Based on National Curriculum of Pakistan 2022-23

Textbook of

Biology

Grade 10

National Curriculum Council
Ministry of Federal Education and Professional Training

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Textbook of Biology for Grade 10
based on National Curriculum of Pakistan (NCP) 2022-23

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PREFACE

This Textbook for Basic Medical Sciences: Biology Grade 10 has been developed by NBF according to the National Curriculum of Pakistan 2022-2023. The aim of this textbook is to enhance learning abilities through inculcation of logical thinking in learners, and to develop higher order thinking processes by systematically building the foundation of learning from the previous grades. A key emphasis of the present textbook is creating real life linkage of the concepts and methods introduced. This approach was devised with the intent of enabling students to solve daily life problems as they grow up in the learning curve and also to fully grasp the conceptual basis that will be built in subsequent grades.

After amalgamation of the efforts of experts and experienced author, this book was reviewed and finalized after extensive reviews by professional educationists. Efforts were made to make the contents student friendly and to develop the concepts in interesting ways.

The National Book Foundation is always striving for improvement in the quality of its textbooks. The present textbook features an improved design, better illustration and interesting activities relating to real life to make it attractive for young learners. However, there is always room for improvement, the suggestions and feedback of students, teachers and the community are most welcome for further enriching the subsequent editions of this textbook.

May Allah guide and help us (Ameen).

Murad Ali Mohmand
Managing Director

UTILITY OR PRACTICAL APPLICATIONS OF THE SUBJECT

1. **Digestive system:** The digestive system has several practical applications in daily life that directly impact out health, energy levels, and over all wellbeing. It includes: energy for physical and mental activity, healthy eating habits, weight management, hydration, stress management, probiotics (like yogurt etc.) and gut health, preventing digestive disorders, healthy aging. The digestive system is important for converting the food we eat into the nutrients and energy needed for everyday task.

2. **Circulatory system:** The circulatory system plays a crucial role in our daily lives by supporting various physiological processes essential for health and survival. The practical applications include: oxygen transport, nutrient delivery, waste removal, body temperature regulation, immune response, wound healing, hormonal distribution. The circulatory system is fundamental to keeping us alive and enabling our bodies to adapt to different conditions and needs throughout the day.

3. **Respiratory system:** The respiratory system plays a vital role in daily life, as it is responsible for gas exchange, ensuring that oxygen enters the body and carbon dioxide is expelled. Here are some practical applications of respiratory system in daily life. These include: breathing for energy, physical exercise, speaking and singing, managing stress, sense of smell, maintain blood pH, immune defense. These everyday functions highlight the essential role of the respiratory system in keeping the body functioning properly.

4. **Urinary system:** The urinary system plays a vital role in maintaining homeostasis and overall health in our daily lives. Some of its practical applications are: waste elimination, water balance, electrolyte balance, blood pressure regulation, pH balance, detoxification and vitamin D activation. In daily life, the urinary system's continuous filtering and balancing functions are critical to keeping the body in optimal working condition and preventing issues like dehydration, kidney stones or electrolyte imbalance.

5. **Nervous system:** The nervous system is critical in regulating and coordinating nearly all bodily functions, enabling us to interact with and respond to our environment. Some of the practical applications of the nervous system in daily life are: reflexes and quick reactions, coordination of movement, learning and memory, sensory perception, communication, emotional regulation, automatic bodily function, focus and attention, sleep regulation. The nervous system is central to almost every action and experience in daily life, from basic survival reflexes to complex emotional response and intellectual activities.

6. **Animal Reproduction:** The reproductive system's primary function is to enable reproduction, but it also plays roles in hormonal regulation and overall health. Here are some practical applications of the reproductive system in daily life. It includes: reproduction, sexual health and immunity, hormonal balance, puberty and development. In everyday life reproductive system is essential not only for reproduction but also for overall health, influencing physical, emotional and hormonal balance across different stages of life.

7. **Inheritance:** Inheritance can be compared to many real-life situations where traits, behaviors, or properties are passed from one entity to another. Here are a few application of inheritance in daily life: family and genetic trait, educational system, business hierarchies,

vehicles, software development. These examples highlight how inheritance helps to reuse common functioning of specific needs, making it an efficient approach in both real-world and programming contexts.

8. Diseases: Knowledge of diseases plays a crucial role in daily life, helping individuals make informed decisions to maintain health, prevent illness and manage existing conditions, Here are some practical applications: preventing health practices e.g., COVID 19, knowing risk factors e.g., diabetes heart diseases etc., early detection and screening, managing chronic conditions, infection control at home, mental health awareness, travel and disease awareness, emergency situation, caring for vulnerable population. Awareness of diseases helps in making proactive health quality of life and potentially preventing complications or the spread.

9. Immunity: Immunity plays a crucial role in protecting our bodies from infections and diseases. Understanding and apply knowledge of immunity in daily life has several practical benefits, which help maintain health and promote well-being. The some of the practical applications of immunity are: vaccination, healthy lifestyle to boost immunity, understanding autoimmune diseases, allergy management, hygiene and immune function, breastfeeding and infant immunity, exposure and immune system strengthening, travel and immunity. By understanding how immunity works, people can make informed decisions to enhance their immune system's functionality, avoid harmful overreactions and reduce risk of infections. This proactive approach helps maintain overall health and wee-being in daily life.

10. Biotechnology: Biotechnology has numerous practical applications that impact daily life, ranging from health and agriculture to environmental sustainability. Here are some keys ways biotechnology is applied in daily life: vaccines and therapeutics, personalized medicine e.g., (insulin production), agriculture,(genetically modified organisms ,bio-fertilizers and bio-pesticides, disease-resistant plants), food and beverage industry (fermentation technology, food preservatives, plant-based and cultured meat) environmental sustainability (bioremediation, biofuels, biodegradable plastics), household products (enzymes and detergents, personal care products e.g., skin and hair care products), forensic and law enforcement (DNA fingerprinting, paternity testing),animal health and breeding genetic engineering in livestock, veterinary vaccines, health monitoring, genome sequencing, water treatment. Biotechnology has a profound impact on daily life by improving health care, food production, environmental sustainability and even the products we use in our homes.

11. Biostatics and data analysis: Biostatistics has several practical applications in daily life, often related to health, medicine and public policy. Here are some ways it is applied: medical research and treatment (clinical trials, epidemiology), health risk assessments (disease risk prediction, survival analysis) , Public health Policy (vaccination programs, healthcare resource allocation), nutrition and diet studies, insurance and risk calculation, environmental health. Biostatistics impacts many aspects of health, disease prevention and policy decision-making in ways that influence daily life outcomes and wellbeing.

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بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ

اللہ کے نام سے شروع جو بڑا مہربان، نہایت رحم والا ہے

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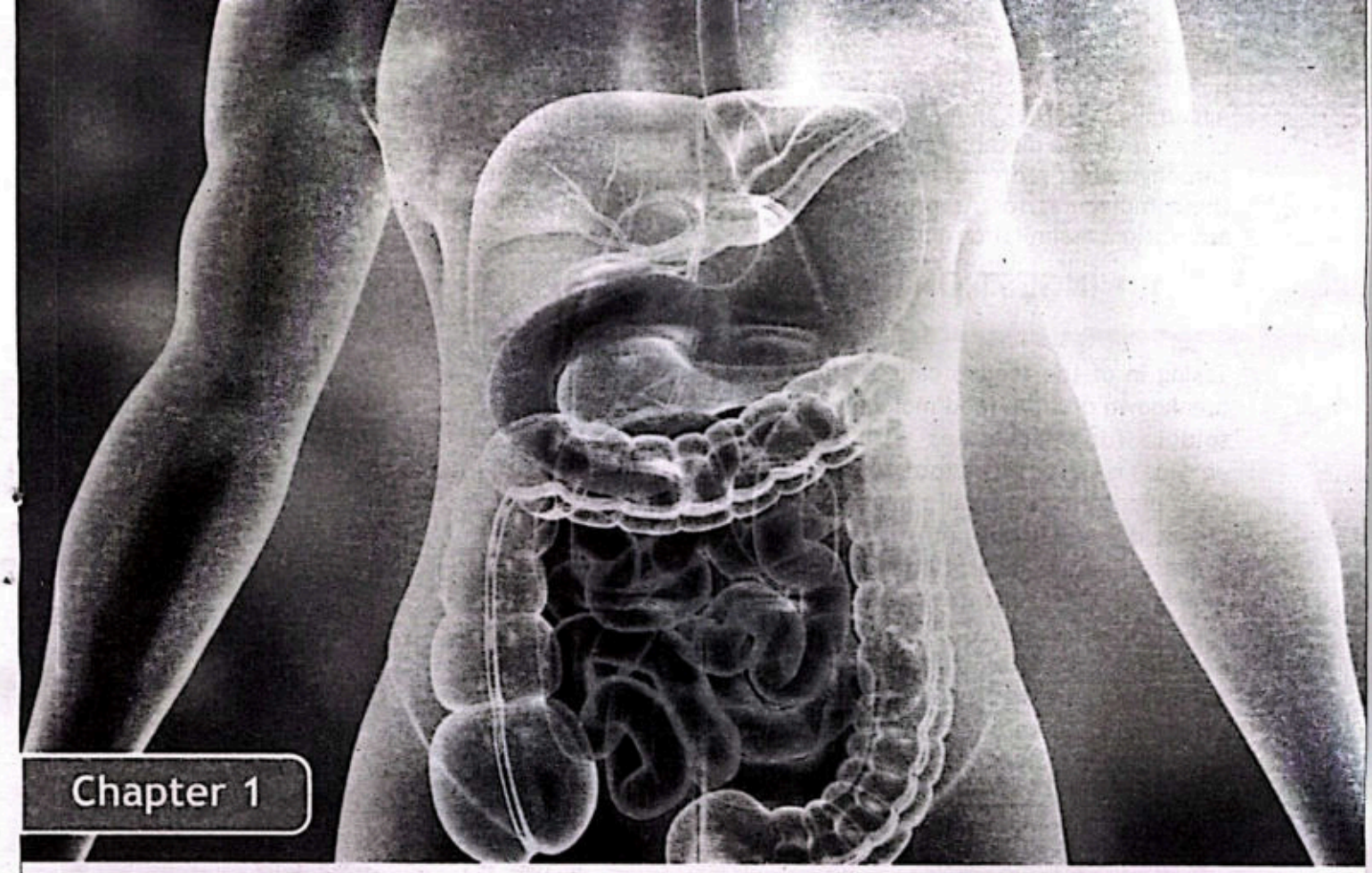


Chapter 1

DIGESTIVE SYSTEM

SLOs: After completing this lesson, the student will be able to:

1. [B-10-R-01] Describe the needs of ingestion, digestion, absorption, assimilation and egestion.
2. [B-10-R-02] Identify and describe the structures of the main regions of the alimentary canal and associated organs.
3. [B-10-R-03] Describe swallowing and peristalsis.
4. [B-10-R-04] Sort out the actions of enzymes in specific regions of alimentary canal, with respect to their substrate and products.
5. [B-10-R-05] State the role of liver.
6. [B-10-R-06] Describe the structure of villus, including the role of capillaries and lacteal.
7. [B-10-R-07] State sign and symptoms, causes, treatments and prevention of the disorders of gut i.e., diarrhea, constipation and ulcer.

A man like all other animals needs energy for the maintenance of his life processes. The energy comes from the metabolism of food substances which need to be digested. Our food consists of carbohydrates, proteins, and fats. These are very large molecules. Every cell of the body needs these molecules for its proper functioning. Digestive system performs ingestion, digestion, absorption, assimilation and egestion.

1.1 INGESTION, DIGESTION, ABSORPTION, ASSIMILATION AND EGESTION

Taking in of the food is called **ingestion**. The breakdown of large food molecules, into small soluble food molecules with the help of enzymes is called **digestion**. When the food has been digested, the small molecules must pass out of digestive tube into the blood and the process is called **absorption**. From blood these molecules are taken into the cells and are used for various purposes by a process called **assimilation**. The process by which the undigested part of the food is removed out of the body is called **egestion**. Digestive system cannot work alone. It is helped by transport system to take digested food from digestive tube to all parts of the body.

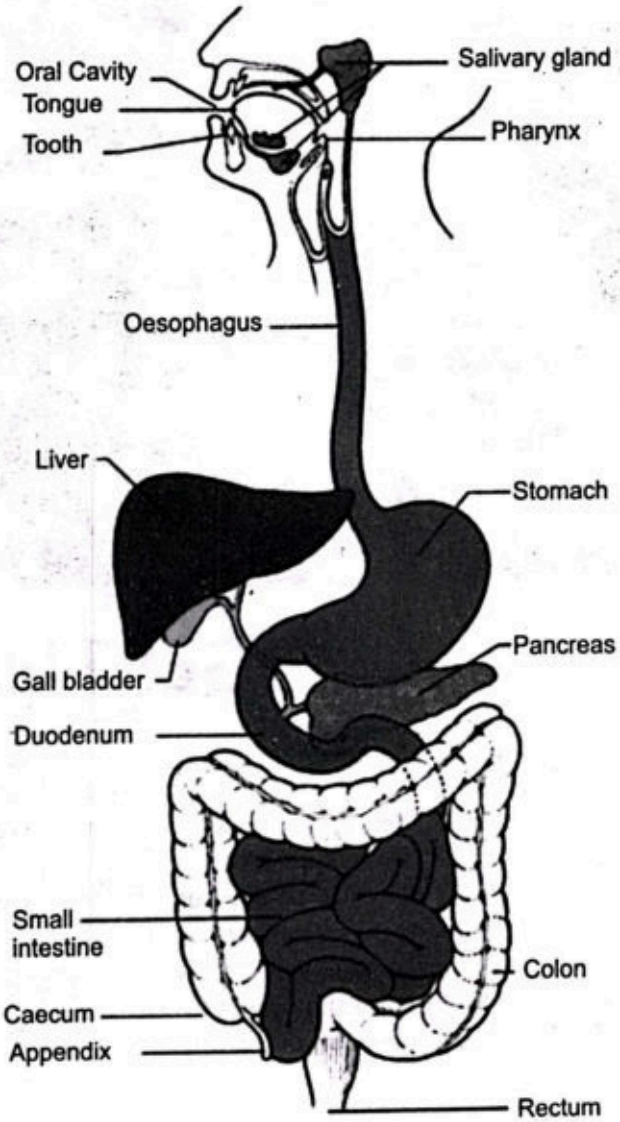


Fig. 1.1: The Human digestive system

1.2 HUMAN ALIMENTARY CANAL

The organs, which take part in the process of digestion, make the digestive system. The human digestive system consists of two sets of organs.

1. The **alimentary canal** is concerned with ingestion, digestion, absorption and egestion of undigested food. The parts of the alimentary canal are mouth, oral cavity, pharynx, oesophagus (esophagus), stomach, small intestine and large intestine.
2. The **digestive glands** are associated with the alimentary canal and help in digestion.

The digestive glands are, salivary glands, gastric glands, intestinal glands, liver and pancreas.

1.2.1 Alimentary Canal

Alimentary canal is also known as gut or digestive tract or gastrointestinal tract. It is a continuous tube. The tube is about 9 meters long in adult. It is specialized at various points along its length. It's each region is designed to carry out a different function in the overall process of digestion, absorption and egestion. Alimentary canal begins from the mouth and ends at the anus. It is lined internally by mucous membrane.

Mouth: It is the external opening that leads into the oral cavity or mouth cavity.

Oral Cavity: Around the sides and front of the oral cavity are the upper and lower jaws. The upper jaw is fixed while the lower is movable. The oral cavity contains teeth and tongue.

Pharynx: It leads from the mouth and nasal cavity to the oesophagus and to the trachea. The pharynx is a common passage for food and air.

Oesophagus: It is muscular tube, about 25 cm long. It leads from pharynx to the stomach. In oesophagus no digestion takes place.

Stomach: The stomach is the dilated part of the digestive tube. It is roughly J shaped and somewhat transversely placed on the left of the abdomen just beneath the diaphragm. It has two openings, which are guarded by valves.

The opening between oesophagus and stomach is called **cardiac opening**, which is guarded by cardiac sphincter. The region of the stomach around the cardiac opening is the **cardiac end**. The opening of stomach into the duodenum is called **pyloric opening** which is guarded by muscles called **pyloric sphincter.**

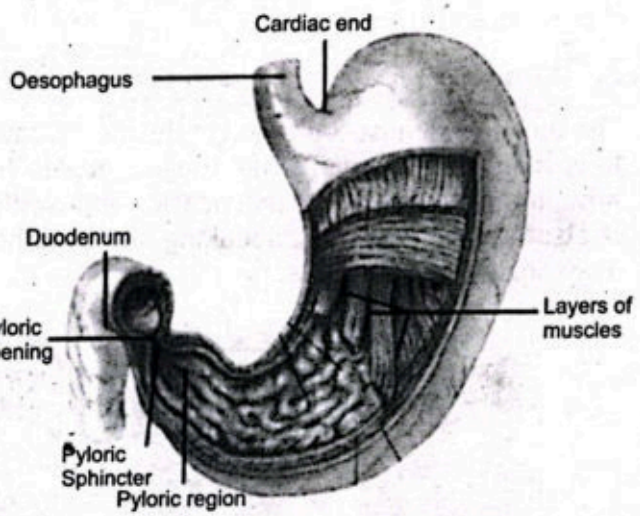


Fig. 1.2: Structure of Stomach

Small Intestine: The small intestine is small in diameter. It is divided into three parts: duodenum, jejunum and ileum. **Duodenum** is about 20-25 cm long. Bile duct from gall bladder, hepatic duct from liver and pancreatic duct from pancreas empties its secretions, in the duodenum. **Jejunum** is about 2.5 meters long and **ileum** about 4 meters long.

Large Intestine: The large intestine is a tube leading from the small intestine to the anus. It is 1, 5 meters in length. It is larger than small intestine in diameter. The **large intestine** is made up of three parts the colon, the rectum and the anus. The **colon** can also be divided into parts. The caecum is the first part of the colon. The ileum enters it from the side. The **caecum** has a pouch like end to its base **appendix** is attached which is 10 cm long. The rest of the colon is divided into segments:, the **ascending colon** (right) , the **transverse colon** (across) , the **descending colon** (left) , and the **sigmoid colon**, which connects to the **rectum**. The rectum is a straight, 8-inch chamber that connects the large intestine to the anus. The rectum temporarily stores the feces. The **anus** is the last part of the digestive tract. It is a 2-inch long canal. The anus is surrounded by sphincter muscles that are important in allowing control of stool.

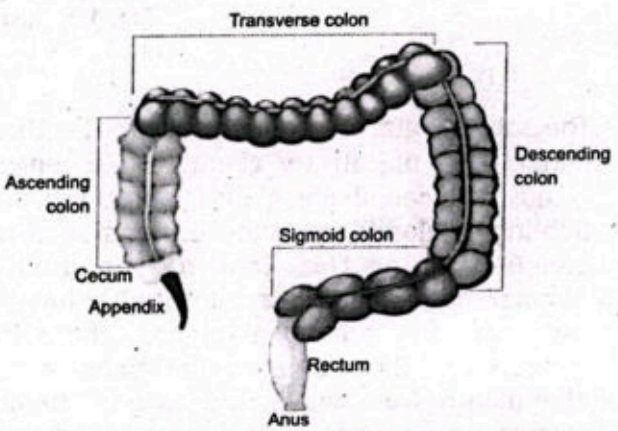


Fig. 1.3: Large intestine

1.2.2 Associated Organs

It includes teeth, tongue, salivary glands, liver, gallbladder and pancreas.

1. Teeth

The four types of teeth are **incisors**, canines, premolars, and molars. Incisors bite into food and cut it into smaller pieces. **Canines** are used to tear food. **Premolars** help to chew and grind up food. **Molars** chew food and grind it up.

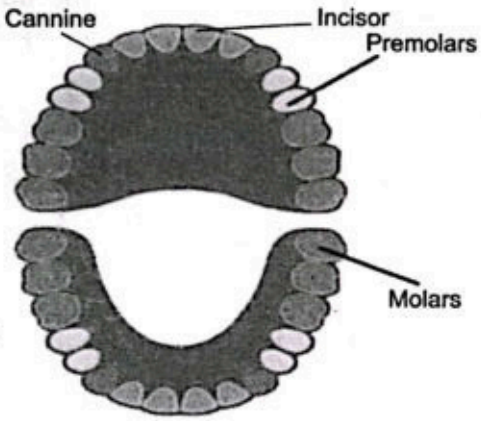


Fig. 1.4: The four types of human teeth

2. Tongue

The tongue is a muscular organ in the mouth cavity. It is a digestive organ. The tongue moves food around the mouth to help mastication and swallow. It also helps in chewing, speaking and breathing. The tongue has taste buds.

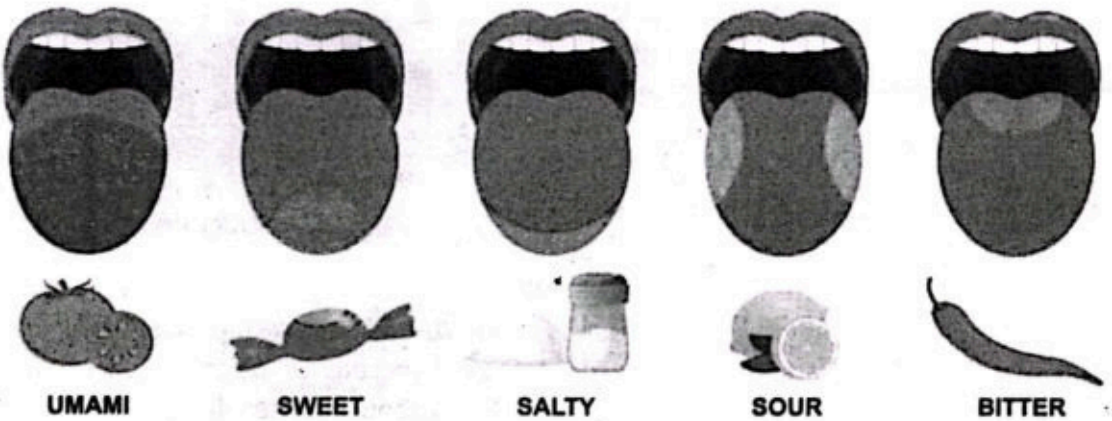


Fig. 1.5: Taste buds on tongue

3. Salivary glands

The salivary glands produce saliva. The three major pairs of salivary glands are sublingual glands, submandibular glands, parotid glands. **Sublingual glands** are below either side of the tongue, under the floor of the mouth. **Submandibular glands** are located below the jaw. Like the sublingual glands, the saliva produced in the submandibular glands enters the mouth from under the tongue. **Parotid glands** are just in front of the ears. The saliva produced by the parotid glands enters the mouth from small ducts near the upper molars.

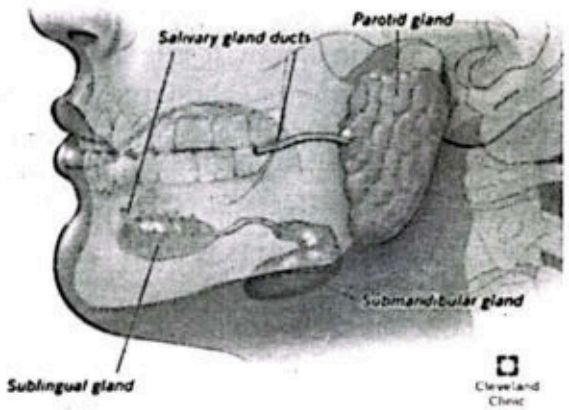


Fig. 1.6: Salivary glands

4. Liver

The human liver is an organ and gland in the human body. It is spongy, wedge-shaped, and reddish-brown in color. The liver is located on the right side of the body, under the ribs. Liver secretes **bile**. The liver has two main parts: the larger right lobe and the smaller left lobe. The lobes contain many blood vessels.

Blood travels through the liver. The lobes also contain thousands of small lobes i.e., lobules. These lobules connect with many bile ducts. These ducts transport bile from the liver to the duodenum.

5. Gallbladder

The gallbladder is just below the liver. Bile is stored in the gallbladder and flows through the **cystic duct** and the **common bile duct** into the small intestine when food is being digested.

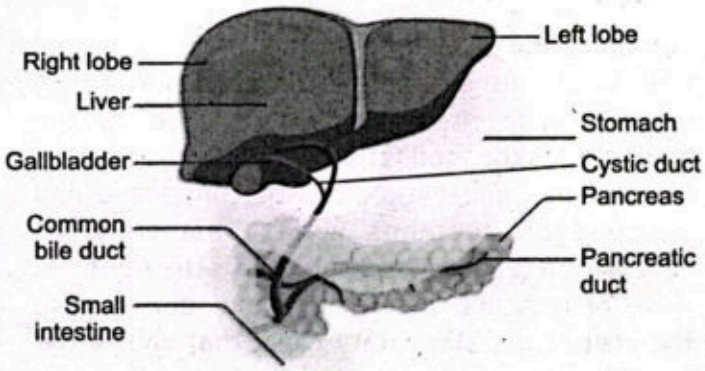


Fig. 1.7: Liver, gallbladder and pancreas

6. Pancreas

The pancreas is behind the stomach and in front of the vertebral column. It is surrounded by gallbladder, liver and spleen. The head of the pancreas is on the right side of the body. It is tucked beside the curve of the duodenum. The tail of the pancreas extends over to the left side of the body, near spleen.

1.3 SWALLOWING AND PERISTALSIS

The two main processes that take place in the digestion of food are **Swallowing** and **Peristalsis.**

1.3.1 Swallowing

In swallowing the following actions take place: (a) The tongue presses upwards and back against the roof of the mouth forcing bolus, to the back of the mouth. (b) The soft palate closes the nasal cavity at the back. (c) The larynx cartilage around the top of the trachea is pulled upwards so that glottis (opening of trachea) lies under the back of the tongue. (d) The epiglottis (a flap of cartilage) helps to prevent the food from entering glottis instead of oesophagus.
The beginning of the swallowing action is voluntary, but once the food reaches the back of the mouth, swallowing becomes an automatic or involuntary action. The food is forced into and down the oesophagus by peristalsis.

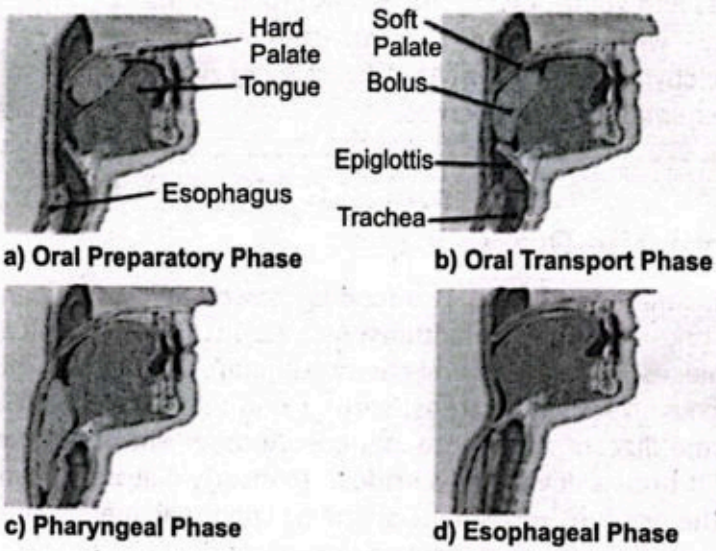


Fig. 1.8: The process of swallowing in man

1.3.2 Peristalsis

The alimentary canal has layers of muscle in its wall which pushes the ingested food forward. A contraction of circular muscles just behind the bolus pushes the food forward into the next region where longitudinal muscles are contracted and oesophagus becomes wide. This wave of contraction is called peristalsis. It is the rhythmic wave of muscular contraction and relaxation in the wall of the alimentary canal that causes the food to move through the alimentary canal.

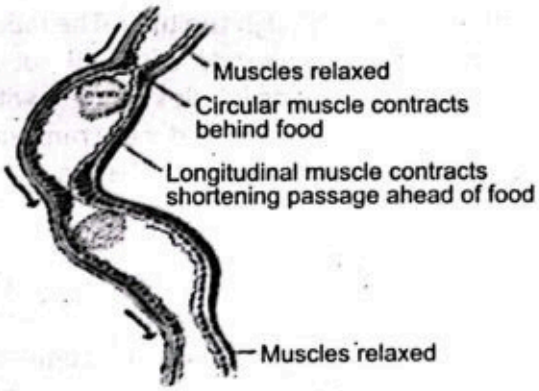


Fig. 1.9: Peristalsis

STEAM ACTIVITY 1.1 PERISTALSIS

Materials needed: Clear, flexible plastic straw, about 20 cm in length and about 6 mm in diameter. Round bead about 5-6 mm in diameter (You may use a seed, pebble etc., for the bead).

Procedure

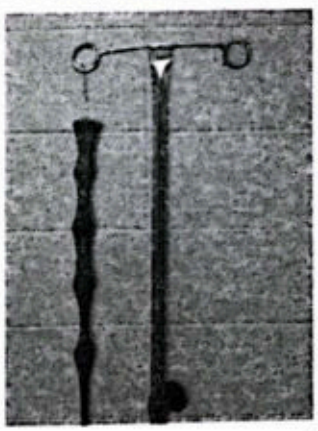
1. Obtain a clear, flexible plastic straw.
2. Hold the straw vertically and insert a small bead, into the top of the straw. The bead should fit tightly into the straw.

Caution: Do not put the straw in your mouth or blow into the straw.

3. Pinch the straw above the bead so the bead begins to move down the length of the tubing.
4. Repeat the step 3 until the bead exits the straw.

Q. How does this action compare with peristalsis?

Q. What do the bead and straw represents.



Science Titbits

Mucus is secreted in large amount by duodenal glands, intestinal glands, and goblet cells. The mucus provides the wall of intestine with protection against the irritating effects of acidic chyme and against the digestive enzymes that enter duodenum from the pancreas.

1.4 CHEMICAL DIGESTION

1.4.1 Digestion in the Oral Cavity

Here food is tasted, smelled and felt. The food is chewed by crushing and grinding. The teeth, cheeks and tongue take part in these actions. As a result, food is physically and quickly broken down into smaller pieces. Food in the oral cavity stimulates the salivary glands to secrete saliva. The water and mucous in saliva moistens, softens and lubricate food. Saliva contains **salivary amylase**. This enzyme digests starch into maltose. Another enzyme, **lipase**, is produced by the cells in the tongue. It breaks down triglycerides, to mostly diglyceride and free fatty acids. The food is rolled by the tongue into small, slippery, spherical mass called **bolus**. The bolus is swallowed and enters the oesophagus through the pharynx.

1.4.2 Digestion in Stomach

On the peristaltic reflex the cardiac sphincter relaxes to allow food in the stomach.

Gastric Juice: The food in the stomach stimulates the gastric glands to secrete gastric juice. It consists of mucous, HCl, pepsin and rennin.

Mucous: Mucous forms a coating over the stomach. It prevents the digestion of stomach wall by the enzyme pepsin.

Hydrochloric Acid: HCl performs the following functions: (a) Stops the action of salivary amylase. (b) It converts the inactive form of enzyme (pepsinogen) to active form (pepsin). It provides acidic medium suitable for the action of enzymes. (c) It kills many microorganisms.

Pepsin: It is secreted as inactive **pepsinogen**. HCl or already activated pepsin converts pepsinogen to **pepsin**. Pepsin digests proteins to polypeptides (chain of many amino acids) and peptides (chain of few amino acids).

Renin: Rennin is secreted only in infants. It helps in the digestion of milk protein.

By the churning action of stomach wall, the food gets mixed into a soupy mixture called **chyme**. When the chyme reaches a certain degree of acidity the pyloric sphincter relaxes and a little food passes into the duodenum.

1.4.3 Digestion in the Small Intestine

Starch, proteins and fats all are enzymatically broken down in the small intestine. When food enters the duod enum, the chyme stimulates:

(a) The gall bladder to release bile. (b) The pancreas to secrete pancreatic juice.

(c) The intestinal glands to secrete intestinal juice.

All these secretions are alkaline and neutralize the acidic chyme. The pancreatic and intestinal enzymes can work only in this alkaline medium.

Bile

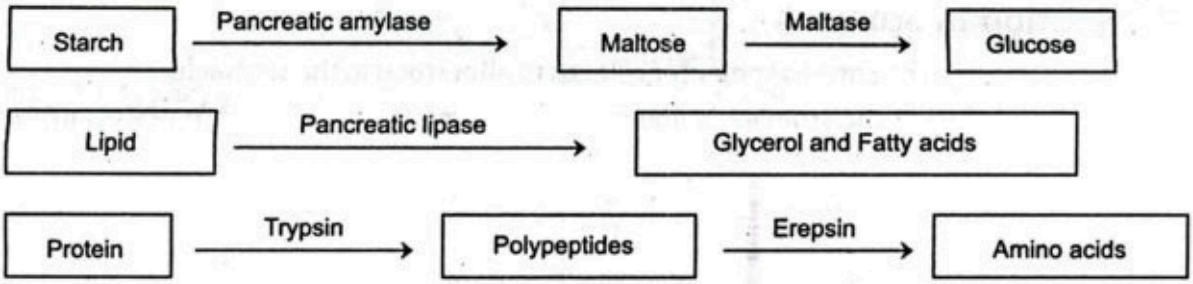
Bile is a greenish yellow liquid manufactured in the liver. Bile is stored in the gallbladder and is released as soon as food enters the duodenum. Bile emulsifies fats causing them to breakdown into small droplets called emulsion. Emulsification provides relatively large surface areas of lipid for the action of lipase enzymes.

Pancreatic Juice

The secretion of pancreas is called pancreatic juice. It contains enzymes amylase, lipase and trypsinogen. **Pancreatic amylase** is the starch-digesting enzyme. It converts polysaccharides to maltose and even to glucose. **Pancreatic lipase** converts neutral fats (i.e. triglyceroids) into glycerol and fatty acids. **Trypsin** converts proteins into polypeptides.

Digestion in Jejunum and Ileum

The lining of the jejunum and ileum secrete several enzymes such as erepsin which converts peptides into amino acids. It also secretes Enterokinase which activates pancreatic trypsinogen into its active form trypsin. Lactase converts lactose to glucose. Maltase converts maltose to glucose etc. In the ileum digestion process is complete.



1.4.4 Absorption in the Small Intestine

The internal lining of small intestine is modified to make tiny finger like projections called **villi**. Simple sugars and amino acids pass through the wall of the villi into the blood capillaries of villi. Mineral salts and vitamins also pass in the blood capillaries of villi. Absorption occurs by a combination of diffusion and active transport. Glycerol and fatty acids are absorbed by the lacteal and ultimately will be poured into the blood.

The absorbed food in the blood capillaries of the villi passes into the blood stream. They are then carried away in the capillaries, which join up to form veins. These veins unite to form one large vein called the **hepatic portal vein**. This vein carries all the blood from the intestine to the liver, which may store or alter any of the digestion products.

1.4.5 Absorption in large intestine

From large intestine water and some vitamins are absorbed into the blood.

1.4.6 Assimilation

The products of digestion are carried round the body by the blood. These are absorbed by the body cells. The body cells use glucose, amino acids and fats. This uptake and use of food is known as assimilation. All the cells use glucose during cellular respiration to produce ATP.

Defecation

The semi solid waste, the faeces or stool is passed into the rectum by peristalsis and is expelled at intervals through the anus. The removal of undigested matter from the body is called **egestion** or **defecation**.

1.5 ROLE OF LIVER

The liver has many functions. Some of the most vital roles of liver are:

1. The liver cells manufacture bile.
2. Excess quantity of glucose is stored by the liver as glycogen.
3. Liver converts glycerol and amino acids to glucose molecules.
4. Liver removes amino group from amino acids. It is called deamination.
5. Ammonia is converted into urea in the liver.
6. Majority of the plasma proteins are synthesized in the liver.
7. It destroys old red blood cells.
8. It stores fat-soluble vitamins (A, D, E and K) and mineral ions such as iron.

1.6 STRUCUTRE OF VILLUS

Villus (plural: villi) are found in small intestine. Each villus is covered by simple **columnar epithelium**. It contains a **blood capillary** network and a lymph capillary called a **lacteal**.

Crypt means small cavity. Interstitial crypts are small tubular glands formed in the small intestine in between the bases of the villi. Crypt cells of the small intestine provide stem cells for renewal of the intestinal epithelium. The villi increase surface area for absorption. A villus also has goblet cells. The primary function of goblet cells is to secrete mucin and create a protective mucus layer.

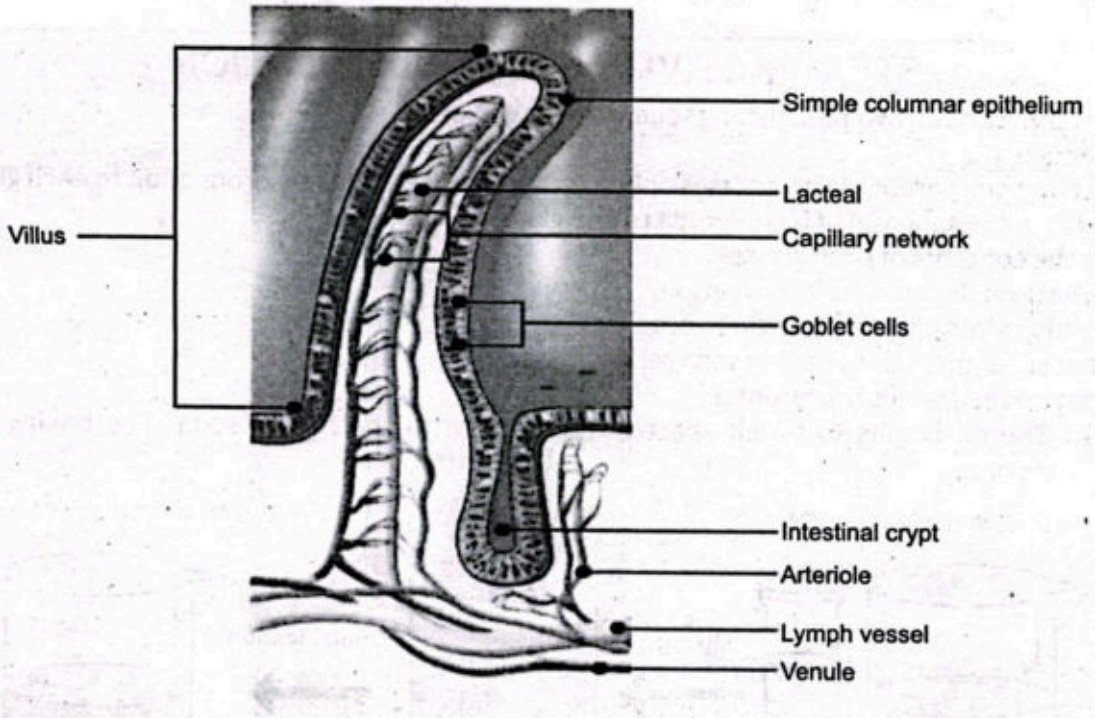


Fig. 1.10: Structure of villus

1.7 DISORDERS OF GUT

Here we will discuss the causes, prevention, and treatment of the disorders of related to digestive system e.g., diarrhoea, constipation, and ulcer.

Diarrhoea

The symptoms of diarrhoea are that the stools becomes watery. There is an increased frequency of defecation. The major causes are infection of the lower GI tract and nervous stimulation. In case of infection such as food poisoning caused by eating contaminated food the intestinal wall becomes irritated and peristalsis increases. Diarrhoea may result in dehydration, so ORS (oral rehydration solution), or mixture of salt and sugar solution is given to the patient.

Constipation

The symptoms of constipation include decrease in frequency of daily stools, or difficulty in defecation which may result in abdominal pain. The faeces move too slowly along the large intestine. As a result, more water is absorbed from the faeces than usual. The faeces become so hard that defecation becomes difficult and painful. Some of the most common causes of constipation are: medications, lack of exercise, not enough liquids, and not enough fiber in the diet such as fruit, vegetables and cereals, a change in your routine or lifestyle, such as a change in your eating habits. For the treatment of constipation laxative is taken to make the faeces soft for easy discharge. Constipation is called the mother of all diseases. As a preventive measure one should take plenty of water or fluids and fibrous food, fruits, vegetables etc.

Ulcer

An ulcer is an open sore in the wall of the gut caused by the gradual disintegration of the tissue. It may be gastric (stomach) ulcer or peptic (duodenal) ulcer. The main symptom of ulcer is stomach pain. The causes of ulcer are acidity, smoking, and bacterial infection. For the prevention of ulcer, (a) stop smoking, (b) avoid spicy food and food containing acids (c) avoid stress.

STEAM ACTIVITY 1.2 EMULSIFICATION

Materials needed: Two jars, baking soda, stirring rod or spoon.

Procedure

1. Fill two transparent plastic glasses or beakers with water. Add few drops of oil to each glass.
2. Add about ¼ spoonful of baking soda to one glass.
3. Stir the contents of both glasses.

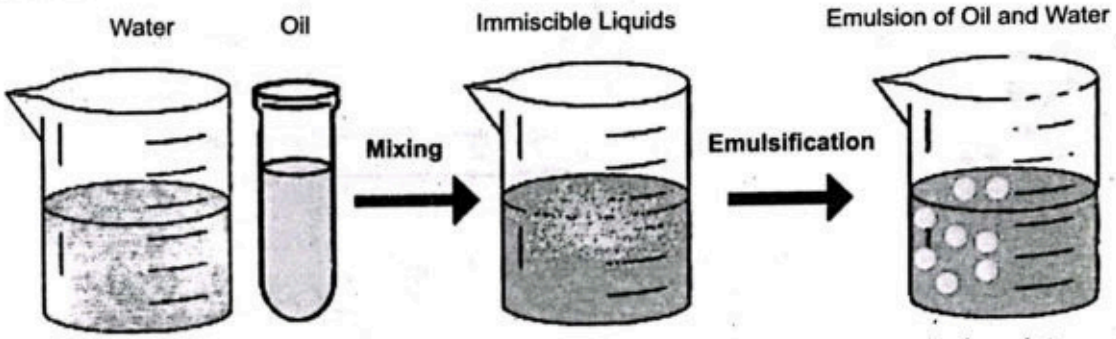
Observation: Record your observation.

Q. In which glass did the oil begin to break up?

Q. What substances does baking soda represents?

Q. What do the glasses represents?

Result: The oil begins to break apart in the glass with the baking soda. The baking soda represents bile.



Emulsificiation is the process of combining two immiscible liquids into a single mixture. It is the process of creating liquids into a single mixture. It is the process of creating phases in a liquid-liquid mixture that results in the creation of emulsion.

SUMMARY

1. Digestion of carbohydrates begins in mouth. As food is swallowed it is propelled through the pharynx and oesophagus.
2. A bolus of food is moved through the digestive tract by peristaltic action.
3. In the stomach, food is mechanically digested by vigorous, churning.
4. Proteins are enzymatically digested by the action of pepsin present in the gastric juice.
5. Most enzymatic digestion takes place in the duodenum which receives secretions from the liver and pancreas and produces several digestive enzymes of its own.
6. The liver produces bile, which emulsifies fats.
7. The pancreas releases enzymes that digest proteins, carbohydrates, fats etc.
8. chains of glucose are digested to maltose by salivary and pancreatic amylases.
9. Maltase in the small intestine splits maltose into glucose.
10. Proteins are split by pepsin in the stomach and by enzymes in the pancreatic juice.
11. Most nutrients are absorbed through the thin walls of the intestine. The large intestine is responsible for the elimination of undigested wastes.
12. Diarrhoea, constipation, ulcer, are some of the disorders of the gut.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Emulsification of fat will not occur in the absence of:

   A) lipase B) bile C) pancreatic juice D) gastric juice

2. Which enzyme, substrate and pH conditions are needed for the digestion of food in the stomach?

	Enzyme	Substrate	pH
A)	Amylase	Starch	Low
B)	Lipase	Lipid	High
C)	Protease	Protein	Low
D)	Protease	Protein	High

3. Bile is formed in:

   A) liver B) gall bladder C) pancreas D) duodenum

4. Glycogen is stored in:

   A) gall bladder B) spleen C) liver D) pancreas

5. Common passage for swallowing food and breathing is:

   A) pharynx B) glottis C) larynx D) mouth

6. Digestion of both starch and protein is carried out by:

   A) gastric juice B) saliva C) bile D) pancreatic juice

7. If the mucous lining covering the stomach breaks down and stomach tissues are damaged by:

   A) gastric juice B) saliva C) bile D) pancreatic juice

8. Part of the digestive system, which is not in contact with food, is

   A) small intestine B) liver C) caecum D) stomach

9. The diet component which prevent constipation is:

   A) fibre B) protein C) minerals D) vitamin

10. Fatty acids and glycerol are first absorbed by

    A) lymph vessel B) villi C) blood capillaries D) hepatic portal vein

11. Which secretion, released into the alimentary canal, contains no enzyme but speeds up fat digestion?

    A) bile B) pancreatic juice C) saliva D) gastric juice

12. Enzyme trypsinogen is changed to trypsin by

    A) gastrin B) enterokinase C) secretin D) hydrochloric acid

13. How does food move through your digestive tract?

    A) By gravity B) By wavelike muscle contractions

    C) By cilia D) by chemical absorption

14. Where the majority of the water from the indigestible food is absorbed?

A) small intestine B) large intestine C) stomach D) pancreas

Section II: Short Answer Questions

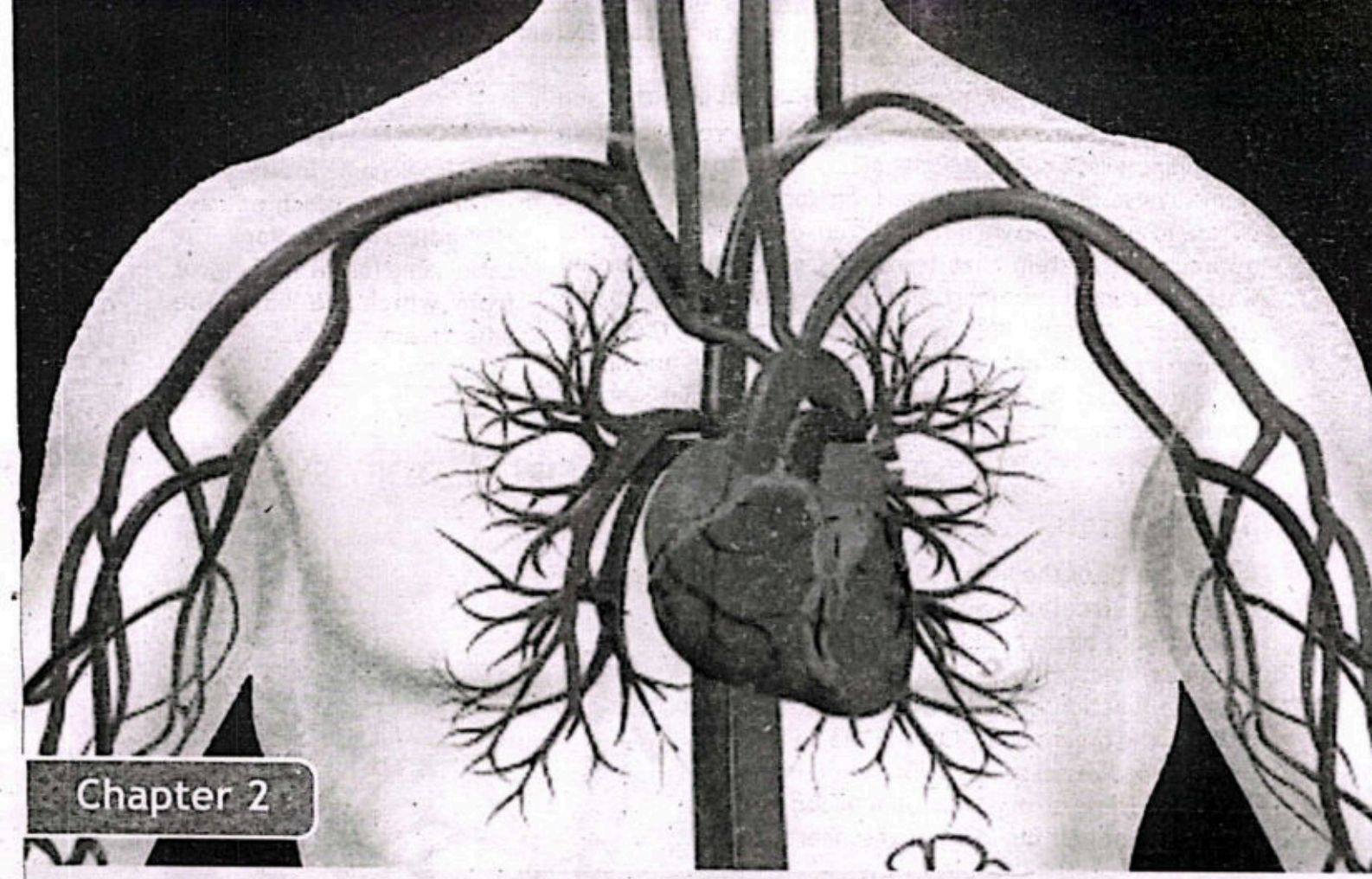
1. Write the functions of: saliva, gall bladder, pancreas, villus, bile, gastric gland, renin, HCl in stomach, hepatic portal vein.
2. Draw and label longitudinal section of villus.
3. Name the structures that secrete enzymes necessary for human digestion?
4. Why is pepsin formed in inactive form pepsinogen?
5. Why must digested food be distributed by blood in man and other animals?
6. How is chewing important to your digestion?
7. What would happen if pancreatic juice did not reach to your small intestine?
8. Why pepsin is unable to perform its enzymatic activity in small intestine?
9. Which parts of digestive system can come in contact with bile?
10. Some cells of the stomach secrete mucous for protection of stomach wall. Suggest what the stomach wall need to be protected against.
11. Following table shows the names of three enzymes found in alimentary canal. Complete the table by writing names of substrate and product for each enzyme.

Name of enzyme	Substrate	Product
Protease		
Amylase		
Lipase		

12. Write the function of each type of teeth
13. Describe digestion in oral cavity.
14. Differentiate between mechanical and chemical digestion

Section III: Extensive Answer Questions

1. Describe the structures of the main regions of alimentary canal.
2. Describe the structures of the associated organs of alimentary canal.
3. Describe the process of swallowing of food in man.
4. Describe the process of peristalsis in man with diagram.
5. Describe the process of digestion in stomach.
6. How the process of digestion takes place in the small intestine.
7. Draw and describe the structure of villus.
8. State the role of liver.
9. Write symptoms, cause, treatment and prevention of the following disorder of the digestive system.
    a. diarrhea
    b. constipation
    c. ulcer



Chapter 2

CIRCULATORY SYSTEM

SLOs: After completing this lesson, the student will be able to:

1. [B-10-R-10] Identify different types of organs connected to the blood circulatory system and their roles.
2. [B-10-R-11] Identify the different components that make up the blood.
3. [B-10-R-12] Name the cell types found in blood and their roles.
4. [B-10-1-07] Describe the process of blood clotting.
5. [B-10-R-13] Explain the structure of heart with a diagram.
6. [B-10-R-08] Describe how the blood is circulated inside the human body.
7. [B-10-R-09] Explain how blood is used to transport materials throughout the human body.
8. [B-10-R-14] Explain common heart diseases.(Coronary heart disease, Myocardial infarction, Angina)
9. [B-10-R-15] Explain the harmful effects of smoking related to heart diseases.

All the cells of our body need food from small intestine and oxygen from lungs. Carbon dioxide has to be removed from the lungs. Likewise waste chemicals have to be removed from kidneys. Our bodies are too large for materials to simple diffuse in and out. So we have a system of internal transport, a circulatory system that transports gases, nutrients and waste products. The heart and blood vessels make up the circulatory system. The heart pumps blood to the body through a network of blood vessels called arteries and veins. Circulatory system is also known as cardiovascular system. Cardio means heart, and vascular refers to blood vessels.

Do you know ?

The Greek name for the heart is *cardia* from which we have the adjective **cardiac.** The Latin name for the heart is *cor* from which we have the adjective **coronary.**

2.1 ORGANS CONNECTED TO BLOOD CIRCULATORY SYSTEM

Blood Vessels

All the organs of the human body are connected to blood circulatory system. The organs connected to blood circulatory system are head and neck, heart, liver, intestine, kidney, arms, leg. The function of blood vessels is to deliver blood to the organs and tissues in the body. Each type of blood vessel serves a different function:

Arteries: These strong, muscular blood vessels carry oxygen-rich blood from the heart to the body.

Arterioles: Arteries branch into smaller vessels called arterioles. Both arteries and arterioles are very flexible. They get bigger or smaller to help maintain your body's blood pressure.

Capillaries: These tiny blood vessels have thin walls. Oxygen and nutrients from the blood can move through the walls and get into organs and tissues.

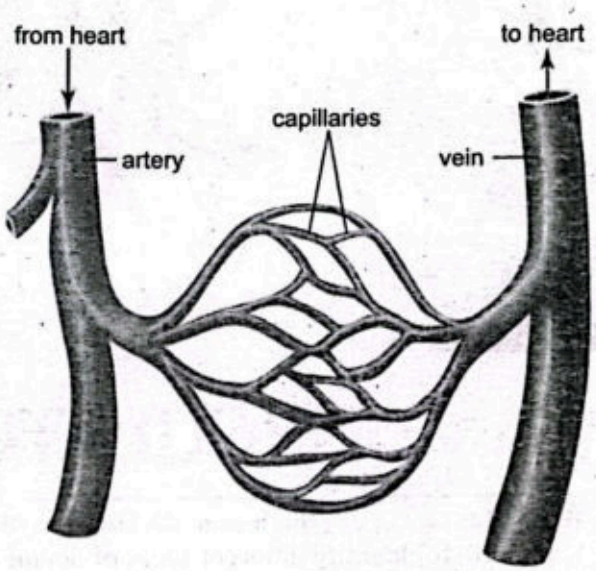


Fig. 2.1: Blood vessels

The capillaries also take waste products away from your tissues. Capillaries are where oxygen and nutrients are exchanged for carbon dioxide and waste.

Venules: Veins begin as tiny vessels called venules and get gradually larger as they near your heart. Venules receive blood from capillaries.

Veins: Veins carry large volumes of deoxygenated blood back to the heart. Thin, less elastic walls help them handle high volumes and low pressure. Most veins have valves that open and close. The valves control blood flow and keep the blood flowing in one direction.

Contributions of William Harvey (1578-1657)

William Harvey discovered pumping action of the heart. He described pulmonary and systemic circulation in more elaborated way. He recognized valves in veins and their role to maintain one way flow of blood. He also described that blood flows in a closed circuit.

Contributions of Ibn al Nafees (1213-1288)

Ibn al Nafees was a polymath who made many contributions in medicine and surgery. He was the first scientist who described circulation. He stated that;

- There is no direct movement of blood between right and left side of the heart.
- Blood moves from right side of the heart to lungs and then returns to the left side of the heart.
- The small connections (now known as capillaries) are present between arteries and veins in lungs.
- Pulse results from pumping action of heart.

