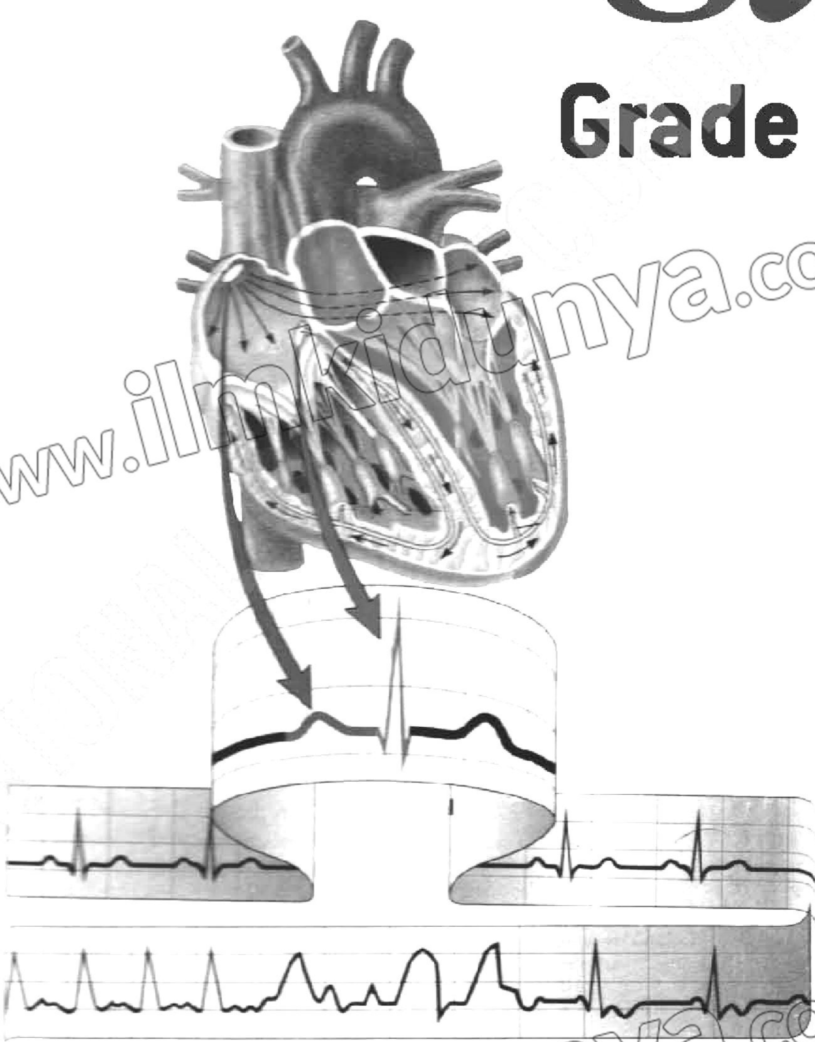
Based on National Curriculum of Pakistan 2022-23

Textbook of

Biology

Grade 12



National Book Foundation as
Federal Textbook Board Islamabad

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National Curriculum Council
Ministry of Federal Education and Professional Training

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PREFACE

This Textbook for Biology Grade 12 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).

Dr. Kamran Jahangir
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. **Endocrine System:** The main function of the endocrine system is to release hormones into the blood while continuously monitoring the levels. The hormones affect nearly all aspects of health; directly or indirectly. Some examples are metabolism, homeostasis, growth and development, reproduction, sleep-wake cycle, and mood etc.
7. **Skeletal System:** The skeletal system is the body's support structure. It gives the body its shape, allows movement, makes blood cells, provides protection for the organs and stores minerals.
8. **Thermoregulation:** It ensures your body stays at the right temperature, preventing you from getting too cold or too hot.
   Homeostasis: It is highly developed in warm-blooded animals living on land, which must maintain body temperature, fluid balance, pH and oxygen within rather narrow limits.
9. **Immunity:** Your body has three lines of defence against germ attack. First line keeps them out of your body, second line combats all invading microbes while third line conquers infections. Antibodies provide resistance against future infections. Allergies, autoimmune disorders and transplant rejections are defective immune responses.

10. **Biotechnology:** Studying biotechnology is important in many ways. Biotechnology is rapidly growing field in biology that offers numerous career in life including research, pharmaceuticals, agriculture, environmental management and bioengineering. Biotechnology lead advancements in healthcare, help in development of new drugs, vaccines and diagnostic tools. It plays a key role in treating diseases like cancer, genetic disorders and infections through personalized medicine and gene therapy. Biotechnology play a role in agricultural Improvement by developing genetically modified crops that increase crop yield and are pests, diseases and environmental stress resistant varieties. Biotechnology help to solve environmental issues by bioremediation like pollution, waste management and the conservation of biodiversity.

11. **Biostatics and data analysis:** Studying biostatistics is important for several reasons, especially in health and life sciences: Biostatistics is used in data analysis for medical and researchers. It plays a key role in clinical trials and epidemiological studies. It is highly important in the field of public health by tracking disease outbreaks, understanding health trends public health awareness. Scientific Research in biological and medical fields used biostatistics to design experiments, manage data and interpret results. It is also important for risk assessment and factors for diseases, identifying correlations between health behaviors prediction of future health risks.

12. **Structural biology and computational biology:** Structural and computational biology are emerging fields of biology. These include advanced studies and complex techniques but they provide hope for the treatment of cancer, AIDS, Alzheimer's and genetic diseases. Scientists of the world add their findings on online platforms like PDB so that everyone can freely access them and attain seemingly impossible achievements.

13. **Climate change:** The concepts taught in this chapter about climate change, its impacts on ocean ecosystems, and species extinction have practical applications that can directly influence daily life. By understanding how climate change affects ocean temperatures, acidification, and biodiversity, individuals are encouraged to make eco-friendly choices, such as reducing their carbon footprint, using energy-efficient appliances, and opting for sustainable transportation. Awareness of the vulnerability of marine species can guide people to support sustainable seafood choices and marine conservation efforts, such as participating in beach clean-ups and supporting conservation organizations.

    Knowledge about ocean acidification and the role of carbon dioxide absorption can drive personal actions like supporting reforestation and using renewable energy sources. People can also contribute to reducing climate impacts by supporting renewable energy projects, minimizing plastic use to protect marine life, and engaging in local efforts to conserve wetlands and native habitats. Educating others, especially the younger generation, about the impacts of climate change helps build a community that prioritizes sustainability and conservation.

    By understanding these changes, communities can also adapt better to extreme weather events, shifting their agricultural practices to more climate-resilient methods and preparing urban infrastructure for changing conditions. Through these actions, individuals can play a vital role in both mitigating climate change and adapting to its effects, ultimately helping to preserve biodiversity and maintain the health of ecosystems.

14. **Selected Topics:**Understanding biological warfare is important because it helps us prepare for potential threats to public health, like those seen in the past with plague and anthrax attacks. Practical biodefense measures, such as tracking disease outbreaks and developing vaccines, can help communities respond quickly to any biological threats. By learning about these strategies, we can create safer environments and work together to protect ourselves and our neighbors from possible attacks.

15. **Pharmacological Drugs:** Use of these drugs helps bridge the gap between theoretical knowledge about medicines and its practical application to patients.

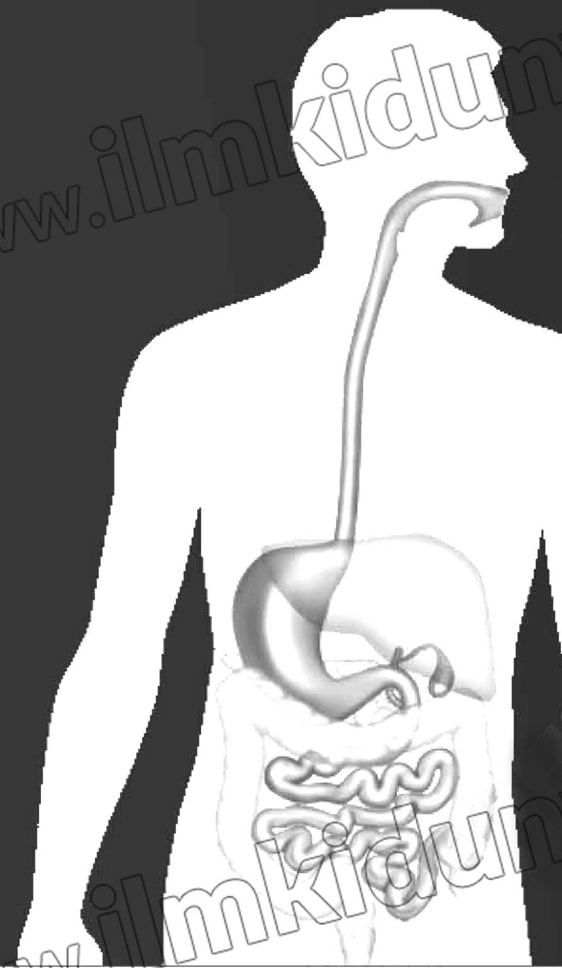
(Authors)

بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ

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

Contents

Chapter 1



DIGESTIVE SYSTEM OF MAN

Students' learning outcomes
After studying this chapter, students will be able to:

1. [B-12-R-24] Describe the mechanical and chemical digestion in the oral cavity.
2. [B-12-R-25] Explain swallowing and peristalsis.
3. [B-12-R-26] Illustrate with a diagram the structure of the stomach and relate each component with mechanical and chemical digestion in the stomach.
4. [B-12-R-27] Identify the role of the nervous system and gastrin hormone on the secretion of gastric juice.
5. [B-12-R-28] Describe major actions carried out on food in the three regions of small intestine.
6. [B-12-R-29] Trace the absorption of digested products from the small intestine lumen to the blood capillaries and lacteals of the villi.
7. [B-12-R-30] Describe the component parts of the large intestine with their respective roles.
8. [B-12-R-31] Correlate the involuntary reflex for egestion in infants and the voluntary control in adults.
9. [B-12-R-32] Explain the storage and metabolic role of liver.
10. [B-12-R-33] Describe the composition of bile and relate the constituents with respective roles.
11. [B-12-R-34] Outline the structure of pancreas and explain its function as an exocrine gland.
12. [B-12-R-35] Relate secretion of bile and pancreatic juice with the secretin of hormone.

Our body needs nutrients from the food we eat in order to stay healthy and function properly. Nutrients include carbohydrates, proteins, fats, vitamins, minerals and water. The digestive system breaks down and absorbs nutrients to use for important activities like energy, growth and repairing cells.

Anatomically and functionally the digestive system can be divided into a tubular gastrointestinal tract (GIT) and accessory digestive organs. The organs of GI tract are oral cavity, pharynx, esophagus, stomach, small intestine and large intestine. The accessory digestive organs are the teeth, tongue, salivary glands, liver, gall bladder and pancreas.

The GIT is a continuous tube from mouth to the anus. It is specialized at various points along its length, with each region designed to carry out different role. GIT is approximately 9 m (30 ft.) long. It passes across the thoracic cavity and enters the abdominal cavity at the level of diaphragm.

The digestive tube consists of four major layers: an internal mucosa and an external serosa with a submucosa and muscularis in between. These four layers are present in all areas of the digestive tract from esophagus to the anus.

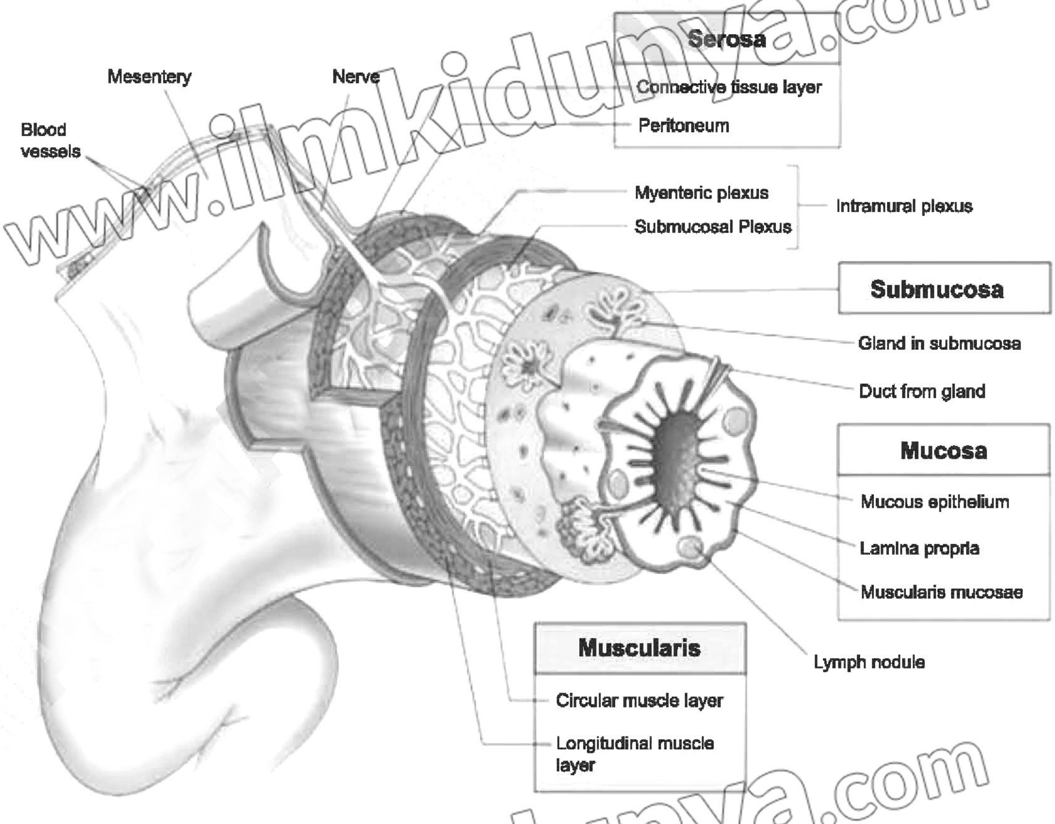


Fig. 1.1: Histological layers of the digestive tract

1.1 ORAL CAVITY

The oral cavity is surrounded by the lips, cheeks, a tongue and a palate and includes a chamber between the palate and tongue called **oral cavity**. The **tongue** has rough projections called

papillae on the surface of the tongue cause friction; useful in handling the food. The papillae also contain **taste buds.** The palate forms the roof of the oral cavity. Different **teeth** are adapted to handle food in different ways. There are three pairs of **salivary glands**. These glands secrete saliva having saliva. In the oral cavity mechanical and chemical digestion takes place.

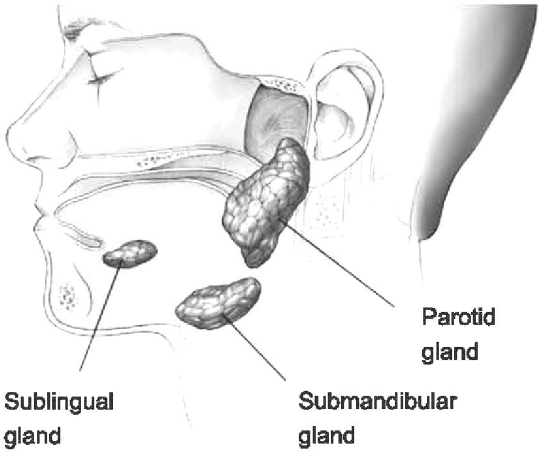


Fig. 1.2: Human salivary glands

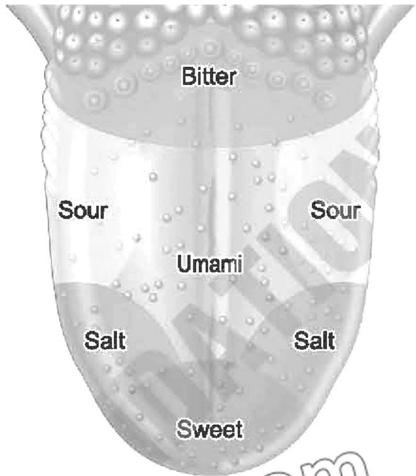


Fig. 1.3: Human taste buds map

Mechanical digestion

Mechanical digestion is the physical division of a mass of food into smaller pieces. Cooking and through chewing of food destroys the cellulose of starch covering and increases the efficiency of the digestive process. Food taken into the mouth is chewed or masticated by the teeth. **Mastication** breaks large food particles into smaller ones, which have a much larger surface total surface area for the action of digestive enzymes.

