بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ

(In the Name of Allah, the Most Merciful, the Most Compassionate.)

BIOLOGY

10

BASED ON REVISED NATIONAL CURRICULUM OF PAKISTAN 2023

PECTAA
Transformation, Innovation and Excellence

PUNJAB EDUCATION, CURRICULUM,
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EXPERIMENTAL EDITION

CONTENTS

Chapter 1	**Human Digestive System**	**1**

1.1- Nutrition and its Importance
1.2- Human Digestive System
1.3- Disorders of the Digestive System

Chapter 2	**Human Respiratory System**	**12**

2.1- Human Respiratory System
2.2- The Mechanism of Breathing
2.3- Respiratory Disorders

Chapter 3	**Human Blood Circulatory System**	**24**

3.1- Blood and its Components
3.2- Human Heart
3.3- Blood Vessels
3.4- Arterial & Venous Systems
3.5- Cardiovascular Disorders

Chapter 4	**Human Urinary System**	**38**

4.1- Human Urinary System
4.2- Functioning of the Kidney
4.3- Disorders of Kidney
4.1- Human Urinary System

Chapter 5	**Coordination**	**48**

5.1- Neurons – The Units of Nervous System
5.2- Divisions of the Nervous System
5.3- Endocrine System

Chapter 6	**Reproduction**	**64**

6.1- Formation of Gametes and Fertilization
6.2- Role of Hormones in Sexual Development
6.3- Reproductive Systems
6.4- Sexually Transmitted Diseases

Chapter 7	**Inheritance**	**73**
7.1-	Structure of Chromosome	
7.2-	DNA and RNA	
7.3-	Mendel's Laws of Inheritance	
Chapter 8	**Biotechnology**	**86**
8.1-	Introduction of Biotechnology	
8.2-	Genetic Engineering	
8.3-	Applications of Biotechnology	
8.4-	Potential Risks of Biotechnology	
Chapter 9	**Diseases and Immunity**	**96**
9.1-	Disease	
9.2-	Pathogens	
9.3-	Immunity	
Chapter 10	**Evolution**	**106**
10.1-	Darwin's Observations	
10.2-	Theory of Evolution by Natural Selection	
10.3-	Species and Speciation	
10.4-	Sources of Variation	
10.5-	Evidences of Evolution	
	Glossary	**117**
	Pairing Scheme	**121**
	Model Paper	**122**

1

HUMAN DIGESTIVE SYSTEM

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe the needs of ingestion, digestion, absorption, assimilation and egestion.
- Identify and describe the structures of the main regions of the alimentary canal and the associated organs.
- Describe swallowing and peristalsis.
- Sort out the action of enzymes in specific regions of alimentary canal, with respect to their substrates and products.
- State the role of the liver.
- Describe the structure of a villus, including the roles of capillaries and lacteals.
- State the signs and symptoms, causes, treatments and preventions of the disorders of gut i.e., diarrhoea, constipation, and ulcer.

Everything our body does - like moving, growing, and staying healthy - depends on nutrients. In order to get these nutrients, the food must first be broken down into simpler parts so the body cells can absorb them. This process happens inside our digestive system. In this chapter, we will discover how the digestive system works to turn food into usable nutrients.

1.1 NUTRITION AND ITS IMPORTANCE

Nutrition is how organisms get and use nutrients. It helps them to grow, stay healthy, and repair their bodies. Animals, including humans, cannot make their own food. They get it from other organisms. This is called **heterotrophic** nutrition. In animals, nutrition takes place in the following main steps:

1. **Ingestion:** Taking in food and drinks through the mouth.
2. **Digestion:** Breaking food into smaller parts the body can absorb.
3. **Absorption:** Moving nutrients from the digested food into the blood or lymph.
4. **Assimilation:** Using the absorbed nutrients in cells and tissues.
5. **Egestion:** Removing undigested food and waste from the body.

Autotrophic nutrition is a mode of nutrition in which organisms produce their own food from inorganic substances using light or chemical energy.

Heterotrophic nutrition is a mode of nutrition in which organisms obtain their food by consuming other organisms or organic matter.

The food we eat consists of polymers i.e., large molecules like carbohydrates, proteins, and fats. They cannot pass through cell membranes. These polymers must be broken down into smaller, soluble parts called monomers - like sugars, amino acids, and fatty acids. This process is called **digestion**. These small molecules can enter the cells.

1.2 HUMAN DIGESTIVE SYSTEM

The human digestive system consists of a long tube and some helper (accessory) organs. The tube is called the **alimentary canal**. It starts at the mouth and ends at the anus. The salivary glands, liver, and pancreas send their juices into the alimentary canal and aid in digestion.

1. Oral Cavity

The space behind mouth is called oral cavity or mouth cavity. It contains **taste buds** on the surface of tongue for the taste of food. The **mechanical digestion** of food begins in oral cavity. During mechanical digestion, the teeth cut and grind

During this grinding, tongue keeps the food between the teeth.

food into smaller pieces.

In oral cavity, **partial chemical digestion** of carbohydrates is done by three pairs of **salivary glands**. These glands are attached with oral cavity and secrete **saliva** - a mixture of water, mucus, and a digestive enzyme called **salivary amylase**. Water and mucous moisten the food pieces. Salivary amylase breaks down the starch present in food into maltose.

> Starch is a polysaccharide (made up of many glucose molecules). Maltose is a disaccharide (made of two glucose molecules).

Swallowing: After the physical and partial chemical digestion, the food mass in oral cavity is called **bolus**. It is swallowed by pushing it into the pharynx. For swallowing, the tongue moves the bolus to the back of the oral cavity. The swallowed food enters the pharynx.

> During swallowing, the palate (roof of oral cavity) moves upward to close the opening of the nasal cavity.

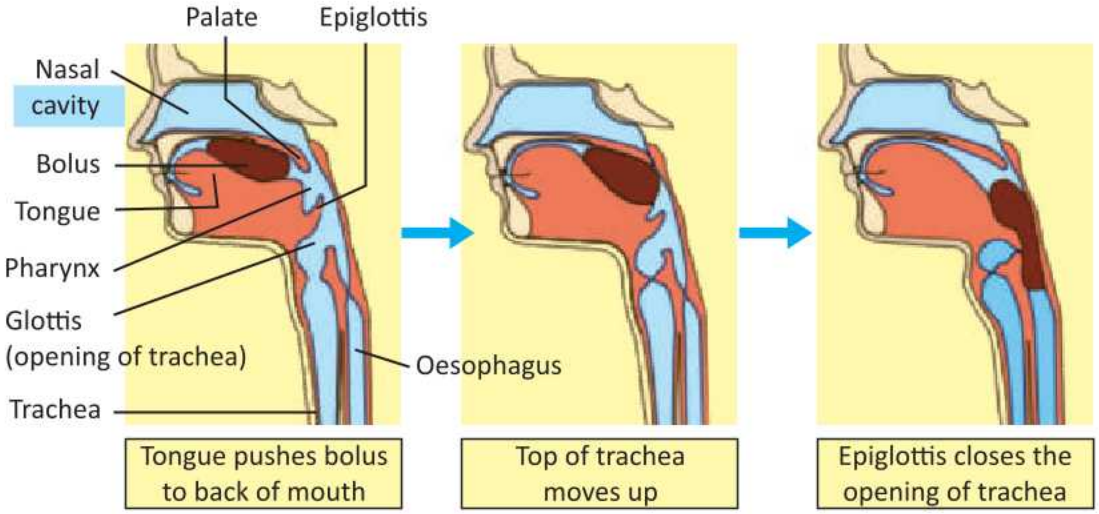


FIGURE 1.1: Oral cavity and steps in swallowing

2. Pharynx and Oesophagus

Pharynx is a short tube-like part behind oral cavity. It connects oral cavity to **oesophagus** and also connects nose to windpipe (trachea). The process of chemical digestion that started in oral cavity continues here. An important function of pharynx is to prevent the entry of food particles into lungs. It is done with the help of an elastic cartilage tissue called **epiglottis**. When swallowed food passes through the pharynx, the top of trachea (windpipe) is pushed up against epiglottis. In this way, the opening of trachea (glottis) closes and the swallowed food passes over it.

Oesophagus is a long tube (about 25 cm long). It connects the pharynx to the stomach. When food enters oesophagus, successive waves of contraction are generated in its muscular walls. These waves of contractions move food along the oesophagus to the stomach. These waves of muscular contraction are called **peristalsis**.

3. Stomach

J-shaped stomach is located in the upper left side of the abdominal cavity, below the diaphragm. The part of stomach immediately after oesophagus is called **cardiac end** while the part before small intestine is called **pyloric end**. At the junction of the oesophagus and stomach, there is sphincter (ring of muscles) called **cardiac sphincter** (lower oesophageal sphincter). It prevents food from flowing back from stomach into the oesophagus. Similarly, **pyloric sphincter** is present between stomach and small intestine.

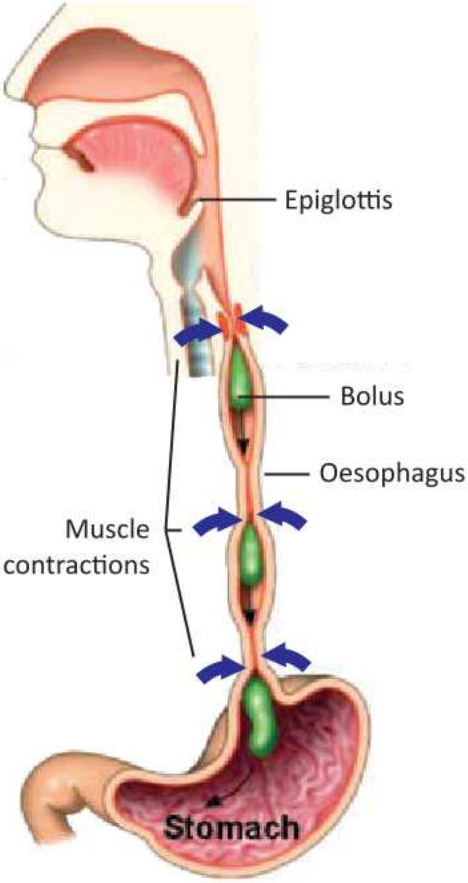


FIGURE 1.2: Peristalsis

Stomach is responsible for the mechanical and partial chemical digestion of food. It also stores food. The walls of stomach are made of thick smooth muscles. When food arrives in stomach, these muscles contract rigorously. Their contractions help in the churning (breaking down) of food into smaller particles. Heat is also produced due to this churning. This heat helps to melt the lipids.

Many small **gastric glands** present in the inner walls of stomach secrete **gastric juice**. It contains hydrochloric acid, an inactive enzyme pepsinogen, and mucus. Hydrochloric acid converts **pepsinogen** into an active enzyme **pepsin**. Pepsin breaks large proteins into shorter chains of amino acids called **peptides**. Hydrochloric acid also kills pathogenic bacteria present in food.

> The stomach's HCl is so strong that it can dissolve metal! But your stomach is protected by the thick mucus lining that keeps it safe from its own acid.

The **mucus** forms a protective layer on the inner walls of stomach where, it neutralizes the HCl. So, pepsinogen cannot be activated and the walls are

protected from breakdown.

Food usually remains in stomach for three to four hours. Due to the actions in stomach, the food becomes a soup-like mixture called **chyme**. The pyloric sphincter controls the flow of chyme. Each time the pyloric sphincter opens, about 5 to 15 mL of chyme moves into the small intestine.

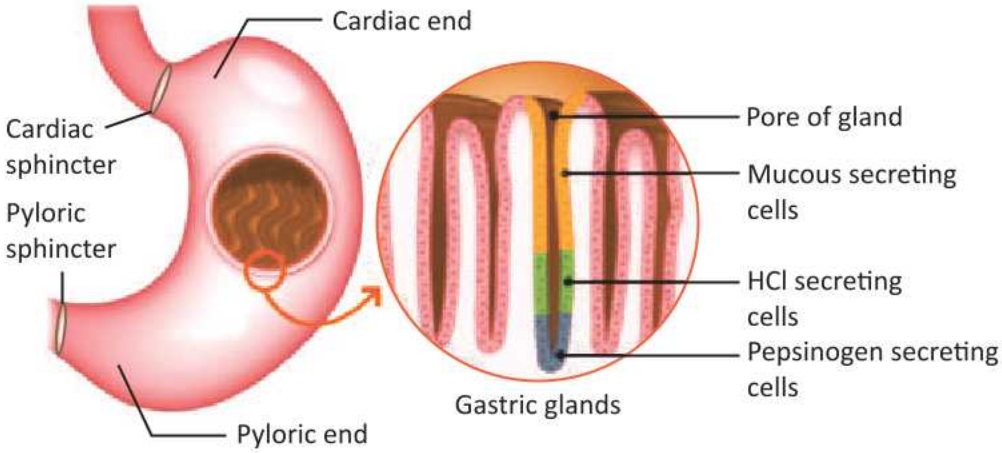


FIGURE 1.3: Structure of stomach

4. Small Intestine

Small intestine is highly coiled tube and is nearly 7 m long. It has three parts:

i. **Duodenum** is the first part. It is about 25 cm long.

ii. **Jejunum** is the middle part. It is about 2.5 m long.

iii. **Ileum** is the last part. It is about 4 m (about 13 feet) long.

In duodenum, secretions of liver and pancreas act on food. The secretion of liver i.e., **bile** enters duodenum through common bile duct. It contains salts which break large fats into small droplets. In this way, a milky fluid is formed in which fat droplets are kept separate. This process is called **emulsification**. The secretion of pancreas i.e., **pancreatic juice** enters duodenum through pancreatic duct, which joins the common bile duct before entering duodenum.

> Bile also contains pigments that are formed when RBCs are broken in liver. These pigments are removed from the body with faeces.

Pancreatic juice contains many enzymes e.g., **trypsin, pancreatic amylase** and **lipase**. These enzymes digest proteins, carbohydrates and lipids respectively. Pancreatic juice also contains sodium bicarbonate that neutralizes the acidity of chyme. The glands present in the walls of small intestine also secrete enzymes for the complete digestion of all types of food.

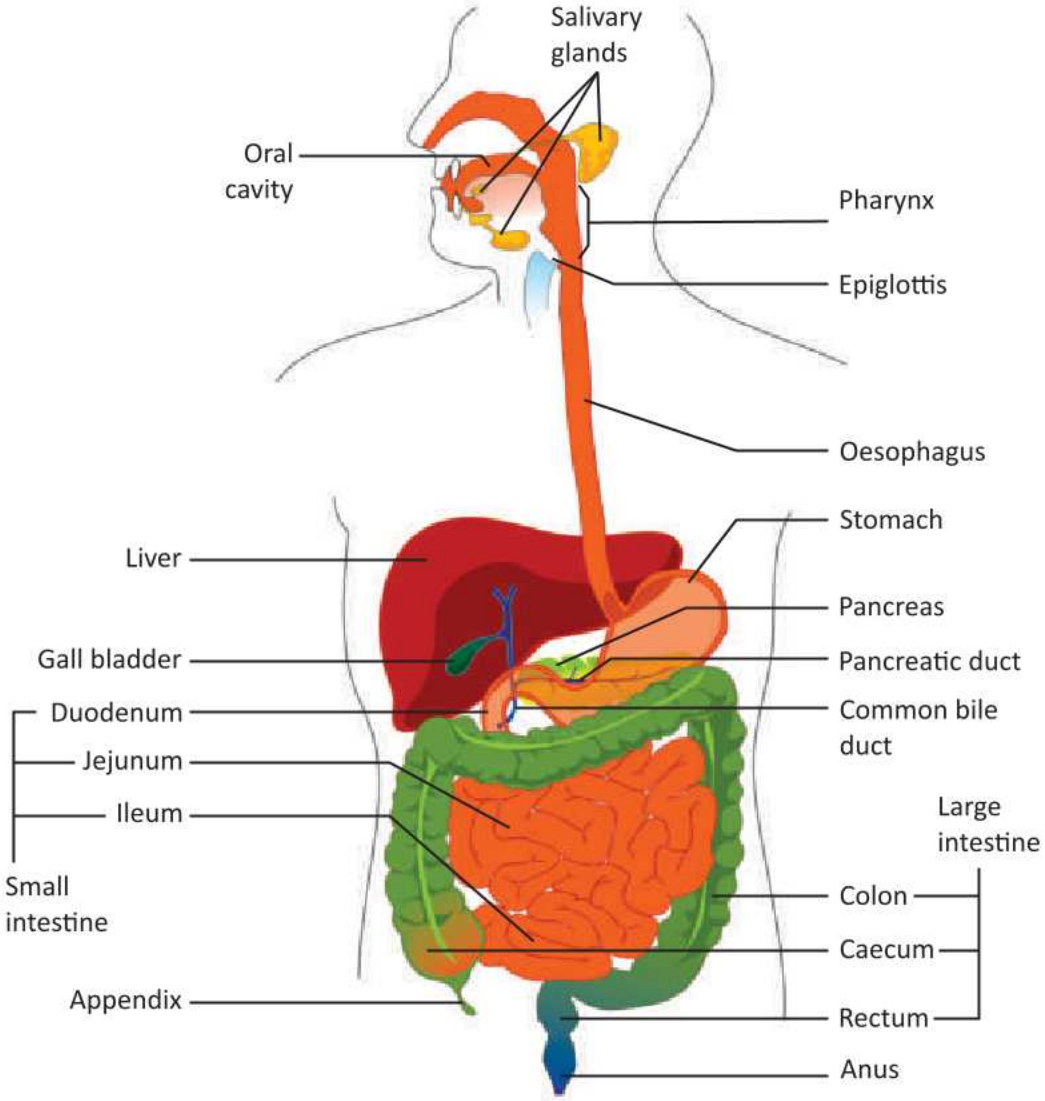


FIGURE 1.4: Human digestive system

Absorption of Food

After the complete digestion of food, the end products i.e., amino acids, simple sugars, glycerol, and fatty acids etc. move from alimentary canal into the circulatory system. The inner walls of small intestine are highly folded. Moreover, these folds have millions of finger-like projections called **villi** (singular; villus). The folds and villi provide a large surface area for the absorption of food. Food molecules are absorbed through this surface through diffusion and active transport. The wall of a villus is made of a single layer of cells. Inside the villus,

there are **blood capillaries** and a lymph vessel called **lacteal**.

The glycerol and fatty acids present in small intestine enter the lacteals of villi. The lacteals carry them to the main lymph vessels, which empty into the blood vessels near the heart. Amino acids and simple sugars enter the blood capillaries of villi. These capillaries join to make **hepatic portal vein** which carries the amino acids and sugars to liver. From liver, the hepatic vein carries these nutrients to heart and then to all parts of the body.

There is a small finger-like **appendix** at the blind end of caecum.

Infection in appendix causes severe pain. If infected appendix is not removed surgically, it can burst and infection may spread in abdomen.

5. Large intestine

Carotene is a natural organic pigment found in fruits and vegetables e.g., carrots and mangoes which are essential for vision, growth and immunity.

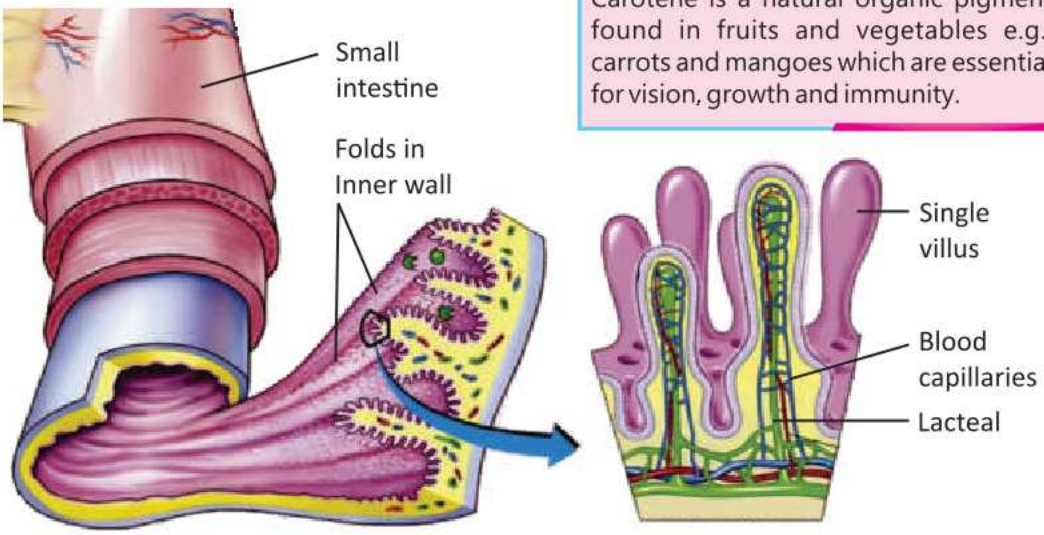


FIGURE 1.5: Small intestine and Villi

Table 1.1: The action of enzymes in the regions of alimentary canal

Region	Enzyme	Substrate	Product
Oral Cavity	Salivary Amylase	Starch	Maltose
Stomach	Pepsin	Proteins	Peptides
Small Intestine	Pancreatic Amylase	Starch	Maltose
	Trypsin	Proteins	Peptides
	Chymotrypsin	Proteins	Peptides
	Peptidase	Peptides	Amino acids and peptides
	Lipase	Fats	Fatty acids glycerol

Nucleases	Nucleic acids	Nucleotides
Maltase	Maltose	Glucose
Sucrase	Sucrose	Glucose and Fructose
Lactase	Lactose	Glucose and Galactose
Dipeptidases	Dipeptides	Amino acids

After the absorption of digested food material and some water, the undigested material and water move to the large intestine by peristalsis. Large intestine has 3 parts i.e. **caecum** (a pouch that forms junction with small intestine), the **colon**, and **rectum**. Absorption of more water occurs from large intestine. Due to it, the undigested material solidifies and is now called **faeces**. The faeces contain the undigested material, large number of bacteria, broken cells of alimentary canal, bile pigments and water. Faeces are temporarily stored in the rectum. During egestion, faeces are expelled out through anus.

Role of liver

Liver is a large organ located to the right of the stomach. In an adult human, it weighs about 1.5 kg. There is a sac-like organ, called **gall bladder**, on the ventral side of liver. Liver secretes bile, which is stored in gall bladder. The common bile duct carries bile from gall bladder into duodenum. Bile does not contain enzymes but it has salts which break fats into small droplets. Bile salts also keep fat droplets separate from one another. It helps the enzymes to attack on lipids. Liver also performs many other functions in the body. For example,

- Stores glucose as glycogen and breaks glycogen to glucose when required.
- Stores of fat-soluble vitamins.
- Breaks amino acids. In this process, harmful ammonia is produced.
- Converts ammonia into less toxic urea for excretion through urine.
- Breaks toxic substances e.g., alcohol.
- Breaks the RBCs which have completed their life spans.
- Prepares vitamin A from carotene.
- Produces heat in cold temperatures by speeding up metabolism.

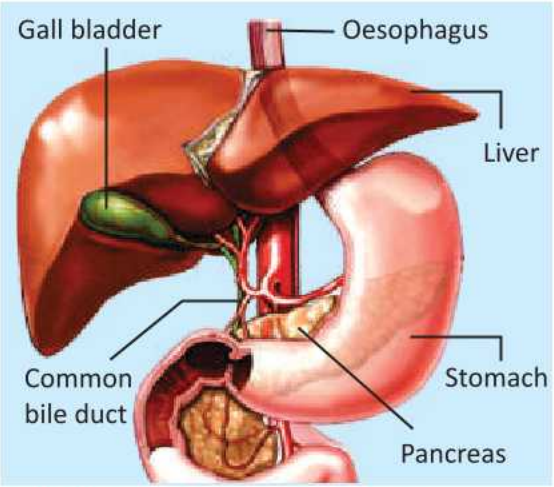


FIGURE 1.6: Liver and associated organs

1.3 DISORDERS OF THE DIGESTIVE SYSTEM

1. Diarrhoea

Diarrhoea is characterized by frequent, loose, or watery stools. Diarrhoea can lead to dehydration, especially in children and the elderly.

Signs and Symptoms: Abdominal cramps or pain, bloating, and dehydration (thirst, dry mouth, dark urine).

Causes: Infections (bacterial, viral, or parasitic), food allergies, stress, certain medications (e.g., antibiotics).

Treatment: Drinking plenty of fluids, use of ORS, eating a soft diet, using anti-diarrheal medications, taking antibiotics or other treatments (in severe cases).

Prevention: Washing hands regularly, especially before eating or after using the bathroom, avoiding contaminated food or water, avoid stress

2. Constipation

Constipation is a condition in which faeces are not eliminated from the body at regular intervals.

Signs and Symptoms: Infrequent or difficult bowel movements (less than 3 times a week), hard and dry stools, abdominal discomfort or bloating.

Causes: Lack of fibre in diet, dehydration, lack of physical activity, certain medicines (e.g., painkillers, iron supplements), other diseases (e.g., diabetes).

Treatment: Increasing fibre intake (fruits, vegetables, whole grains), drinking plenty of water, regular exercise, use medicines as prescribed by the doctor.

Prevention: Eating a high-fibre diet, drinking plenty of fluids.

3. Ulcers

Peptic ulcers are sores that develop in the walls of alimentary canal. Ulcer usually develops in the walls of stomach and is called **gastric ulcer**. However, ulcers may also develop in duodenum (duodenal ulcer) or oesophagus (oesophageal ulcer).

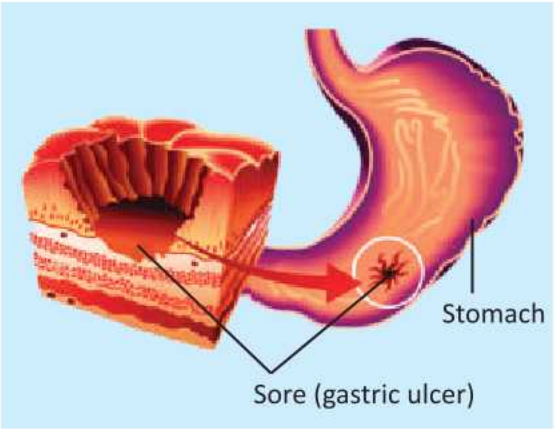


FIGURE 1.7: Gastric ulcers

Signs and Symptoms:

Burning stomach pain, rush of saliva after regurgitation, loss of

appetite, weight loss, blood vomiting (in severe cases).

Causes: Infection due to *Helicobacter pylori* bacteria, long-term use of nonsteroidal anti-inflammatory drugs (NSAIDs), excessive alcohol consumption, smoking, stress (though not a direct cause, it can make symptoms worse).

Treatment: Antibiotics to clear *H. pylori* infection, medicines called antacids and proton pump inhibitors.

Prevention: Avoiding excessive use of painkillers (NSAIDs), avoiding spicy foods, eating a balanced diet.

EXERCISE

A. Select the correct answers for the following questions.

1. The three portions of the small intestine, in the correct order, are;
   a) Duodenum, jejunum, ileum
   b) Ileum, duodenum, jejunum
   c) Colon, caecum, rectum
   d) Caecum, colon, rectum
2. The wavelike movement of muscles that pushes food through the digestive system is called;
   a) Chemical digestion
   b) Mechanical digestion
   c) Peristalsis
   d) Absorption
3. The part of the digestive system where no chemical digestion takes place is;
   a) Oral cavity
   b) Oesophagus
   c) Stomach
   d) Duodenum
4. Which group of enzymes breaks up starches?
   a) Proteases
   b) Lipases
   c) Amylases
   d) Pepsin
5. The pancreas produces digestive enzymes and releases them into;
   a) Colon
   b) Gall bladder
   c) Liver
   d) Duodenum
6. In stomach, pepsinogen is converted into pepsin by the action of;
   a) Bile salts
   d) Hormones
   c) HCl
   d) Bicarbonate
7. In which part are the carbohydrates, lipids and proteins digested?
   a) Oral cavity
   b) Stomach
   c) Small intestine
   d) Large intestine

8. The enzyme trypsin is found in;

a) Pancreatic juice
b) Bile
c) Gastric juice
d) Saliva

9. The common bile duct carries bile from gall bladder to;

a) Stomach
b) Duodenum
c) Colon
d) Pancreas

10. Why the small intestine has many folds and contains villi and microvilli?

a) To slow down the passage of food.
b) To promote food absorption.
c) To prevent the backflow of chyme.
d) To produce enzymes.

B. Write short answers.

1. State the role of salivary glands in digestion.
2. What do the terms swallowing and peristalsis mean?
3. What are the functions of HCl in gastric juice?
4. State the role of pancreatic juice in digestion of food.
5. Write a brief note on the structure of villi.
6. What are the causes and symptoms of ulcers?

C. Write answers in detail.

1. Describe the absorption of food in small intestine.
2. Explain the role of oral cavity in the digestive system.
3. Explain the structure and functions of stomach.
4. Justify the importance of liver and pancreas in digestion.

D. Inquisitive Questions

1. Why does someone with liver disease have difficulty in digesting fats?
2. Why is it important to maintain a healthy balance of gut bacteria?
3. How can a malfunction in the cardiac sphincter lead to acid reflux?
4. Why is it necessary to store bile in the gallbladder before it is released?

2 HUMAN RESPIRATORY SYSTEM

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe the roles of the parts of the air passageway and lungs.
- Describe the mechanism of breathing in terms of movements of ribs and diaphragm.
- Differentiate between the composition of inspired and expired air.
- Discuss briefly diseases related to respiratory system like bronchitis, emphysema, pneumonia, asthma, and lung cancer.

Organisms get energy by doing **cellular respiration**. It is the process in which cells oxidize food (glucose) and get energy. For this purpose, organisms need to carry oxygen to the cells and to remove carbon dioxide from the cells. **Gaseous exchange** is the process in which oxygen present in the inhaled air (in lungs) moves into blood, and carbon dioxide from the blood moves into the air to be exhaled. For gaseous exchange, animals do breathing.

> In aerobic respiration, oxygen is utilized while carbon dioxide and water are produced.

Breathing

Breathing is the process in which animals move air in and out of their body. It is done to get oxygen from air and to release carbon dioxide in it. Breathing and respiration are not the same processes. Respiration is a chemical process while breathing is a physical process. Breathing helps in gaseous exchange. Gaseous exchange, in turn, helps in respiration.

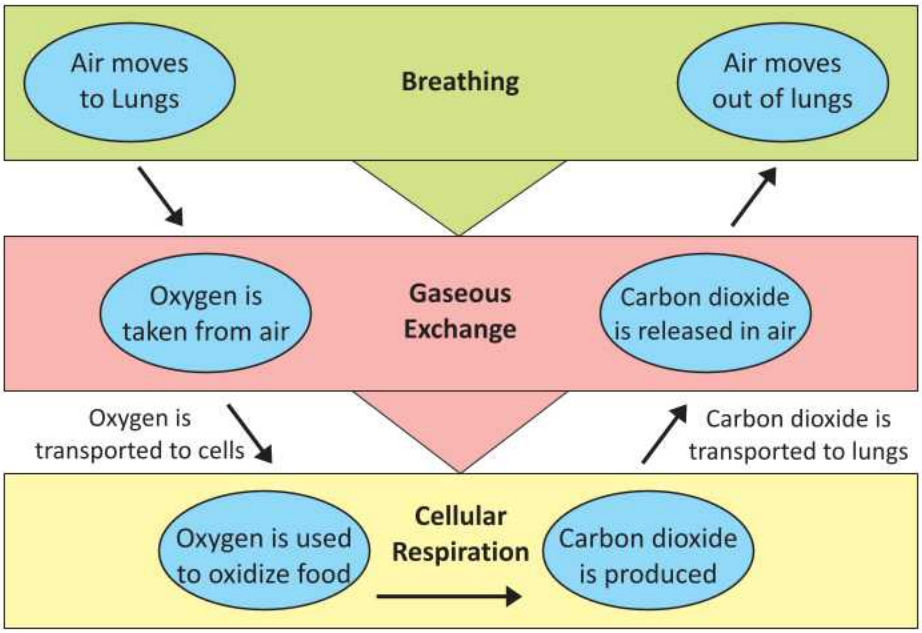


FIGURE 2.1: Relationship between respiration, gaseous exchange and breathing

2.1 HUMAN RESPIRATORY SYSTEM

Respiratory system is responsible for breathing and gaseous exchange. The human respiratory system consists of two major parts i.e., air passageway and lungs.

A. The Air Passageway

When air enters the body, it passes through connected tubes to reach the

lungs. After gaseous exchange, air moves from the lungs to outside through the same connected tubes. These connected tubes are collectively called air passageway. It consists of the following parts.

1. Nostrils and Nasal cavity

The nasal cavity is made up of two narrow cavities between nostrils and pharynx. Air enters the nasal cavity through nostrils. **Fine hairs** in nasal cavity filter the incoming air by trapping large dust particles. **Mucus** on the walls of nasal cavity traps small dust particles. Mucus also warms the air and keeps its temperature nearly equal to the temperature of body.

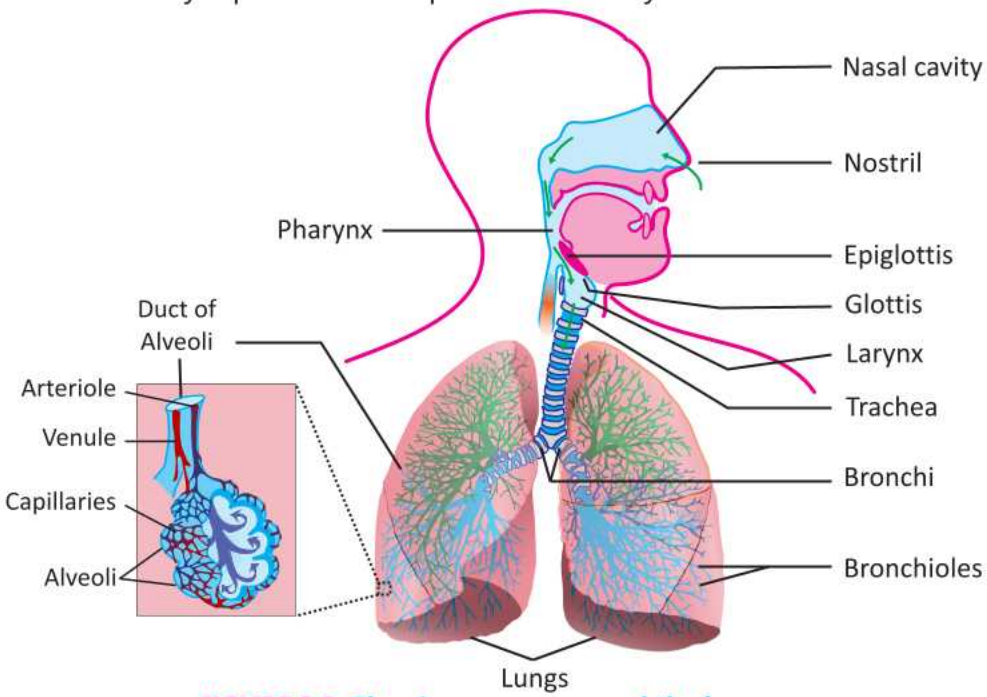


FIGURE 2.2: The air passageway and the lungs

2. Pharynx

Nasal cavity opens into pharynx. At the floor of pharynx there is an opening called **glottis**. It opens in larynx. The glottis is guarded by a flap called **epiglottis**. It prevents food and liquid from entering the windpipe and lungs.

> **Recalling:**
> Pharynx is a common passage for food to oesophagus and for air to larynx.

3. Larynx

It is a box present between pharynx and trachea. Larynx is also called the **voice box**. Two fibrous bands called vocal cords are

> The vibrations of vocal cords and the movements of lips, cheeks, tongue and jaws produce specific sounds which result in speech.

attached to the inner walls of larynx. The vibrations of vocal cords produce sounds.

4. Trachea and Bronchi

Trachea (windpipe) is a 12 cm long tube attached with larynx. It ends in two branches called **bronchi** (*singular*: bronchus). Each bronchus enters into the lung of its side.

The inner walls of trachea and bronchi are lined with mucus and cilia. Mucus traps fine dust particles and bacteria. Cilia move these particles and mucus upwards to the pharynx. In the walls of trachea, **C-shaped cartilages** are present. While the walls of bronchi have plate-like cartilages. These cartilages prevent trachea and bronchi from collapsing even when there is no air in them.