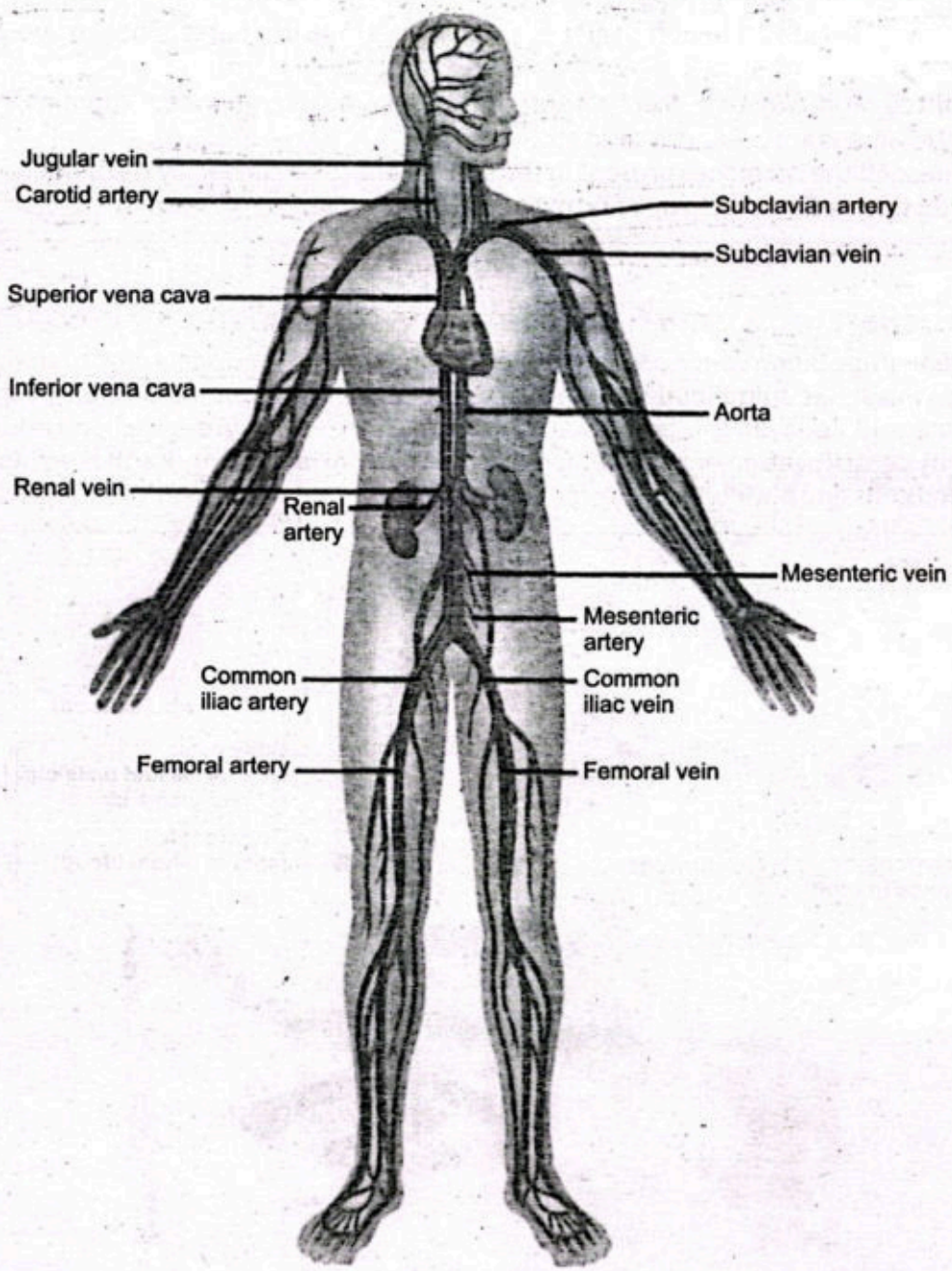


Fig. 2.2: Major arteries and veins

2.2 COMPONENTS OF BLOOD

Blood is a type of special connective tissue with cells suspended in a fluid medium. The blood circulates in the blood vessels. Almost all the substances to be transported are present either dissolved or suspended in the blood. Blood consists of plasma and blood cells.

Plasma

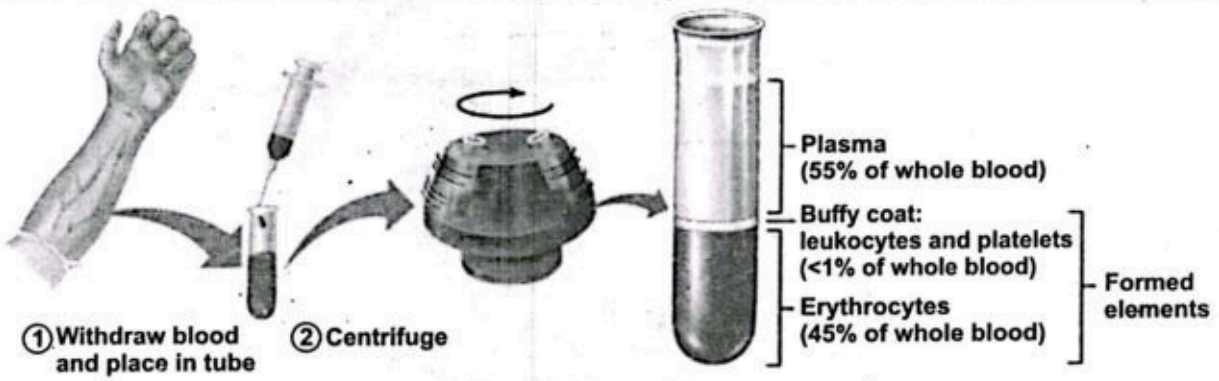
The liquid part of the blood is called plasma. It constitutes about 55% by volume of blood in a normal person. Plasma contains 90% water and dissolved substances 10%.

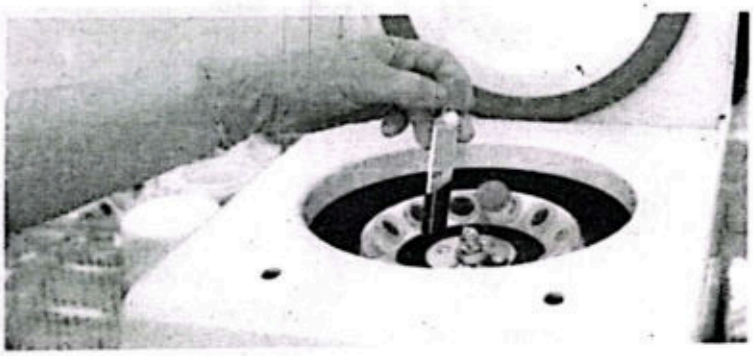
1. **Plasma Proteins:** 7-9% of the plasma is made of different types of proteins e.g., fibrinogen takes part in blood clotting, immunoglobulins (antibodies) defend against diseases and albumins maintain osmotic pressure.
2. **Mineral Ions:** Dissolved mineral salts e.g., chlorides, bicarbonates, sodium, potassium and calcium.
3. **Metabolites and Wastes:** Metabolites are amino acids, glucose, vitamins, lipids and metabolic wastes are urea, uric acid etc.
4. **Hormones:** All the hormones present in the plasma are to be carried by the blood.
5. **Dissolved Gases:** Carbon dioxide and oxygen in the plasma.

Do you know?

How to separate plasma from the other components of blood?

You can centrifuge blood which separates the components of blood according to their density. Centrifuge machines spin blood samples very fast to separate out. The yellow, top layer is plasma, the middle layer is a buffy coat (Buffy coats are leukocyte-enriched residual units obtained by centrifugation of whole blood) and the bottom layer contains the red blood cells, white blood cells and platelets.





Centrifuge Machine

2.3 CELL TYPES FOUND IN BLOOD

Blood cells form about 45% by volume of the blood. These include red blood cells, white blood cells and platelets.

a. Red Blood Cells

These are called **erythrocytes**. A single R.B.C is a circular flattened, biconcave disc and has no nucleus. RBCs have iron-containing pigment haemoglobin in its cytoplasm, which gives red colour to the blood. RBCs are formed in bone marrow after birth. Their life span is 120 days. When they are worn-out, they are destroyed in spleen and liver. RBCs carry oxygen and also transport a small amount of carbon dioxide.

b. White Blood Cells

White blood cells are called **leukocytes**. Their life span is 3-4 days. Each white blood cell is irregular in shape and contains a nucleus. WBC's can be divided into two main types:
1. Granular leukocytes 2. Agranular leukocytes

Granular Leukocytes

Their nucleus is variable in shape. Cytoplasm contains fine granules. These cells originate in bone marrow. Granular leukocytes are of three types, neutrophils, eosinophils and basophils.

Neutrophils: Neutrophils engulf pathogens during phagocytosis.

Eosinophils: Eosinophils are involved in the control of allergic reactions.

Basophils: Basophils release histamine in injured tissue and in allergic response.

Agranular Leukocytes

The cytoplasm of agranular leukocytes is clear. These are of two types i.e., monocytes and lymphocytes.

Monocytes: These are phagocytic and ingest bacteria and dead cells at the damaged tissue region.

Lymphocytes: There are two types of lymphocytes. **B Lymphocytes** protect us by producing antibodies. **T lymphocytes** directly destroy any cell that can be harmful e.g., virus infected cells and cancerous cells.

Do you know?

White blood cells are transparent. To distinguish them from red blood cells they are called white blood cells.

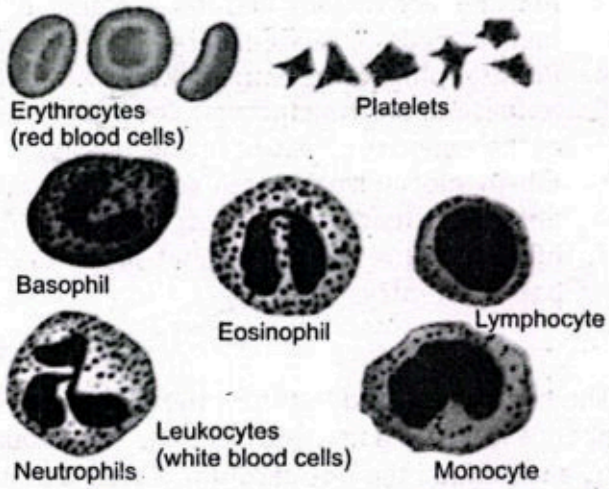


Fig. 2.3: Blood cells

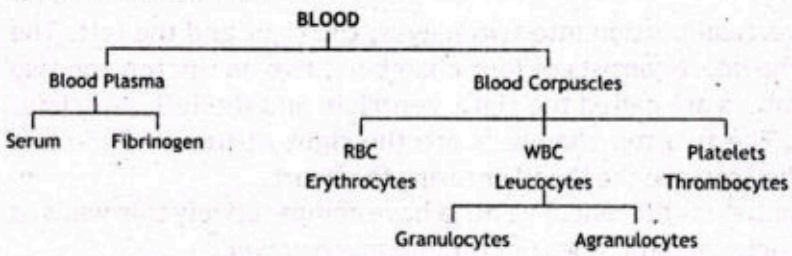


Fig. 2.4: Components of blood

Do you know?

Serum is the clear liquid part of the blood that remains after blood cells and clotting proteins have been removed.

c. Platelets

Platelets are also known as **thrombocytes**. Bone marrow cells called **megakaryocytes** form fragments called **platelets**. Platelets play an important role in blood clotting.

2.4 BLOOD CLOTTING

Blood clotting, or coagulation, is an important process that prevents excessive bleeding when a blood vessel is injured. Platelets and plasma proteins (Thrombin, fibrinogen etc.) work together to stop the bleeding by forming a clot over the injury. While its primary function is to maintain homeostasis, blood clotting also plays a role in immunity.

Steps of blood clotting

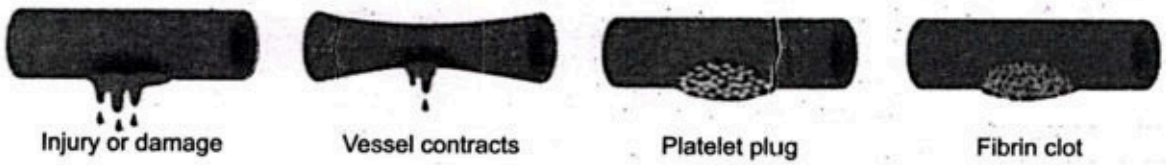


Fig. 2.5: Steps of Blood Clotting

1. **Injury:** Blood vessel is injured or ruptured. Vessel damage exposes collagen and activates platelets.
2. **Constriction:** Blood vessel around wound constricts to reduce blood flow to the damaged area.
3. **Platelet activation:** Platelets release chemical signals which attract more platelets and immune cells. Activated platelets stick to injury site.
4. **Platelet plug formation:** Sticky platelets clump together to form platelet plug.
5. **Release of clotting factors:** The injured tissue cells and the platelets disintegrate at the site of the wound to release clotting factors.
6. **Fibrin clot formation:** A series of reactions involving clotting factors (e.g., thrombin, fibrinogen) leads to fibrin clot formation.
7. **Fibrin clot:** A solid mass that provides a physical barrier to prevent blood loss and stop pathogen entry.

2.5 HEART

The heart is located between the lungs behind the sternum and above the diaphragm. It's only about the size of a fist, and it weighs 7 to 15 ounces. It's a hollow, muscular organ. It is surrounded by a sac called the **pericardium**. There is a fluid between the heart and the pericardium called **pericardial fluid**. It is lubricating fluid, which reduces friction between the pericardium and heart. The thick middle layer of the heart is called **myocardium**. The smooth inner surface of the heart chambers is **endocardium**.

2.5.1 The Heart Chambers

Internally, the heart is divided by a vertical portion into two halves, the right and the left. The vertical partition is called **septum**. The heart consists of four chambers, two on the top and two on the bottom. The two bottom chambers are called the **right ventricle** and the **left ventricle**. They pump blood out of the heart. The two top chambers are the **right atrium** and the **left atrium**, the plural of which is **atria**. They receive the blood entering the heart.
The thickness of the walls of each chamber is different. The atria have comparatively thin walls as they have to force blood into the ventricles and this does not require much power.

On the other hand, the ventricles have to force blood out of the heart hence they have relatively thick walls, especially the left ventricle which has to pump blood around the whole body. The right ventricle has thinner than the left ventricle in a ratio of 1:3; it pumps blood to the lungs, which are at a short distance from the heart. The human heart is myogenic (A heart that does not require neural input to beat is called myogenic heart.)

2.5.2 The Heart Valves

The heart also has four valves, which separate the top chambers from the bottom chambers and also move blood.

Atrioventricular valves separate the atria from the ventricles. Each valve is composed of cusps or flaps. The valve between the right atrium and right ventricle has three cusps and is called **tricuspid valve.**

The valve between left atrium and left ventricle has two cusps and is called **bicuspid** or **mitral** valve. **Tricuspid valve** separates the right side, and the bicuspid valve separates the left side. Two additional valves separate the ventricles from the large blood vessels that carry blood leaving the heart. The **pulmonic semilunar valve** is between the right ventricle and pulmonary artery. It carries blood to the lungs. The **aortic semilunar valve** is between the left ventricle and the aorta. It carries blood to the body.

The atria receive blood and the ventricles distribute it. Blood from the head, neck and arms is returned to the right atrium by superior vena cava. Blood from lower parts of the body is brought back by the inferior vena cava to the right atrium. Thus, the right atrium receives deoxygenated blood from the superior and inferior vena cava. When the right atrium contracts, the blood flows into the right ventricle through the tricuspid valve.

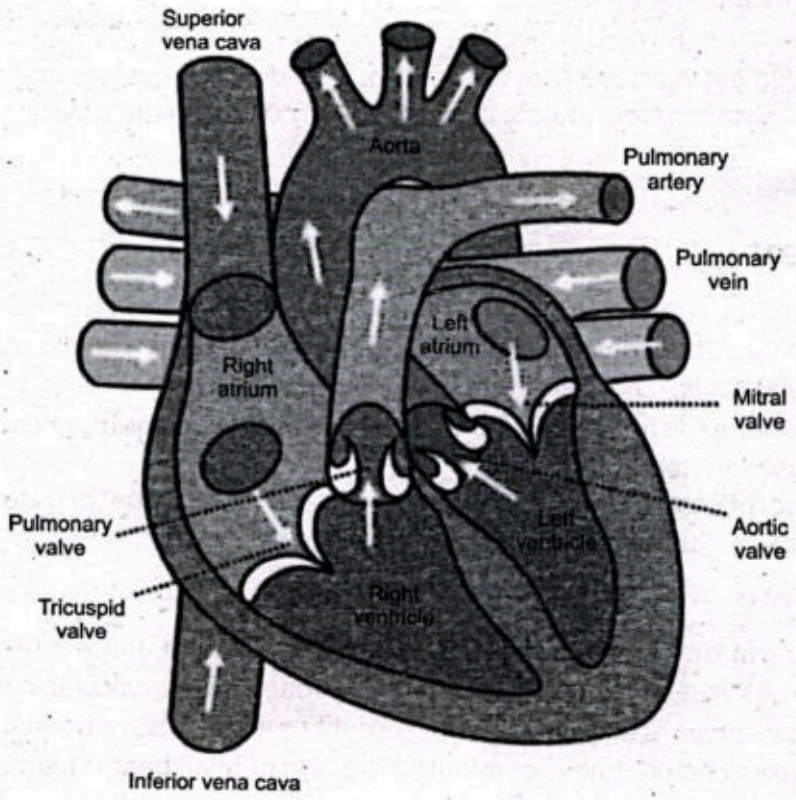


Fig. 2.6: Human heart

When the right ventricle contracts the blood pressure closes tricuspid valve. This prevents back flow of blood into the atrium. The blood leaves the right ventricle by pulmonary trunk. The pulmonary trunk divides into two pulmonary arteries one to each lung. Return of blood into the ventricle is prevented by semilunar valves in the pulmonary trunk. Oxygenated blood from the lungs is brought back to the heart by way of the pulmonary veins, which open into the left atrium. When the left atrium contracts the blood enters the left ventricle through bicuspid valve.

When the left ventricle contracts, blood leaves by a large artery, the aorta. From the aorta blood is distributed to all parts of the body except lungs. Aorta also has semilunar valves to prevent back flow into the left ventricle.

Right ventricle pumps deoxygenated blood to lungs at low pressure. This is because blood has to travel short distance from heart to lungs. Also, lungs are filled with air which creates very little resistance. The pulmonary arteries are not as muscular as systemic arteries. The low pressure in pulmonary circulation allows easy exchange of gases in alveoli.

Left ventricle pumps blood to the body at high pressure because it has to drive the blood out from the heart and all the way down to the legs and arms. It is required to overcome the resistance from muscles and other body tissue on the way.

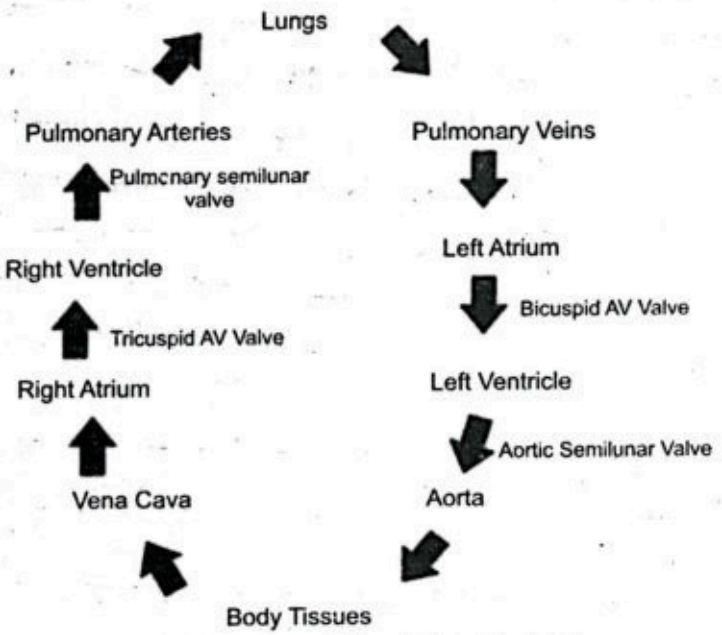


Fig. 2.7: Passage of blood through heart

For your information

Heartbeat

The alternating contraction and relaxation of the atria and ventricles is called cardiac cycle. The two atria contract simultaneously emptying blood into ventricles. A fraction of a second later, the two ventricles contract simultaneously, forcing blood into arteries leaving the heart. Both the ventricles then relax for less than a second before the cycle is repeated.

The period of contraction is called systole and the period of relaxation is called diastole. A heartbeat includes one systole and one diastole.

Pulse Rate

The beating of the heart is also felt in the arteries as pulse. Pulse is the vibration felt in arterial walls due to expansion of the aorta following ventricular contraction. If you place fingers on an artery on the wrist you will feel the pulse. A normal adult pulse rate can vary from 60-100 times per minute. The rate of heartbeat is indicated by the pulse rate.

Arterial system

We will see here major arteries that supply blood the organs and veins that bring blood back to the heart. The **systemic circulation** includes all of the other arteries and veins. The largest artery in the systemic circuit is the **aorta**, which branches into arteries leading to the organs. The following major arteries are:

1. **Coronary arteries:** Supply blood to the heart itself.
2. **Carotid arteries:** Supply blood to the head and neck.
3. **Subclavian arteries:** Supply blood to shoulders and arms.
4. **Dorsal aorta:** Aorta curls backward and continues downwards as the dorsal aorta.

From the dorsal aorta, the following arteries are given off:

(a) **Hepatic artery:** Supplies blood to the liver.
(b) **Mesenteric arteries:** Supply blood to the intestine.
(c) **Renal arteries:** Supply blood one to each kidney.
(d) **Common iliac arteries:** Supply blood one to each leg. This artery divides into **femoral artery**.

Do you know?

- There are 160, kilometers of blood vessels in your body.
- Your body makes one billion red blood cells everyday.

Venous system

Blood is returned to the heart by the main veins as follows:

1. **Jugular veins:** Bring blood from head and neck.
2. **Subclavian veins:** Bring blood from the shoulders and arms.
3. **Superior vena cava:** Jugular and subclavian veins unite to form the superior vena cava which opens into the right atrium of the heart.
4. **Common iliac veins and femoral veins:** Brings blood from the lower limbs.
5. **Renal veins:** Bring blood from the kidneys.
6. **Hepatic veins:** Bring blood from liver and digestive system.
7. **Inferior vena cava:** Iliac, renal and hepatic veins join to form inferior vena cava. It opens into the right atrium of the heart.
8. **Hepatic Portal Vein:** The veins from the digestive system do not open directly into the inferior vena cava. They unite to form the **hepatic portal vein**. It enters the liver and breaks up into many capillaries. The capillaries join to form hepatic vein. A **portal vein** is so called because it carries blood form one capillary network to another.

2.6 CIRCULATION OF BLOOD

The circulatory system provides blood to all the body's tissues so they can function. The circulatory system has three circuits. Blood circulates through heart and through these circuits in a continuous pattern:

a. **The pulmonary circuit:** This circuit carries deoxygenated blood (blood without oxygen) from the heart to the lungs. The pulmonary veins return oxygenated blood to the heart.

b. **The systemic circuit:** In this circuit oxygenated blood (blood with oxygen), travels from the heart to the rest of the body. In the veins, the blood picks up carbon dioxide and other waste products as the body uses up the oxygen. The veins bring the blood back to the heart.

c. **The coronary circuit:** Coronary refers to the arteries of the heart. This circuit provides the heart muscle with oxygenated blood. The coronary circuit then returns deoxygenated blood to the heart's right upper chamber (atrium) to send to the lungs for oxygen.

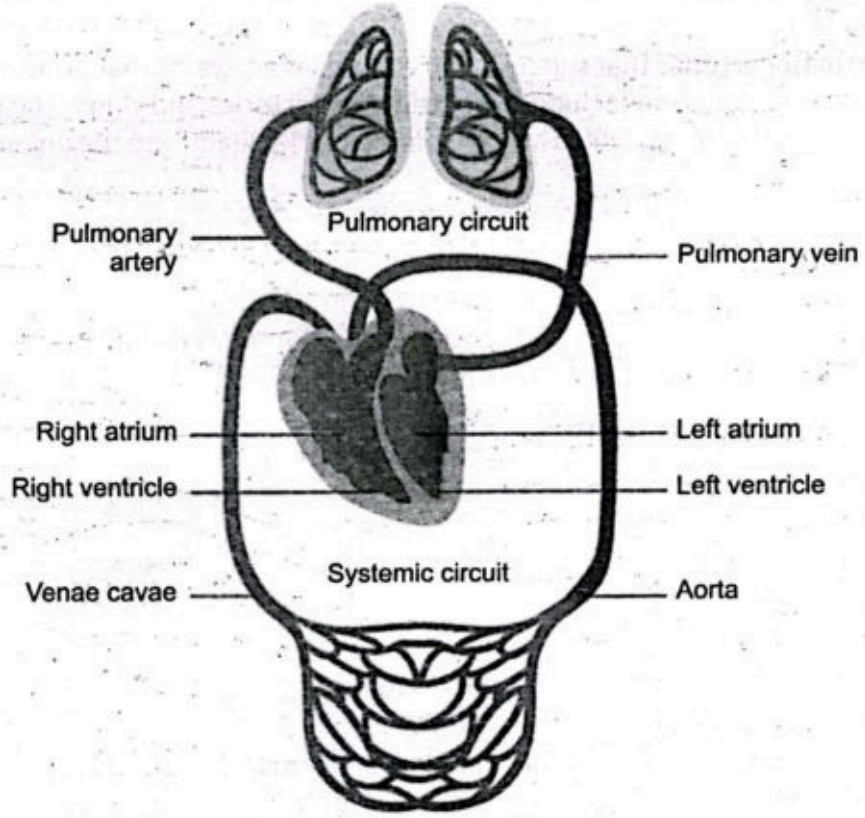


Fig. 2.9: Circulation of blood in human body

2.7 TRANSPORTATION OF MATERIAL THROUGH BLOOD

One of the main functions of blood is transport. The materials that are transported through blood are digested food, oxygen, carbon dioxide, excretory waste, hormones and heat.

The functions of the blood are:

1. **Transport of digested food:** The digested substances transported from the alimentary canal to tissues are simple sugars like glucose, amino acids, vitamins, mineral salts, etc. Amino acids and simple sugars are absorbed into the blood through the blood capillaries. Fatty acids are absorbed by the lacteals.
2. **Transport of oxygen:** Oxygen is transported by red blood cells. The red blood cells contain a pigment called **haemoglobin**. Each molecule of which binds four oxygen molecules forming **oxyhaemoglobin.** The oxygen molecules are carried to the cells in the body tissue. The oxyhaemoglobin release the oxygen to the tissues.
3. **Transport of carbon dioxide:** There are three means by which carbon dioxide is transported in the bloodstream from tissues and back to the lungs: (a) in the form of bicarbonate ions(b) in the form of **carboxyhaemoglbin** (c) A small amount of carbon dioxide is transported as dissolved in plasma.
4. **Transport of excretory materials:** Wastes are excreted from cells. They get dissolved in the blood. The blood carries them to kidneys through blood capillaries. The waste materials get filtered out of the blood while useful substances and excess water are reabsorbed into the blood.
5. **Transport of hormones:** Hormones are transported through the blood from the place of origin to the target cells. Each hormone acts upon only those cells which have specific receptors. The cells which are acted upon by hormones are called target cells.

6. **Distribution of heat:** The blood plays a role in temperature regulation. It distributes heat throughout the body. By changing the blood flow to the skin, the body can control heat exchange at its surface with its surroundings.

2.8 COMMON HEART DISEASES

The disorders of the heart and blood vessels are called cardiovascular disorders. Cardiovascular disorders are the leading cause of untimely death in man.

2.8.1 Coronary Heart Diseases

Arteriosclerosis is hardening of the arteries. **Atherosclerosis** is the deposition of materials in the arteries. The deposits of cholesterol are called **plaques** which increase in size and begin to block arteries. Plaques can cause a clot to form on the irregular arterial wall. As long as the clot remains stationary, it is called a **thrombus**. If the clots breakaway, it may block artery at another location. The dislodged clot moving along with the blood is called an **embolus**. Hardened arteries lose their elasticity and may get ruptured, a process known as **haemorrhage**.

2.8.2 Myocardial Infarction

If the embolus or large plaque blocks vessel in one of the coronary arteries of the heart, a portion of the heart muscle will not get supply of oxygen. Due to lack of oxygen, this portion of heart muscle dies. Infarction means death due to lack of oxygen. The whole process is called **myocardial infarction**.

Treatment

1. Medical treatment includes the use of an enzyme that dissolves blood clot.
2. **Coronary bypass surgery** is carried out to treat blocked arteries. In this surgery blood vessel from elsewhere in the patient body are grafted to coronary arteries to improve blood supply to heart muscles.
3. **Angioplasty** is the mechanical widening of a narrow or totally blocked coronary artery.

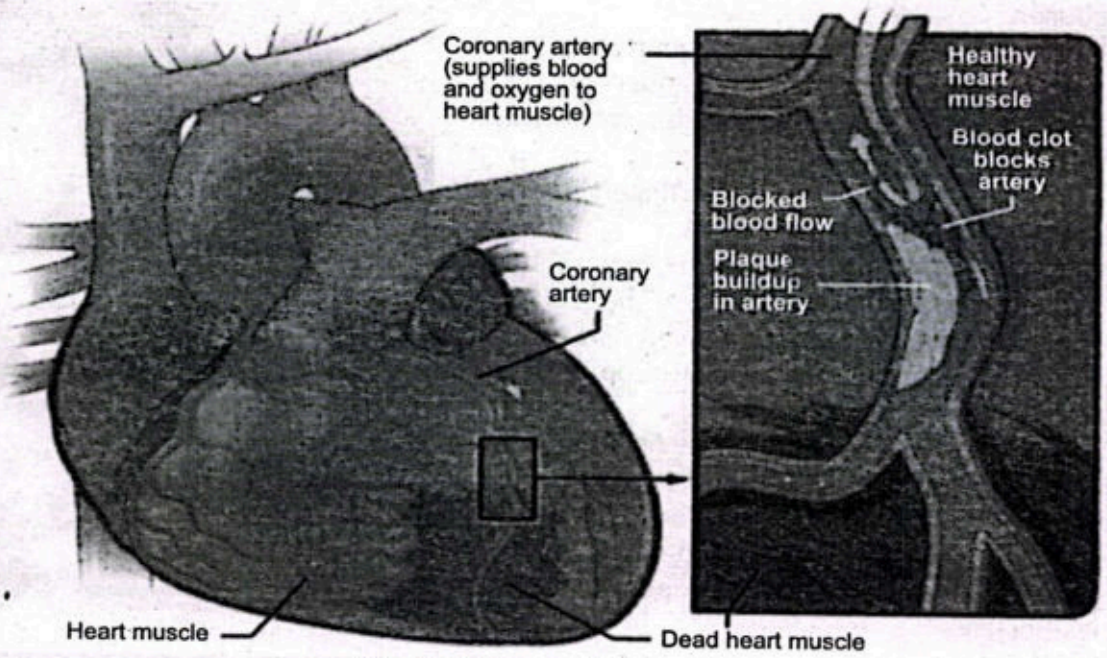


Fig. 2.10: Myocardial Infarction

Prevention

1. Avoid food rich in salt and fats. 2. Maintain healthy body weight. 3. Control blood pressure. 4. Do regular walk and exercise. 5. Avoid smoking 6. Avoid stress.

2.8.3 Angina

Angina is chest pain or discomfort that happens when the heart is not receiving enough oxygen-rich blood. As a result, the heart may beat faster and harder to gain more blood, causing a noticeable pain. Angina is not a disease. It is a symptom and a warning sign of heart disease. The main symptoms of angina are fatigue, nausea or vomiting, shortness of breath and sweating a lot.

2.9 HARMFUL EFFECTS OF SMOKING ON HEART

Smoking damages the heart and blood vessels. Smoking speeds up the clogging and narrowing of coronary arteries. This can reduce the flow of blood to the heart and increases the risk of heart attack. Tobacco smoke contains thousands of chemicals including:

a. Nicotine is an addictive drug that affects brain and muscle activity and increases blood pressure, making the heart work harder.

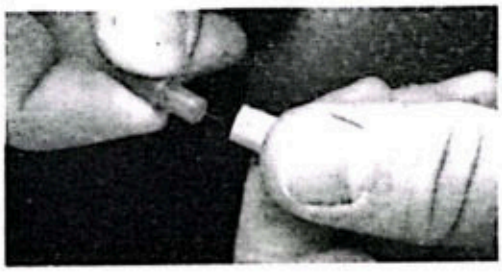
b. Carbon monoxide is a poisonous gas that replaces oxygen in the blood, reducing the supply of oxygen to the heart and other organs. If you smoke, your risk of a. heart attack is more than twice as high as someone who does not smoke b. stroke is more than twice as high as someone who does not smoke.

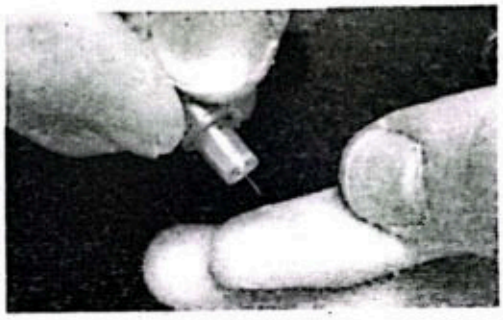
STEAM ACTIVITY 2.1 (To be demonstrated by teacher)
PREPARING HUMAN BLOOD SMEAR

Materials needed:
cotton, alcohol, lancet, glass slides, coverslips, light microscope, Wright's stain
Blood smears are made usually using fresh blood

Procedure:

1. Using lens paper or silk cloth, gently wipe two glass slides to remove any dust or glass fragments. Place the glass slides on an even surface.
2. Thoroughly scrub the skin of one fingertip with a cotton swab and rubbing alcohol.
3. Open a lancet to expose the sharp point (about 3 mm long). Quickly puncture the cleaned fingertip, put the lancet down, and gently squeeze the finger until a small drop of blood forms on the fingertip.
4. Place the drop of blood from the finger into the middle of the glass slide and then wipe the fingertip to clean excess blood. (Bleeding should not be a problem, but if it persists, apply pressure with a cotton ball or paper towel until it stops).





5. Place a small drop of blood on one end of one glass slide. Hold the top and bottom edges of the slide with the thumb of your non-dominant hand.
6. Using your dominant hand, place the edge of the other slide at an approximately 35-45⁰ angle on the first glass slide, in front of the blood drop. Using gentle pressure, gently pull the second slide back into the blood drop and allow the blood to spread to the edge of the slide.
7. To spread the blood, rapidly but gently push the top slide forward through the remainder of the slide. It is important to keep gentle, equal pressure throughout the whole process, and do not lift the top slide before it reaches the edge of the bottom slide. A feathered edge should be present.
8. After preparation, the smear should be labeled and dried (air dryer or waving method). Put a drop of Wright's stain
9. Put a coverslip.
10. Put the covered blood smear on the microscope stage with the cover slip toward the objective lens and focus until blood cells are visible.

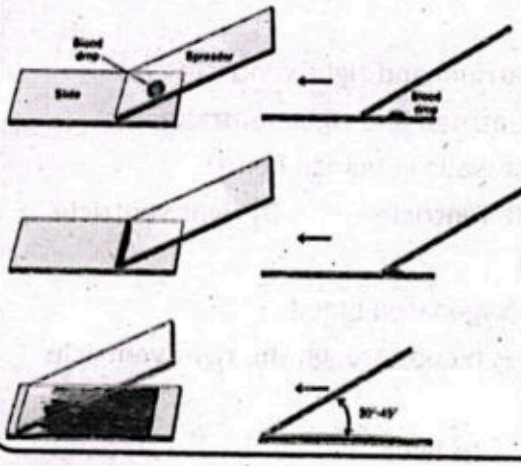
Red blood cells are by far the most numerous. White blood cells are slightly larger. There is usually only about one white blood cell for every 1,000 red blood cells.

Wright's stain: Contains eosin Y and methylene blue, which stain different parts of WBCs. Eosin Y stains the cytoplasm pink or orange, while methylene blue stains the nucleus blue. It stains RBCs red

Permanent slide: Observe prepared permanent slide of human blood film under a light microscope and identify the blood cell.





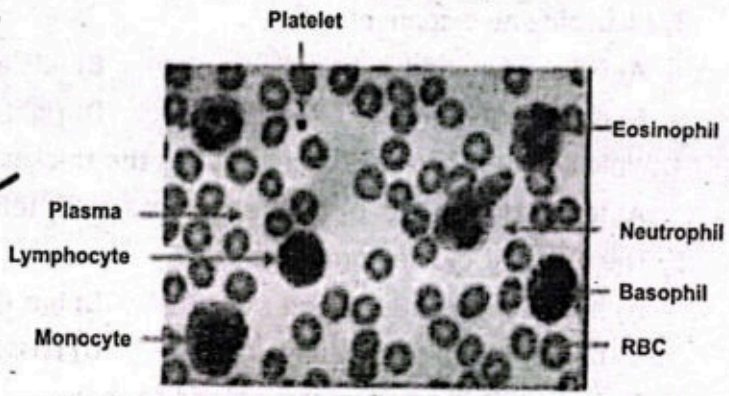


Fig.: Permanent prepared slide of human blood film

SUMMARY

1. Human blood consists of liquid plasma in which red blood cells, white blood cells and platelets are suspended.
2. Red blood cells transport oxygen and small amount of carbon dioxide.
3. White blood cells defend the body against diseases. Lymphocytes and monocytes are agranular white blood cells while neutrophils, eosinophils and basophils are granular white blood cells.
4. Platelets patch damaged blood vessels and release substances essential for blood clotting.
5. Arteries carry blood away from the heart chambers; veins return blood to the heart chambers.
6. Capillaries are the thin-walled vessels through which materials pass back and forth between the blood and tissues.
7. The human heart consists of two atria, which receive blood from veins and two ventricles, which pump blood into the arteries.
8. The heart is enclosed by pericardium and has valves that prevent backflow of blood.
9. The pulmonary circulation connects heart and lungs. The systemic circulation connects the heart with the other body organs.
10. In pulmonary circulation, the right ventricle pumps blood in two pulmonary arteries, and one of these carries blood to each lung. Blood circulates through pulmonary capillaries in the lungs and is then conducted to the left atrium by a pulmonary vein.
11. In the systemic circulation, the left ventricle pumps blood into the aorta, which branches into arteries leading to the body organs. After flowing through the capillary networks within various organs, blood flows into vein that conducts it to the right atrium.
12. The coronary circulation supplies blood to the heart muscles.
13. The disorder of the heart and blood vessels is called cardiovascular disorder e.g., atherosclerosis, arteriosclerosis and myocardial infarction

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. The heart's upper chambers are called

   A) ventricles B) atria C) valves D) arteries

2. Blood components that help the body to control bleeding are

   A) platelets B) red blood cells C) white blood cells D) haemoglobin

3. Bicuspid valve connects

   A) left atrium and right atrium B) left atrium and right ventricle

   C) right atrium and left ventricle D) right atrium and right ventricle

4. Which of the following chambers has the thickest walls in human heart?

   A) left atrium B) right atrium C) left ventricle D) right ventricle

5. The left half of the human heart:

   A) has deoxygenated blood B) has oxygenated blood

   C) pumps blood to the lungs D) passes blood through the right ventricle

6. The pulmonary arteries carry blood to the:

   A) brain B) heart C) liver D) lungs

7. Which one of the following helps to fight germs?

A) Red blood cells B) White blood cells C) Platelets D) Plasma

8. The blood vessels that carry blood from heart to the various parts of the body are called:

A) septum B) arteries C) veins D) capillaries

9. Which one of the following is a double membrane sac that covers the human heart?

A) epicardium B) pericardum C) myocardium D) endocardium

10. The alternating expansion and relaxation of the artery that you feel in your wrist is the:

A) pulse B) coronary artery C) blood pressure D) plasma

11. Nutrients are exchanged between the blood and body cells in the:

A) arteries B) capillaries C) veins D) aorta

12. Which is the largest artery in the human body?

A) pulmonary artery B) aorta C) common iliac artery D) femoral artery

13. What is the valve in the opening between the right atrium and the right ventricle called?

A) pulmonary valve B) aortic valve C) tricuspid valve D) bicuspid valve

14. Human heart is:

A) myogenic B) neurogenic C) cardiogenic D) digenic

15. Pacemaker is situated in heart

A) in the wall of right atrium B) on interauricular septum
C) on interventricular septum D) in the wall of the left atrium

Section II: Short Answer Questions

1. Write the functions of:

a. pericardium
b. left atrium
c. right atrium
d. left ventricle
e. right ventricle
f. bicuspid valve
g. tricuspid valve
h. semilunar valve
I. septum
j. aorta
k. pulmonary artery
l. pulmonary vein
m. plasma
n. red blood cells
o. white blood cells
p. platelets

2. Differentiate between:

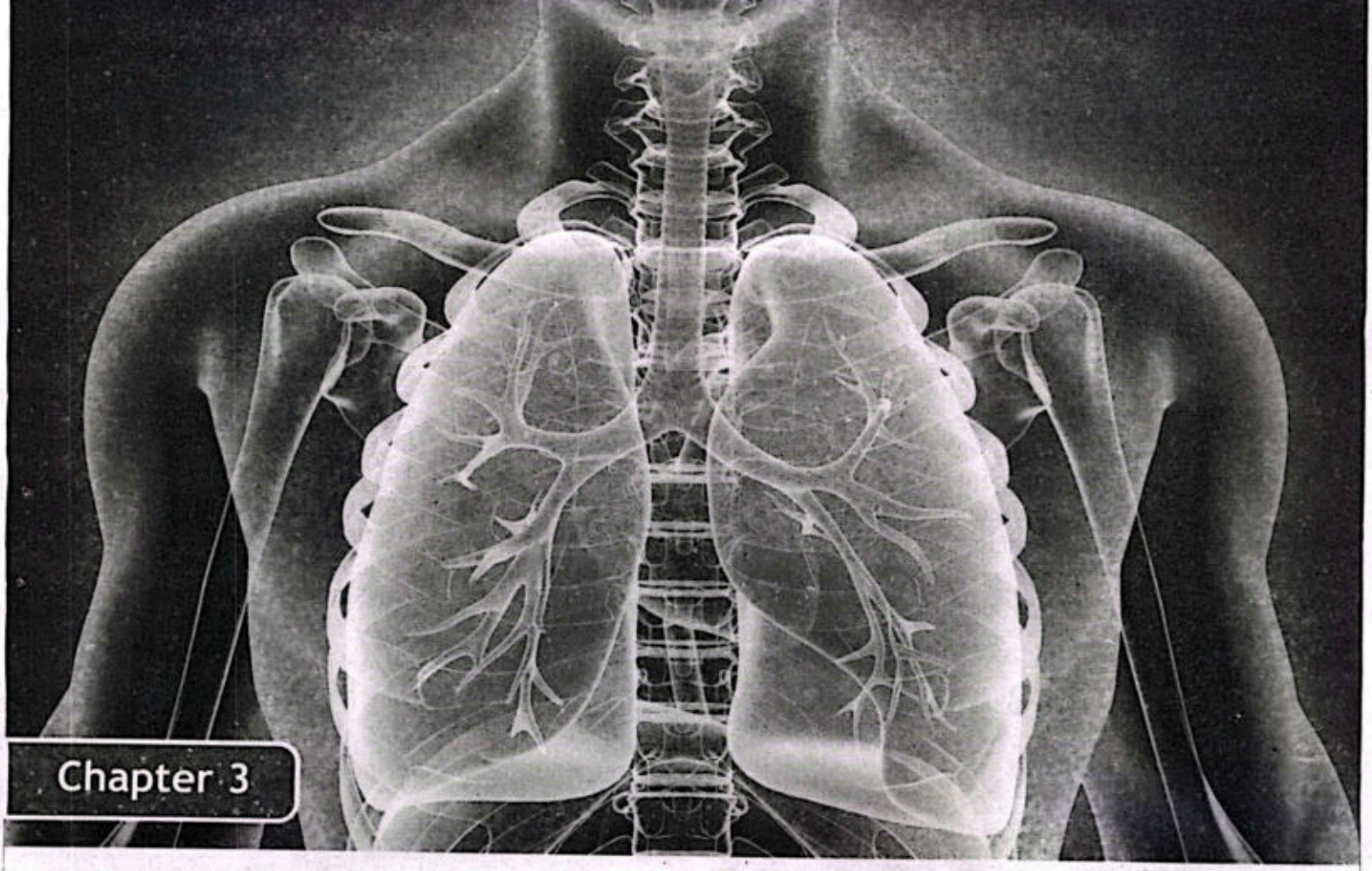
a. Serum and blood
b. Artery and vein
c. Tricuspid and bicuspid valve
d. Systole and diastole

e. Red blood cells and white blood cells
f. Pulmonary artery and pulmonary vein

3. Why is a circulatory system necessary?
4. Name the three circuits of the circulatory system.
5. Describe coronary circuit.
6. Write the six functions of blood.
7. What are the organs that are connected to the circulatory system?
8. Name the types of blood vessels.
9. What are the types of white blood cells? Why these are called white blood cells?
10. In what ways does pulmonary artery differ from all other arteries?
11. How are the valves of human heart important?
12. Suggest why an injury that cuts open artery is much more dangerous than an injury to vein?
13. Why are valves present in veins but not in arteries?
14. Why are the walls of the atria thinner than the walls of the ventricle?
15. Why is the muscle of the left ventricle thicker than that of right ventricle?

Section III: Extensive Answer Questions

1. Describe the pulmonary and systemic circuits of the circulatory system.
2. How are the materials transported through the blood?
3. What are the organs connected to blood circulatory system? Explain.
4. What are the components of blood.
5. Describe the cell types found in blood.
6. Draw and describe the structure of human heart.
7. Explain the circulation of blood through the human heart.
8. Discuss the following heart diseases in human:
   a. Coronary heart disease
   b. Myocardial infarction
   c. Angina
9. Explain the harmful effects of smoking related to heart diseases



Chapter 3

RESPIRATORY SYSTEM

SLOs: After completing this lesson, the student will be able to:

1. [B-10-R-24] Describe the roles of the parts of the air passageway and lungs.
2. [B-10-R-25] Describe the mechanism of breathing in terms of movements of ribs and muscles.
3. [B-10-R-26] Differentiate between composition of inspired and expired air.
4. [B-10-R-27] Discuss briefly diseases related to respiratory system like bronchitis, emphysema, pneumonia, asthma and lung cancer.

What happens when we burn anything? Oxygen is used up and carbon dioxide is produced. The flame gives off light and heat. The same sort of thing happens in our body. The food we take has glucose. Oxygen is needed to break the glucose down and release the energy. **Respiration** is the process by which cells obtain energy from glucose. Oxygen is needed for the process of respiration so it is called **aerobic respiration**. The process, in which oxygen and glucose undergo a series of chemical reactions inside the cell, is called **cellular respiration**. Respiration is different from breathing. The movement of air into and out of the lungs is called **breathing**. Respiration is the chemical reaction inside the cell. As a result of respiration the cells release energy, that is needed for growth and other cell processes. The **respiratory system** moves oxygen from outside the environment into the body. It also removes carbon dioxide from the body.

3.1 AIR PASSAGE WAY

Man faces the same general problems of obtaining oxygen and getting rid of carbon dioxide, as do all other large and complex animals. He must have moist and thin respiratory surface across which gaseous exchange with the environment can occur. In addition, he must have some means of transporting oxygen and carbon dioxide to and from the cells. We breathe in air to get oxygen and breathe out carbon dioxide. This is called gas exchange.

3.1.1 Air Passageway and Lungs

The organs responsible for gas exchange in man are the two lungs and the air passages which lead to the lungs.

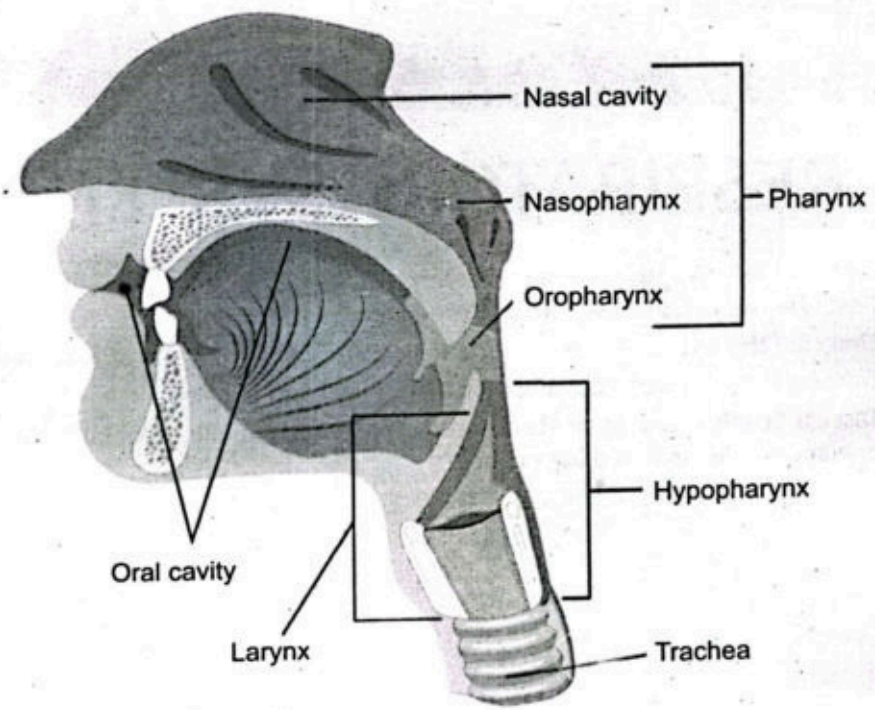


Fig. 3.1: Nasal passage

The air passageway consists of nose, pharynx, larynx, trachea, bronchi, and bronchioles.
Nose: The nose is an elevated structure. It is divided into two parts. The external openings of the nose are **nostrils** having hairs. The nostrils lead into a **nasal cavity.** The top of the nasal cavity has *lining of nerve cells, which are responsible for sense of smell. The walls and the base of the nasal* passage are lined with **cilia.** Between the ciliated epithelial cells are **goblet cells**, which produce sticky fluid, called **mucus.**

The nasal cavity performs important **functions**. The air entering the respiratory system must be warmed, moistened and filtered to keep the lung tissue healthy. The hairs lining the entrance to the nasal cavity trap large dust particles. The thin layer of mucus moistens the air and also traps particles of dust or smoke. The cilia sweep the trapped particles and mucus towards the pharynx. These are either swallowed or spit out. By the time air the lungs it is relatively dust free, germ free, warm and moist. These protective measures keep the lungs clean, so that the lungs can perform the important work of gas exchange.

Do You Know?

All the cilia in the respiratory system beat toward the back of the throat, up from the lungs and down from the nose. Cilia may beat 1,000 times a minute.

Pharynx: Air is drawn out of the nasal passages into a channel called **pharynx**, at the back of the mouth. There are several openings in the pharynx. The air is channelized from the pharynx into the larynx. **Larynx** or voice box is a cartilaginous structure. It surrounds the upper end of the trachea. The cavity of the larynx is called **glottis**. **Epiglottis** is a cartilaginous structure.

Trachea: The trachea is a tube running from the pharynx to the lungs. It is held permanently open by C shaped rings of cartilage in its walls. The cartilage rings also keep the trachea open when it develops a low internal air pressure during every intake of breath.

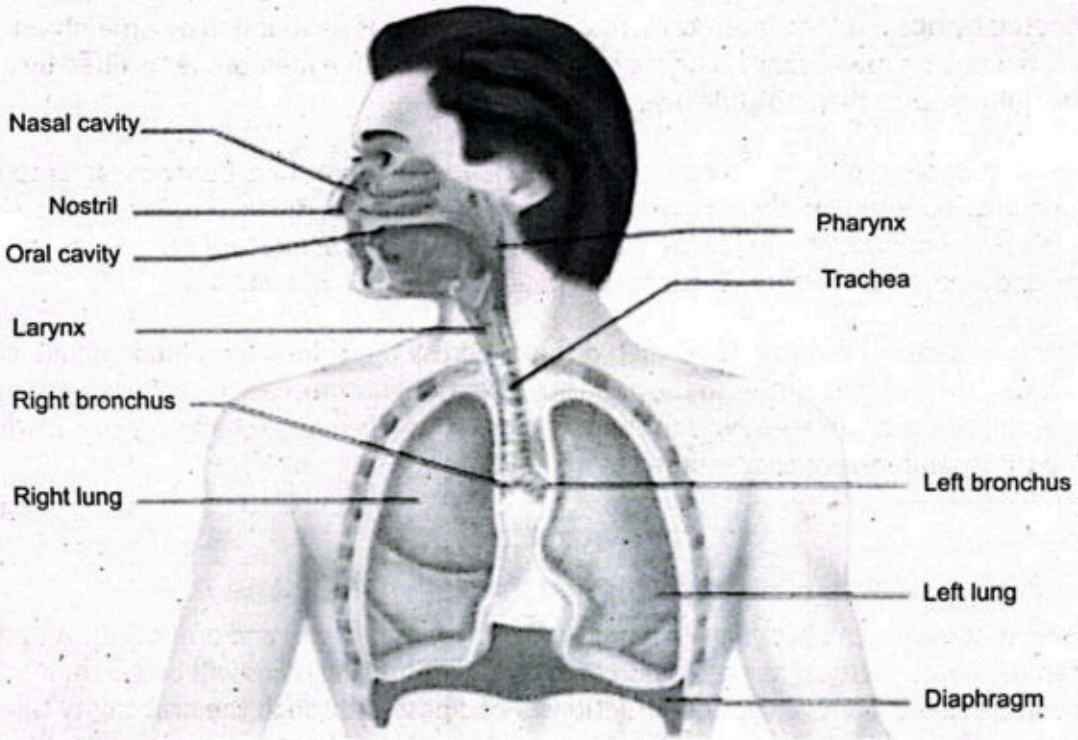


Fig. 3.2: Human respiratory system

The trachea divides into two **bronchus**,(Plural: bronchi) the one leading to each lung. Inside the lungs each bronchus divides again and again to form a mass of very fine branches called **bronchioles**. Bronchi have irregularly shaped plates of cartilage, which keep the tubes permanently open.

The bronchioles branch into many short tubes of equal diameter called **alveolar ducts**, which end in tiny hollow bags called **air sacs**. The air sacs have many bubble-like pockets in their walls called **alveoli**. The alveoli are the respiratory surface of a mammal.