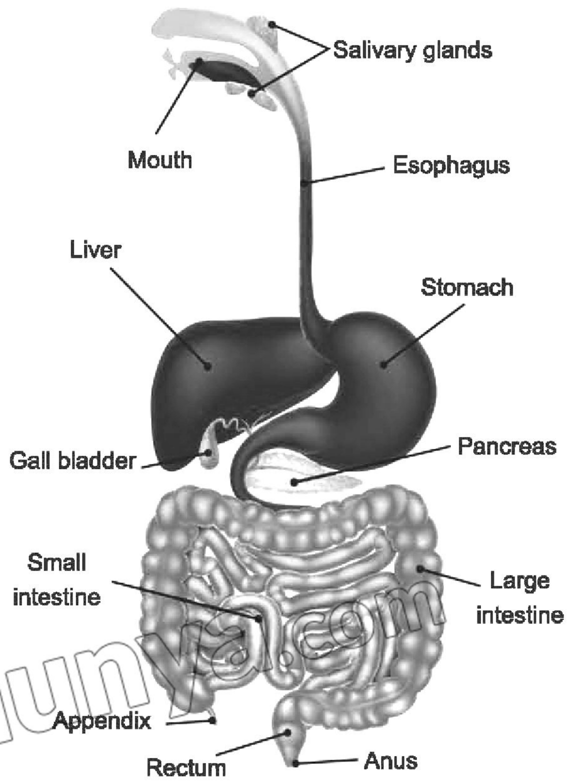


Fig. 1.4: Human digestive system

Chemical digestion

Chemical digestion in the oral cavity is minor. The two enzymes secreted in the oral cavity are **salivary amylase** and **lingual lipase**. The watery part of saliva contains the digestive enzyme called salivary amylase (ptyalin, or alpha-amylase). Salivary amylase is chemically identical to pancreatic amylase and digests starch. It breaks the covalent bonds between glucose molecules in starch and other polysaccharides to produce maltose, maltotriose, (maltotriose is a trisaccharide consisting of three glucose molecules linked with α-1,4 glycosidic bonds) and isomaltose (isomaltose is a disaccharide similar to maltose, but with a α-(1-6)-linkage instead of the α-(1-4)-linkage.). Lingual lipase hydrolyzes triglyceride ester bonds to form diacylglycerols and monoacylglycerols.

1.2 SWALLOWING AND PERISTALSIS

Pharynx is a cavity behind the mouth.

Swallowing Mechanism

The act of swallowing involves a set of reflexes. It can be divided into three phases.

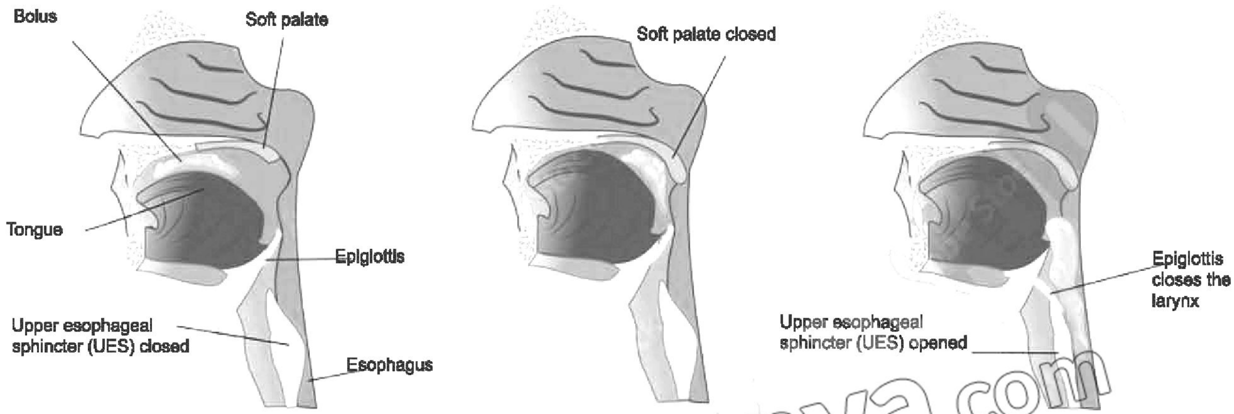


Fig. 1.5: Process of swallowing

Phase 1: Oral Phase

This process is the only voluntary part of swallowing. Food is moistened with saliva and food bolus is formed. The tongue pushes the bolus to the back of the throat. It starts with lip closure.

Phase 2: Pharyngeal Phase

Starts with stimulation of tactile receptors in the pharynx, swallow reflexes are initiated. Soft palate lifts to cut off nasal airways. Bolus moves over back tongue and the tongue blocks the oral cavity to prevent the food going to the oral cavity. **Epiglottis** is pushed backward over larynx. Larynx and vocal folds contract covering the entry of the trachea to protect airways, respiration temporary arrested. **Upper esophageal sphincter** opens to allow passages to the esophagus.

Phase 3: Esophageal Phase

Food bolus is propelled down the esophagus by peristalsis. The larynx moves down back to the original position.

Peristalsis

Peristalsis is a wave-like muscular contraction that propels food and fluids through the digestive tract and other tubular organs. It's an involuntary, rhythmic process that moves contents along in an anterograde (forward) direction, starting from the esophagus and continuing through the intestines and other systems.

Anti-peristalsis is the wave-like muscle contractions in the digestive tract that move contents backward instead of the usual forward direction. This is typically associated with vomiting reflex.

Functions of Peristalsis

Propulsion: Peristalsis pushes food and fluids through the digestive system, enabling digestion and absorption.

Mixing: In the stomach and small intestine, peristalsis helps mix the food with digestive juices and exposes it to the absorptive surfaces.
Waste Removal: In the large intestine, peristalsis drives waste products towards the rectum for elimination.
Other Systems: Peristalsis also occurs in other tubular organs like the urinary tract (moving urine from the kidneys to the bladder) and bile ducts (moving bile from the gallbladder to the duodenum).

Mechanism of Peristalsis

Muscle Contractions: Peristalsis involves the contraction of circular and longitudinal muscles in the walls of the digestive tract and other tubes.
Wave-like Movement: These contractions create a wave-like motion that pushes the contents along.
Involuntary: The process is controlled by the nervous system, particularly the **myenteric plexus** in the digestive tract.

> The **myenteric plexus** lies in between the outer longitudinal and inner circular smooth muscle layers of the intestines. By stimulating these muscles, it controls motility along the gastrointestinal tract.

Examples of Peristalsis

Swallowing: When you swallow, the muscles in your esophagus contract in a peristaltic wave to move the food bolus down to the stomach.
Digestion: In the small intestine, peristalsis moves the digested food (chyme) along, allowing nutrients to be absorbed.
Waste Removal: In the large intestine, peristaltic waves push waste products towards the rectum, where they are eliminated as stool.

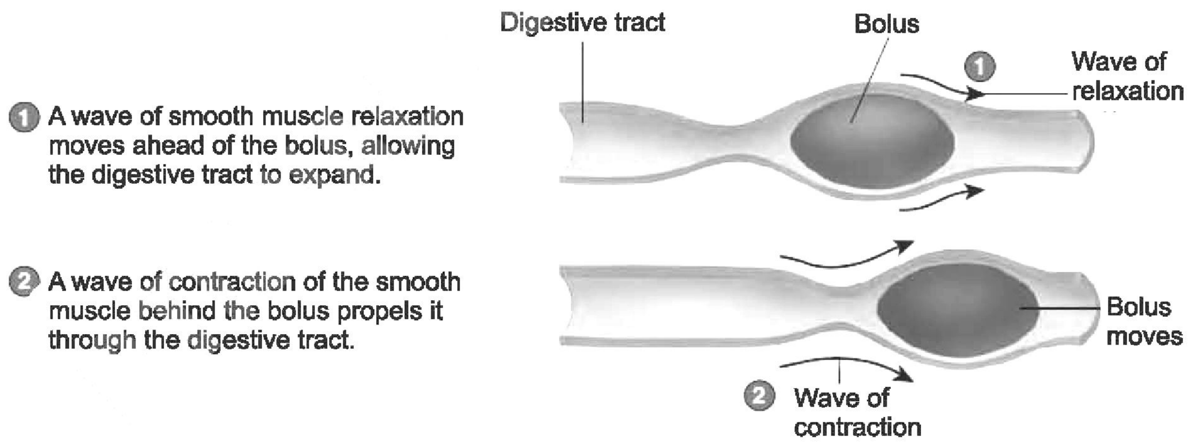


Fig. 1.6: Peristalsis

1.3 ESOPHAGUS AND STOMACH

Here we will discuss the structure of esophagus and stomach. We will relate each component of stomach with mechanical and chemical digestion.

Esophagus

The esophagus or oesophagus is located in the center of the chest in an area called the

mediastinum. It lies behind trachea and in front of the vertebral column. It is about 25cm long.

At the opening of the upper esophagus, there's a ring-shaped muscle called the **upper esophageal sphincter**. It senses when food or liquid is coming towards it. When it gets the signal, the sphincter relaxes or opens so that food can enter esophagus. When there is no food or liquid in sight, it stays closed. The esophagus passes through diaphragm and connects to the stomach. Once inside the esophagus, peristalsis pushes the food downward and reaches the lower esophagus.