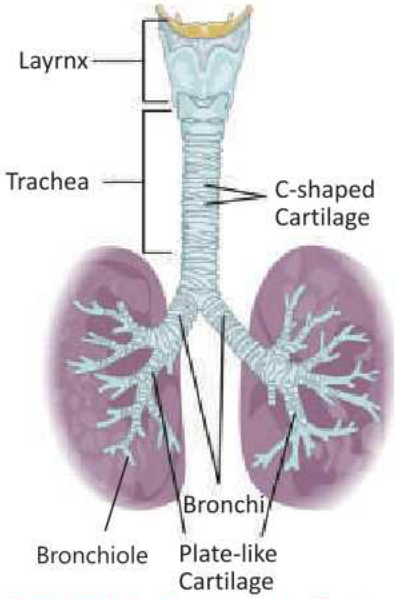


FIGURE 2.3: Cartilage in Trachea and Bronchi

5. Bronchioles and Alveoli

Inside lungs, both bronchi continue to divide into very small tubes called bronchioles. As the branching continues, the amount of cartilage in the walls decreases. Cartilage is absent in the smallest bronchioles. Each bronchiole ends at an alveolar duct. This duct opens into a cluster of pouches. These thin-walled pouches are called alveoli (*singular:* alveolus). Each alveolus is surrounded by blood capillaries. When air reaches alveoli, oxygen moves from the air into blood, and carbon dioxide passes out of blood into the air in the alveoli.

> The chest wall is made up of 12 pairs of ribs and the rib muscles called **inter-costal muscles**.

B. The Lungs

There is a pair of lungs in the thoracic cavity. From above and sides, lungs are enclosed by the chest wall. A thick muscular structure, called **diaphragm** below lungs. Lungs are spongy and elastic organs. The left lung is slightly smaller than the right lung. There are two lobes in the left lung while right lung has three lobes. Lungs are enclosed

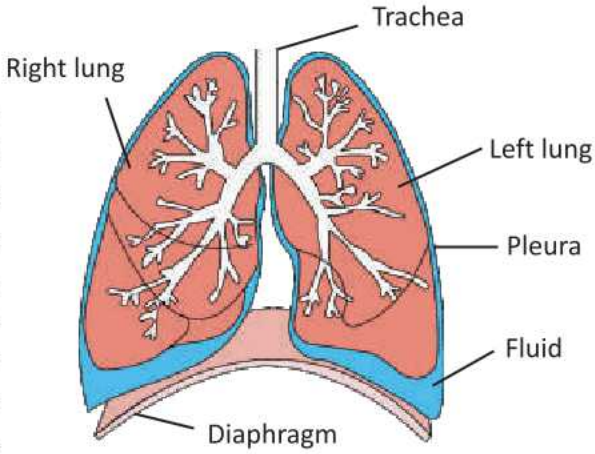


Figure 2.4: Lungs

in a double membrane called **pleura**. Its inner layer is attached to the surface of the lungs while the outer layer lines the inner surface of the chest wall and the diaphragm. It contains a **pleural fluid** for reducing friction between lungs and the chest wall.

Blood Circulation in Lungs

Pulmonary artery carries deoxygenated blood from heart to lungs. Inside each lung, the pulmonary artery divides into smaller arterioles. The arterioles divide further and make capillaries around the alveoli. After surrounding the alveoli, the capillaries join to form venules. The venules join to form pulmonary vein which carries oxygenated blood back to heart.

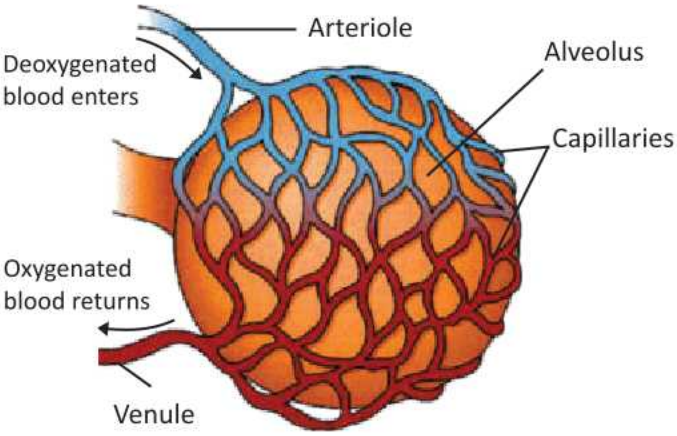


Figure 2.5: Blood circulation in lungs (around an alveolus)

2.2 THE MECHANISM OF BREATHING

Breathing is a physical process in which air is taken into the lungs and expelled out the lungs. There are two steps of respiration.

1. Inhalation (inspiration)

Inhalation means intake of air to the lungs. The following events occur

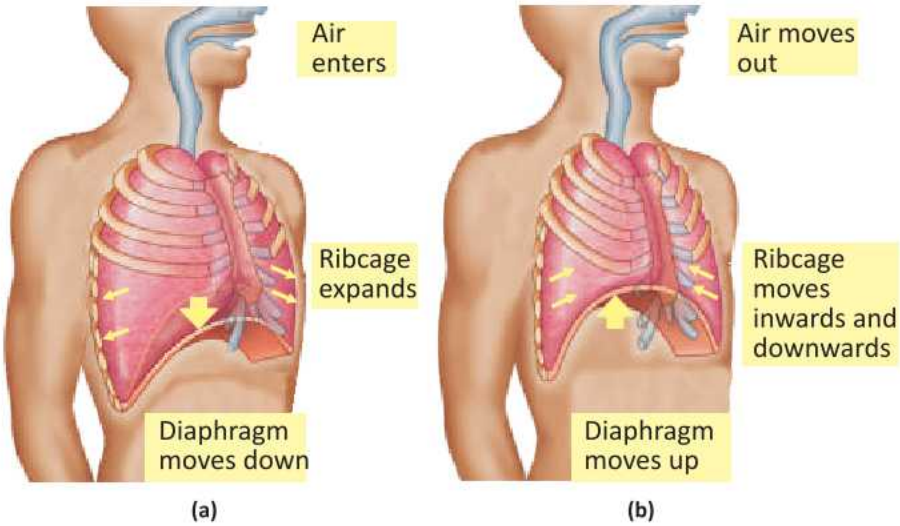


Figure 2.6: Breathing; (a)- Inhalation (b)- Exhalation

during inhalation;

The **intercostal muscles** (muscles located between the ribs) contract for the upward and outward movement of ribcage. At the same time, **diaphragm** also contracts and moves down. These two contractions increase the volume of the chest. So, pressure inside the chest is reduced and air is moved into lungs.

2. Exhalation (expiration)

Exhalation means moving the air out of the lungs. The following events occur during exhalation;

The **intercostal muscles** relax to move ribcage inwards. At the same time **diaphragm** also relaxes and moves up. These two movements decrease the volume of the chest. So, pressure inside the chest increases and air is forced out.

> We lose half a litre of water a day through breathing. This is the water vapour we see when we breathe onto glass.

The Rate of Breathing

Humans breathe **16 -20 times per minute** in normal conditions i.e., at rest. During exercise or hard job, muscles carry out cellular respiration at greater rate. So, more carbon dioxide is produced. The respiratory centre in brain detects greater concentration of carbon dioxide in blood. It sends messages to the muscles of ribs and diaphragm at greater speed. The speed of contraction and relaxation of these muscles increases. So, the breathing rate increases up to 30-40 times per minute.

Composition of the Inhaled and the Exhaled Air

Feature	Inspired Air	Expired Air
Oxygen %age	21	16
Carbon dioxide %age	0.04	4
Nitrogen %age	79	79
Water vapours	Variable	Saturated
Temperature	Variable	Almost equal to body temperature
Dust particles	Variable	Almost none

2.3 RESPIRATORY DISORDERS

1. Bronchitis

Bronchitis means inflammation (swelling) in bronchi or bronchioles. In

bronchitis, the inner space of bronchioles decreases. It may be short term i.e., acute (1-2 weeks) or long-term i.e., chronic (3months to 2 years). In chronic bronchitis, mucus-producing cells in the walls of bronchi increase in number. Thus, there is thick mucus in bronchi. It obstructs breathing.

Causes: Infections by viruses or bacteria and chemical irritants (e.g., tobacco smoke).

Symptoms: Coughing, wheezing, fever, chills and shortness of breath.

Treatment: Medications (cough suppressants) to ease breathing, antibiotics (if it is due to bacterial infection), antiviral medicines (if it is due to viral infection), avoiding irritants like smoke and pollution.

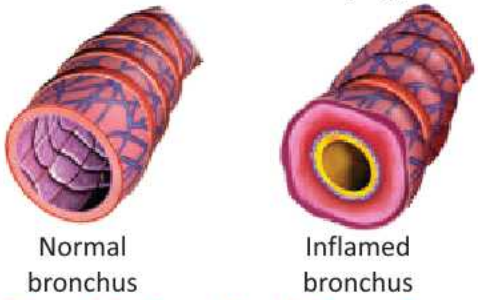


Figure 2.7: Normal and inflamed bronchi

2. Emphysema

In emphysema, the inner walls of alveoli become weak and then rupture. Thus, one larger air space is created instead of many small ones. So, the space for gaseous exchange decreases and the patient cannot breath properly.

Causes: Long-term exposure to irritants in air e.g., tobacco smoke, chemical fumes and other air pollutants.

Symptoms: Shortness of breath, chronic cough (with or without mucus), wheezing and chest tightness.

Treatment: Medicines to relieve cough and breathing problems. Emphysema cannot be cured completely.

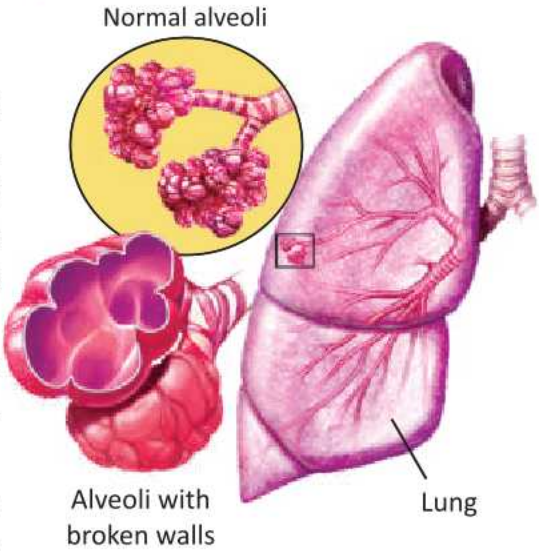


Figure 2.8: Emphysema

3. Pneumonia

Pneumonia is an inflammation in the lungs, due to infection in alveoli. These are filled with pus.

Causes: Infections by bacteria, viruses and fungi.

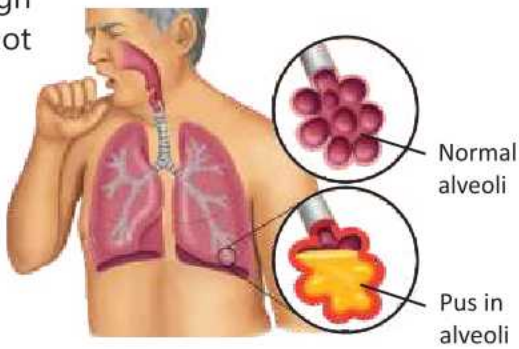


Figure 2.9: Pneumonia

Symptoms: The pneumonia patient suffers from high fever, chills, shortness of breath, and cough with sputum.

Treatment: Bacterial pneumonia is treated by using antibiotics. The viral and fungal pneumonia are treated by using antiviral and antifungal drugs respectively. Bacterial vaccines are also available to prevent bacterial pneumonia.

4. Asthma

It is an inflammation of bronchi in which bronchi and bronchioles swell and are constricted.

Symptoms: Recurring attacks of shortness of breath, wheezing (whistling sound when breathing out), coughing and chest tightness.

Causes: Allergens (dust mites, pollen, mold, and pet dander), air pollutants (smoke, chemical fumes, and strong fragrances), weather changes, especially cold air, genetic factors (family history of asthma or allergies).

Treatment: Medicines (bronchodilators) to dilate bronchioles during asthma attack.

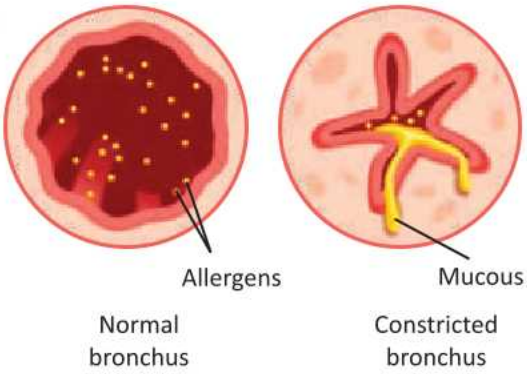


Figure 2.10: Asthma

5. Lung Cancer

Cancer means uncontrolled increase in the number of cells in any part of the body. When the masses of non-functional cells are formed in lungs, it is called lung cancer. It is the most common cancer in the whole world.

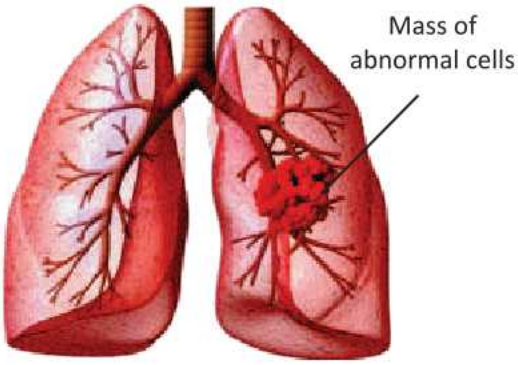


Figure 2.11: Lung cancer

Causes: Carcinogens (such as those in tobacco smoke), ionizing radiation, viral infection. Passive smoking i.e., the inhalation of smoke from another's smoking is also a cause of lung cancer. The smoke from the upper burning portion of cigarette is

Lung cancer is the most frequently diagnosed cancer globally, accounting for about 12.4% of all new cancer cases. In the world, it causes more than 1.5 million deaths annually.

In Pakistan, lung cancer accounts for about 5.1% of all new cancer cases annually. There are about 22,000 new lung cancer cases each year.

Source: World Health Organization

more dangerous than smoke exhaled by the smoker.

Symptoms: The most common symptoms are shortness of breath, coughing (including coughing up blood), and weight loss.

Treatment: The patient of lung cancer is given one or more treatments, including surgery, chemotherapy, or radiation therapy.

Effects of Smoking

Smokers have a much higher risk of developing life-threatening diseases. The most important risk of smoking is the abnormalities and cancers in lungs, kidneys, oral cavity, larynx, breast, bladder, oesophagus, pancreas and stomach.

Non-smokers who inhale the smoke of others have 30% more chances of heart diseases and lung cancer.

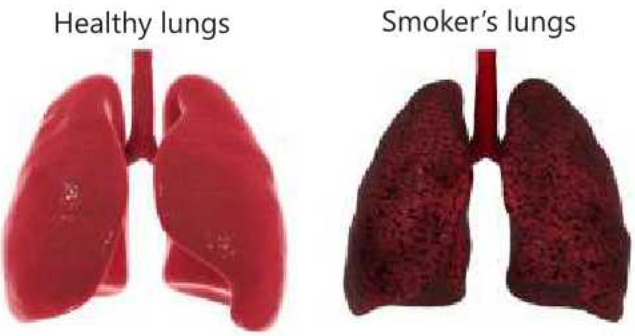


FIGURE 2.12: Effect of smoking on lungs

Tobacco smoke contains over 4,000 different chemicals e.g., nicotine and carbon monoxide. Out of these, there are more than 69 known **carcinogens** (cause cancer in humans). For example: tar and benzene etc.

In Pakistan, 12% of adults do smoke. 7.6% of all deaths in Pakistan are caused by tobacco use.

- **Nicotine** is the major component of cigarettes. It damages many tissues including brain. It also hardens the walls of arteries and results in heart problem.
- **Carbon monoxide** is produced when tobacco is burnt during smoking. It is a poisonous gas. It combines with RBCs and prevents oxygen transport.
- **Tar** is present in cigarettes in the form of solid particles. When it is inhaled along with smoke, it is deposited in lungs. It reduces the surface area for gaseous exchange.
- **Benzene** is a major component of cigarettes. It is a carcinogen and

Vaping refers to inhaling vapor produced by an e-cigarette. These devices heat a liquid, which may contain nicotine, flavours, and other chemicals.

Many young people are attracted to vaping. They believe it a safer alternative to cigarettes, though this is not true.

Vaping can cause lung inflammation and lung injury. Nicotine and other chemicals in vape increase heart rate and blood pressure, contributing to heart disease.

causes blood cancer (leukaemia). Similarly, **formaldehyde** present in cigarettes causes cancers, respiratory, skin and gastrointestinal problems.

- **Ammonia** frees nicotine from tobacco turning it into a gas. It is poisonous for the body.
- There are many other **irritants** in cigarettes. These irritants damage the air passageways (respiratory tract) and cause many respiratory diseases, including cancer.

Other Effects of Smoking

Smoking also increases blood cholesterol levels, blood pressure. It weakens blood vessels. Smoking causes the staining of teeth and bad breath. Tooth loss is 2 to 3 times higher in smokers than in non-smokers. Smoking increases the risk of tuberculosis by two to four times, and of pneumonia by four times.

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

EXERCISE

A. Select the correct answers for the following questions.

1. Breathing means;
   a) Breakdown of C-H bonds to produce energy
   b) Movements that take air in and out of body
   c) Getting oxygen from the air and removing carbon dioxide
   d) Transport of oxygen through blood to different parts of the body
2. Which path does air take immediately after passing through the larynx?
   a) Pharynx b) Bronchi
   c) Trachea d) Alveoli
3. Why are alveoli surrounded by capillaries?
   a) To absorb water b) To exchange gases
   c) To produce mucus d) To trap dust particles
4. Which feature of alveoli helps in rapid gas exchange?
   a) Thick walls b) Large diameter
   c) Moist surface d) Strong muscles
5. Which action increases lung volume during breathing?
   a) Relaxing the diaphragm b) Contracting intercostal muscles
   c) Closing the trachea d) Stiffening alveolar walls

6. Inhaled air contains 21% oxygen. What is its percentage in exhaled air?
   a) 0% b) 16% c) 21% d) 42%
7. Which factor controls the breathing rate?
   a) Carbon dioxide in blood b) Oxygen in blood
   c) Carbon dioxide in muscles d) Oxygen in muscles
8. The walls of alveoli are broken in:
   a) Pneumonia b) Bronchitis c) Emphysema d) Asthma
9. Smoking leads to lung cancer by:
   a) Increasing oxygen uptake
   b) Promoting uncontrolled cell division
   c) Slowing down healing
   d) Enlarging the trachea
10. Which chemical in cigarette smoke directly leads to addiction?
    a) Carbon monoxide b) Tar c) Nicotine d) Formaldehyde

B. Write short answers.

1. Differentiate between gaseous exchange and breathing.
2. Differentiate between breathing and cellular respiration.
3. What is the function of cartilages present in the walls of trachea and bronchi?
4. What is the average breathing rate in human at rest and during exercise?
5. How does the structure of alveoli maximize gas exchange?
6. List the symptoms, causes, and treatments of bronchitis.
7. Mention the symptoms and treatments of emphysema.
8. What are carcinogens? Name any two carcinogens present in cigarettes.
9. Complete the following table:

Feature	Inspired Air	Expired Air
Oxygen	21%	
Carbon dioxide		4%
Nitrogen	79%	

C. Write answers in detail.

1. Explain the process of inhalation and exhalation step by step.
2. Write a short note on the major parts of the human air passageway.

3. Describe the functions and locations of the bronchus, trachea, and alveoli.
4. What are the possible causes of lung cancer? Explain the harmful effects of smoking apart from lung cancer.

D. Inquisitive Questions

1. What can happen to breathing if diaphragm stops working properly?
2. Why is it dangerous when smoke particles settle inside lungs?
3. Why does the trachea has C-shaped cartilage rings while bronchioles do not have them?
4. During asthma attacks, patients feel harder to exhale than to inhale. Why is it so?

3 HUMAN BLOOD CIRCULARITY SYSTEM

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe how the blood is circulated inside the human body.
- Explain how blood is used to transport materials throughout the human body.
- Identify the different types of organs connected to the blood system and their roles.
- Identify the different components that make up the blood.
- Name the cell types found in blood and their roles.
- Explain the structure of the heart with a diagram.
- Explain common heart diseases (coronary heart disease, myocardial infarction, angina).
- Explain the harmful effects of smoking related to heart diseases.

The transport system consists of two key parts i.e., (i) blood circulatory system, and (ii) lymphatic system. In this chapter, you will study the details of the blood circulatory system. The main components of human blood circulatory system are blood, heart, and blood vessels.

3.1 BLOOD AND ITS COMPONENTS

Blood is a type of connective tissue. Its main function is to transport materials through the body. It carries important materials to where they are needed. It transports oxygen from the lungs to all body cells and carries carbon dioxide back to the lungs for removal. Blood also delivers nutrients from the digestive system to the cells, hormones from glands to target organs, and waste products from the cells to kidneys for excretion.

About 55% of blood is composed of a fluid portion called **plasma** while 45% of blood is made up of cells or cell-like bodies. The adult human has about 5 litres blood in the body.

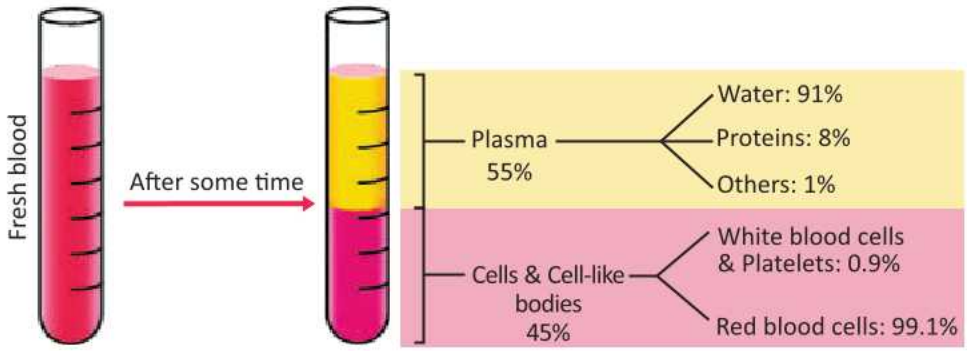


FIGURE 3.1: Percentage composition of blood

1. Blood Plasma

It is the liquid portion of blood. Plasma is composed 90-92% of water, 7-9% of proteins and 1% of other substances.

> If fibrinogen is removed from blood plasma, the rest is called **serum**.

- **Proteins:** Antibodies are important plasma proteins. Antibodies defend the body against pathogens. Fibrinogen is also a plasma protein. It is responsible for blood clotting. Albumin is a plasma protein which maintains the osmotic pressure of blood.
- **Salts:** The important plasma salts are made of sodium, chloride, and bicarbonate ions. In addition, there are little amounts of calcium, magnesium, copper, potassium, and zinc.
- **Nutrients, wastes and hormones:** Plasma contains nutrients like

glucose, lipids, and amino acids etc. These nutrients enter into the blood from the digestive system. The wastes produced by cells are also present in plasma. Hormones secreted by endocrine glands are also carried by plasma.

- **Respiratory gases:**

  Small amounts of carbon dioxide and oxygen are dissolved in plasma. Oxygen is mainly carried by RBCs but about 1.5% of oxygen is also present in plasma in dissolved form. Similarly, about 5-7% of carbon dioxide is carried as dissolved in plasma mostly in the form of bicarbonate ions.

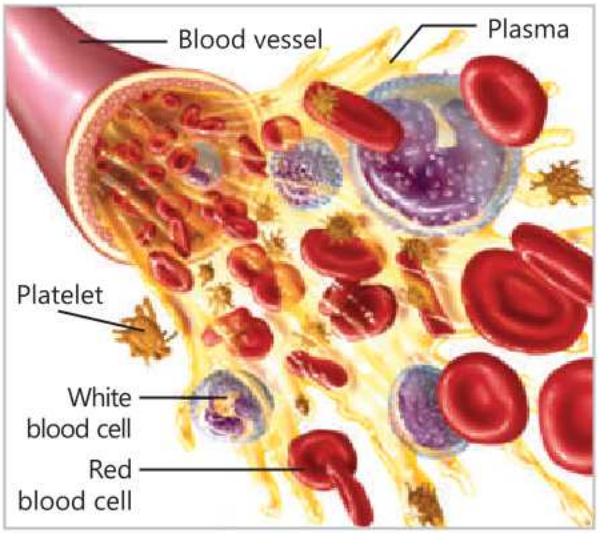


FIGURE 3.2: Blood composition

2. Blood Cells (and Cell-like Bodies)

Red Blood Cells (Erythrocytes)

Red blood cells (RBCs) are disc-shaped (biconcave) cells with a depression at the centre. They contain **haemoglobin** which turns bright red in presence of oxygen and dark red when deoxygnated. It transports oxygen and little amount of carbon dioxide. There are 4 to 5.5 million RBCs per mm^3 of blood. Before and immediately after birth, RBCs are formed in **liver and spleen**. In adults, they are formed in the **red bone marrow** of short bones (sternum, ribs and vertebrae). During the formation of an RBC, its nucleus and organelles are broken down. The average life span of an RBC is about 120 days. When RBCs complete their age, they are removed by spleen and liver.

> There are more than 30 trillion RBCs throughout the body. About 2 million RBCs die and are replaced every second.

White Blood Cells (Leukocytes)

White blood cells (WBCs) are colourless and have irregular shapes. They are formed in the red bone marrow. Some WBCs mature in lymph nodes, tonsils, thymus, or spleen. WBCs are larger in size and less in number than RBCs. An average of 7000 WBCs per mm^3 of blood is present within the normal range for adults. They defend the body against diseases. Their life span depends upon the needs. There are several types of WBCs.

1. **Granulocytes:** These WBCs have granules in cytoplasm. They include **neutrophils, eosinophils,** and **basophils.** Their names tell the staining properties of their cytoplasm. Neutrophils destroy bacteria and clean up dead cells at infection sites. Eosinophils fight with parasites and cause allergic reactions. Basophils release histamine to cause inflammation and produce allergic reactions.
2. **Agranulocytes:** They have clear cytoplasm. There are two types of agranulocytes i.e., monocytes and lymphocytes. **Monocytes** make **macrophages** which engulf the germs and dead cells. **Lymphocytes** make antibodies against pathogens.

Cell-like bodies i.e., Platelets (Thrombocytes)

Platelets are not whole cells. They are small fragments of large cells of bone marrow. Platelets lack a nucleus. Their life span is 7 to 12 days. A mm^3 of blood contains 250,000 platelets.

When a blood vessel is damaged, platelets gather at the damaged site. Here, they convert plasma protein fibrinogen into **fibrin**. The fibrin molecules form a net that traps RBCs. The mass of fibrin and RBCs hardens. This hard mass is called a **clot**. The clot prevents bleeding until the damaged vessel is repaired.

Macrophages die in the process of killing the germs. The dead cells accumulate and make the white substance called **pus**, seen at infection sites.

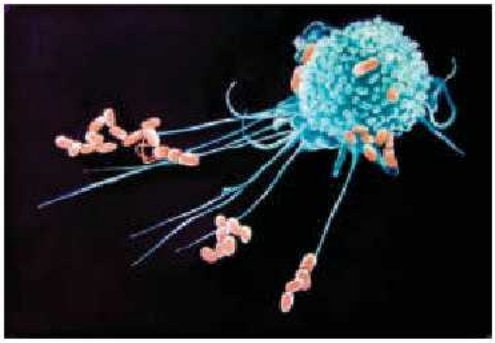


FIGURE 3.3: A macrophage engulfing the bacteria

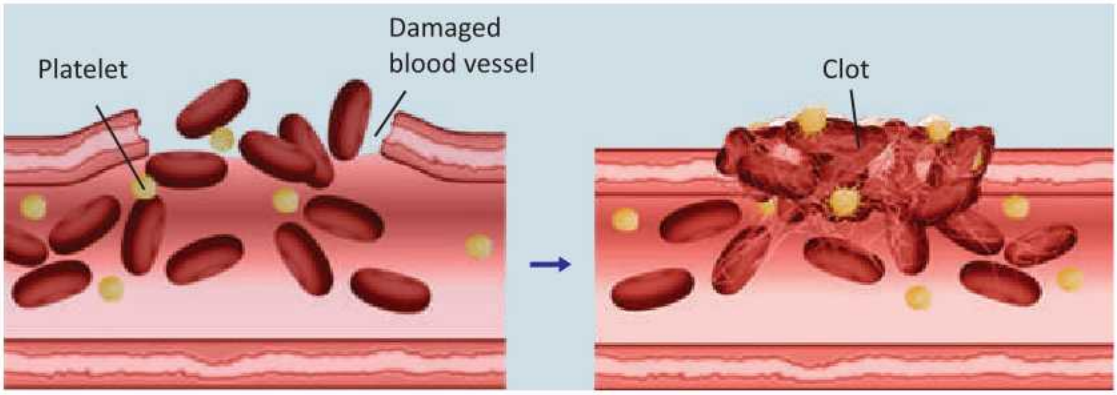


FIGURE 3.4: Formation of clot by platelets

3.2 HUMAN HEART

The heart is a muscular organ that pumps blood through a network of blood vessels. The heart lies within the chest cavity, beneath the sternum, between the two lungs.

Structure of the Heart

There is a tough, sac-like membrane around the heart. It is called **pericardium**. It secretes a fluid around heart. This fluid reduces friction between the pericardium and heart. Like birds and other mammals, human heart has two sides. The wall between the left and right sides is called **septum**. Each side is divided into two chambers. The upper chambers are called **atria** (singular: atrium), and lower chambers are called **ventricles**. The atria have thinner walls as compared to ventricles.

> The left ventricle is the largest, thickest and strongest chamber in the heart.

Special flaps called **valves** are present between the chambers of both sides. The valves open in only one direction. The valve between right atrium and right ventricle is called **tricuspid valve** (made of 3 flaps). The valve between left atrium and left ventricle is called **bicuspid valve** (made of 2 flaps). As the ventricles contract, tricuspid and bicuspid valves close. So, the blood cannot flow back into atria. In this way, blood is pumped from the ventricles into large vessels. A **semilunar valve** is present between each ventricles and large vessels. These valves prevent blood from flowing back into the ventricles.

The Circulation of Blood

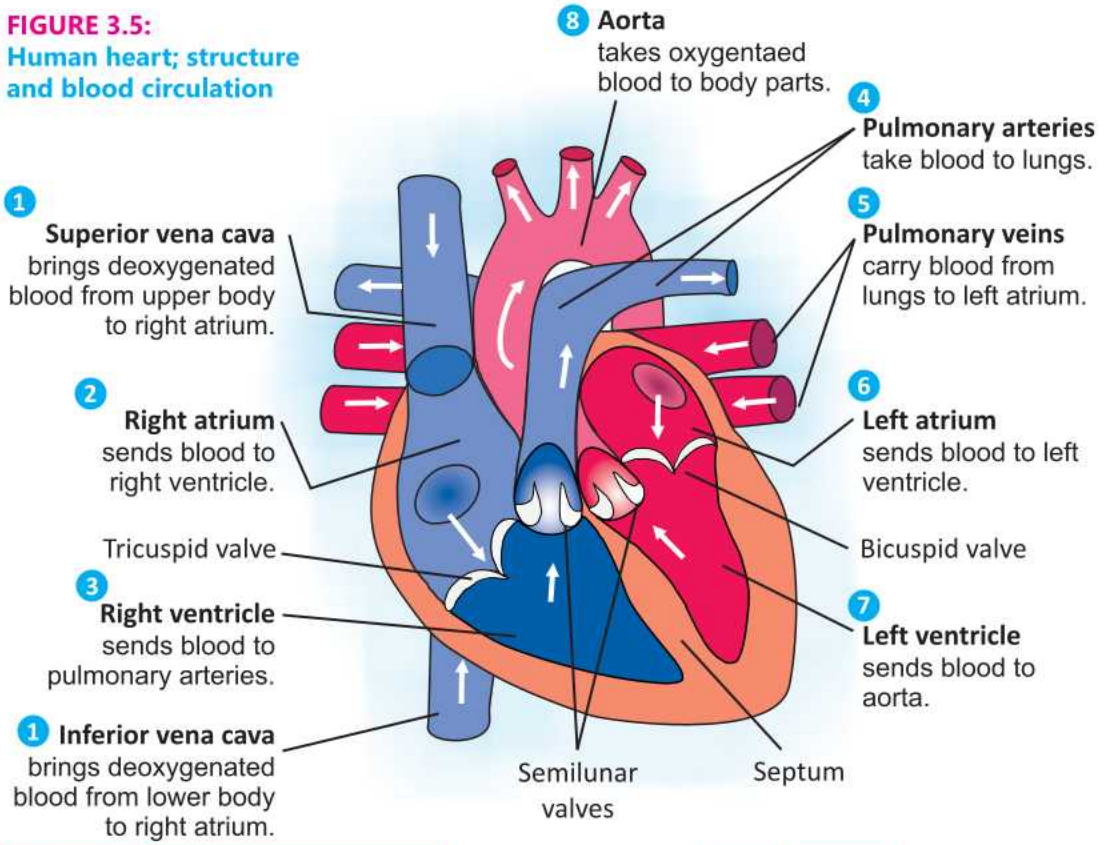
The right side of the heart collects blood from body and sends it to the lungs while the left side collects blood from the lungs and sends it to the body. It means that human heart works as a **double pump**. It is done in the following way.

> Oxygenated blood is bright red. Deoxygenated blood is dark red.

Two veins i.e., superior and inferior vena cavae bring **deoxygenated blood** (with high concentration of CO_2 and low concentration of O_2) from parts of the body (other than lungs). These veins open in the right atrium. The right atrium contracts and sends this blood into the right ventricle. The right ventricle contracts and pumps this blood into pulmonary arteries. The pulmonary arteries take this blood to lungs. In lungs, CO_2 diffuses out of the blood, and O_2 diffuses into the blood.

From lungs, pulmonary veins carry the **oxygenated blood** (low concentration of CO_2 and high concentration of O_2) back. These veins open in the

FIGURE 3.5: Human heart; structure and blood circulation



Due to high pressure in systemic circulation, blood can reach to all body parts. On the other hand, due to low pressure in pulmonary circulation, blood flows in lungs in slow speed. It gives sufficient time for gaseous exchange in lungs.

left atrium of heart. This blood is pumped into left ventricle. When left ventricle contracts it pumps the blood into a large blood vessel called **aorta.** From aorta, this blood is transported to all parts of the body.

Pulmonary and systemic circulations: The flow of blood from heart to lungs and then from lungs to heart is called **pulmonary**

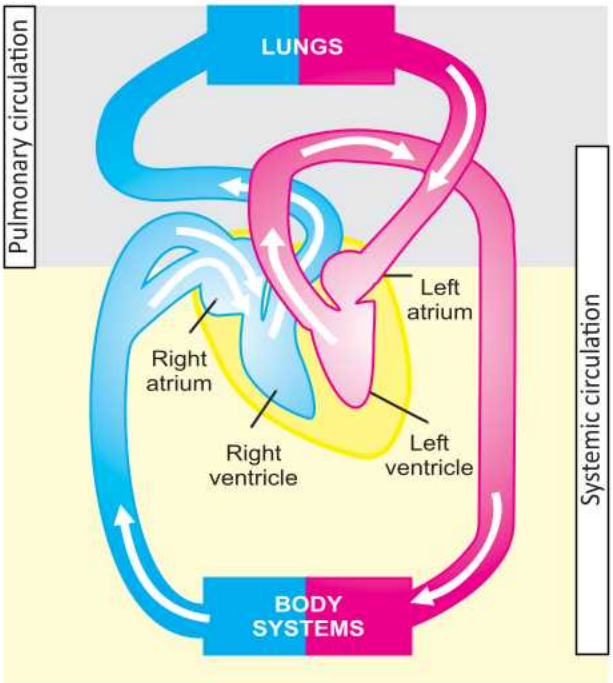


FIGURE 3.6: Pulmonary and systemic circulations

circulation. Similarly, the flow of blood from heart to the body tissues and then from body tissues to heart is called **systemic circulation**.

Heartbeat

The alternating contraction (systole) and relaxation (diastole) of heart chambers makes one heartbeat. The average human heart beats 70 times per minute. This is also called the heart rate. A heartbeat has two phases.

- **Systole** occurs when both ventricles contract to pump the blood into pulmonary arteries and aorta.
- **Diastole** occurs immediately after systole when both atria relax so that blood enters the atria. Contraction of the atria fills the ventricles.

During systole **"lubb"** sound is produced due to the closing of tricuspid and bicuspid valves.

During diastole **"dubb"** sound is produced due to the closing of semilunar valves.