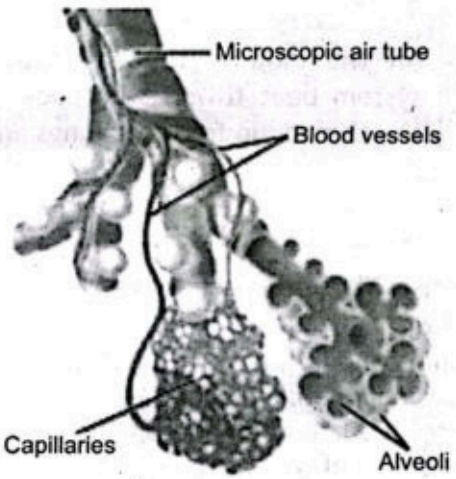


Fig. 3.3: Bronchioles and alveoli

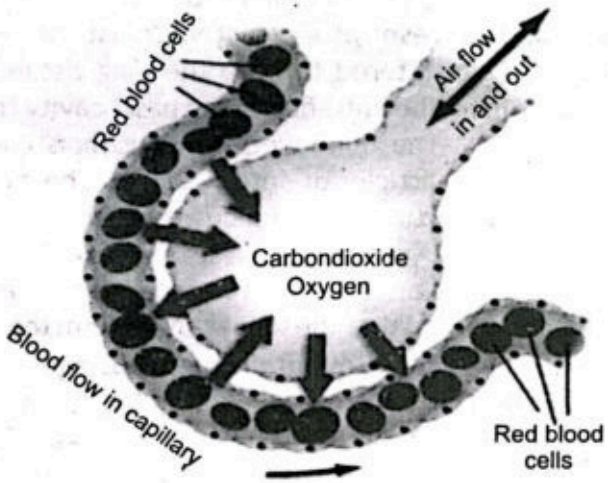


Fig. 3.4: Section through alveolus showing gas exchange

Lungs

There are two lungs. The two lungs are lying in the thorax on either side of the heart. The lungs are protected by ribs, and the intercostal muscles. Each lung is surrounded by a membrane called **pleura**. It is a double membrane. The space between the double membranes is filled by a film of fluid. The fluid enables them to glide over one another.

The lungs are spongy due to presence of alveoli. Alveoli look like bunches of grapes. The arrangement of bubble-like alveoli gives the lungs a far greater surface area. Each alveolus is surrounded by a network of capillaries. Here the real work of respiratory system takes place as the blood and air are side by side. The inner surface of the alveoli has moisture.

Oxygen dissolves in this moisture and then diffuses across the thin-walled blood capillaries into the blood. Carbon dioxide diffuses in the opposite direction. It diffuses across the membrane of an alveolus and into the air present within the alveolus. Thus, the gas exchange occurs by diffusion across the thin membrane of an alveolus and a capillary.

Science Titbits

Importance of Keeping Nasal and Oral Cavity Clean

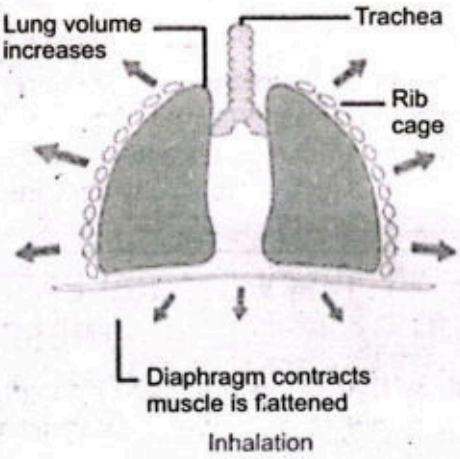
Anything that enters the body has to pass through the nasal cavity and oral cavity. Air passes through the nasal cavity, if the cavity is clean then air entering lungs will be clean, and thus lungs will be saved from germs and infections. Food passes through the oral cavity to enter the gut. If the oral cavity is not clean germs along with food enter the gut and will cause disorders of gut. You will breathe out bad odour. Your teeth will start decaying.

3.2 MECHANISM OF BREATHING

Breathing is a mechanical process. It is the movement of air into and out of the lungs. The force that drives air into the lungs comes from ordinary air pressure.
The lungs themselves neither draw in air nor push it out. The expansion and contraction of the lungs is accomplished by the diaphragm, and by intercostal muscles. The mechanism of breathing consists of two phases: 1. Inspiration or inhalation 2. Expiration or exhalation.

When you breathe in or inhale these changes happen:

1. The muscles in diaphragm contract. This pulls the diaphragm downwards.
2. The intercostal muscles contract. This pull the ribs upwards and outwards
3. The lungs expand. When the volume increases, the pressure decreases in the lungs.
4. Air moves into the lungs from nose/mouth.



When you breathe out or exhale these changes occur

1. The diaphragm muscles relax. This allow the diaphragm to become normal, domed shape
2. The intercostal muscles relax. This allow the ribs to move downwards and inwards
3. The lungs are compressed. When the volume decreases, the pressure increases in the lungs
4. Air is forced out from the lungs to the surrounding air

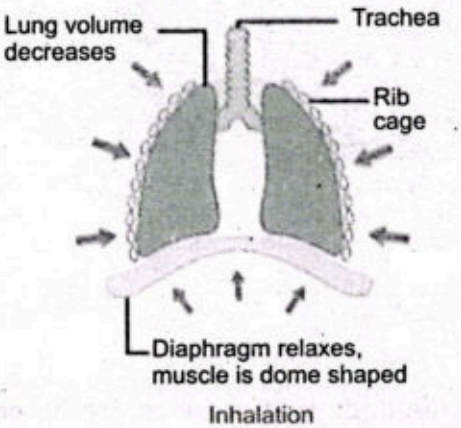


Fig. 3.5: Mechanism of breathing

3.3 COMPOSITION OF INSPIRED AND EXPIRED AIR

We will see the composition of inspired and expired air in the given table

Table 10.1: Composition of Inspired and Expired Air

	Gas	Inspired Air	Expired Air
1	Oxygen	21%	16%
2	Carbon dioxide	0.04%	4%
3	Nitrogen	79%	79%
4	Water vapour	Variable	Saturated
5	Temperature	Variable	About body temperature
6	Dust particles	Variable	Little, if any

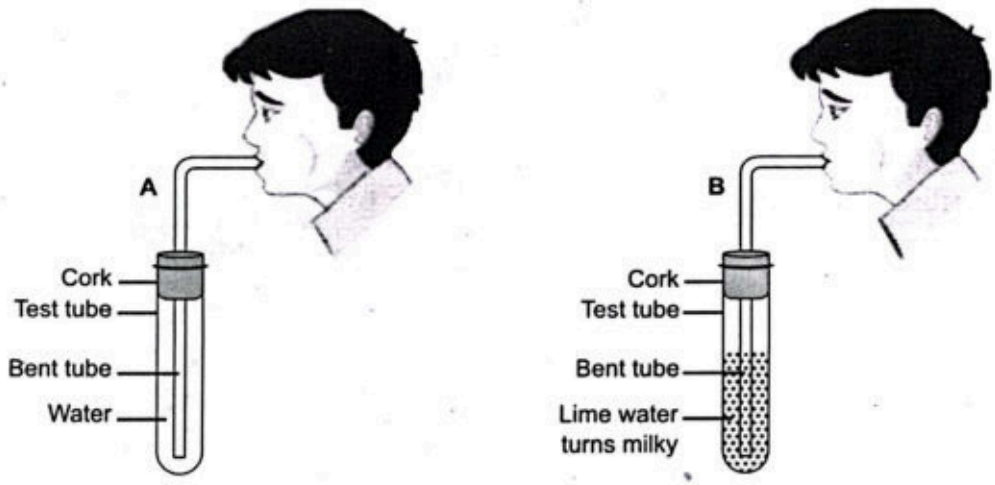
Do you know?

Importance of breathing in fresh air

Oxygen is needed for respiration. Respiration is needed for energy, thus the net result of breathing in fresh air is to get more energy. Fresh air is free of pollutants i.e., carbon monoxide, smoke, chemicals and other disease-causing agents. Thus, breathing in fresh air is the best way of prevention from many infections and diseases.

STEAM ACTIVITY 3.1 RELEASE OF CARBON DIOXIDE THROUGH RESPIRATION

Aim: To show that CO_2 is produced during respiration. The composition of CO_2 in the air we breathe out is more than that of the normal air.



Materials needed: Two test tubes, Freshly prepared lime water, Water, Bent glass tube

Procedure:

1. Pour water in test tube labelled A.
2. Pour the freshly prepared lime water into test tube labelled B.
3. With the help of a bent glass tube, blow air in the test tube labelled A and B.

Observation: The lime water in test tube B turns milky is showing that we exhale CO_2. In test tube A, there is no change of colour in water.

Inference: Lime water turns milky when CO_2 is mixed with it. Air blown from the mouth contains CO_2, approximately 4%. The composition of CO_2 in atmosphere is 0.04%. This proves that the percentage of CO_2 in the air during exhalation is higher than the CO_2 in the atmosphere.

Questions:

1. Which process is being tested in the activity?
2. What is the result of the activity? Give reasons.

Answer:

1. Exhalation process during respiration
2. The lime water in test tube 'B' turns milky but water in tube A remains unchanged. Because CO_2 is present in the exhaled air, it mixes with lime water in 'B' and turns it milky.

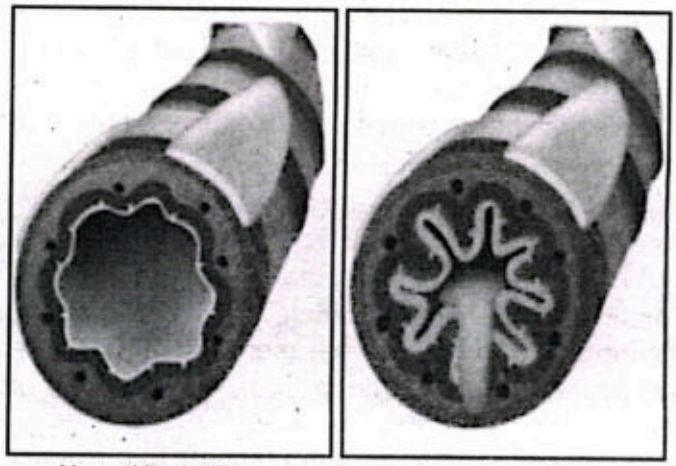
3.4 DISEASES RELATED TO RESPIRATORY SYSTEM

The common respiratory disorders are Bronchitis, Emphysema, Pneumonia, Asthma and Lung cancer.

3.4.1 Bronchitis

Bronchitis is the inflammation of lining of the air passages like trachea, bronchi and bronchioles.

Symptoms: One of the symptoms is secretion of excess mucus from the goblet cells in response to the irritation. The main symptom is cough, which occurs repeatedly. Coughing and breathlessness increases as the disease progress. Bronchitis can be acute or chronic.



Normal bronchi Acute bronchitis

Fig. 3.6: Bronchi

Cause: Acute bronchitis usually lasts a few days only and is a side effect of viral infections like flu. Chronic bronchitis is most commonly caused by smoking and to a lesser extent by air pollution. It may last for months. The sensation of breathlessness occurs, due to the reduced gases exchange.

Acute bronchitis: Short term bronchitis inflammation of the bronchi of the lungs.

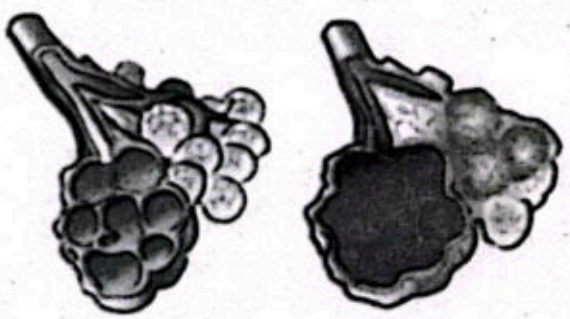
Chronic bronchitis: It is the long term inflammation and irritation of the bronchi.

Treatment: The infection will generally go away on its own within one week. One should take the following steps for some relief: (a) Do not smoke. (b) Drink plenty of fluids. (c) Take rest. (d) An inhaler may be taken. (e)If your doctor thinks that you have a secondary bacterial infection, antibiotics may be prescribed.

3.4.2 Emphysema

Emphysema is a respiratory disease where there is over-inflammation of the alveoli in the lungs, causing a decrease in lung function.

Symptoms: The main sign of emphysema is increasing breathlessness. In advance case the patient finds it difficult to walk. The lungs loose elasticity, so that it becomes more difficult to exhale air. Inflammation and narrowing of the finer bronchioles also occur.



Normal alveoli Emphysema

Fig. 3.7: Alveoli

Cause: It is due to gradual breakdown of the thin walls of alveoli and the total surface area for gaseous exchange decreases. The main cause is the long-term irritation of the lungs, most commonly by cigarette smoke, air pollution or industrial dust.

Treatment: Treatment methods for emphysema do not cure or reverse the damage to the lungs. The best way to prevent emphysema is to avoid smoking. A variety of medications may be used in the treatment of emphysema.

3.4.3 Pneumonia

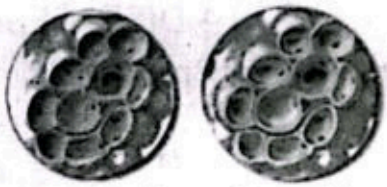


Fig. 3.8: Alveoli

Pneumonia is defined as an inflammation of alveoli of lungs caused by acute infection. Double pneumonia is a lung infection that affects both lungs.

Symptoms: Fever, shaking chills, chest pain, cough, headache, sore throat, nausea, diarrhoea etc.

Cause: The most common cause of pneumonia is bacteria *Streptococcus pneumoniae*.

Treatment: Antibiotics are prescribed for bacterial pneumonia.

3.4.4 Asthma

Asthma is the common chronic inflammatory disease of the airways.

Symptoms: The person has more difficulty in breathing out than breathing in. A characteristic whistling sound is caused by breathing. There is secretion of excess of mucus and swelling of the lining of the respiratory pathway.

Cause: It is due to an allergic response to substances like pollen, household dust, a particular food or feathers from pillow, cold air, exercise, and smoking etc., emotional disturbance may also provoke an attack.

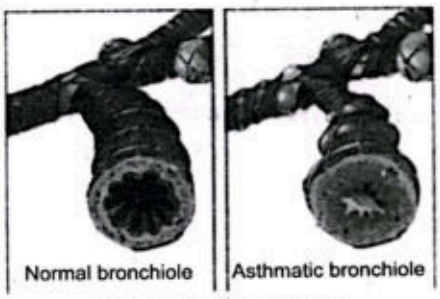


Fig. 3.9: Bronchiole

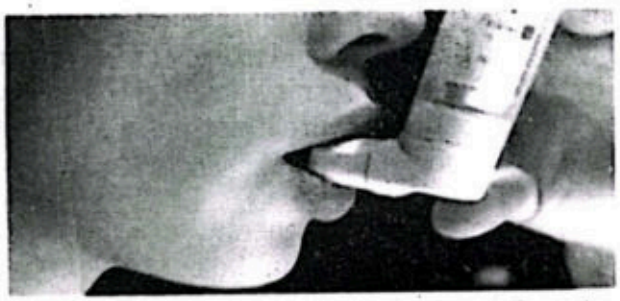


Fig. 3.10: Inhalers help asthma patient to breathe

Treatment: Mild attack of asthma is controlled with bronchodilators that dilate the airway. Different devices called **inhalers** help asthma patient to breathe. Asthma is a long-term disease that has no cure. Asthma is treated with two types of medicines: long-term control and quick-relief medicines.

3.4.5 Lung cancer

Cancer is caused by cells dividing repeatedly out of control and form unspecialised masses of cells called **tumours**. Lung cancer usually starts in the epithelium of the bronchioles. It then usually spreads throughout the lungs.

Symptoms: The first event appears to be thickening and callusing of the cells lining the bronchi. Then there is a loss of cilia, so that it is impossible to prevent dust and dirt from setting in the lungs. After that a tumour consisting of cancerous cells with a typical nucleus appears at one location. Due to metastasis the cancer spreads. The tumour may grow until the bronchus is blocked, cutting off the supply of air to that lung.

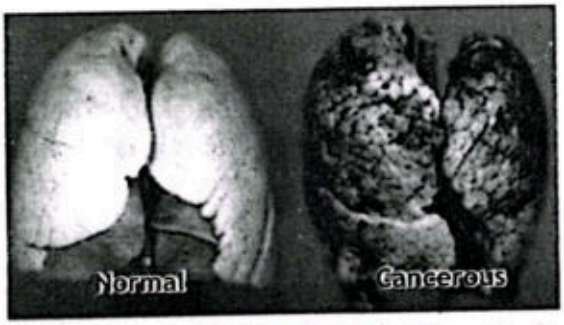


Fig. 3.11: Lungs

Cause: Tobacco smoke is the main cause of cancer. Air pollution also increases the risk of lung cancer specially car exhaust, asbestos and arsenic.
Treatment: The only treatment is pneumonectomy i.e., to remove a lobe or the lung completely or destroying it through radiation.

Do you know?

Bad effects of smoking

It causes cancer, chronic bronchitis, emphysema, early morning cough. Smokers are likely to get pneumonia. Smoking can make it hard to breathe. Smoking can also worsen asthma and allergies.

STEAM ACTIVITY 3.2 Construction of lung model

An experiment to demonstrate how the diaphragm works during breathing

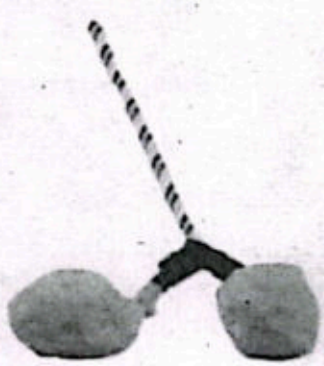
Materials needed: 2 litre plastic bottle, Straws, Scissors, Quality tape, 3 large balloons, Plasticine/Blu-Tac, Elastic bands

Procedure

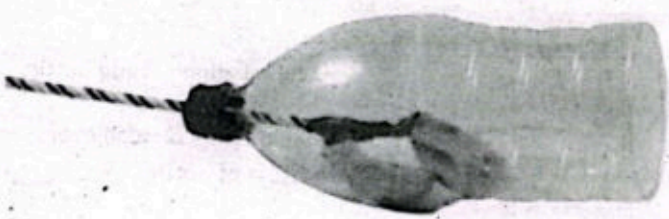
1. Cut the bottom off the two litre bottle, make the cut a smooth as possible.

2. **Create a Y shaped connector.**
Cut one straw open (1cmfrom the end) and fold it out to create two small legs to make a Y. Cut 8 cm off the 2nd straw, gently fold in half and cut out a 2 cm diamond shape (fold is in the middle). Place Y of straw 1 over the diamond shaped hole in straw 2 and tape it in place. Make the seal airtight.

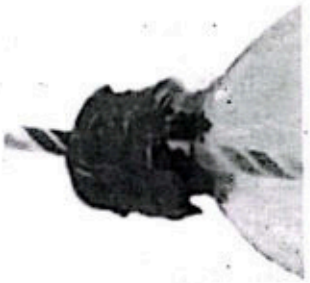
3. Add a balloon to each end of the Y-shaped connector. Secure in place with tape or elastic bands.



4. Place the balloon and straw connector structure inside the plastic bottle. Carefully thread the long straw portion through the neck of the bottle.



5. Create an airtightseal around the straw and bottle using tape. Alternatively, drill a hole in bottle top to thread straw through and seal with plasticine/Blu Tac.



6. Tie a knot at the end of remaining balloon, cut balloon in half across largest part. Stretch the balloon, with knot on outside, across bottom of bottle opening. Tape in place.

Working mechanism

a. To understand the working mechanism of lungs hold the large, bottom balloon and pull it downwards slowly.

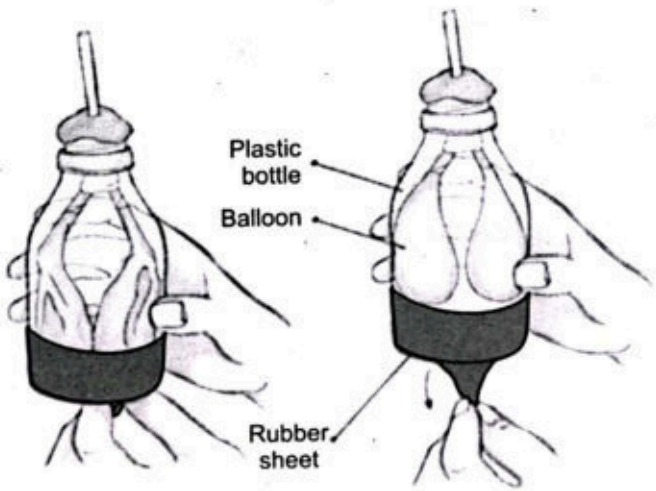
b. Now push the rubber/plastic sheet up and observe the balloons.

Observation

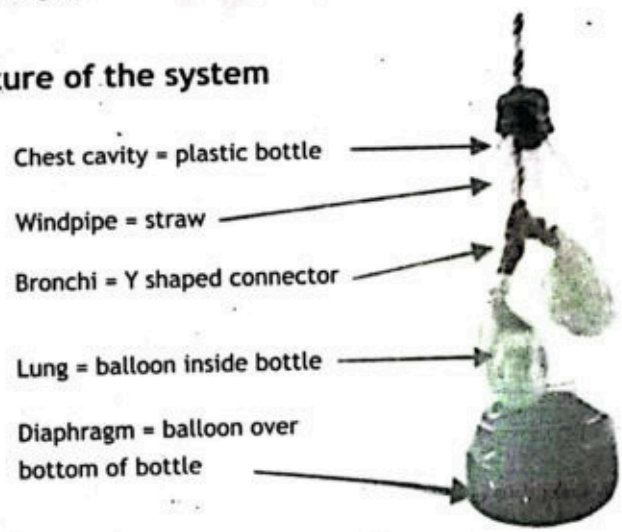
From this model we can conclude that when we pull down the balloons inflate and deflate, due to pressure inside the bottle similar to the lungs.

Inference

On comparing this model with our respiratory system we can infer that the balloons represent the lungs, the bottle represents the thorax and the rubber sheet represents the diaphragm.



Structure of the system



SUMMARY

1. Respiration is the exchange of oxygen and carbon dioxide between cells and the environment.
2. Respiration is the process by which cells obtain energy from the glucose.
3. The air passage consists of nose, pharynx, larynx, trachea, bronchi and bronchioles.
4. Nose provides air for respiration, conditions the air by filtering, warming, and moistening it, and cleans itself of foreign debris extracted from inhalations.
5. Air is drawn out of the nasal passage into pharynx.
6. The tube running from the pharynx to the lungs is called trachea which divides into two bronchi.
7. Inside the lungs each bronchus divides to form bronchioles.
8. The bronchioles divide into alveolar ducts which end into air sacs. The air sacs have alveoli.
9. The lungs are the pair of spongy, pinkish-grey organs where exchange of gases takes place.
10. Breathing is the movement of air into and out of the lungs.
11. Inhalation is the process by which other gases or air enters the lungs.
12. During exhalation, the diaphragm relaxes and moves upward, causing compression of the lungs and an outward flow of air.
13. The common respiratory disorders are bronchitis, emphysema, asthma, pneumonia, and lung cancer.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. One reason for emphysema is:

   A) smoking B) exercise C) food D) iron deficiency

2. In humans during expiration:

   A) diaphragm is lowered and ribs are raised B) both diaphragm and ribs are raised

   C) diaphragm is raised and ribs are lowered D) both diaphragm and ribs are lowered

3. The inner most chamber of the respiratory system into which air can be drawn:

   A) bronchiole B) bronchus C) bronchial tube D) alveoli

4. What is the percentage of oxygen in expired air when a person is resting?

   A) 8 % B) 12 % C) 16 % D) 20 %

5. Which process does not use energy released by respiration?

   A) active transport to the glucose into the villi

   B) diffusion of oxygen across the alveolar surface

   C) maintenance of constant body temperature

   D) passage of nerve impulses

6. Which path does a molecule of oxygen take as it enters the body?

A)	bronchiole	bronchus	larynx	trachea
B)	bronchiole	bronchus	trachea	larynx
C)	trachea	bronchiole	bronchus	alveolus
D)	trachea	bronchus	bronchiole	alveolus

7. When you inhale, the diaphragm:

A) relaxes and moves upward
B) relaxes and moves downward
C) contracts and moves upward
D) contracts and moves downward

8. Respiration in living organisms always involves:

A) carbon dioxide production
B) energy release
C) gaseous exchange
D) oxygen consumption

9. The gas exchange portion of the human respiratory system is the:

A) trachea B) bronchi C) larynx D) alveoli

10. The disease involving breakdown of air sacs of the lungs is:

A) pneumonia B) bronchitis C) emphysema D) asthma

11. Which blood vessel surrounds the alveoli?

A) capillary B) vein C) venule D) artery

12. In asthma, shortness of breath occurs due to:

A) constriction of bronchi.
B) rupturing of alveolar walls.
C) rupturing of bronchial walls.
D) accumulation of pus in alveoli.

13. The percentage of oxygen gas in inspired is 21% and in expired air it is 16%. This difference in the amount of oxygen gas is due to the:

A) storage of oxygen gas in lung tissues.
B) non-reactivity of oxygen gas with the blood.
C) liberation of oxygen gas as a metabolic waste.
D) utilisation of oxygen gas in energy production.

14. Which one of the following row best describes the action of different structures associated with the process of inhalation?

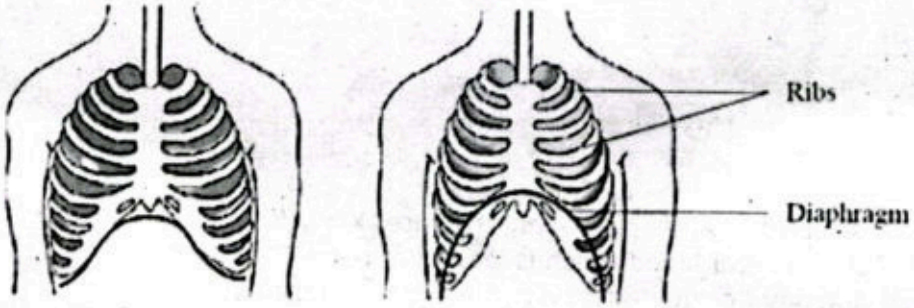
	Diaphragm	Rib muscles	Ribs
A)	contract	relax	remain unchanged
B)	relax	relax	raised
C)	contract	contract	raised
D)	relax	contract	remain unchanged

15. Which row correctly describe the functions of the diaphragm, cilia and mucous in human gaseous exchange system?

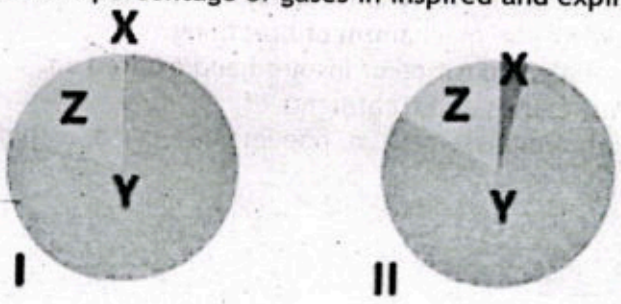
	Diaphragm	Cilia	Mucous
A)	Contracts to cause breathing out	Trap bacteria from air	Absorb CO_2 coming from alveoli
B)	Contracts to cause breathing in	Carry mucous to the throat	Trap dust and bacteria from air
C)	Relaxes to cause breathing in	Filter dust from air	help in sound production
D)	Relaxes to cause breathing out	Produce mucous	Decrease acidity

Section II: Short Answer Questions

1. How exchange of gases takes place in alveoli?
2. What is the effect of exercise on the rate of breathing?
3. Compare inspired air and expired air.
4. How viral infections like Covid-19 affect bronchi?
5. What is the importance of breathing in fresh air?
6. What is the importance of keeping nasal and oral cavity clear?
7. Differentiate between:
   a. Respiration and Breathing
   b. Respiration and Photosynthesis
   c. Inhalation and Exhalation
   d. Smoker and Passive smoker
   e. Bronchitis and Pneumonia
   f. Aerobic and Anaerobic respiration
   g. Pharynx and Larynx
   h. Glottis and Epiglottis
   i. Bronchi and bronchioles
   j. Air sacs and alveoli
   k. Oxyhaemoglobin and carboxyhaemoglobin
8. Breathing through nose is healthier than breathing by mouth. Why?
9. What are the conditions necessary for efficient gaseous exchange between organism and environment?
10. The two steps of breathing are shown in the given diagrams. Which of the given diagrams, A or B, shows the process of exhalation? Support your answer with a reason.

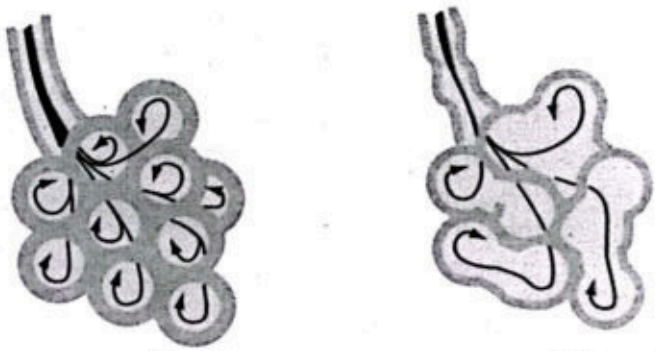


11. Describe the effects of cigarette smoking on the inner walls of trachea of human beings.
12. The diagram shows percentage of gases in inspired and expired air.

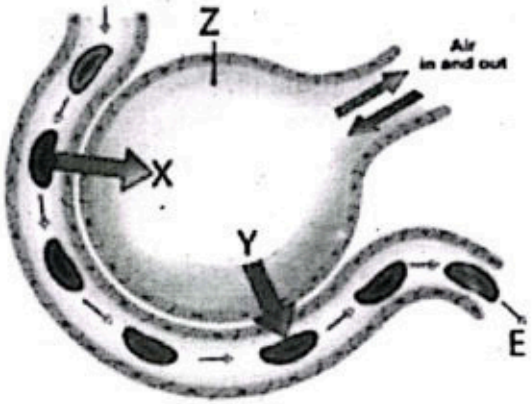


a. Identify I, II, X, Y and Z.
b. Why gas X is almost negligible in figure I?
c. How the percentage of X is increased in figure II?

13. The figure shows a healthy lung and a diseased lung
    a. Identify the disease and affected part of the lung.
    b. How the part B show structural variation from part A.
    c. Write any two symptoms of the disease.



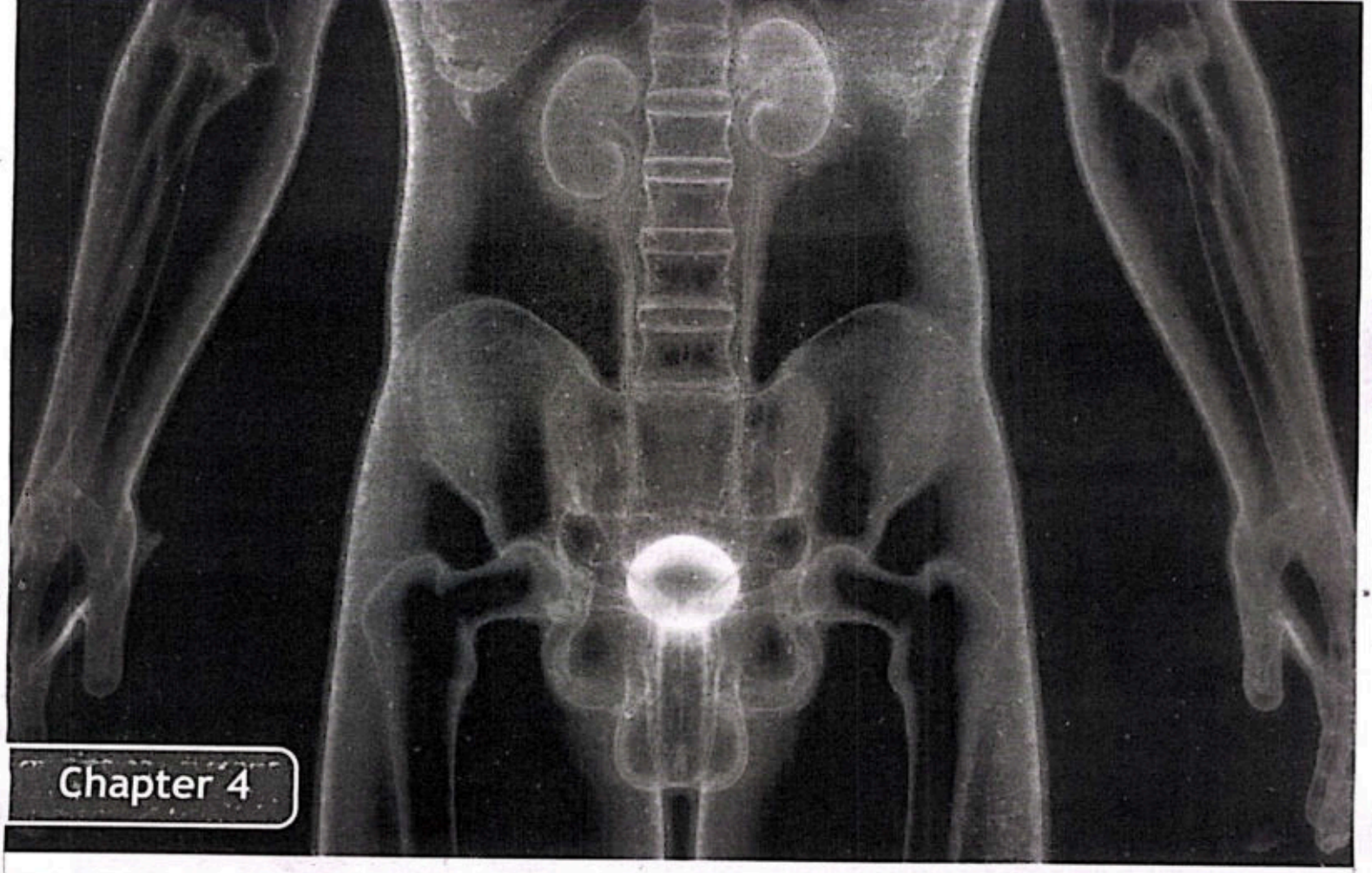
14. The diagram shows structural and functional unit of lungs.



    a. Identify structure Z. b. Name the gases X and Y.
    c. What is the name of blood which is leaving at point E?
15. How nose and nasal cavity function in filtering incoming air?
16. What is the role of 'pharynx; in human respiration?

Section III: Extensive Answer Questions

1. Describe the structure of human respiratory system.
2. Define breathing. Write the mechanism of breathing.
3. Differentiate between composition of inspired and expired air.
4. State the symptoms, causes and treatments of:
    a. bronchitis b. emphysema c. pneumonia d. asthma
    e. lung cancer.



Chapter 4

URINARY SYSTEM

SLOs: After completing this lesson, the student will be able to:

1. [B-10-R-16] Identify the different organs of urinary system.
2. [B-10-R-17] Related the structure of the kidney with its function.
3. [B-10-R-18] State that nephron is the excretory unit of kidney.
4. [B-10-R-19] Locate the different parts of nephron and relate them with their function.
5. [B-10-R-20] State the main role of kidney in urine formation.
6. [B-10-R-21] State that urine formation involves three processes i.e., filtration, reabsorption and secretion.
7. [B-10-R-22] Explain that kidney play an important role in osmoregulation. Identify the causes and treatment of kidney stones.
8. [B-10-R-23] Outline the causes of kidney failure and treatments.

The body cells form a variety of waste, and if these substances are allowed to accumulate, their effects are likely to be toxic. The blood and lymph carry wastes away from the tissue that produce them. Other parts of the body remove these wastes from the blood and transport them to outside such as urinary system. The urinary system removes various salts and nitrogenous waste.

4.1 HUMAN URINARY SYSTEM

The products of metabolism which are not needed by the organism are called **waste products.** These are harmful if allowed to accumulate in the body. They must be either removed or deposited as harmless insoluble form. The waste products include urea, uric acid; toxic substances such as pesticides, drugs, food additives.

Do you know?

The science concerned with structure, functions and diseases of the kidneys is called nephrology.

Carbon dioxide and water vapour produced during respiration are also metabolic wastes. The process by which metabolic waste products and toxic materials are removed from the body of an organism is called **excretion.**

4.1.1 Urinary system

The urinary system of man consists of:
a. pair of kidneys b. pair of ureters
c. urinary bladder d. urethra

Kidney: The kidney is reddish brown in colour. It is bean shaped and enclosed in tough transparent membrane the **capsule.** Right kidney is slightly lower than the left kidney.

Ureter: From the kidney a thin tube ureter, comes out and extends downwards to join the urinary bladder.

Urinary Bladder: Urine from each kidney passes through the ureter to the urinary bladder. The bladder is an elastic muscular bag which stores urine.

Urethra: The urinary bladder has only one exit, a tube called urethra which leads out of the body.

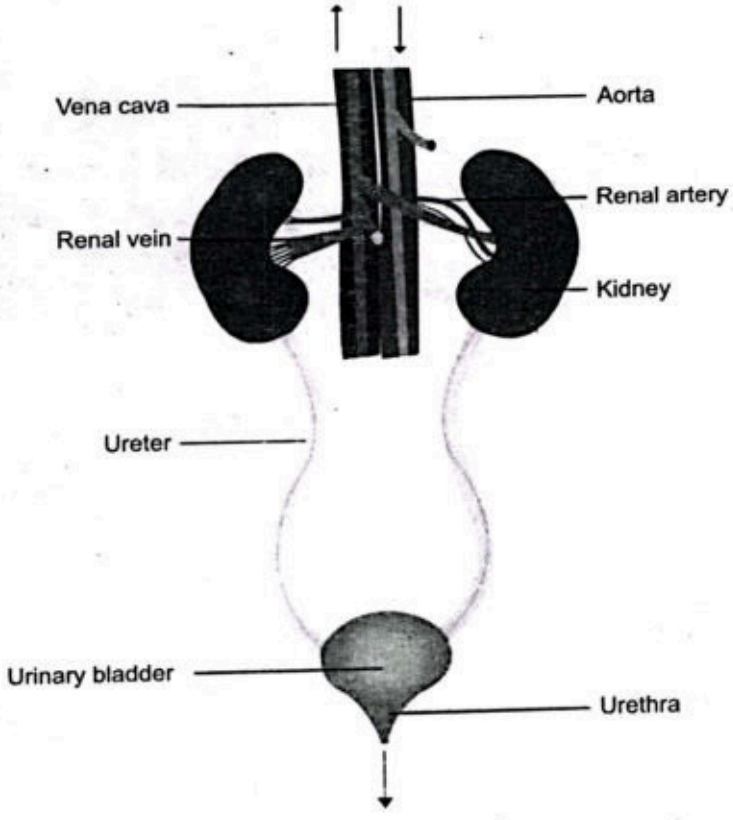


Fig. 4.1: Urinary system of man

4.2 STRUCUTRE AND FUNCTION OF KIDNEY

The kidneys are located at the back of the abdominal cavity, one on each side of the vertebral column. The concave side of the kidney faces the vertebral column. The kidney receives blood from the dorsal aorta via renal arteries and the renal veins return blood to the inferior vena cava. At the centre of the concave surface is a depression called **hilus,** where the renal artery, renal vein and the nerves are connected to kidney.

4.2.1 Structure of Kidney

In vertical section the kidney shows the following:

Renal cortex is the darker outer region. It is dark brown in colour because of the large network of blood capillaries. **Renal medulla** is the light inner region. The medulla consists of conical structures called **renal pyramid. Renal pelvis** is the hollow chamber and it is the enlarged end of the **ureter** within the kidney.

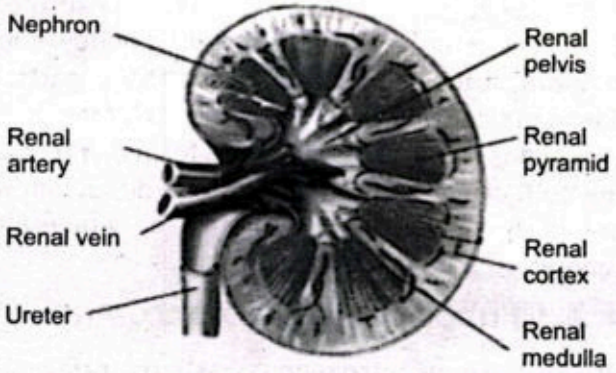


Fig. 4.2: Internal structure of human kidney (vertical section)

4.3 NEPHRON

The **nephron** is the structural and functional unit of the kidney. Each kidney, in a human, contains about one million nephrons. The nephron consists of a long tubule. Each nephron is composed of **renal corpuscle** and **renal tubule.**

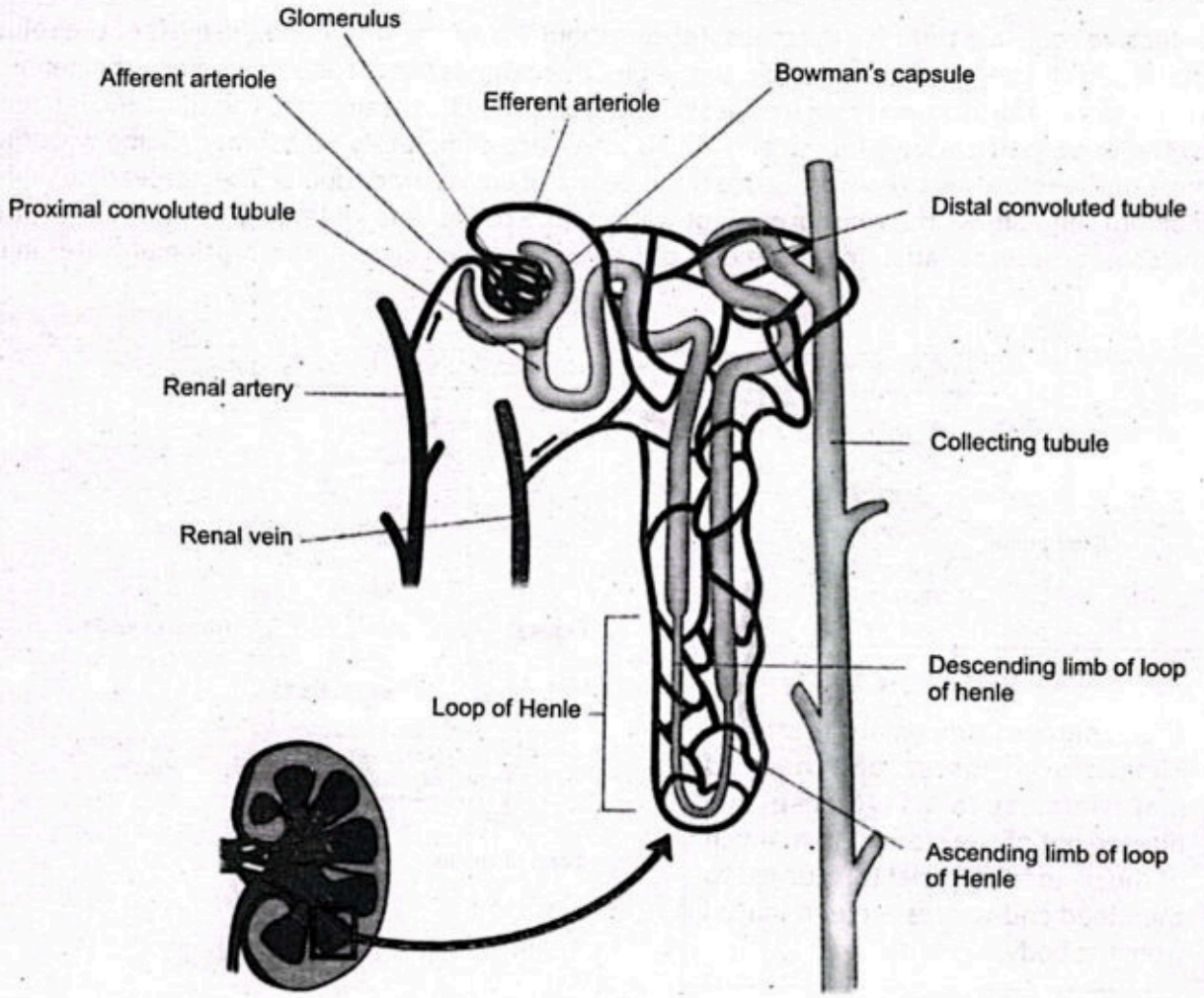


Fig. 4.3: Structure of nephron

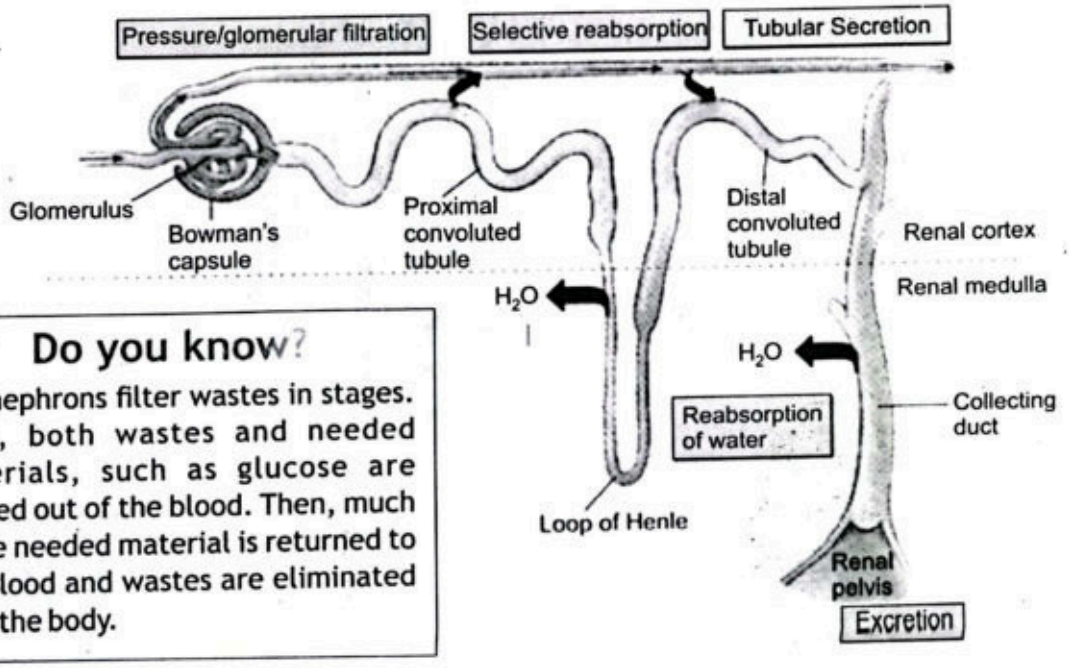
Renal corpuscle consists of Bowman's capsule and glomerulus of the **Bowman's capsule.** The Bowman's capsule is a double-walled hollow cup that surrounds a tuft of blood capillaries known as **glomerulus.** Renal tubule has three parts. **Proximal convoluted tubule** begins from the Bowman's capsule. The U-shaped structure is called **loop of Henle.** At the end of the loop the nephron is highly coiled again to form **distal convoluted tubule.** The nephron finally merges into the **collecting duct.** The collecting ducts join with even larger ducts which open into the **renal pelvis.** Blood capillary after leaving glomerulus forms a network of capillaries around renal tubule.

4.3.1 Functioning of Nephron and Urine Formation

Urea is the main nitrogenous waste material in the urine of man. Urea is formed in the liver and is carried to the kidney. The function of the kidney is to remove urea and form urine. It involves three processes in the nephron pressure or glomerular filtration, tubular or selective reabsorption and tubular secretion.

Glomerular filtration: It is the movement of small molecules across the glomerular wall as a result of blood pressure. When blood enters the glomerulus, blood pressure is sufficient to cause small molecules, such as water, nutrients, salts and wastes, to move from the glomerulus to the inside of the Bowman's capsule. The fluid that leaves the blood is called glomerular filtrate. Blood proteins and blood cells are too large to be part of this filtrate, so they remain in the blood.

Selective reabsorption: During reabsorption, about 99% of the water and the most of the solutes that enter the nephron are returned to the bloodstream, as the filtrate flows along the nephron. This reabsorption occurs through osmosis, diffusion and active transport. The substances needed by the body, particularly glucose and amino acids, are completely reabsorbed. Some water and most of the solutes are reabsorbed from the proximal convoluted tubule. The descending limb of loop of Henle allows the reabsorption of water while the ascending limb of loop of Henle allows the reabsorption of salts. The distal convoluted tubule again allows reabsorption of water in the blood.



Do you know?

The nephrons filter wastes in stages. First, both wastes and needed materials, such as glucose are filtered out of the blood. Then, much of the needed material is returned to the blood and wastes are eliminated from the body.

Fig. 4.4: Function of nephron

Tubular secretion: Some substances are actively transported from the blood capillaries into the nephron tubule by tubular secretion. These substances include K^+ and H^+ ions, drugs, uric acid and creatinine. After these steps, the filtrate present in renal tubules is known as **urine.** It moves into collecting ducts and then into pelvis.

The movement of a molecule of urea from blood to urethra is as following:

Liver → Urea → Blood → Kidney → Nephron → Glomerulus → Bowman's capsule → Proximal Convoluted tubule → Loop of Henle → Distal convoluted tubule → Collecting duct → Ureter → Urinary bladder → Urethra → Urea given out of body in the form of urine

Table 4.1: Normal Chemical Composition of Urine	
Water	95%
Urea	9.3 g/L (g / L = grams per liter)
Chloride ions	1.87 g/L
Sodium ions	1.17 g/L
Potassium ions	0.750 g/L
Other ions and compounds	Variable amounts

4.5 OSMOREGULATORY FUNCTION OF KIDNEY

The kidneys are osmoregulatory organs which regulate the concentration of water and salts in the blood. If the blood is dilute i.e., contains too much water, less water is absorbed from the renal tubules, leaving more water to enter the urinary bladder. Thus, after drinking a lot, large volume of dilute urine is produced and the human body gets rid of extra water. If the blood is too concentrated more water is absorbed back into the blood from kidney tubule. A rise in the blood concentration is thought to stimulate a thirst centre (hypothalamus) in the brain. The drinking which follows this stimulation restores the blood to its correct concentration. Besides excretion the kidneys help to maintain the pH, blood pressure and composition of the blood plasma.

4.6 DISORDERS OF HUMAN URINARY SYSTEM

There are many types of illnesses that lead to renal diseases and renal failure. Urinary tract infections are common particularly in the female. The most common causes of kidney damage are diabetes, high blood pressure, infections, kidney stones and glomerular blockage.

4.6.1 Kidney Stones and Treatment

Stones may develop in any part of the urinary system. Kidney stones are usually composed of uric acid crystal or calcium oxalate etc.

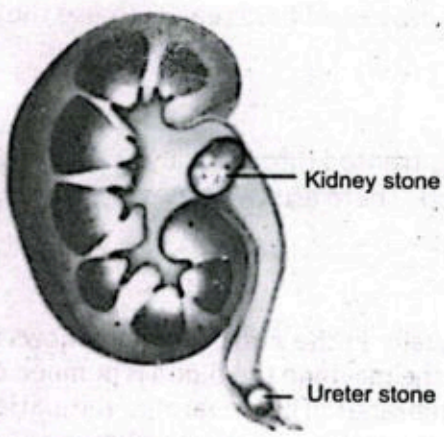


Fig. 4.5: Kidney stone

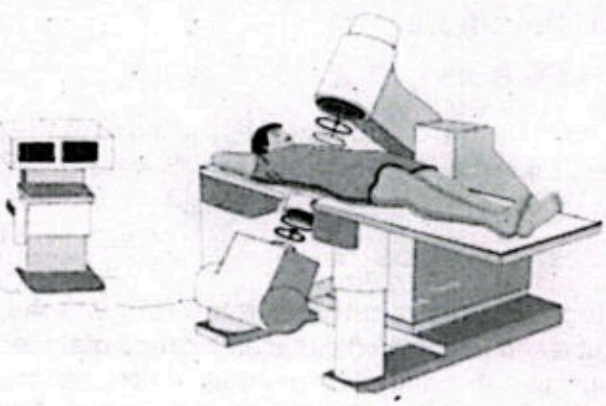


Fig. 4.6: Lithotripsy

The causes of kidney stone are: (1) Presence of high level of calcium in the blood because of other diseases. (2) Presence of higher level of oxalate in the blood results in the formation of calcium oxalate stones. (3) A decrease in water intake. (4) Age and family history.
About 90% of all kidney stones can pass through the urinary system by drinking plenty of water. The kidney stone may be removed by **surgery**. There is a non-surgical method of stone removal called **lithotripsy**. It is a technique to breakup stones that form in the kidney, and ureter by shock waves targeted from outside the body. If a kidney stone passes into a ureter it may stimulate severe pain in the kidney, abdomen, pelvis and legs accompanied by nausea and vomiting.

4.6.2 Kidney Failure

If one kidney fails to function, the person can still lead a normal life with another kidney. If both the kidneys fail to work, it is fatal. A general term for declined kidney function is called **kidney failure**. The rise in urea causes increase in blood pressure and anaemia etc. If kidney failure is not treated, death will result within a couple of weeks.

4.6.3 Causes of Kidney Failure

Kidney failure can be acute (sudden) or chronic (over time). Acute kidney failure, also known as acute kidney injury (AKI), can often be treated and the kidneys return to normal. Chronic kidney disease (CKD) is a permanent loss of kidney function.

Kidney failure can be caused by many different medical conditions. Following are the causes of kidney failure.

1. **Diabetes:** The most common cause of kidney failure is diabetes. It can damage the kidneys even if it is well managed.
2. **High blood pressure:** It is the second most common cause of kidney failure. High blood pressure can damage the small blood vessels in the kidneys.
3. **Autoimmune diseases:** Such as lupus etc., disease can damage the kidneys.
4. **Genetic diseases:** Such as polycystic kidney disease, genetic diseases can cause kidney failure.
5. **Urinary tract problems:** Such as kidney stones etc., urinary tract problems can block the flow of urine and damage the kidneys.
6. **Medications:** Some drugs, such as lithium etc., can cause kidney failure.
7. **Dehydration:** Losing too much body fluid can cause kidney failure.
8. **Kidney trauma:** An injury to the kidney from an outside force, such as a fall, accident, or high-contact sport, can cause kidney damage.
9. **Processed foods:** A 2022 study found that eating a lot of processed foods can increase the risk of kidney disease.

4.6.4 Dialysis

To remove the nitrogenous wastes the blood of the patient is treated through dialysis. Dialysis is a process for removing waste and excess water from the blood. There are two types of dialysis. (a) Haemodialysis (b) Peritoneal dialysis.

a. Haemodialysis

In this process first a **catheter** is inserted into the vein, usually in the arm. The blood flows into the tube and then into the machine called **dialyzer**. Inside the machine the blood is pumped over the surface of a dialysis membrane (semi-permeable membrane). This separates the patient's blood from the dialysis fluid. Urea diffuses out of the blood, across the dialysis membrane and into the dialysis fluid. The dialysis fluid already has sugar and salts in it.

So, sugars and salts from the blood will not diffuse across into the fluid. Urea and other wastes pass into the dialysis fluid. The patient's cleaner blood passes back into the other vein of the arm through a second catheter. Fresh dialysis fluid enters the machine from one end. The used dialysis fluid with waste leaves the machine from the other end.