At the opening of the lower esophagus, there's another ring-shaped muscle called the **lower esophageal sphincter (LES)**. Like the upper esophageal sphincter (UES), it senses when food and liquid are coming. It relaxes and lets the food pass through to the stomach. When no food or liquid is coming its way, it usually stays shut to prevent stomach acid and digestive juices from getting into the esophagus.

As esophagus is a passage way so no digestion takes place here.

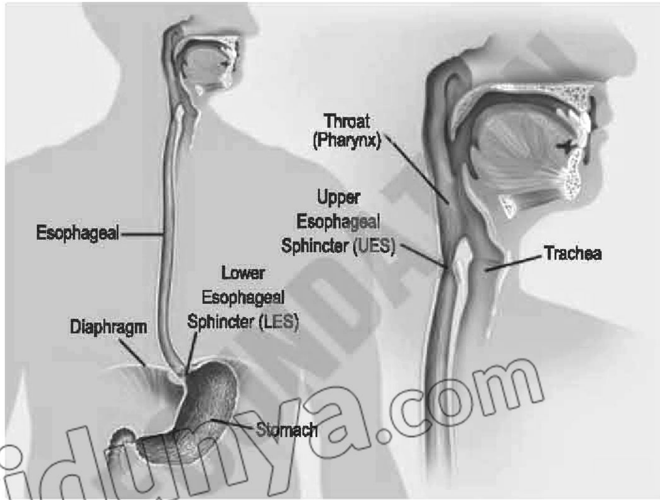


Fig. 1.7: Esophagus

Stomach

Anatomical Structure

Divisions of the Stomach: The stomach has four main anatomical divisions; the cardia, fundus, body and pylorus:

a. **Cardia:** It surrounds the superior opening of the stomach.

b. **Fundus:** It is the rounded, often gas filled portion superior to and left of the cardia.

c. **Body:** It is the large central portion inferior to the fundus.

d. **Pylorus:** This area connects the stomach to the duodenum. It is divided into the pyloric antrum, pyloric canal and pyloric sphincter. .

e. **Pyloric antrum**: It is the lower or distal portion above the duodenum. The opening between the stomach and the small intestine is the **pylorus**, and the very powerful sphincter, which regulates the passage of chyme into the duodenum, is called the **pyloric sphincter**.

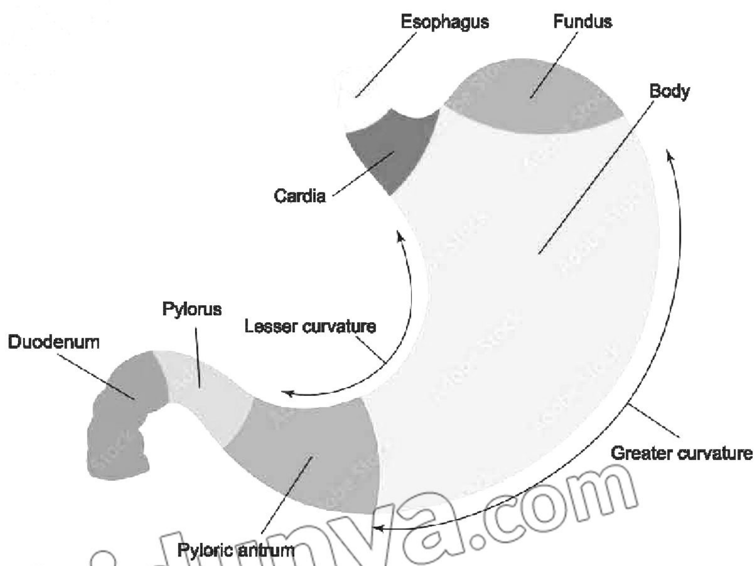


Fig. 1.8: Division of the stomach

Greater and Lesser Curvatures

The medial and lateral borders of the stomach are curved, forming the lesser and greater curvatures.

a. **Greater curvature:** It forms the long, convex, lateral border of the stomach. Arising at the cardiac notch, it arches backwards and passes inferiorly to the left. It curves to the right as it continues medially to reach the pyloric antrum.

b. **Lesser curvature:** It forms the shorter, concave, medial surface of the stomach.

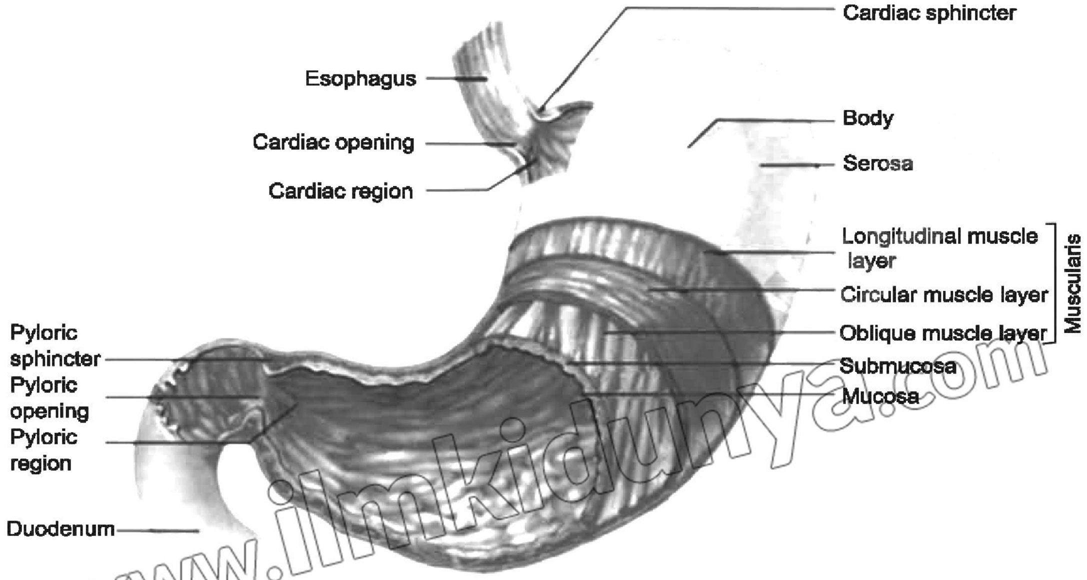


Fig. 1.9: Cutaway section of the stomach reveals muscular layers and internal anatomy

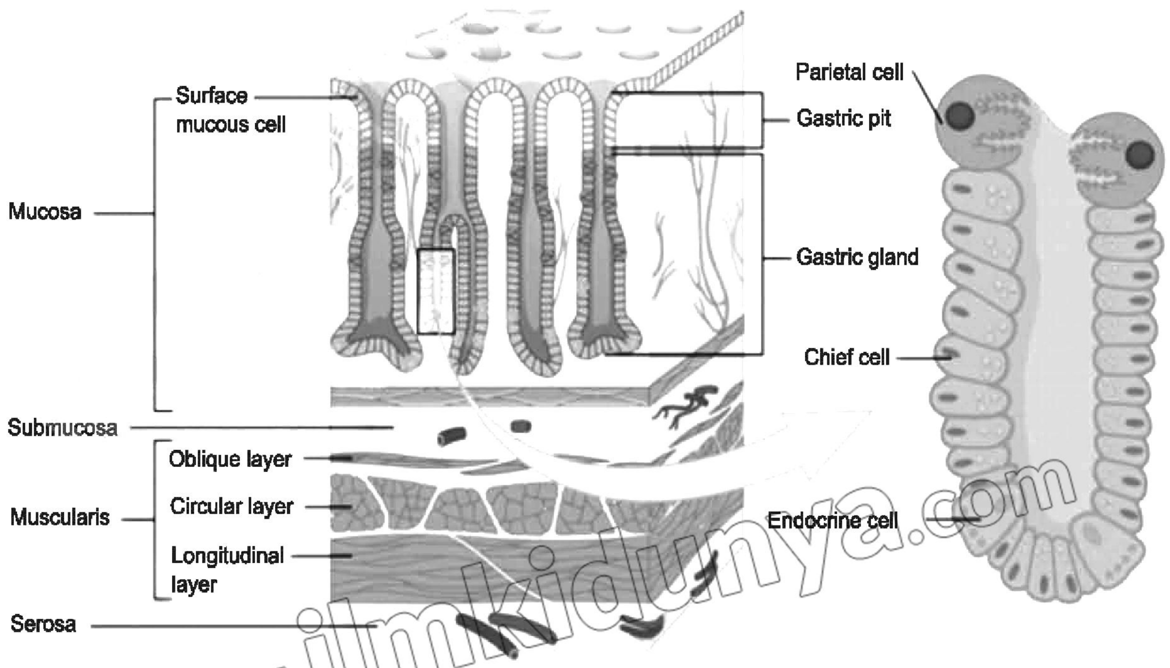


Fig. 1.10: A section of stomach wall that illustrates its histology, including several gastric pits and glands

There are four distinct layers in the stomach wall. The **serosa** is the outer most layer of the stomach. The **muscularis** of the stomach consists of three layers: an outer longitudinal muscle layer, a middle circular muscle layer and an inner oblique muscle layer. The next two layers are **submucosa** and **mucosa**. The stomach is lined with simple columnar epithelium. The mucosal surface forms numerous tube like **gastric pits**, which are the openings for the gastric glands. The epithelial cells of stomach can be divided into four main types. The first type is **surface mucous cells**, which produce mucus, is on the surface and lines the gastric pit. The remaining three are in the gastric gland. They are: (1) **Parietal (oxyntic) cells** produce hydrochloric acid and intrinsic factors (2) **Chief (zymogenic) cells** secrete pepsinogen (3) **Endocrine cells** secrete the hormone gastrin into the blood.