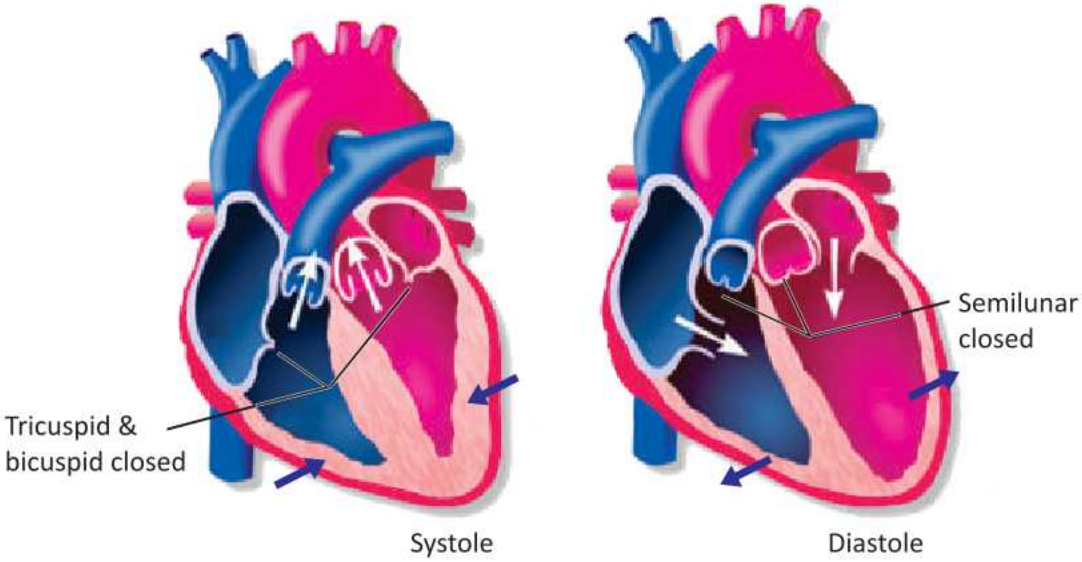


FIGURE 3.7: One Heartbeat

3.3 BLOOD VESSELS

1. Arteries

Arteries carry blood away from the heart. In adults, all arteries carry oxygenated blood, except of pulmonary arteries. The thick walls of arteries are made of: an inner layer of **endothelium**, a middle layer of **smooth muscles** and **elastic tissues**, and an outer layer of **connective tissue**. Arteries are strong and elastic. The hollow internal cavity of arteries in which the blood flows is called **lumen**. When arteries enter body organs, they divide into smaller vessels known

as arterioles. The arterioles enter tissues and divide into capillaries.

2. Capillaries

Capillaries are the smallest blood vessels. The walls of capillaries are composed of only a single layer of cells i.e., **endothelium**. This layer is so thin that water, nutrients and oxygen can pass through it to enter the tissue fluid. Similarly, carbon dioxide and other wastes present in tissue fluid can pass through it to enter blood. In tissues, capillaries unite to form small veins, called **venules**. The venules unite to form veins.

3. Veins

Veins carry blood towards the heart. In adults, all veins carry deoxygenated blood, except of pulmonary veins. The walls of veins are composed of the same three layers as are present in the artery wall i.e., an inner layer of **endothelium**, a middle layer of **smooth muscle** and elastic tissues, and an outer layer of **connective tissue**. In veins, the middle layer is comparatively thin as compared to arteries. It has lesser smooth muscles and elastic tissues. The lumen of the veins is broader than that of arteries. Most veins have **valves** that prevent the back flow of blood.

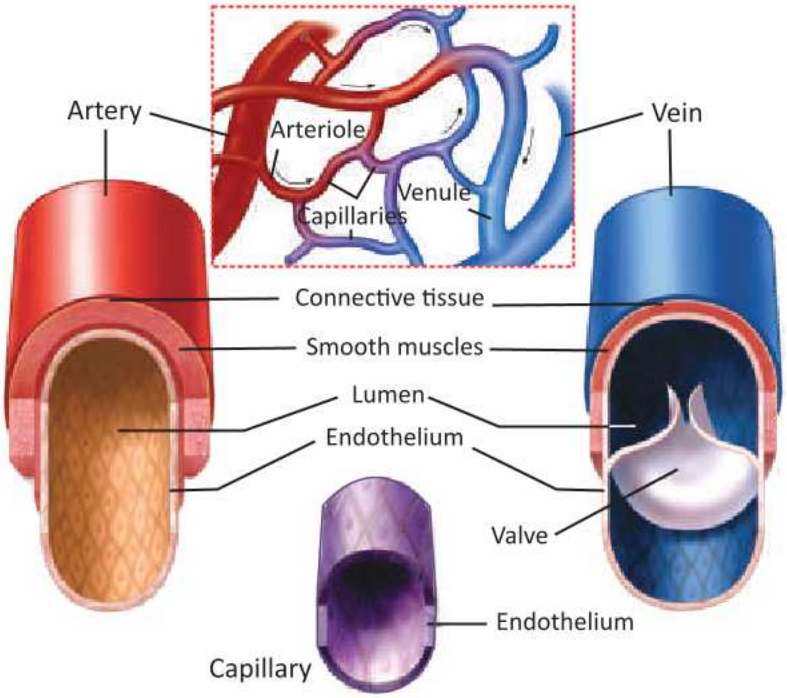
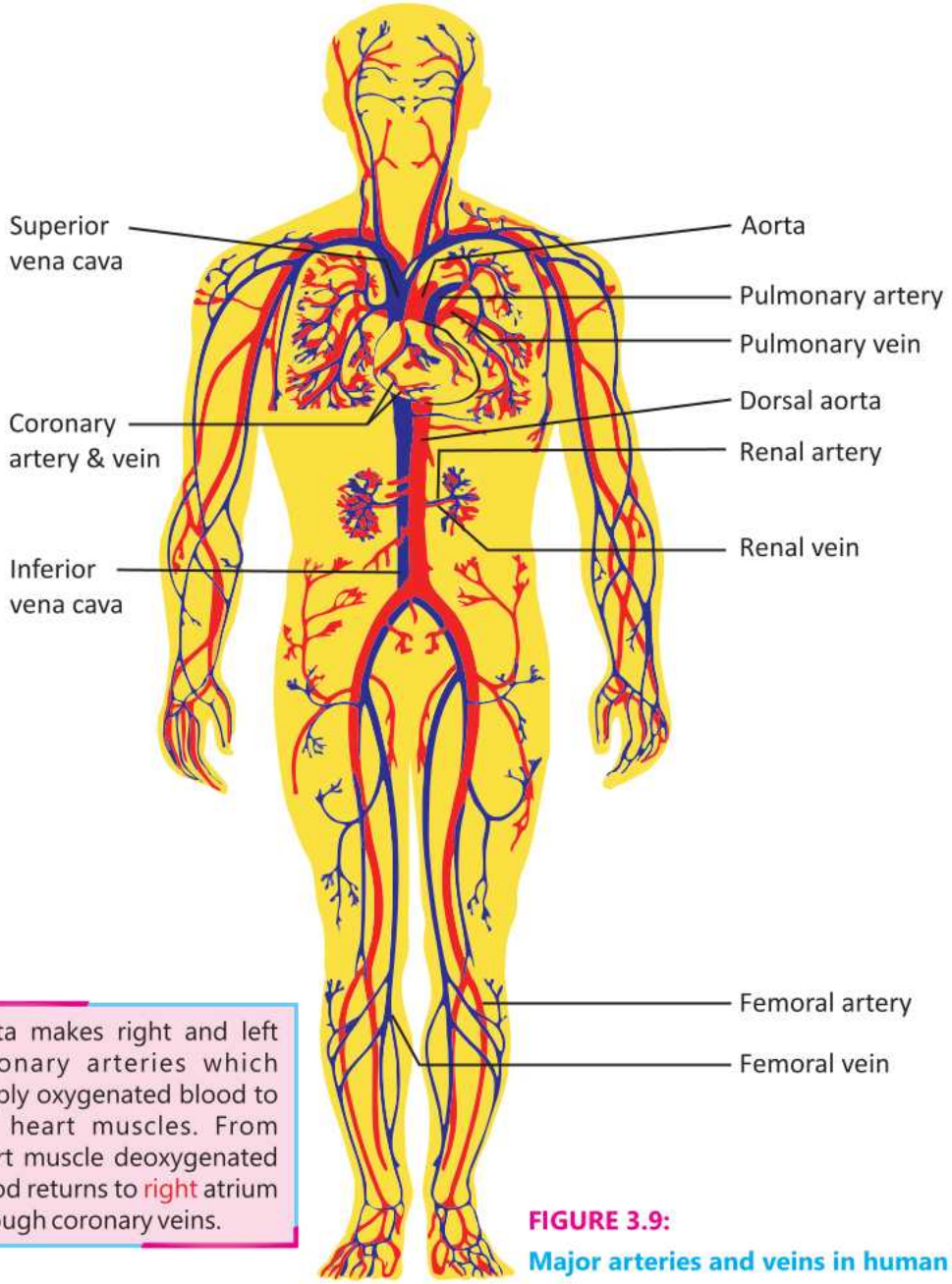


FIGURE 3.8: Blood vessels

3.4 ARTERIAL AND VENOUS SYSTEMS

Arterial System

- **Arteries of Pulmonary circulation:** A large artery called **pulmonary trunk** carries deoxygenated blood from right ventricle. It branches into two smaller pulmonary arteries, each artery supplying blood to each lung.



Aorta makes right and left coronary arteries which supply oxygenated blood to the heart muscles. From heart muscle deoxygenated blood returns to right atrium through coronary veins.

FIGURE 3.9:
Major arteries and veins in human body

- **Arteries of Systemic circulation:** Oxygenated blood is pumped from left ventricle into **aorta**. It forms arteries which supply blood to head, shoulders and arms. Aorta passes through the thorax and becomes **dorsal aorta**. It makes many arteries that supply blood to all parts of the lower region. For example, **hepatic artery** supplies blood to the liver and **renal arteries** supply blood to kidneys. Aorta divides and makes two **femoral arteries** which supply blood to legs.

Venous System

- **Veins of Pulmonary circulation:** Two **pulmonary veins** carry oxygenated blood from lungs to the left atrium of heart.

> Veins are blue-looking, but the blood inside is actually dark red.

- **Veins of Systemic circulation:** Two major veins i.e., superior vena cava and the inferior vena cava carry deoxygenated blood from body to right atrium. The **superior vena cava** is made by joining of veins from head, shoulders and arms. The **inferior vena cava** is made of many veins from parts of the lower region. For example, two **femoral veins** from legs empty into inferior vena cava. **Renal** veins carry blood from the kidneys. The **hepatic portal vein** carries blood from alimentary canal to the liver. From liver, a **hepatic vein** carries blood to the inferior vena cava.

3.5 CARDIOVASCULAR DISORDERS

The diseases that involve the heart or blood vessels are collectively called **cardiovascular disorders** or cardiovascular diseases (CVDs).

1. Coronary Heart Disease (CHD)

It is the narrowing or blockage of the coronary arteries, which supply blood to the heart muscle. This condition is primarily caused by **atherosclerosis** i.e., accumulation of fatty deposits (plaques) inside arteries.

> **Arteriosclerosis** is the general hardening and thickening of arterial walls.
>
> **Atherosclerosis** is a specific type of arteriosclerosis. caused by the build-up of fats, cholesterol, and other substances (plaque) inside the arteries.

Causes: High levels of low-density lipoproteins (e.g., cholesterol) in blood, high blood pressure, smoking, diabetes, sedentary lifestyle.

Symptoms: Asymptomatic in early stages; may lead to chest pain or discomfort as the condition progresses.

> According to the World Health organization (WHO), cardiovascular disorders are responsible for about 32% of all global deaths.
>
> In Pakistan, CVDs contribute to nearly 29% of all fatalities

Risk Factors: Family history, obesity, high blood pressure, high cholesterol levels, and lifestyle factors.

Prevention: Healthy diet, regular exercise, smoking cessation, and management of blood pressure and cholesterol levels.

Complications: If left untreated, CHD can lead to more severe conditions, including myocardial infarction and heart failure.

2. Myocardial Infarction

"Myocardium" means heart muscle. "Infarction" means tissue death. The death of heart muscles is called myocardial infarction. It is commonly known as a **"heart attack"**. It occurs when blood flow to a part of the heart muscle is blocked for a prolonged period, leading to death of the heart muscle.

Sometime heart attack occurs without symptoms. It is called **silent heart attack.** It is more common in the elderly and in patients with diabetes

Causes: A blockage in one or more coronary arteries often caused by a blood clot that forms over atherosclerotic plaques.

World Heart Day is held on 29 September every year. Its objective is to give awareness to common people about the risks of cardiovascular disorders.

Symptoms: Chest pain, tightness, and pressure; shortness of breath; sweating; pain radiating to the arm, neck, or jaw.

Treatment: Emergency treatment (medicines to dissolve clots), angioplasty to open blocked arteries, and stenting to keep arteries open.

Complications:

Heart failure, arrhythmias (irregular heartbeats), and sudden cardiac arrest.

Prevention:

Maintaining weight with a healthy diet; avoid smoking; exercise regularly; control blood pressure, cholesterol and diabetes.

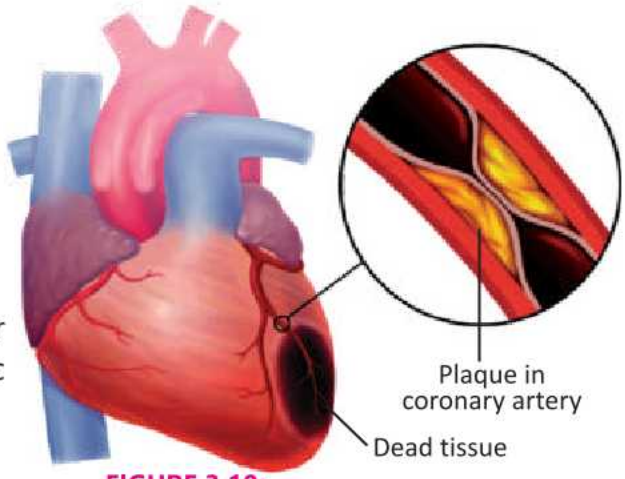


FIGURE 3.10: Atherosclerosis and resulting Myocardial infarction

3. Angina Pectoris

Angina Pectoris (commonly called Angina) is chest pain or discomfort caused by reduced blood flow to the heart muscle, typically due to coronary

artery disease. Angina is a symptom of CHD and often indicates that the heart is not getting enough oxygen.

Symptoms: Chest pain or discomfort, chest pressure, squeezing, or heaviness. Pain can radiate to the shoulders, neck, or arms.

Treatment: Lifestyle changes, medications, procedures like angioplasty or stent placement.

Complications: If untreated, can progress to myocardial infarction and increase the risk of heart failure.

Harmful Effects of Smoking Related to Heart Diseases

Smoking is the major risk factor for the development of heart diseases. Here's an overview of how smoking adversely impacts heart health:

1. **Increased Risk of Atherosclerosis:** Smoking accelerates atherosclerosis by damaging the endothelium of arteries.
2. **Increased Risk of Blood Clot Formation:** Smoking increases the chances for blood to clot by promoting platelet aggregation. The clots that can block coronary arteries and lead to myocardial infarction.
3. **Elevated Blood Pressure:** Smoking contributes to elevated blood pressure by causing vasoconstriction.
4. **Heart Rate and Rhythm Abnormalities:** Arrhythmias are irregular heartbeats that can be dangerous. Smoking affects heart rhythm by increasing heart rate.

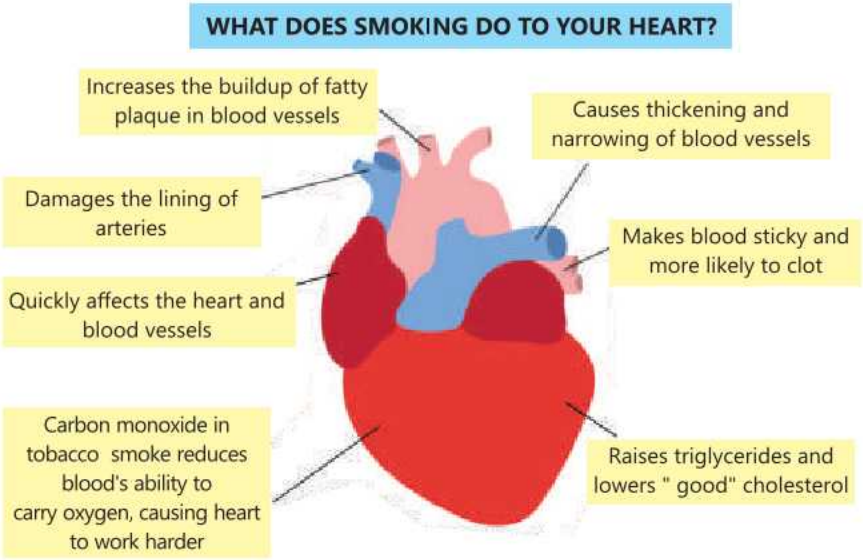


FIGURE 3.11: Public awareness poster on "Effects of Smoking on Heart"

5. **Reduced Oxygen Delivery:** Carbon monoxide from cigarette smoke binds to haemoglobin in RBCs more effectively than oxygen, reducing the blood's oxygen-carrying capacity.

6. **Impact on Overall Cardiovascular Health:** Smoking contributes to the narrowing of arteries in the legs, which can further strain the heart.

EXERCISE

A. Select the correct answers for the following questions.

1. Which component of blood is mainly responsible for carrying oxygen?
   a) White blood cells b) Platelets
   c) Red blood cells d) Plasma
2. A person with low platelet count is likely to face difficulty in:
   a) Fighting infections b) Breathing
   c) Clotting blood d) Transporting oxygen
3. Which of the following layer is found in all blood vessels?
   a) Smooth muscle b) Endothelium
   c) Skeletal muscle d) Connective tissue
4. Which of the following contains deoxygenated blood in an adult human?
   a) Left atrium b) Pulmonary artery
   c) Pulmonary vein d) Aorta
5. When fibrinogen makes blood clot it separates from blood and the rest is;
   a) Plasma b) Lymph c) Serum d) Pus
6. Which heart chamber has the thickest walls?
   a) Right atrium b) Left atrium c) Left ventricle d) Right ventricle
7. The exchange of materials between the blood and tissues occurs in;
   a) Arteries b) Veins
   c) Capillaries d) Arteries and veins
8. All veins carry deoxygenated blood except the _____ vein.
   a) Vena cava b) Hepatic portal
   c) Pulmonary d) Renal
9. Myocardial infarction is due to blockage of blood flow in;
   a) Aorta b) Pulmonary artery
   c) Coronary artery d) Hepatic artery

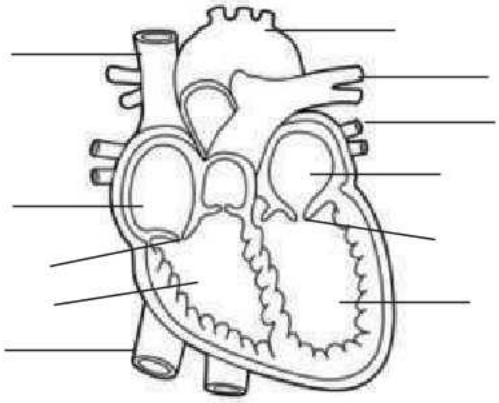
10. If the bicuspid valve is damaged, which flow of blood will be affected?

a) From left atrium to left ventricle b) From right atrium to right ventricle

c) From left ventricle to aorta d) From lungs to left atrium

B. Write short answers.

1. List the types of cells present in blood along with their functions.
2. Differentiate between atria and ventricles.
3. Trace the flow of blood from the vena cava to various body parts.
4. Identify the causes and treatments of myocardial infarction.
5. Colour the following diagram of heart to show oxygenated and deoxygenated blood. Label the different structures as marked.

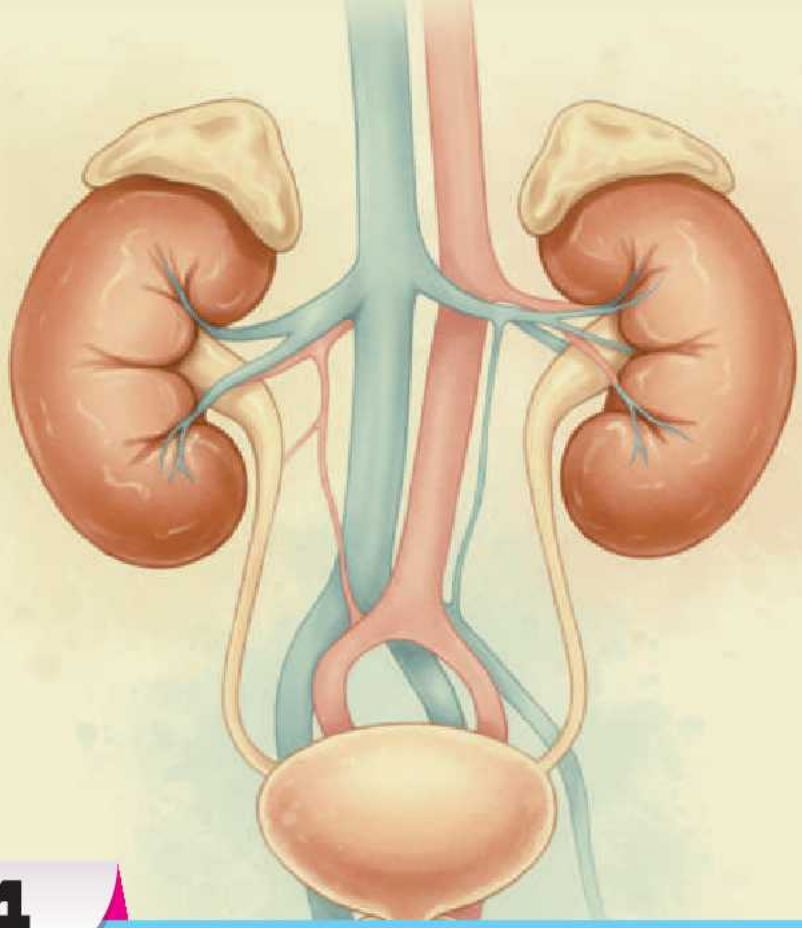


C. Write answers in detail.

1. Describe the functions of the components of blood.
2. Explain how blood transports materials throughout the human body.
3. Explain the structure of the heart with a diagram.
4. Explain the harmful effects of smoking related to heart diseases.
5. Compare the structure and function of an artery, a vein and a capillary.

D. Inquisitive questions

1. Why is oxygenated blood separated from deoxygenated blood in heart?
2. How does regular exercise strengthen the circulatory system?
3. How can lifestyle choices prevent cardiovascular diseases?
5. If cholesterol levels in the blood are never regulated, how can it impact the heart and blood vessels over time?



4 HUMAN URINARY SYSTEM

Students Learning Outcomes

After studying this chapter, students will be able to:

- Identify the different organs of urinary system.
- Relate the structure of the kidney with its function.
- State that nephron is the excretory unit of kidney.
- Locate the different parts of nephrons and relate them with their function.
- State that main role of the kidney is urine formation.
- Describe that urine formation involves three processes i.e., filtration, reabsorption and secretion.
- Explain that the kidney plays an important role in osmoregulation.
- Identify the causes and treatment of kidney stones.
- Outline the causes of kidney failure and treatments.

The urinary system regulates the internal environment of body. It ensures that waste products and excess substances are removed from body. In this chapter, we will study the structure and functions of the human urinary system and the related kidney disorders.

4.1 HUMAN URINARY SYSTEM

The human **urinary system** (excretory system) consists of a pair of kidneys, a pair of ureter, a urinary bladder and a urethra. **Kidneys** remove extra water, salts and nitrogenous wastes from blood and make urine. From each kidney, a tube called **ureter** carries urine to the urinary bladder. The **urinary bladder** temporarily stores urine. The **urethra** is the tube that carries urine from the urinary bladder to the outside.

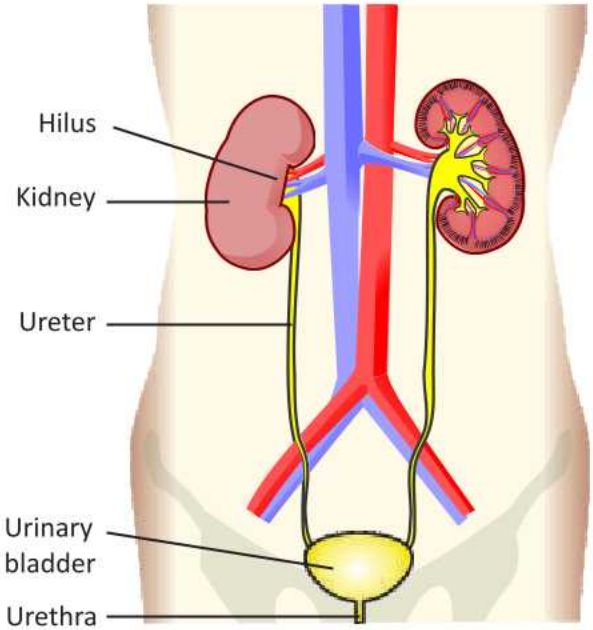


FIGURE 4.1: The Urinary System

The Kidneys

Kidneys are the major organs of urinary system. Renal arteries supply them blood with metabolic wastes (e.g., urea, extra water and salts). Kidneys filter these wastes from blood and then excrete them in the form of urine.

Kidneys are bean-shaped organs having a concave and a convex side. They are present in the abdominal cavity, below the diaphragm, on the sides of vertebral column. The concave side of each kidney is towards vertebral column. The left kidney is a little higher than the right. Kidneys are dark-red in colour. Each kidney is about 10 cm long, 5 cm wide and 4 cm thick.

Structure of the Kidney

External structure: Kidney is surrounded by a tough tissue called **renal capsule**. On the concave side of kidney, there is a depression called **hilus**. It is the point from where renal artery enters in kidney and renal vein and ureter leave kidney.

Internal structure: Internally, a kidney is divided into two regions. The outer region is called **renal cortex** while the inner one is called **renal medulla**. There are many cone-shaped areas in renal medulla, called **renal pyramids**. The base of each pyramid faces the renal cortex while its tip is in a cavity called **renal pelvis**. It extends to outside of kidneys and forms a ureter.

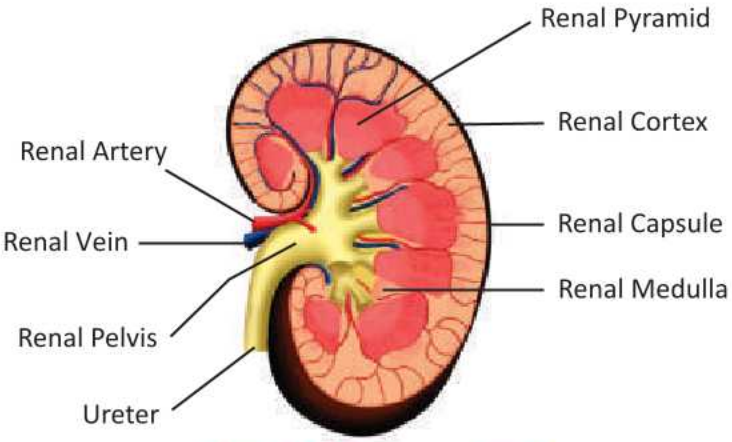


FIGURE 4.2: Structure of kidney

Nephron

The functional unit of kidney are called **nephrons**. There are more than one

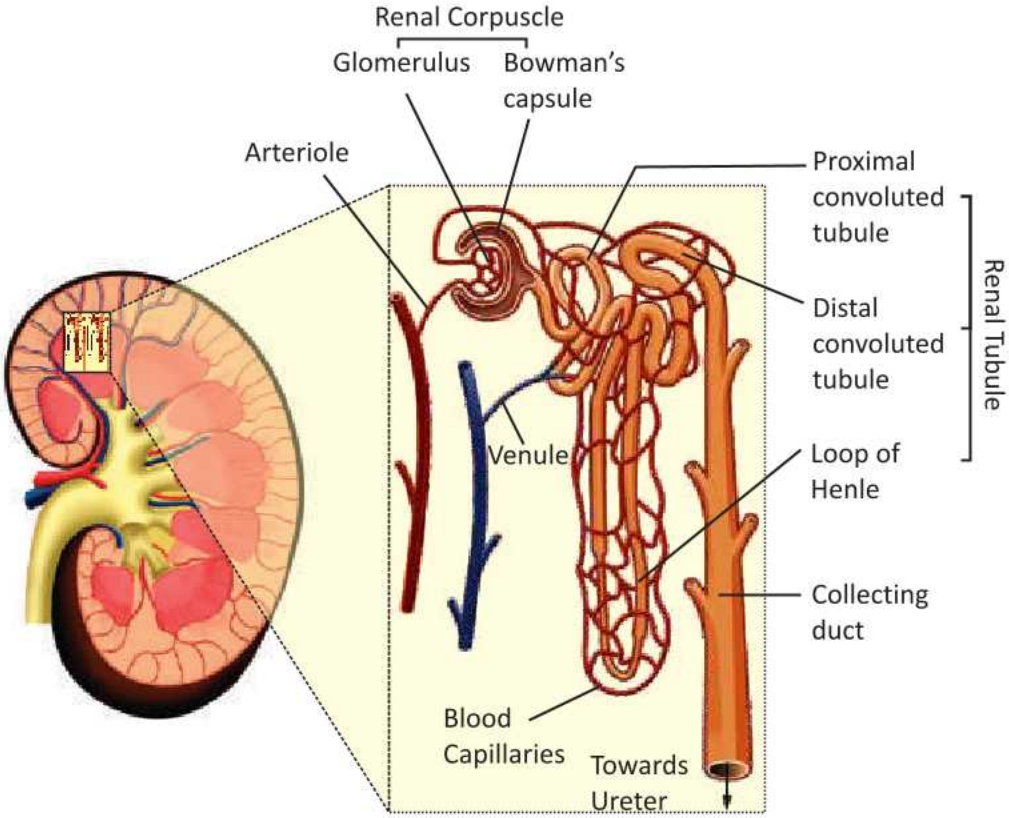


FIGURE 4.3: The Structure of Nephron

million nephrons in each kidney. A nephron consists of two parts i.e., renal corpuscle and renal tubule.

1. **Renal corpuscle:** It is the first part of nephron and is composed of glomerulus and the Bowman's capsule. The **glomerulus** is a network of capillaries while the **Bowman's capsule** is the cup-shaped structure around the glomerulus.
2. **Renal tubule:** It is a long tube attached with the Bowman's capsule. It has three parts. The first part is convoluted and is called the **proximal convoluted tubule**. The middle part is U-shaped and is called the **Loop of Henle**. The last part is again convoluted and is called the **distal convoluted tubule**.

The distal convoluted tubules of many nephrons open in a single **collecting duct**. Many collecting ducts join together and open into the renal pelvis.

4.2 FUNCTIONING OF THE KIDNEY

Kidneys control the chemical composition of blood. They take waste materials from blood and convert them to urine. It occurs in three steps.

1. Pressure Filtration

Blood enters kidney through a renal artery. The artery divides into many arterioles. Each arteriole divides into the capillaries of glomerulus. When blood reaches glomerulus, its pressure is very high. So, many small molecules (water, salts, glucose and urea etc.) move out of the glomerulus. These materials enter Bowman's capsule. This step is called **pressure filtration**. The filtered material in Bowman's capsule is called **glomerular filtrate**. It is about 20% of the blood plasma that enters the glomerulus.

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

2. Reabsorption

The glomerular filtrate moves to the next part of nephron i.e., renal tubule. Many useful materials are reabsorbed from glomerular filtrate into the blood capillaries surrounding the renal tubule.

- Large amount of water, nearly 100% of glucose and amino acids, and most of the salts are reabsorbed from proximal convoluted tube.
- Some water is reabsorbed from descending limb of the loop of Henle. Large amounts of salts are reabsorbed from ascending limb of the loop of Henle.

- Some water is also reabsorbed from distal convoluted tubule and collecting duct.

3. Tubular Secretion

When useful materials are reabsorbed into blood, some of the remaining wastes present in blood are secreted from blood capillaries to renal tubule. It is an active transport process and is called tubular secretion.

After reabsorption and tubular secretion, the filtrate in the renal tubules is known as **urine**. Urine from all nephrons moves to the renal pelvis. From renal pelvis, urine moves to the urinary bladder via ureters. Here it is stored. When the urinary bladder is filled, urine is passed out through urethra.

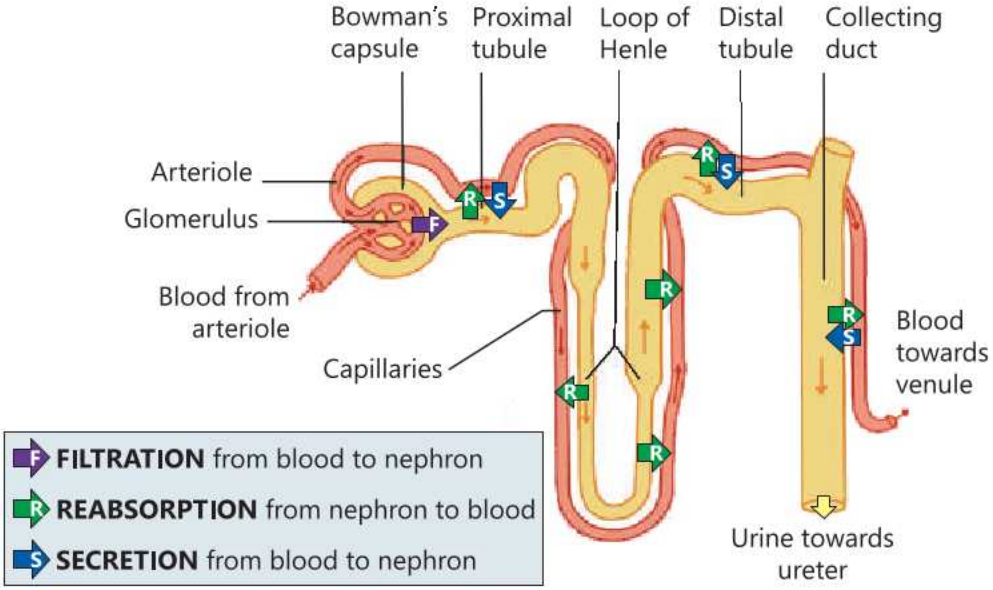


FIGURE 4.4: Functioning of Kidney

Role of Kidneys in Osmoregulation

Osmoregulation means the control of the amount of water according to body's needs. Kidneys are the main organs which work for osmoregulation. They control the amount of solutes in blood. So, the amount of solutes in other body fluids is also controlled.

- **Diluted Urine:** If there is excess water in blood, more water is filtered from the glomerulus to Bowman's capsule. There is less reabsorption of water from renal tubule to capillaries. In this way, abundant dilute urine is produced and the amount of water in blood is brought to normal.
- **Concentrated Urine:** If the amount of water in blood is less than normal,

less water is filtered from the glomerulus to Bowman's capsule. There is more reabsorption of water from renal tubule to capillaries. In this way, concentrated urine is produced and the water is retained in blood.

4.3 DISORDERS OF KIDNEY

1. Kidney Stones

Sometimes, the filtered minerals and salts (e.g., calcium oxalate, calcium and ammonium phosphate, and uric acid etc.) gather in kidneys and make hard, crystalline deposits. Such deposits cannot pass in urine and are called **kidney stones**. Some stones may leave kidneys and may be trapped in ureter or urinary bladder.

Symptoms: Severe pain in kidney or lower abdomen, burning in urethra, frequent urination, foul-smelling urine, blood and pus in urine, nausea, vomiting, bloating.

Causes: Presence of more calcium oxalate, calcium and ammonium phosphates in diet (green vegetables, fats, dairy products), extra amounts of vitamins C and D in diet, reduced water intake, excess uric acid in blood, urinary tract infections, and alcohol consumption.

Treatment: If kidney stones are small in size, the patient is advised to drink plenty of water so that stones can pass through the urine.

Lithotripsy is another method for the removal of kidney stones. In lithotripsy, non-electric shock waves are fired on kidney from outside. The waves hit the stones and break them into smaller pieces, which pass out through urine.

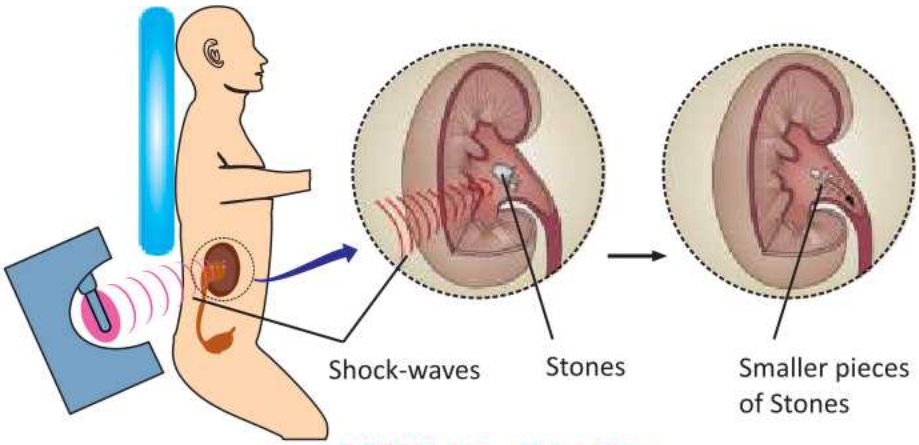


FIGURE 4.5: Lithotripsy

If stones are large and cannot pass easily, the patient has to undergo **surgery** for the removal of stones.

2. Kidney (Renal) Failure

When one or both kidneys are not able to perform their function (removing waste materials from blood and then passing them out), the condition is called kidney failure.