Fig. 4.7: A patient undergoing haemodialysis

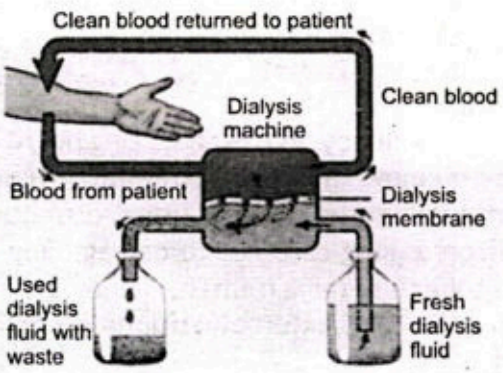


Fig. 4.8: Haemodialysis

b. Peritoneal Dialysis

In this process, the dialysis fluid is pumped into the **peritoneal cavity** which is the space around gut. The **peritoneum** which lines the peritoneal cavity functions as the dialysis membrane. Dialysis fluid is added to the abdominal cavity through the tube. It is left for several hours before removal. Exchange takes place between the dialysis fluid and the tissue fluid in the abdomen. This type of dialysis can be performed at home. It must be done regularly, 3 or 4 times a day.

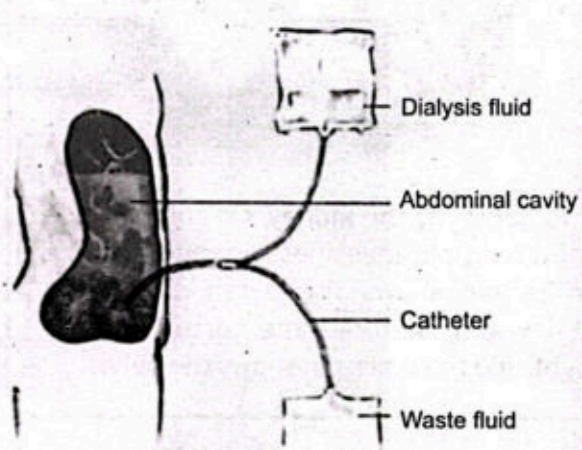


Fig. 4.9: Peritoneal dialysis

4.6.5 Kidney Transplant

The kidney of a healthy person can be transplanted to a diseased one. The kidney may be donated by a donor. The tissue and blood chemistry of the donor should be similar to that of the patient. If the kidney is not matching 'tissue rejection' may occur and the patient's immune system destroys the donated kidney.

STEAM ACTIVITY 4.1

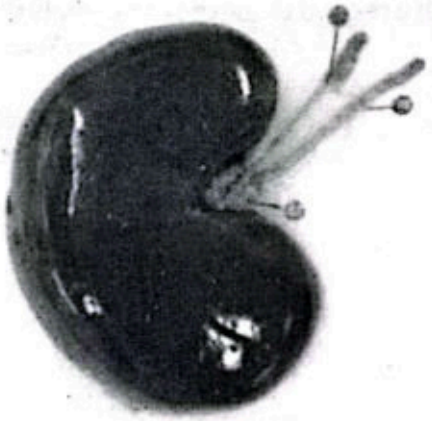
Study of kidney of a goat

(To be demonstrated by teacher)

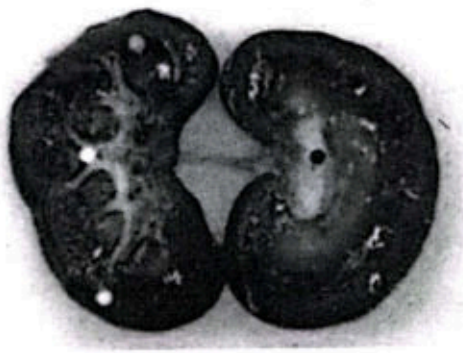
Materials needed: Scalpels, scissors, forceps, dissecting tray or board.

Procedure:

1. Place the kidney on the dissecting board or tray. Remove any protective fatty tissue surrounding the kidney using dissecting scissors taking care not to damage any of the tubes emerging from the kidney.
2. Examine the external structure of the kidney.
3. Gently separate, as much as possible, the three tubes emerging from the kidney's concave side (these may have been cut from the kidney).
4. Try to identify the:
   a. a renal artery, a narrow tube with thick elastic walls which takes blood into the kidney b. renal vein, a wide tube with limp walls which carries blood out of the kidney c. ureter, a tough white tube which carries urine from the kidney to the bladder.
5. Cut the kidney in half lengthways using sharp pointed dissecting scissors or scalpel, starting from the concave side just to one side of the centre line. Leave the tubes intact in one side of the dissection.
6. Observe the internal appearance and structure of the kidney.
7. Identify the cortex, medulla and pelvis of the kidney. Note the colour, thickness and texture of these structures.



External view of a goat kidney. The red pin identifies the renal artery and the blue pin shows the renal vein. Below the green pin identifies the ureter which has been cut close to the kidney.



Two halves of the kidney. On the left side the green pin identifies the medulla, the white pin shows the pyramid and the yellow pin identifies the cortex. On the right side the black pin shows the pelvis.

SUMMARY

1. The kidney is located on the posterior wall of the abdominal cavity.
2. Kidney tissue is divided into a medulla and a cortex.
3. The kidneys remove metabolic wastes from the blood and excrete them to the outside.
4. Arterial blood flows through the renal artery. Venous blood returns through a series of vessels.
5. A nephron is the functional unit of the kidney.
6. A nephron consists of renal corpuscle and renal tubule. The corpuscle consists of glomerulus and Bowmans's capsule.

7. Portions of the renal tubule include the proximal convoluted tubule, loop of Henle (ascending and descending limb), distal convoluted tubule and collecting duct.
8. The glomerular capillary receives blood from the afferent arteriole and passes it to efferent arteriole. The efferent arteriole gives to the peritubular capillary system, which surrounds the renal tubule.
9. The function of nephron is to remove wastes from the blood and regulate water and electrolyte concentration. Urine is the end product of these functions.
10. Urine formation begins when water and dissolved materials are filtered out of the glomerular filtration.
11. The peritubular capillary is adapted for reabsorption as it is very permeable. Most reabsorption occurs in proximal tubule. Glucose, amino acids and sodium ions are reabsorbed by active transport. Water is passively absorbed by osmosis.
12. Most of the sodium is reabsorbed before the urine is excreted.
13. Urea is reabsorbed by diffusion and excreted.
14. Uric acid is reabsorbed by active transport and secreted into the renal tubule.
15. Tubular secretion is the process by which certain substances are transported from plasma to the tubular fluid.
16. Urine is about 95% water and it usually contains urea and uric acid.
17. The kidneys are osmoregulatory organs. They regulate concentration of water and salts in the blood.
18. Blood carries many substances, including nutrients, glucose, hormones, wastes and dissolved gases. Urea, water, glucose and a small amount of other materials are returned to the blood. Urea and other wastes leave the body in urine.
19. Kidney stones are usually composed of uric acid crystal and calcium oxalate etc. Kidney stones are removed by surgery of lithotripsy.
20. A general term for decline of kidney function is called kidney failure.
21. Dialysis is a process for removing waste and excess water from the blood.
22. Kidney of a healthy person can be transplanted to a diseased one.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Nephron, the functional unit of kidney is composed of all of the following except:
   A) Bowman's capsules B) loop of Henle C) glomerulus D) ureter
2. Osmoregulation involves:
   A) active transport B) diffusion C) facilitated diffusion D) osmosis
3. Urine passes from bladder to the:
   A) medulla B) urethra C) ureter D) cortex
4. Where is urea produced?
   A) urinary bladder B) blood cells C) kidney D) liver
5. Which substance is present at a lower concentration in the renal artery than in the renal vein?
   A) amino acid B) carbon dioxide C) glucose D) urea

6. In a kidney machine what must be at the same concentration in the dialysis fluid and in the blood?

A) glucose and salts B) protein C) urea D) water

7. The four structures listed are part of the human excretory system.

1. bladder 2. kidney 3. ureter 4. urethra

In which order does a molecule of urea pass through these structures?

	First → Last			
A)	1	2	3	4
B)	1	4	3	2
C)	2	1	3	4
D)	2	3	1	4

8. In a kidney machine, which of the following passes from the blood to the dialysis fluid?

A) glucose B) plasma protein C) red blood cells D) urea

9. Which blood vessel carries blood with the lowest concentration of urea?

A) hepatic portal vein B) pulmonary vein C) renal vein D) vena cava

10. Lithotripsy is a procedure that breaks large kidney stones into smaller ones by using:

A) X-rays B) microwaves C) sound waves D) ultraviolet rays

11. Which row shows substances that are present in each of the structures of excretory system of a healthy human?

	Renal artery	Renal vein	Ureter	Urinary bladder
A)	glucose	glucose	salts	urea
B)	protein	salts	water	protein
C)	salts	water	protein	glucose
D)	urea	glucose	protein	salts

12. The filtration of waste takes place inside the kidneys in:

A) ureter B) urethra C) urinary bladder D) nephron

13. The function of glomerulus and Bowman's capsule of the nephron is to

A) reabsorb water into the blood B) eliminate ammonia from the body
C) reabsorb salts and amino acids D) filter the blood and capture the filtrate

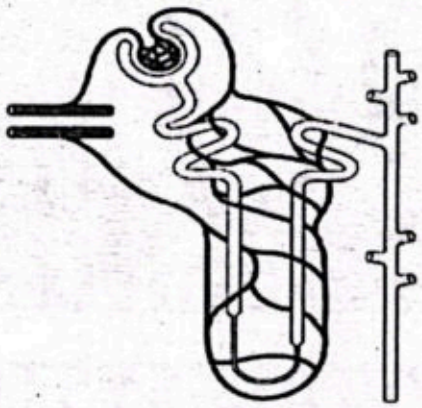
14. Evidence for glomerular filtration in the kidney could be obtained by comparing the sizes of the molecules present in Bowman's capsule with those in the

A) afferent blood vessel B) collecting duct
C) loop of Henle D) proximal tubule

Section II: Short Answer Questions

1. What is the role of urinary system in the body?
2. Name the structures of urinary system.
3. Write the functions of: kidney, ureter, urinary bladder, urethra, pelvis of kidney, capsule of kidney, dialysis.
4. What materials are returned to the blood?

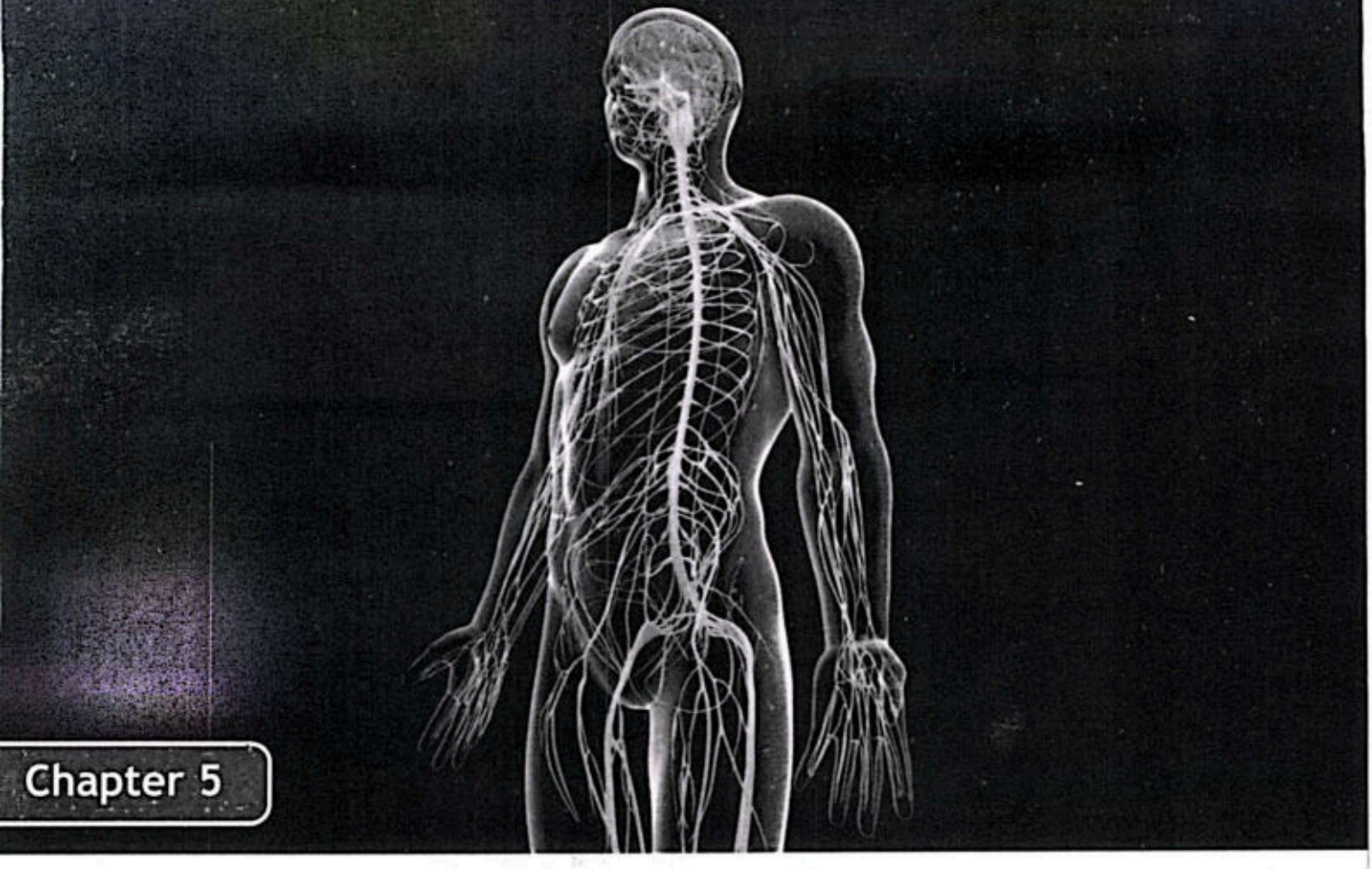
5. What materials leave the body in urine?
6. Name the disorders of kidney.
7. Write the causes of formation of kidney stone.
8. Name the structures in the urinary system of man that is associated with each of these:
   a. Urea formation
   b. Urine formation
   c. Filtration
   d. Re-absorption
   e. Tubular secretion
   f. Temporary storage of urine
   g. Conduction of urine out of the body
9. The given diagram shows the structure of a human nephron.
   Trace the pathway of blood with the help of arrows (→) in the given diagram.
   (Note: Do NOT show pathway of the filtrate.)



10. Describe the kidney transplant.
11. What is kidney failure and dialysis?

Section III: Extensive Answer Questions

1. Describe human urinary system.
2. Relate the structure of the kidney with its function.
3. Describe the structure of nephron.
4. Explain the process of urine formation in human.
5. Describe the osmoregulatory function of kidney.
6. Discuss the kidney stones and it's treatment.
7. Describe the following two types of Dialysis
   a. Haemodialysis
   b. Peritoneal Dialysis
8. Outline the causes of kidney failure and its treatment.



Chapter 5

NERVOUS SYSTEM

SLOs: After completing this lesson, the student will be able to:

1. [B-10-G-01] Describe the nervous system and its role.
2. [B-10-G-02] Describe central nervous system and peripheral nervous system.
3. [B-10-G-03] Outline the types of neuron with diagrams.
4. [B-10-G-04] Define stimulus with example.
5. [B-10-G-05] State the nerve impulses are electrical signals that travel across neuron.
6. [B-10-G-06] Define and sketch synapse.
7. [B-10-G-07] Introduce neurotransmitters.
8. [B-10-G-08] Explain through sketching a diagram the involvement of nervous system when a person accidently touches something painfully hot and withdraws their hands as a reflex.
9. [B-10-G-09] Explain the endocrine system.
10. [B-10-G-10] Identify major endocrine glands and hormones with their functions.

The body of a human is very complex. To ensure that different parts work together effectively there is a need of communication. The nervous system is made up of specialized cells that allow body to communicate. They carry information from one part of the body to another. The nervous system regulates complicated processes like thoughts and memory. It also plays an essential role in the things your body does without thinking, like blushing, sweating and blinking. The nervous system keeps track of what's going on inside and outside of your body and decides how to respond to any situation you are in.

5.1 NERVOUS SYSTEM AND ITS ROLE

Through the sense organs you receive information from the environment. The sense organs include eyes, ears, nose, tongue and skin. Information from the sense organs travels along a nerve to the brain. The brain interprets the message. You can see a picture, hear a sound, smell a rose, taste an apple or feel the cold winter air. The human body is made up of different organs. Each of these organs plays its role in carrying out the process that keeps us alive. The functions performed by each part of the body are coordinated. This coordination is brought about by the organ system called **nervous system.**

Do you know?

The study of the structure of nervous system is called neurology.

5.1.1 Role of Nervous System

Sensitivity is a main feature of all living organism. Any change in the environment of an organism is called **stimulus.** Reaction to the stimulus is known as **response.** The stimulus is received by a **receptor.** The structures that give responses are called **effectors.**

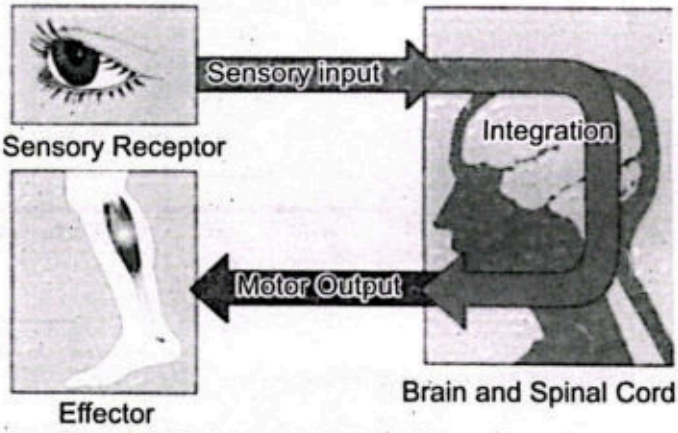


Fig. 5.1: Basic organization of nervous system

The basic organization of a nervous system has three interconnected functions: the sensory input, integration and motor output. Sensory input is triggered by stimuli, such as light or touch. **Sensory input** is the conduction of signals from sensory receptors, to **processing centres** the brain and the spinal cord or the central nervous system. **Integration** is interpretation of the sensory signals and the formulation of responses within processing centre.

Motor output is the conduction of signals from a processing centre to **effector cells,** such as muscle cells and gland cells. Information in the form of signals passes from receptors to processing centres and from there to effector. The electrical signals or nerve impulse travel along pathways of cells called **neurons.**

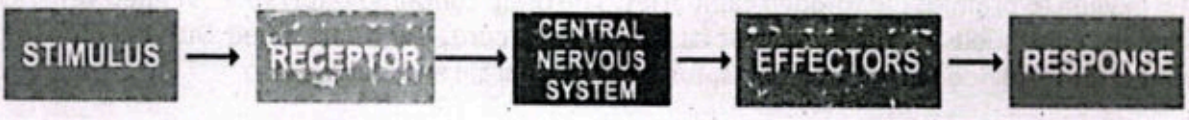


Fig. 5.2: Nervous co-ordination

The nervous system controls all the functions such as: heartbeat and blood pressure, breathing, muscle movements, thoughts, memory, learning and feelings, sleep, healing and aging, stress response, hormone regulation, digestion, sense of hunger and thirst, senses (response to what you see, hear, feel, touch and taste).

5.2 HUMAN NERVOUS SYSTEM

The human nervous system comprises of central nervous system and peripheral nervous system. The **central nervous system** consists of brain which narrows into a long tube called the **spinal cord**. The **peripheral nervous system** consists of cranial nerves from the brain and spinal nerves from the spinal cord. The structural and functional unit of nervous system is **neuron**. An outline of division of human nervous system is given below.

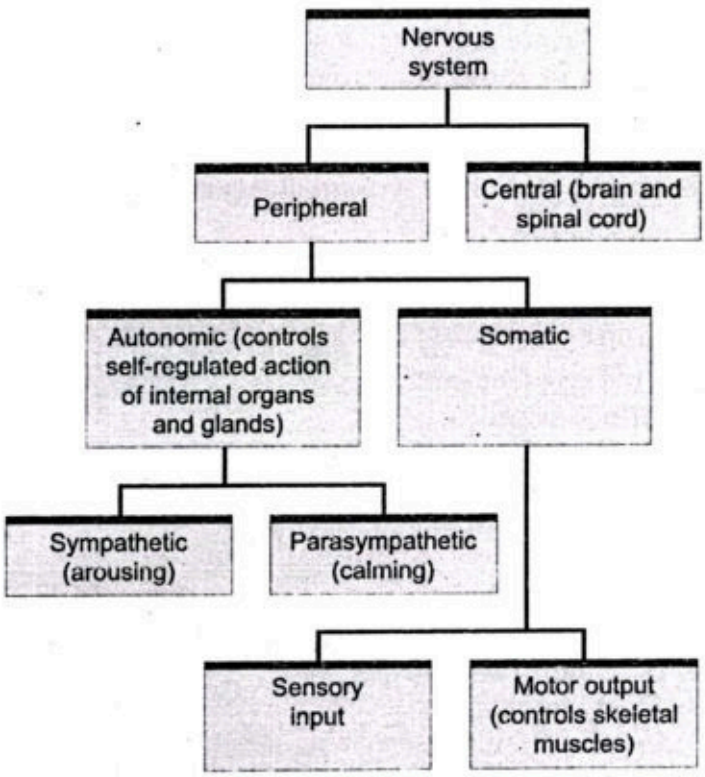


Fig. 5.3: The functional divisions of the human nervous system

5.2.1 Components of Central Nervous System

Here we will discuss the brain and spinal cord as the components of human nervous system.

Brain

It is enclosed within the cranium (skull). The brain and the spinal cord are covered with three protective membranes called **meninges**. Between the inner and middle layer there is a fluid, the cerebrospinal fluid, which helps to cushion the brain from shock. Meninges also provide nutrients and oxygen to brain tissue through capillaries. The brain contains hollow spaces called **ventricles** that are continuous with the central canal of spinal cord. These are filled with **cerebrospinal fluid**. Brain is divided in to three parts, forebrain, midbrain and hindbrain.

Forebrain

The forebrain consists of cerebrum, thalamus and hypothalamus. Cerebrum is the largest part of

the human brain. **Cerebrum** is the main centre of various sensations e.g., hearing, sight smell, memory voluntary action, intelligence, and reasoning. Cerebrum is divided into two **cerebral hemispheres**. Each cerebral hemisphere is divided into four major lobes. 1. frontal lobe 2. parietal lobe 3. temporal lobe 4. occipital lobe.

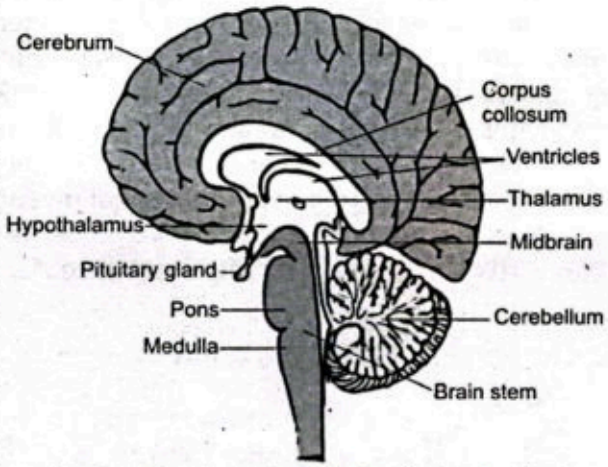


Fig. 5.4: Section through head showing brain

Occipital lobe is responsible for vision. **Temporal lobe** is concerned with hearing and smelling. **Frontal lobe** controls movement of skeletal muscles including movement involved in speech. **Parietal lobe** receives stimuli from skin and provides awareness of body position. The right and left hemispheres control the opposite sides of the body. The two hemispheres are connected by a bundle of nerve fibres called corpus callosum.

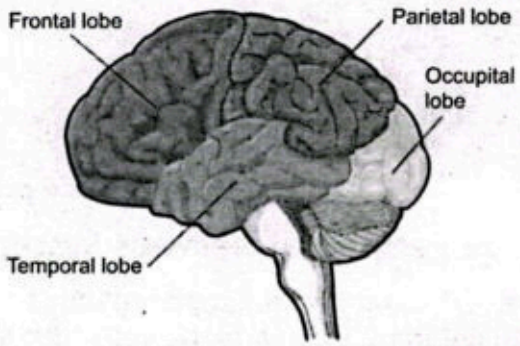


Fig. 5.5: Lobes of Forebrain

Thalamus is below the cerebrum. Thalamus receives nearly all impulses arriving from sensory areas of the body, before passing them to cerebrum. Thalamus is also involved in pain reception and consciousness.

Hypothalamus lies below thalamus. It regulates body temperature, appetite, water balance blood pressure, feeling of mood etc. It links nervous system and endocrine system as it regulates the secretion of pituitary gland. Just below the hypothalamus lies the **pituitary gland**. It is a very small gland about the size of a pea. It is an endocrine gland.

Midbrain

The midbrain is just a mass of tract below the cerebrum. The midbrain receives sensory information and sends it to the appropriate part of the forebrain. It also controls some auditory reflexes and posture.

Hindbrain

The hindbrain includes cerebellum, pons and medulla. **Cerebellum** is the second largest part of the brain. It controls balance and muscle coordination. **Medulla oblongata** is the last part of the brain, just above the spinal cord. Medulla controls involuntary processes of the body like heartbeat, blood pressure and respiration etc. Medulla also controls reflexes such as coughing, sneezing and vomiting etc. Information is passed through medulla between the spinal cord and rest of the brain. **Pons** is small lobe like structure lying just above the medulla. It assists medulla in controlling breathing process. It also serves as a connection between cerebellum and spinal cord.

Spinal Cord

The human spinal cord is an oval shaped hollow cylinder of nervous tissue. It runs from the base of the brain. It is protected by the vertebrae of the backbone. 31 pairs of nerves originate from

spinal cord. Each spinal nerve has a dorsal root of sensory neurons and ventral root of motor neuron. Therefore, all spinal nerves are mixed nerves. The spinal cord serves as a link between body parts and brain. It receives sensory information from the receptors and sends out motor commands to the effector. The spinal cord works as coordinator. It carries out the reflex actions. It also helps in better functioning of brain.

The cross section of the brain and spinal cord shows that the central nervous system has two distinct areas. **White matter** consists of myelinated fibres. **Grey matter** is mainly cell bodies and non-myelinated fibres. In spinal cord butterfly shaped grey matter is surrounded by white matter. While in brain, grey matter makes up the outer layer having some white matter in the centre.

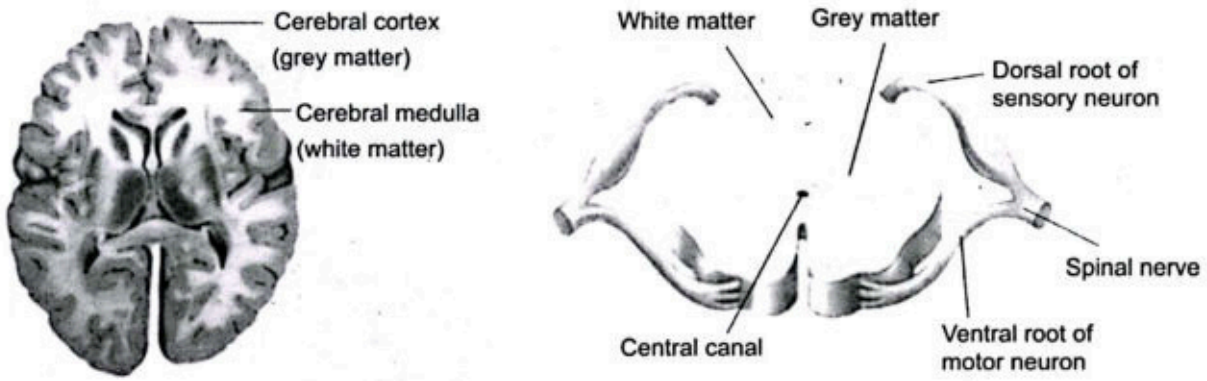


Fig. 5.6: Cross section view of brain and spinal cord

5.2.2 Peripheral Nervous System

The peripheral nervous system (PNS) is composed of nerves which link central nervous system with different body parts. Nerves which arise from brain are called **cranial nerves**. The nerves which arise from spinal cord are called **spinal nerves**. There are 12 pairs of cranial nerves and 31 pairs of spinal nerves in the human body. Some cranial nerves are sensory, some are motor and some are mixed. While, all spinal nerves are mixed nerves.

The peripheral nervous system can be divided into somatic and autonomic nervous system.

Somatic nervous system: Generally it consists of the cranial and spinal nerve fibers that connect the CNS to skin and skeletal muscles.

Autonomic nervous system: It includes those fibres that connect the CNS to the visceral organs, such as the heart, stomach, intestines and various glands. It is concerned with the unconscious activities. The autonomic nervous system is divided into sympathetic and parasympathetic nervous system.

Sympathetic system: It consists of only spinal nerves. It functions only in the state of emergency. It prepares the body to fight or flight response.

Parasympathetic system: It consists of few cranial and spinal nerves. It controls various autonomic nerves during the state of rest. In short it returns the body functions to normal after they have been altered by sympathetic stimulation.

5.3 NEURON

The structural and functional unit of nervous system is neuron. Neurons are long, thin delicate cells. A single neuron may extend from the spinal cord of man to the foot. Bundles of neuron fibres are called **nerves**. The portion of the neuron most resembling other cells is the **cell body**. The cell body contains a nucleus and cytoplasm. The long fibre of a neuron leading away from the cell body is the **axon**. An axon transmits impulses away from the cell body. The other end of the neuron is a highly branched structure called **dendrites**. Impulses move toward the cell body from the dendrites and from cell body to axon.

Long neuron fibres are covered by a fatty **myelin sheath.** Cells of myelin sheath are called **Schwann cells.** Small gaps between consecutive Schwann cells are called **nodes of Ranvier.** Both myelin sheath and the nodes of Ranvier are important in determining the speed with which impulses are conducted. Myelin sheath is an insulator so the membrane coated with this sheath does not conduct nerve impulse. In such a neuron, impulse jumps over the myelin going from node to node. These jumping or **saltatory impulses** increase the speed of nerve impulse.

5.3.1 Types of Neurons

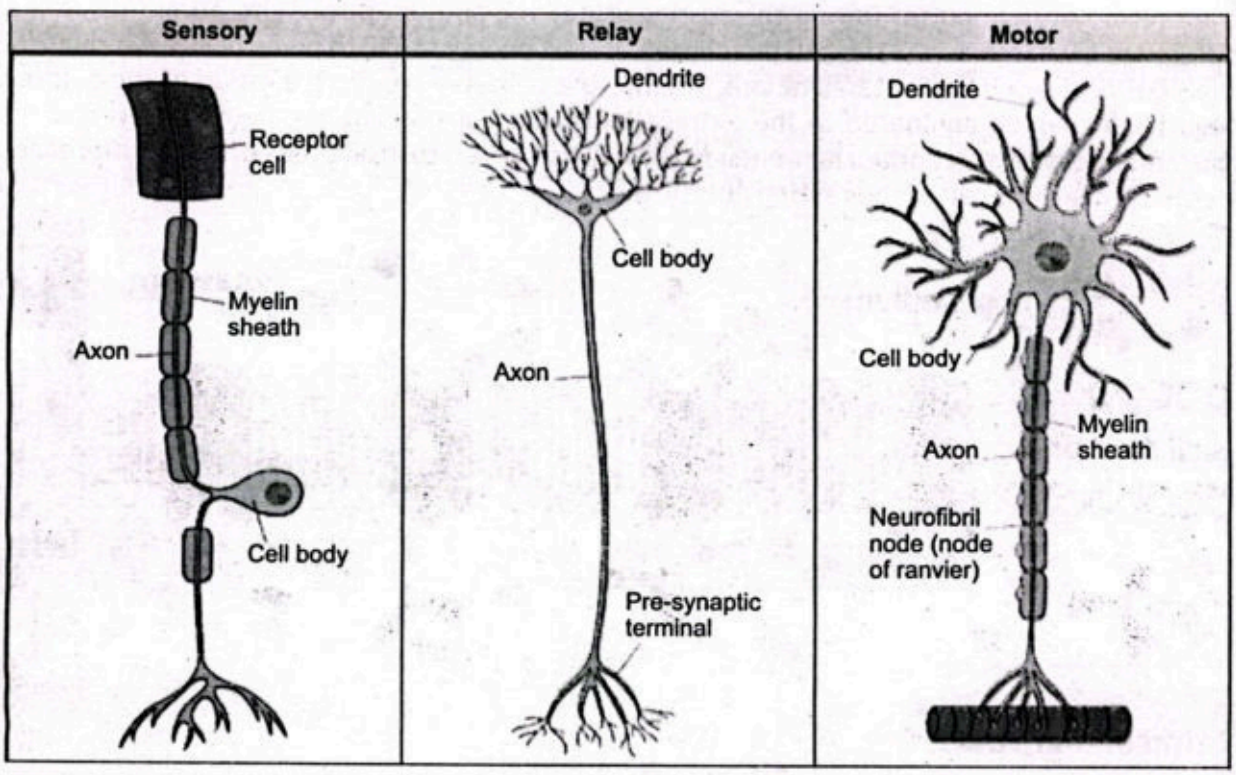


Fig. 5.7: Types of Neuron

The neurons differ in structure and in direction toward which they carry impulses.

Sensory Neurons: They carry sensory information from receptor to the brain and spinal cord. It has one dendrite and one axon.

Motor Neurons: They carry impulses from the brain and spinal cord to the effectors. They have many dendrites and one axon.

Interneurons: These are found in brain and spinal cord. They have many dendrites and axons. The interneuron carries impulses from sensory neuron to motor neuron.

5.4 STIMULUS

Any change or signal in the environment that can make an organism react is called a **stimulus.** (Plural: **stimuli**). Stimuli can be external or internal. External sensory stimuli generally activated by the external changes and include pain, touch, vision, smell, taste, sound, and balance. Internal stimulus is the type of stimulus that comes from inside of the body. One example is of hunger which makes our body get food as there is low energy in the body. Other example includes, level of glucose in the blood, blood pressure and homeostasis etc.

Fig. 5.8: Stimulus

5.5 NERVE IMPUSLES

Nerve impulses are electrical in nature. They result from a difference in electrical charge across the plasma membrane of a neuron. How does this difference in electrical charge come about? The answer involves ions, which are electrically charged atoms or molecules.

Resting Potential

When a neuron is not actively transmitting a nerve impulse, it is in a resting state, ready to transmit a nerve impulse. During the resting state, the **sodium-potassium pump** maintains a difference in charge across the cell membrane. It uses energy in ATP to pump positive sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. As a result, the inside of the neuron is negatively charged compared to the extracellular fluid surrounding the neuron. This is due to many more positively charged ions outside the cell compared to inside the cell. This difference in electrical charge is called the **resting potential**.

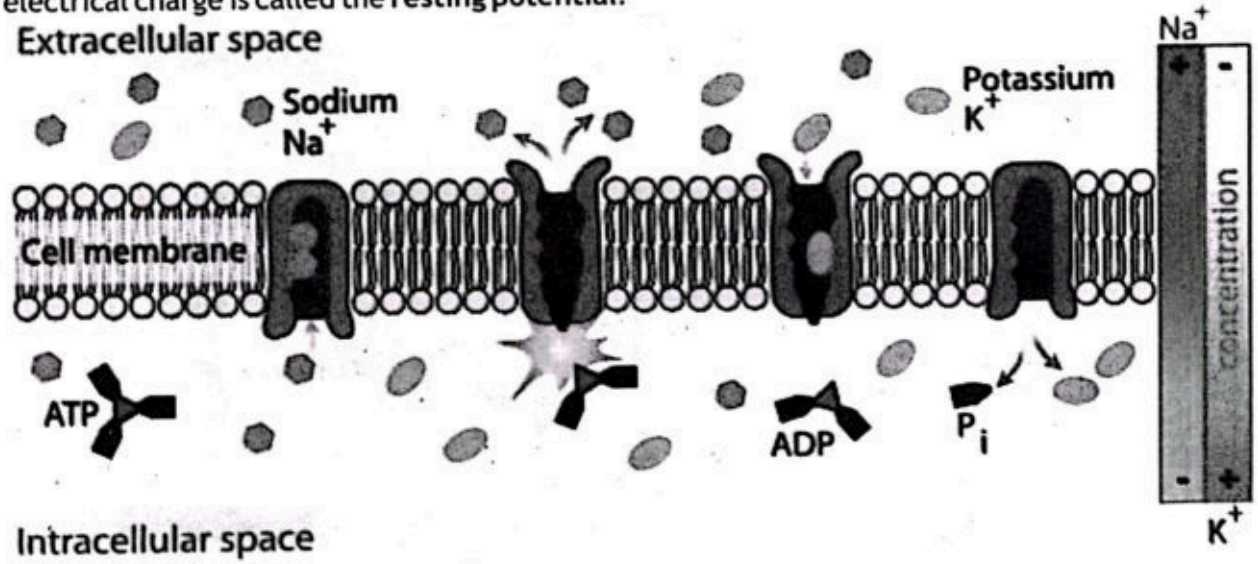


Fig. 5.9: The sodium-potassium pump maintains the resting potential of a neuron.

Action Potential

A **nerve impulse** is a sudden reversal of the electrical charge across the membrane of a resting neuron. The reversal of charge is called an **action potential**. It begins when the neuron receives a chemical signal from another cell. The signal causes gates in sodium ion channels to open, allowing positive sodium ions to flow back into the cell. As a result, the inside of the cell becomes positively charged compared to the outside of the cell. This reversal of charge ripples down the axon very rapidly as an electric current.

Do you Know?

An action potential speeds along an axon in milliseconds.

For your information

In neurons with myelin sheaths, ions flow across the membrane only at the nodes between sections of myelin. As a result, the action potential jumps along the axon membrane from node to node, rather than spreading smoothly along the entire membrane. This increases the speed at which it travels.

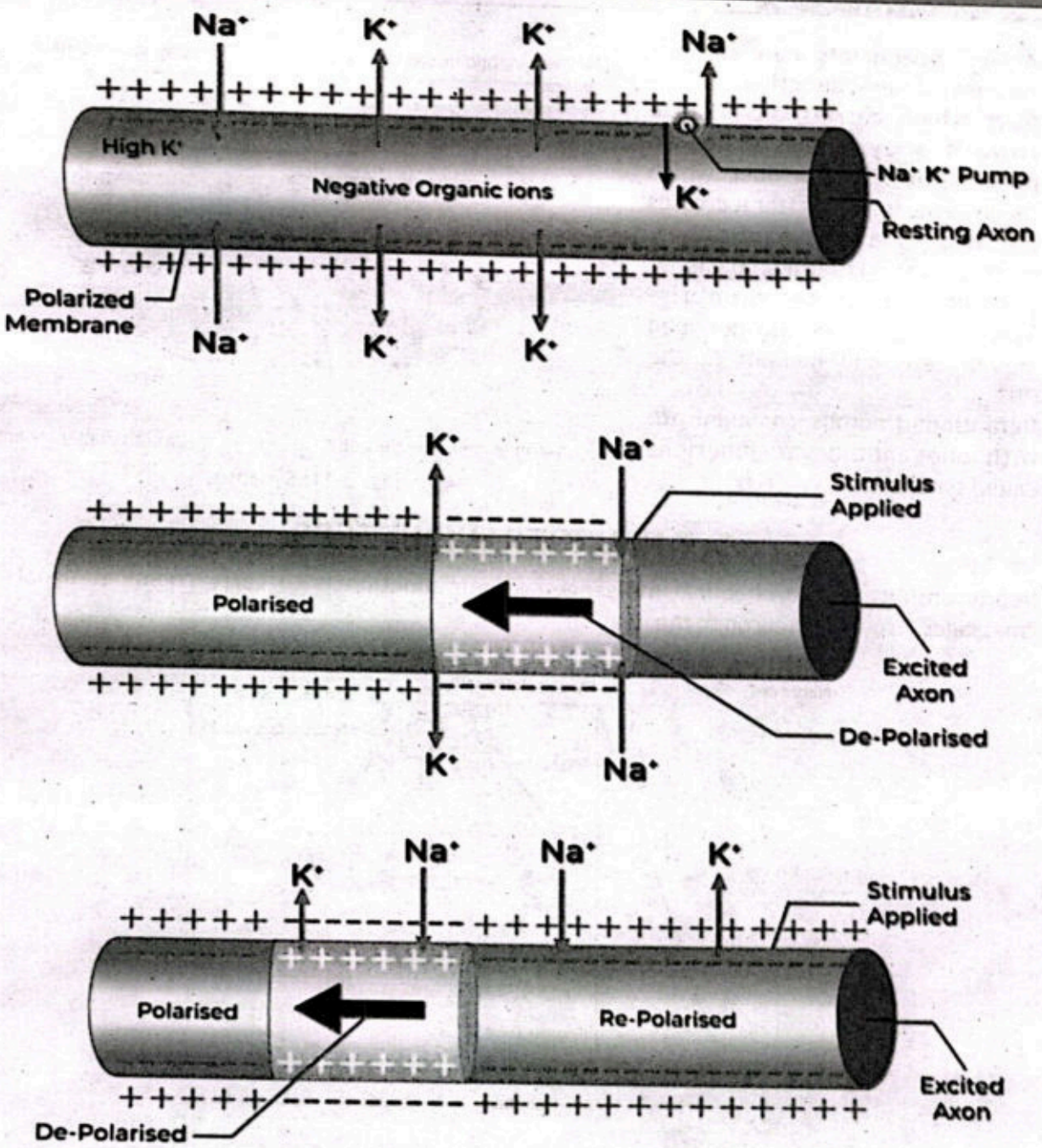


Fig. 5.10: Nerve impulse

5.6 SYNAPSE

The term 'synapse' comes from the Greek words '*syn*', which means 'together' and '*haptein*' meaning 'to clasp'. Action potential do not cease at the end of a single neuron. They are passed on to another excitable cell. The junction between two neurons is called a **synapse** (Sai-naps). Actually, the neurons are not in direct contact at a synapse. There is a gap called **synaptic cleft** between them. For an impulse to continue along a nerve pathway, it must cross this gap. The process of crossing the gap at a synapse is called **synaptic transmission.**

Action potentials can cross a synapse in one direction only. A fiber which carries an impulse toward a synapse is called **presynaptic fiber.** A fiber which receives the impulse after it crosses the synapse is a **postsynaptic fiber.** It serves as structural basis of communication between the neurons in the CNS and between muscle cells and neurons in the PNS.

Definition: Neurons communicate with one another at junctions called **synapses.**

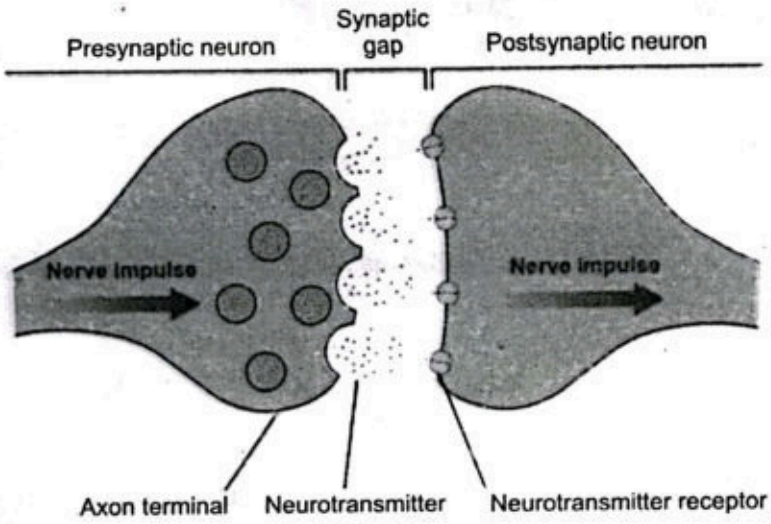


Fig. 5.11: Synapses

5.7 NEUROTRANSMITTERS

Neurotransmitters are chemical messengers. Their function is to carry chemical signals or "messages" from one neuron to the next target cell.

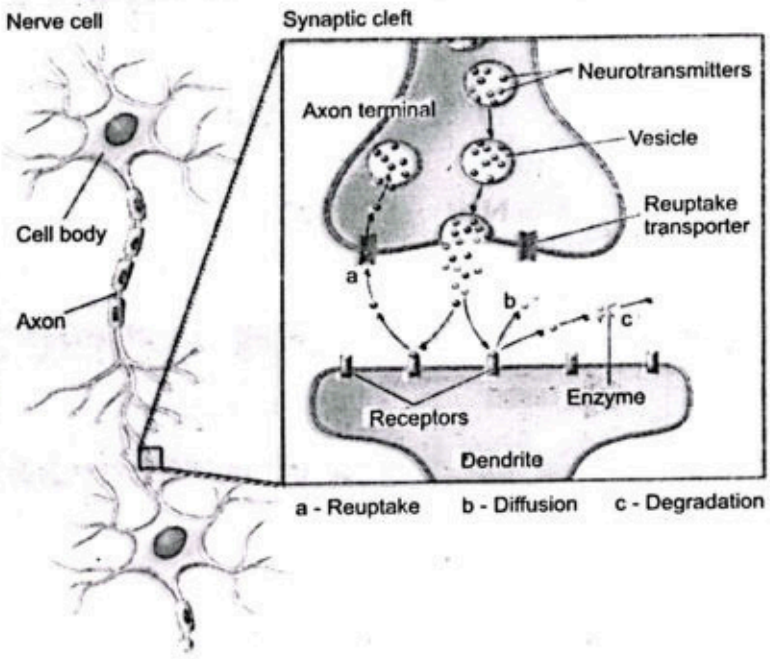


Fig. 5.12: Synaptic transmission

Neurotransmitters are located in the **axon terminal.** They are stored within thin-walled sacs called **synaptic vesicles.** Each vesicle can contain thousands of neurotransmitter molecules.

As a message or signal travels along a nerve cell, the electrical charge of the signal causes the vesicles of neurotransmitters to fuse with the nerve cell membrane at the very edge of the cell. The neurotransmitters, which now carry the message, are then released from the axon terminal into a fluid-filled space that's between one nerve cell and the next target cell.

Each type of neurotransmitter lands on and binds to a specific receptor on the target cell. After binding, the neurotransmitter then triggers a change or action in the target cell, like an electrical signal in another nerve cell, a muscle contraction or the release of hormones from a cell in a gland.

Examples of neurotransmitters are: epinephrine and norepinephrine, glycine and serotonin.

Do you know?

After neurotransmitters deliver their message, the molecules must be cleared from the synaptic cleft. They do this in one of three ways.

Neurotransmitters: a. Fade away (a process called diffusion). b. Are reabsorbed and reused by the nerve cell that released it (a process called reuptake). c. Are broken down by enzymes within the synapse so it can't be recognized or bind to the receptor cell (a process called degradation).

5.8 REFLEX ACTION

The actions performed by our bodies are voluntary and involuntary.

Voluntary actions are the responses by the will and may not be automatic or immediate. Example: Running, walking etc.

Involuntary actions are the actions that occur automatically and without our awareness.

Examples: Heartbeat, secretion of gastric glands, peristalsis, reflexes etc.

Reflex Action

Reflex actions are also called **reflexes**. Reflexes are the responses to external and internal environmental changes. The responses are immediate or automatic and without the intervention of will. Certain responses are without the help of the brain. In this case the spinal cord acts as the control centre. Such a response is a reflex, which involves no conscious control.

Example: The nervous pathway for a well-known reflex called the withdrawal of hand on touching hot object.

Sequence of events that occur when the hand touches a hot object:

1. The heat on the object stimulates nerve endings (receptor) in the skin.
2. Impulses are produced. The impulses travel along the sensory neuron to the spinal cord.
3. In the spinal cord, the impulses are transmitted first across a synapse to the interneuron and then across another synapse to the motor neuron.
4. Impulses leave the spinal cord along motor neuron to the effector.
5. The effector is the arm muscle which then contracts. This brings about a sudden withdrawal of the hand.

Other examples of **reflex actions** are sneezing, coughing, blushing, scratching, and the sudden blinking of the eye when a hand is waved in front of it.

Reflex Arc

In each of the examples mentioned above, there is a particular pathway by which the impulses can travel from the receptor to the effector. This nervous pathway is known as the **reflex arc.**

A reflex arc consists of: 1. sense organ. 2. sensory neuron. 3. interneuron of reflex centre (spinal cord or brain) 4. motor neuron. 5. effector (muscle or gland)

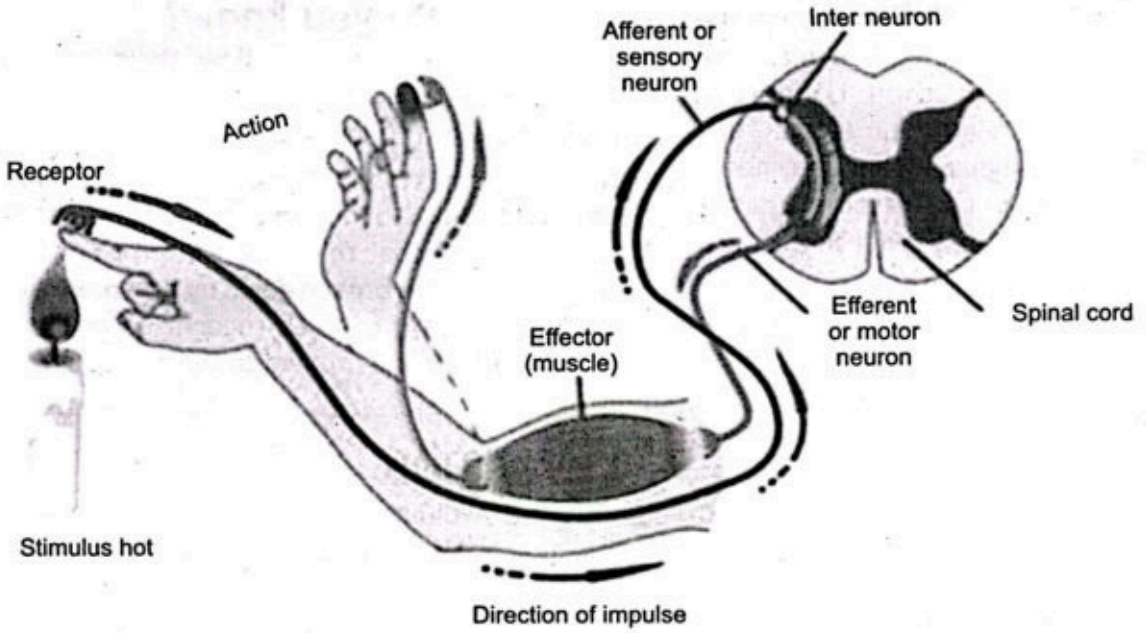


Fig. 5.13: Reflex arc

5.9 ENDOCRINE SYSTEM

Hormones are chemicals produced by the ductless endocrine glands. Small amounts of these chemicals are carried around the body in the blood. The organ on which a particular hormone acts is called **target organ.** Hormones speed up or slow down or alter the activities of these organs. **Hormones** are chemical messengers which regulate and control a number of activities of the body. The hormonal system is slower acting and regulates processes that occur over days or even month. Why it is beneficial for an animal to have two different systems for coordinating activities? Having two systems allow an animal to respond to two different types of stimuli - those requiring immediate action and those that depend on a long-term response.

The gland that secretes a substance out through a duct is called exocrine gland. The secretion is either inside the body or on a surface of the body.

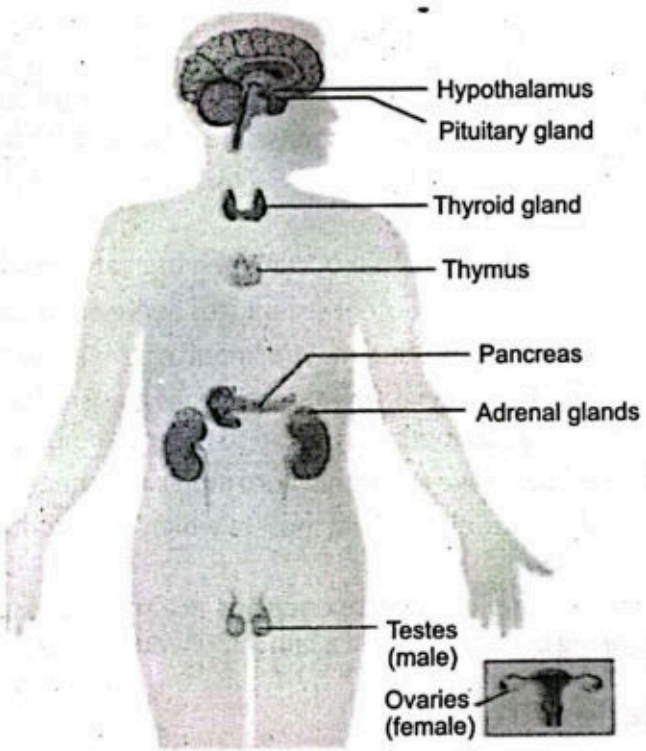


Fig. 5.14: Endocrine system in man

Following major endocrine glands are present is man:

1. Pituitary gland
2. Thyroid gland
3. Parathyroid glands
4. Pancreas
5. Adrenal glands
6. Gonads

5.9.1 Pituitary Glands

Pituitary gland is attached with the hypothalamus. It is about the size of a pea, and consists of two distinct lobes, the anterior and the posterior lobe. It is called master gland because it controls the activity of other endocrine glands.

Anterior Lobe

It mainly affects, regulates and maintains the development and functions of the endocrine glands. It is the larger one and secretes many hormones. **Thyroid stimulating hormones** control development and maintenance of the thyroid glands including production of thyroid hormone. **Growth hormone** or **somatotropic hormone** affects height of the individual. If less growth hormone is produced during childhood, the individual becomes **pituitary dwarf**. If too much growth hormone is produced the individual, is a **pituitary giant**. When there is overproduction of growth hormone in the adult a condition called **acromegaly** results. Since only the feet, hands and face can respond, these portions of the body become overly large. The other hormones of the anterior lobe influence gonads and adrenal glands.

Posterior lobe

It secretes two hormones, oxytocin and antidiuretic hormone.
Oxytocin: It causes powerful contractions of uterus during birth. It causes the ejection of milk.
Antidiuretic hormone. It causes reabsorption of water from the nephrons. It's under secretion results in large quantity of dilute urine. This disease is called diabetes insipidus.

5.9.2 Thyroid Gland

The thyroid gland is located in the neck and fits closely around and sides of trachea just below larynx. The thyroid gland has two lobes. The thyroid hormones are thyroxin and calcitonin.
Thyroxin regulates basic metabolism. It regulates process of growth especially maturation, mental and skeletal development in children. The deficiency of iodine in diet causes the disease goitre, which is the enlargement of thyroid gland itself. It is common in mountain areas due to lack of iodine in soil and water. **Calcitonin** is secreted when blood calcium level is high. It stimulates the deposition of extra calcium in bones.

5.9.3 Parathyroid Glands

Located on the thyroid glands are two pairs of very small structures called parathyroid glands. They secrete the hormone called **parathormone**. Parathormone has function opposite to the function of calcitonin. It controls the balance of calcium ions and phosphate in body.