Functions of stomach

Digestion in the stomach can be divided into two types: mechanical digestion and chemical digestion.

Mechanical digestion: The mixing action of the stomach walls allows mechanical digestion to occur in the stomach. The smooth muscles of the stomach produce contractions known as **mixing waves**. This is made more efficient by the fact that unlike other region of the alimentary canal the stomach has three layers of smooth muscles. The churning action of the stomach or mixing waves mix the boluses of food with gastric juice. This mixing leads to the production of the thick liquid known as **chyme**.

Chemical digestion: Stomach secretions include mucus, hydrochloric acid, gastrin, intrinsic factor and pepsinogen. The mucous cells secrete viscous and alkaline mucus. The thick layer of mucous lubricates and protects the epithelial cells of the stomach wall from the damaging effect of the acidic chyme and pepsin. **Parietal cells** in the gastric glands of the pyloric region secrete **intrinsic factor** and a concentrated solution of hydrochloric acid. Intrinsic factor is a glycoprotein that binds with vitamin B12 and makes the vitamin more readily absorbed in the ileum.

Hydrochloric acid produces the low pH of the stomach, which is normally between 1 and 3, but is usually close to 2. Although the hydrochloric acid secreted into the stomach has a minor digestive effect on digested food, one of its main functions is to kill bacteria that are ingested with essentially everything humans put into their mouths. The low pH of the stomach also stops carbohydrate digestion by inactivating salivary amylase. The low pH also denatures many proteins so that proteolytic enzymes can reach internal peptide bonds, and it provides the proper pH environment for the function of pepsin.

Chief cells within the gastric glands secrete inactive **pepsinogen**. Pepsinogen is packaged in **zymogen** granules, which are released by **exocytosis** when pepsinogen secretion is stimulated. Once **pepsinogen** enters the lumen of the stomach, it is converted to **pepsin** by hydrochloric acid and previously formed pepsin molecules. Pepsin exhibits optimum enzymatic activity at a pH of 3 or less. Pepsin catalyzes the cleavage of some covalent bonds in proteins, breaking them into smaller peptide chains.

1.4 ROLE OF THE NERVOUS SYSTEM AND GASTRIN HORMONE ON THE SECRETION OF GASTRIC JUICE

Approximately 2-3 litres of gastric juice are produced each day. Both nervous and hormonal mechanisms regulate gastric secretions. Hormones that regulate stomach secretions include gastrin, secretin, gastric inhibitory polypeptide, and cholecystokinin.

The sensations of the taste and smell of food, stimulation of tactile receptors during the process of chewing and swallowing, and pleasant thoughts of food stimulate centres within the medulla that influences **gastric secretion**. Neuronal stimulation of the stomach mucosa results in the secretion of **acetylcholine**, which stimulates the secretory activity of both the parietal and chief cells and stimulates the secretion of **gastrin** from endocrine cells. Gastrin is released into the circulation and travels to the parietal cells, where it stimulates additional gastric juice secretion.

The greatest volume of gastric secretions is initiated by the presence of food in the stomach. The primary stimuli are distention of the stomach and the presence of amino acids and peptides in the stomach. Peristaltic waves occur less frequently, are significantly more powerful than mixing waves, and force the chyme near the periphery of the stomach toward the pyloric sphincter. The pyloric sphincter usually remains partially closed because of mild tonic contraction. Each peristaltic contraction is sufficiently strong to force a small amount of chyme through the pyloric opening and into the duodenum.

1.5 SMALL INTESTINE

The small intestine is part of the digestive system. When food leaves stomach, it enters the small intestine. The small intestine connects to the large intestine. The intestines are responsible for breaking food down, absorbing its nutrients and solidifying the waste. The small intestine is the longest part of the GI tract, and it is where most of the digestion takes place.

The small intestine consists of three parts: the duodenum, the jejunum and the ileum. The entire small intestine is about 6 m long.

Duodenum

The duodenum is the first part of the small intestine. It extends from the pyloric sphincter of the stomach. It is a short structure ranging from 20-25 cm (8-10 inch) in length, and shaped like a "C". It surrounds the head of the pancreas.

Pancreatic juice: The secretion of pancreas is called pancreatic juice. It is poured through the pancreatic duct. Pancreatic juice is slightly alkaline. Its pH is about 8. It neutralizes the acidic action of digestive enzymes secreted by the stomach. The important enzymes are (a) Pancreatic amylase (b) Pancreatic lipase (c) Trypsinogen (4) Chymotrypsinogen.

Pancreatic amylase: It is the starch digesting enzyme. It hydrolyses the polysaccharides to maltose and even to glucose.

Pancreatic lipase: It is the principal enzyme for the hydrolysis of fats. It hydrolyses fats to neutral fat in parts to its (i) mono and diglycerols (diglycerides). (ii) glycerol (iii) fatty acids.

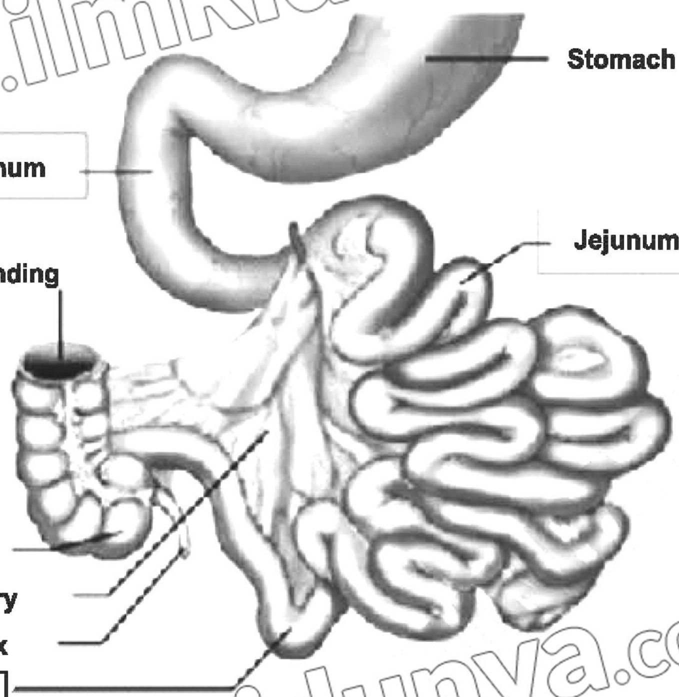


Fig. 1.11: Small intestine

Enzyme precursors

Two important enzyme precursors are found in pancreatic juice. They are trypsinogen and chymotrypsinogen. Both are the inactive forms.

Trypsinogen: The intestinal glands secrete an activator enzyme called **enterokinase**. The enterokinase converts trypsinogen into trypsin. Trypsin then activates more trypsinogen. The trypsin is the active form, which acts on proteins and converts them into polypeptides.

Chymotrypsinogen: The inactive chymotrypsinogen is converted to active form chymotrypsin by trypsin.

Bile: Bile is manufactured in liver but stored in gall bladder. Bile emulsifies fat causing them to breakdown into numerous small droplets called **emulsion. Emulsification** provides relative large surface area of lipid for the action of lipase enzyme and hence speed up the digestion of fats and oils.

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 the duodenum from the pancreas.

Jejunum and ileum

Jejunum is about 2.5 m long and ileum is about 3.5 m long. Here the digestion of protein carbohydrates and fats is completed. The lining of the jejunum and ileum secrete several enzymes.