Symptoms: Increases concentration of wastes in blood, rise in volume of body fluids, weight loss, and blood in urine, swelling in legs, feet and face.

Causes: Long-term diabetes mellitus, and hypertension, dehydration, severe kidney infections, overuse of certain medicines (e.g., nonsteroidal anti-inflammatory drugs - NSAIDs), large kidney stones, physical damage to kidneys, heart or liver failure.

Treatment of Kidney Failure

a. Dialysis

Dialysis is a method in which wastes are extracted from blood by using a **dialysis fluid**. There are two methods of dialysis.

1. Haemodialysis: In haemodialysis, the patient's blood is pumped through a machine called **dialyzer**. The dialyzer contains long tubes. Blood flows inside the tubes while dialysis fluid flows outside. Extra water and wastes move from blood and enter the dialysis fluid. The purified blood is then returned back to the body.

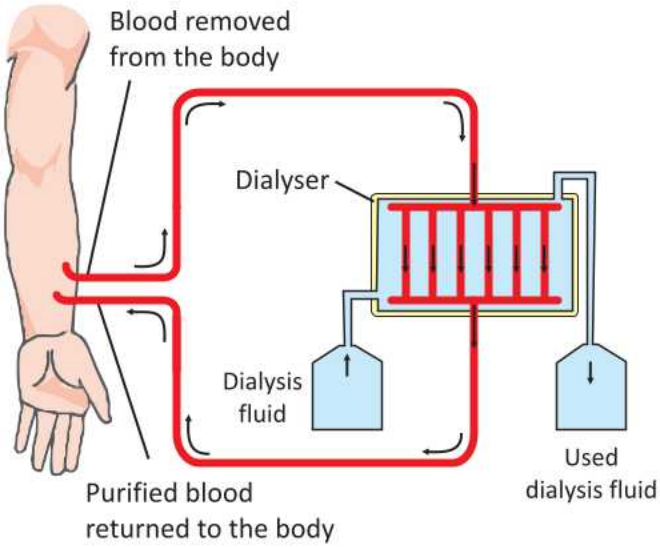


FIGURE 4.6: Haemodialysis

2. Peritoneal Dialysis: In this method, dialysis fluid is pumped into the peritoneal cavity (the space around gut in abdomen). The walls of peritoneal cavity are lined with peritoneal membrane. The wastes pass from the blood present in blood vessels of peritoneal membrane into the dialysis fluid. After some time, the dialysis fluid is drained.

b. Kidney Transplantation

Kidney transplantation is done for advanced treatment of kidney

In Punjab, organ transplantation is controlled by **Punjab Human Organ Transplant Authority**. It ensures that people can have suitable transplantation with safety and quality.

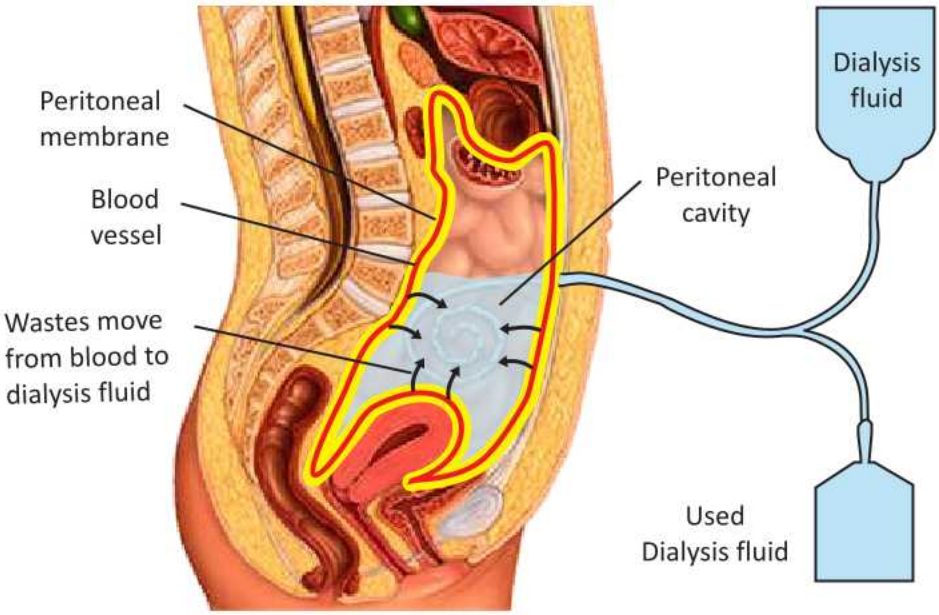


FIGURE 4.7: Peritoneal Dialysis

failure. In this treatment, a healthy kidney from some donor is transplanted in patient's body, along with the damaged kidney. The donor of kidney may be a deceased person or a living one. Living-donor may or may not be a relative of the patient. In all cases, the donor's kidney is matched with the patient's immune system. When a matching kidney is transplanted, it may work normally in patient's body for ten to fifteen years.

EXERCISE

A. Select the correct answers for the following questions.

1. The process of regulating the amount of water in body fluid is called;
   a) Filtration b) Reabsorption
   c) Tubular secretion d) Osmoregulation
2. What happens in the proximal convoluted tubule of nephron?
   a) Blood is filtered by glomerulus
   b) Reabsorption of water and nutrients occurs
   c) Urine is stored
   d) Water is secreted into the bloodstream
3. Which structure is responsible for filtering blood to produce urine?
   a) Nephron b) Renal pelvis c) Ureter d) Renal capsule

4. Which structure in nephron is responsible for filtering blood?

a) Loop of Henle
b) Glomerulus
c) Proximal convoluted tubule
d) Distal convoluted tubule

5. In which part of nephron, the reabsorption of nutrients occurs?

a) Glomerulus
b) Proximal convoluted tubule
c) Loop of Henle
d) Distal convoluted tubule

6. Which process in nephron involves the active transport of materials from blood into nephron?

a) Filtration
b) Reabsorption
c) Secretion
d) Excretion

7. Which is NOT present in the filtrate entering the Bowman's capsule of nephron?

a) Water
b) Calcium ions
c) Blood cells
d) Urea

8. In which procedure a machine is used to filter blood outside the body?

a) Peritoneal dialysis
b) Haemodialysis
c) Lithotripsy
d) Renal surgery

9. What is the primary purpose of haemodialysis?

a) To rehydrate the body
b) To replace lost nutrients
c) To filter waste products from blood
d) To regulate blood pressure

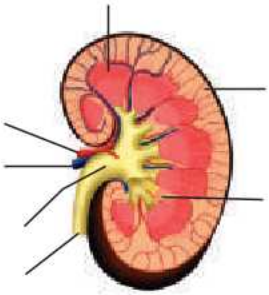
10. In peritoneal dialysis, what acts as the filtering membrane?

a) Dialysis machine
b) Renal cortex
c) Peritoneal membrane
d) Renal tubules

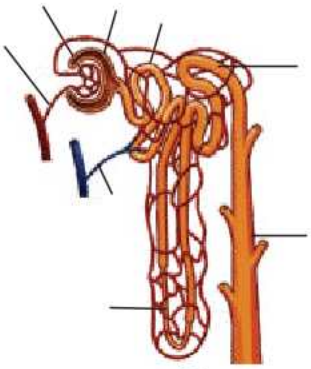
B. Write short answers.

1. Enlist the main parts of the human urinary system.
2. Briefly describe how kidneys control the composition of blood.
3. Name the major parts of a nephron.
4. What materials in diet can cause kidney stones?
5. What do you mean by lithotripsy?
6. Define kidney failure. Name the treatments for kidney failure.

7. Differentiate between:
   i. Excretion and osmoregulation
   ii. Renal cortex and renal medulla
   iii. Renal corpuscle and renal tubule
   iv. Pressure filtration and tubular secretion
   v. Haemodialysis and peritoneal dialysis
8. Label the parts of the diagrams (A) and (B):



(A)



(B)

C. Write answers in detail.

1. Write a note on the structure of kidney.
2. Describe the structure of a nephron and draw a labelled diagram.
3. Describe the process of pressure filtration and re-absorption in kidneys.
4. What is tubular secretion? How it helps in removing wastes from blood?
5. Write a comprehensive note on kidney stones describing the causes, symptoms and treatments.
6. Write down the symptoms and causes of kidney failure.
7. Define dialysis and describe the processes of peritoneal dialysis and haemodialysis.

D. Inquisitive questions

1. "Along with excretion, kidneys also play role in osmoregulation." Comment on this statement.
2. How does the nephron ensure that essential nutrients are not lost in urine?
3. Why is long loop of Henle important in the balance of water and salts in body?
4. How can chronic diseases like diabetes lead to kidney failure?

5

COORDINATION

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe the nervous system and its role.
- Discuss the central nervous system and peripheral nervous system.
- Outline the types of neurons with diagrams.
- Define a stimulus with examples.
- State that nerve impulses are electrical signals that travel across neuron.
- Define and sketch synapses.
- Introduce neurotransmitters.
- Explain through sketching a diagram the involvement of the nervous system when a person accidentally touches something painfully hot and withdraws their hands as a reflex.
- Explain the endocrine system.
- Identify the major endocrine glands and hormones with their functions.

BACKGROUND INFORMATION

Coordinated Action: A coordinated action has five components;

1. Stimulus

Any change in external or internal environment, which can initiate a response in the body, is called a stimulus. For example, touch, light, sound, heat, cold, pressure, infection etc. are the stimuli.

2. Receptor

The organ, tissue or cell which receives stimuli is called the receptor. For example, ears are the receptors for the stimulus of sound. Receptors send the messages of stimulus to coordinators.

> The junction between two neurons and between a neuron and another cell is called **synapse**.

3. Coordinator

A coordinator receives information from receptors and sends impulses to particular organs for proper action. In nervous coordination, **brain** and **spinal cord** are coordinators. In chemical coordination, **endocrine glands** are the coordinators.

4. Effector

These are the parts of the body which receive coordinator's message and perform specific actions. In nervous coordination, **muscles** and **glands** are the effectors. While in chemical coordination, different tissues of the body act as effectors.

5. Response

A response is the action performed by effectors, on receiving the message from coordinator. For example, pulling our hand away from something very hot.

Coordination means integration among different parts of the body and their response to stimuli in order to keep harmony with the environment. Coordination occurs in all living organisms. Animals possess two systems for this function i.e., nervous system and endocrine system.

5.1 NEURONS – THE UNITS OF NERVOUS SYSTEM

Neurons or nerve cells are the cells that transmit impulses in the body in the form of nerve impulses.

Nerve Impulse: It is a wave of electrochemical change that travels across the membrane of a neuron.

Structure of Neuron

A neuron consists of three major parts i.e., cell body, dendrites and axon. The **cell body** contains the nucleus, other organelles and most of the cytoplasm. Small branches which project from the cell body are called **dendrites**. They transmit nerve impulses towards cell body. **Axon** is a long branch from cell body. Its terminal end is further branched. Axon transmits nerve impulses from cell body to other neurons, muscles, or glands.

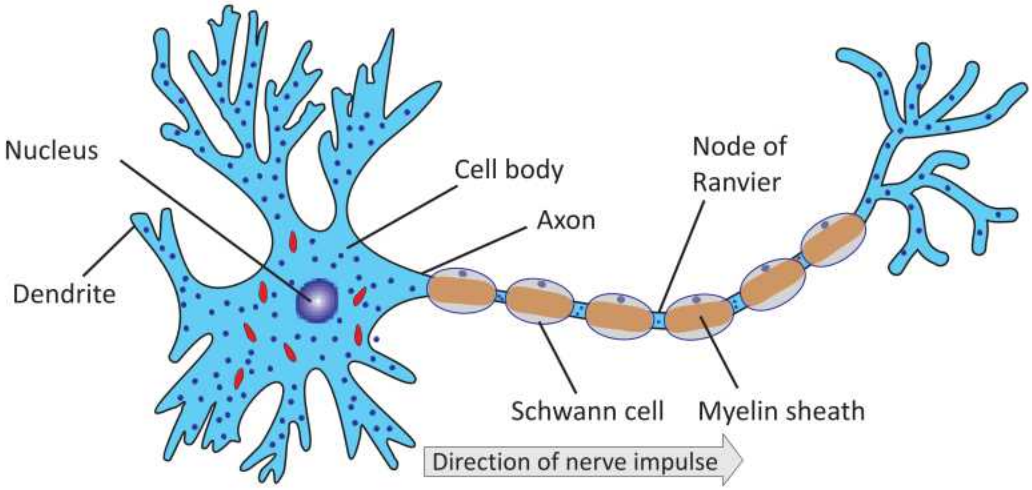


FIGURE 5.1: A Model Neuron (Motor Neuron)

Neurons are supported by specialized cells, called **neuroglia. Schwann cells** are a type of neuroglia. In many neurons, Schwann cells produce insulating covering called **myelin sheath** over the membrane of axon. Axons which are covered by myelin sheath are called myelinated. The axons which are not covered with myelin sheath are called non-myelinated. The myelin sheath is interrupted at intervals by small gaps called **nodes of Ranvier**. In myelinated neurons, nerve impulses 'jump' from node to node. This increases the speed of nerve impulse.

> In the Central Nervous System (CNS), myelinated axons form the **white matter**, and the non-myelinated axons, dendrites and cell bodies form the **grey matter**

Synapse and Neurotransmitters

A synapse is a small gap between two neurons or between a neuron and an effector cell. When nerve impulse reaches the end of a neuron, it cannot jump directly to the next neuron or effector. Neurotransmitters are special chemicals that help to carry messages across a synapse.

When a nerve impulse reaches the end of a neuron, it releases

neurotransmitters. They travel across the synapse and attached to the dendrite next neuron or effector cell. It helps the nerve impulse to continue its journey. Examples of neurotransmitters include dopamine, serotonin and acetylcholine.

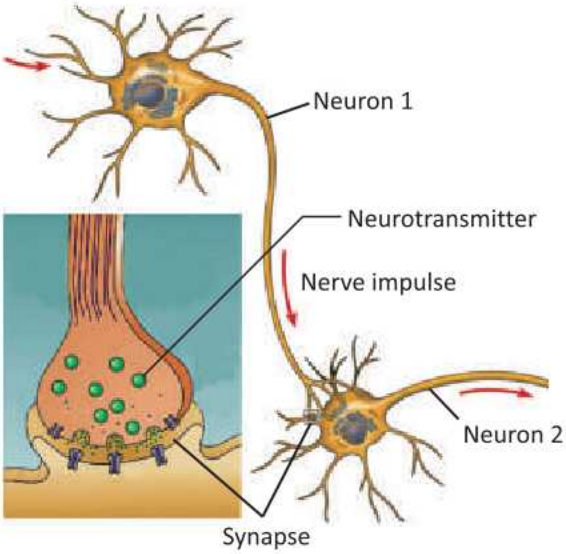


FIGURE 5.2: Synapse

Types of Neurons

1. **Sensory neurons** transmit nerve impulses from receptors to the CNS.
2. **Inter-neurons** are present in brain and spinal cord. They receive impulses from sensory neurons and transmit them to motor neurons.
3. **Motor neurons** transmit nerve impulses from inter-neurons to effectors (muscle or glands).

In certain parts of body, the cell bodies of neurons form groups enveloped by membranes. The groups of cell bodies are called **ganglia** (*Singular:* **ganglion**).

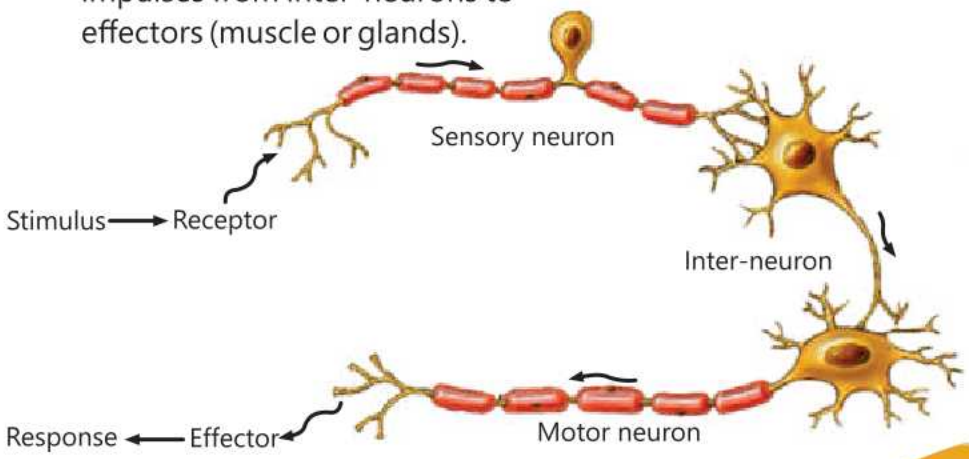


FIGURE 5.3: Types of Neuron

Nerve

A nerve is collection of axons that are enveloped by a covering of connective tissue. Nerves arise from brain and spinal cord and make the **Peripheral Nervous System (PNS)**. There are three types of nerves, on the basis of axons present in them. **Sensory nerves** contain the axons of

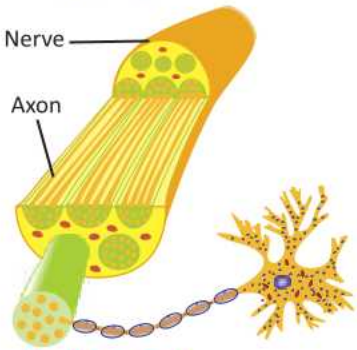


FIGURE 5.4: Nerve

sensory neurons only. **Motor nerves** contain the axons of motor neurons only. **Mixed nerves** contain the axons of sensory and motor neurons.

5.2 DIVISIONS OF THE NERVOUS SYSTEM

There are two major components of nervous system i.e., **central nervous system (CNS)** and **peripheral nervous system (PNS)**. The CNS comprises of brain and spinal cord. The PNS consists of nerves that arise from brain and spinal cord and spread in different parts of body.

All these components are made of neurons and supporting (neuroglial) cells.

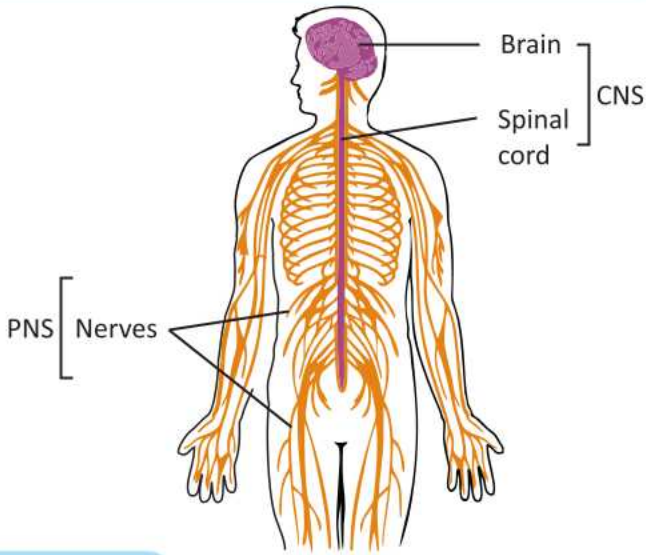


FIGURE 5.5: CNS and PNS

1. Central Nervous System (CNS)

The central nervous system consists of brain and spinal cord.

A. Brain

All life activities are under the control of brain. Brain is present inside **cranium** (part of skull). Inside cranium, brain is covered by three layers of membranes, collectively called **meninges**. Meninges protect the brain from harmful substances. Brain contains fluid-filled cavities called **ventricles**. The ventricles of brain are continuous with the central canal of spinal cord. Fluid within ventricles and central canal is called **cerebrospinal fluid** (CSF). The brain can be divided into three major parts: forebrain, midbrain and hindbrain.

> The average adult human brain weighs 1.4 kg, or about 2% of total body weight. It contains about 100 billion neurons.

1. Forebrain

It is the largest area of brain. Following are the major parts of this region.

(i)- Cerebrum is the largest part of forebrain. A deep groove (longitudinal fissure) divides the cerebrum into right and left **cerebral hemispheres**.

The upper layer of both hemispheres is highly folded and is called cerebral cortex. It is made of

> Each hemisphere receives information from the opposite side of the body and sends message to that side. For example, the sensation of a touch on the right hand is received by the left hemisphere.

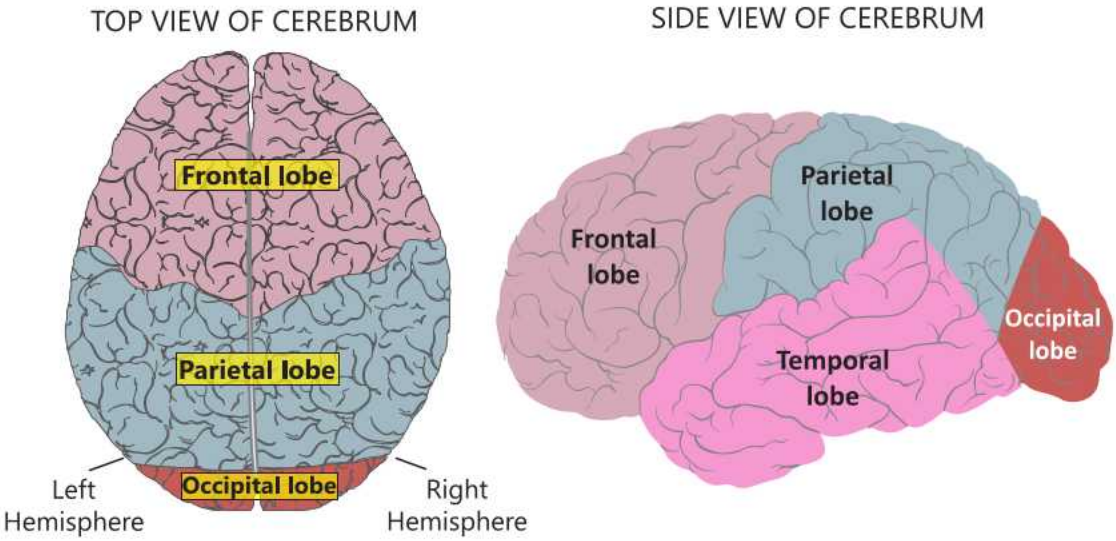


FIGURE 5.6: Cerebral hemispheres and the 4 lobes

grey matter (containing cell bodies and non-myelinated axons). The material beneath cortex is **white matter** (containing myelinated axons).

Each hemisphere is further divided into four lobes. The **frontal lobe** contains regions for problem solving, judgment, speaking, and movements. The **parietal lobe** has regions for language and touch. The **temporal lobe** contains regions which deal with memory, learning, feelings, and hearing. The **occipital lobe** has regions for vision and color perception.

(ii)- Thalamus is a structure wrapped by the cerebrum. It conveys information coming from receptors to the cerebrum. Thalamus is also involved in pain perception and consciousness.

(iii)- Hypothalamus lies above midbrain and just below thalamus. In humans, it is about the size of an almond. It regulates body temperature, hunger, thirst, sleep, and emotional states. It also controls the secretions of the major endocrine gland i.e., **pituitary gland**.

2. Midbrain

The midbrain is located between forebrain and hindbrain. So, it is a bridge between these two parts. It conveys information between them. It also enables the body to make adjustments to movements. It is also responsible for sleep/wake, alertness and temperature regulation.

> Medulla oblongata, pons, and midbrain connect the rest of brain to spinal cord. They are collectively called **brain stem**.

3. Hindbrain

Hindbrain controls all automatic body functions. It consists of three parts.

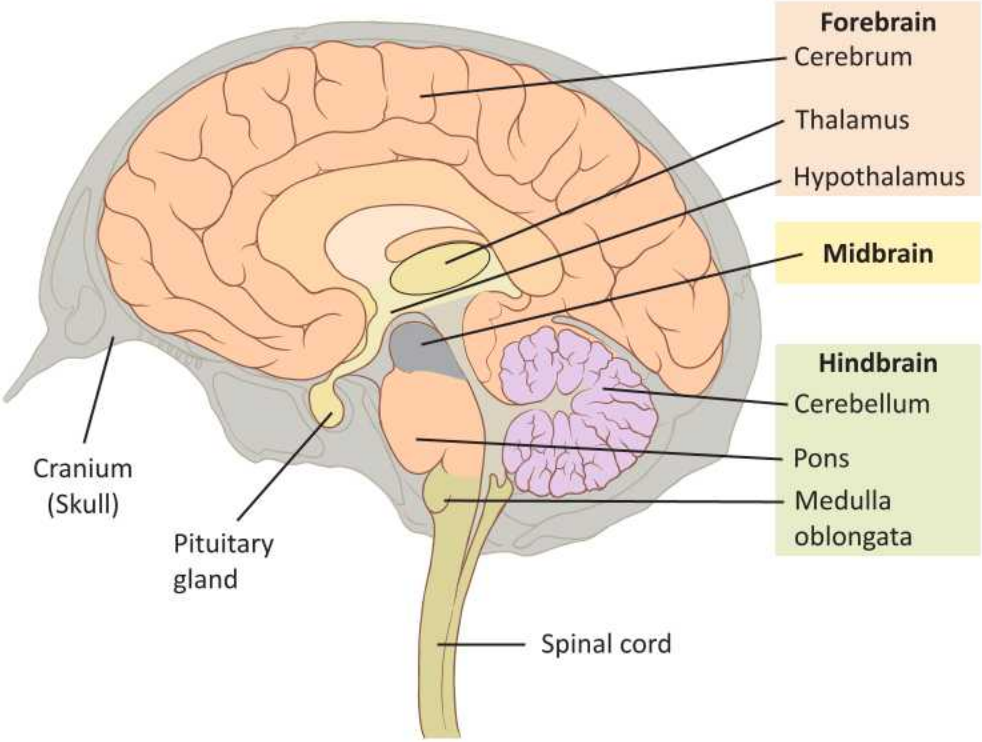


FIGURE 5.7: Structure of brain

(i)- Medulla oblongata is on the top of the spinal cord. It transmits impulses between spinal cord and the higher parts of brain. It controls autonomic functions such as heartbeat, heart rate, breathing and blood pressure. It also controls reflexes such as vomiting, coughing, sneezing.

(ii)- Cerebellum is behind medulla oblongata. It is the second largest part. Its surface is highly folded. It coordinates balance and muscle movements.

(iii)- Pons is present on top of the medulla. It makes connections between the spinal cord and cerebellum, and between cerebrum and cerebellum. It also regulates alertness, sleep, and wakefulness.

B. Spinal Cord

It is a tubular bundle of nerves that starts from brain and extends to lower back. It is located in vertebral column. It is also covered by **meninges**. Spinal cord transmits impulses between brain and body parts. It also acts as a coordinating centre for some simple reflexes.

The outer region of spinal cord is made of **white matter**. The central region is made of **grey matter**. It is butterfly shaped and surrounds the central canal. Thirty-one pairs of spinal nerves arise from spinal cord. All the spinal nerves are **"mixed"** nerves because each contains axons of both sensory and

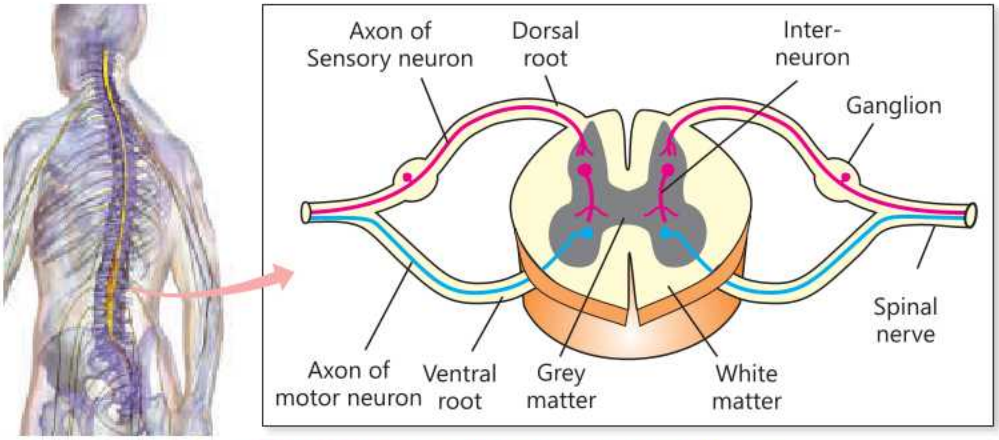


FIGURE 5.8: Spinal Cord and Spinal Nerves

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

2. Peripheral Nervous System (PNS)

It is composed of nerves and their ganglia. Humans have 12 pairs of **cranial nerves** and 31 pairs of **spinal nerves**. Some cranial nerves are sensory,

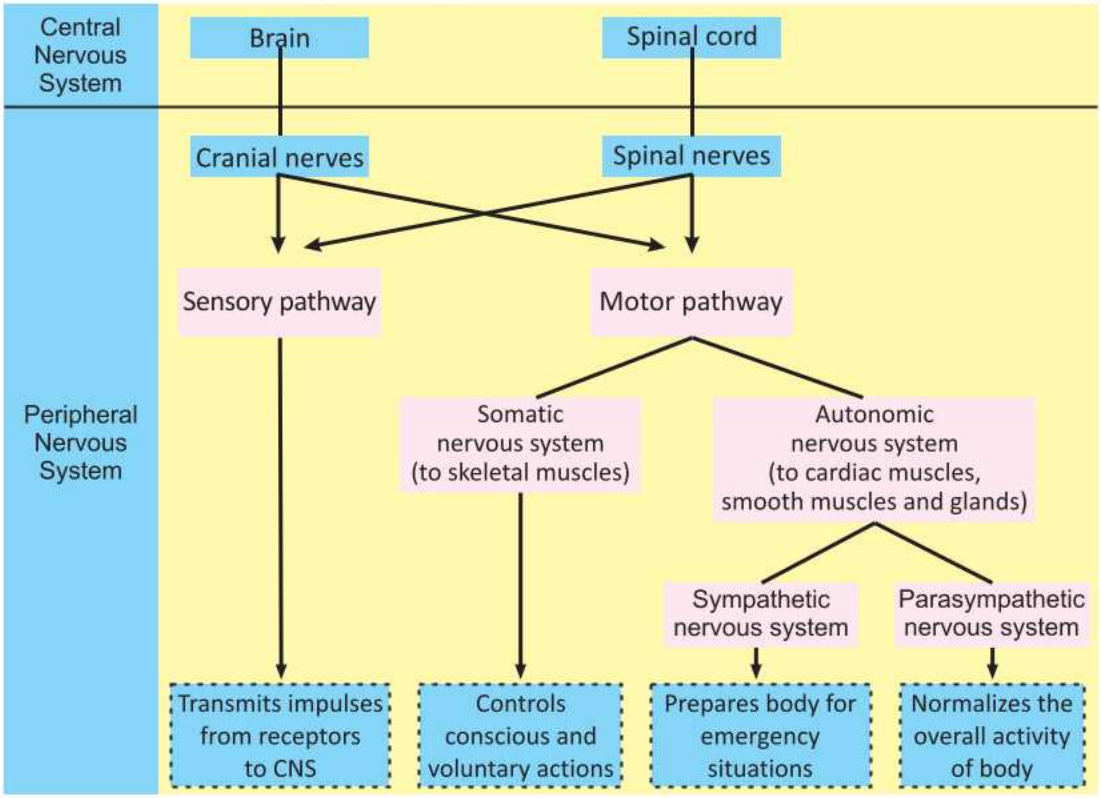


FIGURE 5.9: The Divisions of Nervous System

some are motor and some are mixed. On the other hand, all spinal nerves are mixed. 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 controls conscious and voluntary actions. It includes all of the motor neurons that are connected to skeletal muscles.

Autonomic Nervous System: It consists of motor neurons that are connected to cardiac muscles, smooth muscle and glands. It is generally without conscious control. Autonomic nervous system consists of sympathetic and parasympathetic systems. **Sympathetic** nervous system prepares body in emergency situations. This is often called the **"fight or flight"** response. This system dilates pupils, speeds up heartbeat, increases breathing rate and inhibits digestion. When there is no stress, **parasympathetic** nervous system normalizes the activity of body. It is called **"rest and digest"** response. It causes pupils to contract, promotes digestion, and normalizes the rate of heartbeat.

Reflex Action

Reflex actions are the **quick involuntary response** in which brain is not involved. Reflex actions are controlled by a reflex

When a receptor is stimulated, it sends information to the brain. The higher centres of brain (regions of cerebrum) analyse the information and send messages for appropriate actions. Such actions are under our conscious control and are called **voluntary actions**. Some regions of brain control actions without any conscious control. Such actions are called **involuntary actions**

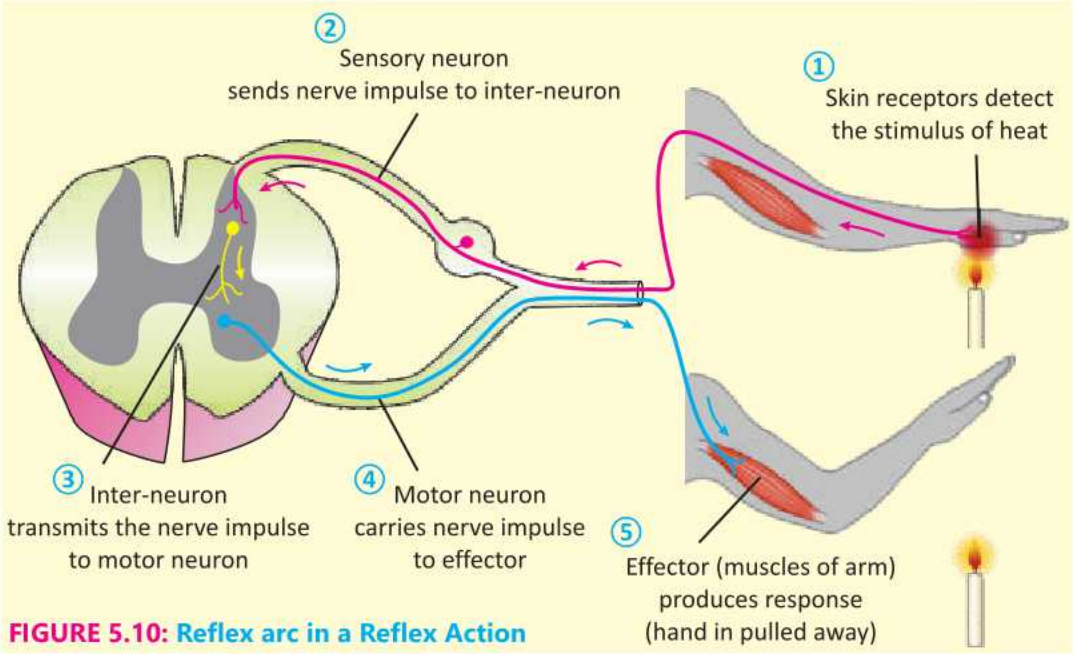


FIGURE 5.10: Reflex arc in a Reflex Action

arc. A **reflex arc** is the pathway of neurons over which the nerve impulses travel during a reflex action.

Example:

We pull our hand away from a hot flame without thinking about it. It is a reflex action and happens in the following way;

1. Skin receptors detect the stimulus of heat.
2. Sensory neuron sends nerve impulse to inter-neuron of spinal cord.
3. The inter-neuron transmits the nerve impulse to motor neuron.
4. The motor neuron carries the nerve impulse to effector (muscles of arm).
5. The effector produces a response by contracting. So, our hand is pulled away.

5.3 ENDOCRINE SYSTEM

It is another system responsible for coordination in animals. The **endocrine system** consists of special endocrine glands which produce and secrete hormones. **Hormones** are the chemicals, released from endocrine gland, which regulate different body functions like growth, reproduction, and glucose level in blood etc.

The secretion of saliva from salivary glands is an involuntary action. When we start chewing food in mouth, brain sends message to salivary glands to secrete saliva. It can also happen when we smell, see or even imagine food.

The endocrine glands do not have ducts to pour their hormones. That is why; they are also called **ductless glands**. They secrete hormones into blood which carries them to different parts of the body. The following are the major endocrine glands and their important hormones.

1. Pituitary Gland

It is a small gland present in the brain. It is suspended from the hypothalamus by a short stalk. There are two lobes of pituitary gland i.e., anterior lobe and posterior lobe.

a. Hormones of Anterior Lobe of Pituitary

1. Growth hormone (GH) stimulates the growth of muscle, bone, and other tissues. If growth hormone is produced more than normal, it results in extra growth in body. This condition is called **gigantism**. On the

Naseer Soomro was once the tallest man in Pakistan. He was born normal size, but developed pituitary gland problem at the age of 10. His pituitary gland produced excess amounts of the **Growth Hormone**.

other hand, if growth hormone is produced less than normal, it results in less growth in the body. This condition is known as **dwarfism**.

2. Adreno-cortico-tropic hormone (ACTH) stimulates the adrenal cortex gland to produce its hormones which control stress.

3. Thyroid-stimulating hormone (TSH) stimulates the thyroid gland to produce its hormone (thyroxine) which controls metabolism.