5.9.4 Pancreas

It is present in the abdominal cavity near the stomach. It is an endocrine as well as exocrine gland. Within the pancreas are certain cells called **Islets of Langerhans**. The islets contain two special groups of cells called alpha and beta cells. Alpha cells secrete **glucagon** and beta cells secrete **insulin**.
Insulin: Insulin is secreted when the level of blood sugar rises, such as right after a meal. The most important effect of insulin is to facilitate glucose transport across cell membrane. Insulin also enhances the conversion of glucose to glycogen.
Glucagon: Glucagon has function opposite to the function of insulin. Its most important job is to increase glucose concentration by stimulating the liver to convert glycogen to glucose.
Diabetes Mellitus: Diabetes, is caused when beta cells do not produce enough insulin. When this happens, glucose accumulates in the blood and is excreted with urine. It requires treatment with regular injections of insulin or medicines prescribed by the physician.

Table 5.1: Hormones and their functions that are produced by the endocrine system.

Secreting gland(s)	Hormone	Function
adrenal	adrenaline	increases blood pressure, heart rate, and metabolism in reaction to stress
adrenal	aldosterone	controls the body's salt and water balance
adrenal	cortisol	plays a role in stress response
adrenal	dehydroepiandrosterone sulfate (DHEA-S)	aids in production of body odor and growth of body hair during puberty
ovary	estrogen	develop female sex characteristics; aids in sperm production
pituitary	follicle-stimulating hormone (FSH)	controls the production of eggs and sperm
pancreas	glucagon	helps increase levels of blood glucose (blood sugar)
pancreas	insulin	helps reduce the blood glucose levels
pituitary	luteinizing hormone (LH)	controls estrogen and testosterone production.
pineal	melatonin	controls sleep-wake cycles
pituitary	oxytocin	helps with lactation, childbirth, and mother-child bonding
parathyroid	parathyroid hormone	controls calcium levels in bones and blood
ovary	progesterone	helps prepare the body for pregnancy when an egg is fertilized
pituitary	prolactin	promotes breast-milk production
ovary, testes, adrenal	testosterone	contributes to body density in males and females as well as development of male sex characteristics
thyroid	thyroid hormone	helps control several body functions, including the rate of metabolism and energy levels

5.9.5 Adrenal Glands

The two adrenal glands rest on the top of kidneys. Each adrenal gland has two parts. Adrenal cortex and adrenal medulla. **Adrenal cortex** secretes several hormones collectively called **corticosteroids.**

Adrenal medulla produces hormones called adrenaline and nor-adrenaline. **Adrenaline** is secreted to meet emergency situation e.g., fight and flight. It is also secreted during fear and anxiety. Adrenaline increases the rate and intensity of heart beat, blood pressure and blood flow to the limbs. Such changes prepare the body to face any emergency situation. **Noradrenalin** raises blood pressure and is responsible for the constriction of blood vessel.

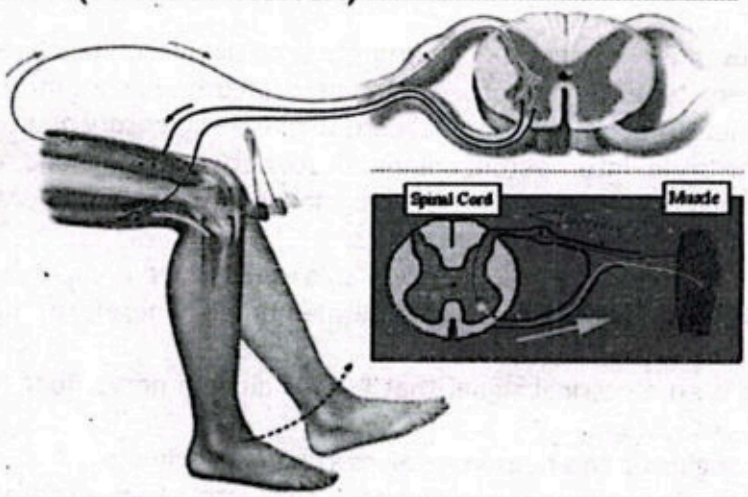
Gonads

The gonads are testes and ovaries. Their hormones are required for reproduction. The male hormone **testosterone** is secreted by the **testes** of males. It is responsible for the appearance of secondary sexual characters at puberty e.g., appearance of beard, coarseness of voice etc. The female hormone **oestrogen** (also known as estrogen) is secreted by the **ovaries.** Oestrogen also stimulates the development of secondary sexual characteristics.

Some examples of hormones and their functions that are produced by the endocrine system are given in table 5.1.

STEAM ACTIVITY 5.1

Knee Jerk Reflex (Patellar Reflex)



Procedure

Have a partner sit with his legs crossed so that his leg can swing freely. Hit his leg just below the knee with the side of your hand. **Do not use a hammer.** The leg will kick out immediately (if you hit the right place).

The knee jerk reflex (seen in the figure) is called a monosynaptic reflex because there is only one synapse in the circuit needed to complete the reflex. It only takes about 50 milliseconds between the tap and the start of the leg kick. That is fast. The tap below the knee causes the thigh muscle to stretch. Information is then sent to the spinal cord. After one synapse in the ventral horn of the spinal cord, the information is sent back out to the thigh muscle that then contracts.

SUMMARY

1. The nervous system's main function is to send messages from various parts of the body to the brain and from brain back out to the body to tell body what to do.
2. These messages regulate: Thoughts, memory, learning and feelings, Movements, balance, coordination, senses i.e., how the brain interprets what you see, hear, taste, touch and feel, wound healing, sleep, heartbeat, digestion etc.
3. The nervous system has two main parts: The brain and spinal cord make up the central nervous system. Peripheral nervous system is made up of a network of nerves. The nerves branch out from spinal cord. This system relays information from brain and spinal cord to the organs, arms, legs, fingers etc.
4. The brain and spinal cord are covered with three protective membranes called meninges.
5. Brain is divided into three parts, forebrain, midbrain, and hindbrain.
6. The forebrain consists of cerebrum, thalamus and hypothalamus.
7. The cerebral cortex is convoluted. The cerebrum receives sensory information and controls motor response. It is the center for speech, intelligence, memory etc. Taste, smell, sound and vision are interpreted by cerebrum.
8. The midbrain is a relay center between the forebrain and hindbrain.
9. The hindbrain is composed the cerebellum and medulla oblongata. The cerebellum analyzes cerebral impulses and controls posture and muscle tone. The medulla controls involuntary responses of internal organs.
10. The spinal cord connects the brain and the peripheral nervous system.
11. Spinal nerves bring information to the spinal cord from receptors and carry impulses to the effectors.
12. Nervous system uses nerve cells called neurons to send signals, or messages, all over the body. There are different types of neurons. Each type of neuron has a different function. Motor neurons take signals from brain and spinal cord to muscles. Sensory neurons take information from senses to the brain. Interneurons communicate between motor and sensory neurons.
13. A stimulus is defined as a chemical or physical change in the environment that triggers some sort of the behavioral change in a living organism.
14. A series of action potentials sweeping down an axon is a nerve impulse. A nerve impulse is generated by the flow of ions across the cell membrane. Therefore, a nerve impulse is an electrochemical reaction.
15. A nerve impulse is an electrical signal that travels along a nerve fiber to carry information through the nervous system.
16. A nerve impulse begins when a neuron receives a chemical stimulus.
17. The impulse travels down the axon membrane as an electrical action potential.
18. The impulse reaches the axon terminal, which releases neurotransmitters that carry the impulse to the next cell.
19. The impulse travels rapidly along the axon through a process of local depolarization and repolarization.
20. The impulse is received at synapses, which are junctions between neurons.
21. At the synapse, the neurotransmitters released by the presynaptic neuron can either excite or inhibit the postsynaptic neuron.
22. The impulse is formed by voltage-gated ion channels and ion pumps, which allow certain ions to pass through the cell membrane.
23. Neurons communicate with one another at junctions called synapses.

24. Neurotransmitters are the body's chemical messengers. They carry messages from one nerve cell across a space to the next nerve, muscle or gland cell.
25. A reflex act is a simple response which involves no conscious control. The path of an impulse in a reflex act is a reflex arc. A reflex arc involves receptors, sensory neurons, association neurons, motor neurons and effectors.
26. The endocrine system is a complex network of glands and organs. It uses hormones to control and coordinate the metabolism, energy level, reproduction, growth and development, and response to injury, stress, and mood.
27. The endocrine glands are: pituitary gland, thyroid gland, parathyroid glands, pancreas, adrenal glands, and gonads.
28. Pituitary gland is a small, pea-sized gland at the base of the brain below the hypothalamus. It releases eight hormones, some of which trigger other endocrine glands to release hormones.
29. Thyroid gland is a small, butterfly-shaped gland at the front of the neck under the skin. It releases hormones that help control metabolism.
30. Parathyroid glands are four pea-sized glands that are typically behind the thyroid. They release parathyroid hormone , which controls the level of calcium in the blood.
31. Adrenal glands are small, triangle-shaped glands on top of each of the two kidneys. They release several hormones that manage bodily processes, like metabolism, blood pressure and stress response.
32. Gonads are glands that produce hormones that are involved in reproduction and other functions of the body. Those hormones include estrogen, progesterone and testosterone.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Reaction to any stimulus is called:

   A) receptor B) impulse C) responses D) effector

2. The unit of structure and function in the nervous system is:

   A) neuron B) muscle cell C) nephron D) cardiac cell

3. Thyroid gland has the ability to store:

   A) iodine B) chlorine C) fluorine D) zinc

4. Endocrine glands pour their secretion directly into:

   A) lymph B) blood C) organs D) muscles

5. Islet of Langerhans are parts of the:

   A) thyroid gland B) adrenal gland C) pancreas D) gonads

6. Nerve impulse is best described as:

   A) chemical B) electrical C) osmotic D) electrochemical

7. When a person is frightened, which substance increases the blood sugar level?

   A) adrenaline B) amylase C) glycogen D) insulin

8. Which part of the brain detects temperature changes in the blood?

A) cerebellum B) cerebral hemispheres C) hypothalamus D) medulla

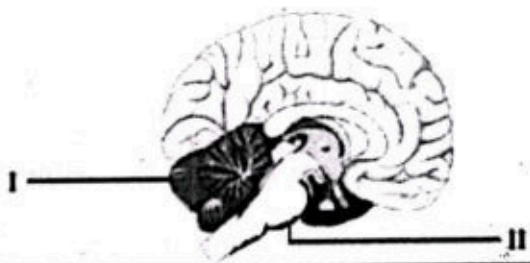
10. In contrast to nerve ls, the response produced by hormones takes longer because:

A) hormones are specific in their action.
B) hormones are transported through blood.
C) hormones are produced in small amounts.
D) the molecules of hormones are small in size.

11. Once released, neurotransmitter molecules typically produce signals in postsynaptic neurons by

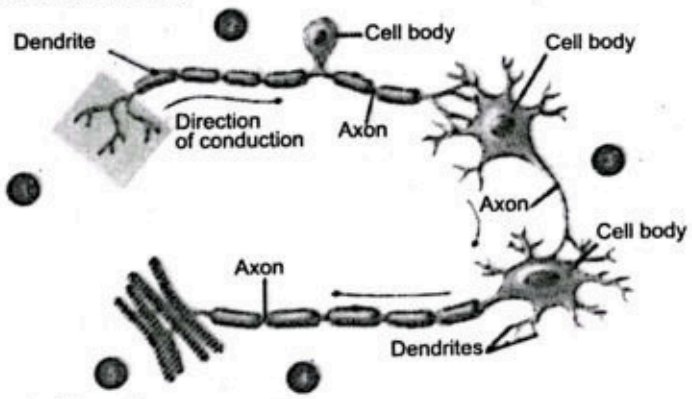
A) entering the postsynaptic neuron B) attaching to vesicles
C) binding to presynaptic receptors D) binding to postsynaptic receptors

12. The parts of brain represented by I and II are:



	I	II
A)	cerebellum	pons
B)	cerebrum	pons
C)	cerebellum	medulla oblongata
D)	cerebrum	medulla oblongata

13. The diagram shows Reflex arc.



The components of this reflex arc are:

	1	2	3	4	5
A)	Receptor	Sensory neuron	Motor neuron	Interneuron	Effector
B)	Sensory neuron	Motor neuron	Interneuron	Receptor	Effector
C)	Receptor	Effector	Sensory neuron	Interneuron	Motor neuron
D)	Receptor	Sensory neuron	Interneuron	Motor neuron	Effector

14. Four characters of a specific hormone are listed below

    i. Increased rate and intensity of heartbeat
    ii. Increased blood pressure
    iii. Decreased blood flow to skin & alimentary canal
    iv. Increased blood flow to limb

    Which is this hormone?

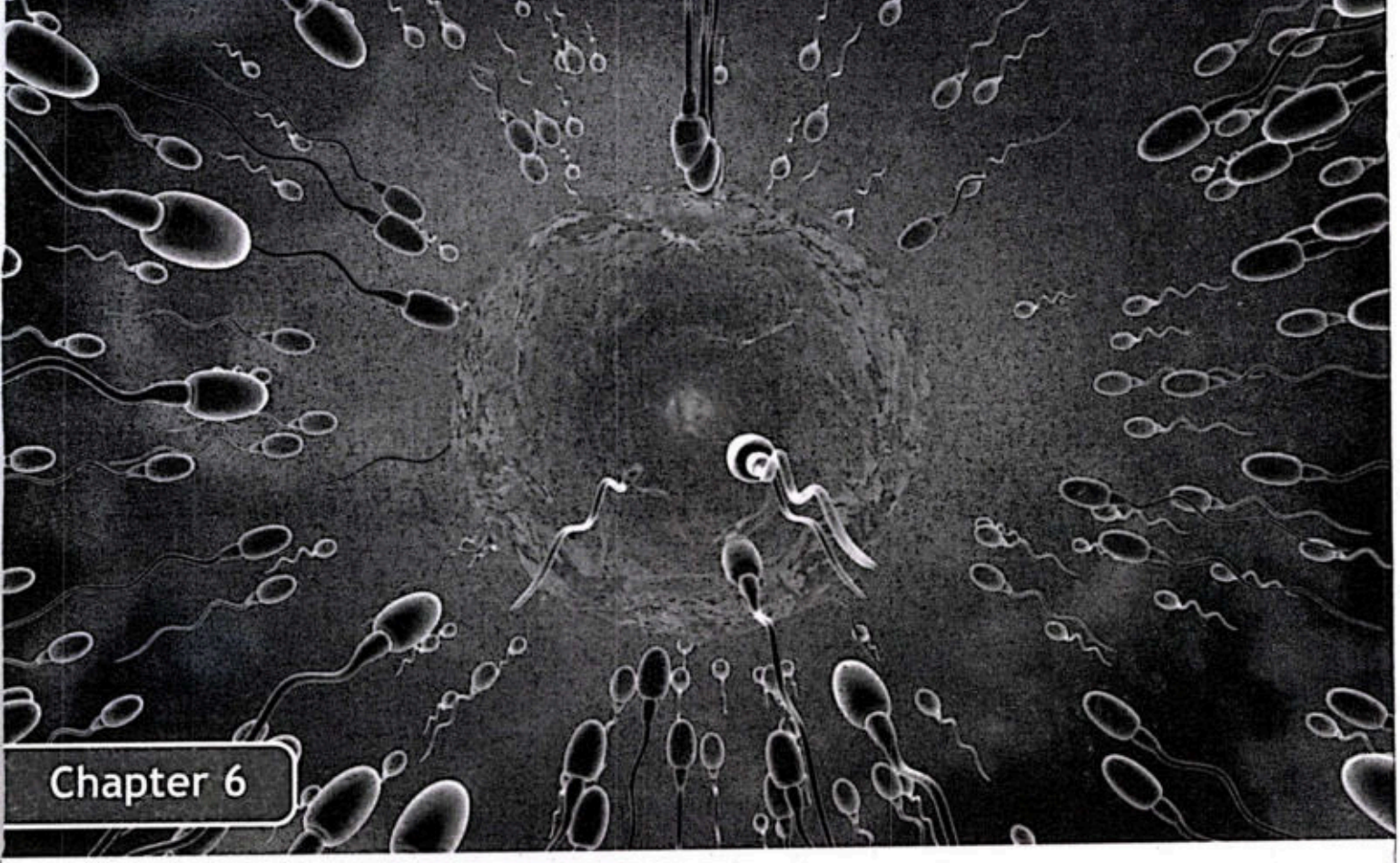
    A) adrenaline B) glucagon C) insulin D) testosterone

Section II: Short Answer Questions

1. What is nervous system?
2. What is the role of nervous system?
3. Differentiate between central nervous system and peripheral nervous system.
4. Name the parts of human brain.
5. Write two functions of cerebellum.
6. How are brain and spinal cord protected?
7. Describe peripheral nervous system.
8. What are the types of neuron? What are their functions?
9. Define stimulus with examples.
10. Define and sketch synapse.
11. How does an impulse cross a synapse?
12. What action or change do neurotransmitters transmit to the target cell?
13. What happens to neurotransmitters after they deliver their message?
14. How many different types of neurotransmitters are there?
15. What is a reflex action?
16. Name the endocrine glands of man.
17. Name the hormones secreted by each of the endocrine gland.
18. Differentiate between: cerebrum and cerebellum, sensory and motor neuron, voluntary and involuntary action, nerve impulse and hormonal transmission, endocrine glands and exocrine glands.

Section III: Extensive Answer Questions

1. Describe the nervous system and its role in human.
2. Draw a vertical section of human brain and label it. Write the functions of each part.
3. Draw, label cross section of human spinal cord and write its structure and function.
4. Outline the types of neuron with diagram.
5. Explain that nerve impulses are electrical that travel across neuron.
6. What are neurotransmitters?
7. Explain reflex action with diagram.
8. Identify the major endocrine hormones with their functions.



Chapter 6

ANIMAL REPRODUCTION

SLOs: After completing this lesson, the student will be able to:

1. [B-10-H-01] Describe the role of hormones in both male and female sexual development.
2. [B-10-H-02] Describe the process of gametogenesis and fertilization.
3. [B-10-H-03] Describe asexual reproduction and sexual reproduction mechanisms with examples (plants and animals)
4. [B-10-H-04] Describe sex determination in human

Reproduction is a biological process by which new individuals of a species are produced from existing one. Although reproduction is not required for the survival of a single living being, it is essential for the survival and continuation of a species. There are two main types of reproduction: asexual and sexual. Each type has different mechanisms and occurs in both plants and animals. In grade 9, you have learned about plant reproduction. In the current chapter, you will be able to understand fundamental concepts of animal reproduction.

6.1 ROLE OF HORMONES IN MALE AND FEMALE SEXUAL DEVELOPMENT

Unlike other organ systems, the reproductive system is unique because it becomes functional at a certain age after birth, called **puberty**. Sexual development that leads to the puberty in both males and females is controlled by some substances, called **hormones**. The hormones are chemical messengers that are produced and released by **endocrine glands** in blood. The hormones interact with their target cells due to the presence of specific receptors on the target cells.

6.1.1 Male Sexual Development

In males, the hormones responsible for sexual development and maintenance of reproductive functions are testosterone and follicle stimulating hormone (FSH).

I) Testosterone

Testosterone is mainly produced by the specific cells of testes under the influence of pituitary gland hormone. In female body, ICSH is also called luteinizing hormone (LH). **Testosterone** is very important for the development of male reproductive organs during puberty. It controls maturation of sperm and the maintenance of the male reproductive system. It stimulates the development of spermatocytes into spermatids and eventually into mature sperm. Testosterone also promotes the development of secondary sexual characteristics, such as the growth of facial hair, deepening of the voice, and increased muscle mass.

ii) Follicle stimulating hormone (FSH)

Follicle stimulating hormone (FSH) is produced by the anterior pituitary gland. It stimulates these cells to support the development of sperm cells and regulate the early stages of spermatogenesis.

Both testosterone and FSH are necessary for normal spermatogenesis, but they act at different points in the process. Testosterone promotes the final maturation of sperm and maintenance of the reproductive environment, while FSH initiates and regulates the early stages of sperm production.

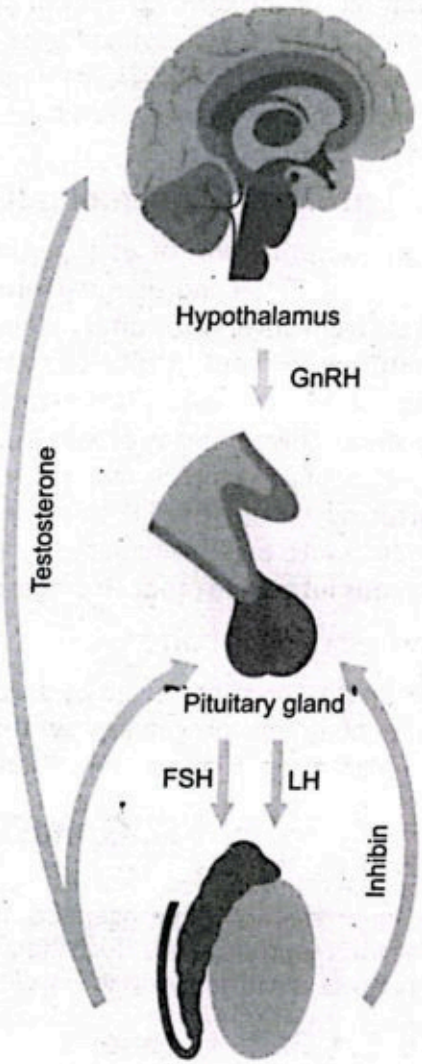


Fig. 6.1: Role of hormones in female sexual development and maintenance

6.1.2 Female Sexual Development

In females, the hormones responsible for sexual development and maintenance of reproductive functions are oestrogen (also written as estrogen), follicle stimulating hormone (FSH), luteinizing hormone (LH), and progesterone.

i) Estrogen

Estrogen is produced by the developing follicle in the ovaries under the influence of FSH. Estrogen is responsible for the development of female reproductive organs, such as the uterus, fallopian tubes, and secondary sexual characteristics during puberty.

ii) Follicle stimulating hormone (FSH)

FSH (produced by anterior pituitary gland) is essential for the development of ovarian follicles, one of these follicles undergoes oogenesis and produce ovum or egg (female gamete). It also stimulates the estrogen production and prepare the body for ovulation.

iii) Luteinizing hormone (LH)

High concentration of estrogen inhibits the FSH secretion. This condition leads to the production of LH from anterior pituitary gland. LH causes the rupturing of matured follicle in which a developing ovum is present which ultimately released in the oviduct. This rupturing of matured follicle and the release of developing ovum is called **ovulation**. After ovulation, the LH transforms the ruptured follicle into a yellow-colored glandular mass, the **corpus luteum** to produce progesterone.

iv) Progesterone

Progesterone is produced by corpus luteum in the ovary. It plays an important role in preparing the body for pregnancy by thickening the uterine lining, which is essential for embryo implantation. High concentration of progesterone also inhibits the release of FSH.

For your information

FSH and LH are collectively called gonadotropins. Anterior lobe of pituitary gland releases FSH and LH under the stimulation of gonadotropin releasing hormone (GnRH) from hypothalamus.

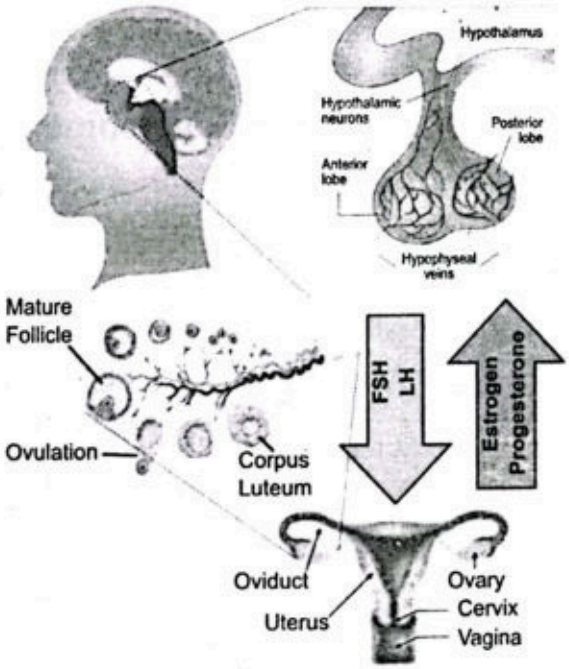


Fig. 6.2: Role of hormones in female sexual development and maintenance

6.2 GAMETOGENESIS AND FERTILIZATION

Sexual reproduction involves the steps: gametogenesis, fertilization and development of zygote. The process of gametogenesis and fertilization are closely related and form the foundation of sexual reproduction. Together, they ensure the combination of genetic material from two parents, resulting in offspring with genetic diversity.

6.2.1 Gametogenesis

Gametogenesis is the first step in the sexual reproduction in which the specialized sex cells, called **gametes**, are produced in the reproductive organs. This process involves meiosis, a type of cell division that reduces the chromosome number by half.

In males, this process is called **spermatogenesis**, where sperm cells are produced in the testes.

In females, it is called **oogenesis**, where egg cells (ova) are produced in the ovaries. Each gamete (sperm or egg) contains half the number of chromosomes (haploid) compared to somatic (body) cells. Gametogenesis ensures genetic variation through the processes of **independent assortment** and **crossing over** during meiosis.

i) Spermatogenesis

Spermatogenesis is a continuous event that starts from puberty and remains continue throughout the life simultaneously in both testes. During spermatogenesis, some cells in the walls of the **seminiferous tubules** in the testes keep dividing through mitosis to create many diploid cells called **spermatogonia**. Some of these spermatogonia develop into **primary spermatocytes**. Each primary spermatocyte undergoes the first division of meiosis (meiosis I) to produce two haploid cells known as **secondary spermatocytes**. These secondary spermatocytes then go through the second division of meiosis (meiosis II), resulting in four haploid cells called **spermatids**. Spermatids are non-motile, and they go through changes to become motile. Their nuclei shrink, and structures such as the acrosome, a tail, and a mitochondrial ring are formed. After these changes, the spermatids become **sperms**.

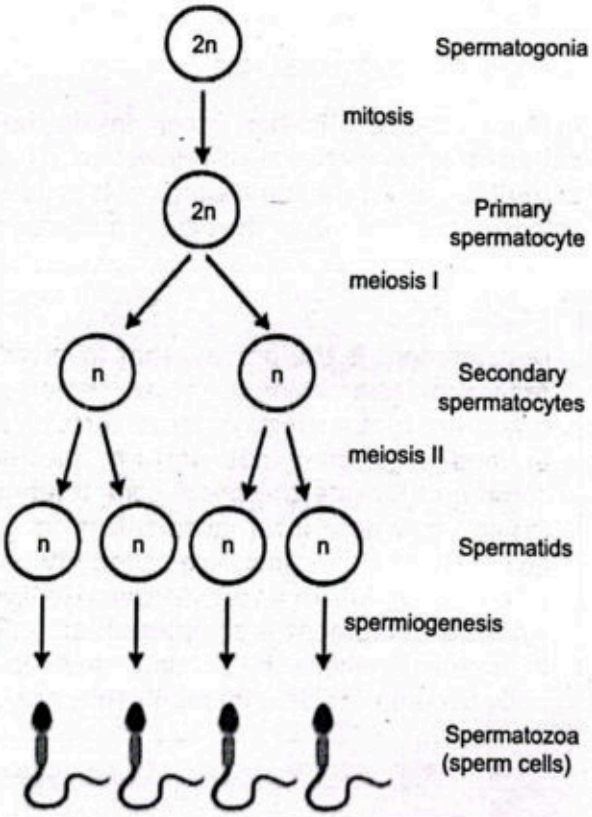


Fig. 6.3: Process of spermatogenesis

ii) Oogenesis

Oogenesis is a cyclic event that generally occurs only once in the period of one reproductive cycle. It starts before birth of an individual but arrests in prophase I. At puberty, it restarts and remain continue alternatively in both ovaries till specific age in the life. During oogenesis, some cells in the ovary form vesicular structures called **follicles**, each contains one diploid cell called **oogonium** (plural **oogonia**). Some of these **oogonia** develop into diploid **primary oocytes** which acts as egg mother cell. One primary oocyte undergoes the first stage of meiosis (meiosis I), producing two haploid cells. The smaller cell is called the **first polar body**, while the larger one is the **secondary oocyte**. The secondary oocyte then completes the second stage of meiosis (meiosis II), producing two haploid cells: the **second polar body** and an **egg cell**. In oogenesis, the meiosis II generally occurs after ovulation if the sperms are available in female reproductive tract.

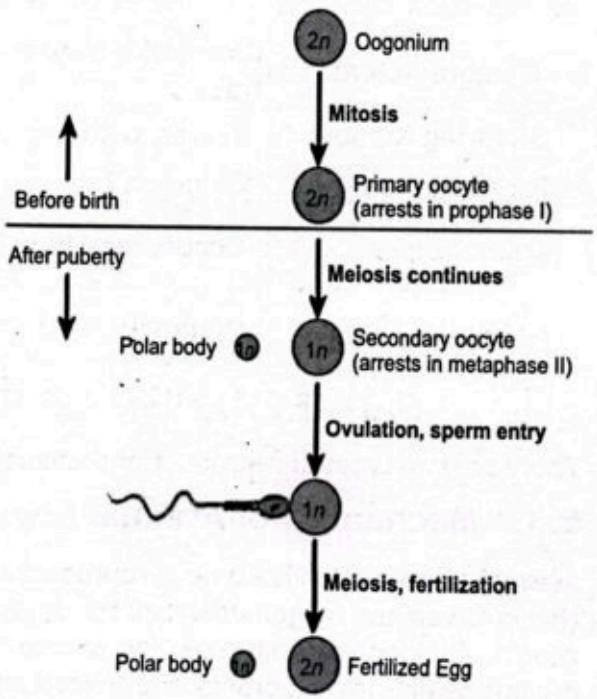


Fig. 6.4: Process of Oogenesis

6.2.2 Fertilization

Fertilization is the union of a male gamete (sperm) and a female gamete (egg) to form a zygote. It restores the diploid number of chromosomes (46 in humans), with each parent contributing half of the genetic material (23 chromosomes each).

Types of fertilization

In human the fertilization occurs inside the body of female within oviduct. Such fertilization is called **internal fertilization**. However, in most animals living in aquatic environment such as fish, amphibians etc., the female animal lays its eggs in water at suitable place. The male animal, then releases its sperms over the eggs. This fertilization is called **external fertilization**.

For your information

Development is the process that involves a series of progressive changes, transforming an organism from a simpler stage (zygote) to a more complex one (newborn). In aquatic organisms that perform external fertilization, development occurs entirely outside the body. In land organisms that perform internal fertilization, development can occur either completely inside the body, completely outside, or partially inside and partially outside. Organisms where internal fertilization leads to complete internal development, and they give birth to live young, are called **viviparous** (e.g., human, cats, dogs, whale). Organisms where, after internal fertilization, the zygote is released as a shelled egg outside the body, where development is completed, are called **oviparous** (e.g., birds, reptiles, amphibians). In organisms where the partially developed embryo is released in a shelled egg outside the body to complete development, they are known as **ovoviviparous** (e.g., sharks, rays).

Table: 6.1 Difference between internal fertilization external fertilization.

Characteristic	Internal Fertilization	External Fertilization
Fertilization Location	Inside the female body	Outside the female body
Gamete Release	Directed into female reproductive tract	Released into the environment
Offspring Number	Fewer, with higher survival rate	Many, with lower survival rate
Parental Care	Common	Rare
Animal types	Occurs mostly in land animals	Occurs mostly in aquatic animals
Examples	Mammals, birds, reptiles	Fish, amphibians, marine invertebrates

6.3 MECHANISM OF REPRODUCTION IN ANIMALS

There are two types of reproduction; asexual reproduction and sexual reproduction.

6.3.1 Mechanism of Asexual Reproduction in Animals

Asexual reproduction is a type of reproduction in which a single parent produces offspring without the involvement of gametes (sperm or egg cells). This process results in offspring that are genetically identical to the parent, known as clones. Asexual reproduction is common in simpler organisms like invertebrates and unicellular animals, but some multicellular animals can also reproduce asexually under certain conditions.

Asexual reproduction allows organisms to rapidly increase their population as there is No need for a mate, making it easier in environments where finding a partner may be difficult. However, the offspring produced by asexual reproduction lack of genetic diversity means that all offspring are clones of the parent, which may make them more susceptible to diseases or environmental changes. In animals, there are several mechanisms of asexual reproduction, which can be understood easily:

Do you know?
Compare sexual and asexual reproduction and analyze which one is advantageous for the animal?

i) Binary fission

In binary fission, the parent organism splits into two equal parts, each of which develops into a new organism. This process is usually found in protozoan (animal-like protists) like Amoeba and Paramecium, in which the nucleus of the parent cell divides (mitosis), followed by the division of the cytoplasm. This results in two daughter cells that are identical to the parent.

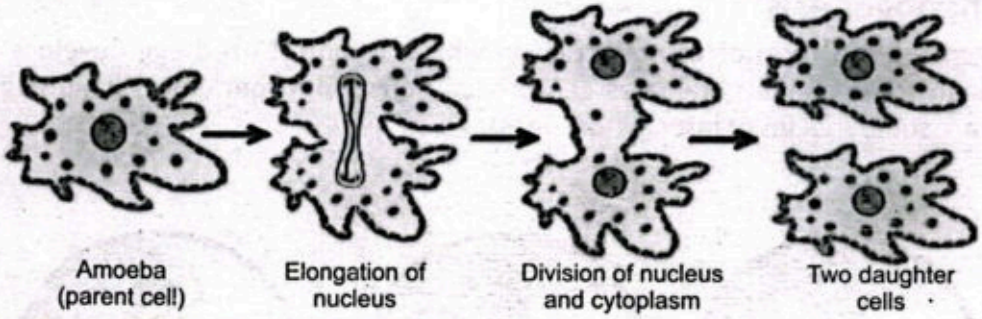


Fig. 6.5: Binary fission in Amoeba

ii) Budding

In budding, a small bud or outgrowth forms on the parent organism. This bud eventually grows and detaches to become a new individual. In this process, a group of cells divides by mitosis, forming a bud. This bud may stay attached to the parent for a while before detaching and living independently. Its best example is Hydra.

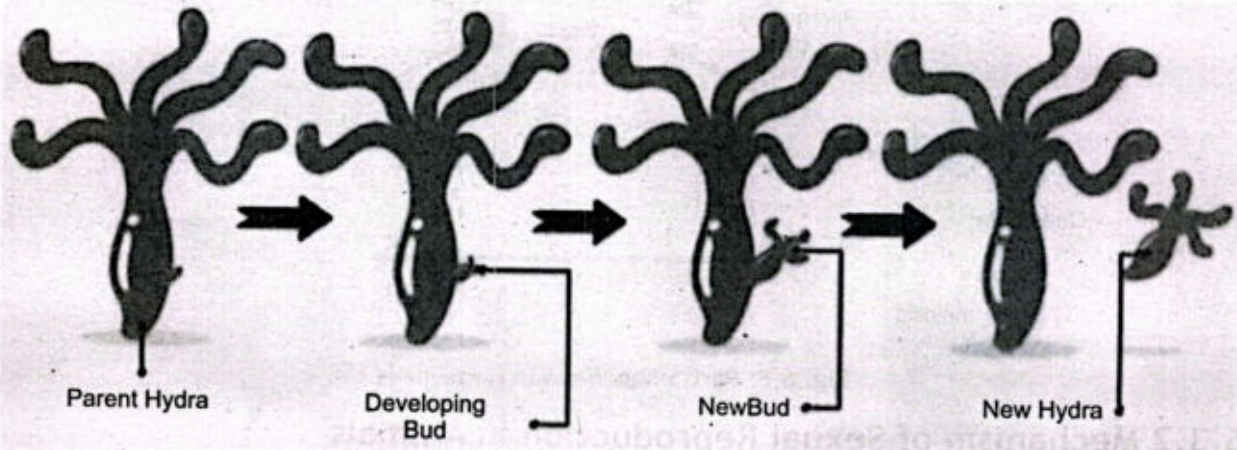


Fig. 6.6: Budding in Hydra

iii) Fragmentation and regeneration

In fragmentation, an organism breaks into two or more pieces, and each piece regenerates into a complete individual. In this process, the parent organism is split either naturally or due to

external forces. Each fragment has the ability to grow into a new organism. As it happens in planaria (a type of flatworm) and starfish that can regenerate from fragments.

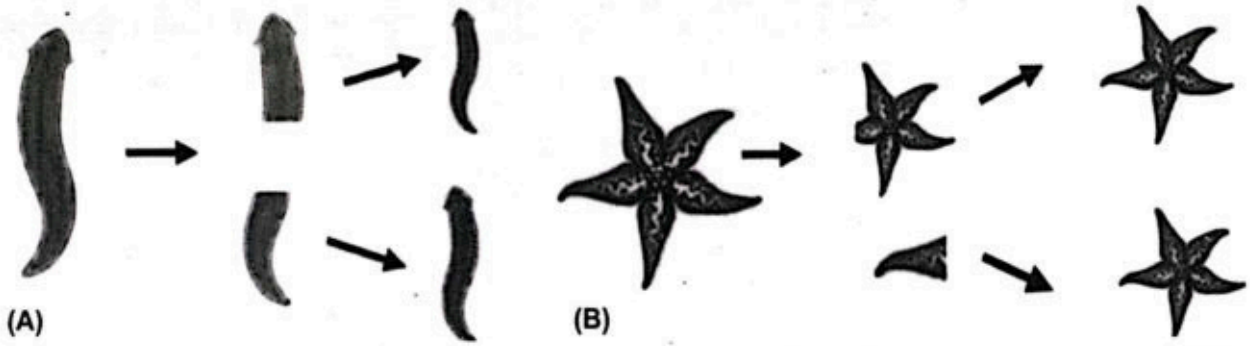


Fig. 6.7: Fragmentation and regeneration in Planaria (A) and Star fish (B)

iv) Parthenogenesis

Parthenogenesis is a form of reproduction in which an unfertilized egg develops into a new individual. In some animals, females can produce offspring from unfertilized eggs. Common examples are some species of insects (like bees).

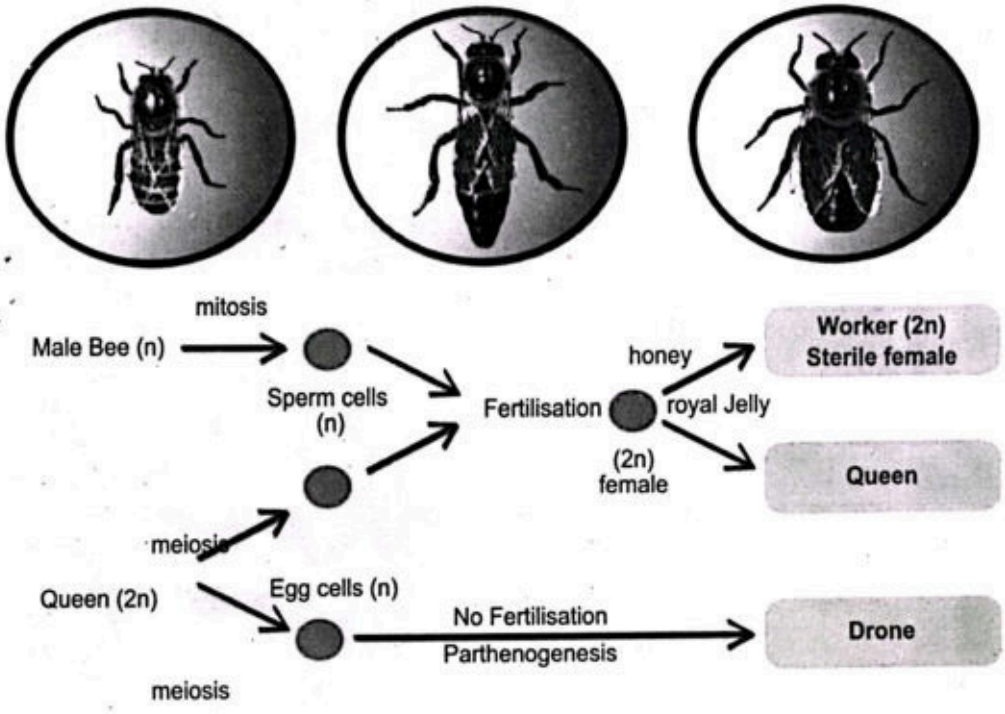


Fig. 6.8: Parthenogenesis in Honeybees

6.3.2 Mechanism of Sexual Reproduction in Animals

Sexual reproduction is the common way of reproduction in animals. Most animals are dioecious i.e., male and female reproductive organs are found in separate individuals. The mechanism of sexual reproduction in animals following three key steps: gametogenesis, fertilization and development. For the understanding of this mechanism, we will describe the reproductive systems of rabbit (a model animal used in biological research)

1. Male Reproductive System of Rabbit

The male reproductive system of a rabbit includes a pair of **testes** that produce sperm, **ducts** that transport the sperm, and glands that add fluids to the sperm. The testes are located in a pouch of skin called the scrotum, which hangs below the body. Each testis contains coiled tubes called **seminiferous tubules**, where sperm is formed. Once the sperm matures, it collects in the ducts of the testes and moves to the **epididymis**.

From the epididymis, the sperm travels through a sperm duct called the **vas deferens**. Both vas deferens join the **urethra** just below the **urinary bladder**. The urethra serves as a passage for both sperm and urine. **Semen** is the fluid that contains sperm, with about 10% sperm and 90% fluid.

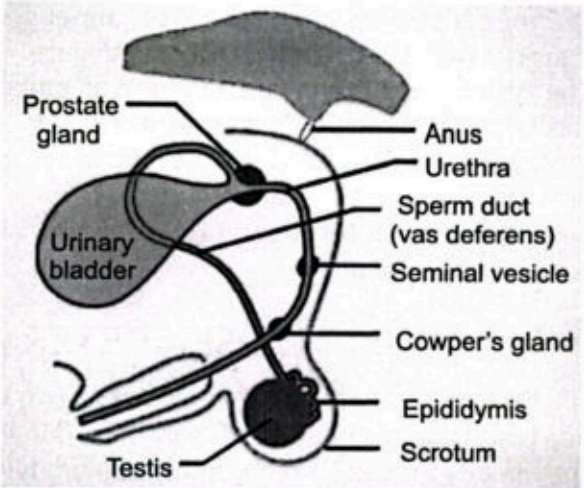


Fig. 6.9: Male reproductive system of a rabbit

As sperm moves from the testes to the urethra, different glands add fluids. **Seminal vesicles** provide nutrients for the sperm, the **prostate gland** adds a fluid that neutralizes acidity, and **Cowper's glands** produce a lubricant for the ducts.

2. Female Reproductive System of Rabbit

The female reproductive system of a rabbit includes the ovaries and associated ducts. The ovaries are small, oval-shaped organs located in the abdominal cavity, just below the kidneys. Like most animals, female rabbits have two **ovaries**. The outer part of each ovary produces egg cells. Each egg cell is surrounded and nourished by a cluster of specialized cells called a **follicle**.

When an egg cell is released from the ovary, it enters the fallopian tube, which is located close to the ovary. Fertilization happens in the fallopian tubes, and if the egg is fertilized, the resulting zygote is carried to the **uterus**. In rabbits, the uterus is divided into two sections, known as **uterine horns**, which eventually join and lead to the vagina (also known as the birth canal). The **cervix** is the part of the uterus that separates it from the birth canal, where sperm is deposited during mating.

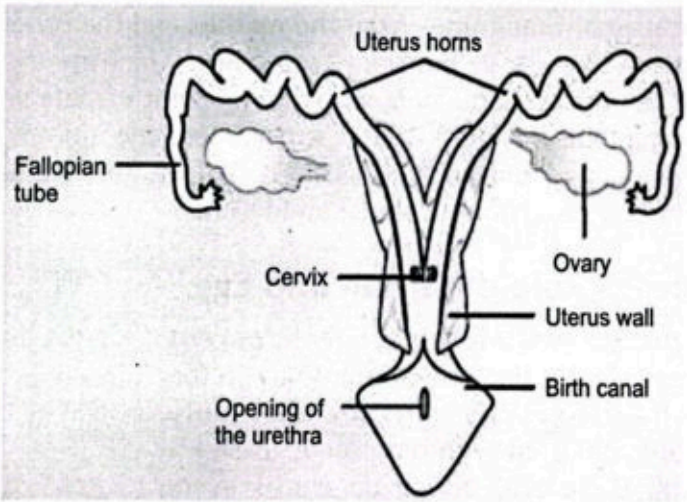


Fig. 6.10: Female reproductive system of a rabbit

3. Fertilization and Development in Rabbit

Rabbits can breed all year round, but high heat can cause a temporary reduction in sperm count and motility, leading to sterility in male rabbits during the summer. Fertilization in rabbits occurs internally after mating. During mating, the male rabbit deposits sperm into the female rabbit's vagina. The sperm swim from the vagina, through the cervix, and into the uterus. From the uterus, they move into the fallopian tubes. Female rabbits are **induced ovulators**, meaning that ovulation (the release of eggs from the ovaries) happens after mating due to stimulation. The eggs are released from the ovaries into the fallopian tubes. In the fallopian tubes, sperm meet

the egg (or eggs) that have been released from the ovaries. One sperm penetrates and fertilizes an egg, combining genetic material from both parents to form a zygote.

Do you know?
Why male rabbits become sterile in summer season?

The zygote begins to divide and form an embryo as it travels down the fallopian tube towards the uterus. Once in the uterus, the embryo implants itself into the uterine wall, where it continues to develop until birth. This process takes place relatively quickly, with **pregnancy period** of about 30-32 days in rabbits. Since the internal fertilization leads to the complete internal development, therefore, the rabbit is a **viviparous** animal.

6.4 SEX DETERMINATION IN HUMAN

Sex determination means that a newborn would be a male baby like father or female baby like the mother. The mechanism of sex determination in humans is controlled by genetic factors, specifically the sex chromosomes. Humans have two types of sex chromosomes: X and Y. The combination of these chromosomes inherited from the parents determines the biological sex of the individual.

6.4.1 Chromosomal Basis of Sex Determination

Humans have 46 chromosomes in total, arranged in 23 homologous pairs. Each homologous pair consists of two structurally similar but functionally different chromosomes. One of which is maternal that comes from the mother and the other is paternal that comes from father. Out of these 23 pairs, 22 pairs are autosomes, which are the same in both males and females, and 1 pair is sex chromosome pair, which is different in male and female individuals. As show in the human karyotype in figure 6.10. In females, the sex chromosome pair consists of two completely homologous chromosomes called XX. In males, the sex chromosome pair consists of two partially homologous chromosomes called X and Y.

6.4.2 Role of Sperm and Egg

During reproduction, each parent contributes one sex chromosome to the offspring. The mother can only contribute an X chromosome, as she is XX, therefore, during oogenesis every time the egg would take either of the X chromosome. Since mother can produce only same type of gametes, therefore, the human female is called homogametic sex.

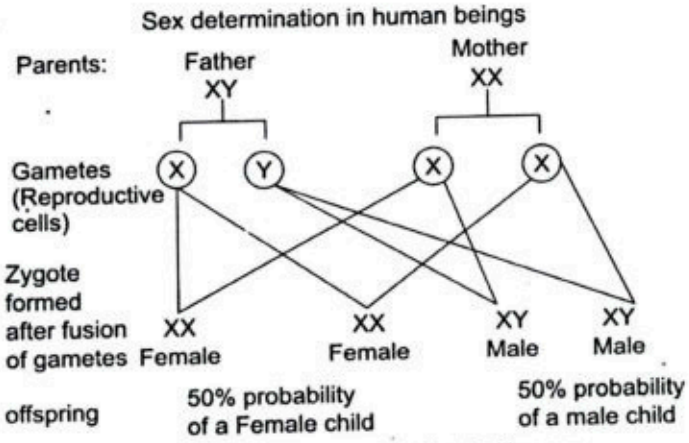


Fig. 6.11: Sex determination in Human

The father can contribute either an X or a Y chromosome as he is XY, therefore, during spermatogenesis every time the sperm would take either X chromosome or Y chromosomes. Since father can produce two different types of gametes, therefore, the human male is called **heterogametic** sex.

When male and female gametes are fused, the combination of these chromosomes determines the sex of the baby. If the baby inherits an X chromosome from the father, the combination will be XX and the baby will be female. If the baby inherits a Y chromosome from the father, the combination will be XY and the baby will be male.

6.4.3 The probability of a son or a daughter to be born

The probability (chance) for a couple to have a son or a daughter during each pregnancy is 50% means there is equal chance of a son or a daughter to be born. Since, the mechanism of sex determination in human completely depends upon the father instead of mother, therefore, the male individual is called **Sex determinator.**

SUMMARY

1. Reproduction is a biological process that allows species to produce new individuals, ensuring the survival and continuation of a species. It can occur through asexual or sexual methods. Asexual reproduction results in genetically identical offspring, while sexual reproduction involves the fusion of male and female gametes, leading to genetically diverse offspring. In sexual reproduction, hormones play a crucial role in sexual development, especially during puberty.
2. For males, testosterone and follicle-stimulating hormone (FSH) are key hormones that regulate sperm production and the development of male reproductive organs. Testosterone promotes the maturation of sperm and the development of secondary sexual characteristics, while FSH supports the early stages of sperm production.
3. In females, several hormones regulate sexual development and reproductive functions, including estrogen, FSH, luteinizing hormone (LH), and progesterone. Estrogen is crucial for the development of female reproductive organs and secondary sexual characteristics. FSH stimulates ovarian follicle development and estrogen production. LH triggers ovulation, and progesterone prepares the body for pregnancy by thickening the uterine lining.
4. Gametogenesis is the process of producing gametes (sperm in males and eggs in females) through meiosis, ensuring genetic diversity. Fertilization, the union of sperm and egg, restores the diploid number of chromosomes and results in the formation of a zygote, which develops into a new organism.
5. In animals, reproduction can be either sexual or asexual. Sexual reproduction involves gametogenesis, fertilization, and development, while asexual reproduction occurs through mechanisms like binary fission, budding, fragmentation, and parthenogenesis.
6. The reproductive systems of animals like rabbits involve specialized organs and processes to facilitate fertilization and development.
7. Sex determination in humans is based on the combination of sex chromosomes (XX for females and XY for males) inherited from the parents. The Y chromosome, specifically the SRY gene, triggers the development of male reproductive organs. The probability of having a son or daughter is equal (50%).

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

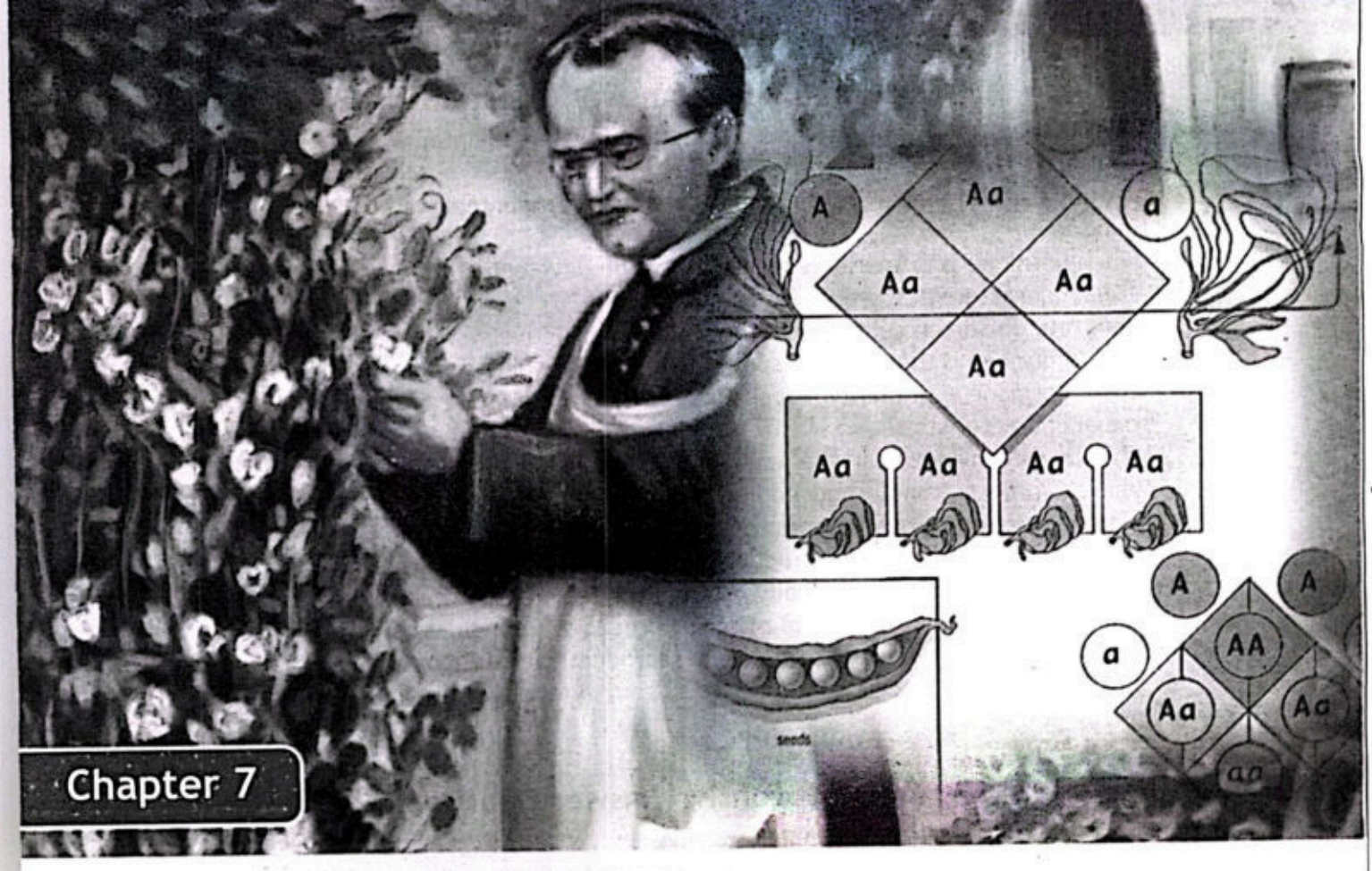
1. What marks the functional beginning of the reproductive system?
   A) Birth B) Puberty C) Childhood D) Adulthood
2. What is the primary function of reproduction in living organisms?
   A) Survival of an individual B) Survival and continuation of a species
   C) Growth and development of organs D) Production of hormones
3. Which hormone is primarily responsible for male sexual development?
   A) Estrogen B) Testosterone C) Progesterone D) Luteinizing hormone (LH)
4. In males, testosterone is produced by which cells?
   A) Sertoli cells B) Interstitial (Leydig) cells C) Follicular cells D) Endocrine cells
5. What triggers the release of luteinizing hormone (LH) in females?
   A) Low levels of estrogen B) High levels of estrogen C) Ovulation D) Menstruation
6. In which part of the male reproductive system does spermatogenesis occur?
   A) Epididymis B) Vas deferens C) Seminiferous tubules D) Prostate gland
7. What is the first step in sexual reproduction?
   A) Fertilization B) Development C) Gametogenesis D) Ovulation
8. Where does fertilization occur in humans?
   A) Uterus B) Fallopian tubes C) Ovaries D) Vagina
9. Which of the following organisms is viviparous?
   A) Fish B) Birds C) Humans D) Reptiles
10. Which asexual reproduction method involves an organism splitting into two equal parts?
    A) Budding B) Binary fission C) Parthenogenesis D) Fragmentation
11. In sex determination in humans, what combination of sex chromosomes results in a female?
    A) XY B) XX C) X D) YY
12. Which gene on the Y chromosome triggers the development of male characteristics?
    A) SRY gene B) LH gene C) FSH gene D) Estrogen gene
13. What is the probability of a couple having a son during each pregnancy?
    A) 25% B) 50% C) 75% D) 100%
14. Which of the following is true about asexual reproduction?
    A) It requires two parents. B) It leads to genetic diversity.
    C) It produces clones. D) It involves the fusion of gametes.
15. What is the role of the scrotum in the male reproductive system of a rabbit?
    A) Producing sperm B) Transporting sperm
    C) Adding fluids to sperm D) Housing the testes

Section II: Short Answer Questions

1. What is the primary purpose of reproduction in living organisms?
2. What are the two main types of reproduction?
3. At what stage of human development does the reproductive system become functional?
4. Which hormone is primarily responsible for the development of male secondary sexual characteristics?
5. What role do Sertoli cells play in the male reproductive system?
6. Which hormone is essential for spermatogenesis and acts on Sertoli cells?
7. Which hormone is primarily responsible for the development of female secondary sexual characteristics?
8. What triggers ovulation in the female reproductive cycle?
9. Where is progesterone produced in the female reproductive system after ovulation?
10. What is the term for the process of sperm cell production?
11. In which part of the male reproductive system does spermatogenesis occur?
12. Where does fertilization typically occur in the female reproductive system?
13. What is the genetic outcome of offspring produced through asexual reproduction?
14. What role does the scrotum play in the reproductive system of a male rabbit?
15. Which part of the female reproductive system in rabbits is the typical site for fertilization?