- **Amino peptidase:** It splits polypeptides into dipetides.

- **Erepsin:** It splits peptides into amino acids.
- **Lactase:** It converts lactose to glucose and galactose
- **Maltase:** It converts maltose to glucose.
- **Sucrase:** It converts sucrose to glucose and fructose.
- **Pancreatic lipase:** It completes the digestion of fats into fatty acids and glycerol.
- **Chyle:** By the action of enzymes, chyme is turned into a watery emulsion called chyle.

1.6 ABSORPTION OF DIGESTION PRODUCTS

The ileum is the major site of nutrient absorption. Tiny finger like projections of the mucosa form numerous villi, which are 0.5-1.5 mm in length. Each villus is covered by simple columnar epithelium. It contains a blood capillary network and a lymph capillary called a lacteal. The structural features increase the surface area of small intestine and make it the largest part of the alimentary canal. The internal walls are folded to increase surface area for absorption. Villi and microvilli further increase surface area for absorption. To reach the blood or lymph a nutrient molecule must pass through an epithelial cell of the intestinal lining and through a cell lining the blood capillaries or lymph vessel.

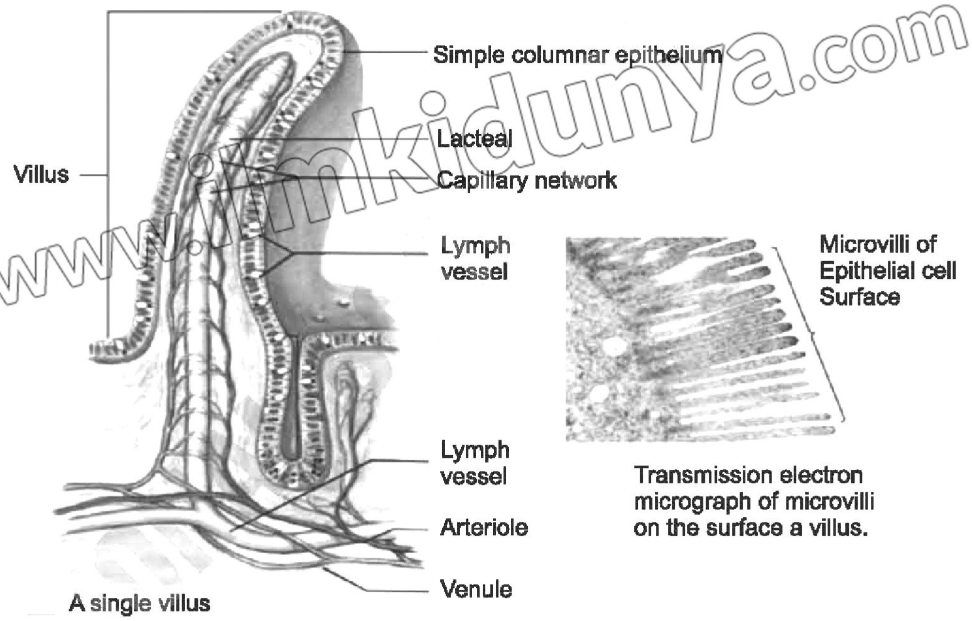


Fig. 1.12: Structure of villus

Absorption of carbohydrates

Absorption occurs by a combination of simple diffusion and active transport. The monosaccharides are transferred by facilitated diffusion to the capillaries of intestinal villi and are carried by the hepatic portal system to the liver, where non-glucose sugars are converted to glucose. Glucose enters the cell through facilitated diffusion.

SCIENCE TITBITS

Lipoproteins are referred to as high or low-density lipoproteins. A lipoprotein with high lipid content has a very low density (LDL), whereas a lipoprotein with high protein content has a relatively high density (HDL). Chylomicrons, which are made up of 99% lipid and only 1% protein, have an extremely very low density.

Absorption of lipids

Lipids are digested into fatty acids and glycerol. After glycerol and fatty acid are absorbed by epithelial cells, they are recombined into fats within these cells. The fats are then mixed with cholesterol and proteins, forming small globules called **chylomicrons**, most of which are transported by exocytosis out of epithelial cells into lacteals. Lymph containing chylomicrons, eventually drains from the lymphatic system into large veins that return blood to the heart.

SCIENCE TITBITS

The appendix contains a small amount of mucus associated lymphoid tissue which gives the appendix an undetermined role in immunity. However, the appendix is known to be important in foetal or fetal life as it contains endocrine cells that release biogenic amines and peptide hormones important for homeostasis for during early growth and development. Appendicitis is an inflammation of the vermiform appendix and usually occurs because of obstruction of the appendix. The removal of appendix is called appendectomy.

Absorption of protein

Individual amino acids are absorbed in epithelial cells of villi and enter in the **hepatic portal system**, which transports them to the liver. The amino acids may be modified in the liver or released into the bloodstream and distributed throughout the body. Most amino acids are used as building blocks to form new proteins, but some amino acids may be used for energy.

1.7 LARGE INTESTINE

The junction between ileum and intestine is **ileocecal junction** guarded by **ileocecal sphincter**. The **caecum** or **cecum** which is the proximal end of the large intestine, is where the large and small intestines meet. Attached to the caecum is a small blind tube about 9 cm long called the **vermiform appendix**. The walls of the appendix contain many lymph nodules. The **colon** is about 1.5 m long and consists of four parts: the **ascending colon**, **transverse colon**, **descending colon**, and **sigmoid colon**. The **rectum** is a straight, muscular tube that begins at the termination of the sigmoid colon and ends at the anus guarded by sphincter.

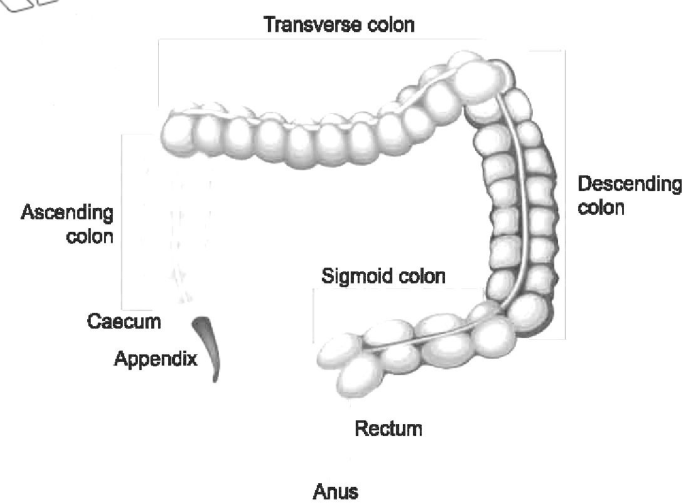


Fig. 1.13: Large intestine

Functions of large intestine

The large intestine performs several important functions. The major functions of the large intestine are: (a) Absorbing water and electrolytes (b) Absorption of vitamins (c) Reducing acidity and protecting from infections.

Absorbing water and electrolytes: Further digestion or breaking down of nutrients does not take place in the large intestine. The proximal half of the large intestine functions to reabsorb some of the water and electrolytes making the stool solid. The substances that remain in the tube becomes faeces, which is stored for a time in the distal portion (rectum) of the large intestine.

Absorption of vitamins: The large intestine also helps in absorption of vitamins made by bacteria that normally live in the large intestine. These bacteria also produce large amounts of vitamins. The most important of these is Vitamin K and Biotin (a B vitamin).

Reducing acidity and protecting from infections: The mucosa of the large intestine also:

(a) Secretes bicarbonates to neutralize the increased acidity resulting from the formation of these fatty acids and other digestive components at earlier parts of the intestines. (b) Acts as a mucosal barrier and protects from microbial infections and invasions.

1.8 DEFAECATION

Defaecation is the term for the act of expelling feces from the digestive tract via the anus

Defaecation reflex in infants

In infants the defaecation reflex causes automating emptying of the lower bowel at inconvenient times during the day because of lack of conscious control exercised through voluntary contraction of the external anal sphincter.

Defaecation reflex in adults

When it is appropriate, a person usually can initiate the defaecation reflex (North America spelling: defecation) by holding a deep breath and contracting the abdnominal muscles. The action increases the internal pressure and forces the faeces or feces into the rectum. When the rectum is filled, its wall is distended and the defaecation reflex is triggered. As a result, peristaltic waves in the descending colon are stimulated, and the internal and anal sphincter relaxes. The external anal sphincter is signalled to relax and the faeces are forced to the outside. The defaecation reflex persists only for a few minutes and quickly dies. A person usually can inhibit defaecation voluntarily by keeping the external sphincter contracted.

