the rods of the retina
Rods: The photosensitive cells present in the retina of the eye; sensitive to dim light
Saltatory conduction: Fast nerve impulses; jump over the areas of myelin going from node to node
Schwann cells: The supporting cells around neurons; form the myelin sheath
Sclera: The tough, white outer layer of the eye
Scrotum: A sac of skin outside the body wall in which the testes of the male are located
Sedatives: Types of drugs that interact with the central nervous system to depress its activities; make a person calm or drowsy
Seed coat: Testa: Outer covering of a seed; develops from the integument of the ovule; protects the embryo from mechanical injury and from drying out.
Seed dormancy: A period, during which there is no growth in the seed; seeds in dormancy are ripe seeds but do not germinate; under favourable conditions, the seeds break dormancy and begin to germinate
Selective re-absorption: The second step in urine formation; in it about 99% of the glomerular filtrate is reabsorbed into the blood capillaries surrounding the renal tubule
Semen: The material containing sperms in a fluid
Semicircular canals: The three bony canals present posterior to the vestibule in the inner ear
Seminal vesicle: The associated gland in male reproductive system; produces secretions having nutrients for the sperms

Seminiferous tubule: The coiled tubes present in testes; sperms are formed in these tubules
Sensory nerves: The nerves which contain only the axons of sensory neurons
Single-Cell Protein: The protein content extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria; the micro-organisms are grown in fermenters where they produce a high yield of protein
Skeleton: The framework of hard, articulated structures that provide physical support, attachment for skeletal muscles, and protection for the bodies of animals
Somatic Nervous system: The part of the motor pathway of the peripheral nervous system; gives voluntary control; includes all of the motor neurons that conduct impulses from the CNS to the skeletal muscles
Somatotrophin: Growth hormone: A hormone of the anterior pituitary; promotes the growth of the body
Sperm: The male gamete
Spermatid: The immature non-motile forms of sperms; are converted into sperms after many changes
Spermatogenesis: The formation of sperms
Spermatogonia: The diploid cells in semineferous tubules of the testes; divide mitotically and produce primary spermatocytes
Spinal nerves: The nerves which arise from the spinal cord
Spongy bone: The soft and porous interior of the bone; contains blood vessels and bone marrow
Sporophyte: The diploid generation in plant life cycle; produces spores
Stamen: The part of the androcium; consists of anther and filament
Sternum: The chest bone
Stigma: The upper part of the carpel
Style: The middle portion of the carpel
Sulfonamides: Sulpha drugs: Synthetic antibiotics that contain the sulfonamide group; bacteriostatic in action
Suspensory ligament: The ring that attaches the lens of the eye to the ciliary muscles
Symbiosis: Long or short term relationship between members of different species; three forms are parasitism, commensalism and mutualism
Sympathetic nervous system: Part of the autonomic nervous system; prepares the body to deal with emergency situations
Synapse: A junction between a neuron and another cell; transmits nerve impulse from one neuron to the next neuron or to effector's cell
Tendon: Tough connective tissue that attaches muscles to bones