Section III: Extensive Answer Questions

1. Explain the role of hormones in male sexual development, detailing the specific functions of testosterone and follicle-stimulating hormone (FSH). How do these hormones interact to regulate spermatogenesis?
2. Compare and contrast the processes of spermatogenesis and oogenesis.
3. Discuss the process of fertilization in humans, explaining the significance of internal versus external fertilization. How does fertilization restore the diploid chromosome number?
4. Outline the key steps involved in sexual reproduction, using the rabbit as an example to describe the male and female reproductive systems, fertilization, and subsequent development.
5. Describe the mechanisms of asexual reproduction in animals. Provide examples of binary fission, budding, fragmentation, regeneration, and parthenogenesis, explaining how each process contributes to the reproduction of organisms.
6. Explain the process of sex determination in humans. What is the chromosomal basis for determining the sex of an individual, and how do sperm and eggs contribute to this process? Discuss the role of the SRY gene in the development of male sex organs.
7. Discuss the differences between viviparous, oviparous, and ovoviviparous animals. Provide examples of each and explain how their reproductive strategies are adapted to their environments.
8. Explain the significance of gametogenesis in sexual reproduction. How does meiosis contribute to genetic variation in offspring, and why is this variation important for the survival and evolution of species?



Chapter 7

INHERITANCE

SLOs: After completing this lesson, the student will be able to:

1. [B-10-H-05] Sketch the structure of chromosomes.
2. [B-10-H-06] Define genotype and phenotype, allele homozygous, heterozygous, dominant, recessive
3. [B-10-H-07] Illustrate Mendelian inheritance laws through monohybrid and dihybrid cross.

Inheritance is the process by which traits are passed from parents to offspring. These traits may base on the similarities between parent and their offspring (**heredity**) or difference between them (**variation**). The study of heredity and variation is called **genetics**. Gregor Mendel's pioneering work with pea plants established key principles of inheritance, now known as **Mendelian genetics**. He identified that traits are controlled by genes, which can be dominant or recessive, and are inherited in predictable patterns. This chapter will explore how traits are passed through generations, the role of chromosomes, and Mendel's laws of inheritance, providing insight into the genetic mechanisms that drive biological diversity.

7.1 STRUCTURE OF CHROMOSOME

Chromosomes are thread-like structures found in the nucleus of cells, made up of DNA (Deoxyribonucleic Acid) and proteins. During interphase, the chromosomes are present in the form of a thin fibrous network called **chromatin**. The DNA in chromosomes carries the genetic information necessary for the development, functioning, and reproduction of organisms.

7.1.1 Parts of a chromosomes

A chromosome consists of three main parts: chromatids, centromere and telomeres.

i) Chromatid: A single chromosome, before S-phase (DNA replication), consists of one thread-like structure called chromatid. After S-phase, a chromosome consists of two identical chromatids called sister chromatids that are attached together at centromere. These chromatids are the duplicated copies of the chromosome.

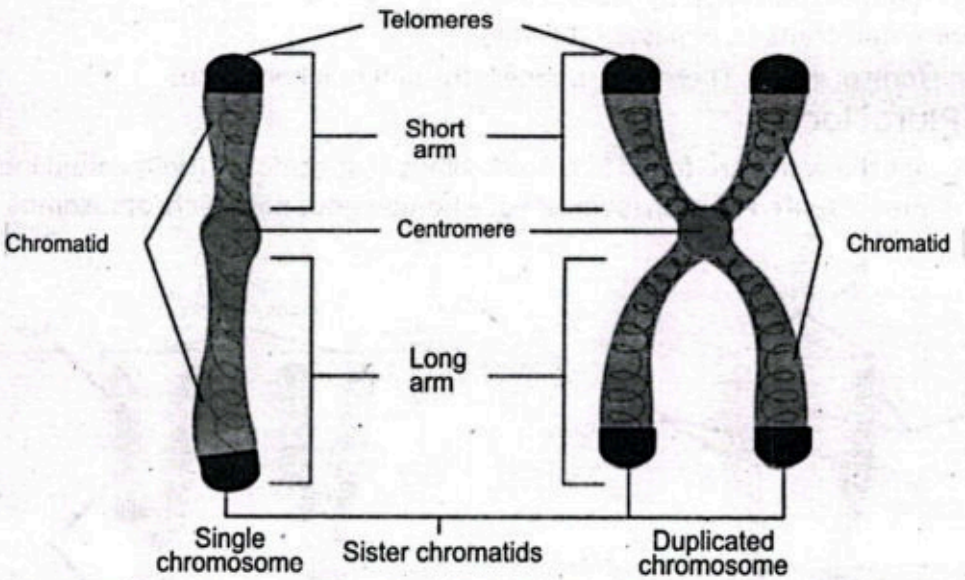


Fig. 7.1: Parts of a chromosome

ii) Centromere: The centromere is the constricted region of a chromosome where the two chromatids are attached. The kinetochore is a protein complex in the centromere which serves as the attachment site for spindle fibers (microtubules) during mitosis and meiosis. The centromeres ensure that chromosomes are evenly distributed between the daughter cells.

iii) Telomeres: These are repetitive nucleotide sequences at the ends of chromosomes, protecting them from degradation and preventing the loss of important genetic information during cell division.

7.2 GENOTYPES AND PHENOTYPES

A discussion of Mendelian genetics usually requires an understanding of some basic genetic terms, such as gene, allele, genotype (homozygous or heterozygous), phenotype (dominant or recessive), genome, and gene pool. These terms help explain how traits are inherited and expressed in living organisms.

7.2.1 Genes, Alleles and Loci

i) Genes

Each characteristic and function of the body is controlled by factor called gene. The parental traits are passed to their offspring in the form of genes. Therefore, a gene is the unit of inheritance. Basically, **a gene is a specific segment of DNA, comprising a unique sequence of nucleotides that encodes the sequence of amino acid in a particular polypeptide.** Mendel was the first person who proposed the idea of gene, he called them "factors" or "elementens" and used to represent the genes of different characteristics with alphabetical symbols. Each characteristic and function of the body is controlled by factor called gene. The parental traits are passed to their offspring in the form of genes. Therefore, a gene is the unit of inheritance.

For your information

The complete set of an individual's genes is called the **genome.** The number of chromosomes that carry the entire genome is referred to as a **set of chromosomes,** represented by "n" or **monoploid.** A cell with two sets of chromosomes is called **diploid** or 2n. In humans, the full genome is spread across 23 chromosomes, which make up one set. The term haploid is used to represent a cell that contains half than the number of chromosomes of somatic cells (body cells other than gametes).

ii) Locus (Plural loci)

Now we know that the genes are found in chromosomes at specific positions called loci (**singular locus**). A locus is represented on both members of a **homologous pair of chromosomes**

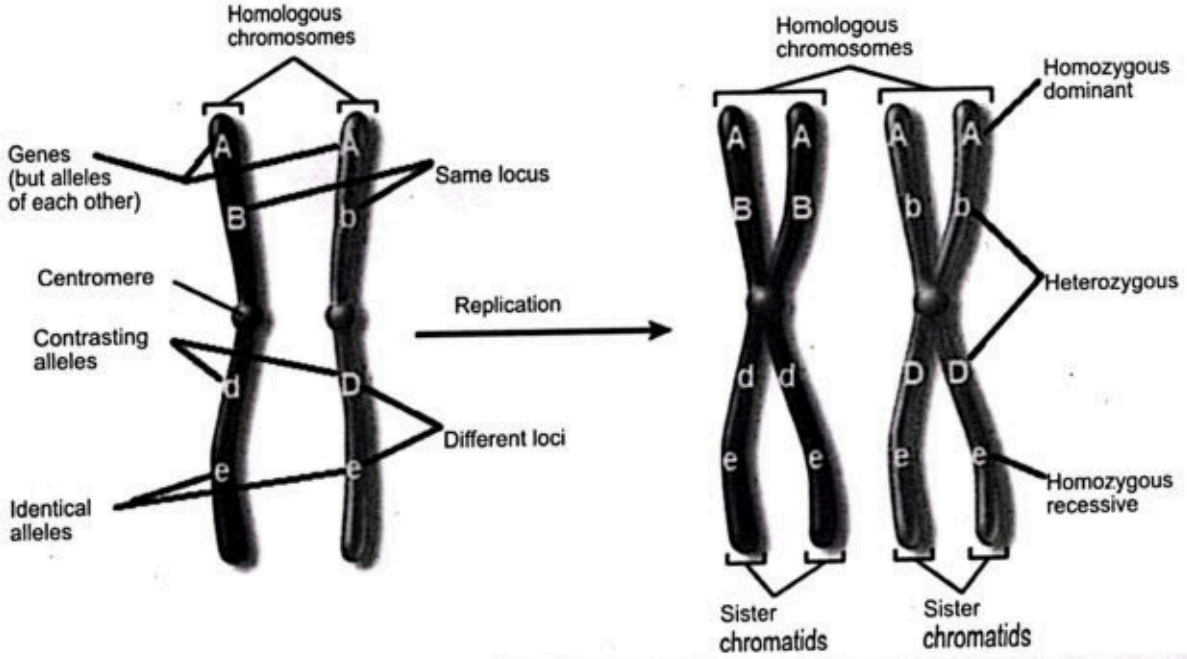


Fig. 7.2: Arrangement of genes in homologous chromosomes

iii) Allele

At each locus on a chromosome, a gene can exist in two or more forms. These different forms or variations of a gene are called **alleles**. Alleles are versions of the same gene that occupy the same position on a chromosome. For example, in humans, earlobes can either be free or attached. The gene for free earlobes is represented by "**E**" and the gene for attached earlobes is "**e**". Both "E" and "e" are located at the same locus and are alleles of each other. Although "E" and "e" are different alleles, they are both considered genes as well.

7.2.2 Genotype and Phenotypes

i) Genotype

The genetic makeup of a trait at each locus is called the **genotype**. A genotype usually consists of a pair of genes or alleles. For example, the genotype for free earlobes can be represented as "**EE**" or "**Ee**," while the genotype for attached earlobes is "**ee**." If the genotype has two identical alleles (like "**EE**" or "**ee**"), it is called **homozygous**. If it has two different alleles (like "**Ee**"), it is called **heterozygous**. An individual with a homozygous genotype is considered a "**true breed**," as it always produces offspring with the same trait when self-fertilized. In contrast, a heterozygous individual is "**non-true breed**" because it can produce offspring with either form of the trait when self-fertilized. For example, a true bree round seeded pea plant (RR) always produces round seeded offspring upon self-fertilization. Similarly, a non-true breed round seeded plant (Rr) can produce both round seeded and wrinkled seeded plants upon self-fertilization.

For your information

Self-fertilization is a type of reproduction where an organism's own sperm fertilizes its own eggs. This process commonly occurs in plants and some hermaphroditic animals. In self-fertilization, the offspring usually inherit genes from a single parent, leading to less genetic variation compared to cross-fertilization.

ii) Phenotype

The physical appearance of a trait is called the phenotype, which is determined by the genotype. For example, when "**EE**" or "**Ee**" genotypes are expressed, they produce free ear lobes and when "**ee**" is expressed, it produces attached earlobe. A phenotype that is visible even in the heterozygous state is called a **dominant phenotype**, while a phenotype that only appears in the homozygous state is called a **recessive phenotype**. The gene for a dominant phenotype is usually represented by a **capital letter**, while the gene for a recessive phenotype is represented by a **lowercase letter**.

For your information

A **gene pool** is the complete set of all the genes and their different alleles on specific locus present in all the individuals of a population. For example. Total number of earlobe genes or alleles ("**E**" and "**e**") in a population of 500 individuals, is the gene pool of earlobe. **Gene frequency**, also known as **allele frequency**, refers to how often a particular allele appears in the gene pool. For example, total number of free earlobe genes (E) in the population is the **dominant gene frequency** and total number of attached earlobe genes (e) in the population is the **recessive gene frequency**. These frequencies reflect the genetic diversity of a population and can change over time due to factors like natural selection or mutation.

7.3 MENDELIAN INHERITANCE

The field of genetics began in 1900 with the rediscovery of a paper published in 1866 by **Gregor Johann Mendel**, an Augustinian monk. Mendel was the first person who successfully explained *mode of* inheritance of traits from one generation to the next through his experiments on pea plants. The mode of inheritance according to the principle proposed by Mendel is kanown as **Mendelian inheritance.** Mendel's work laid the foundation for the science of inheritance, which is why he has been titled as the **"Father of Genetics".**

First, he developed **true-breeding plants,** which consistently produced offspring with the same traits after self-fertilization. This was achieved by repeated self-fertilization over successive generations. Mendel worked with seven pairs of contrasting traits, creating true-breeding plants for each.

Mendelian Traits in Pea plant

	Seed Shape	Seed Color	Pod/fruit shape	Pod/fruit color	Flower color	Flower position	Stem Length
Dominant	 Round	 Yellow	 Inflated	 Green	 Purple	 Axial	 Tall
Recessive	 Wrinkled	 Green	 Constricted	 Yellow	 White	 Terminal	 Short

Fig. 7.3: Seven pairs of contrasting traits of pea plant studied by Mendel

Mendel then carried out **hybridization,** where he cross-fertilized plants with different traits. For example, he crossed a round-seed plant with a wrinkled-seed plant to study a single trait (monohybrid cross) and a round, yellow-seed plant with a wrinkled, green-seed plant to study two traits (dihybrid cross).

A **monohybrid cross** involves parents differing in one trait, while a **dihybrid cross** involves parents differing in two traits. Mendel ensured specific matings of different pea plants by removing the stamen of one plant and transferring pollen using a paintbrush.

By analyzing the inheritance of one, two, or three traits at a time, Mendel formulated what are now known as **Mendel's laws of inheritance.**

7.3.1 Inheritance of Single Trait by Monohybrid Cross

Mendel's study of inheritance for a single trait, known as a monohybrid cross, involved crossing two plants that differed in one trait, such as seed shape.

Mendel's Procedure and observations

He crossed a true-breeding round-seed plant with a true-breeding wrinkled-seed plant. In the first filial generation (F_1), all offspring displayed the round seed trait (he designated this phenotype as dominant while other as recessive). However, when these F_1 plants self-fertilized, their offspring (F_2) exhibited both round and wrinkled seeds in a 3:1 ratio. Further investigation revealed that 25% F_2 generation were true breed round, 50% were non-true breed round and 25% were true breed wrinkled. So the genotypic ratio in F_2 generation was 1:2:1. Similar results were obtained when he studied other pairs of contrasting traits.

Conclusion/Interpretation of the results

Mendel concluded that:

(i) The traits are controlled by factors or elementens (now called genes) passed from parents to offspring through gametes.

(ii) Each plant carries two factors (alleles) for each trait—one from each parent.

(iii) Dominant alleles, like "R" for round seeds, are expressed, while recessive alleles, like "r" for wrinkled seeds, are not expressed in F_1 but reappear in F_2 generation.

(iv) During gamete formation both alleles of a gene pair segregate from each other and pass into different gamete.

(v) The gene pair is restored when gametes are fertilized to make the next generation.

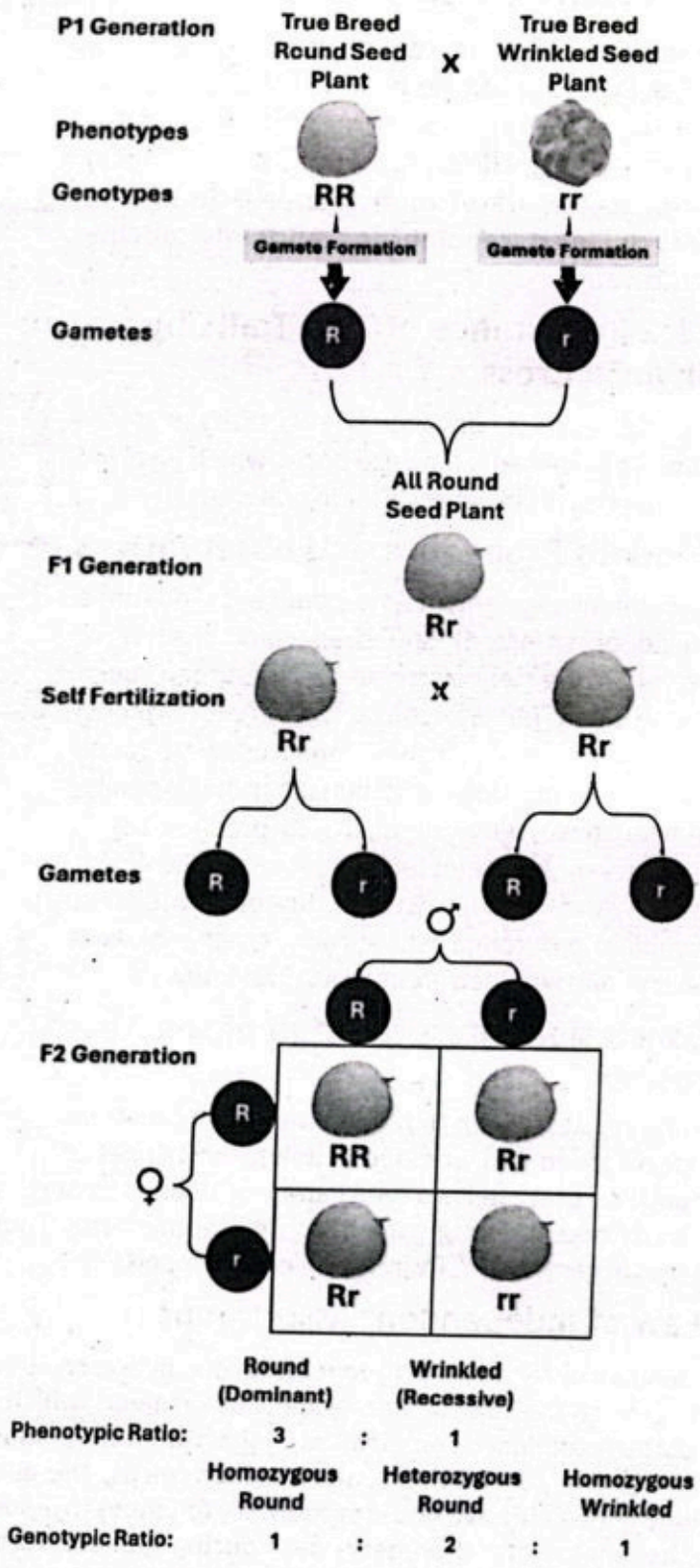


Fig. 7.4: Outcome of F1 and F2 Generation in Monohybrid cross

Law of segregation

Mendel's analysis in monohybrid cross while studying the inheritance of single trait led to the formulation of the law of segregation which states that **co-existing alleles (occupy the same locus) segregate (separate) during gamete formation (Meiosis) and recombine randomly during fertilization.**

7.3.2 Inheritance of Two Traits by Dihybrid Cross

In studying the inheritance of two traits at once, Mendel performed a dihybrid cross, which involves crossing individuals that differ in two traits.

Mendel's Procedure and observations

In one of his experiments, he examined seed shape (round or wrinkled) and seed color (yellow or green). When Mendel crossed a true breed round yellow plant (RRYY) with a true breed wrinkled green plant (rryy), all the F_1 offspring were round and yellow, showing the dominant traits. When he self-fertilized these F1 plants to produce the F_2 generation, he expected a 3:1 ratio like in his monohybrid cross. Instead, he observed four combinations: round yellow, round green, wrinkled yellow, and wrinkled green in a 9:3:3:1 ratio.

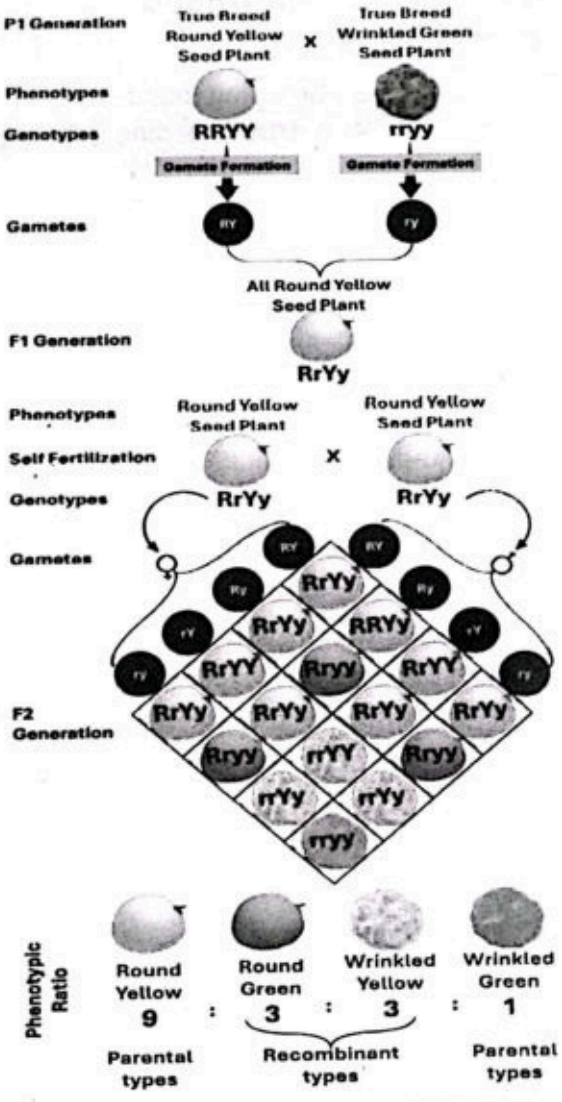


Fig. 7.5: Outcome of F1 and F2 Generation in Dihybrid cross

Conclusion/Interpretation of the results

This result, which included new combinations (round green and wrinkled yellow), led Mendel to conclude that alleles of one gene pair (R and r) assort independently to the alleles of other gene pair (Y and y) during gamete formation (meiosis). Therefore, the F1 individuals produced four kinds of gamete (RY, Ry, rY, ry) in equal proportions.

Law of Independent Assortment

Mendel's observation in F_2 generation of dihybrid cross became known as the law of independent assortment, which states that **the alleles for one trait are inherited independently of the alleles for another trait. In other words, the alleles of one gene pair have equal probability (chance) to assort with the alleles of other gene pair during gamete formation (meiosis).** However, in case of linked genes (whose loci are present on the same chromosome), the independent assortment of alleles is conditional to the occurrence of crossing over between those two kinked genes during meiosis.

Do you know?

Mendel performed test crosses to confirm the genotype of his F_1 plants and to validate his ideas about how traits are inherited. This helped him conclude whether the traits were homozygous or heterozygous, thus supporting his laws of segregation and independent assortment.

STEAM ACTIVITY 7.1 EXPLORING MENDEL'S LAWS THROUGH A GENETIC SIMULATION

Objective

To understand and apply Mendel's **Law of Segregation** and **Law of Independent Assortment** using a hands-on simulation with colored beads.

Materials Needed

- Two sets of colored beads (e.g., red and blue for one gene, yellow and green for another gene)
- Two small bowls or cups labeled Parent 1 and Parent 2
- A dice or coin (optional for independent assortment simulation)
- A data sheet for recording results
- Ziploc bags for storing beads
- Chart paper and markers (for visualizing results)
- Calculator (optional, for calculating probabilities)

Procedure

PART 1: LAW OF SEGREGATION

1. Setup

Assign colors to represent alleles for a single trait (e.g., **R = Red, r = Blue**). Alternatively, you can use circular plastic or cardboard discs and write gene symbols on them. Each parent (bowl) contains two alleles for the trait (e.g., Rr = one red bead and one blue bead or two cardboard discs labelled with gene symbols).

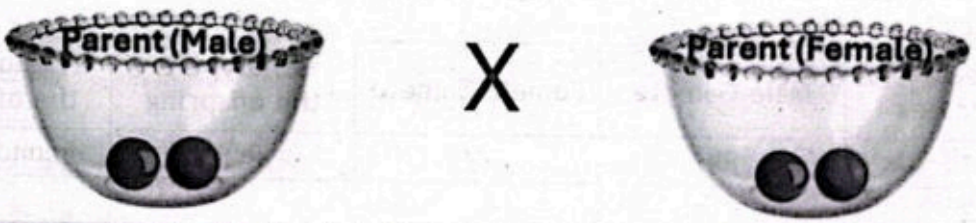


Fig. 7.6: Monohybrid cross (Inheritance of seed shape)

2. Simulation

Students randomly draw one bead from each parent to simulate gamete formation. Combine the beads from both parents to form an offspring genotype (e.g., RR, Rr, or rr).

3. Repeat/ replication

Perform the draw 50 times to simulate multiple offspring. Record the genotypes and phenotypes on a data sheet (sample is given below).

Repeats / Replicates	Male Gamete	Female Gamete	Genotype of the offspring	Phenotype of the offspring
1	R	r	Rr	Round
2				
3				
And so, on up to 50				

4. Analysis
Tally the frequency of each genotype and phenotype. Compare the results to the expected 1:2:1 genotypic ratio and 3:1 phenotypic ratio.

PART 2: LAW OF INDEPENDENT ASSORTMENT

1. Setup
Add another trait to the simulation. Assign yellow and green beads to represent another gene (**Y = Yellow, y = Green**). Alternatively, you can use circular plastic or cardboard discs and write gene symbols on them. Each parent now contains four beads (e.g., RrYy = one red, one blue, one yellow, one green or four plastic or four cardboard discs labelled with gene symbols).

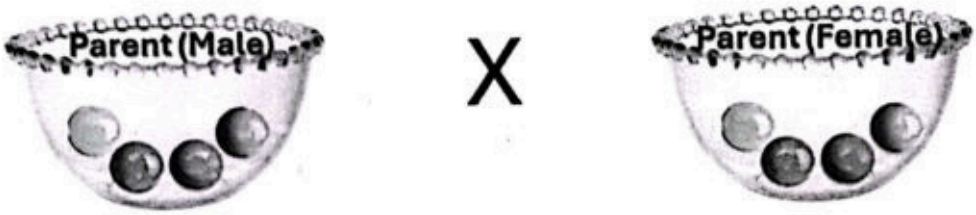


Fig. 7.7: Dihybrid cross (Inheritance of seed shape and seed color)

2. Simulation
Students randomly draw one bead for each gene (one for R/r and one for Y/y) from each parent. Combine the beads to determine the offspring's genotype (e.g., RrYy, rrYy, etc.).

3. Repeat/ Replicates
Conduct 50 trials and record the offspring genotypes and phenotypes in datasheet (sample is given below).

Repeats / Replicates	Male Gamete	Female Gamete	Genotype of the offspring	Phenotype of the offspring
1	RY	ry	RrYy	Round Yellow
2				
3				
And so, on up to 50				

4. Analysis
Tally the frequency of each genotype (e.g., RrYy, RRyy, etc.). Verify the 9:3:3:1 phenotypic ratio for dihybrid crosses.

Integration of STEAM

- Science involves understanding of Mendel's principles of heredity and exploring genetic variation and probability.
- Technology involves the use of spreadsheet software (e.g., Excel) to tabulate and analysis of data.
- Engineering involves the designing an efficient way to simulate large sample sizes using beads and tools.
- Art involves the creation of visual Punnett squares and frequency graphs to illustrate results.
- Mathematics involves the calculation of observed ratios and comparing them with theoretical ratios. It also involves the use of percentages and probabilities for analysis.

Follow-Up Discussion Questions

1. How do your results compare to the expected ratios? Were there any deviations? Why might that occur?
2. How does the random drawing of beads mimic Mendel's experiments with pea plants?
3. Why is it important to have a large sample size in genetic studies?
4. How can the laws of segregation and independent assortment explain genetic variation in offspring?

SUMMARY

1. Inheritance is the process through which traits are passed from parents to offspring, involving heredity (similarities) and variation (differences). The study of inheritance, or genetics, was pioneered by Gregor Mendel, whose experiments with pea plants laid the foundation for modern genetics. Mendel discovered that traits are controlled by genes, which can be dominant or recessive, and are inherited in predictable patterns across generations.
2. Chromosomes are thread-like structures in the cell nucleus made of DNA and proteins. They contain genetic information essential for development and reproduction. Each chromosome consists of chromatids, a centromere (the point where chromatids are joined), and telomeres (protective ends). DNA is coiled around histone proteins to form chromatin, which condenses during cell division to create chromosomes.
3. Chromosomes carry genes that direct the production of proteins, which determine traits and carry out essential cellular functions. The DNA in chromosomes is transcribed into mRNA, which is then translated into proteins. These proteins serve various functions, such as acting as enzymes, hormones, or structural components of the body.
4. A genotype refers to the genetic makeup of an organism, including the alleles inherited from both parents. Alleles are variations of a gene located at specific positions (loci) on chromosomes. A phenotype is the physical expression of a trait, determined by the genotype. Dominant traits are expressed even if only one dominant allele is present, while recessive traits require two recessive alleles to be expressed.
5. Mendel's experiments revealed that traits are passed from one generation to the next through predictable patterns. His Law of Segregation states that alleles for a trait separate during gamete formation, ensuring offspring inherit one allele from each parent. His Law of Independent Assortment states that alleles for different traits are inherited independently of one another, explaining genetic variation in offspring.
6. Mendel used test crosses to determine the genotype of individuals expressing dominant traits by crossing them with recessive individuals. This allowed him to distinguish between homozygous and heterozygous individuals. His experiments confirmed his laws of segregation and independent assortment.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Which of the following terms refers to the similarities between parents and their offspring?

   A) Variation B) Evolution C) Heredity D) Mutation

2. Which part of the chromosome is responsible for protecting it from degradation?
   A) Centromere B) Telomere C) Chromatid D) Histone
3. What does each nucleosome consist of?
   A) RNA molecules
   B) DNA wrapped around eight histone proteins
   C) Chromatids and centromeres
   D) Telomeres and kinetochores
4. What is the function of chromosomes in protein synthesis?
   A) They produce energy for cells
   B) They protect the cell from external damage
   C) They carry genes that encode proteins
   D) They replicate during cell division
5. Which of the following best defines a gene?
   A) A segment of RNA that produces proteins
   B) A sequence of amino acids
   C) A unit of inheritance found in DNA
   D) A type of chromosome
6. Alleles are:
   A) Different forms of a gene located at the same locus
   B) Different species of organisms
   C) Mutated chromosomes
   D) Copies of RNA molecules
7. What is a genotype?
   A) The visible traits of an organism
   B) The genetic makeup of an organism
   C) The protein synthesis process in an organism
   D) The evolutionary history of a species
8. In Mendelian genetics, a dominant allele:
   A) Is always expressed when present
   B) Is never expressed
   C) Is only expressed in the presence of a recessive allele
   D) Is the same as a recessive allele
9. Mendel's conclusion that each parent contributes one factor (allele) for each trait is known as:
   A) Law of Mutation
   B) Law of Independent Assortment
   C) Law of Segregation
   D) Law of Evolution
10. In a dihybrid cross, what was the phenotypic ratio Mendel observed in the F2 generation?
    A) 3:1 B) 9:3:3:1 C) 1:1 D) 2:1
11. Mendel's Law of Independent Assortment states that:
    A) Alleles of different genes are inherited independently
    B) Genes do not change over time
    C) Dominant alleles are inherited together
    D) All traits are linked to one another

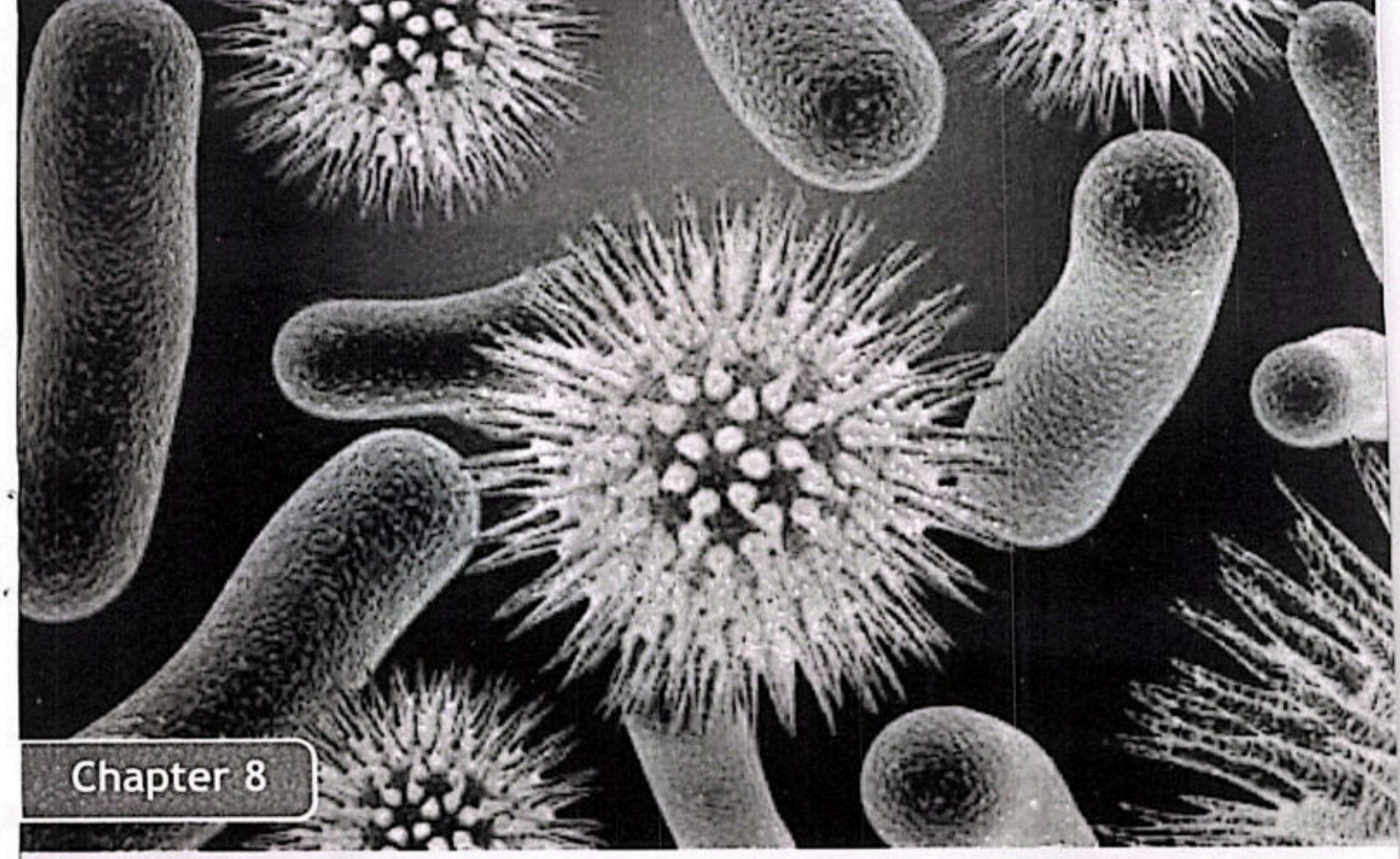
12. In a test cross, if all offspring display the dominant trait, the parent with the dominant phenotype is:
    A) Heterozygous
    B) Homozygous
    C) Mutated
    D) Recessive
13. What is the purpose of a test cross?
    A) To determine the phenotype of an individual
    B) To determine the genotype of an individual showing a dominant trait
    C) To identify new mutations
    D) To observe the effects of environmental factors on inheritance
14. Which of the following is true of a homozygous genotype?
    A) It contains two different alleles
    B) It contains two identical alleles
    C) It contains no alleles
    D) It contains only one allele
15. What ratio did Mendel observe in the F2 generation of a monohybrid cross?
    A) 1:1
    B) 2:1
    C) 3:1
    D) 9:3:3:1

Section II: Short Answer Questions

1. Why do chromosomes need to compact into thick chromatids during cell division?
2. How does the structure of telomeres help protect genetic information during cell division?
3. How do Mendel's experiments with pea plants support the idea of dominant and recessive traits?
4. Why did Mendel use true-breeding plants in his experiments?
5. How can two parents with free earlobes have a child with attached earlobes?
6. How does the law of segregation ensure genetic diversity in offspring?
7. Why did Mendel's dihybrid cross results differ from his monohybrid cross results?
8. In pea plants, the allele for round seeds (R) is dominant over the allele for wrinkled seeds (r). If a heterozygous round-seed plant (Rr) is crossed with a homozygous wrinkled-seed plant (rr), what will be the genotypic and phenotypic ratios of their offspring?
9. If a true-breeding tall pea plant (TT) is crossed with a short pea plant (tt), what will be the genotype and phenotype of the F1 generation? What will be the genotypic and phenotypic ratios of the F2 generation if two F1 plants are crossed?
10. In humans, free earlobes (E) are dominant over attached earlobes (e). A person with free earlobes has a child with attached earlobes. What is the genotype of the parent with free earlobes, and what are the possible genotypes of the offspring?
11. Two pea plants, one with yellow round seeds (YYRR) and another with green wrinkled seeds (yyrr), are crossed. What are the phenotypic ratios in the F2 generation if the F1 generation self-fertilizes?
12. In a dihybrid cross, two pea plants with the genotype RrYy are crossed. What is the probability (chance) that an offspring will have round, yellow seeds (RRYY) in the F2 generation?

Section III: Extensive Answer Questions

1. Describe the different parts of a chromosome, including chromatids, centromeres, and telomeres.
2. Explain how DNA is organized within the chromosome, including the role of histone proteins and nucleosomes.
3. Describe Mendel's procedure of crossing a true-breeding round-seeded pea plant with a *wrinkled*-seeded plant. Also draw the diagram of the cross.
4. Explain the results of the F1 and F2 generations in monohybrid cross and describe the conclusions he drew regarding dominant and recessive traits.
5. Define genotype and phenotype, providing examples to illustrate how different genotypes (homozygous and heterozygous) can lead to different phenotypes.
6. Explain what a test cross is and how it can be used to determine whether an organism displaying a dominant trait is homozygous or heterozygous.



Chapter 8

DISEASES

SLOs: After completing this lesson, the student will be able to:

1. [B-10-1-01] Define disease, illness and infection and pathogen.
2. [B-10-1-02] List the 4 different types of pathogens (Viruses, Bacteria, Plasmodium, Fungi). and list their common diseases.
3. [B-10-1-03] Discuss antibiotics.
4. [B-10-1-04] Discuss the development of resistance in bacteria.
5. [B-10-1-10] Describe discovery of pencillin.
5. [B-10-I-11] Define Diabetes and its subtypes explain the effects on the human body.
6. [B-10-1-12] Discuss cancer and its effects on the human body.
7. [B-10-1-13] Narrate Covid 19 and list the harmful effects on the human body.
8. [B-10-1-14] Discuss that HIV compromises the Immune system and over times leads to development Acquired Immune Deficiency Syndrome (AIDS)
9. [B-10-1-15] Explain plant diseases commonly present in Pakistan, in terms of their effect on plant health and yield and their treatment. (Rust, smut, red rot of sugarcane)
10. [B-10-R-28] Describe infectious and non-infectious diseases and their types with examples
11. [B-10-R-29] Define zoonotic diseases and give their types.
12. [B-10-R-30] Describe vector borne diseases with examples

You are quite familiar with the name of the diseases like dengue, COVID-19, hepatitis B, and typhoid. Now, let us explore the topic of diseases.

8.1 DISEASES

A **disease** is a condition that affects the normal functioning of an organism, causing harm or discomfort. It can be caused by genetics, environment, lifestyle, or infection. A disease has a more objective, biological, or pathological basis. While often used interchangeably, "disease" and "illness" have distinct meanings. An illness is a person's subjective experience of feeling unwell. It may or may not be related to a specific disease. While disease focuses on the medical aspect, illness includes personal, social, and cultural factors.

According to duration, diseases are of two types:

1. Acute Diseases: Short-term diseases that resolve on their own or with treatment (e.g., pneumonia).
2. Chronic Diseases: Long-term diseases that persist or worsen over time (e.g., diabetes).

According to causes, diseases are either infectious or non-infectious.

8.2 INFECTIOUS DISEASES

Infectious diseases can spread from person to person or from animals to people. An infection occurs when a pathogen enters and multiplies inside a person's body, causing disease. A pathogen is an agent that causes disease or infection. Types of pathogens include viruses, bacteria, fungi, protozoans and parasitic worms.

They can spread in several different ways, through: skin contact, the transfer of bodily fluids, with faeces, ingesting contaminated food or water, inhaling airborne particles or droplets, touching an object that a person carrying the pathogen has also touched.

8.2.1 Types of Infectious Diseases

The types of infections are viral infection, bacterial infection, fungal infection, protozoan infection and parasitic infection.

Table 8.1: Types of pathogens, their description, examples and diseases

Pathogen	Description	Example	Disease
Bacteria 	Unicellular organisms without nucleus	*Salmonella typhi*	Typhoid
Viruses 	Non-living particles that reproduce by taking over living cells	*Coronavirus SARS-CoV-2*	COVID-19 disease
Fungi 	Simple organisms that grow as thread like filaments	Dermatophytes (skin fungi)	Ringworm
Protozoa 	Unicellular organisms, animal like Protista	*Plasmodium*	Malaria
Parasites 	Multicellular organisms that live as ectoparasites or endoparasites	*Ascaris*	Ascariasis

8.3 ZOONOTIC DISEASES

A zoonotic disease or zoonosis is an infectious disease that is directly transmitted from animal to humans, such as rabies and bird flu. Almost any animal can carry zoonotic disease e.g., mammals, birds etc.

Causes zoonotic diseases: Many different pathogens can cause zoonosis. These are viruses, bacteria, Parasites (protozoa and parasitic worms), fungi.

Symptoms of zoonotic diseases: Symptoms of zoonotic diseases vary depending on the specific illness. For example, symptoms of bird flu are fever, cough, tiredness, muscle aches, sore throat, shortness of breath, runny nose and headache.

8.3.1 Types of Zoonotic Diseases

Viral zoonoses: The examples of diseases caused by zoonotic viruses are rabies which can be transmitted from all mammals and bird flu which is transmitted from birds.

Bacterial zoonoses: Examples of bacterial zoonoses are anthrax which is transmitted from cattle and plague which is transmitted from rat fleas.

Fungal zoonoses: The example of zoonoses caused by fungus is ring worm which is transmitted from cats and cattle.

Protozoan zoonoses: Examples of protozoan zoonoses are African sleeping sickness which is transmitted from an African fly and beaver fever which is transmitted from beavers.

Parasitic worm zoonoses: Examples of parasitic worm zoonoses are snail fever which is transmitted from snails and tape worm which is transmitted from pig.

8.3.2 Transmission of Zoonotic Diseases

Zoonotic illness can spread through bites, scratches, inhalation, ingestion, or contact with contaminated animal waste or products.

Do you know?

Do you know that over 60% of human pathogens are zoonotic in origin?

8.4 VECTOR BORNE DISEASES

A **vector** is a living organism that transmits an infectious agent from an infected animal to a human or another animal. Vectors are common insects that carry and transmit diseases causing bacteria, viruses and parasite. The examples of vector are mosquitoes, ticks, flies, fleas and lice etc. Vectors may be biological vectors are mechanical vectors.

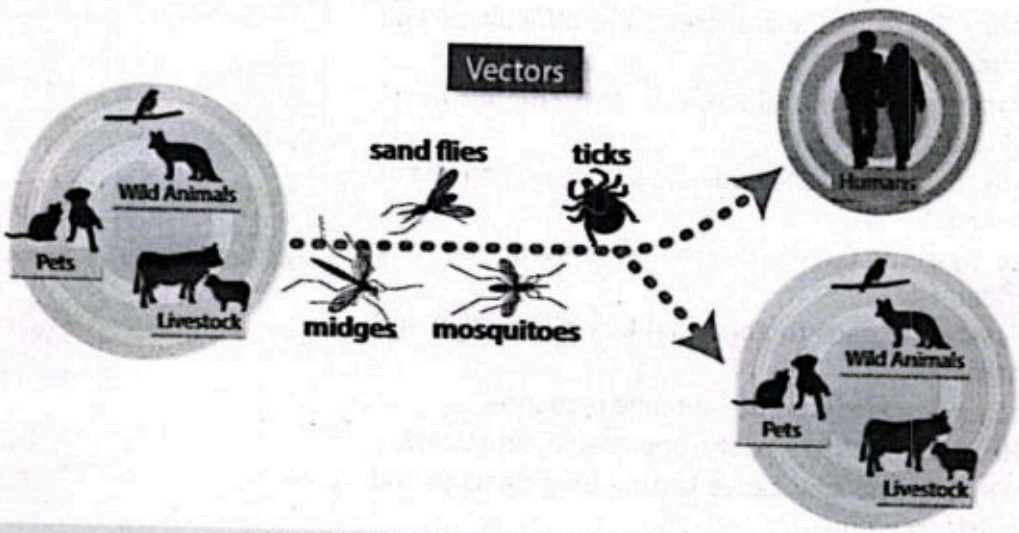


Fig. 8.1: Spread of Vector-borne diseases

a. **Biting vectors:** The examples are mosquito, mite, flea and tick. They may carry pathogens that can multiply within their bodies and be delivered to new hosts, usually by biting.
b. **Carrier vectors:** The example is flies that can pick up infectious agents on the outside of their bodies. Then they and transmit infectious agents through physical contact.
Examples of vector-borne diseases include Dengue fever, Lyme disease, and malaria etc.
Vector-Borne Diseases are transmitted through vectors like insects. For example, malaria and dengue are spread by mosquitoes. A vector is an organism that acts as an intermediate host for a pathogen. Most importantly the vector transfers the pathogen from one host to the next host.

8.5 NON-INFECTIOUS DISEASES

Non-infectious diseases are not caused by pathogens and cannot spread from person to person. These include:
1. Physiological diseases (e.g., type 2 diabetes, cancer)
2. Genetic disorders (e.g., sickle cell anaemia, colour blindness)
3. Autoimmune diseases (e.g., type 1 diabetes, rheumatoid arthritis)
4. Nutritional deficiency diseases (e.g., scurvy, rickets)
5. Environmental diseases (e.g., lung cancer from smoking, skin cancer from UV rays)
6. Degenerative diseases (e.g., osteoarthritis, Alzheimer's disease)
7. Psychological disorders (e.g., anxiety disorders, depression)

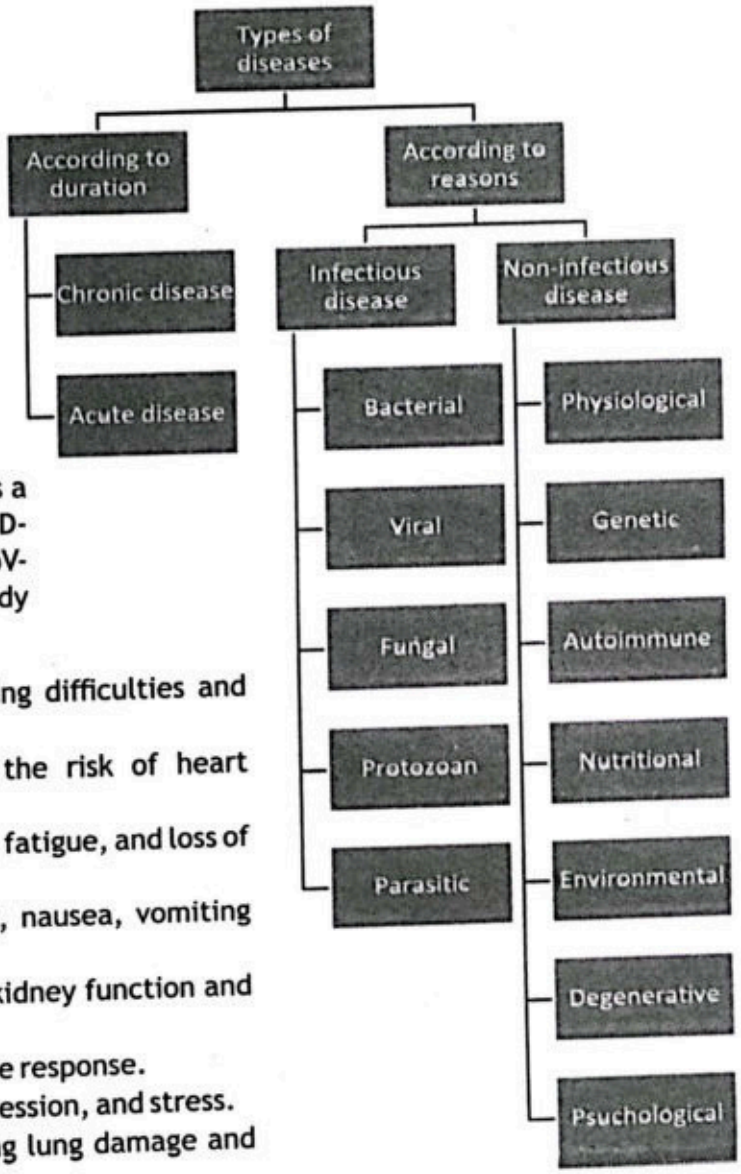


Fig. 8.2: Types of diseases

8.6 COVID-19

You all are familiar with Covid-19. It was a global pandemic during 2020-2022. COVID-19 is caused by the coronavirus SARS-CoV-2. It is an acute disease. It affects the body in many ways:

1. **Respiratory System:** Causes breathing difficulties and pneumonia.
2. **Cardiovascular System:** Increases the risk of heart attacks and strokes.
3. **Nervous System:** Leads to headaches, fatigue, and loss of taste and smell.
4. **Digestive System:** Causes diarrhoea, nausea, vomiting and liver damage.
5. **Urinary system:** Leads to abnormal kidney function and kidney damage.
6. **Immune System:** Weakens the immune response.
7. **Mental Health:** Leads to anxiety, depression, and stress.
8. **Long-term Effects:** May cause lasting lung damage and other health problems.

Prevention: COVID-19 can be prevented by following practices:

1. Washing hands frequently
2. Wearing masks
3. Social distancing
4. Staying home if symptomatic
5. Vaccination

Do you know?

COVID-19 has led to the rapid development of m RNA vaccines, a technology that could revolutionize vaccine production for other diseases!

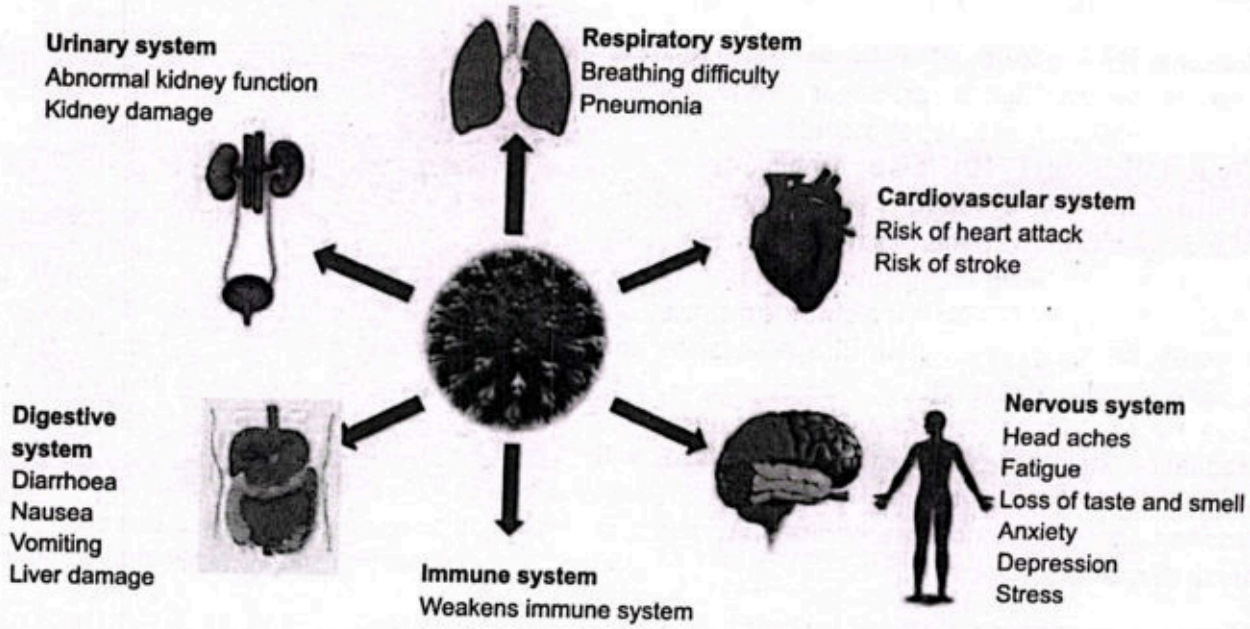


Fig. 8.3: COVID-19 effects on different body systems

8.7 AIDS

HIV (Human Immunodeficiency Virus) attacks the immune system, specifically helper T cells (CD4 T cells). It weakens the body's ability to fight infections. Without treatment, HIV can lead to AIDS (Acquired Immune Deficiency Syndrome) which is a chronic disease. The symptoms of AIDS include fever, headache, muscle aches, joint pain, swollen lymph nodes, diarrhoea, weight loss and severe immune dysfunction. In the final stages due to immune dysfunction lots of opportunistic infections attack the patient.

HIV is transmitted through patient's blood and body fluids. Infected needles, blood and instruments are mainly responsible for the spread of this disease. After infection there are four clinical stages showing the progression from HIV to AIDS. Stage 1 is without any symptoms and it lasts for few weeks. Stage 2 has mild symptoms and it can last up to 10 years. In stage 3 the immune system weakens and opportunistic infections start to appear.