1.9 STORAGE AND METABOLIC ROLE OF LIVER

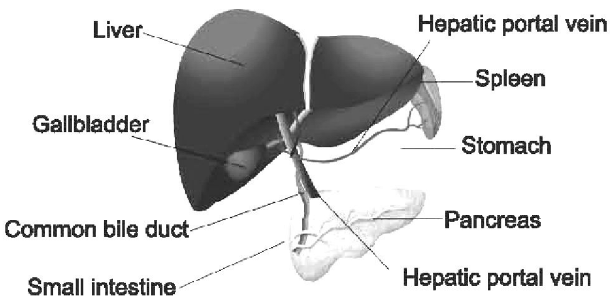


Fig. 1.14: Liver

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 liver filters (cleans) the blood, removing toxins and waste that eventually leave the body through urine and faeces. The lobes also contain thousands of lobules (small lobes). These lobules connect with many bile ducts, tubes that transport bile from the liver to the small intestine. There are two distinct sources that supply blood to the liver, including: Oxygenated blood flows in from the hepatic artery and nutrient-rich blood flows in from the hepatic portal vein.

The liver regulates most chemical levels in the blood and excretes a product called bile. This helps carry away waste products from the liver. All the blood leaving the stomach and intestines passes through the liver. The liver processes this blood and breaks down, balances, and creates the nutrients and also metabolizes drugs into forms that are easier to use for the rest of the body or that are nontoxic. More than 500 vital functions have been identified with the liver.

Some of the more well-known functions are given below:

1. Production of bile, which helps carry away waste and breakdown fats in the small intestine during digestion
2. Production of certain proteins for blood plasma e.g. serum albumin, globulins and fibrinogen
3. Production of cholesterol and special proteins to help carry fats through the body
4. Conversion of excess glucose into glycogen for storage (glycogen can later be converted back to glucose for energy) and to balance and make glucose as needed
5. Regulation of blood levels of amino acids, which form the building blocks of proteins
6. Processing of hemoglobin for use of its iron content (the liver stores iron)
7. Conversion of poisonous ammonia to urea (urea is an end product of protein metabolism and is excreted in the urine)
8. Clearing the blood of drugs and other poisonous substances
9. Regulating blood clotting
10. Resisting infections by making immune factors and removing bacteria from the bloodstream
11. Clearance of bilirubin, also from red blood cells. If there is an accumulation of bilirubin, the skin and eyes turn yellow.

When the liver has broken down harmful substances, its by-products are excreted into the bile or blood. Bile by-products enter the intestine and leave the body in the form of feces. Blood by-products are filtered out by the kidneys, and leave the body in the form of urine.

1.10 COMPOSITION AND ROLE OF BILE

The **gall bladder** (North American spelling: gallbladder) is a saclike structure on the inferior surface of the liver that is about 8 cm long and 4 cm wide. The gall bladder is connected to the common bile duct by the cystic duct. **Bile** is continually secreted by the liver and stored in the gall bladder.

Composition of bile: The liver produces and secretes bile. It is stored in the gall bladder. Bile contains no digestive enzymes. Bile consists of water, bile salts: sodium glycocholate and sodium taurocholate, bile pigment, bilirubin, cholesterols, lecithin (a phospholipid) mucus, cells and cell debris.

Role of constituents of bile: Bile salts reduce the surface tension of fat globules and emulsify them into droplets and thus increase their total surface area. This process is called **emulsification**. These small droplets are then acted upon by the enzyme lipase. **Bilirubin** results from the breakdown of haemoglobin. In the intestine, bacteria convert bilirubin into pigments that give the faeces its characteristic brown colour. Some of these pigments are absorbed from intestine, modified in the kidneys and excreted in the urine, contributing to the characteristic yellowish colour of the urine. Bile salts help in the absorption of fatty acids from the intestinal tract.

1.11 STRUCTURE AND FUNCTION OF PANCREAS

The pancreas is a complex organ composed of both endocrine and exocrine tissues that perform several functions. The endocrine part of the pancreas consists of pancreatic islets (islets of Langerhans). The pancreas consists of a head, located within the curvature of the duodenum, a body and a tail, which extends to the spleen.

Head: The widest part, located in the C-shaped curve of the duodenum (the first part of the small intestine).
Neck: Connects the head to the body.
Body: The main part of the pancreas, located behind the stomach and to the left of the superior mesenteric vessels.
Tail: The tapered end, located near the splenic hilum (the point where the spleen connects to other structures).

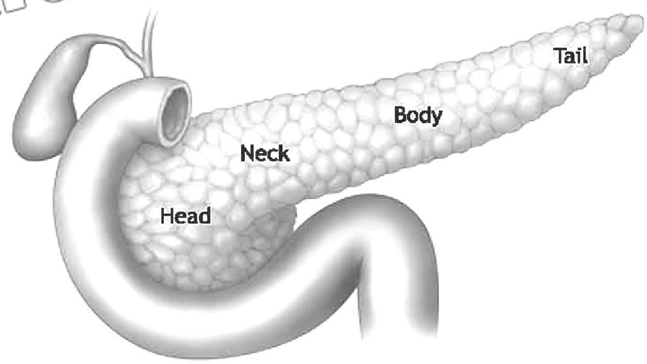


Fig. 1.15: Structure of pancreas

Pancreas as an exocrine gland

The exocrine secretion of the pancreas is called pancreatic juice and has two major components: an aqueous component and an enzymatic component. Bicarbonate neutralizes the acidic chyme that enters the small intestine from the stomach. The enzymatic component of the pancreatic juice is important for the digestion of all major classes of food. The major proteolytic enzymes are **trypsin, chymotrypsin**, and **carboxypeptidase**.
They are secreted in their inactive forms as trypsinogen, chymotrypsinogen, and procarboxypeptidase and are activated by the removal of certain peptides from the larger precursor proteins. If these were produced in their active forms, they would digest the tissues producing them. **Trypsinogen** is activated by the proteolytic enzyme enterokinase into **trypsin**. **Trypsin** then activates more trypsinogen, as well as **chymotrypsinogen** and **procarboxypeptidase. Amylase**, continues the polysaccharide digestion that was initiated in the oral cavity. **Pancreatic lipases**, breakdown lipids into free fatty acids, glycerides, cholesterol. **Deoxyribonucleases** and **ribonucleases**, reduce DNA and ribonucleic acid to their component nucleotides, respectively.

1.12 RELATION OF SECRETION OF BILE AND PANCREATIC JUICE WITH THE SECRETIN OF HORMONE

Secretion of bile and pancreatic juice is related to the hormone secretin.

Secretion of bile is related to secretin hormone

Fatty acids in the lumen of the duodenum stimulate endocrine cells to release the hormone **cholecystokinin** (CCK). CCK stimulates contractions in the smooth muscle of the gall bladder allowing bile release into the duodenum.
Acidic chyme in the lumen of the duodenum stimulates other endocrine cells to release the hormone **secretin**. Secretin produced by the duodenum is carried through the circulatory system to the liver and stimulates liver to release bicarbonate into the bile.

Secretion of pancreatic juice is related to secretin hormone

Pancreatic juice secretion is regulated by the hormones **secretin** and **cholecystokinin** which is produced by the walls of the duodenum upon detection of acidic food, proteins, fats and vitamins. Pancreatic secretion consists of an aqueous bicarbonate component from the duct cells and enzymatic component from the **acinar cells**. A clear alkaline secretion of the pancreas containing enzymes that aid in the digestion of proteins, carbohydrates, and fats.

The predominant effect of **secretin** on the pancreas is to stimulate duct cells to secrete water and bicarbonate. As soon as this occurs, the enzymes secreted by the **acinar cells** are flushed out of the pancreas, through the pancreatic duct into the duodenum.