4. Luteinizing hormone (LH) is needed for the release of egg cells from ovary (ovulation) in females. In males, it stimulates the testes to produce sex hormones. Anterior lobe also produces **follicle stimulating hormone (FSH)** that is involved in the reproductive system.

b. Hormones of Posterior Lobe of Pituitary

The hypothalamus produces two hormones that are stored in the posterior lobe of pituitary gland.

1. Antidiuretic hormone (ADH), also called **vasopressin**, increases the reabsorption of water from nephrons in kidneys. Hence, control blood volume and blood pressure

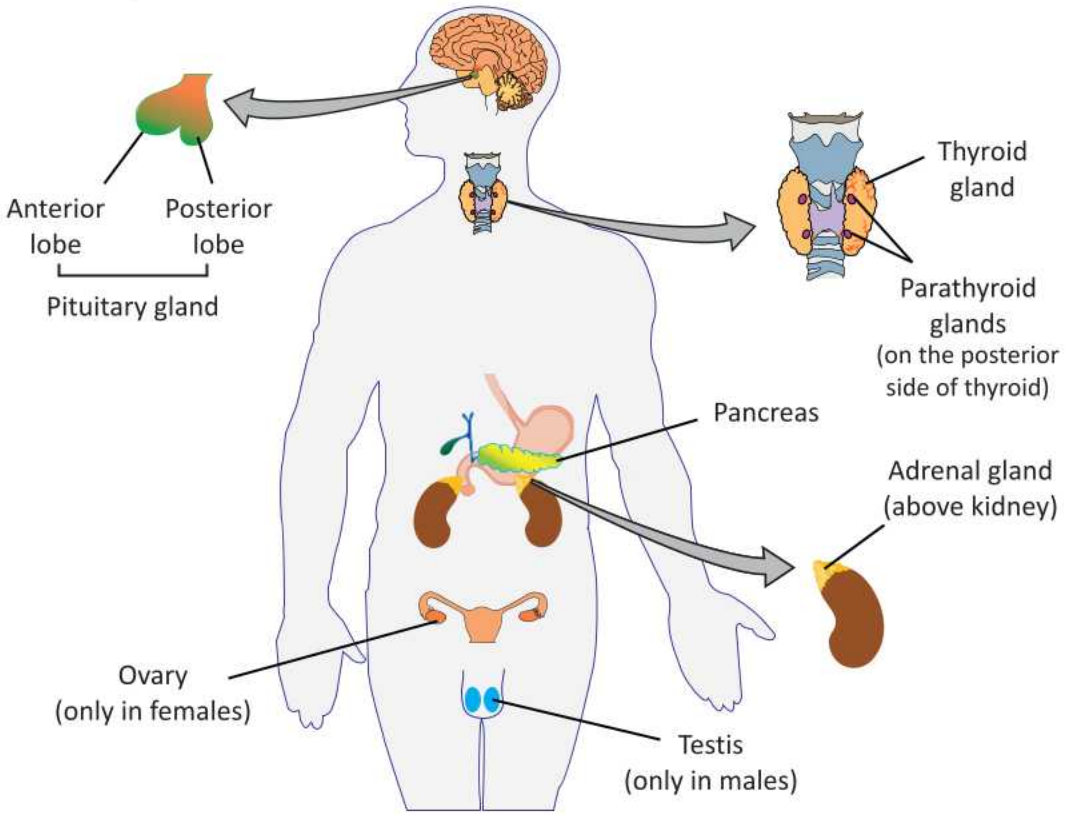


FIGURE 5.11: Important endocrine glands in human body

2. Oxytocin initiates contractions in uterus during childbirth. It also stimulates the flow of milk during breastfeeding.

2. Thyroid gland

It is located near the lower part of the larynx. It secretes two hormones.

i. Thyroxin stimulates enzymes of cellular metabolism (glucose oxidation) for energy production. It increases basal metabolic rate and produces heat.

If thyroxine is produced less than the required amount, cellular metabolism slows down. It results in lethargy, weight gain, low heart rate and low body temperature.

If thyroxine is produced more than required, cellular metabolism becomes faster. It results in weight loss, high blood pressure, high heart rate, and high body temperature.

Iodine is required for the production of thyroxine. If a person lacks iodine in diet, thyroid gland cannot make hormone. In this condition, thyroid gland enlarges. This disorder is called **goitre**. Goiter is now rare in Pakistan because iodine is added to commercially available table salt.

ii. Calcitonin stimulates the transfer of calcium ions from blood to bone, where the calcium ions can be used to generate bone tissue. In this way, calcitonin acts to decrease blood calcium levels.

When there is more parathormone, more calcium is transferred from bones to blood. So, the bones become weak. The deficiency of parathormone results in decreased blood calcium level. It leads to tetany (muscle twitching, cramps and convulsions).

3 Parathyroid glands

The four parathyroid glands are embedded in the back of the thyroid gland. They secrete a hormone called **parathormone**. It stimulates the transfer of calcium ions from the bones to the blood. Thus, it has the opposite effect of calcitonin.

4. Adrenal glands

An adrenal gland is located above each kidney. Each adrenal gland has an inner core, the **medulla**, and an outer layer, the **cortex**.

The **adrenal medulla** produces two hormones: **epinephrine** (adrenaline) and **nor-epinephrine** (nor-adrenaline). These hormones take part in the emergency response of the sympathetic nervous system. When a person is in emergency, the medulla releases its hormones to prepare the body for **"fight or flight"** response. These hormones increase heart rate, blood

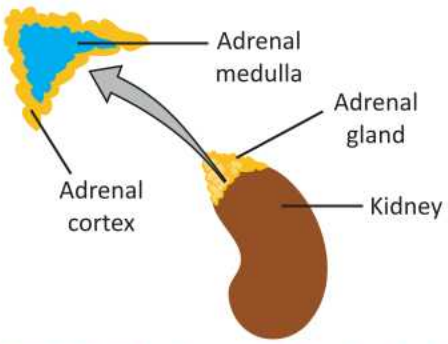


FIGURE 5.12: Parts of adrenal gland

pressure, blood glucose level, and blood flow to the heart and lungs. They also stimulate enlargement of the bronchioles and dilation of the pupils.

The **adrenal cortex** secretes hormones cortisol and aldosterone. **Cortisol** promotes the production of glucose from proteins. **Aldosterone** raises blood pressure and volume by stimulating salt absorption and water retention by the kidneys.

v. Pancreas

Pancreas has two functions. It is a part of digestive system, where it plays the role of a ducted (exocrine) gland and secretes digestive enzymes. It also has special cells called the **islets of Langerhans** (discovered in 1869 by a German student, Paul Langerhans). These cells function as an endocrine gland. They secrete two hormones i.e., **insulin** and **glucagon**. They regulate the level of glucose in the blood. **Insulin** lowers the blood glucose level by stimulating body cells to store glucose or use it for energy. In contrast, **glucagon** stimulates release of glucose from liver into the bloodstream.

In **diabetes mellitus**, the cells are unable to obtain glucose resulting in high blood glucose concentrations. In type-1 diabetes mellitus, the pancreas does not produce required insulin. Such patients are treated with daily injections of insulin. In type-2 diabetes, insulin is produced but the target cells do not respond to it. This type of diabetes can be controlled through exercise and diet.

In diabetes, excess glucose inhibits water reabsorption by the kidneys, producing large amounts of urine. It results in dehydration and can cause kidney damage. Excess glucose may also lead to imbalance in water and salt concentration in body. The patients also experience loss of body weight, weakening of muscles and tiredness.

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 fasting), randomly (anytime) and after a meal. The results of some BGC tests are given here.

Table 5.1: Different Blood Glucose Concentrations according to WHO

Blood Glucose After 8 – 10 hours Fast		Blood Glucose 2 hours after a 75-gram Glucose intake	
BGC	**Diagnosis**	**BGC**	**Diagnosis**
From 70 to 99 mg/100mL	Normal	Less than 140 mg/100mL	Normal
From 100 to 125 mg/100mL	Pre-diabetes	From 140 to 200 mg/100mL	Pre-diabetes
126 mg/100mL and above	Diabetes	Over 200 mg/100mL	Diabetes

Table 5.2: Major Endocrine Glands and Their Functions		
Gland	**Hormone**	**Functions**
Anterior lobe of Pituitary	Growth hormone	Regulates development of muscles and bones
	Adrenocorticotropic hormone	Stimulates secretion of cortisol and aldosterone by the adrenal cortex
	Thyroid stimulating hormone	Stimulates the thyroid gland to produce its hormone
	Luteinizing hormone	Stimulates the ovary to release egg Stimulates the testes to produce sex hormones
Posterior lobe of Pituitary	Antidiuretic hormone	Increases the reabsorption of water from nephrons
	Oxytocin	Initiates contractions in uterus during childbirth Stimulates flow of milk from breasts
Thyroid	Thyroxine	Stimulates enzymes of cellular metabolism
	Calcitonin	Decreases blood calcium concentration
Parathyroid	Parathormone	Increases blood calcium concentration
Adrenal medulla	Epinephrine, Norepinephrine	Initiate body's response to stress and the "fight-or-flight" response to danger
Adrenal cortex	Cortisol	Promotes production of glucose from proteins
	Aldosterone	Promotes salt and water retention by the kidneys
Pancreas	Insulin	Lowers the blood glucose level by stimulating body cells to store glucose or use it
	Glucagon	Stimulates release of glucose from liver into blood
Ovaries	Oestrogen and Progesterone	Cause the release of egg from the ovary and regulate female secondary sex characteristics
Testes	Androgens (Testosterone)	Regulate male secondary sex characteristics

6. Gonads

Gonads (ovaries in females and testes in males) are gamete-producing organs. They also produce sex hormones.

In females, the ovaries secrete hormones called **estrogen** and **progesterone**. These hormones cause the release of egg from the ovary and regulate female secondary sex characteristics (e.g., development of breast).

In males, the testes secrete a group of sex hormones called **androgens (e.g., testosterone)**. It regulates male secondary sex characteristics (e.g., growth of hair on face and coarseness of voice etc.)

EXERCISE

A. Select the correct answers for the following questions.

1. Schwann cells are the supporting cells for neurons. They make:
   a) Cell body b) Axon c) Myelin sheath d) Dendrites
2. Which part of the brain controls balance while riding a bicycle?
   a) Cerebrum b) Medulla c) Cerebellum d) Spinal cord
3. Which part is responsible for sensations of temperature, hunger, thirst, and sleep?
   a) Hypothalamus b) Thalamus c) Pons d) Cerebellum
4. If a patient cannot remember things, which part of their brain may be affected?
   a) Cerebrum b) Cerebellum c) Medulla d) Spinal cord
5. During danger, which system activates quickly?
   a) Parasympathetic b) Skeletal c) Endocrine d) Sympathetic
6. Why are reflex actions faster than normal actions?
   a) Brain processes them quickly b) Brain is not involved
   c) Signals move slower d) They need thinking
7. Which of these acts as exocrine as well as endocrine gland?
   a) Pituitary b) Thyroid c) Adrenal d) Pancreas
8. The chemical messengers of the endocrine system are called;
   a) Neurotransmitters b) Hormones c) Neurons d) Enzymes
9. What could happen if hormone of parathyroid gland were missing?
   a) Low calcium levels b) High blood sugar
   c) Weak muscles d) Poor digestion
10. Which endocrine gland prepares the body for "fight or flight" response?
    a) Thyroid b) Pituitary c) Adrenal d) Pancreas

B. Write short answers.

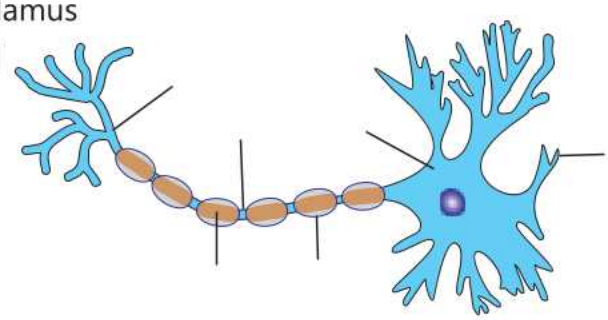
1. Define stimulus with examples.
2. Differentiate between sensory, motor, and inter-neurons.
3. Define reflex action and the reflex arc.
4. Differentiate between the following:

(a) Dendrite and axon

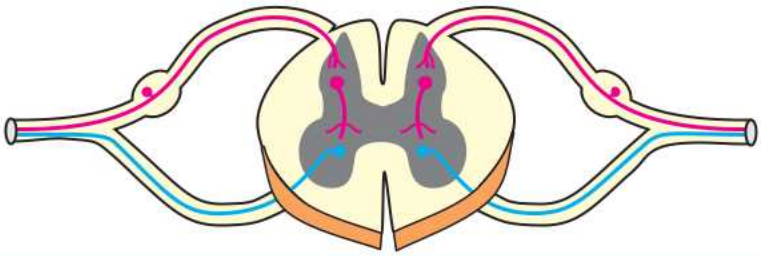
(b) Cerebrum and Cerebellum

(c) Thalamus and Hypothalamus

5. Identify the diagram and label the different parts.



6. Identify the following diagram, and locate the white matter, grey matter, three types of neuron, and ganglia.



C. Write answers in detail.

1. Describe the structure of a neuron and support your answer with a labelled diagram.
2. What are the differences and similarities among the three types of neurons?
3. Write the major functions of the forebrain, midbrain, and hindbrain.
4. What is meant by reflex action? Describe an example of reflex action and identify the reflex arc in this example.
5. State the hormones of the pituitary gland and write their functions.
6. Write notes on adrenal glands, pancreas, ovaries and testes.

D. Inquisitive questions

1. Why is the spinal cord important in reflex actions?
2. Why is adrenaline called an "emergency hormone"?
3. If pancreas releases too much insulin, what happens to blood sugar?
4. If the medulla of a patient is injured, which function is most at risk?

6 REPRODUCTIVE SYSTEM

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe the role of hormones in both male and female sexual development.
- Describe the process of gametogenesis and fertilization.
- Identify, on diagrams of the parts of male reproductive system and describe their functions.
- Identify, on diagrams of the parts of female reproductive system and describe their functions.
- Explain AIDS as an example of sexually transmitted diseases.

All organisms have the ability to produce new individual or their kind. **Sexual reproduction** involves the joining (fusion) of male and female gametes.

6.1 FORMATION OF GAMETES AND FERTILIZATION

Animals have special organs i.e., gonads where special cells called gametes are made. The gonads in male animals are called testes (Singular: testis) where male gametes i.e., sperms are produced. The gonads in female animals are

called ovaries where female gametes i.e., egg cells or ova are produced.

Formation of Gametes

The process of formation of gametes is called **gametogenesis**. It involves the cell division meiosis. Meiosis results in a reduction of the number of chromosomes in gametes to haploid (1n) as compared to the diploid (2n) number in other body cells.

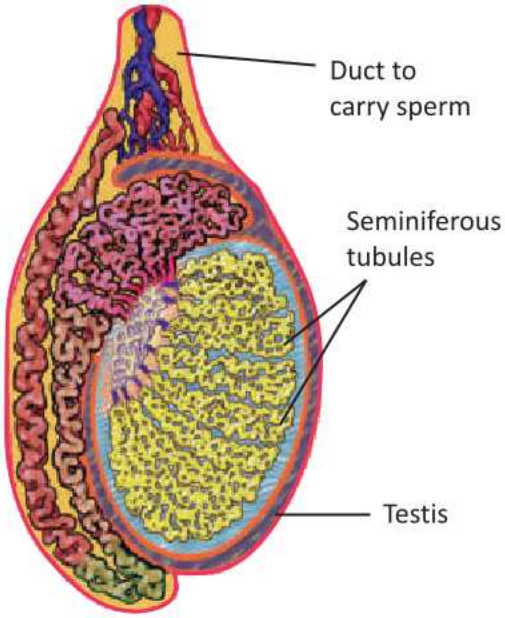


FIGURE 6.1: A testis

(a) Formation of Male Gametes

The formation of male gametes (sperms) is called **spermatogenesis**. This process occurs in **seminiferous tubules** of testes. Follicle stimulating hormone (FSH) along with the male sex hormone i.e., testosterone stimulate sperm production. FSH is produced by the anterior pituitary gland while testosterone is produced by testes.

In seminiferous tubules, the diploid gamete mother cells, called **primary spermatocytes** are present. Each primary spermatocyte divides by meiosis-I and forms two haploid secondary spermatocytes. Each secondary spermatocyte divides by meiosis-II. In this way, four haploid **spermatids** are formed. These are immature sperms. Changes occur in spermatids and they mature into motile **sperms**.

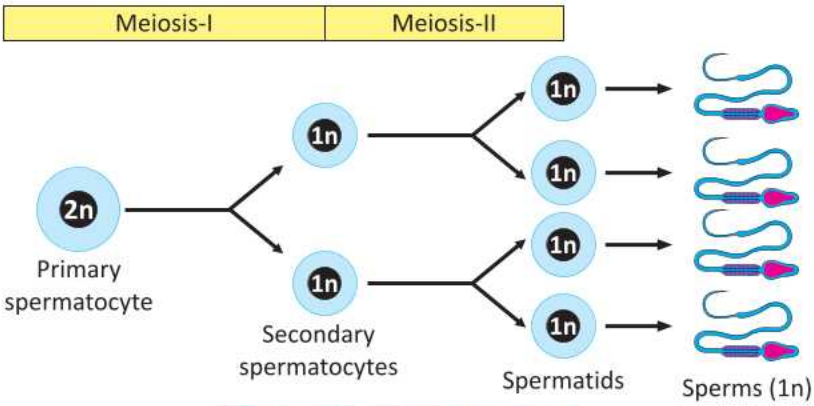


Figure 6.2: Spermatogenesis

(b) Formation of Female Gametes

The formation of female gametes (egg or ovum) is called **oogenesis**. It

occurs in ovary in a small, fluid-filled sac called **follicle**. Follicle stimulating hormone released by the anterior lobe of pituitary gland stimulates the formation of ovum in follicle.

In follicle, there is a diploid gamete mother cell called **primary oocyte**. It divides by meiosis. As a result of first meiotic division, two haploid cells are produced. The larger cell is called **secondary oocyte** while the smaller cell is called **first polar body**. In meiosis II, secondary oocyte produces two haploid cells i.e., a **second polar body** and an **egg**.

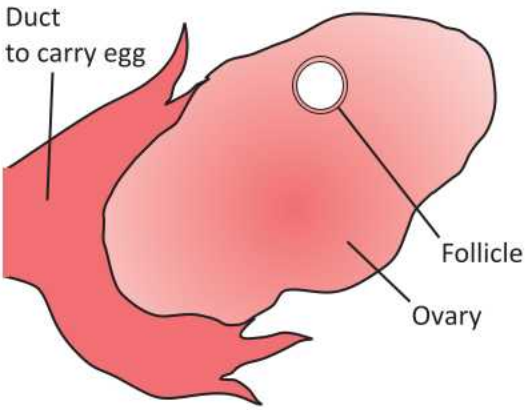


FIGURE 6.3: An ovary

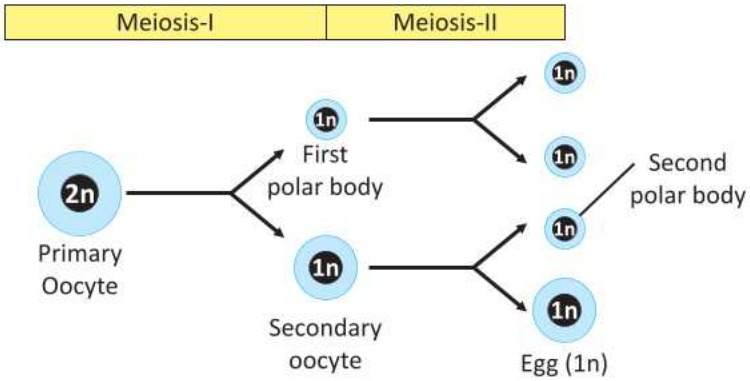


FIGURE 6.4: Oogenesis

Fertilization

Fertilization means the fusion of male and female gametes to form a new cell, called zygote. In humans, fertilization occurs inside the body of female after the release of egg cell from ovary i.e., **ovulation**. Fertilization occurs in the following steps:

1. Sperms move towards the egg due to the chemical signals released by the egg or surrounding cells.
2. The acrosome, a cap-like structure on the head of the sperm, releases enzymes which digest the egg's outer layers, allowing the sperm to reach the egg cell membrane.
3. The sperm and egg cell membranes fuse. This fusion triggers reactions in egg. So, the egg's outer layers become impermeable for more sperms.

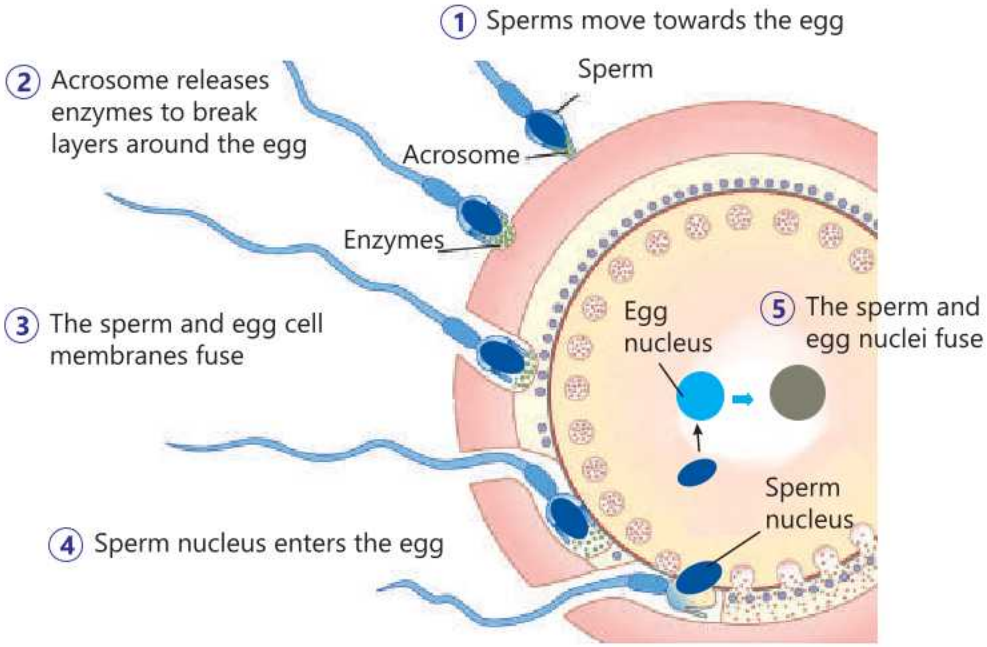


FIGURE 6.5: Steps of fertilization

4. After fusion of membranes, the sperm nucleus enters the egg.
5. Both nuclei fuse to form a diploid zygote.

6.2 ROLE OF HORMONES IN SEXUAL DEVELOPMENT

Hormones in Male Sexual Development

1- Testosterone: It is primarily produced by the testes. It initiates and regulates the development of male secondary sexual characteristics during puberty, such as deepening of the voice, growth of facial and body hair, and increased muscle mass. It is also essential for spermatogenesis.

2- Follicle-Stimulating Hormone (FSH): In males, it is produced by the anterior pituitary gland. It stimulates the testes to produce sperm.

3- Luteinizing Hormone (LH): It is produced by the anterior pituitary gland. It stimulates the production of testosterone by the testes.

4- Gonadotropin-Releasing Hormone (GnRH): It is released by hypothalamus. It stimulates the pituitary to release LH and FSH.

Hormones in Female Sexual Development

1- Oestrogen: It is primarily produced by the ovaries. It initiates and regulates the development of female secondary sexual characteristics during puberty, such as breast development, widening of the hips, and the onset of

menstrual cycles. It also regulates the female reproductive cycle.

2- **Progesterone:** It is produced by the ovaries after ovulation. It prepares the uterus walls for implantation of fertilized egg. It maintains pregnancy by preventing contractions of the uterus.

3- **Follicle-Stimulating Hormone (FSH):** It is released from anterior pituitary gland. In females, it stimulates the growth of follicles, which contain the eggs. It also stimulates the production of oestrogen.

4- **Luteinizing Hormone (LH):** In females, it triggers ovulation (the release of an egg from the ovary) and stimulates the production of progesterone.

5- **Gonadotropin-Releasing Hormone (GnRH):** In females, it stimulates the pituitary to release LH and FSH.

6.3 REPRODUCTIVE SYSTEMS

Male Reproductive System

It consists of the following parts:

> The average male produces around 1,500 sperm per second — that's over 100 million per day!

Testes: Pair of oval-shaped glands that produce sperm and the male hormone testosterone.

Epididymis: A long, coiled tube attached to each testis where sperm are stored and matured.

Vas deferens: A muscular tube that transports mature sperm from the epididymis to the urethra.

Seminal vesicles: Two small glands behind the bladder that produce a sugary fluid to nourish sperm.

Prostate gland: A walnut-sized gland below the bladder that adds protective fluid to the semen.

Urethra: A tube inside the penis that carries semen and urine to the outside of the body

Penis: An external organ that transfers sperm into female reproductive tract.

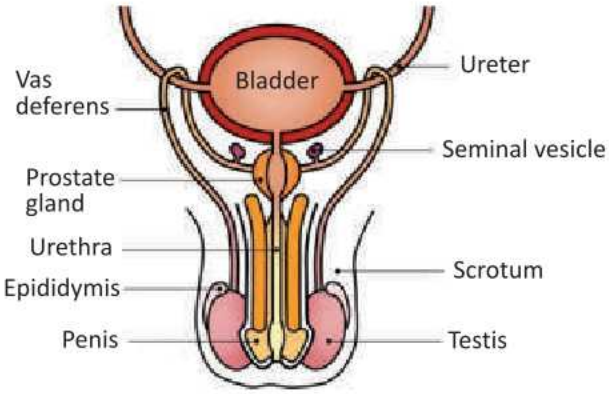


FIGURE 6.6: Male reproductive system

Female Reproductive System

It consists of the following main parts:

Ovaries: Pair of almond-shaped glands that produce eggs (ova) and hormones like oestrogen and progesterone.

Fallopian Tubes: Two tubes that transport eggs from the ovaries to the uterus. Fertilization occurs here.

Uterus: A hollow, muscular organ where a fertilized egg implants and develops into a foetus during pregnancy.

Cervix: The lower, narrow part of the uterus.

Vagina: A muscular canal that connects the cervix to the outside.

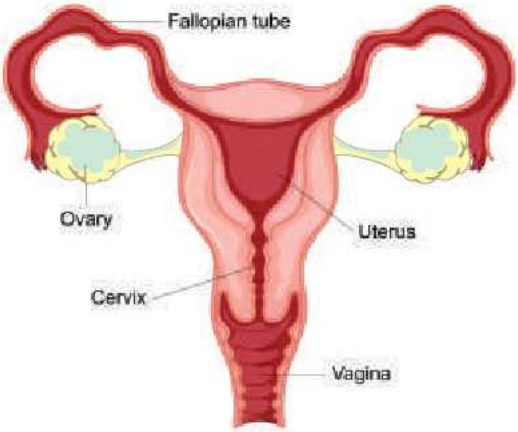


FIGURE 6.7: Female reproductive system

6.4 SEXUALLY TRANSMITTED DISEASES

Sexually transmitted diseases (STDs) are the infections which are primarily transmitted through sexual contact. These diseases can be caused by bacteria, viruses, or parasites. STDs often affect the genital, urinary, and reproductive organs. Common STDs include HIV/AIDS, syphilis, herpes etc. Many STDs can be asymptomatic, meaning individuals may carry and spread the infection without showing signs. If STDs are left untreated, they can lead to serious health complications such as infertility, organ damage, and other infections.

> Low awareness about STDs, especially in rural areas, of Pakistan often leads to delayed treatment and serious complications like infertility.

Acquired Immunodeficiency Syndrome (AIDS)

AIDS is a serious and life-threatening disease caused by the Human Immunodeficiency Virus (HIV). HIV primarily attacks and weakens the body's immune system, making it difficult to fight infections and certain cancers.

> In Pakistan, HIV cases are increasing, particularly due to unsafe injections, unregulated blood transfusions, and lack of awareness among youth.

Causes: The HIV spreads mainly through sexual contact, sharing of contaminated needles, transfusion of infected blood, and from an infected mother to her child during childbirth or breastfeeding.

Signs and Symptoms: Early signs and symptoms are fever, fatigue, swollen

lymph nodes, and skin rashes. As the disease progresses, individuals become vulnerable to severe infections, weight loss, chronic diarrhoea, pneumonia, and certain cancers.

Treatment: There is no cure for AIDS. Antiretroviral therapy (ART) can control the virus, strengthen the immune system, and help patients live longer, healthier lives.

EXERCISE

A. Select the correct answers for the following questions.

1. In which part of the body oogenesis takes place?
   a) Oviduct b) Ovary
   c) Uterus d) Fallopian tube
2. Which of the following is NOT a part of the male reproductive system?
   a) Testes b) Uterus
   c) Epididymis d) Prostate gland
3. Which hormone directly triggers ovulation?
   a) Oestrogen
   b) Progesterone
   c) Luteinizing hormone (LH)
   d) Follicle-stimulating hormone (FSH)
4. Which hormone is responsible for the development of male secondary sexual characteristics?
   a) Follicle Stimulating Hormone b) Oestrogen
   c) Testosterone d) Leutinizing Hormone
5. What is the function of a crosome?
   a) Guides the sperm towards egg cell
   b) Releases enzymes that help sperm penetrate the egg's outer layers
   c.) Activates the egg for fertilization
   d) Helps in the fusion of sperm and egg nuclei
6. What is the function of the Fallopian tubes?
   a) Site of fertilization b) Storage of eggs
   c) Secretion of oestrogen d) Transport of sperm to testes

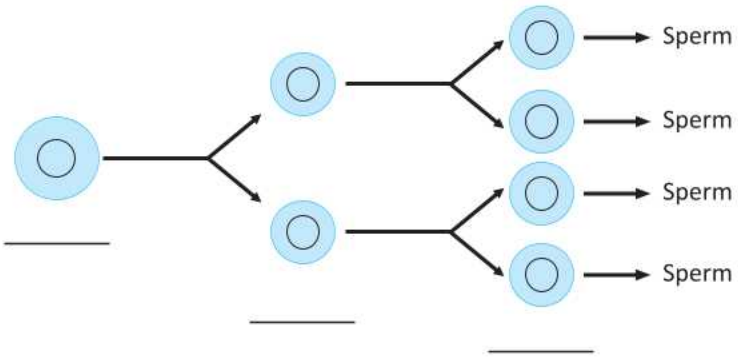
7. Which hormone is primarily responsible for the development of male secondary sexual characteristics?

a) Oestrogen b) Testosterone

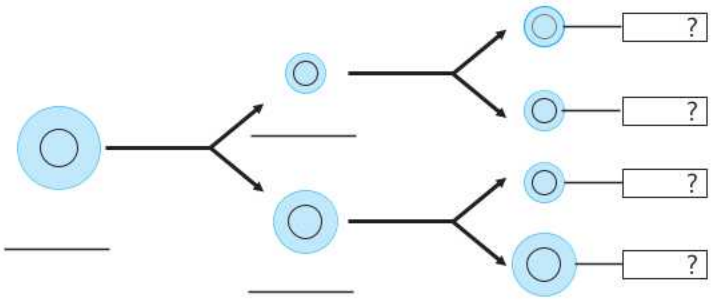
c) Progesterone d) FSH

B. Write short answers.

1. Complete the chart of spermatogenesis by mentioning the names of cells and number of chromosomes (2n or 1n).



2. Complete the chart of oogenesis by mentioning the names of cells and number of chromosomes (2n or 1n).



3. Name the parts of the testis and ovary where gamete formation takes place.
4. What happens to the egg after it is released from the ovary?
5. Compare spermatogenesis and oogenesis in terms of the number of gametes produced.
6. Describe two major ways through which HIV can be transmitted.
7. Differentiate between;
   i. Oestrogen and progesterone

ii. Spermatogenesis and oogenesis

iii. Spermatocyte and oocyte

C. Write answers in detail.

1. Describe the role of hormones in male sexual development.
2. Describe the role of hormones in female sexual development.
3. Describe the process of spermatogenesis.
4. Describe the functions of the major parts of male reproductive system.
5. Describe the functions the parts of female reproductive system.
6. Explain AIDS as an example of sexually transmitted diseases.

D. Inquisitive questions

1. Why only one egg is usually produced from one primary oocyte?
2. How does the structure of a sperm cell relate to its function?
3. What steps can individuals take to prevent HIV transmission?

7

INHERITANCE

Students Learning Outcomes

After studying this chapter, students will be able to:

- Sketch the structure of chromosomes.
- Define genotype and phenotype, allele, homozygous, heterozygous, dominant, recessive
- Illustrate Mendelian inheritance laws through monohybrid and dihybrid cross.
- Outline function of DNA as carrier of hereditary information
- Describe briefly the structure of RNA as single stranded macromolecule made of nucleotides with nitrogenous base overhangs.
- Outline the function of RNA as aid in converting hereditary information into useful proteins.
- Outline how information in the DNA is converted to information on RNA and then into proteins.

An organism is made up of many structural and behavioural characteristics. Organisms are able to pass these characteristics to their offspring. Offspring get some characteristics from each parent. The process by which characteristics are transferred from parents to offspring is called **inheritance** or **heredity**.

Every cell in the body contains the instructions for making characteristics. Inside the cells, this information is present in long molecules of Deoxyribonucleic acid (DNA). The cells use the information in their DNA to produce particular proteins. The proteins made by a cell determine its characteristics.

7.1 STRUCTURE OF CHROMOSOME

Chromosome is made up of **chromatin** material. In eukaryotes, chromatin consists of **DNA** and special proteins called **histones**. Chromatin is a thread-like material. In chromatin, a long molecule of DNA is wrapped around the bundles

Recalling:

- All the cells of the organisms of a species have a constant number of chromosomes.
- The body cells are diploid (2n). It means that the chromosomes are in pairs (homologous chromosomes).
- Before cell division, the DNA makes a copy of itself. In this way, chromatids are formed. When the cell divides, each daughter cell receives one chromatid from each chromosome.

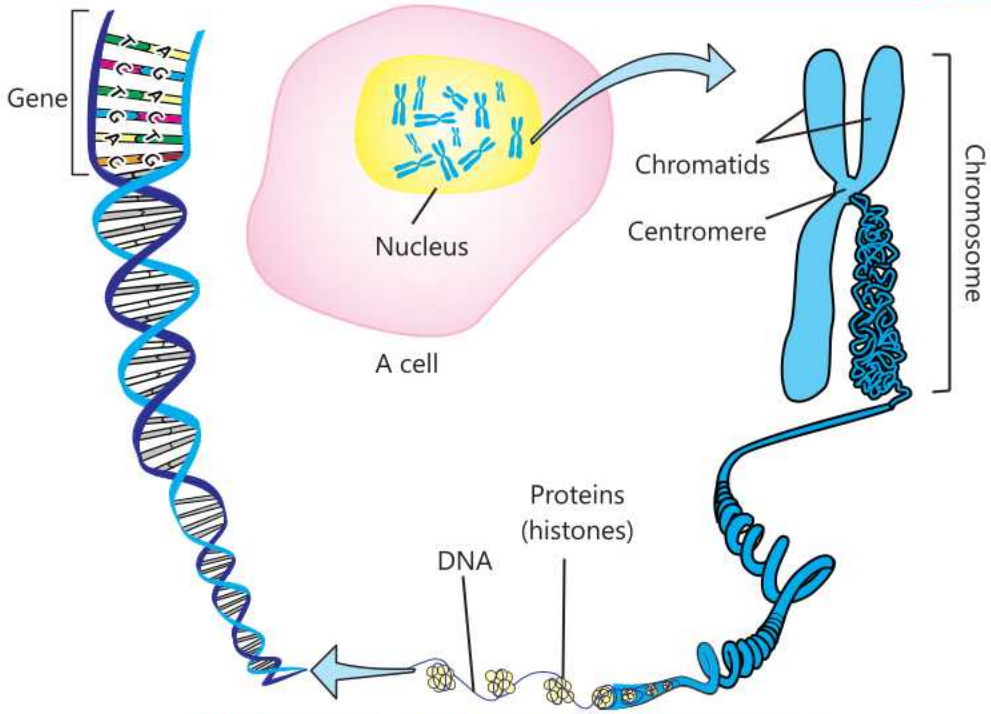


FIGURE 7.1: Chemical composition of chromosome

of **histones**. When a cell is not dividing its chromatin is in the form of fine thread, scattered in the nucleus. During cell division, chromatin coils and makes compact structures of chromosomes.

A **chromosome** is rod-shaped and consists of two identical halves. Each half of chromosome is called a **chromatid.** The two chromatids of a chromosome are attached at a point called **centromere.** The centromere holds the two chromatids together until they separate during cell division.