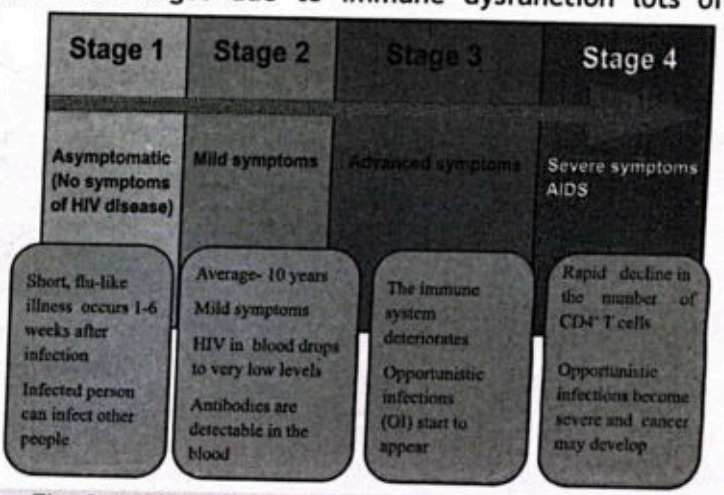


Fig. 8.4: Clinical stages showing the progression from HIV to AIDS

After that severe symptoms of AIDS start when infections become severe and cancer may develop. Infected persons of all stages can infect other people.
Antiretroviral therapy (ART) can manage HIV and prevent AIDS progression. Early detection and treatment are crucial.

Do you know?

The Berlin Patient is the only person in the world to have been cured of HIV after receiving a bone marrow transplant!

8.8 DIABETES

Diabetes is a group of metabolic disorders characterized by high blood sugar levels. It is a chronic disease. Its main types include:

1. **Type 1 Diabetes (T1D):** It is a chronic disease. An autoimmune disease destroying insulin-producing cells in the pancreas. It can be treated by taking regular injections of insulin.
2. **Type 2 Diabetes (T2D):** It is a chronic disease. A metabolic disorder from insulin resistance and impaired insulin secretion.
3. **Gestational Diabetes (GDM):** Develops during pregnancy. Most cases of gestational diabetes will reverse shortly after delivery.

Proper management includes medication, diet, and lifestyle changes.

Fig. 8.5: Key steps for Type 2 Diabetes prevention and management

Effects of unmanaged diabetes include:

1. **Short-term effects:** Increased thirst, urination, fatigue, blurred vision, slow-healing wounds.
2. **Long-term effects:** Heart diseases, high blood pressure, irregular heartbeat, kidney damage, nerve damage, retina damage, high cholesterol level, high lipid level, high uric acid level, high risk of COVID-19, ketoacidosis, foot ulcers and memory loss.

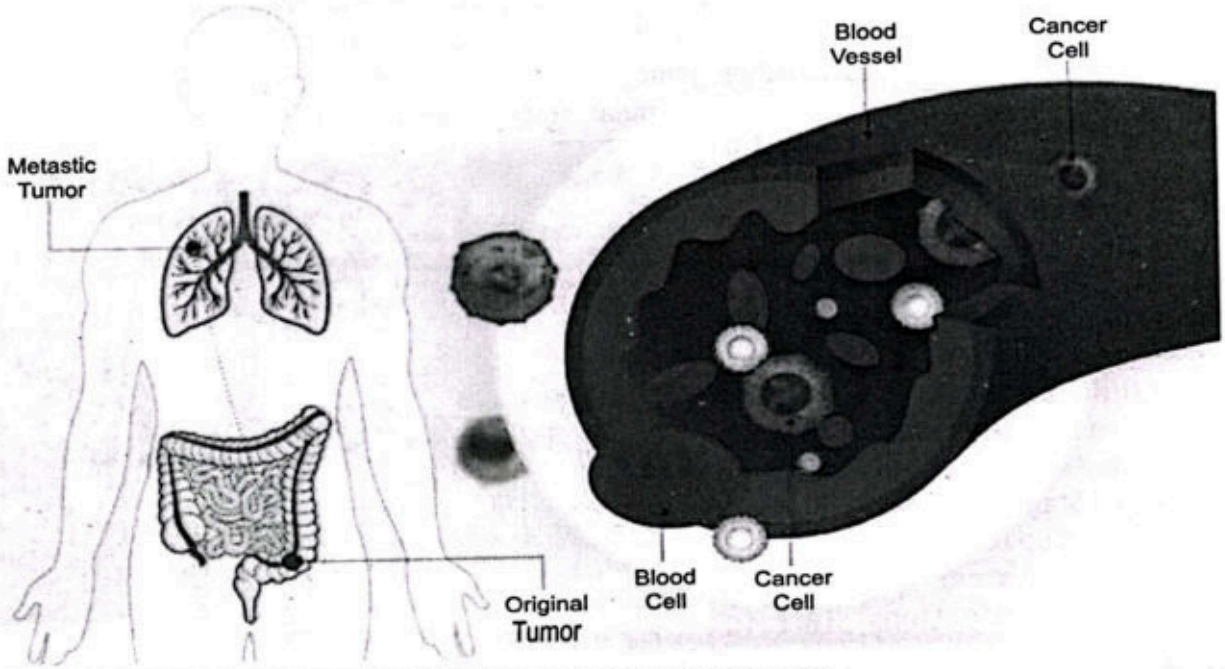


Fig. 8.6: Spread of cancer in the body

8.9 PLANT DISEASES IN PAKISTAN

Pakistan is an agricultural country. Crops and their yields are the back bone of our economy. Some common plant diseases caused by fungi in Pakistan are following.

Rust: Wheat leaf rust is a fungal disease caused by Puccinia rust fungus. It infects plants such aswheat, barley, rye. It gets transmitted from one plant to another through spores or air. Rust infections can lead up to 20% yield loss.

Smut: Smut is also a fungus that affects wheat crops and some grasses. Smut gets its name from the sooty, black appearance of infected wheat plants. The fungus produces spores in the leaves, grains or ears. These fungi are damaging pathogens of cereal crops, reducing yield and quality of harvested grain. It is caused by fungi *Ustilago tritici*.

Do you know?

Plants can get sick too, just like humans! Some plant diseases have been around for centuries.

Red rot of Sugarcane: Red rot is a very serious disease of sugarcane. The main symptom of the disease is the reddening of the internal tissues and reduced sugar content. It is caused by fungi *Colletotrichum falcatum*.

Effective disease management includes resistant varieties, crop rotation, and fungicides, along with proper diagnosis and monitoring.

Fig. 8.7: Fungal plant diseases in Pakistan a. Rust on wheat leaves b. Smut on wheat kernels c. Red rot in sugar cane

8.10 ANTIBIOTICS

Antibiotics are chemicals produced by microorganisms which are capable of destroying or inhibiting the growth of another microorganism. The microorganisms that produce antibiotics are mostly bacteria and a few fungi. Now synthetic antibiotics are also available. Antibiotics are effective against bacterial infections but are of no use against viruses.

8.10.1 Discovery of Penicillin

The discovery of penicillin is attributed to Alexander Fleming in 1928. He was studying bacteria in his lab. He left a dish with bacteria uncovered. When he returned to his laboratory after a holiday, he noticed a mold, *Penicillium notatum*, growing on that bacterial culture.

To his surprise, the mold killed the bacteria around it. He realized the mold was producing a special substance that could kill a wide range of harmful bacteria. He isolated the substance and named it penicillin.

Fleming thought penicillin could be used to treat bacterial infections, but he needed help to develop it. He worked with two other scientists, Florey and Chain, to purify and mass-produce penicillin.

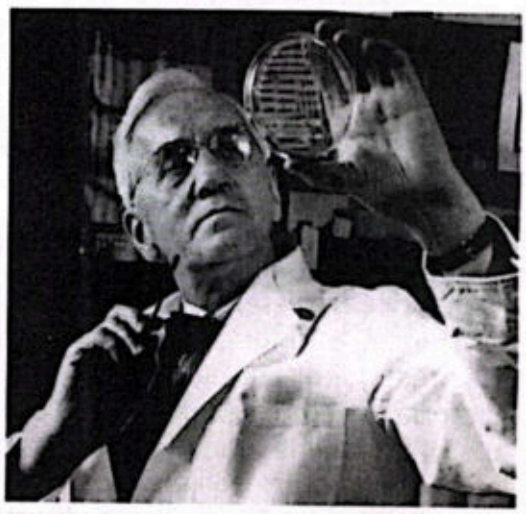


Fig. 8.8: Alexander Fleming

Finally, penicillin was ready to use, and it revolutionized the treatment of bacterial infections. It saved many lives and became a widely used medicine. In short, Fleming's discovery of penicillin was an accident that led to a breakthrough in medicine. It has been estimated that Penicillin has saved over 500 million lives.

Penicillin was the first successful antibiotic used in medicine. From 1940s to 1960s it was widely used throughout the world against bacterial infections. But afterwards many bacteria get resistant against penicillin. Penicillin is still used to treat some bacterial infections.

8.10.2 Sources of Antibiotics

Antibiotics are derived from various natural sources, including:

1. **Bacteria:** Many antibiotics are produced by bacteria, e.g., streptomycin, tetracycline and erythromycin.
2. **Fungi:** Fungi like Penicillium (penicillin) and Cephalosporium (cephalosporins) produce antibiotics.
3. **Plants:** Some plants produce antibiotics e.g., garlic.
4. **Animals:** Some animals, like frogs and insects, produce antibiotics as a defense mechanism.

8.10.3 Mode of Action of Antibiotics

Antibiotics work by targeting specific biochemical processes in bacteria, ultimately leading to their death or inhibition of growth by inhibiting cell wall synthesis, protein synthesis, DNA, replication and metabolism.

1. **Cell Wall Inhibition:** Antibiotics like penicillins and cephalosporins inhibit the synthesis of the bacterial cell wall, causing it to weaken and eventually burst.
2. **Protein Synthesis Inhibition:** Antibiotics like tetracyclines and erythromycin bind to the bacterial ribosome, preventing protein synthesis and essential cellular functions.
3. **DNA Replication Inhibition:** Antibiotics like gentamicin bind to the bacterial DNA, inhibiting replication and repair.
4. **Membrane Disruption:** Antibiotics like polymyxins interact with the bacterial cell membrane, disrupting its structure and function.
5. **Metabolic Inhibition:** Antibiotics like sulfonamides inhibit specific metabolic pathways, depriving bacteria of essential nutrients.

By targeting these critical processes, antibiotics effectively prevent bacterial growth and proliferation, helping to clear infections.

8.10.4 Antibiotics Classification

Antibiotics that inhibit bacterial growth are called **bacteriostatic** and those that kill bacteria are bactericidal. The antibiotics that act against limited variety of bacteria are called **narrow spectrum antibiotics** e.g., penicillin. The antibiotics that act against a wide range of bacteria are called broad spectrum antibiotics e.g., tetracyclines. Some major groups of antibiotics are: sulphonamides, tetracycline and cephalosporin.

8.10.5 Antibiotic Resistance

Antibiotics are essential in medicine, but their overuse and misuse have contributed to antibiotic resistance. Antibiotic resistance in bacteria refers to the ability of bacteria to survive and grow in the presence of antibiotics, which are designed to kill or inhibit their growth. This occurs when bacteria develop mechanisms to avoid the effects of antibiotics, making these life-saving drugs less effective. It leads to untreatable infections that result in increased mortality. Resistant infections require longer treatment, increasing healthcare costs and make certain medical procedures risky. For example, drug resistant typhoid, drug resistant TB etc.

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The development of resistance in bacteria is a natural process that occurs through various

For your information

Mechanisms of resistance

Antibiotic resistant bacteria utilize following mechanisms:
1. **Enzyme production:** Bacteria produce enzymes that degrade antibiotics.
2. **Altered target site:** Bacteria modify their target sites, making antibiotics less effective.
3. **Active outflow:** Bacteria pump antibiotics out of their cells.
4. **Biofilm formation:** Bacteria form protective biofilms, reducing antibiotic effectiveness.

Factors contributing to resistance

There are many factors which are responsible for increasing antibiotics resistance in pathogenic bacteria. These include excessive use of antibiotics for humans, agricultural use in animal feed and lack of new antibiotic development.

Prevention

To combat resistance, it's essential to:
1. Use antibiotics judiciously: Only use antibiotics when necessary.
2. Develop new antibiotics: Invest in research and development.
3. Improve infection control: Enhance sterilization and hygiene practices.
4. Monitor and track resistance: Surveillance and data collection to inform strategies.

SUMMARY

1. A disease is a condition that affects the normal functioning of an organism, causing harm or discomfort.
2. An illness is a person's subjective experience of feeling unwell or sick.
3. Infectious diseases are illnesses caused by pathogens that get into body. The most common causes are viruses, bacteria, fungi and parasites. Infectious diseases usually spread from person to person, through contaminated food or water and through bug bites.
4. Zoonotic diseases are infections that are spread between people and animals. These infections are caused by germs, such as viruses, bacteria, parasites, and fungi.
5. Vector may be any organism (vertebrate or invertebrate) that functions as a carrier of an infectious agent between organisms of a different species.
6. Vector-borne diseases are infectious diseases caused by parasites, bacteria, or viruses such as malaria, dengue.
7. Non-infectious diseases include all diseases that are not caused by pathogens.
8. COVID-19 is a disease caused by a coronavirus that affects the human body in many ways.
9. HIV (Human Immunodeficiency Virus) attacks and compromises the immune system,

specifically targeting helper T cells, which are crucial for fighting off infections and diseases.

10. Diabetes is a group of metabolic disorders characterized by high blood sugar levels, which can lead to a variety of complications if left unmanaged.
11. Cancer is a group of diseases that can affect any part of the body and can lead to death. Cancer is caused by the rapid creation of abnormal cells that grow and spread to other organs.
12. Some common plant diseases caused by fungi in Pakistan are rust, smut and red rot of sugar cane.
13. Alexander Fleming in 1928 discovered penicillin accidentally.
14. Antibiotics are chemicals produced by microorganisms which are capable of destroying or inhibiting the growth of another microorganism. The microorganisms that produce antibiotics are mostly bacteria and a few fungi.
15. When bacteria are exposed to the same antibiotic for a long time, they acquire resistance against that antibiotic. Antibiotic resistance is accelerated by the misuse and overuse of antibiotics.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. What the patient feels when he goes to the doctor is:

   A) disease B) illness C) acute infection D) diagnosis

2. Bone fracture is a/an:

   A) acute disease B) chronic disease C) infectious disease D) zoonotic disease

3. Virus and bacteria are examples of:

   A) vectors B) pathogens C) disease D) illness

4. Mosquito is the deadliest animals on earth because:

   A) it has poison glands B) it can cause infection
   C) it can spread pathogens D) it sucks blood

5. The non-infectious diseases that run in the family are:

   A) physiological disorders B) genetic disorders
   C) autoimmune disorders D) nutritional disorders

6. COVID-19 is a/an:

   A) acute bacterial infection B) chronic bacterial infection
   C) acute viral infection D) chronic viral infection

7. COVID-19 spread as global pandemic was reduced after:

   A) lockdowns B) social distancing C) sanitization D) vaccination

8. HIV positive person can stay up to 10 years in stage:

A) 1 B) 2 C) 3 D) 4

9. According to the International Diabetes Federation, in 2022, 26.7% of adults in Pakistan are affected by diabetes. This number is alarmingly high and is also increasing with each passing year. We can:

A) do nothing about it B) make prayers to stop it

C) make life style changes to prevent it D) use vaccination to cure it

10. The rapid creation of abnormal cells that grow beyond their usual boundaries and spread to other organs is due to:

A) AIDS B) diabetes C) cancer D) COVID-19

11. Which of the following CORRECTLY matches the antibiotic with its source?

	Antibiotics	Source
A)	Streptomycin	Fungi
B)	Cephalosporin	Animal
C)	Penicillin	Plant
D)	Tetracycline	Bacteria

12. First antibiotic discovered by Alexander Fleming in 1928 was:

A) Streptomycin B) Cephalosporin C) Penicillin D) Tetracycline

13. Drug resistant typhoid is lethal due to:

A) highly toxic bacteria B) antibiotics resistance

C) severe complications D) allergic reactions

14. If all pathogenic bacteria develop antibiotic resistance then health issues will increase regarding:

A) all infectious diseases B) non infectious diseases

C) viral diseases D) bacterial diseases

15. Membrane disruption antibiotics can be grouped as:

A) bacteriostatic B) bactericidal C) pesticide D) antiviral

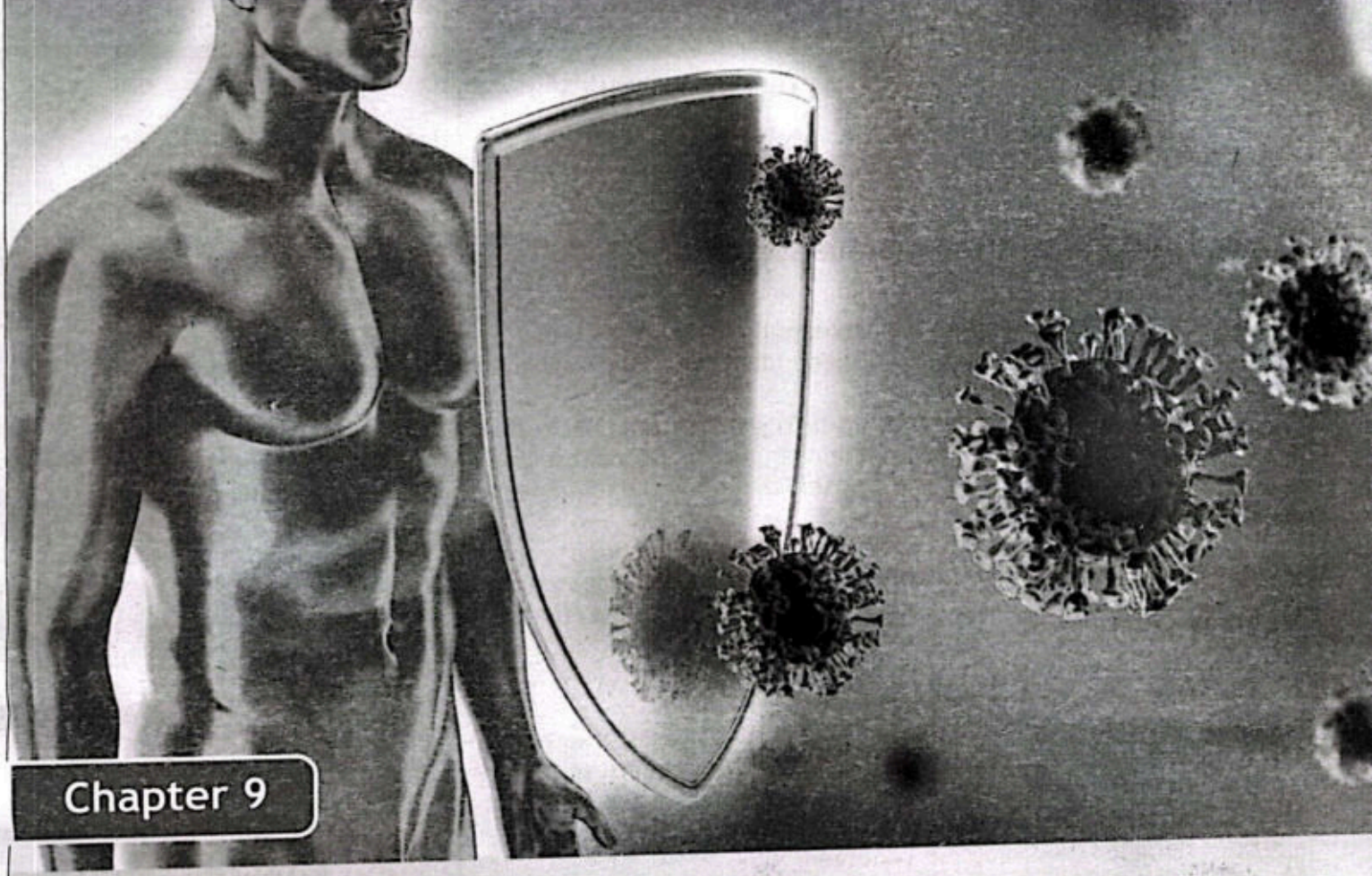
Section II: Short Answer Questions

1. What are zoonotic diseases?
2. Enlist types of pathogens with examples.
3. What are different types of non-infectious diseases?
4. What are the effects of diabetes on human body?
5. What are different types of diabetes?
6. How diabetes can be prevented and managed?
7. How cancer develops and spreads in the body?
8. How cancer can be treated?
9. Which systems of the body are affected by COVID-19? 10.What are the clinical stages of AIDS?
10. What are the sources of antibiotics?
11. What are different ways in which antibiotics act on bacteria?

12. Which factors contribute to the resistance of antibiotics and how it can be prevented?
13. Write the differences between:
    a. Disease and illness
    b. Infectious and non-infectious diseases
    c. Vector and pathogen
    d. Acute and chronic diseases

Section III: Extensive Answer Questions

1. Describe infectious and non-infectious diseases and their types with examples.
2. Describe diabetes and its subtypes. Explain the effects of diabetes on the human body.
3. Discuss cancer and its effects on the human body.
4. Explain Covid-19 and its harmful effects on the human body.
5. Discuss that HIV compromises the Immune system and over times leads to development Acquired Immune Deficiency Syndrome (AIDS)
6. Explain plant diseases commonly present in Pakistan, in terms of their effect on plant health and yield and their treatment.
7. Narrate the discovery of first antibiotic.
8. Discuss antibiotics in detail.
9. Describe antibiotic resistance and its effects.



Chapter 9

IMMUNITY AND THE IMMUNE SYSTEM

SLOs: After completing this lesson, the student will be able to:

1. [B-10-1-05] Define immunity and List the roles of the immune system.
2. [B-10-1-06] Describe the components of the immune system (Lymphatic system (lymph nodes), Types of immune cells and their roles, Innate immunity, adaptive immunity and the three lines of defence).
3. [B-10-1-08] State that the function of adaptive immunity.
4. [B-10-1-09] Discuss that vaccines help boost immunity with examples.
5. [B-10-R-31] Enlist allergies with some common types.

9.1 IMMUNITY

Immunity refers to the body's ability to resist or combat infections, diseases, and foreign substances. The immune system plays a crucial role in protecting the body against pathogens, such as bacteria, viruses, fungi, parasites and other foreign substances.

9.1.1 Roles of the Immune System

A balanced and functioning immune system is crucial for maintaining health and preventing disease. Following are main roles of the immune system.

1. **Recognition of foreign antigen:** Identifying and recognizing antigens of pathogens and foreign substances.
2. **Activation of immune response:** Triggering an immune response to eliminate pathogens.
3. **Elimination of pathogens:** Removing pathogens and foreign substances from the body.
4. **Regulation of immune response:** Regulating the immune response to prevent overactive or underactive immune responses.
5. **Memory:** Remembering specific pathogens to produce a rapid response upon future exposure.
6. **Surveillance:** Continuously monitoring the body for potential threats.
7. **Inflammation:** Initiating inflammation to isolate and eliminate pathogens.
8. **Antibody Production:** Producing antibodies to neutralize pathogens.
9. **Cell-Mediated Immunity:** Using immune cells (e.g., T cells, macrophages) to attack pathogens.
10. **Tissue Repair:** Repairing damaged tissues and restoring normal function.
11. **Self-tolerance:** Identifying and not reacting against self-antigens.
12. **Cancer prevention:** Fighting off cancer or pre-cancer cells on daily basis.
13. **Allergy:** Over reaction of immune response to harmless substances i.e., allergen.
14. **Clotting:** Immune response to damaged blood vessels and invading pathogens to limit the blood loss and promote healing.
15. **Removal of cell debris:** Identifying and removing damaged and dead cell debris.

Do you know?

The immune system can recognize and remember millions of different antigens and can produce specific responses to each one.

9.1.2 Immune System

An extensive network of tissues, organs, proteins, and cells make up the body's immune system. An immune system working correctly can distinguish healthy tissue and foreign objects. It will initiate a complex attack to defend the body from invaders if it identifies it as foreign. But, the immune system is not always reliable. For example, in allergies, the immune system misinterprets harmless substances and starts an unwanted immune response, resulting in painful and life-threatening symptoms.

The immune system functions like a police force. It roams the entire body and alerts for assistance when it notices a disturbance. It differs from other systems in this way because it must be able to respond in any area of the body.

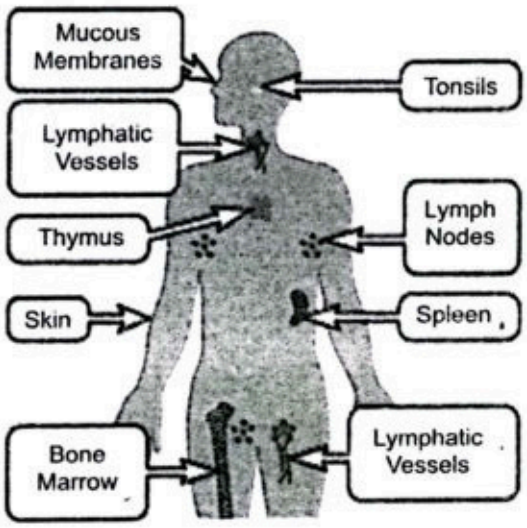


Fig. 9.1: Organs of immune system

9.2 ORGANS OF THE IMMUNE SYSTEM

Organs and tissues important to the proper functioning of the immune system are following. Bone marrow, thymus, lymph nodes and vessels, spleen, liver, tonsils, adenoids, skin and mucous membranes.

1. Bone Marrow: Red blood cells, many types of white blood cells, and platelets are produced from stem cells found in the spongy interior of the bones. Every day, the bone marrow produces billions of new blood cells and releases them into the blood. B-cells and T-cells are also produced in bone marrow. The B-cell maturation takes place in the bone marrow.

2. Thymus: This tiny organ, located in the upper chest below the breast bone, is responsible for T-cell maturation.

3. Lymph Nodes and Vessels: The lymphatic system in our body contains lymph vessels and lymph nodes. The networks of lymph vessels are connected by lymph nodes. These tiny nodes filter and kill pathogens to prevent germs from spreading to other body areas. Lymph nodes have collections of B cells and T cells throughout the body. Cells collect in lymph nodes to communicate with each other. Lymph nodes can become swollen when they are fighting an infection.

4. Spleen: Spleen is a lymphoid organ located near stomach. Spleen filter blood, capture pathogens in blood, and fight blood infections. The spleen has a collection of B cells, T cells, and monocytes.

5. Liver: The liver is the major organ responsible for producing proteins of the complement system. In addition, it contains large numbers of phagocytic cells that eat bacteria in the blood as it passes through the liver.

6. Tonsils and adenoids: The adenoids and tonsils function as a part of the body's immune system. Acting as our first line of defence, they trap and kill harmful pathogens like bacteria and viruses that enter our mouth and nose. These are made up of lymphoid tissue which is densely filled with lymphocytes.

7. Skin: The human skin serves as a barrier against microbial invasion, protecting the body from potential pathogens. The skin's primary defensive features include:

The outermost layer of the skin is called **epidermis.** It is composed of tightly packed cells that provide a physical barrier. Skin cells contain a tough protein **Keratin,** making them resistant to abrasion and water loss.

Do you know?

Do you know that bone marrow, thymus, lymph nodes and vessels, spleen, liver, tonsils and adenoids are lymphoid organs? All lymphoid organs are connected with lymphatic system.

The skin surface has a slightly acidic **pH** (around 5.5), which inhibits the growth of many pathogens. The process of shedding dead skin cells helps remove attached microbes.**Dermis** of skin contains oil glands, sweat glands, hair follicles, receptors, nerves and blood vessels. Oil and sweat play important role in inhibiting and killing microorganisms.

8. Mucous membrane: Mucous membranes line digestive and respiratory tracts. The **digestive tract** mucous membrane kills bacteria present in food by producing **stomach acid** and **digestive enzymes.** The **respiratory system** mucous membrane can trap and remove airborne microbes. It has ciliated epithelium and produces mucus. **Mucus** traps dust, microbes, and other particles and cilia remove them from respiratory system.

Do you know?

Do you know that skin is the largest organ of the body and plays a key role in the first line of defence?

9.2.1 Types of Immune Cells and Their Roles

White blood cells (WBC) play a significant role in the immune system by protecting the body from infectious disease and foreign invaders. WBC are of three main types i.e., granulocytes, monocytes and lymphocytes.

(I) Granulocytes: Granulocytes have granular cytoplasm and nuclei with different shapes. It has three types.

1. **Neutrophils:** Neutrophils rapidly ingests microorganisms and kills them through phagocytosis.
2. **Basophils:** Basophils defend human body from allergens, pathogens and parasites. Basophils release enzymes to improve blood flow and prevent blood clots.
3. **Eosinophils:** Eosinophils protect your body from parasites, allergens, foreign bacteria and outside organisms.

(II) Monocytes: Monocytes are the largest type of white blood cells. Monocytes typically circulate in the blood for 1-3 days before migrating into tissues, where they become macrophages or dendritic cells.

1. **Macrophages:** Macrophages are specialised cells involved in the detection, phagocytosis and destruction of bacteria and other harmful organisms. In addition, they can also present antigens to T cells and initiate inflammation.
2. **Dendritic cells:** These cells instruct T cells on what to attack, also known as antigen-presenting cells.

Dendritic cells are specialized to take up antigen and display it for recognition by lymphocytes.

(III) Lymphocytes: Lymphocytes help your body's immune system fight cancer and foreign viruses and bacteria (antigens). Lymphocytes help your immune system remember every antigen it comes in contact with. There are three types of lymphocyte, NK cells, B-cells and T-cells.

1. **NK cells:** Natural killer cells (NK cells) are found in blood and lymph. They can destroy infected and diseased cells, like cancer cells. NK cells develop in bone marrow, lymph nodes, thymus, liver, and uterus.
2. **B cells:** These lymphocytes arise and mature in the bone marrow. When immune system detects antigens, then B cells produce antibodies to fight the invader pathogen. Activated B cells differentiate into plasma cells and memory B cells.
   (a) **Plasma cells:** These cells develop from B cells and they make specific type of immunoglobulin (antibodies).
   (b) **Memory B cells:** After an encounter, some B cells turn into memory B cells. They are long-lived and can produce that specific antibody when the same pathogen attacks in future.
3. **T cells:** These lymphocytes arise in the bone marrow and mature in the thymus. They gather in lymph nodes. T cells upon activation form four types of T cells.

(a) **Cytotoxic T cells:** These are responsible for killing cells infected with viruses.

(b) **Helper T cells:** These specialized lymphocytes help other T cells and B cells to perform their functions.

(c) **Memory T cells:** These cells are formed. They are long-lived and can protect against the same pathogen in future.

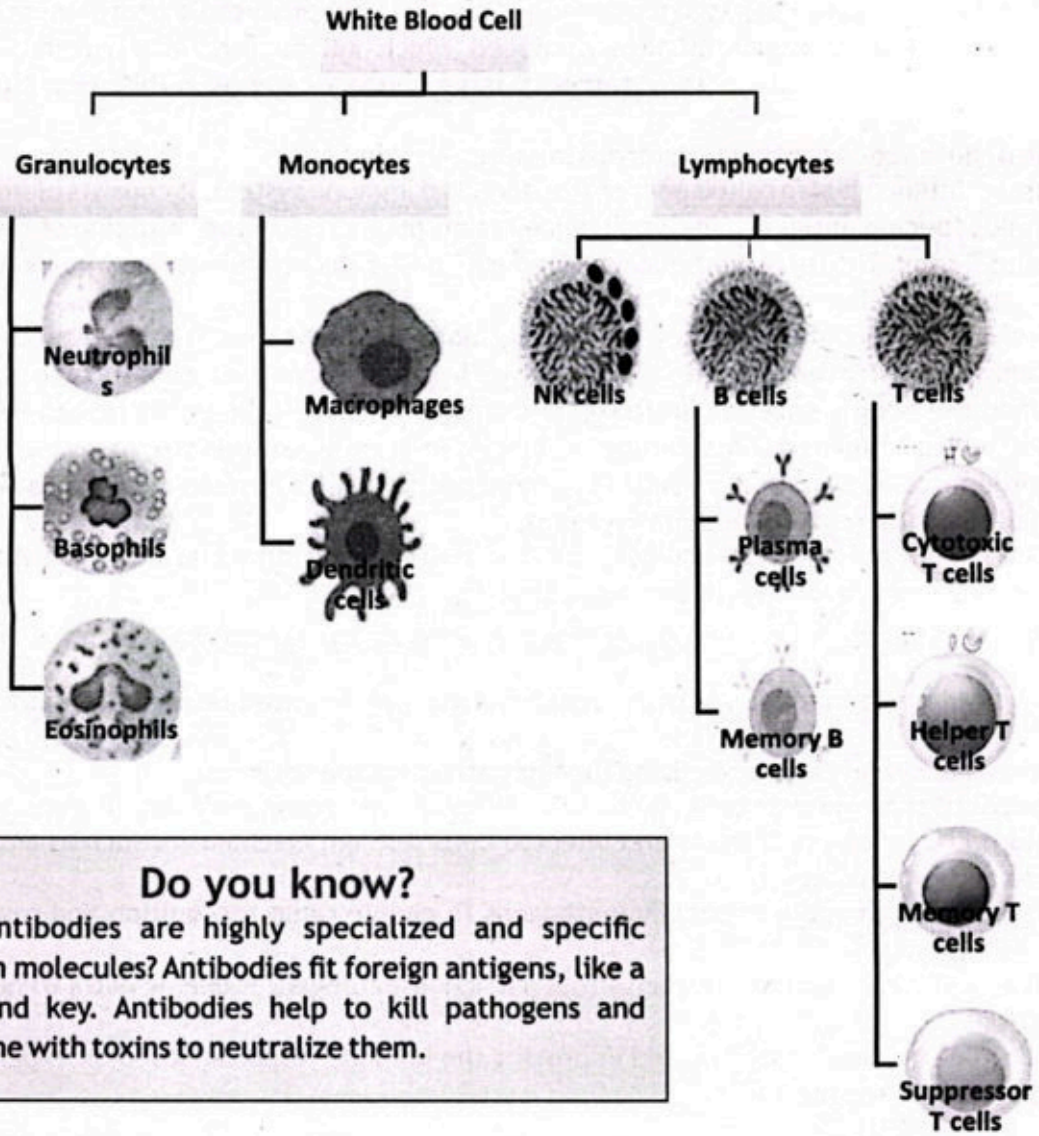
(d) **Suppressor T cells:** After infection is controlled suppressor T cells are formed to shut down the immune response.

Do you know?

The antigens are markers that indicate a threat like a bacteria or virus has entered your body? Antigens are present on the surface of all cells.

9.2.2 Components of the Immune System

The immune system is composed of two basic parts:
1. The innate immune system: Individuals are born with this immune system.
2. The adaptive immune system: Individuals develop this immunity when exposed to pathogens or chemicals released by pathogens.



Do you know?

The antibodies are highly specialized and specific protein molecules? Antibodies fit foreign antigens, like a lock and key. Antibodies help to kill pathogens and combine with toxins to neutralize them.

Fig. 9.2: Types of Immune cells

9.2.2 Innate Immune System

People have some immunity from birth, ready to fight against invaders immediately. This response is non-specific and general. It has first and second line of defence.

1. First Line of Defence

The external barriers of our body serve as the first line of defence against pathogens. It includes **skin** and **mucous membranes** of digestive and respiratory system. The multiple defences including chemical, physical and biological barriers make the first line of defence extremely effective to prevent microbial entry.

2. Second Line of Defence

If pathogens successfully enter the skin or mucous membranes, a second line of defence is activated to combat these foreign invaders. It consists of four nonspecific internal defences. First, the body keeps a constant army of **phagocytes, neutrophils** and **natural killer cells** which kill pathogens by phagocytosis. Second, the invasion of bacteria produces **inflammation** which removes pathogens and initiates healing process. Third, the body develops **fever** to make the environment less favourable for pathogen growth. Fourth, many **protective proteins** including complement proteins and interferons are produced which kill bacteria and viruses. These defences are nonspecific because they target a large range of germs rather than specific microbes.

3. Third line of defence/ Adaptive (Acquired) Immune System

The third line of defence is also called adaptive or acquired immune system. It consists of immune cells that target specific antigens. The immune cells that play a role in the third line of defence are B-cells and T-cells. The B-cells produce antibodies. The T-cells help identify pathogenic cells and destroy targeted cells.

This acquired ability to defend against infections improves over time. The body produces a variety of antibodies to various pathogens due to immunizations and exposure to various diseases. When the body creates an antibody, it stores its memory cells so that it can respond more quickly the next time the same pathogen attacks. In general, exposure to many pathogens strengthens the immune system. By adulthood, most people will have been exposed to several pathogens and strengthened their immune systems.

Making healthy food and exercise choices, quitting smoking and drinking, and receiving the necessary vaccinations are all ways to increase immunity.

9.3 FUNCTIONS OF ADAPTIVE IMMUNITY

The function of adaptive immunity is to provide a specific and targeted response to pathogens, including:

1. **Recognition:** Identifying and recognizing specific pathogens and antigens.
2. **Activation:** Activating immune cells, such as T cells and B cells, to respond to pathogens.
3. **Elimination:** Eliminating pathogens and infected cells through mechanisms such as antibody production and cytotoxicity.
4. **Memory:** Retaining memory of specific pathogens to enable rapid recognition and response upon future exposure.
5. **Specificity:** Mounting a specific response to a particular pathogen, reducing harm to healthy cells and tissues.
6. **Adaptation:** Continuously adapting and improving the immune response based on experience and exposure to pathogens.

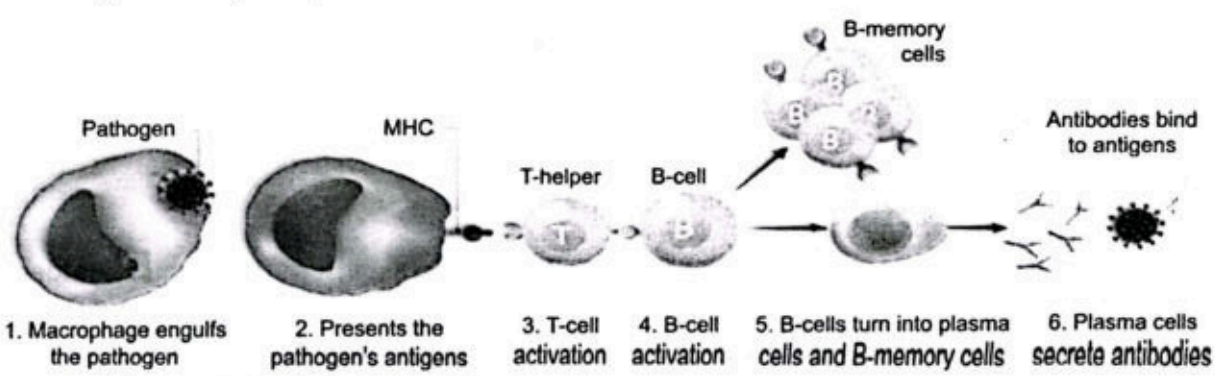


Fig. 9.3: Steps of Immune Response

7. Protection: Providing long-term protection against specific pathogens and diseases.
Adaptive immunity is a highly specialized and efficient defence mechanism that plays a crucial role in protecting against infections and diseases, and is a key component of the overall immune system.

9.4 VACCINES

Vaccines play a crucial role in boosting immunity by introducing a small, harmless piece of a pathogen (antigen) to the body, which triggers a specific immune response. This response prepares the immune system to recognize and fight future infections. Here are some examples:

1. Influenza (Flu) Vaccine: The flu vaccine helps boost immunity against seasonal influenza viruses. It reduces the risk of illness, hospitalization, and death.

2. MMR Vaccine: The measles, mumps, and rubella (MMR) vaccine boosts immunity against these three highly contagious diseases. It prevents serious complications and epidemics.

3. DTaP Vaccine: The diphtheria, tetanus, and pertussis (DTaP) vaccine helps boost immunity against these three bacterial infections. It protects against severe illnesses and complications.

4. COVID-19 Vaccines: COVID-19 vaccines have proven highly effective in boosting immunity against SARS-CoV-2 virus. It reduces the risk of severe illness, hospitalization, and death from COVID-19.

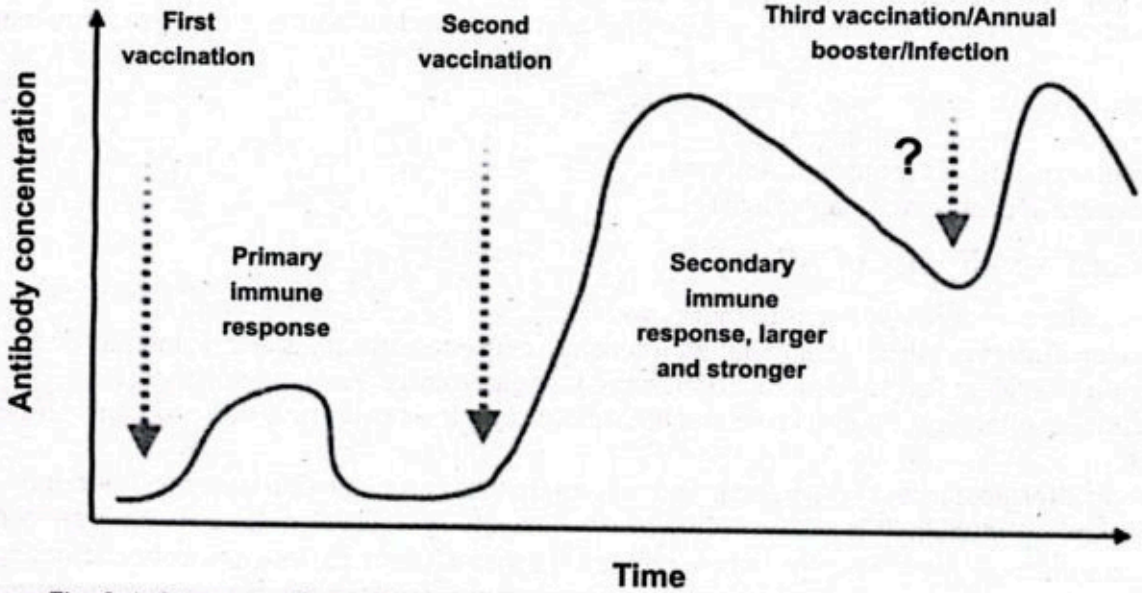


Fig. 9.4: Primary and secondary immune response after different doses of vaccination

Do you know?

Vaccines work by stimulating adaptive immunity, providing protection against specific pathogens.

Most vaccines are given in many doses. First dose of vaccine produces **primary immune response. Booster doses of vaccine produces secondary immune response.** By boosting immunity through vaccination, individuals not only protect themselves but also contribute to herd immunity, helping prevent the spread of diseases in their communities. Vaccination is also called immunization.

Do you know?

Edward Jenner developed the first vaccine in 1796 to protect against smallpox.

9.5 ALLERGIES

An **allergy** is an overreaction of the immune system to a harmless substance, known as an allergen. When an allergen enters the body, the immune system mistakenly identifies it as harmful and attempts to fight it off, leading to an allergic reaction. Common **causes** of allergies include:

1. **Genetics:** Family history and genetic predisposition
2. **Environmental factors:** Exposure to allergens at a young age, hygiene hypothesis
3. **Imbalanced gut microbiome:** Alterations in the gut flora
4. **Overactive immune system:** Hyperactive immune response
5. **Leaky gut syndrome:** Intestinal permeability allowing allergens to pass through

Allergens can be:

1. **Airborne:** Pollen, dust mites, mold
2. **Food:** Peanuts, tree nuts, milk, eggs, fish, shellfish
3. **Insect stings:** Bee, wasp, hornet, yellow jacket
4. **Medications:** Antibiotics, nonsteroidal anti-inflammatory drugs (NSAIDs)
5. **Plants:** Poison ivy, oak
6. **Latex:** Gloves, balloons
7. **Pets:** Dog, cat, bird
8. **Household chemicals:** Cleaners, fragrances, cosmetics

Symptoms of allergic reactions vary depending on the individual and the allergen, but may include:

a. Respiratory issues (congestion, sneezing, coughing)
b. Skin problems (hives, itching, rashes)
c. Gastrointestinal issues (nausea, diarrhoea)
d. Cardiovascular problems (anaphylaxis)

9.5.1 Common Types of Allergies

Allergies can be broadly classified into four types:

1. **Inhalation allergies:** Airborne and pet allergens can cause respiratory issues on inhalation.
2. **Ingestion allergies:** Food and medications can cause gastrointestinal issues on ingestion.
3. **Skin contact allergies:** Plants, latex and household chemicals can cause skin problems on skin contact.
4. **Injection allergies:** Insect stings and injectable medicines can cause skin issues on injection.
5. **Anaphylaxis:** Anaphylaxis is a severe, life-threatening allergic reaction. It can happen seconds or minutes after you've been exposed to something you're allergic to. Peanuts or bee stings are examples.

If you suspect an allergy, consult a healthcare professional for proper diagnosis and treatment.

SUMMARY

1. Immunity is the body's ability to resist or combat infections, diseases, and foreign substances.
2. A balanced and functioning immune system is crucial for maintaining health and preventing disease.
3. Immune system is an extensive network of tissues, organs, proteins, and cells.
4. Organs and tissues of the immune system are bone marrow, thymus, lymph nodes and vessels, spleen, liver, tonsils, adenoids, skin and mucous membranes.
5. WBCs protect the body from infectious disease and foreign invaders.

6. Innate immunity is the body's first and second line of defence which prevents infection and attack of invading pathogens. It is present at birth and lasts a person's entire life.
7. Adaptive immunity is a type of specific immunity that develops when immune system responds to foreign substance or microorganism, such as after an infection or vaccination. It includes third line of defence.
8. First line of defence is the external barriers of our body to stop entry of pathogens. It is nonspecific and includes skin and mucous membranes.
9. Second line of defence is when pathogens successfully enter the skin or mucous membranes, it is activated to combat these foreign invaders. It is nonspecific and includes some WBCs, inflammation, fever and protective proteins.
10. Third line of defence is specific adaptive immunity and consists of immune cells that target specific antigens.
11. Vaccines boost immunity by introducing a small, harmless piece of a pathogen (antigen) to the body, which triggers a specific immune response.
12. Allergy is an overreaction of the immune system to any harmless substance.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Cytotoxic cells are:

   A) the same as memory T cells
   B) suppresses the immune response
   C) T cells that are actively killing other cells
   D) inactive T cells carried in the plasma

2. Antibodies provide adaptive immunity by:

   A) attaching with specific antigen
   B) killing pathogens after recognition
   C) neutralizing toxins by combining with them
   D) all of the above

3. Innate immune system can protect us from disease by acting on:

   A) specific pathogens only
   B) all types of invaders
   C) producing antibodies
   D) recognizing pathogens

4. Fever is harmful for:

   A) our normal metabolism
   B) growth of pathogens
   C) our growth and development
   D) working of immune system

5. Macrophages and dendritic cells are:

   A) lymphocytes B) granulocytes C) monocytes D) red blood cells

6. After birth, all types of blood cells are formed in:

   A) thymus B) adenoids C) lymph nodes D) bone marrow

7. When one receives a booster dose of vaccine for COVID-19, which type of T cell is most directly stimulated?

   A) cytotoxic T-cells B) memory T cells C) helper T cells D) suppressor T cells

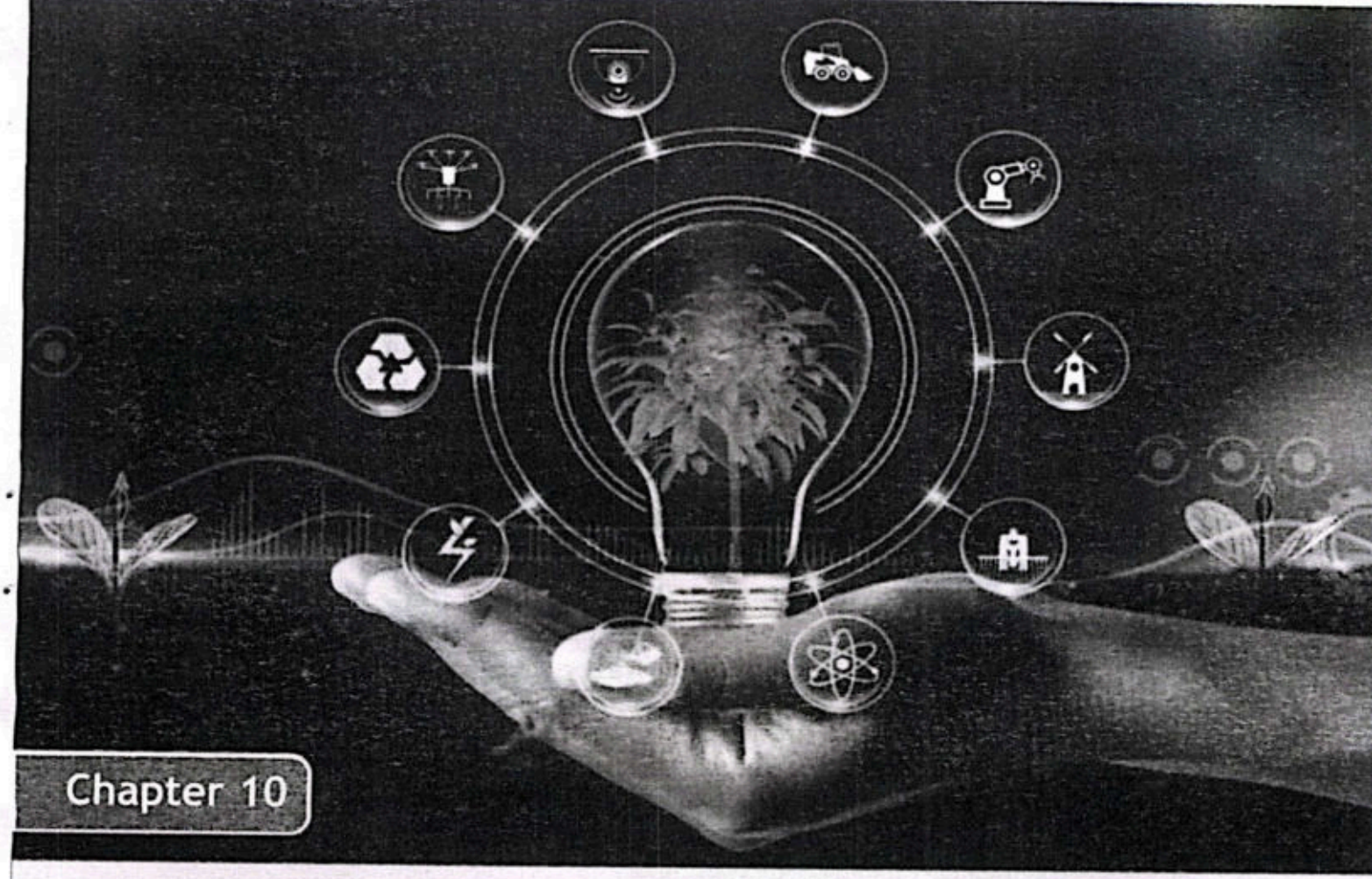
8. Role of clotting in immunity is to prevent:
   A) loss of blood plasma
   B) entry of pathogens
   C) loss of blood cells
   D) spread of wound
9. Vaccination and disease exposure strengthens:
   A) first line of defence
   B) second line of defence
   C) third line of defence
   D) innate immunity
10. Allergy is overreaction of immune system to:
   A) harmless substances
   B) harmful substances
   C) pathogens
   D) virus and bacteria

Section II: Short Answer Questions

1. Enlist the steps of immune response?
2. Draw a flow chart of different types of white blood cells.
3. How lymph nodes prevent the spread of pathogens in human body?
4. Name few vaccines and the diseases they control.
5. What are the types of memory cells? Why they are important?
6. Why booster doses of vaccine are important?
7. What are the symptoms of allergy?
8. Name different causes of allergy?
9. Which substances cause allergy? Enlist them.
10. Write the differences between:
    a. Granulocytes and lymphocytes
    b. macrophages and dendritic cells
    c. allergy and allergen
    d. cytotoxic T cells and helper T cell
    e. plasma cells and memory B cells
    f. primary and secondary immune response
    g. innate immunity and acquired immunity

Section III: Extensive Answer Questions

1. Describe the role of immune system in human body.
2. Explain immune system and its organs.
3. Immune system is made up of white blood cells. What are the different types of white blood cells? Give their role.
4. Compare innate and adaptive immunity. Which type of immunity increases in most people when they reach adulthood?
5. Explain three lines of defence and their components.
6. What is allergy? Explain its types.
7. How vaccination helped humans to eradicate diseases like small pox?



Chapter 10

BIOTECHNOLOGY

SLOs: After completing this lesson, the student will be able to:

1. [B-10-J-01] Introduce biotechnology.
2. [B-10-J-02] Explain with examples that food biotechnology has advanced agriculture especially inside Pakistan.
3. [B-10-J-03] Explain with examples that medical biotechnology has advanced healthcare in diabetes and cancer.
4. [B-10-J-04] State the potential advantages that genetic editing provides with examples in the context of medicine and agriculture.
5. [B-10-J-05] Describe with examples the benefits of marine biotechnology.
6. [B-10-J-06] Describe that bioremediation can help us in taking better care of our environment with an example.
7. [B-10-J-07] Explain the concept and applications of industrial biotechnology with examples.

10.1 INTRODUCTION TO BIOTECHNOLOGY

The history of biotechnology is found parallel to the civilization history of man. Use of biotechnology can be traced back to the earliest human society. Human realized that, to get good and continuous food they should plant their own crops, breed and domesticate their own animals. Study of biotechnology began when human discovered to produce yogurt and cheese from fermented milk. Early human made wine or beer from fermented juices of fruit, sugarcane and malted barley. Since early times of civilization, human are naturally acting as unqualified biotechnologists by baking soft, spongy and tasty bread and bakery items. The first farmer who grafted a more beneficial plant over the other less beneficial plants to increase his yield and quality was a performing biotechnologist.

Rapidly growing human population, led the human to develop new animals with dream characteristics. Scientists planned to grow more nutritive and naturally pest- resistant crops. Researchers hoped to develop unlimited and purest sources of human medicines. Human found the natural ways to remove pollutants form environment and to increase the fertility of the soil and kill insect pest.

Biotechnology can be defined as the "use of living organisms or their processes and products for the welfare of mankind". Early biotechnologists have been using Yeast, to raise bread dough and to prepare alcoholic drinks by alcoholic fermentation and using specific bacteria to make yogurt, butter and cheese by lactic acid fermentation. Lather tanning is a prehistoric biotechnological industry which also involve the use of multiple bacteria and other pathogens where people have been preparing the leather even without knowing the underlying mechanism.

Over the last few decades, advancement in microscopy and fundamental discoveries of

biochemical processes in the cells have given rise to modern biotechnology. Now biotechnologists have much better understanding to select and use so many new microorganisms and their cell products for human welfare. Applications and outcome of modern biotechnology are far advanced than traditional methods like fermentation and selective breeding. Modern biotechnology techniques involve genetic engineering, cell fusion, genetically modified organisms, single cell proteins, cell therapies, gene therapies and Nano-biotechnology.

Modern Biotechnology is now one of the fastest growing areas of science, hence this century has

rightly been termed as 'Century of Biology. In view of these developments, Biotechnology has been included among the six priority areas of Science and Technology by the National Commission of Science & Technology of Pakistan.