The prokaryotes have only one chromosome which is made of a circular DNA molecule. It is not bound by a nuclear envelop and is present in cytoplasm.

7.2 DNA AND RNA

DNA (Deoxyribonucleic Acid): DNA is a double-stranded, helical molecule. It is made of nucleotides. Each nucleotide of DNA is made of a deoxyribose sugar, a phosphate group, and a nitrogenous base (adenine, thymine, cytosine, or guanine). The two strands are held together by base pairing (A with T, and C with G).

RNA (Ribonucleic Acid): RNA is single-stranded chain of nucleotides. Its nucleotides have a sugar called ribose, a phosphate group, and nitrogenous bases (adenine, uracil, cytosine, and guanine).

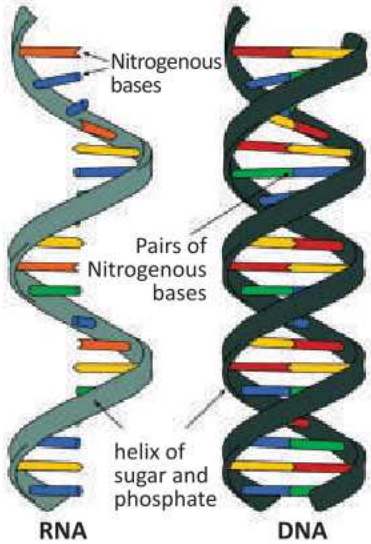


FIGURE 7.2: RNA and DNA

Functioning of DNA and RNA

A gene is a segment of DNA that has the information for making a particular protein. The following processes occur for making a protein according to the information present in a gene:

1. The segment of DNA (gene) acts as a template. A type of RNA, called messenger RNA (mRNA), is synthesised according to this template. In this way, DNA transfers the information to mRNA. This process is called **transcription**. mRNA acts as aid in converting information into proteins.
2. The mRNA moves out into the cytoplasm. Here, ribosome attaches with mRNA. The ribosome joins amino acids according to the information present on mRNA. In this way, a protein is produced. This process is called **translation**.

This concept of the working of a gene is called **central dogma** and is

symbolized as;

DNA ⟶ **mRNA** ⟶ **Protein**

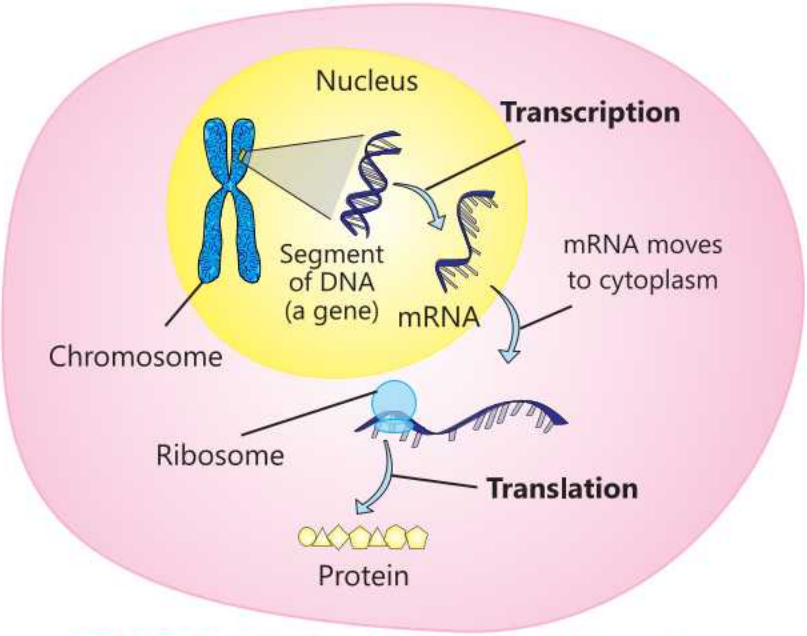


FIGURE 7.3: Working of a gene (central dogma)

Gene and Allele

A **gene** is a segment of DNA that contains the information for a hereditary character. For example, the gene for eye colour, gene for earlobe shape, and gene for the hair texture. Genes are located on chromosomes. The locations or positions of genes on chromosomes are known as **loci** (singular locus). Like chromosomes, genes are also in pairs.

The pair of genes on homologous chromosomes may not contain identical genes. The homologous chromosomes may have different forms of the same gene. These alternate (different) forms of a gene are called its **alleles**. For example, the gene of hair colour can have two alleles. One allele makes hair pigments while the other does not make pigments.

Genotype

The combination of the alleles is called **genotype**. When both alleles are the same, the genotype is **homozygous**. The genotype, in which both alleles are different, is called **heterozygous**. For example, in Fig. 7.4, a cell has genes for eye colour, hair shape and ear shape. All genes are in pairs.

- Both alleles of the eye colour gene are similar. It means that the genotype for eye colour is homozygous. Similarly, both alleles of the hair shape gene are similar. It means that its genotype is also homozygous.

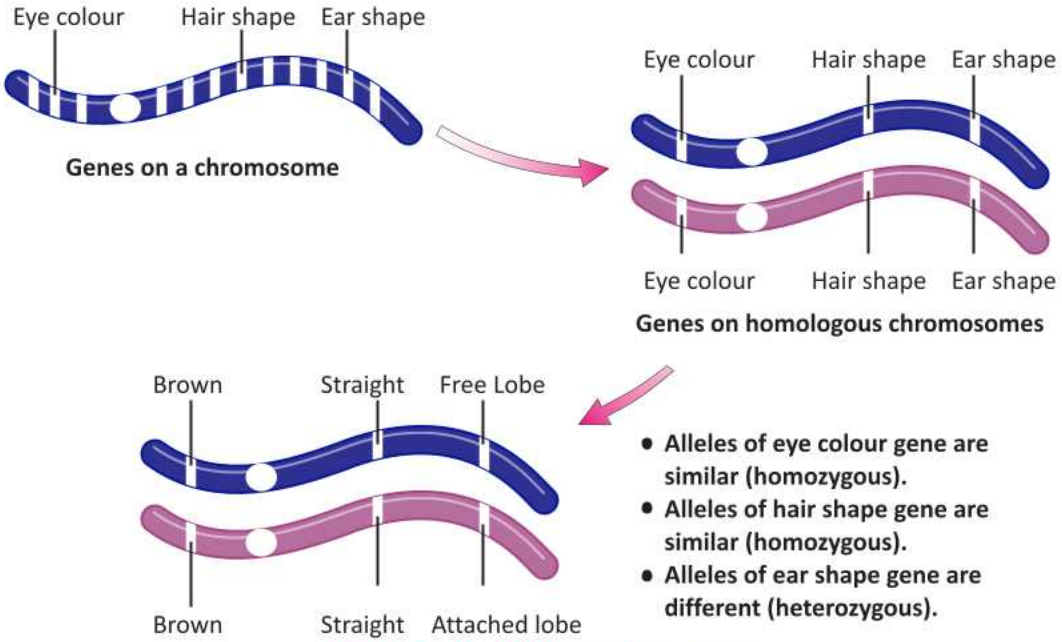


FIGURE 7.4: Alleles and genotypes

- The alleles of the ear shape gene make different characteristics. One allele makes free earlobe while the other allele makes attached earlobe. It means that the genotype for ear shape is heterozygous.

In the heterozygous genotype one allele may mask the working of the other allele. Such an allele is called the **dominant allele**. The allele which is masked (not expressed) is called **recessive allele**. Dominant alleles are expressed by capital letters while the recessive alleles are expressed by lowercase letters. For example, in the pair Tt, the dominant alleles T is responsible for tall plant while the recessive allele t is for dwarf plant. So, if a plant has genotype Tt, it will be a tall plant. The observable outcome of genotype, in the form of characteristic, is called **phenotype**.

7.3 MENDEL'S LAWS OF INHERITANCE

Gregor Mendel was an Austrian monk, working in a monastery. From 1856 to 1863, he performed experiments on garden pea. The results of these experiments cleared the views of heredity.

FIGURE 7.5: Gregor Mendel

Selection of garden pea for experiments

Mendel selected the garden pea for his experiments. His choice was a good one for several

	Flower colour	Seed colour	Seed shape	Pod colour	Pod shape	Flower position	Plant height
Character 1	Purple	Yellow	Round	Green	Flat	Axial	Tall
Character 2	White	Green	Wrinkled	Yellow	Constricted	Terminal	Short (dwarf)

FIGURE 7.6: Distinguishing characters in plant, studied by Mendel

reasons.

1. Pea plants have a relatively short generation time.
2. Pea plant has seven easily distinguishable characteristics, such as round versus wrinkled seeds and purple versus white flowers.
3. Normally, self-pollination occurs in pea flowers. But cross-pollination can also be performed. For this purpose, the stamens of a flower are removed and its pollen grains are transferred to the flower of another plant.

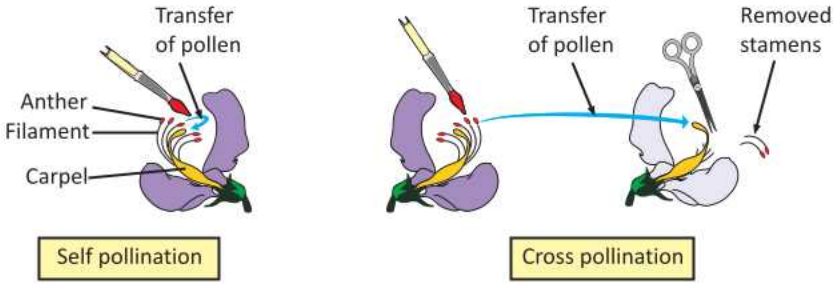


FIGURE 7.7: Self and Cross-pollination in pea plants

Mendel's Experiments

Mendel got the true-breeding plants for each characteristic. If a plant with a characteristic produces offspring with the same characteristic on self-pollination; it means that the plant is **true-breeding** for that characteristic. For example, when a true-breeding tall plant self-pollinates, it will always produce tall plants. After choosing the true-breeding varieties, Mendel performed **monohybrid crosses**. It is a cross in which only one characteristic is studied.

Experiment 1

Mendel crossed a true-breeding tall plant with a true-breeding short plant. He called these true-breeding parents as **P generation.** The offspring of this cross were called the first filial generation, or **F1 generation**. All offspring of F1 were all tall.

During Mendel's time, most people believed that characteristics of both parents are mixed together and are passed to offsprings. For example, if a short plant is crossed with a tall plant, the offsprings will be medium sized.

Next, Mendel allowed the tall plants of F1 generation to self-pollinate. He called the next generation as F2 generation. He found that 75% of F2 offspring were tall, while 25% were short.

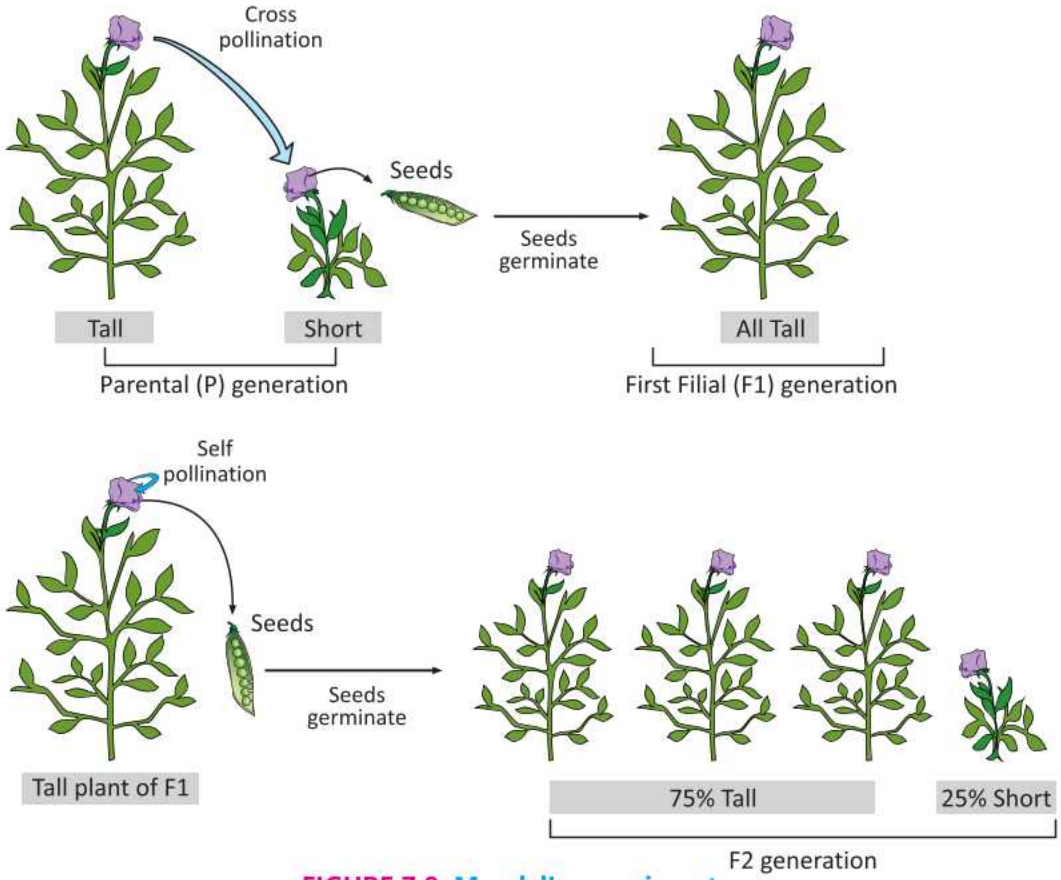


FIGURE 7.8: Mendel's experiment

Mendel found the same results over and over again with all the characteristics.

Conclusions

Concept of Dominance: Mendel explained his results and proposed that there were two forms (alleles) of the gene of plant height. When two different alleles

are together in an organism, one allele may mask the expression of the other. The allele that shows its effect is called dominant, while the one that is hidden is called recessive. This is called as the concept of **dominance**.

Law of Segregation: Mendel explained that each parent has two alleles of a gene. But a parent can only pass one allele to the offspring. During gamete formation, the alleles separate and there is only one allele in each gamete. When fertilization occurs, the offspring has the two alleles again. It is called the **law of segregation**. It states that "the alleles are separated during gamete formation and each gamete receives one or the other allele, but not both".

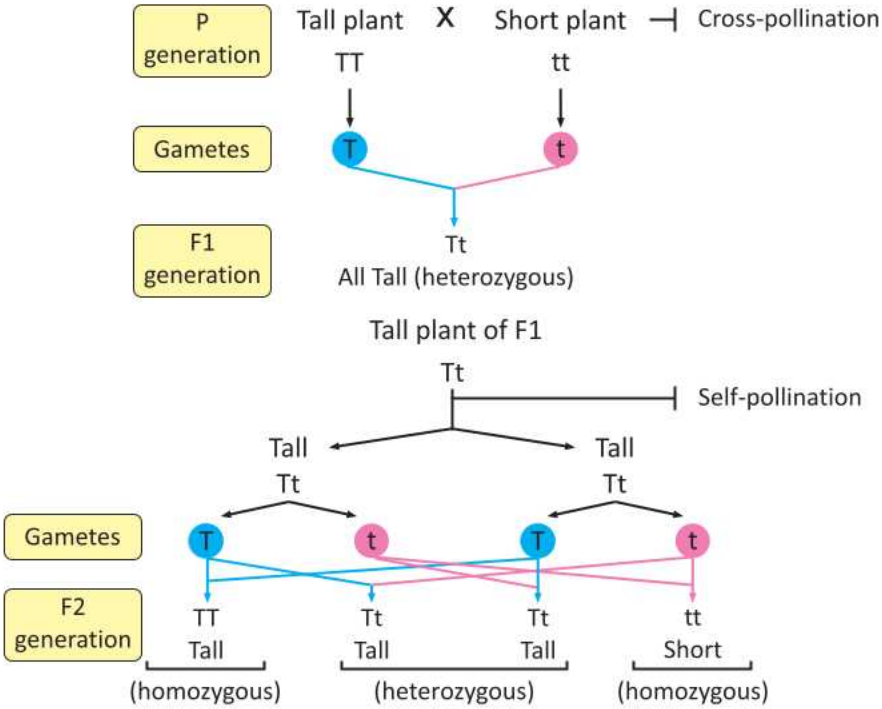


FIGURE 7.9: Segregation of alleles

In pea plant, the allele for tallness is dominant. In parent (P) generation, one parent had alleles TT. Each of its gametes received a single T allele. The second parent had alleles tt. Each of its gametes had a single t allele. When these gametes (T and t) joined, the new plants in F1 plant received the pair as Tt. So, all F1 plants were tall. When self-pollination was allowed in F1 tall plant, the results were:

- 25% of the F2 generation received both alleles of shortness i.e., tt. So, they were short.
- 50% plants of F2 received one T allele and one t. So, they were tall (Tt).
- 25% plants of F2 received both alleles of tallness i.e., TT. So, they were also tall.

Experiment 2

In his next experiments, Mendel did **dihybrid crosses**. In a dihybrid cross, the inheritance of two characteristics was studied at the same time. In such experiments, studied the characteristics of seed shape (round or wrinkled) and seed colour (yellow or green). He first grew true-breeding varieties of pea plants. One plant had round yellow seeds and the other had wrinkled green seeds.

Mendel crossed these true-breeding plants. All F1 plants produced round

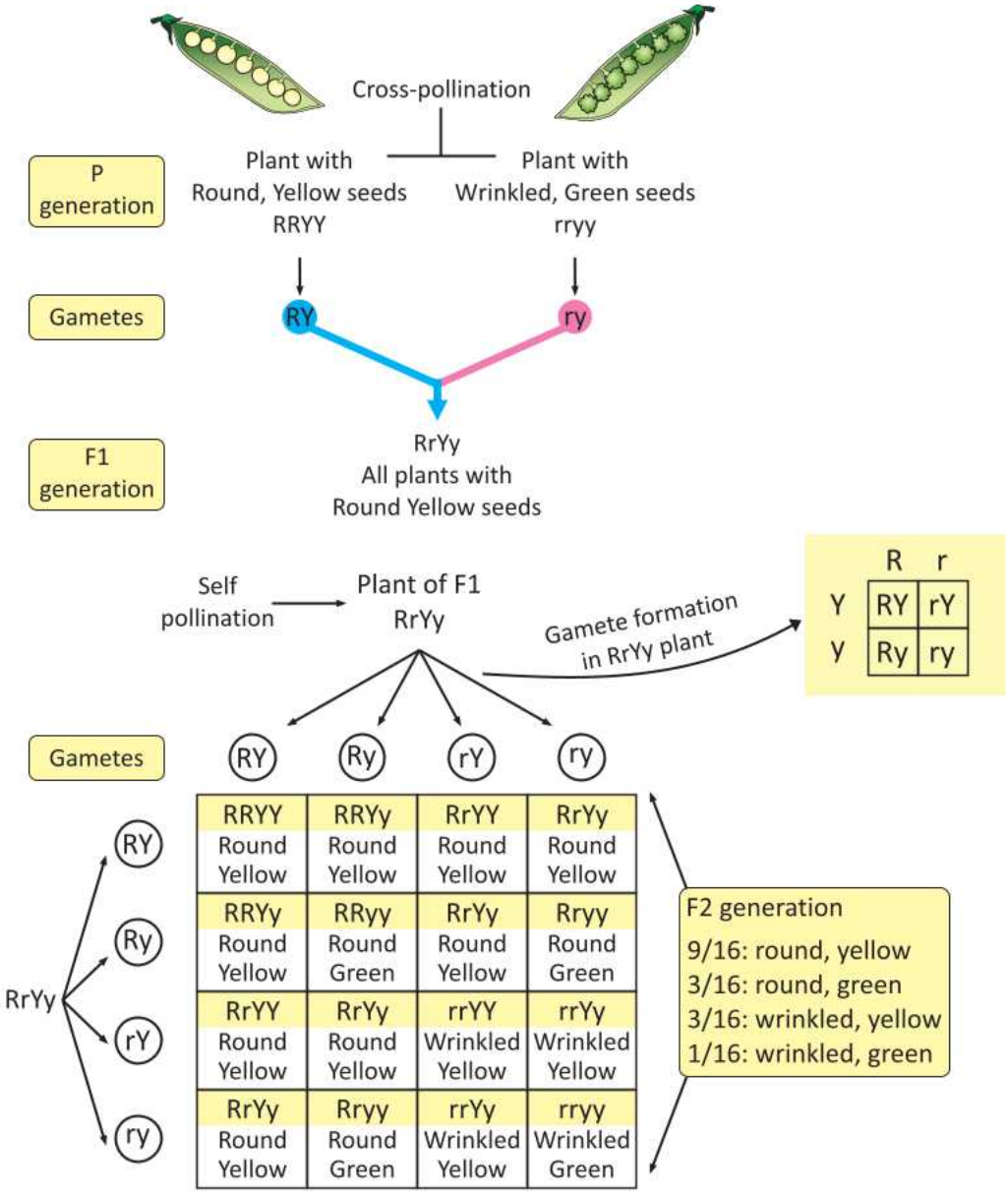


FIGURE 7.10: Independent assortment of alleles

yellow seeds. It proved that the allele for round seeds (R) is dominant over the allele for wrinkled seeds (r). Similarly, the allele for yellow seeds (Y) is dominant over the allele for green seeds (y). All the F1 plants were heterozygous for both seed shape and seed colour (genotype: RrYy).

He allowed self-pollination in the F1 plants and got the F2 generation. The F2 generation had the following four phenotypes:

- 9/16 that have round, yellow seeds (genotypes: RRYY, RRYy, RrYY, and RrYy)
- 3/16 that have round, green seeds (genotypes: RRyy and Rryy)
- 3/16 that have wrinkled, yellow seeds (genotypes: rrYY and rrYy)
- 1/16 that have wrinkled, green seeds (genotype: rryy)

Conclusions:

Law of Independent Assortment

The F1 plants (RrYy), produced four types of gametes i.e., RY, Ry, rY, and ry. When these plants were allowed to self-pollinate, there were 16 combinations of alleles in F2 generation. It means that alleles R and r segregated independently of the alleles Y and y. Mendel's discovery is referred to as the **law of independent assortment**. It states that "alleles separate independently of one another during the formation of gametes".

EXERCISE

A. Select the correct answers for the following questions.

1. Chromosomes of eukaryotes are made of;
   a) Lipids and proteins
   b) Lipids and DNA
   c) RNA and proteins
   d) DNA and proteins
2. What is the relationship between a gene and an allele?
   a) Alleles are alternative forms of a gene
   b) Genes are alternative forms of an allele
   c) Genes mask the effects of genes
   d) Alleles and genes are unrelated
3. Which molecule is formed during transcription?
   a) DNA b) Protein c) mRNA d) Ribosome

4. The central dogma of molecular biology is best represented by;

a) DNA + RNA = Protein
b) DNA -----> RNA + Protein
c) DNA -----> RNA -----> Protein
d) Protein -----> RNA -----> DNA

5. What happens during transcription?

a) A new polypeptide is created
b) RNA is scanned by a ribosome.
c) A new copy of DNA is produced
d) A copy of RNA is made

6. What is the role of DNA in protein synthesis?

a) Produces amino acids
b) Provides the template for mRNA formation
c) Transports proteins
d) Stores proteins

7. The allele that is expressed, when two separate alleles are inherited;

a) Dominant
b) Recessive
c) Homozygous
d) Heterozygous

8. Which of these is a reason why pea plants were suitable for Mendel's experiments?

a) Long life cycle
b) Easy to cross-pollinate
c) Few seeds produced per plant
d) No variation in traits

9. What does Mendel's Law of Segregation state?

a) Genes are linked together
b) Each allele separates during gamete formation
c) Dominant traits appear in all generations
d) Alleles blend together

10. In peas, allele for purple flower (P) is dominant over the allele for white flower (p). If a white flower is crossed with a heterozygous purple flower (Pp), what will be the ratio of offspring?

a) 100% purple
b) 75% purple & 25% white
c) 50% purple & 50% white
d) 100% white

B. Write short answers.

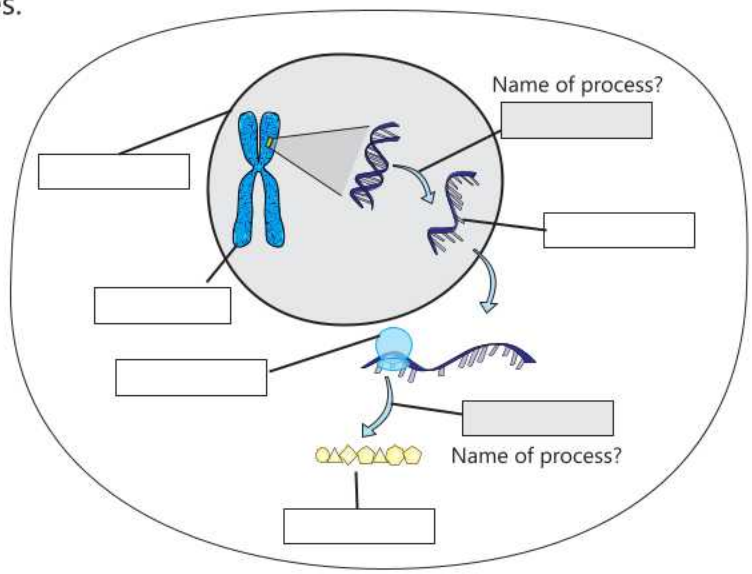
1. Write down the combination of alleles in the gametes of a plant, which has genotype Rryy.
2. State Mendel's law of segregation.
3. State Mendel's law of independent assortment.
4. Define monohybrid cross and a dihybrid cross and give an example of

each.

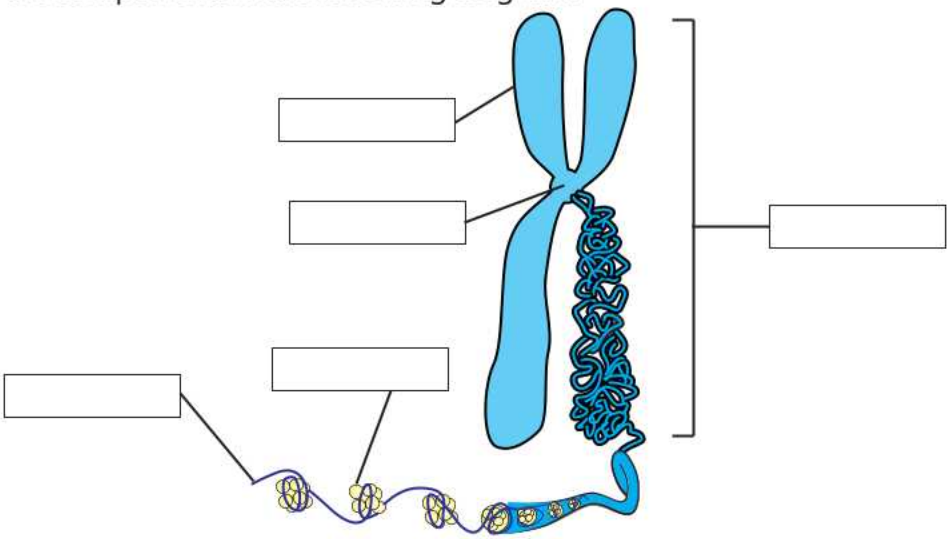
5. Draw a cross between two pea plants. One of them has round green seeds (RRyy) while the other has wrinkled yellow seeds (rrYY).

6. Differentiate between:
   - Gene and allele
   - Dominant and recessive
   - Genotype and phenotype
   - F1 and F2 generations
   - Homozygous and heterozygous

7. In the following diagram of a cell, label the components and the processes.



8. Label the components in the following diagram.

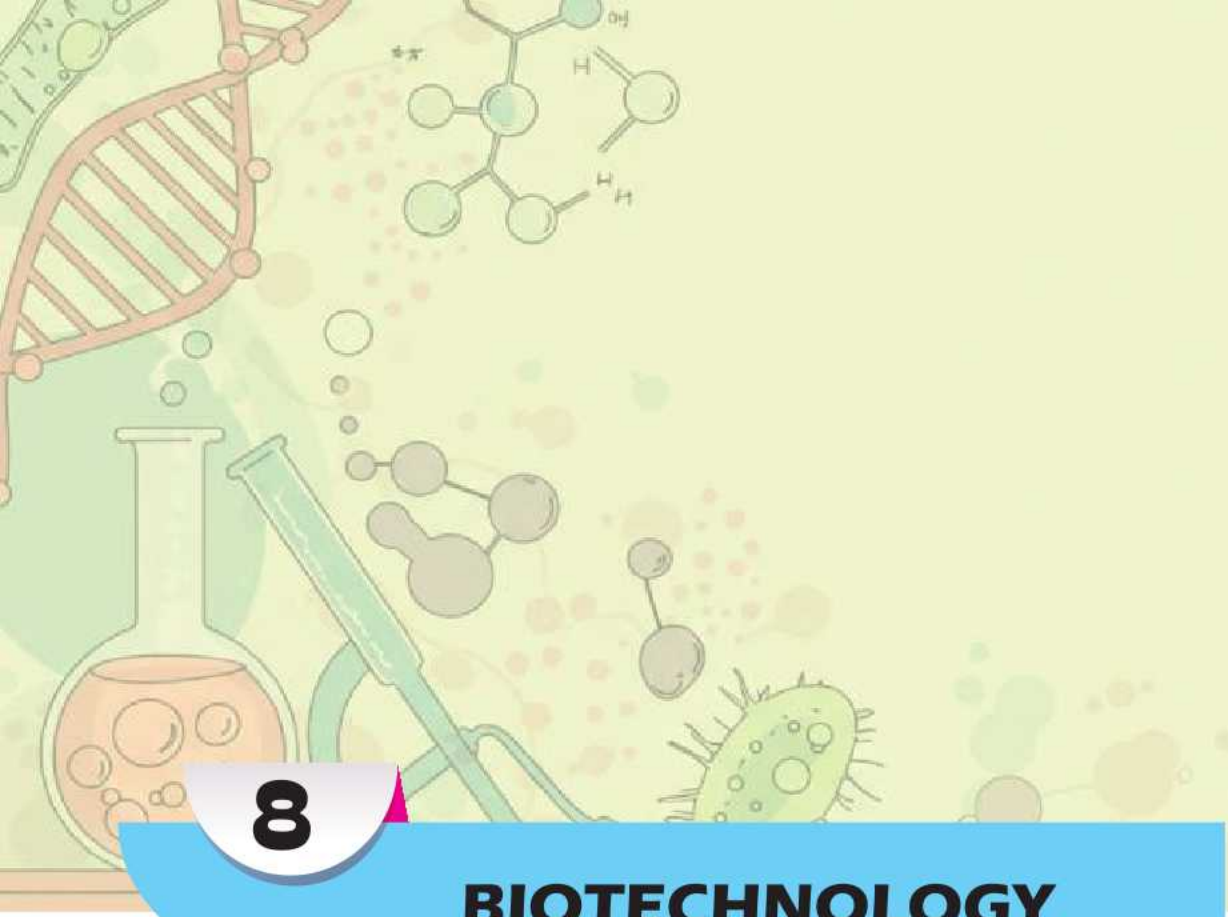


C. Write answers in detail.

1. Write a note on the structure and composition of chromosome.
2. Why did Mendel choose pea plants for his genetic experiments?
3. Describe Mendel's experiment on two-character inheritance and state the law he proposed.
4. Describe Mendel's Law of Segregation? Give an example.
5. Describe how DNA and RNA take part in the synthesis of a protein.

D. Inquisitive questions

1. How do genes control the traits and characteristics of an organism?
2. Why can different alleles of the same gene lead to different physical traits?



8 BIOTECHNOLOGY

Students Learning Outcomes

After studying this chapter, students will be able to:

- Introduce biotechnology.
- Explain the role of yeast in the production of bread and ethanol.
- Understand that bacteria are useful in biotechnology and genetic modification.
- Describe the basic method of genetic engineering/genetic modification.
- Discuss potential advantages and risks of genetic modification.

Biotechnology is a new branch of biology that deals manipulation of organisms at molecular and cellular level to get services and products beneficial for human welfare. This field provides benefits in the areas of human health, agriculture, industries, and environment. In this chapter, we will study the basics of biotechnology and its useful applications.

8.1 INTRODUCTION OF BIOTECHNOLOGY

In 1919, Hungarian engineer **Karl Ereky** first proposed the term "biotechnology". It may be defined as the use of living cells or organisms to create products or processes for specific purposes. Through this technology;

- The hereditary characteristics of organisms are modified.
- New organisms with desired characters are developed from a cell or a part of an organism.
- Any required substance is produced from the modified organism.

Modern biotechnology emerged after the invention of the structure and function of DNA in 1953. The techniques being used in modern biotechnology include fermentation, recombinant DNA technology, cell culture, gene editing, genetic engineering, and tissue culturing etc.

Sir Ian Wilmut is a British embryologist. He was the leader of the research group that in 1997 first produced a mammal (a lamb named Dolly) from an adult body cell.

Importance of Yeast in Fermentation

Yeast is a microscopic fungus that plays a crucial role in both bread making and ethanol production through a process called fermentation.

Fermentation is the oldest form of biotechnology. It is used for making bread, beer, and yogurt thousands of years ago.

Role in Bread Making

Yeast ferments the sugars present in the dough and produces carbon dioxide (CO_2) gas. This gas forms bubbles in the dough, causing it to rise and become soft and airy. The alcohol produced during this process evaporates during baking.

Role in Ethanol Production

Yeast ferments sugars from crops like sugarcane or corn to produce ethanol (alcohol) and carbon dioxide. The ethanol is then purified and used as a biofuel or in alcoholic beverages.

Importance of Bacteria in Biotechnology

Bacteria are essential microorganisms used in biotechnology because they are simple, fast-growing, and can easily accept new genetic material. Scientists use them for producing medicines, studying genes, and creating **genetically modified organisms (GMOs)**.

Role in Biotechnology

Certain bacteria produce important substances like antibiotics (e.g., *Streptomyces* produces streptomycin). Many bacteria produce enzymes which scientists use in making cheese and detergents. Similarly, many bacteria produce vitamins (like vitamin B12). Scientists also use bacteria to clean up oil spills and waste through a process called **bioremediation**. In the food industry, bacteria like *Lactobacillus* help in making yogurt and cheese by fermenting milk.

Role in Genetic Modification

Scientists use special structures called plasmids (small loops of DNA found in bacteria) as carriers to introduce new genes into bacterial cells. In this way, the modified bacteria start producing proteins from that foreign gene. This method is used to produce:

- Human insulin for treating diabetes
- Human growth hormone for growth disorders
- Vaccines against diseases

Some bacteria are also used to introduce new genes into plant cells during the creation of genetically modified crops.

8.2 GENETIC ENGINEERING

Genetic engineering is defined as the process of altering (editing) the genes of organisms or transferring the genes from one organism into other organisms. In genetic engineering, special enzymes are used to cut and attach DNA at specific locations. As a result of genetic engineering, **Genetically Modified Organisms** are produced. The following are the two main examples of genetic engineering.

1. Gene Editing

Gene editing is a technique in which scientists make changes in the DNA (genes) of an organism. These can involve adding, removing, or replacing specific parts of DNA. It allows scientists to add, delete, or change parts of the DNA. It is done to correct genetic abnormalities and to improve characteristics.

Examples of Gene Editing

1. **Curing Genetic Diseases:** Scientists are researching how gene editing can cure diseases caused by abnormal genes, such as sickle cell anaemia (a blood disorder), cystic fibrosis (a lung disease).

> Gene editing is done very carefully because changes made to DNA can have unexpected effects.

2. **Improving Crops:** Gene editing can create crops that grow faster, resist

pests and diseases, and survive droughts better. For example, virus resistant varieties of tomato and tobacco have been developed. Modified varieties of soybeans, corn, tomato, and cotton have been produced which show resistance against herbicides.

3. **Producing Better Medicines:** Gene editing helps create bacteria that produce important medicines, like insulin for diabetes.

2- Gene Transfer

Genetic engineers use special **vectors** to transfer genes into an organism.

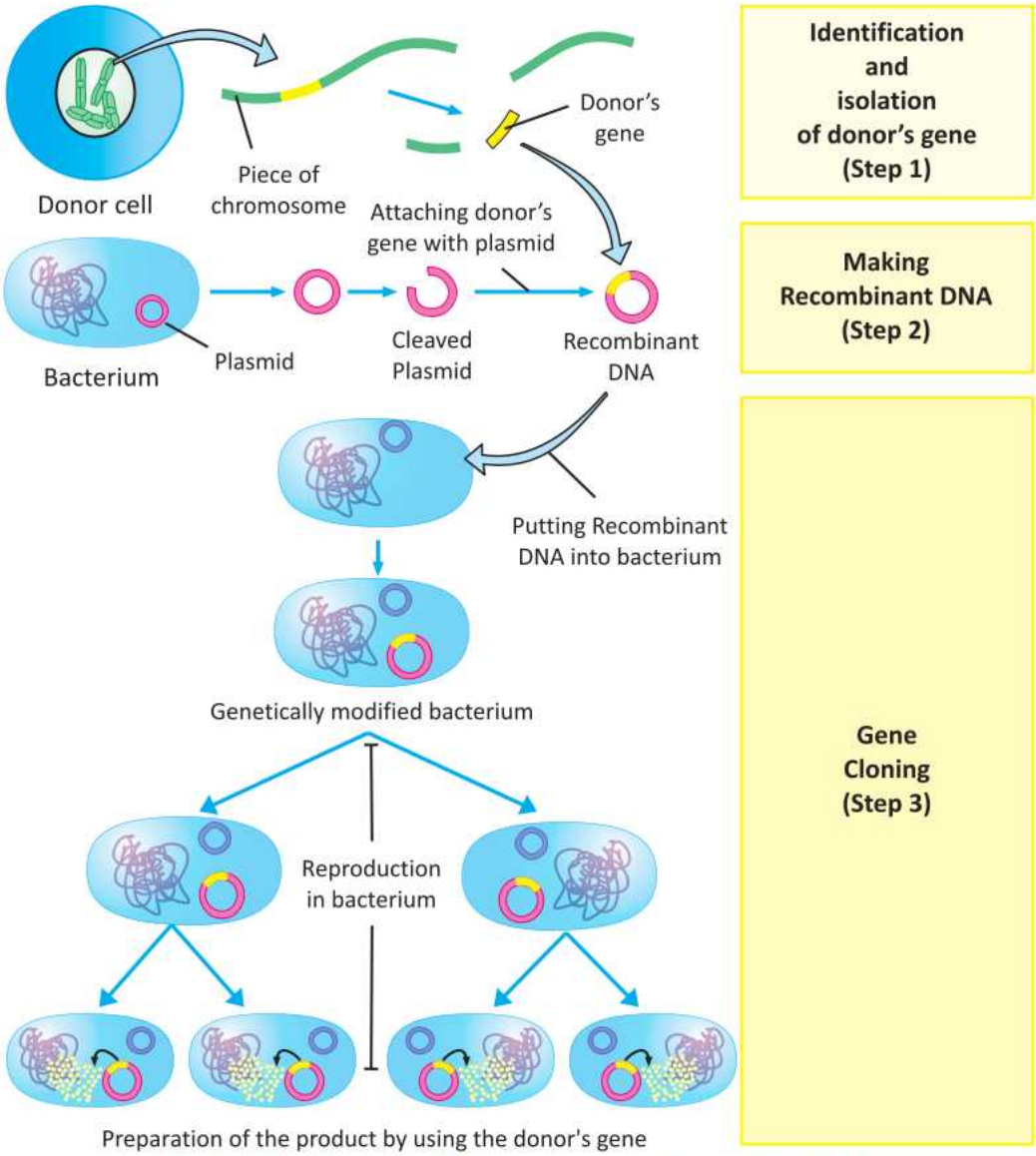


FIGURE 8.1: Transfer of gene to an organism and its cloning

The most commonly used vectors to transfer genes into bacteria are plasmids and bacteriophages. **Plasmids** are small, circular DNA molecules present in some bacteria. **Bacteriophages** are the viruses that can enter bacteria. The following are the steps for transferring a gene into organism e.g. bacteria.

1. The gene of donor organism is **identified** and **isolated** from its chromosome.
2. A plasmid is removed from a bacterial cell. The plasmid DNA is cut. Donor's gene is attached at the cut ends of the plasmid. The plasmid is now a combination of its original DNA and the new DNA (donor's gene). Now it is called **recombinant DNA**.
3. The recombinant DNA is transferred into a bacterial cell. When bacterial cell reproduces to form a colony of cells, all genetically modified bacteria contain the recombinant DNA. In this way, the bacterial colony contains many copies of the donor's gene. This step is also called **gene cloning**.

Examples of Gene Transfer

1. The human insulin gene is transferred into a bacterium. The modified bacteria produce insulin, which is collected for treating diabetic patients.
2. Human growth hormone is produced in genetically modified bacteria. It is used to treat dwarfism.
3. Interferon (anti-virus protein) is made in modified bacteria.
4. In gene therapy, genetic engineers introduce genes into a patient's cells. It is used to treat genetic disorders of blood (e.g., thalassaemia).
5. Vaccine against Hepatitis B virus has been produced from yeast through genetic modification.
6. A gene from a bacterium is transferred into cotton and corn crops. The genetically modified crops then produce a natural toxin that kills insects but is safe for humans.
7. Gene from a bacterium is transferred into rice plants. The rice produces beta-carotene, which the body converts into vitamin A. Such genetically modified rice help prevent blindness caused by vitamin A deficiency.

Some COVID-19 vaccines are made by using mRNA. This mRNA carries instructions to make a harmless proteins of the corona virus, which trains the immune system to fight the real virus.

FIGURE 8.2: Golden rice & White rice

Table 8.1: Products made by using Gene Transfer			
Product	**Genetic Material Transferred**	**Organism or Technology Used**	**Purpose**
Insulin	Human insulin gene	Bacteria	Treat diabetes
Growth Hormone	Human growth hormone gene	Bacteria	Treat growth disorders
Interferon	Human interferon gene	Bacteria	Treat viral infections and boost immunity
Hepatitis B Vaccine	Surface protein gene of Hepatitis B virus	Yeast cells	Protect against Hepatitis B
Bt Crops	Bt toxin gene	Cotton, Corn plants	Insect resistance
Golden Rice	Beta-carotene producing genes	Rice plants	Prevent vitamin A deficiency

8.3 APPLICATIONS OF BIOTECHNOLOGY

The following are the applications of biotechnology.

1. Food Biotechnology

- Biotechnologists have developed virus resistant, pest resistant, and drought resistant varieties of many crop plants.
- Enzymes extracted from certain microbes are used in different industries for the production of alcohol.

Research in Pakistan has led to the development of rice varieties that are resistant to certain diseases and pests.

Pakistan has also advanced in using tissue culture technology for the mass propagation of high-yielding fruit crops such as mangoes and citrus.

2. Medical Biotechnology

In medical field, biotechnology is helping in the following:

- Making proteins e.g., hormones and enzymes used for treating various diseases.
- Developing vaccines to prevent viral and bacterial infections.
- Correcting defective genes responsible for genetic disorders.
- Production of targeted antibodies for disease diagnosis and treatment.
- Identifying inherited diseases and genetic conditions early.

In humans, more than 3500 disorders are due to errors in genes. Biotechnologists are trying to remove such disorders through biotechnology.

In **Human Genome Project**, biologists discovered the locations of all genes in human body. They also found the characteristics controlled by each gene.

3. Environmental Biotechnology

Environmental Biotechnology is the application of biological organisms or processes to protect and improve the environment.

Bioremediation is defined as the use of organisms such as bacteria, plants, or fungi to remove or neutralize pollutants from the environment. Genetically modified bacteria are used to break down the harmful chemicals present in waste matters and industrial discharge.

FIGURE 8.3: Saplings to grow forest

- Large number of saplings of different plants are produced through tissue culture. These saplings are planted to grow new forests in limited time.
- Modified bacteria are also used for extracting different minerals e.g., copper and uranium.
- Microbes such as bacteria, blue green algae and fungi are used to produce manure.

4. Marine Biotechnology

It deals with the marine organisms to develop new products, treatments, and technologies. For example:

- Genetic modifications in many fishes have led to faster growth rates.
- Compounds extracted from marine organisms (sponges, corals, and marine bacteria) are used to develop new cancer drugs, antibiotics and antiviral medicines.
- Certain marine bacteria are used to degrade oil spills, helping to clean up marine environments.
- Marine algae are cultivated in large quantities and processed into biodiesel, ethanol, and other types of renewable energy.
- Enzymes extracted from marine organisms are used in various industries. For example, an enzyme extracted from marine bacteria is used to produce high-fructose corn syrup (common sweetener in the food industry).

5. Industrial Biotechnology

The following are the main applications of industrial biotechnology.

- Biofuels like ethanol, biodiesel, and biogas are produced. For example,

yeast is used to ferment sugars from crops (corn, sugarcane) into ethanol. This ethanol can be blended with petrol to produce a cleaner fuel.

- Biodegradable plastic (bioplastic) is produced from fermented plant starch (usually corn or sugarcane).
- Pharmaceutical products are prepared through microbial fermentation and genetic engineering. For example, the production of antibiotics, such as penicillin, involves the fermentation of specific molds like *"Penicillium"*. Similarly, human insulin is produced through bacteria.

8.4 POTENTIAL RISKS OF BIOTECHNOLOGY

Health Concerns: Some people worry that consuming genetically modified foods could cause allergic reactions or long-term health problems. There is also concern that new genes might interact with human cells in unexpected ways.

Environmental Impact: GM plants can sometimes cross-pollinate with wild plants. So, the modified genes can be spread in natural ecosystems. It can lead to create such species that may harm the environment.

Loss of Biodiversity: If farmers mostly grow GM crops then traditional and naturally diverse varieties might become rare or extinct. This can reduce biodiversity.

Development of Resistant Pests and Weeds: Pests exposed repeatedly to GM crops may evolve into "powerful pests" that are no longer affected by the crop's built-in defences.

Ethical Issues: Many people feel that it is morally wrong to alter the natural genes of living organisms.

EXERCISE

A. Select the correct answers for the following questions.

1. Why are bacteria commonly used in genetic engineering for producing products?

   a) They naturally produces the required products

   b) They grow quickly and accept human genes

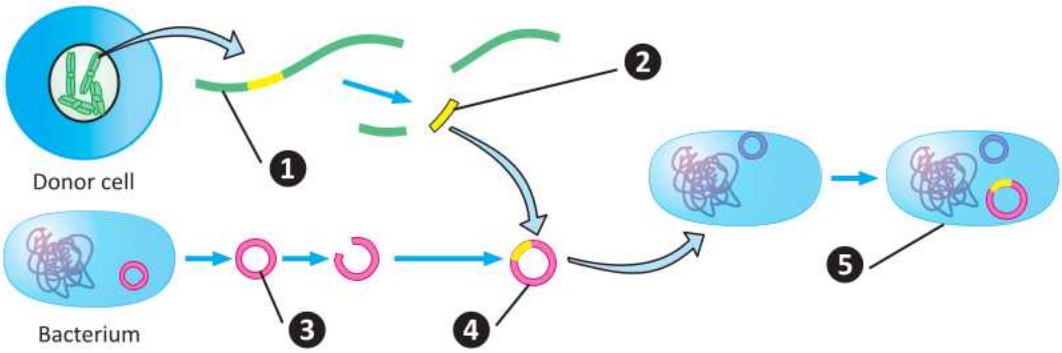
   c) They resist all infections

   d) They have a human-like immune system

2. In genetic engineering, the first step is:
   a) Inserting DNA into the organism
   b) Cutting the desired gene from DNA
   c) Growing the modified organism
   d) Making proteins from the gene
3. Which of these is often used as a vector in genetic engineering?
   a) Virus b) Fungi c) Yeast d) Blood cell
4. In genetic engineering, the desired gene is usually inserted into a bacterium by using:
   a) Protein b) Another bacterium
   c) Vector d) Enzyme
5. In genetic engineering, after inserting the gene, the host cell is allowed to:
   a) Mutate randomly b) Die naturally
   c) Multiply and express the gene d) Produce waste
6. In genetic engineering, "recombinant DNA" means:
   a) Natural DNA b) DNA copied by mistake
   c) DNA joined from two sources d) DNA destroyed by enzymes
7. A gene for toxin production is inserted into a plant for:
   a) Reducing water need b) Increasing vitamin content
   c) Resisting insect attacks d) Speeding up flowering
8. Genetically modified bacteria produce the following products, except;
   a) Hepatitis B vaccine b) Growth hormone
   c) Insulin d) Interferon
9. Which biotechnology products help against viral infections?
   a) Antibiotics b) Vaccines
   c) Clotting factors d) Growth hormone
10. Golden rice is a genetically modified plant to increase:
   a) Protein b) Vitamin A
   c) Iron d) Calcium

B. Write short answers.

1. What is the relation between biotechnology and genetic engineering?
2. What is a plasmid? Why biologists use plasmids in genetic engineering?
3. The following diagram shows how a gene is transferred to bacterial cell. Identify the structures labelled as 1 to 5.



4. What do you mean by genecally modified organism?
5. List two types of medical products that can be produced using genetic engineering.
6. List two ways by which genetic engineering may improve crops.

C. Write answers in detail.

1. Explain with examples that food biotechnology has advanced agriculture.
2. Explain with examples that medical biotechnology has advanced healthcare in diabetes and cancer.
3. Explain the role of yeast in the production of bread and ethanol.
4. Enlist the steps for transferring a human gene into a bacterial cell.
5. Describe the advantages of gene editing.
6. Discuss the potential risks of genetic modification.

D. Inquisitive questions

1. How can inserting a gene into a plant make it pest-resistant?
2. How can biotechnology help in developing vaccines quickly, like for COVID-19?
3. Why is it important to carefully study the effects of genetically modified foods on health?

9 DISEASES AND IMMUNITY

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe infectious and non-infectious diseases and their types with examples.
- Define zoonotic diseases and give their types.
- Describe vector borne diseases with examples.
- Enlist allergies with some common types.

The human body is a complex system designed to maintain health and function despite constant exposure to potential threats. These threats come in various forms including microorganisms, genetic disorders, environmental influences and

According to the World Health Organization (WHO), "health is a state of complete physical, mental, and social well-being and not merely the absence of disease or illness".

lifestyle choices. In this chapter, we will explore the nature of diseases and various types of disease vectors.

9.1 DISEASE

Disease is defined as a specific condition that affects the normal functioning of the body or mind. It covers a wide range of conditions which affect various body systems. Examples of diseases include infections, metabolic disorders, autoimmune diseases, and genetic disorders. The term "illness" means the subjective experience of being unwell due to disease. This includes individual's perception and response towards their health condition.

Basic Types of Diseases

1. Infectious Diseases (Infections)

These are the communicable diseases (can spread from person to person or from the environment to person). Infectious diseases result from harmful organisms (pathogens) entering the body. Common pathogens include viruses, bacteria, fungi, parasitic protozoans (e.g., *Plasmodium*) and worms (e.g., tapeworm). Infectious diseases spread from person to person, through contaminated food, water, or bug bites. Examples include:

> Infections can be localized (e.g., skin infection) and systemic (affecting multiple organs).

- **Viral Infections:** Hepatitis, flu, dengue, measles, HIV, and COVID-19.
- **Bacterial Infections:** Typhoid, strep throat, cholera, tuberculosis.
- **Fungal Infections:** Candidiasis (yeast infection).
- **Infections by Parasitic Protozoan:** Malaria, Amoeabiasis.
- **Infections by Parasitic Worms:** Roundworm, tapeworm infections.

> Overuse of antibiotics by people has caused resistance in many bacteria. It is a major health risk.

2. Non-Infectious Diseases

These are non-communicable diseases (do not transmit from one person to others). Such diseases result from heredity, unhealthy lifestyles, environmental factors, aging etc. Examples include:

> Diabetes and cancers are not solely due to lifestyle choices. These diseases also have genetic basis. Lifestyle choices can however, delay the onset of such diseases.

- Many non-infectious diseases develop due to unhealthy lifestyle. These include heart diseases, hypertension, diabetes, cancer, and stroke. Mental health diseases like depression are also included in this category.

- Genetic diseases are caused by abnormalities in genes or chromosomes. Examples include haemophilia, thalassemia, and muscular dystrophy.
- Some non-infectious diseases result from the gradual decline of body organs or tissues due to aging or other factors. Examples include Alzheimer's disease, Parkinson's disease, and arthritis.

Other Types of Diseases

1. Zoonotic Diseases

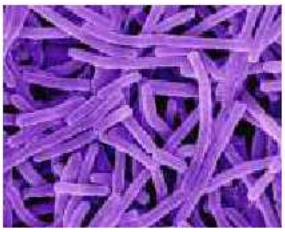
An infectious disease that is naturally transmitted from animals to humans is called zoonotic disease. Zoonotic pathogens may be bacteria, virus or other parasites. Humans can get zoonotic pathogens through direct contact with animals or through food, water or the environment. Examples of zoonosis include:

> Some diseases, such as AIDS, began as a zoonosis but later became human-only diseases.

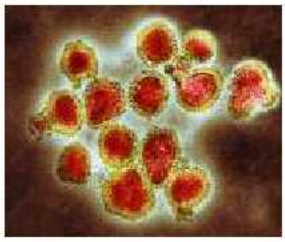
a- Anthrax: It is caused by the bacterium *Bacillus anthracis*. The infection site may be skin, lungs or digestive system. Anthrax is transmitted to humans through contact with contaminated animal products (e.g., hides, wool). Usually, anthrax bacteria enter the body through a wound in the skin, by eating contaminated meat or inhaling the spores of bacteria.

b- Bird Flu (Avian Influenza): It is caused by influenza A virus. The infection sites include nose, throat and lungs. Humans get bird flu through close contact with infected birds.

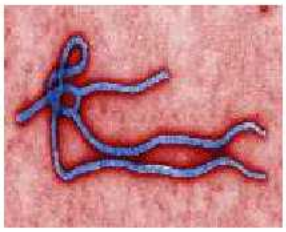
c- Ebola: It is caused by Ebola virus which targets sites in the body including liver, immune system, and blood vessels. The virus spreads through direct contact with body fluids, such as blood from infected humans or animals. It also spreads from contact with contaminated objects.



Bacillus anthracis



Influenza A virus



Ebola virus

FIGURE 9.1: Causative agents of Anthrax, Bird flu and Ebola

2. Vector-Borne Diseases

These are infections that are transmitted by vectors i.e., living organisms that carry pathogens from one host to another. These diseases can be caused by

bacteria, viruses or other parasites. Examples include:

1- Malaria: It is caused by a parasitic protozoan (*Plasmodium*). It primarily affects liver and then the RBCs. If untreated, it can lead to organ damage. It spreads from one human to other through *Anopheles* mosquito.

2. Dengue Fever: It is caused by Dengue virus that transmits through *Aedes* mosquito. Dengue fever affects multiple organs, including skin, blood vessels, and lymph nodes.

3. Lyme Disease: It is caused by bacteria *Borrelia burgdorferi* which spread through ticks. The infection affects the skin, joints, and nervous system.

4. Yellow Fever: It is an infection caused by yellow fever virus that spreads through *Aedes* or *Haemagogus* mosquitoes. The infection initially affects the liver, then involves the kidneys, heart, and nervous system.

Anopheles mosquito

Aedes mosquito

Ixodes ticks

Haemagogus mosquito

FIGURE 9.2: Some vectors that transmit diseases

3- Allergies

An allergy is an abnormal immunological response of the body against a foreign substance that's typically not harmful to the body. Such foreign substances which cause allergies are called **allergens**. Common allergens include pollen, dust mites, certain foods, insect stings, and certain medicines.

The immune system's response to allergens involves the release of inflammatory chemicals such as **histamine**. It results in symptoms that affect the skin, respiratory system, digestive system, and cardiovascular system. The following are the major types of allergies.

Anaphylactic shock is a severe, life-threatening allergic reaction. It can occur suddenly after exposure to an allergen such as certain foods, insect stings, or medicines. It causes difficulty in breathing and sudden drop in blood pressure. It requires immediate medical treatment.

Types of Allergies

1. Respiratory Allergies:

- **Allergic Rhinitis (Hay Fever)** - Caused by airborne allergens like pollen, dust mites etc. Symptoms include sneezing, itching, nasal congestion, and runny nose.

- **Asthma** - A chronic condition where various allergens (ammonia, latex, pesticides, fumes, metal or wood dusts etc.) trigger inflammation and narrowing of the airways. It leads to wheezing, shortness of breath, chest tightness, and coughing.

2. **Skin Allergies:**

- **Eczema (Atopic Dermatitis)** – Chronic skin condition characterized by itchy, inflamed patches of skin. Several allergens can trigger eczema. For example, dust mites, pollen, pet skin flakes, mold spores, certain fabrics, metals etc.
- **Contact Dermatitis** – Skin reaction resulting from direct contact with allergens like nickel, latex, or certain plants. Symptoms include redness, itching, and blisters.

3. **Food Allergies:**

- **Common Food Allergies** – Range from mild (itching and swelling) to severe (difficult breathing, loss of consciousness etc.). Allergens may be peanuts, tree nuts, shellfish, fish, milk, eggs, soy, and wheat.

4. **Insect Sting Allergies:**

- **Venom Allergens** – Bee, wasp, and ant stings can trigger allergic reactions e.g., local pain and swelling, hives, and in severe cases, anaphylaxis.

5. **Drug Allergies:**

- **Common Drugs Allergies** – Range from mild rashes and itching to severe anaphylactic reactions. Allergens may be certain antibiotics, aspirin, and Non-Steroidal Anti-Inflammatory Drugs (NSAIDs).

9.2 PATHOGENS

A pathogen is a microorganism or agent that causes disease in its host. Pathogens include viruses, bacteria, fungi, and other parasites like plasmodium. Each type of pathogen interacts with the body in a unique way, leading to different types of diseases.

Pathogens can spread to humans through the five main ways i.e., air, food, water, person-to-person contact, and bites of animals The following table lists the types of pathogens.

Table 9.1: Types of Pathogens

Type of Pathogen	Example	Disease Caused	Common Transmission Method
Virus	Influenza Virus	Influenza (Flu)	Airborne droplets Direct contact
	Human Immunodeficiency Virus (HIV)	AIDS	Sexual contact Blood transfusion Shared needles
	SARS-CoV-2	COVID-19	Airborne droplets Surface contact
Bacteria	*Streptococcus pyogenes*	Strep Throat	Respiratory droplets Direct contact
	Mycobacterium tuberculosis	Tuberculosis (TB)	Airborne droplets
	Escherichia coli	Food Poisoning	Contaminated food/ water
Fungi	*Candida albicans*	Candidiasis (Yeast Infection)	Fungal growth in warm, moist areas Direct contact
	Tinea pedis	Athlete's Foot	Contaminated surfaces
	Aspergillus fumigatus	Aspergillosis	Inhalation of fungal spores
Parasitic Protists	*Plasmodium falciparum*	Malaria	*Anopheles* mosquito
	Giardia lamblia	Giardiasis	Contaminated water Contaminated food
	Entamoeba histolytica	Amoebiasis	Contaminated food/water

Note: Many invertebrates also live as pathogens. For example; tapeworm and roundworm are invertebrates that live in human intestine and cause infections.

9.3 IMMUNITY

Immunity is the ability of the body to defend itself against disease-causing organisms. The following are the types of immunity:

1- **Innate Immunity:** This type of immunity is present in body by birth. It includes the first line of defence and second line of defence.

2- **Acquired Immunity:** It is acquired during life time. It includes the third line of defence.

First Line of Defence

It is nonspecific defence against any pathogen, regardless of the pathogen's identity. It includes the skin and mucous membranes.

1. Skin serves as a physical barrier to pathogens. In addition, the oil and sweat glands present in skin inhibit the growth of many microbes.
2. Mucous membranes are epithelial tissues that protect the interior surfaces of the body e.g., respiratory and digestive systems, the urethra. Mucous membranes secrete mucus that traps pathogens.

Second Line of Defence

The second line is also a non-specific defence. It includes:

1- Killer cells of blood move through the bloodstream to detect and destroy pathogens. For example:

- **Macrophages** develop from monocytes (a type of WBCs). They ingest bacteria and kill them.
- **Neutrophils** are a type of WBCs. They do phagocytosis (engulfing the pathogen and killing it). They also release killing chemicals on pathogens. They also release network of fibres which bind with pathogens and kill them.

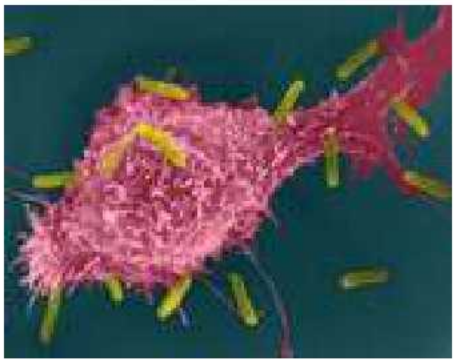


FIGURE 9.3: A macrophage attacking microbes

- **Natural killer cells** are a type of T-lymphocytes. They kill the body cells that are infected by pathogens. They also detect and kill cancer cells.

2- Protective proteins also provide non-specific defences. For example:

- Special proteins form a ring-shaped structure that punctures the membranes of infected cells, causing the cells to die.
- **Interferon** is another protective protein. It is released by cells infected with viruses. Interferon causes nearby cells to make a protein that helps them resist viral infection.

3- **Inflammation:** Infected or injured cells release chemicals called **histamines** which cause local expansion of blood vessels. It results in heat, redness and swelling. This condition is called inflammation. This response is often strong enough to stop the spread of microbes.

4- **Fever:** Fever is also a second line of defence. When macrophages attack

the pathogens, they release chemicals called **pyrogens** in blood. When pyrogens reach the brain, the temperature regulating part of the brain raises the body's temperature above the normal value of 37 °C (98.6 °F). It results in the rise in body temperature. The higher than normal body temperature is known as fever. It increases the activity of phagocytes and slows bacterial and viral growth.

Third Line of Defence

The third line of defence or **acquired immunity** is of two types:

1. In **active immunity**, a type of lymphocytes called B-cells prepare antibodies to kill the pathogen. It may be natural or artificial (vaccination):
2. In **passive immunity**, the individual is given antibodies to combat specific microbes. Passive immunity is short-lived.

Blood Clotting

Blood clotting, or coagulation, is a process that prevents excessive bleeding when a blood vessel is injured. The following are the main steps:

1. When a blood vessel is injured, the exposed collagen fibres activate the blood platelets. Activated platelets adhere to the collagen and the damaged walls of blood vessel. In this way, a temporary "platelet plug" is formed.

2. Platelets release special proteins called clotting factors which convert prothrombin (a plasma protein), into thrombin.

3. Thrombin converts fibrinogen, another plasma protein, into fibrin strands. Fibrin strands weave through the platelet plug, forming a blood clot.

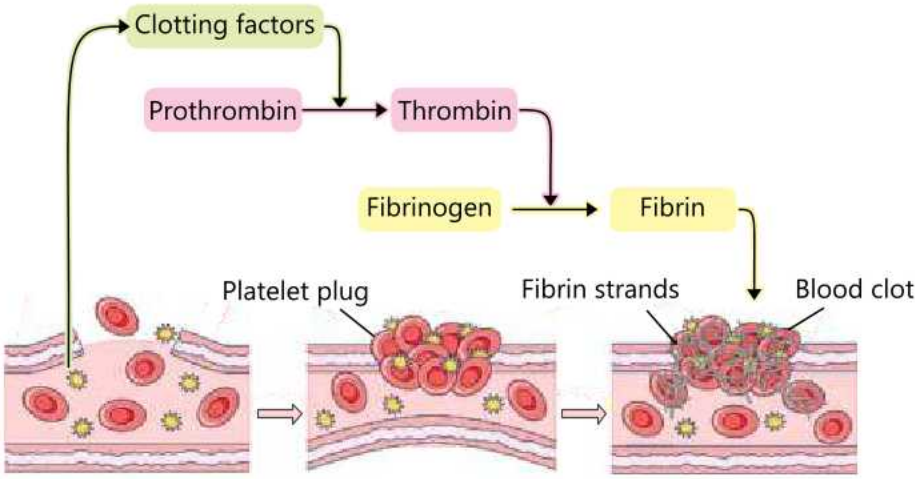


FIGURE 9.4: Formation of blood clot

4. Platelets within the clot contract and reduce the size of wound.

Once the vessel is repaired. A plasma protein breaks down the fibrin clot, dissolving the clot and restoring normal blood flow.

EXERCISE

A. Select the correct answers for the following questions.

1. A doctor finds bacteria in a patient's blood sample. What type of disease is the patient suffering from?
   a) Infectious disease b) Non-infectious disease
   c) Genetic disorder d) Nutritional deficiency
2. Which of the following is an example of an infectious disease?
   a) Diabetes b) Hypertension
   c) Influenza d) Osteoporosis
3. A person develops rabies after being bitten by a dog. This is an example of:
   a) Non-infectious disease b) Food-borne illness
   c) Zoonotic disease d) Genetic disorder
4. Which of the following is a vector-borne disease?
   a) AIDS b) Malaria
   c) Tuberculosis d) Diabetes
5. A person develops dengue fever after a mosquito bite. In this case, the mosquito acts as:
   a) Host b) Pathogen
   c) Vector d) Reservoir
6. Which of the following is the first line of defence against pathogens?
   a) Antibodies
   b) Skin and mucous membranes
   c) T cells
   d) B cells
7. Skin is categorized as;
   a) Non-specific defence b) Specific defence
   c) Acquired immunity d) Passive Immunity

8. What triggers an allergic reaction?

a) Pathogens b) Allergens

c) Antigens d) Antibodies

B. Write short answers.

1. Define infectious diseases.
2. Define zoonotic diseases. Also give examples
3. Enlist allergies with some common types.
4. Differentiate between innate and acquired immunity.
5. Describe the role of skin as a component of defence system.
6. State the role of mucous membranes in defence.

C. Write answers in detail.

1. Describe infectious and non-infectious diseases and their types with examples.
2. Describe vector borne diseases with examples.
3. Describe the roles of T-cells and B-cells in immunity.
4. Write a note on blood clotting.

D. Inquisitive questions

1. Why do infectious diseases spread faster in crowded places?
2. How can genetics increase a person's risk of developing non-infectious diseases?
3. Why do some people develop allergies while others do not?

10 EVOLUTION

Students Learning Outcomes

After studying this chapter, students will be able to:

- Explain the theory of evolution by natural selection with examples.
- Define species.
- Discuss briefly the observations Darwin made during his voyage on HMS Beagle.
- Describe sources of variation which can lead to speciation and evolution.
- Describe evidence of evolution with regards to the following:
  - Paleontology (fossil record)
  - Comparative anatomy (homologous structures, vestigial structures)
  - Selective breeding

Evolution is the change in heritable traits of population over the course of successive generations. It involves gradual changes in characteristics passed from one generation to the next. Such changes allow organisms to adapt to their

environment. Over time, these changes accumulate, resulting in formation of new species. In 1850s, Charles Darwin explained the mechanism of evolution in a comprehensive way.

10.1 DARWIN'S OBSERVATIONS

English naturalist Charles Darwin (1809–1882) went on five-year trip around the world on a His Majesty's Ship (HMS) Beagle. During this voyage, Darwin made a lot of important observations that laid the foundations of his ***Theory of Evolution by Natural Selection***.

FIGURE 10.1: Charles Darwin and his voyage on HMS Beagle

The following are some important observations made by Darwin:

- **Unique species:** He observed a variety of unique plant and animal species in different regions. He observed that different islands and environments had their own distinct sets of species.
- **Variations in same species:** Darwin observed variations among same species living in different environments. He noticed that these were adaptations i.e., special variations in an organism's body or behaviour that help it survive in its environment. He was convinced on the role of adaptations in the

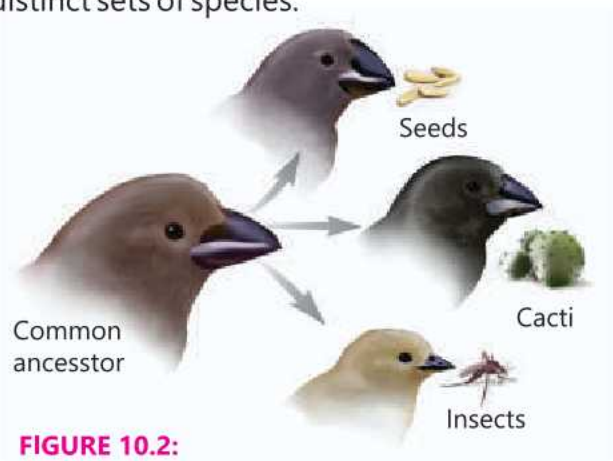


FIGURE 10.2: Finches with different beak sizes and shapes

survival of species.

- **Beaks of finches:** On the Galapagos Islands, he noticed that different species of finches had different sizes and shapes of beaks in different islands. He noticed that different foods e.g., seeds, cacti and insects were available at different islands. The beaks of finches were suited according to the food sources available on specific island.
- **Fossils of extinct animals:** When he observed the fossils of extinct animals, he found their resemblance with modern species. This suggested that species could change over time.

Some whales have tiny leg bones buried deep inside their bodies! These bones no longer serve a purpose in swimming. These are powerful clues to the whale's evolutionary past. They're like fossils inside the body.

After returning from his voyage, Darwin analysed his observations and gathered more evidence to support his ideas. Eventually, in 1859, Darwin published his work in the form of a book, **"On the Origin of Species"**. In this book, he presented his *"theory of evolution by natural selection"*.

10.2 THEORY OF EVOLUTION BY NATURAL SELECTION

The theory of evolution by natural selection states that "living things change over time. Those with helpful characteristics (variations) survive, reproduce, and pass those characteristics to their young. Over many generations, these favourable characteristics become more common in the population. It leads to the evolution of new species.

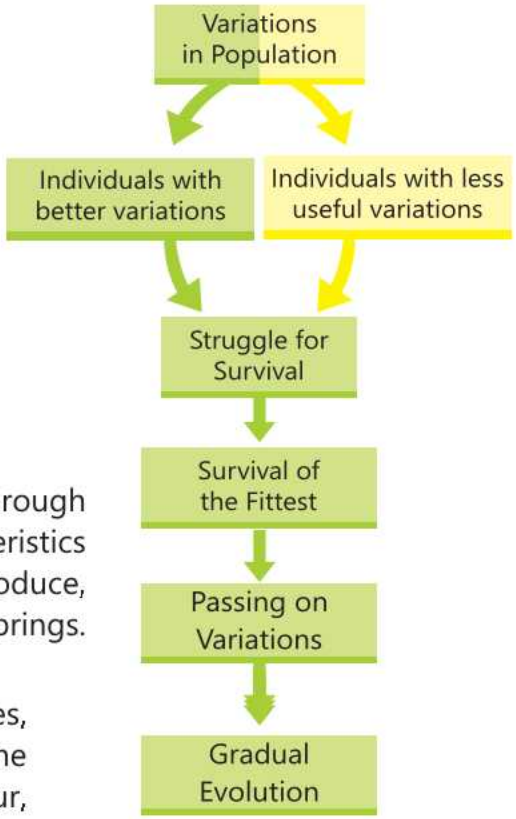


FIGURE 10.3: Mechanism of evolution

Natural Selection

Natural selection is the process through which the individuals with better characteristics (variations) are more likely to live, reproduce, and pass those variations to their offsprings. Natural selection works in three steps.

1. Variations: In every species, individuals are slightly different from one another. These differences may be in colour, size, speed, strength, or ability to find food.

For example: some beetles are green, and some are brown.

2. **Struggle for Survival:** Living things compete for limited resources such as food, water and space. Also, they face threats from predators, diseases, and harsh environments. For example: Birds eat beetles, so beetles must survive by hiding or blending in.

3. **Survival of the Fittest:** The individuals with better variations are more likely to live and reproduce. "Fittest" means best suited, not necessarily the strongest. For example: Brown beetles blend in with the soil better than green beetles. So, they will be difficult to be preyed upon by birds.

4. **Reproduction and Passing on Variations:** The surviving individuals reproduce and pass their useful variations to their offspring. Over time, these helpful variations become more common in the population. For example: More brown beetles are born because the green ones were eaten more often.

5. **Gradual Evolution Over Time:** After many generations, small changes build up. The species slowly changes. If the environment continues to favour certain variations, new species may eventually form. For example: If only brown beetles survive and reproduce over many generations, the whole beetle population may become brown.

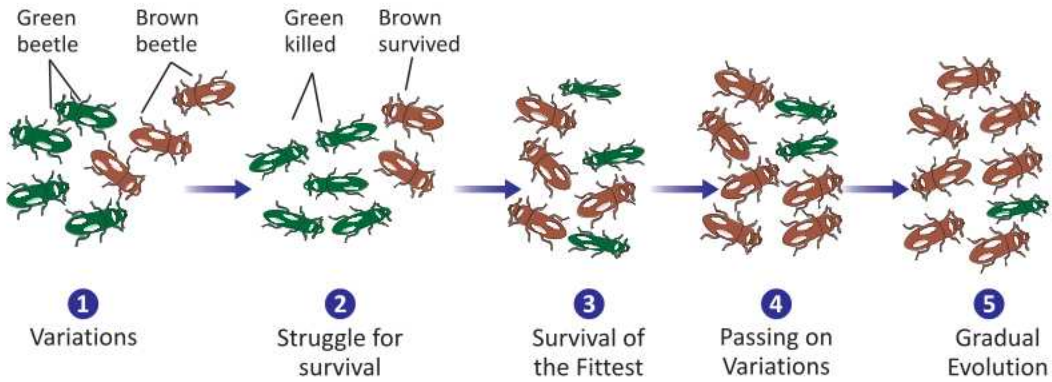


FIGURE 10.4: Process of natural selection

Examples of Natural Selection

1: Giraffe's Long Neck

i. **Variations:** Some giraffes had slightly longer necks than others.

ii. **Struggle for Survival:** Food (leaves on tall trees) was hard to reach, especially during dry seasons.