10.2 FOOD BIOTECHNOLOGY RELATED TO ADVANCED AGRICULTURE IN PAKISTAN

Pakistan is the 5th most populated country in the world having population of over 240 million with an annual growth rate of 2.55%. Rural population is directly dependant on agriculture whereas, increasing trend of urbanization has multiplied the pressure for production of extra food from continuously shrinking agricultural land. To feed this huge population, supply of more, continuous and nutrient enriched food is a huge challenge for the agriculture and the national economy of Pakistan. The importance and crucial role of food biotechnology is obvious to meet the challenges of food security, malnutrition and environmental hazards related to agriculture.

In food Biotechnology, scientists modify the genes of our food sources including domestic animals, plants and microorganisms for production new species. Food biotechnology involves the use of scientific techniques and a wide range of applications that improve the food production,

quality, nutritional value, processing, preservation and agriculture sustainability. Academic institutions and research organizations in Pakistan like NIBGE, NIAB, NCEMB, KIBGE and ASAB are engaged in food biotechnology applied research, to address local agricultural and food challenges. In last three decades, food biotechnology has obviously advanced the agriculture in Pakistan by introducing various techniques and technologies that improve crop yield, nutritional value, resistance to pests and tolerance to drought and salt. Examples of role of food biotechnology in advancement of agriculture includes:

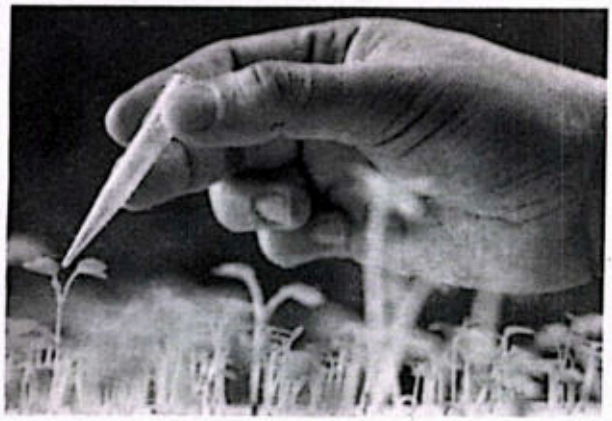


Fig. 10.1: Working of plant biotechnologist

Fig. 10.2: An array of Green House and Containment Facilities at NIBGE, Faisalabad. Pakistan

10.2.1 Genetically Modified (GM) Crops

GM crops including, wheat, rice, maize, sugarcane have been developed to tolerate harsh environmental conditions and pest resistance, thus increasing yields.

a. In Pakistan, Bt cotton (BT derived from *Bacillus thuringiensis*) is a prominent example in which 'cry' gen responsible for the pest resistance is obtained from a bacterium *Bacillus thuringiensis* and transferred to cotton plant. Bt cotton produces its own toxic chemicals to kill the pests including viruses, cotton flies and bollworms, hence there is less need for chemical pesticides and increased productivity of cotton, seed oil and cotton seed cakes (cattle & fish fodder).
b. GM variety of sugarcane, is resistant against sugarcane top borer (pest insect). Sugar yield of this GM variety of sugarcane is significantly higher than natural types.
c. Similarly, GM wheat, sugarcane and potatoes are well grown in phosphate deficient soil thus need of fertilizer is reduced significantly with higher production
d. GM varieties of wheat, sugarcane and potatoes developed in Pakistan are also drought, heat and frost resistant.
e. Another GM wheat variety is herbicide resistant and grown on large areas of Pakistan.
f. Genetically modified tomatoes and chilies are also been developed and grown in Pakistan.

Science Titbits

GM varieties	Characteristics
Bt cotton (Bt MON531- Cry1Ac)	Resistant against Pests e.g. viruses, cotton flies and bollworms
Sugarcane, with Cry1Ac + cry2Ab genes of bacteria	Resistant against Pest e.g. sugarcane top borer (insect)
Wheat, sugarcane and potatoes with AVP1 gene of bacteria	Grow well in phosphate deficient soil and resistant to drought, heat and frost
Wheat with CP4-epsps gene of bacteria	Resistant to herbicide

10.2.2 Improved Nutritional Content

Biotechnology has also enabled the enrichment of nutritional content in food crops by the process called bio-fortification. By this technique biologists have succeeded to increase the levels of essential nutrients including Vitamin A, iron and zinc in rice, maize and wheat which are staple crops of Pakistan. Biotechnologists of Pakistan have successfully prepared and released for farming, five varieties of bio-fortified zinc wheat, which include:
i) Zincol 2016 ii) Akbar 2019 iii) Nawab 2021 iv) Tarnab Rehbar v)Tarnab Gandum-1
Bio-fortified varieties of wheat contain about 40% extra zinc than other natural varieties and help to fulfil the nutrient deficiencies among the Pakistani population. These varieties also have other desirable traits for farmers, such as high yield and resistance to rust diseases.

10.2.3 Disease Resistance food crops

Biotechnology has facilitated the development of crops resistant to diseases that commonly affect crops in Pakistan. For instance, varieties of wheat resistant to wheat rust have been developed through biotechnological methods, ensuring higher yields and better food security. Efforts are being made to identify rust resistance genes and transform common varieties of wheat (Seher 2006, Punjab-11) and partial success has been achieved. This would surly improve wheat yield in near future.

4.2.4 Drought and Salinity Tolerance

Rain pattern in Pakistan is not smooth so floods and drought both extreme challenges are faced by Pakistan resulting water scarcity, salinity and water logging. Biotechnologist have focused on developing crops that can grow well under these such conditions. Drought and salt tolerant varieties of wheat and maize have been developed to ensure stable high yields despite irregular rainfall patterns (examples as given above in GM crops).

10.2.5 Improved Livestock Productivity

Biotechnology has also played positive role in improvement of livestock farming in Pakistan. To boost the livestock productivity and improved quality of dairy and meat products, different techniques have been introduced including embryo transfer, selection, reproduction for hybrid varieties of buffaloes and cows and artificial insemination to develop of cattle with desirable genetic traits. Disease resistant breeds of dairy and poultry are being developed locally for heathy and sufficient supplies. Collectively, these advancements will help in advancement of agricultural output and improved livelihoods in rural communities of Pakistan.

10.2.6 Food Processing

After production of quality food, it is greatly important to preserve and store food for continuous supply throughout the year and for export to other countries. To improve food safety, enhance nutritional content, extend storage life, convert into ready to use foods and packaging multiple biotechnological processes are applied. In food processing industries Enzymes, probiotics and other biotechnological tools are utilized for transforming agricultural products into useable food, or one form of food into another. It can include primary activities like grading, slicing or freezing and secondary activities include packaging and pasteurization to create safe foods for consumption.
Generally food processing involves following categories:
Food preservation: modern methods like canning, refrigeration irradiation and pasteurization as well as traditional methods like drying, smoking, salting, syrup dipping and fermentation.

Food preparation: This includes grinding grain into flour, cooking, mixing different foods.
Food safety: This is the main focus of food processing.
Value-added processing: This includes the development of protein, vitamin & mineral-rich foods and inclusion of food additives, aroma, food colures etc.

10.2.7 Biological Pest Control

Biological control methods have been developed using biotechnology to manage pests and diseases in crops for more sustainably. Viruses, bacteria and insects naturally growing on crops are genetically modified to develop into more farmer friendly for protection of crops. This also includes biotechnologically synthesis of bio-pesticides derived from natural sources to minimize the environmental hazards compared to more toxic chemical pesticides.
In conclusion, food biotechnology has played a crucial role in advancement of agriculture in Pakistan by solving major challenges like pests, diseases, nutrient deficiencies and environmental stresses. These advancements have been contributing significantly for food security, economic gains and sustainable agricultural practices in the Pakistan. However, lack of education and awareness, lower public acceptance, week regulatory obedience, infrastructure restrictions and week access to advanced biotechnological tools are big challenges.

10.3 MEDICAL BIOTECHNOLOGY IN ADVANCEMENT OF HEALTHCARE IN DIABETES AND CANCER

Use of living cells and organisms for the synthesis of diagnostic and pharmaceutical products used in treatment of various diseases is termed as Medical Biotechnology. Medical biotechnology has significantly advanced healthcare to manage the diabetes and cancer through continuously improving the treatments and diagnostic tools for these diseases.

10.3.1 Diabetes

Diagnosis of Diabetes

Diagnosis of type and level of disease is key step in its effective cure. Bio medical technology is being used for earlier, accurate and efficient diagnosis of diabetes. Following are some important contributions of biotechnology in diagnosis of diabetes.

a. **Biosensors for glucose monitoring** (glucose meters) have been developed by experimenting with genetically engineered organisms. Biosensors are used to measure blood glucose levels. The devices have electrodes which sense the level of enzymes in the blood that react with glucose. These devices generate an electrical signal proportional to glucose concentration per unit volume of blood.

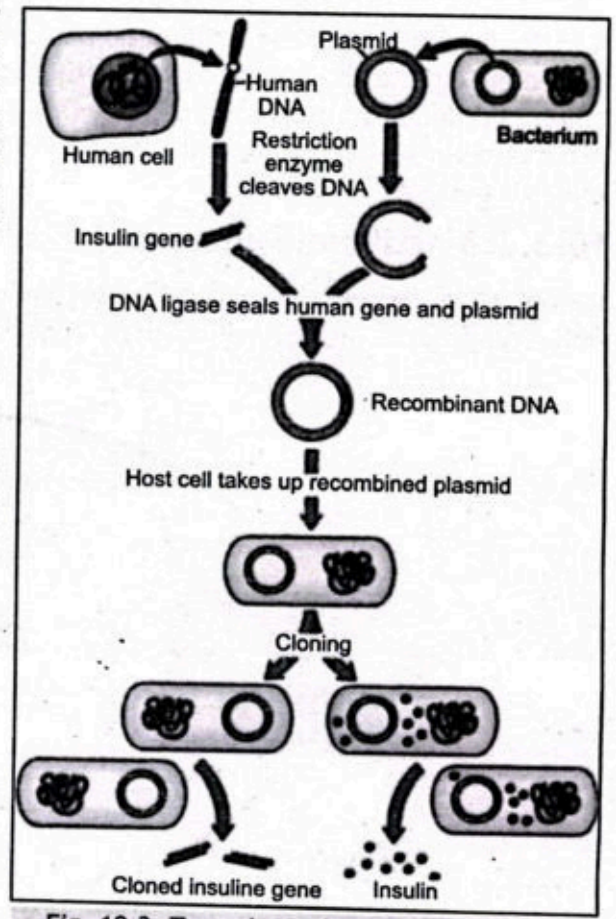


Fig. 10.3: Transplantation and cloning of a gene by the process of genetic engineering

b. **Continuous glucose monitoring (CGM)** devices have been developed which are the product of biotechnological innovation. These devices provide real-time data of blood glucose levels in a diabetic patients to manage their disease condition more effectively. Thus help in timely adjustments of insulin doses and dietary plants for patients.

c. **Assays** have been developed through biotechnology to measure HbA1c levels in blood. HbA1c test measures the amount of blood glucose attached to hemoglobin in RBCs. As RBCs generally live for about three months so, HbA1c levels reflect the average blood glucose levels over the past 2-3 months. This provides insights into long-term glucose control.

Science Titbits

- The CGM sensor checks blood sugar levels every few minutes and wirelessly sends the information to a digital controller. The controller, which can be a computer program in the pump or a mobile app, analyzes the data and instructs the insulin pump to deliver the right amount of insulin. The pump then delivers insulin when blood sugar levels rise above a target range.
- **Biomarker molecules** (proteins or other metabolites) for diabetes have been identified by biotechnologists for diagnosis of disease in its early stages or monitoring the progression of disease.

10.3.1.2 Insulin Production

Initially insulin for the use of diabetic patients have been derived from animal sources but now biotechnology has transformed insulin production by genetically modified bacteria. Insulin is now chiefly produced through recombinant DNA technology. This method is reliable for large-scale production of human insulin with purity and best quality, ensuring a stable and safe supply for diabetic patients worldwide.

10.3.1.3 Artificial Pancreas

Recent advancements in medical biotechnology is the development of the closed-loop insulin delivery systems. Patients with diabetes Type-1 can use this device.

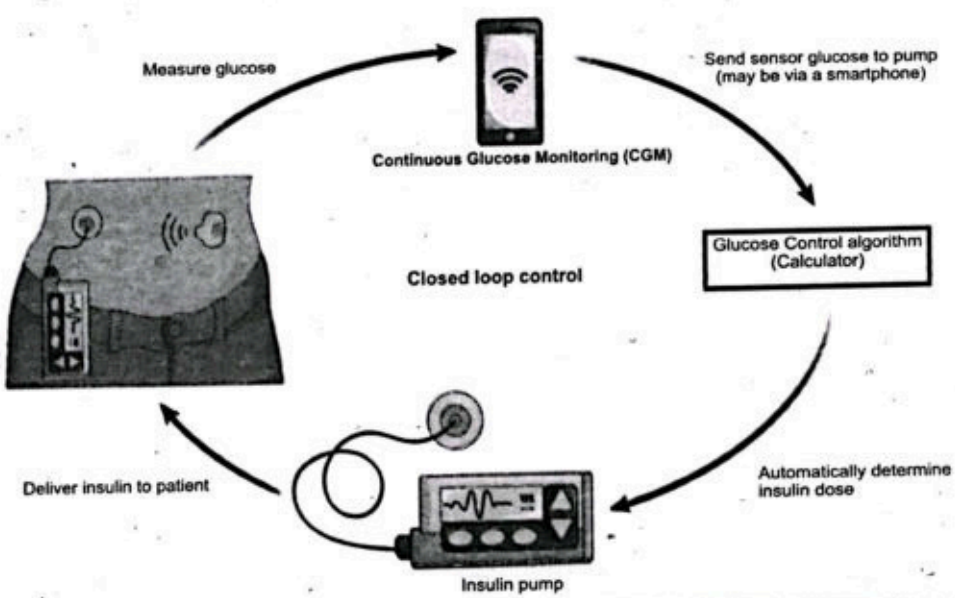


Fig. 10.4: Closed-loop (artificial pancreas) systems for automated insulin delivery

It is an insulin pump which release required amount of insulin after the detection of blood sugar levels. Insulin pump is connected to the monitor through a computer programme which continuously detect the blood sugar levels. This is also called artificial pancreas. These systems improve the glucose control and minimize complications

10.3.4 Cancer

Cancer is one of the most damaging and fatal disease all over the world and its prevalence is rising every year. Uncontrolled divisions of some the body cells is called **tumor**. All tumors are not termed as cancer. Tumor that remain small and localized in the tissue of its origin called **benign tumor** but when tumor grows aggressively to increase in size and spread to neighbouring tissues or organs, it is termed as **malignant tumor**. Spreading of tumor to other body tissues and organs is called **Metastasis. Cancer** is the group of diseases or abnormalities faced by the body due to aggressive growth and spreading malignant tumors.

Cancer may start almost in any organ of the human body. Most prevalent types of cancers include the cancers of lung, breast, prostate, oral and colorectal region. Cancer is the leading cause of deaths globally, with more than 10 million deaths in 2020 (Ali et al., 2022). According to World Health Organization statistics, collected by International Agency for Research on Cancer (IARC) 185,748 new cancer cases and 118 631 deaths have been reported in Pakistan in 2022.

To manage and treat this drastically fatal disease, biotechnology has helped the human in many ways. Effective management and treatment of any type of cancer mainly depends upon following factors:

a. Early and accurate diagnosis
b. Result oriented Targeted therapies
c. Patient Specific Medicine
d. Continuous research for innovative tools of cancer treatment

Early and accurate diagnosis of cancer

Diagnosis of cancer at initial stages is helpful for better and complete cure of cancer with least chances of reoccurrence. Biotechnology research involving different types of cancer cell lines has significantly helped oncologists for early and accurate detection of cancer type and stage of disease.

1. Confirmation of roles of different genes and protein in proliferation and metastasis is carried out by research involving in-vitro growth of the cancer cell lines.
2. Increase or decrease in level of specific proteins in the body of the suspected cancer patient is used as biomarkers. Over production of specific proteins in the human body is used as tumor marker for breast, ovarian and lung cancer. Over production of some proteins is related to aggressive nature of breast cancer. Higher levels of such protein can help in early diagnosis of cancer.
3. Mutations in different genes may lead to initiation and progression of cancer. Mutations in some tumor suppressor genes are significantly associated with high risk of breast, ovarian and uterine cancers.

Science Titbits

- Over production of HER2/neu protein in a cancer patient (called HER2/neu positive) is related to aggressive nature of breast cancer.
- CA125 protein is tumor marker for ovarian and lung cancer.
- BRACA1 and BRACA2 genes are tumor suppressor genes that produce proteins which help in repair of damage to DNA. Mutations in these genes affect the ability to suppressor tumor and significantly increase the risk of breast, ovarian and uterine cancers.

4. Target genes are experimentally knockdown or knockout in cell lines to validate the involvement of specific genes in cancer.
5. Experiments on animal models like rats and rabbits are also performed to confirm the role of specific genes and proteins markers in cancer.
6. Research for screening of cancer patients for the mutations and abnormal levels of specific protein markers also help for early diagnosis of cancer.
7. Biotechnologist have also developed the mechanism to get liquid biopsies instead of direct surgeries. Liquid biopsies are used to isolate and analyze circulating tumor cells, cell free DNA and other biomarkers in blood samples.

Result Oriented Targeted Therapies

Treatment of cancer by chemotherapy and radiotherapy may have wide range of side effects on the normal body tissues. Biotechnological research using different cancer cell lines has developed the drugs or chemicals for targeted therapies for various types of cancer. Multiple anticancer chemicals have been designed which are absorbed mainly by cancer cells and normal body cells either do not absorb these chemicals or absorb in negligible quantities. Thus, these chemicals specifically target tumor cells and thus minimize the damage to healthy tissues of the body. Now, doses of targeted anticancer drugs can be safely raised for effective damage to cancer cells. Monoclonal antibodies and specifically designed molecule inhibit multiple enzymes of cell cycle thus block the specific pathways which are crucial for cancer cell growth. This research has led the oncologists to have improved treatment outcomes with minimal side effects.

Patient Specific Medicine

Every cancer patients has different disease history and need specific medicine for treatment. Biotechnology has been playing an important role to decide precise medicine for cancer treatment. On the basis of their genetic makeup, tumor type, stage of cancer, age, gender and race, specific medicines and doses are decided for individual patients. This approach is continuously helping the oncologists to design the most effective therapies. Actions of newly designed medicines are investigated by experiments on cancel cell lines and animal models before applying to patients. Such patient specific precise plans, predictions and responses lead to greater success in treatment and long term disease free survival.

Continuous research for innovative tools of cancer treatment

Continuous research involving Biotechnology is playing a critical role in improved cancer detection and treatment. Extensive research on cancer biotechnology is in progress to develop innovative tools of cancer treatment.

Science Titbits

Innovative tools of cancer treatment

1. **Liquid biopsy techniques** to detect cancer through a simple blood test by identifying circulating tumor DNA (ctDNA), circulating tumor cells (CTCs) etc. as cancer-related biomarkers.
2. **Next-Generation Sequencing (NGS)** to analyze cancer related genetic mutations in DNA for earlier detection of cancers and its types.
3. **Monoclonal Antibodies** are being designed to specifically target cancer cells without harming healthy tissue e.g. Trastuzumab (Herceptin) for HER2-positive breast cancer.
4. **Immunotherapy** to engineer T-cells of patients to develop receptors for destroying

cancer cells in certain blood cancers.

5. **Gene knockdown** is carried out to reduce the expression of a specific gene temporarily by interfering the gene's mRNA. Thus production of protein, responsible for cancer progression is suppressed. The knockdown gene remains present in the genome so suppression can be reversed anytime.
6. **Gene knockout** is carried out to completely inactivate or remove the gene from the genome. To get the complete and permanent loss of gene function, gene is either completely deleted or mutated in such a way that normal functional protein responsible for cancer progression is not produced.
7. **Animal models** are experimentally used to verify the initial effects of gene mutations, gene knockdown or gene knockout. For this purpose rabbits, mouse or guinea pigs are used instead of direct humans as experimental animals in cancer research.
8. **Cancer Vaccines and Viruses:** vaccines are also being developed by experimentally using cancer cells or antigens of cancer patients to stimulate their immune system. White blood cells of patients start producing antibodies against cancer cells. Similarly, Viruses are engineered to selectively infect and destroy cancer cells only and healthy cells are not affected.
9. **Nanoparticles** are developed and used to deliver cancer drugs directly to specific cancer cells. By using nanoparticles, effectiveness of chemotherapy and radiation therapy is increased to get better cure.
10. **Use of artificial intelligence (AI)** will be greatly helpful for researchers to investigate the outcome of ongoing researches from available data. AI is being used to identify the disease patterns, cancer diagnosis and treatment results in clinical trials. AI will be helpful to biotechnologists in designing novel combinations of vaccines, viruses and targeted therapies of cancer.

10.4 POTENTIAL ADVANTAGES OF GENETIC EDITING WITH EXAMPLES IN MEDICINE AND AGRICULTURE

Genetic editing also called as genome editing. It is group of techniques used by genetic scientists to modify the DNA (genes) of an organism. Genetic editing is done by removing or adding the nucleotides in genes or altering the nucleotide sequence at specific positions of the genome.
Gene editing can be performed in two ways:

Ex-vivo/In-vitro Gene editing

Cells are removed from the body and grown in culture medium for applying any DNA editing technique.

In-vivo Gene editing

This method is much complicated where cells/tissue is not removed from body. Gene editing enzymes or proteins are injected into the body for altering the DNA sequence of specific body tissue.
Major genetic editing techniques include:

1. CRISPR-Cas9

CRISPR-Cas9 is the most commonly and specifically useful tool for genetic editing. Genetic scientists use CRISPR-Cas9 to modify the DNA of living organism. This technique, consists of a **guide RNA** and a **Cas9 enzyme** that cuts the DNA at the specific target site in DNA.

Science Titbits

CRISPR stands for "**C**lustered **R**egularly **I**nterspaced **S**hort **P**alindromic **R**epeats. **CRISPR** are repeated nucleotide sequences present in bacterial genome which are derived from the genome of viruses that have previously infected these bacteria. CRISPR act as memory which help the bacteria to defend against viruses. **Cas9** stands for "CRISPR-associated protein 9". Cas9 protein is an enzyme that works as molecular scissors to cut the DNA strands. **guide RNA (gRNA)** is a synthetic RNA sequence designed to match the target DNA sequence. gRNA directs the Cas9 enzyme to cut the DNA at specific target site.

2. TALENs (Transcription Activator-Like Effector Nucleases)

TALENs is some similar to CRISPR. This technique use a unique protein to recognize specific sequence and a nuclease enzyme to cut the DNA.

3. Zinc-Finger Nucleases (ZFNs)

ZFNs uses DNA cutting enzymes which are specifically designed for each gene to break the DNA at specific sites.

Fig. 10.5: Hand held Biolistic Gene Gun for Field and Lab Plant Transformation.

Base Editing

This technique is a modified form of CRISPR in which highly specific single nucleotide is changed in the DNA without cutting the strands. One nucleotide base may be replaced to other e.g. A is replaced by G or C is replaced by T.

Gene editing has multiple applications in genetic research especially related to medicine and agriculture. Research involving genetic editing has significant potential for the treatment of genetic diseases, improving crop yield and quality. Followings are some major advantages and their examples:

4.4.1 Medicine

Managing genetic diseases

Genetic editing is used to modify the genetic mutations causing genetic diseases for example; Thalassemia, Sickle cell anemia, Cystic fibrosis and Duchenne muscular dystrophy.

Drug Development and Preclinical Testing

Genetic editing help the biotechnologist to develop more accurate disease models for testing

new drugs. For example, human genes are inserted into mice to develop humanized mice. Then different doses of newly developed drugs are applied on model animal. Response of drug on humanized animals precisely guide the researchers about effectiveness of newly developed drugs against specific human disease. To check the effect of new drug on organisms with specific genetic defect, gene knockouts cell lines are used in drug testing.

Cancer Therapy

Biotechnologists are using genetic editing to modify or knockout those genes which are involved in tumor growth and cancer progression. Genetic editing also being used to alter genes responsible for resistance to chemotherapy. This approach is helpful in developing more effective drugs that specifically target cancer cells and do not effect healthy cells.

Viral Resistance

Genetic editing is being used to develop resistance against viral infections such as hepatitis and HIV. Genes producing host cell receptor proteins for viruses are modified to reduce the chances for viral infection and to improve the natural immune response. For example, editing of CCR5 gene in immune cells has been observed potentially effective to develop resistance to HIV infection rate.

10.4.2 Agriculture

Improvement in Food crops

Genetic editing is being used to modify the genomes of important food crops at a specific nucleotide sequences to develop desired traits in the modified plant varieties. Genetic editing useful in developing disease resistance, pest resistant and drought tolerant plants. This technique also useful in producing seeds and fruits enriched in nutrients and taste. For example, CRISPR-Cas9 technique has been used to edit genes in rice, maize and wheat to improve their yield and nutritional quality.

Improvement in Dairy livestock

Genetic editing may be used to modify existing genes or insert new genes for the development of beneficial traits especially in dairy livestock. By this technique animals resistant to viral and bacterial diseases are produced. Modified genes may increase meat and milk production in cattle to solve the problem of food shortage. Gene editing is also used to develop better acclimatization ability in imported cattle breeds to local environmental conditions. For example, modification in the myostatin gene in buffalos may develop extra muscle mass.

Environment friendly farming

Large amount of pesticides are sprayed to protect the food crops and fruit plants. Genetic editing may be helpful to reduce the need for pesticide use and for naturally sustainable agriculture farming. For example, editing of specific genes in food crops develop pest resistance in plants. This practice will gradually decrease the dependence on heavy use pesticide for healthy crops, thus will reduce the environmental pollution and improve the food safety naturally.

Bioethical limitations of gene editing

Although genetic editing is playing a significant role to address global challenges but it has also raised bioethical concerns. Bioethical concerns related to gene editing include compromised safety, unequal chances for humanity and unimaginable consequences. Responsible and regularized use of genetic editing is highly important for more benefits and minimum risks.

10.5 BENEFITS OF MARINE BIOTECHNOLOGY

Marine biotechnology is simply application of biotechnology to marine organisms and is also known as blue biotechnology. It involves the study and use of marine organisms, compounds produced by them and beneficial applications in marine ecosystems. In marine biotechnology researchers use huge resources of biodiversity in the oceans to develop useful products for human welfare in the field of medicine, agriculture, environmental protection and energy sources.
Some applications of marine biotechnology include:

Discovery and development of new pharmaceutical drugs

Marine biotechnologists have highlighted the marine flora and fauna that may be used to treat serious diseases like cancer, hepatitis and leukaemia. Marine sponges, algae and bacteria living in deep sea are rich sources of distinct medicinal compounds. Many of such pharmaceuticals compounds may potentially be used as antibiotics, anti-inflammatory and anticancer chemotherapy agents. For example, a drug ziconotide derived from the venom of cone snail in Pacific Ocean is used for relieve from chronic severe pain. Similarly, Trabectedin is derived from a marine tunicate, is used to treat cancer.

Fig. 10.6: Sample collection bay a Marine Biotechnologist

Medicinal and Cosmetic Products from marine life

Marine fish and algae produce omega-3 fatty acids in their bodies, which are beneficial for cardiovascular health and improved mental functioning. Marine biotechnologists are doing research to optimize the production and processing of high-quality omega-3 supplements. Marine organisms, particularly seaweed and algae are frequently used to prepare cosmetics and skincare compounds due to their moisturizing, anti-aging and antioxidant properties. Purified products obtained from marine extracts are commercially important in cosmetic industry. They are used in cosmetics due to their ability to minimize wrinkles, hydrate the skin and protection against UV light. A powerful antioxidant chemical Astaxanthin, obtained from marine micro-algae and shrimps, is used in skin allergy medicine for its anti-inflammatory role. Marine biotechnology play a role in development of vaccines to protect aquaculture species from viral diseases and improved productivity.

Science Titbits

- A drug, Trabectedin is derived from a marine tunicate, is used to treat cancer.
- A powerful antioxidant chemical Astaxanthin, obtained from marine micro-algae and shrimps, is used in skin allergy medicine for its anti-inflammatory role.
- Enzyme α-amylase that breaks down polysaccharides is isolated from the digestive tract of sea urchins.
- Enzyme β-Agarase that breaks down agar in the marine environment is isolated from crustaceans and seaweeds.
- Enzyme Xylanase that breaks down hemicellulose to sugars is isolated from marine algae, bacteria, fungi, and some protozoans.

Improved aqua-feed formulation

Marine biotechnology has advanced and optimize feed formulations for aquaculture species. Many seaweed and Algae are used to develop purified and concentrated feed for fishes, shrimps and octopus farming. Formulated feed is commercially used to optimize growth of delicious see food and minimize the environmental and disease impacts on them.

Marine Enzymes with unique properties

Enzymes with unique level of stability needed for the harsh conditions of industrial processes, are extracted from marine organisms found in deep-sea hydrothermal vents. These enzymes remain functional in extreme temperatures, diverse range of pH and pressures. These thermostable enzymes are used in food processing, preparation of cosmetics and medicines. Some other marine enzymes, due to their environment friendly nature are used in detergents, polishing and in textile industry. For example, enzymes **α-amylase, β-Agarase** and **Xylanase**.

Genetically modified Aquaculture and Fisheries

Marine biotechnology plays an important role in improving aquaculture and fisheries programs. Innovative breeding experiments involving genetic modification and use of probiotics have improved the health and growth of fish and shellfish. Biotechnology has developed disease resistant and highly nutritious species by modifying wild fishes.

Marine organisms have evolved with exceptional adaptation to survive in diverse environments from deep-sea hydrothermal vents to cold polar waters and corals. Genetics studies of such organisms may guide biotechnologists to understand how life can thrive in such extreme conditions. Specific genes responsible for their thermo-stability can be identified for use in biotechnology to improve the stability of organisms in aquaculture.

Biofuels from marine Algae

Marine algae are a great source environmentally friendly biofuels. Marine microalgae produce large amount of lipids, which are converted to biodiesel. Moreover, marine algae can artificially grow best in salty water which is abundantly present in salinity affected barren land. Growing marine algae in saline water also reduce the competition for freshwater resources. Biofuels obtained from Algae may be a potential renewable energy source, and may help to reduce the dependence on fossil fuels.

Bioremediation

Marine biotechnologists are identifying the role of multiple microorganisms in cleaning up the pollutants in sea water through bioremediation. Many marine bacteria and fungi, which are naturally involved in bioremediation of pollutants are being further engineered genetically. Microorganisms like Alcanivorax borkumensis (an alkane-degrading marine bacterium) naturally propagates in seawater containing crude oil. Genetically modified marine organisms can be employed to break down oil spills, plastics, polythene, pesticides and heavy metals and help in clean-up of polluted marine environments especially coastal areas.

To optimize the use of diverse biological resources of the oceans, biotechnologists and marine industries are continually innovating for human welfare and marine ecosystem conservation.

10.6 BIOREMEDIATION: TAKING BETTER CARE OF OUR ENVIRONMENT

Bioremediation is the process of using living organisms, especially microorganisms including bacteria, fungi and plants to clean up the environment contaminated with pollutants and toxins. Bioremediation is a natural and sustainable method to break down or neutralize the harmful pollutants and toxins from soil, water and air into less toxic or harmless products.
Bioremediation is playing a vital role in restoration and sustainability of natural environment. This method maintains cleaner and healthier ecosystems and help us in taking better care of our environment. Bioremediation is natural way to reduce the human impacts on the land, in air and water.

Types of Bioremediation

1. In-situ bioremediation: This occurs directly at the site of contamination. It does not need digging and transport of contaminated materials.
2. Ex-situ bioremediation: in this method contaminated material is removed, transported from its position and treated in some other area.

Advantages of Bioremediation

1. It is mainly a natural process and stimulates the natural breakdown of pollutants or toxins.
2. It mostly does not need any heavy machinery or labour.
3. It is cost-effective so generally less costly and affordable than conventional methods such as digging, dumping or chemical treatments.
4. It is environmentally friendly and reduce further stress on environmental as it involves minimum use of harmful chemicals.
5. It is Sustainable: It enhances natural processes, promoting long-term ecosystem health.
6. Naturally cleaning microorganisms may be further engineered genetically to any specific type pollutants in any environment.
7. It has diverse type of applications such as
   (a) clean-ups of oil spills at loading or unloading coastal area,
   (b) treatment of soil contaminated with heavy metal and
   (c) Degradation of pesticides and toxic industrial chemicals.

Mechanism of Bioremediation

Mechanism of bioremediation involves following basic steps or conditions.

i. Specific microorganisms (bacteria of Fungi) are stimulated to grow in polluted environment.
ii. Microbes utilize contaminants such as spilled oil, toxins, pesticides and household debris etc. as sources of food and energy.
iii. Growing microorganisms convert contaminants into water, harmless gases e.g. CO_2.
iv. A specific combination of the proper temperature, organic nutrients and moisture are provided. The absence or deficiency of components may stop or prolong clean-up of contaminants.
v. To improve the unfavourable rate of bioremediation, conditions for growth of microbe may be optimized to accelerate the bioremediation. This may be done by adding supporting materials for microbe growth such as molasses, vegetable oil, water or air.

Examples of Bioremediation in Pakistan

1. Oil spill from oil carrying ship, Tasman Spirit at Karachi seaport contaminated the water and sand at seashore and surrounding area badly. Bioremediation work on a portion of contaminated area was carried out by NIBGE (PAEC). Already isolated oil degrading bacteria that can live salinity level of seawater prepared in a laboratory at Atomic Energy Medical Center (AEMC) Karachi. Daily spray of bacteria, nutrients, bio surfactant mixed in water and ploughing was carried out for 75 days. Oil contaminated sandy sea shore was cleared within 75 days of application of bioremediation.
2. Lahore is big industrial city that faces challenges of sewerage water contamination of heavy metals and toxic chemicals. Theses toxins are being added mainly from tanneries, textile mills and paint industries into local water channels and underground water causing severe pollution. Bioremediation techniques have been applied to treat sewerage to usable cleaner water. This process is breaking down organic pollutants and neutralize heavy metals. Especially established wetlands have been used for bioremediation, where specific plants and microbes degrade or absorb pollutants, leading to comparatively cleaner water.

Concept and applications of industrial biotechnology

Industrial biotechnology, involves the use of microorganisms, enzymes and plants to produce products for different industries. It is a sustainable and eco-friendly so also called white biotechnology. It connects the capabilities of biological systems and processes for the production of chemicals, materials, energy and other valuable products.

Industrial biotechnology use renewable raw materials and environment friendly biological processes. Whereas, traditional chemical industry that mainly depends on fossil fuels and are is major cause of environmental pollution.

Major Components of Industrial Biotechnology:

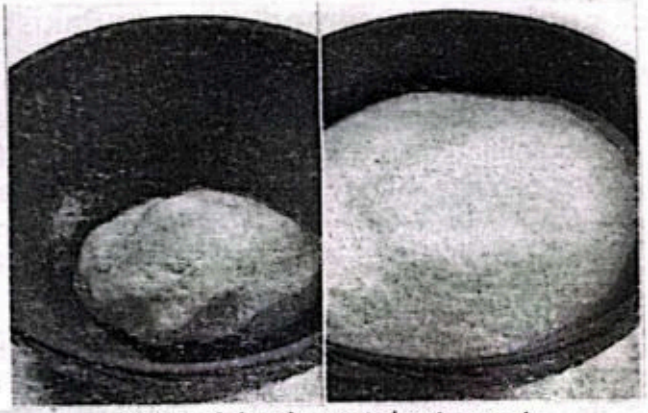
1. Microorganisms like bacteria, yeast and other fungi are used to carry out fermentation and other biochemical processes.
2. Enzymes catalyze specific reactions to improve the productivity and to reduce the environmental effect of industrial processes.
3. Manipulation of Biological systems and processes, to transform raw materials into better final products. Examples includes fermentation, enzymatic reactions and biological conversions of molecules
4. Genetic engineering for modification of biological systems to enhance productivity or synthesis of a new products.

Applications of Industrial Biotechnology

1. Food and Beverage Industry

Industrial biotechnology is carried out to Increase productivity, reduction in cost and synthesis of unique food products. Enzymes are used to enhance food production, for example, Rennet enzyme (found in the stomach of cattle to curdle milk for easier digestion) act on the proteins in milk to coagulation to produce cheese. Similarly, amylase enzyme is used to break down starch in brewing and the production of corn syrup with high fructose contents. Whole baking industry is based on fermentation.

Fig. 10.7: Cheese Production



Rising of dough yeast due to yeast

2. Biopharmaceuticals

For efficient and large scale production of complex biological drugs for example, insulin, vaccines, vitamins and antibodies by using microorganisms such as E. coli or yeast.

3. Agriculture

Industrial biotechnology is applied to improve crop yield and promotes sustainable farming without use of chemical pesticide. Useful bacteria that promote plant growth and protect crops from pests are used to produce bio-fertilizers and bio-pesticides. Plants may be genetically engineered to develop resistance against pests and harsh environmental conditions. Use of bio-pesticide reduces the environmental pollution and reduction of petroleum-based plastics.

4. Production of useful chemicals

By using microorganisms in biotechnological processes various useful chemicals such as citric acid, acetic acid and acetone are produced. Variety of amino acids, alcohols and organic acids are produced by fermentation. These processes of industrial biotechnology are energy-efficient, use renewable sources and produce less amounts of by-products.

5. Biofuels

Microorganisms are used in fermentation of sugars to from bioethanol and biodiesel. Renewable sources such as sugarcane, corn and algae are used are raw material for fermentation. Use of such alternative energy molecules instead of fossil fuels reduces carbon emissions and pollution.

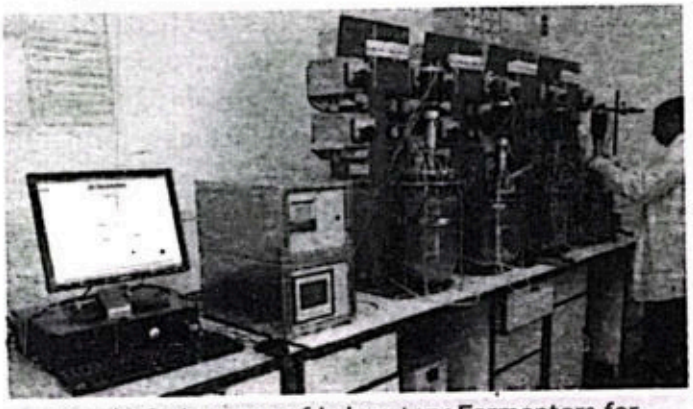


Fig. 10.8: An array of Laboratory Fermenters for Biofuel Production

6. Bioremediation and Environmental protection

Bioremediation uses microorganisms to degrade and detoxify environmental pollutants like oil spills, heavy metals and industrial wastes. Bioremediation associated with industrial processes provides a sustainable and economical solution to environmental pollution.

Industrial biotechnology plays an important role develop sustainable industries that fulfil the economic requirements and also protect environmental.

SUMMARY

1. Biotechnology is the "use of living organisms or their processes and products for the welfare of mankind".
2. Food biotechnology is important and crucial to meet the challenges of food security, malnutrition and environmental hazards related to agriculture.
3. Genetically modified crops produce higher yields of wheat, rice, maize, sugarcane and cotton due to their ability to tolerate harsh environmental conditions and pest resistance.
4. Biotechnologists of Pakistan have successfully prepared and released for farming, five varieties of bio-fortified zinc wheat including Zincol 2016, Akbar 2019, Nawab 2021, Tarnab Rehbar, Tarnab Gandum-1.
5. Food processing involves, food preservation, Food preparation, Food safety, Value-added processing including vitamin & mineral-rich food.
6. Biological control methods manage pests and diseases in crops using biotechnologically engineered Viruses, bacteria and insects naturally to develop farmer friendly crops. Biotechnologically bio-pesticides derived from natural sources minimize the environmental hazards compared to more toxic chemical pesticides.
7. Different ways to manage diabetes include, Biosensors for glucose monitoring, Continuous glucose monitoring, Biomarker molecules, biotechnological Assays to measure HbA1c levels in blood, artificial pancreas.
8. Effective management and treatment of cancer depends upon, early and accurate diagnosis, Result oriented Targeted therapies, Patient Specific Medicine and continuous research for innovative tools of cancer treatment.
9. Gene editing can be performed Ex-vivo/In-vitro Gene editing and In-vivo Gene editing.
10. 10.Gene editing methods include, CRISPR-Cas9, TALENs (Transcription Activator-Like Effector Nucleases), Zinc-Finger Nucleases (ZFNs), Base Editing and Prime Editing.
11. Genetic editing is used to modify the genomes of important food crops to develop disease resistance, pest resistant and drought tolerant plants.
12. Marine biotechnologists use huge resources of biodiversity in the oceans to develop useful products for human welfare in the field of medicine, agriculture, environmental protection and energy sources.
13. Marine biotechnologists identify the role of microorganisms (bacteria and Fungi) and further engineer them genetically to use in cleaning up the pollutants in sea water through bioremediation.
14. Industrial biotechnology use renewable raw materials and environment friendly biological processes.
15. Microorganisms are used in fermentation of sugars to from bioethanol and biodiesel. Renewable sources such as sugarcane, corn and algae are used are raw material for fermentation.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. The use of living organisms or their processes and products for the welfare of mankind is called:

   A) applied science B) technology C) biotechnology D) genetic engineering

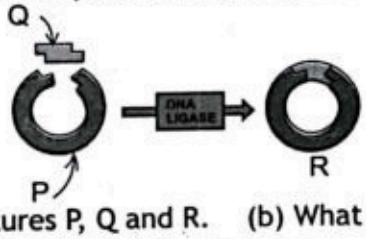
2. Gene "cry" responsible for the pest resistance is obtained from a bacterium:

   A) *Bacillus thuringiensis* B) *Bacillus aurius* C) *E. coli* D) Pseudomonas

3. Genetically modified variety of sugarcane, which have both Cry1Ac + cry2Ab genes of bacteria is resistant against:
   A) high temperature B) drought C) sugarcane top borer D) pH changes
4. These are used in making yogurt:
   A) bacteria B) fungi C) yeast D) alga
5. Biological pest control:
   A) is rapid control B) is slow control C) causes pollution D) damage crops
6. HbA1c test measures the amount of blood glucose:
   A) in plasma B) in liver cells
   C) attached to haemoglobin in RBCs D) attached to muscle cells
8. A bacterium is considered genetically modified when it has:
   A) a foreign gene B) Many plasmids
   C) A complete genome D) Restriction endonucleases
9. Interferons are special proteins produced by human cells that:
   A) Reduce pain B) Cure thalassemia
   C) Dissolve blood clots D) Limit spread of viral infections
10. Microorganisms Alcanivorax borkumensis is naturally propagates in seawater containing crude oil?
   A) an alkane-degrading marine bacterium B) naturally propagates in freshwater
   C) improve crop yield D) causes cancer

Section II: Short Answer Questions

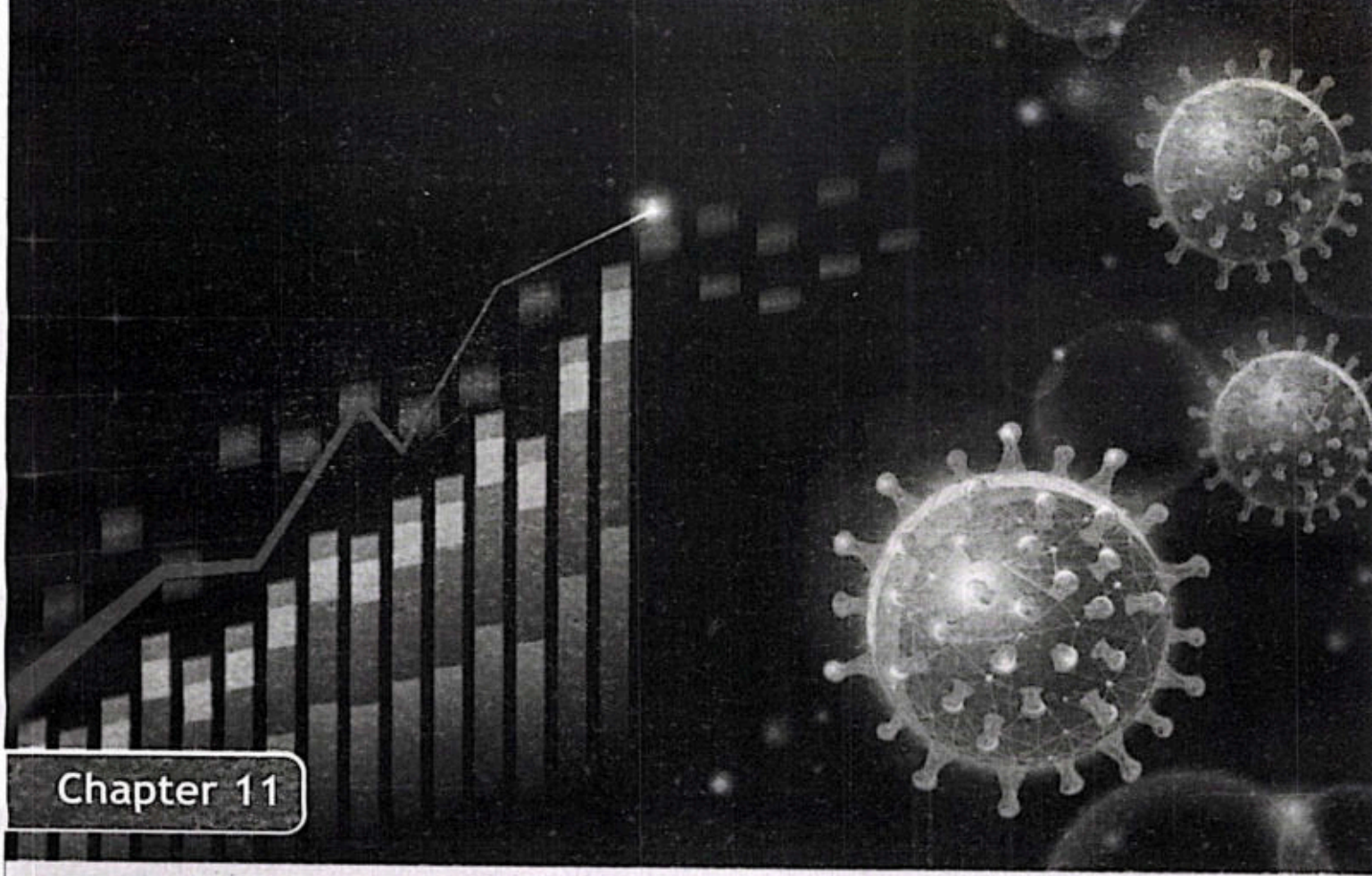
1. What is meant by artificial pancreas. Give its role..
2. How biomarkers work in sugar control?.
3. How has genetic engineering improved the quality of agricultural yield?
4. Effective management and treatment of any type of cancer mainly depends upon which factors?
5. How marine biotechnology is important in Medicinal and Cosmetic Products?
6. (a) Which microbes are involved in baking and dairy products?
   (b) What is the source of the sugars that are fermented in brewing?
   (c) How do bubbles of carbon dioxide gas help to make bread?
7. How Gene knockdown differs from Gene knockout?
8. The diagram shows an important step of genetic engineering.



   (a) Name the structures P, Q and R. (b) What is the next step of this process?
9. Name three Major genetic editing techniques.

Section III: Extensive Answer Questions

1. What is the importance of biotechnology?
2. Describe fermentation in yeast and bacteria.
3. Give details of key areas for modern research on cancer biotechnology?
4. What are the objectives of genetic engineering? How a gene is transplanted?
5. How gene editing technique is important for agriculture improvement?



Chapter 11

BIOSTATISTICS AND DATA HANDLING

SLOs: After completing this lesson, the student will be able to:

1. [B-10-K-01] Define biostatistics and its uses.
2. [B-10-K-02] Define and calculate mean, median and mode,
3. [B-10-K-03] Sketch a bar chart for a given set of biological data.

11.1 BIOSTATISTICS AND ITS USES

11.1.1 Biostatistics

Biostatistics is the application of statistical methods and principles to analyse and interpret the findings of biological, medical and health sciences. Biostatistics mainly deals with the collection, analysis and interpretation of data associated to living organisms and then presentation of findings for possible plans or solutions. Biostatistics is applicable to multiple fields of life sciences particularly health, medicine and agriculture.

Biostatistics help in estimation and calculation of productivity of agriculture, poultry and dairy farming. It is essential part of modern health science. It is used in multiple areas of public health including medicine, epidemiology and research. It plays a crucial role in understanding the disease outbreaks, health trend, possible preventive measure and effectiveness of specific treatment.

Components of Biostatistics studies: In biostatistics studies, following steps or components are followed:

Identification of problem: it is first ever parameter to observe any specific issue affecting the living organisms especially human

Designing experiments: for the solution of any specific issue, one must plan, how to conduct biological experiments

Collecting and analysing data: data collected from the experiments is analyzed thoroughly

Interpreting results: observed reasons and possible future effects are calculated on the basis of data collected from the experiments

Developing new tools: interpretation of experimental results lead to creating new tools or plan for dealing the problem e.g. health related issues

It is highly recommended for every biologist to have at least some basic understanding or learning of biostatistics.

11.1.2 Uses of Biostatistics

1. Agriculture and cattle farming needs for growing population: Biostatistics is involved in the assessment of demands of agriculture and dairy farming according to the rate of population growth. Furthermore it also help the government to assess the need for import or export of food items as per growing population.

2. Medical and Pharmacological Research: Biostatistics helps to design clinical trials and controlled studies to assess the efficacy and safety of newly designed drugs, treatment plan or medical instrument. Findings of medical research guide whether treatment resulted to improvements or side effects. Assessment of the effectiveness and safety of new drugs and deciding optimal doses for any new pharmacological drug.

3. Epidemiological studies and Policy Development: Biostatistics help in monitoring and analysis of data collected from population about the spread of any epidemic disease. Researchers can identify the risk factors, pattern and rate of disease. Epidemiological studies by using biostatic tools help to control and prevent future outbreaks (e.g., prevalence of Hepatitis and Polio, spread of COVID-19 etc.). Biostatistics evidence helps governments and public organizations to make decisions about population management, healthcare strategies and funding sources.

4. Management of Public Health: Each country conduct biostatics studies to estimate health trends within its population. Routine studies include data about birth rates, death rates and prevalence of different disease. It guides the government in planning health initiatives and allocation of resources for public. Biostatistics is useful to monitors and optimize the hospital

performance by calculating patient number, availability of doctors and medicine and effectiveness of treatment.

5. Genetic diseases: Biostatistics is also useful to analyse the data about inheritance patterns of genetic diseases in any population. For example, number of thalassemia and muscular dystrophy patients. It helps in guessing risk factors and behaviour of genetic disorders

6. Pollution indicators and Environmental protection: Biostatistics is used to analyse the pollution level, its causes and impact on population health. Different biostatic tools are designed to monitor the pollution level and potential health risks. It helps in designing policies to reduce health risks from environmental hazards. On the basis of findings, multiple steps are taken to protect the environment. For example, causes of smog, identification of affected areas, possible solution like plantation derives in Punjab especially in Lahore.

7. Survival Analysis: Biostatistics is used to predict and then note the survival rate of patients after a particular treatment. It helps to estimate life expectancy and the chances of success for medical treatments. For example, five years survival after the treatment of cancer is considered a successful treatment.

11.2 DEFINITION AND CALCULATION OF MEAN, MEDIAN AND MODE

In our daily life routine, we commonly hear the somewhat similar to following statements.

i. Heartbeat of human is 72 beats per minute
ii. Death rate due to cancer in Pakistan is 25 per thousand patients.
iii. Production of wheat in Punjab is 2000 Kg per acer.
iv. The price of the bananas in the market is Rs. 120 per dozen.
v. Food consumption of a human is 1kg per day.
vi. The rain fall in Islamabad is 1500mm per year.

If we think on about above mentioned statements, none of them is found exactly correct. In statement no. "i", our heart may not be same 72 in each minute of the day. During running it may be 90 per minute and during sleep it may be 60 per minute. Our heartbeat is approximately 72 in each minute. As given in statement "ii" It is quite possible that in one hospital only 5 cancer patient died out of 1000 visited for treatment and in other hospital 60 patients died out of 1000 patients gone through treatment. The death rate of cancer patients is about 25 per 1000, may not be same all the year and in every hospital. The production of wheat in one district of Punjab may be 1500 Kg from an acer and it may be 2400 Kg from one acer in another district. Although above statements are not exactly true but still they are very important. Actually, these are approximate statements in specific situations. In terms of statistics, we call such statements as average statements. In our daily conversation, we make many statements which have some meaning only on average basis. In different fields of life like agriculture, health, poultry, the idea of average is very important. Many experts at national and international level discuss the findings of studies in averages. The average is also called measure of central tendency.

Calculation of Average: Average is a single value which is calculated to represent the whole data. It may be calculated for a data sample of patients or a population of migrating birds etc. The average is a value which expresses the central idea of the observations. There are different ways to represent average of a data in different situations. For representation of a specific data, proper type of average is used by the expert who is calculating the average.

Types of averages: The following types of averages are commonly used:

(i) Arithmetic Mean (ii) Median (iii) Mode (iv) Geometric mean (v) Harmonic mean

Here in this chapter we will study only first three types of averages in detail.

11.2.1 Arithmetic Mean or simply Mean

Definition: Mean is the sum of all the values of data set divided by the total number of values in the data set. It is the single value which is calculated to represent the whole set of data. The symbol "x" (read as "x bar") represent the sample mean. The bar above the letter x represents the mean of a set of values.

$$\text{Mean} = \frac{\textit{Sum of values}}{\textit{Total number of values}}$$

Antibiotics	Source
$\bar{x} = \frac{\sum x}{n}$	$\bar{x} = \frac{\sum fx}{\sum f}$ (where, $x = \frac{\textit{lower limit} + \textit{upper limit}}{2}$ and f= frequency distribution)

Example 1(un-group data)

Dataset: Team of world health organization (WHO) planned to assess the prevalence of polio disease in Pakistan. Study to record the polio cases in Pakistan continued for consecutive two years. Number of confirmed Polio patients detected each month of 2022 and 2023 are given in table below. Calculate the mean polio patients per month in each year. Also compare the prevalence of Polio disease in both years.

Sr. no.		Number of Polio patients in year 2022	Number of Polio patients in year 2023
1	January	9	7
2	February	13	9
3	March	15	13
4	April	19	17
5	May	22	18
6	June	25	17
7	July	20	15
8	August	22	14
9	September	18	11
10	October	13	9
11	November	10	8
12	December	6	6
Total	**12 months**	**192**	**144**

Mean number of Polio patients per month in 2022 = $\frac{\text{Sum of Polio cases in complete year}}{\text{Total number of Months}} = \frac{192}{12} = 16$

Mean number of Polio patients per month in 2023 = $\frac{\text{Sum of Polio cases in complete year}}{\text{Total number of Months}} = \frac{144}{12} = 12$

Difference of Polio patients per month detected in 2022 and 2023= 16 - 12 = 04
Prevalence of Polio disease decreased in 2023 compared to 2022 by 04 patients per month.