Why do giraffes have such long necks?

It's not just about reaching high leaves. Some scientists suggest long necks also helped male giraffes fight each other.

iii. **Survival of the Fittest:** Giraffes with longer necks could eat leaves from taller trees and survived better during harsh conditions.

iv. **Reproduction and Passing on Traits:** These long-necked giraffes reproduced and passed the long-neck trait to their babies.

v. **Gradual Evolution Over Time:** Over many generations, most giraffes in the population had long necks.

2: Peppered Moth (During Industrial Revolution in England)

i. **Variations:** Some moths were light-coloured, and some were dark-coloured.

ii. **Struggle for Survival:** Birds hunted the moths during the day as they rested on tree bark.

iii. **Survival of the Fittest:** After pollution darkened the tree bark, dark-coloured moths blended in and survived better than light ones.

iv. **Reproduction and Passing on Variations:** Dark moths reproduced more and passed on the dark colour trait.

v. **Gradual Evolution Over Time:** Over time, the population had more dark-coloured moths than light ones.

10.3 SPECIES AND SPECIATION

Species

A species is a group of organisms that can interbreed and produce fertile offspring under natural conditions. Members of the same species are similar and are reproductively isolated from other species. For example, Lions (*Panthera leo*) and Tigers (*Panthera tigris*) are distinct species. They do not naturally interbreed with each other.

Speciation

Speciation is the process by which new species arise by evolution. There are two main types of speciation:

1. Allopatric Speciation: This speciation occurs when a population is geographically separated into two or more populations. The physical barrier (such as a mountain range, river, or ocean) prevents individuals from different groups from breeding. Over time, the isolated populations evolve differently and become distinct species. For example, in the case of the finches of Galapagos Islands, different islands provided unique environment. Over time, populations of finches adapted to each environment, eventually becoming separate species.

2. Sympatric Speciation:

This speciation occurs when reproductive isolation happens within the same geographical area due to habitat preference or behaviour. For example, groups of fishes of same species live in the same lake. Buth the groups are reproductively isolated due to dietary preferences or mate selection. Over time, the groups remain reproductively isolated, resulting in the emergence of new species.

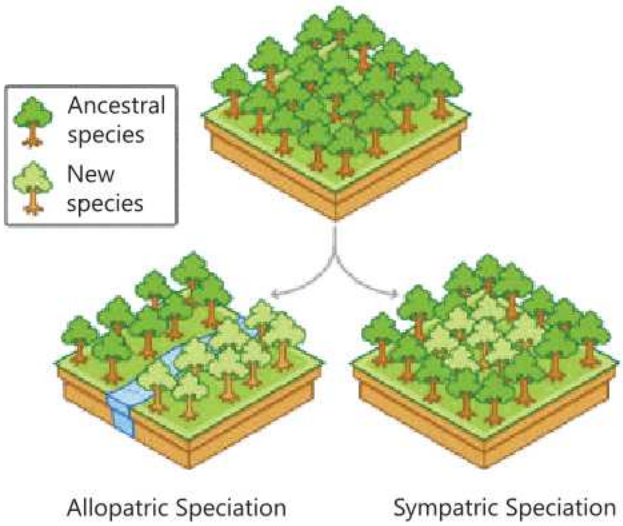


Figure 10.5: Main types of speciation

10.4 SOURCES OF VARIATION

Variations are the inheritable differences among individuals in a population on which natural selection can act. The following are the main sources of variations.

1- Mutations

Mutation is a permanent change in the DNA of an organism that can pass on to the offspring. Mutations can occur spontaneously or by environmental factors such as radiations or chemicals. Mutations result in new characteristics (variations) in organism. Most mutations are neutral or harmful. Some mutations can be beneficial and provide better variations to the organism.

You probably look similar to your parents and siblings. However, you don't look exactly the same, and this is due to **variations.**

Example: In a population of bacteria, a mutation may produce antibiotic resistance in some individuals. These resistant bacteria have more chances to survive and reproduce in the presence of antibiotics. They can pass on this variation to future generations.

2- Genetic Recombination

In sexually reproducing organisms, genetic recombination occurs during the formation of gametes through meiosis. The mixing of genetic material from two parents produces offspring with new combinations of genes.

Bananas have numerous mutations!

Many bananas are triploid, meaning they have three sets of chromosomes. It makes them sterile. They can't reproduce normally. So, every banana is a clone i.e., grown from a cutting of another plant.

This results in variation by creating new combinations of characteristics.

Example: Human siblings have different combinations of characteristics (e.g., hair colour, eye colour) because of the genetic recombination that occurs during the formation of gametes in parents.

3- Gene Flow (Migration)

Gene flow occurs when individuals from one population migrate to another and introduce new genes in that population. This can introduce new variations within a population. If these new variations prove better in the new population, they can spread through the population.

Example: When plants from one area cross-pollinate with plants from a different region, they introduce new characteristics into the population, such as improved drought resistance varieties.

4- Random Pairing of Gametes

During sexual reproduction, the pairing (fusion) of egg and sperm is random. It means that any sperm can fertilize any egg. It increases variation by producing offspring with unique combinations of genes inherited from both parents.

Example: In humans, the random pairing of an egg and one sperm from millions of possibilities leads to children in the same family having different characteristics, even though they share the same parents.

10.5 EVIDENCES OF EVOLUTION

There exists many evidences that species have changed and continue to change over time. The following are important evidences of evolution:

Recalling

Fossils are the remains, impressions or traces of organisms that lived in the past. Most fossils are found in sedimentary rocks.

1. Palaeontology (Fossil Record)

Fossils provide a visual record of evolution. Palaeontologists study fossils to observe sequence of evolutionary changes among organisms. For example, the fossils of vertebrate classes showed that fishes are the earliest vertebrates, following amphibians, reptiles, and then birds and mammals.

Fossils of organisms show characteristics of ancestors and their new generations. These fossils bridge the gaps in the evolutionary history of various species and provide evidence of gradual

FIGURE 10.6: Archaeopteryx

change over time. For example, fossils of *Archaeopteryx* (a bird-like dinosaur) provides evidence that birds evolved from a tetrapod dinosaur (a reptile).

2. Comparative Anatomy

Comparative anatomy involves the similarities and differences in the structures of different organisms.

Homologous Structures

The similar structures in different species that perform different functions are called homologous structures. For example, the forelimbs of mammals (arms of human, legs of cat, flippers of whale, and wings of bat) all have the same structure but different functions. The basic similarity of structure of these forelimbs is the evidence that they evolve from a common ancestor.

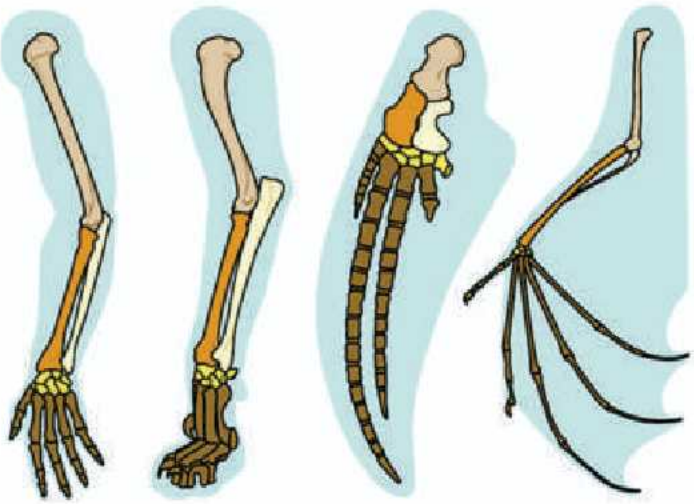


FIGURE 10.7: Homologous structures

Vestigial Structures

Vestigial organs are body parts that have no apparent function but were fully functional in an organism's ancestors. It is believed that through evolution vestigial organs lost their original function over time. For example:

Homologous organs are structurally same but functionally different. **Analogous organs** are functionally same but structurally different e.g. wings of bat, birds and insects etc.

- **Human appendix:** It is a small, tube-like structure attached to the cecum. In humans, it is a vestigial structure. It might have played a more important role in the digestive system of ancestors.
- **Ear muscles in humans:** In many animals, such as cats and dogs, ear muscles move their ears to detect sounds from different directions. However, in humans, these ear muscles are largely non-functional. So, these are vestigial structures in humans.
- **Pelvic bones in whales:** Modern whales have small, non-functional pelvic bones even though they do not have legs.
- **Wings in flightless birds:** Birds like ostriches have wings, but they do not

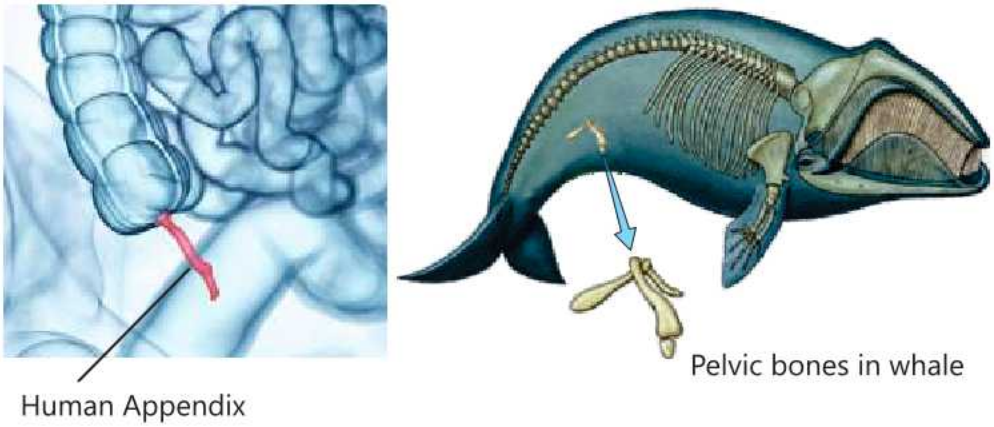


FIGURE 10.8: Vestigial organs

use them for flight.

3. Selective Breeding

Selective breeding means the process in which humans select varieties of plants or animals and breed them to produce offspring with required characteristics. In this way, they can improve characteristics in plants such as grain production or disease resistance. Similarly, they can improve growth rate or milk production in animals.

The varieties of animals which are selectively bred are called **breeds**. The varieties of plants which are selectively bred are known as **varieties** or **cultivars**. Many breeds of sheep, goat, cow, hen etc. have been produced by selective breeding to increase the production of meat, milk, eggs, wool etc.

FIGURE 10.9: Different breeds of hen

Similarly, many plant varieties (cultivars) have been produced for better quantity and quality of food. This process has proved very successful for the improvement of yields in economically important plants like wheat, rice, potato, and apple etc.

FIGURE 10.10: Varieties (cultivars) of potato and apple

Selective breeding provides evidence of the naturally occurring variations among species and their natural selection (evolution).

EXERCISE

A. Select the correct answers for the following questions.

1. The survival and reproduction of individuals with advantageous traits is called:
   a) Mutations b) Gene flow
   c) Natural selection d) Asexual reproduction
2. A population is split by a river. After many generations, both population evolve into different species. What type of speciation may occur?
   a) Sympatric b) Genetic drift c) Mutation d) llopatric
3. Which characteristics in whales supports that their ancestors lived on land?
   a) Big body b) Fins c) Pelvic bones d) Stream-lined body
4. Farmers choose best cows to breed. It is an example of:
   a) Natural selection b) Selective breeding
   c) Adaptation d) Genetic mutation
5. Darwin's observation of finches proved that:
   a) Climate was same on all islands
   b) All finches were identical
   c) They adapted to different foods on different islands
   d) Finches never migrated
6. A new variation appears suddenly and helps survival. What happens next?
   a) It disappears b) It spreads through population
   c) It causes disease d) It's removed by natural selection

7. Which of these is a vestigial structure?

a) Human ear muscles b) Wings of Sparrow

c) Beak of duck d) Tail of cat

8. Which pair are homologous structures?

a) Bird wings and butterfly wings b) Dolphin fins and shark fins

c) Human arms and dolphin fins d) bat wings and bird wings

9. Human appendix is a vestigial organ because it:

a) Has a major digestive function b) Is part of the immune system

c) Is no longer useful for digestion d) Helps in absorbing nutrients

10. Artificial selection is similar to natural selection because;

a) Environmental conditions play role in both

b) Both occur over millions of years

c) Both are carried out by humans

d) Both depend upon variations among individuals

B. Write short answers.

1. Write a short note on selective breeding.
2. What are the two types of speciation?
3. Provide examples of homologous structures.
4. List the steps in the process of natural selection.

C. Write answers in detail.

1. Explain the theory of evolution by natural selection.
2. Write a note on the observations Darwin made during his voyage.
3. Describe the sources of variation.
4. Justify how fossil record provides an evidence of evolution.
5. Write a note on homologous structures as an evidence of evolution.
6. What are vestigial structures? Explain how they provide evidence of evolution.

D. Inquisitive questions

1- Why is variation among individuals important for evolution?

2- How do fossils help scientists understand the history of life on Earth?

3- Why can isolation lead to the formation of new species?

GLOSSARY

A

Acquired Immunity: Immunity developed during a person's life due to exposure to diseases or vaccination.

Adrenal gland: A gland above each kidney that produces hormones like adrenaline and cortisol.

Adreno-cortico-tropic hormone: A hormone from the pituitary gland that signals adrenal glands to release cortisol.

Agranulocytes: White blood cells without granules in their cytoplasm, e.g., lymphocytes and monocytes.

Aldosterone: A hormone that helps control blood pressure by managing salt and water in the body.

Alimentary canal: The continuous muscular tube of the digestive system extending from the mouth to the anus.

Alleles: Different forms of a gene found at the same location on chromosomes.

Allergens: Substances that cause allergic reactions.

Allergies: Immune responses to harmless substances like pollen, dust, or certain foods.

Allopatric speciation: Formation of new species due to geographic isolation.

Alveoli: Tiny air sacs in the lungs where oxygen and carbon dioxide are exchanged between air and blood.

Amylase: An enzyme that breaks down starch into maltose.

Androgens: Male hormones responsible for male features and reproductive functions.

Antibodies: Proteins produced by the immune system to fight specific antigens.

Antidiuretic hormone: A hormone that reduces urine production to save water in the body.

Antigens: Foreign substances, like pathogens, that trigger an immune response in the body.

Arteriosclerosis: Hardening and thickening of arterial walls.

Atrium (Atria): The upper chamber(s) of the heart that receive blood from veins.

Autonomic nervous system: The part of the nervous system that controls involuntary actions like heartbeat and digestion.

B

Bacteriophages: Viruses that infect and reproduce inside bacteria.

Bile: A digestive fluid produced by the liver that helps break down fats.

Bioremediation: Using living organisms to clean up environmental pollution.

Biotechnology: The use of living organisms or biological systems for practical purposes.

Blood plasma: The liquid part of blood that carries cells, nutrients, and waste products.

Bronchi: The two main branches of the trachea that carry air into each lung.

Bronchitis: Inflammation of the bronchi, often due to infection or irritation.

C

Calcitonin: A hormone that helps lower calcium levels in the blood.

Capillaries: The smallest blood vessels where exchange of gases, nutrients, and waste takes place.

Cardiac arrest: A sudden loss of heart function.

Cardiovascular system: The body system consisting of the heart, blood, and blood vessels.

Centromere: The region where two chromatids are joined together in a chromosome.

Chromatid: One half of a duplicated chromosome.

Chromatin: A mix of DNA and proteins in the nucleus, forming chromosomes.

Chromosome: A thread-like structure made of DNA that carries genetic information.

Coordination: The control and regulation of body functions through the nervous and endocrine systems.

Cortisol: A hormone that helps the body respond to stress and regulates metabolism.

D

Deamination: The removal of an amino group from amino acids in the liver.

Diabetes: A disease caused by insufficient insulin production or use, leading to high blood sugar levels.

Dialysis: A medical treatment that removes waste products from the blood when kidneys fail.

Digestion: The breakdown of complex food substances into simpler, absorbable forms.

Dihybrid cross: A genetic cross involving two traits.

DNA (Deoxyribonucleic Acid): A molecule that carries genetic instructions in cells.

Dominant allele: An allele that shows its effect even if only one copy is present.

E

Endocrine system: The system of glands that release hormones to control body activities.

Enzyme: A protein that speeds up chemical reactions in living organisms.

Epiglottis: A flap of tissue that prevents food from entering the windpipe.

Epinephrine: Also called adrenaline, a hormone for emergency responses (fight or flight).

Evolution: The process through which populations and species change over time.

Excretion: The removal of metabolic waste products from the body.

F

Fallopian tube: A tube where the egg travels from the ovary to the uterus.

Fermentation (in biotechnology): The process where microbes break down substances to produce useful products.

Fertilization: The fusion of a male and a female gamete to form a zygote.

First polar body: A small cell formed alongside the secondary oocyte, non-functional.

Follicle: A structure in the ovary where an egg develops.

G

Gametogenesis: The process of forming male or female sex cells (gametes).

Gene cloning: Making many copies of a specific gene.

Gene editing: A technique to change specific DNA sequences in genes.

Gene flow (migration): Movement of genes between populations due to migration.

Gene: A unit of heredity that determines the characteristics of an organism.

Genetic engineering: The direct manipulation of an organism's genes using biotechnology.

Genetic recombination: Mixing of genes during reproduction to create variation.

Genetically modified organism: An organism whose DNA has been changed using biotechnology.

Genotype: The genetic makeup of an organism.

Glomerulus: A cluster of capillaries in the kidney involved in blood filtration.

Glucagon: A hormone that raises blood sugar by telling the liver to release stored glucose.

Growth hormone: A hormone that helps in body growth and development.

H

Haemodialysis: A type of dialysis that uses a machine to clean the blood.

Haemoglobin: A red protein in red blood cells that carries oxygen.

Heterozygous: Having two different alleles for a gene.

Histone: Proteins that DNA wraps around to form chromatin.

Homozygous: Having two identical alleles for a gene.

Hormone: A chemical messenger produced by glands that regulates body functions.

I

Immunity: The body's ability to resist disease.

Infectious diseases: Illnesses caused by pathogens like bacteria or viruses.

Inheritance (heredity): Passing of traits/characteristics from parents to offspring.

Innate Immunity: The natural defence you are born with.

Insulin: A hormone that helps cells absorb glucose from the blood.

L

Large intestine: The part of the digestive system where water is absorbed from waste.

Leucocytes: White blood cells involved in defending the body against infection.

Liver: A large organ that performs many vital functions including detoxification and bile production.

Locus (loci): The specific location of a gene on a chromosome.

Luteinizing hormone: A hormone that helps in egg release in females and testosterone production in males.

Lymph: A fluid that carries white blood cells and drains into the bloodstream.

Lymphocyte: A type of white blood cell involved in specific immune responses.

M

Meiosis: A type of cell division that produces cells with half the number of chromosomes.

Mendel's Laws: Rules describing how traits are inherited from parents to offspring.

Menstruation: Monthly shedding of the uterine lining in females.

Monohybrid cross: A genetic cross involving one trait.

Mutation: A change in the DNA sequence of a gene.

N

Nasal cavity: The inside of the nose, where air is filtered, warmed, and moistened.

Natural selection: The process where organisms with favourable traits survive and reproduce.

Nephron: The functional unit of the kidney that filters blood and forms urine.

Neuron: A nerve cell that carries messages as electrical signals.

Non-Infectious disease: Diseases not spread from person to person, like diabetes.

Nor-epinephrine: A hormone that increases heart rate and blood pressure during stress.

Nutrient: A substance that provides nourishment essential for growth and health.

O

Oesophagus: The muscular tube that carries food from the mouth to the stomach.

Oestrogen: A hormone that controls female reproductive development and functions.

Oogenesis: The process of egg cell formation in females.

Ovary: A female reproductive organ that produces eggs and hormones.

Ovulation: The release of an egg from the ovary.

Oxytocin: A hormone that causes uterine contractions during childbirth and milk release during breastfeeding.

P

Pancreas: An organ that makes hormones (like insulin) and digestive enzymes.

Parathormone: A hormone that increases calcium levels in the blood.

Pathogen: A microorganism that causes disease.

Peristalsis: Rhythmic muscle contractions that move food along the digestive tract.

Phenotype: The observable traits or characteristics of an organism.

Phloem: Tissue in plants that transports food.

Placenta: An organ that connects the developing foetus to the uterus and provides nutrients.

Plasmid: A small DNA ring found in bacteria, used in genetic engineering.

Platelets: Cell fragments in blood that help with clotting.

Pollution: The presence of harmful substances in the environment.

Primary oocyte: An immature egg cell in its first stage of development.

Primary spermatocyte: A diploid cell that begins the process of sperm formation.

Progesterone: A hormone that prepares the uterus for pregnancy.

Prostate gland: A gland that adds more fluid to semen.

Protein synthesis: The process of making proteins using DNA and RNA.

Puberty: The stage of development when a person becomes sexually mature.

R

Recessive allele: An allele that shows its effect only when two copies are present.

Recombinant DNA: DNA formed by combining genes from different sources.

Red blood cells: Blood cells that carry oxygen using haemoglobin.

Reflex action: A quick, automatic response to a stimulus.

Reflex arc: The nerve pathway through which a quick, automatic response (reflex) travels from a sense organ to a muscle or gland, without involving the brain.

RNA (Ribonucleic Acid): A molecule that helps in protein synthesis and gene expression.

S

Salivary glands: Glands in the mouth that secrete saliva to help digest food.

Second polar body: Another small cell formed during egg development, usually non-functional.

Secondary oocyte: An egg cell formed after the first division into genesis.

Secondary spermatocyte: A haploid cell formed after the first division in spermatogenesis.

Semen: The fluid containing sperm and secretions from male glands.

Seminal vesicle: A gland that adds fluid to sperm to form semen.

Sexual reproduction: Reproduction involving the fusion of male and female gametes.

Speciation: The formation of new species through evolution.

Sperm: The male gamete (reproductive cell).

Spermatid: An immature sperm cell that develops into a sperm.

Spermatogenesis: The formation of sperm cells in males.

Spinal cord: A bundle of nerves extending from the brain that controls reflexes and sends messages.

Struggle for survival: Competition among organisms for limited resources.

Survival of the fittest: Organisms best adapted to the environment survive and reproduce.

Sympatric speciation: Formation of new species without geographic separation.

Synapse: The gap between two neurons where nerve impulses are transmitted.

T

Testes: Male reproductive organs that produce sperm and testosterone.

Testosterone: The main male hormone responsible for male features and reproduction.

Thyroid-stimulating hormone: A hormone that controls the thyroid gland and its hormone production.

Thyroxin: A hormone from the thyroid gland that controls the body's metabolism.

Trachea: The windpipe; a tube that carries air to and from the lungs.

Transcription of DNA: The process of making RNA from DNA.

Translation (in genetics): The process of making proteins from RNA.

Transpiration: Loss of water vapor from the surface of plant leaves.

True-breeding: Organisms that produce offspring with the same traits over generations.

U

Ureter: The tube that carries urine from the kidney to the bladder.

Urethra: The tube through which urine exits the body.

Urinary bladder: A muscular sac that stores urine before excretion.

Uterus: A muscular organ where a baby develops during pregnancy.

V

Vaccine: A substance that stimulates the immune system to protect against disease.

Valve: A structure in the heart and veins that prevents the backflow of blood.

Variations (in genetics): Differences in traits among individuals of a species.

Vas deferens: A tube that carries sperm from the testes to the urethra.

Vector-Borne Diseases: Diseases spread by carriers like mosquitoes or ticks.

Vectors (in genetic engineering): Carriers used to transfer genes into organisms.

Ventricle: The lower chamber of the heart that pumps blood out of the heart.

Villi: Small finger-like projections in the small intestine that increase surface area for absorption.

Z

Zoonotic diseases: Diseases that spread from animals to humans.

Zygote: The first cell formed when a sperm fertilizes an egg.

Pairing Scheme / Instructions for Preparation of Exam Paper of Biology for Class-10

The paper of Biology (General) for class 10 will consist of 60 marks. Timing of the paper will be two hours. The paper will be made as per following details:

Part-I: Objective:

Q-1: 12 Multiple Choice Questions. The detail is as follows: 1 × 12 = 12

Chapter	1	2	3	4	5	6	7	8	9	10
MCQs	1	1	1	2	1	1	1	1	1	2

Part-II: Subjective:

Q-2: 5 short answer questions have to be answered out of 8. The detail is as follows: 2 × 5 = 10

Chapter	1	2	5
No. of Short Questions	2	4	2

Q-3: 5 short answer questions have to be answered out of 8. The detail is as follows: 2 × 5 = 10

Chapter	3	4	6	7
No. of Short Questions	2	3	1	2

Q-4: 5 short answer questions have to be answered out of 8. The detail is as follows: 2 × 5 = 10

Chapter	8	9	10
No. of Short Questions	2	2	4

Part-III: Subjective:

This section will contain three detailed questions bifurcated in two-part **a & b** (carrying 5 & 4 marks each) and students have to attempt 2 questions The detail is as follows: 2 × 9 = 18

Q-5:

Chapter	1	3
Part	a	b

Q-6:

Chapter	6	5
Part	a	b

Q-7:

Chapter	9	8
Part	a	b

MODEL PAPER OF BIOLOGY FOR CLASS-10

Objective Type

Time allowed: 15 Min. **Max. Marks: 12**

نوٹ: ہر سوال کے چار ممکنہ جوابات A، B، C اور D دیے گئے ہیں۔ جو انتخاب آپ کے خیال میں درست ہے، اس سوال کے سامنے والے دائرے کو مارکر یا پین کی سیاہی سے بھریں۔ دو یا دو سے زیادہ دائروں کو کاٹنے یا بھرنے کی صورت میں جواب غلط تصور ہو گا۔

Note: Four possible answers A, B, C and D to each question are given. The choice which you think is correct, fill that circle with marker or pen ink in the answer-book. Cutting or filling two or more circles will result in zero mark in that question.

(i) خوراک کی نالی کے فوراً بعد معدے کا حصہ کہلاتا ہے۔

(i) The part of the stomach just after the oesophagus is called:

(a) Fundus فنڈس (b) Pyloric end پائلورک حصہ
(c) Cardiac end کارڈیک حصہ (d) Body جسم

(ii) ان میں سے کون سا ترتیب اس راستے کو درست طور پر ظاہر کرتا ہے جس سے ہوا سانس لینے (Inhalation) کے دوران گزرتی ہے؟

(ii) Which of these correctly orders the structures through which air passes during inhalation?

(a) Pharynx → trachea → larynx → bronchi فیرنکس ← ٹریکیا ← لیرنکس ← برونکائی
(b) Pharynx → larynx → trachea → bronchi فیرنکس ← لیرنکس ← ٹریکیا ← برونکائی
(c) Larynx → pharynx → bronchi → trachea لیرنکس ← فیرنکس ← برونکائی ← ٹریکیا
(d) Larynx → pharynx → trachea → bronchi لیرنکس ← فیرنکس ← ٹریکیا ← برونکائی

(iii) ٹانگوں سے ڈی آکسی جنیٹڈ (deoxygenated) خون کے دل تک واپس آنے کا درست راستہ بتائیں:

(iii) Trace the correct pathway for deoxygenated blood from legs back to the heart:

(a) Femoral veins → Inferior vena cava → Right atrium فیمورل وریدیں ← انفیریئر وینا کیوا ← دایاں ایٹریئم
(b) Femoral arteries → Inferior vena cava → Right atrium فیمورل شریانیں ← انفیریئر وینا کیوا ← دایاں ایٹریئم
(c) Femoral veins → Superior vena cava → Right atrium فیمورل وریدیں ← سپیریئر وینا کیوا ← دایاں ایٹریئم
(d) Femoral arteries → Superior vena cava → Right atrium فیمورل شریانیں ← سپیریئر وینا کیوا ← دایاں ایٹریئم

(iv) یوریٹر گردے سے کس راستے کے ذریعے نکلتا ہے؟

(iv) Ureter leaves the kidney through:

(a) pelvis پیلوس (b) hilus ہائلس
(c) papillary duct پیپی لیری ڈکٹ (d) collecting duct کلیکٹنگ ڈکٹ

(v) ٹیوبیولر سیکریشن کس قسم کا عمل ہے؟

(v) Tubular secretion is a/an:

(a) active transport ایکٹو ٹرانسپورٹ (b) diffusion ڈفیوژن
(c) osmosis اوسموسس (d) passive transport پیسو ٹرانسپورٹ

(vi) گلوکاگون کا کام ہے:

(vi) The function of glucagon is to:

(a) accelerates protein synthesis within cells خلیوں کے اندر پروٹین کی ترکیب کو تیز کرنا
(b) stimulates release of glucose from liver جگر سے گلوکوز کے اخراج کو بڑھانا
(c) decrease release of glucose from liver جگر سے گلوکوز کے اخراج کو کم کرنا
(d) slow down glucose formation from lactic acid لیکٹک ایسڈ سے گلوکوز کی تشکیل کو سست کرنا

(vii) Fertilization usually occurs in the: (vii) عام طور پر فرٹیلائزیشن کہاں ہوتی ہے؟

(a) uterus یوٹرس (b) vagina ویجائنا

(c) fallopian tube فیلوپین ٹیوب (d) cervix سروکس

(viii) If transcription is blocked, what will NOT form? (viii) اگر ٹرانسکرپشن رک جائے تو کون سی چیز تشکیل نہیں پائے گی؟

(a) mRNA ایم آر این اے (b) Amino acids امینو ایسڈز

(c) Proteins پروٹینز (d) Ribosome رائبوسوم

(ix) اگر بیکٹیریا کا جین مکئی میں منتقل کیا جائے تو فائدہ کیا ہوگا؟

(ix) If a gene from bacteria is transferred into corn, the advantage is:

(a) larger corn size مکئی کے سائز میں اضافہ (b) production of natural toxin قدرتی زہر (ٹاکسن) کی پیداوار

(c) more vitamins زیادہ وٹامنز (d) faster growth تیزی سے نشوونما

(x) Arrange the following in correct order: (x) درج ذیل کو درست ترتیب میں لگائیں:

1. Thrombin converts fibrinogen — 1۔ تھرومبن فائبروجن کو تبدیل کرتا ہے
2. Platelets form a temporary plug — 2۔ پلیٹ لیٹس عارضی پلگ بناتے ہیں
3. Clotting factors convert prothrombin — 3۔ کلوٹنگ فیکٹرز پروتھرومبن کو تبدیل کرتے ہیں
4. Platelets contract to reduce wound size — 4۔ پلیٹ لیٹس زخم کے سائز کو کم کرنے کے لیے سکڑتے ہیں

(a) 2 → 3 → 1 → 4 (b) 1 → 2 → 3 → 4

(c) 3 → 2 → 4 → 1 (d) 4 → 3 → 2 → 1

(xi) What does "fittest" mean in evolution? (xi) ارتقا میں "فٹسٹ" سے کیا مراد ہے؟

(a) Strongest سب سے زیادہ طاقتور (b) Largest سب سے بڑا

(c) Best suited سب سے زیادہ موزوں (d) Fastest سب سے تیز

(xii) ایلوپیٹرک اسپیشی ایشن میں جین فلو کو روکنے والا بنیادی عنصر کون سا ہے؟

(xii) In allopatric speciation, the main factor preventing gene flow is:

(a) climate آب و ہوا (b) predation پریڈیشن

(c) physical barrier جسمانی رکاوٹ (d) competition مقابلہ

Subjective Type (Part I)

Time allowed: 1.45 Hrs. **Max. Marks: 48**

Q. 2: Write short answers to any five (05) questions: کوئی سے پانچ (5) سوالات کے مختصر جوابات لکھیے: (4)

(i) State two functions of the liver other than digestion. (i) ہاضمے کے علاوہ جگر کے دو افعال بیان کریں۔

(ii) Differentiate between bolus and chyme. (ii) بولس اور کائم میں فرق بیان کریں۔

(iii) What is pleura? Write its function. (iii) پلیورا کیا ہے؟ اس کا فعل لکھیں۔

(iv) Write about the blood circulation in lungs. (iv) پھیپھڑوں میں خون کی گردش کے بارے میں لکھیں۔

(v) Mention the events during exhalation. (v) ایگزیلیشن (Exhalation) کے دوران ہونے والے واقعات بیان کریں۔

(vi) What are the causes and symptoms of emphysema? (vi) ایمفیسیما کی وجوہات اور علامات کیا ہیں؟

(vii) Compare the functions of thalamus and hypothalamus. (vii) تھیلیمس اور ہائپو تھیلیمس کے افعال کا موازنہ کریں۔

(viii) Name any four hormones secreted by anterior lobe of pituitary gland. (viii) پیچوٹری گلینڈ کے اینٹیریئر لوب سے خارج ہونے والے کسی چار ہارمونز کے نام لکھیں۔

کوئی سے پانچ (5) سوالات کے مختصر جوابات لکھیے: (3)

Q. 3: Write short answers to any five (05) questions: (5X2=10)

(i) خون کے پلازما میں موجود کسی دو پروٹینز کے نام اور ان کے افعال لکھیں۔
(i) Give the names and functions of any two proteins present in blood plasma.

(ii) اَے گرینولوسائٹس کیا ہیں؟ ان کی اقسام لکھیں۔
(ii) What are agranulocytes? Write its types.

(iii) پریشر فلٹریشن اور ٹیوبولر سیکریشن میں فرق بیان کریں۔
(iii) Differentiate between pressure filtration and tubular secretion.

(iv) لیتھوٹرپسی سے کیا مراد ہے؟
(iv) What do you mean by lithotripsy?

(v) رینل پیلوس کی تعریف کریں۔
(v) Define renal pelvis.

(vi) ایسٹروجن اور پروجیسٹرون کے افعال میں موازنہ کریں۔
(vi) Compare the functions of estrogen and progesterone.

(vii) یوکاریوٹک کروماٹن کی ترکیب کیا ہے؟
(vii) What is the composition of eukaryotic chromatin?

(viii) مینڈل نے مٹر کے پودے کو تجرباتی طور پر کیوں منتخب کیا؟ دو وجوہات لکھیں۔
(viii) Why did Mendel choose pea plant as an experimental material? Give two reasons.

کوئی سے پانچ (5) سوالات کے مختصر جوابات لکھیے: (4)

Q. 4: Write short answers to any five (05) questions: (5X2=10)

(i) جینیاتی تبدیلی میں بیکٹیریا کا کردار بیان کریں۔
(i) Mention the role of bacteria in Genetic Modification.

(ii) بائیوٹیکنالوجی کے دو ممکنہ خطرات لکھیں۔
(ii) Write any two potential risks of biotechnology.

(iii) فنگس اور پیراسائٹک پروٹوزوا سے ہونے والی بیماریوں کے نام لکھیں۔
(iii) Name the infections caused by fungi and parasitic protozoan.

(iv) زونوٹک بیماریاں کیا ہیں؟ دو مثالیں دیں۔
(iv) What are zoonotic diseases? Give two examples.

(v) غیر فعال (vestigial) ساختوں کی تعریف کریں۔ انسانوں میں مثالیں دیں۔
(v) Define vestigial structures. Give examples in humans.

(vi) تغیر (Variation) کے بنیادی ذریعہ کے طور پر میوٹیشن کیسے کام کرتا ہے؟
(vi) How does mutation act as the main source of variation?

(vii) سمپیٹرک اسپیشی ایشن کیا ہے؟ ایک مثال دیں۔
(vii) What is Sympatric Speciation? Give an example.

(viii) نیچرل سلیکشن کے مختلف مراحل بیان کریں۔
(viii) List the steps in the process of natural selection.

Subjective Type (Part II)

Note: Attempt any two questions. (2x9=18)

نوٹ: کوئی سے دو سوالات کے جوابات لکھیے۔

Q.5. (a) Describe the absorption of food in small intestine.

(الف) چھوٹی آنت میں غذائی اجزاء کے جذب (Absorption) ہونے کی وضاحت کریں۔

(b) How does blood circulate in human heart?

(ب) انسانی دل میں خون کیسے گردش کرتا ہے؟

Q.6. (a) What are sexually transmitted diseases? Explain with an example of AIDS.

(الف) جنسی طور پر منتقل ہونے والی بیماریاں (STDs) کیا ہیں؟ AIDS کی مثال کے ساتھ وضاحت کریں۔

(b) Describe the hormones with functions of the adrenal gland.

(ب) ایڈرینل گلینڈ کے ہارمونز اور ان کے افعال کی وضاحت کریں۔

Q.7. (a) In what ways do killer cells and protective proteins contribute to the second line of defence?

(الف) کلر خلیے (Killer cells) اور حفاظتی پروٹین دوسری دفاعی لائن میں کس طرح کردار ادا کرتے ہیں؟

(b) How does biotechnology help in medical field?

(ب) طب (Medical field) کے میدان میں بائیوٹیکنالوجی کس طرح مدد کرتی ہے؟