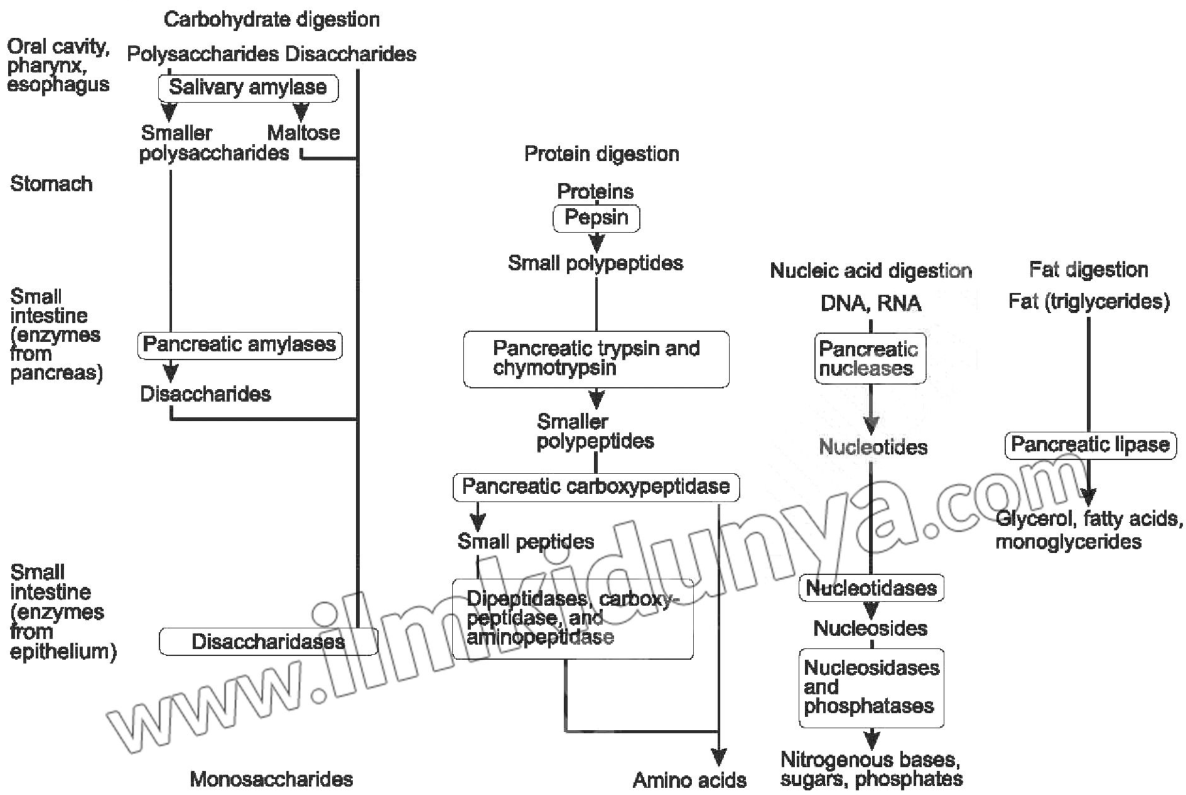


Fig. 1.16: Flow chart showing action of enzymes in GIT from mouth to small intestine

STEAM ACTIVITY 1.1

I. Investigate the action of amylase on starch

Materials required

starch solution, amylase (saliva), water bath, 2 test tubes, and iodine.

Substrate= starch, Enzyme = amylase, Product= maltose

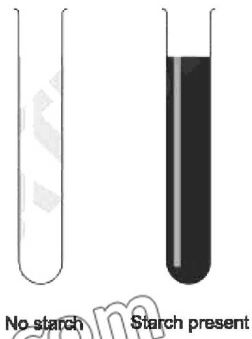
Procedure

1. Dissolve some starch in water to form a starch solution.
2. Add equal amount of starch solution to each of the two test tubes. Mark the test tubes as A and B.
3. Add saliva to the test tube marked as A. Shake the test tube to mix the contents. Do not add saliva in the test tube marked as B
4. Leave both the test tubes for ten minutes in a water bath at 37 °C (body temperature).
5. Add a few drops of iodine solution in both the test tubes.

Content of test tube	Chemical used in the test	Original colour of chemical	Final colour of chemical when added to test tube
Starch and saliva	Iodine	Yellow	Yellow
Starch	Iodine	Yellow	Blue/black

Conclusion:
1. Test tube A = iodine and saliva = yellow coloured solution
2. Test tube B = iodine and saliva = blue/black coloured solution

Therefore, amylase digests starch



II. Carryout qualitative food test for protein

Materials required

2 droppers, test tube, sodium hydroxide, copper sulphate

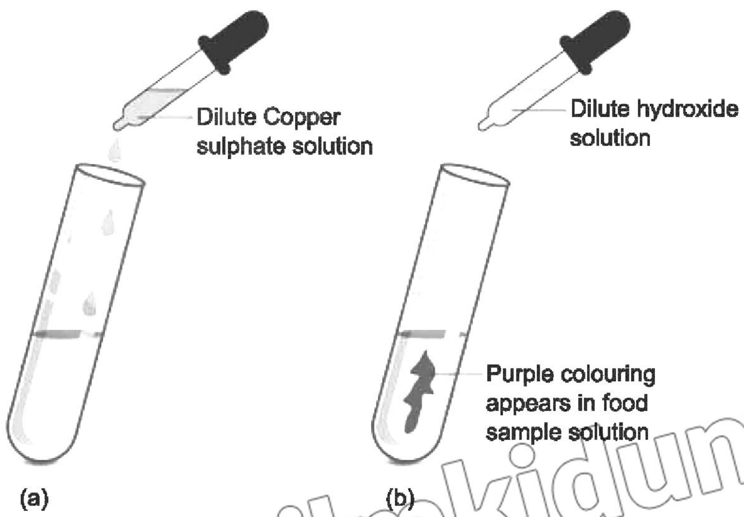
Method
1. Dissolve a sample of food such as yogurt and egg in water.
2. Add a few drops of sodium hydroxide (which is colourless)

Caution: Sodium hydroxide is corrosive; do not let it get on your skin.

3. Add a few drops of copper sulphate (which is blue)

Result: If the colour changes from blue to purple protein is present.

Food tasted	Final colour observed	Protein present or absent
Yogurt	Purple	Present
Egg	Purple	Present



Conclusion: Yogurt and egg contain protein

STEAM ACTIVITY 1.2

Observe, identify draw and label prepared histological slides showing cross section of human: stomach, small intestine, liver and gall bladder.

EXERCISE

Section I: Multiple Choice Questions
Select the correct answer:

1. Which among the following is the longest?
   A. stomach B. esophagus
   C. small intestine D. large intestine
2. Which structure does the appendix come off?
   A. transverse colon B. descending colon
   C. ascending colon D. small intestine
3. Which part of the Large intestine attaches to the appendix?
   A. transverse colon B. descending colon
   C. ascending colon D. cecum
4. What is the name of the part of the stomach attached to the esophagus?
   A. fundus B. pylorus
   C. body D. cardia
5. Where does the pancreatic duct directly join to?
   A. jejunum B. duodenum
   C. ileum D. liver
6. Where does the body of the stomach lie between?
   A. fundus and pyloric antrum B. pyloric antrum and cardia
   C. fundus and cardia D. cardia and pyloric antrum
7. Which one is the largest gland in the body?
   A. liver B. gallbladder
   C. pancreas D. large intestine
8. Pepsinogen is activated to pepsin by
   A. active secretin B. hydrochloric acid
   C. active pepsin and HCL D. gastrin
9. Liver secretes bile into the
   A. duodenum B. ileum
   C. jejunum D. ascending colon

10. Emulsification of fat will not occur in the absence of

A. lipase
B. bile pigment
C. bile salt
D. pancreatic juice

11. Fatty acids and glycerol are first absorbed by

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

12. The hormone responsible for stimulating secretion of hydrochloroic acid by stomach cells is

A. pepsin
B. secretin
C. gastrin
D. insulin

13. Enzyme trypsinogen is changed to trypsin by

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

14. Which of the following hormones stimulates the production of pancreatic juice and bicarbonate?

A. insulin and glucagon
B. cholecystokinin and secretin
C. gastrin and insulin
D. glucagon and insulin

15. Secretin and cholecystokinin are secreted in

A. pyloric region
B. Ileum
C. duodenum
D. esophagus

16. Which of the following is synthesized and stored in the liver cells?

A. galactose
B. lactose
C. glycogen
D. insulin

17. Which juice secreted by the alimentary canal plays an important role in the digestion of fats?

A. pancreatic juice, saliva
C. mucus, Hydrochloric acid
B. saliva, hydrochloric acid
D. bile juice, pancreatic juice

18. What is the role of mucus secreted by the stomach?

A. to digest protein
C. to kill germs in the food
B. to digest fats
D. to protect lining of the stomach

19. The majority of the water from the indigestible food is absorbed in the_______?

A. stomach
B. foodpipe
C. pancreas
D. large intestine

20. Which hydrolytic enzymes react in a low pH environment?

A. peroxidases
B. hydrolases
C. amylases
D. proteases

Section II: Short Answer Questions

1. What is mechanical digestion?
2. What is chemical digestion?
3. Describe peristalsis.
4. Name and write the function of epithelial cells of stomach of man.
5. Give one reason as to why some enzymes in stomach and intestine are secreted in inactive form?
6. Name the enzymes involved in protein digestion.
7. How could no secretion of HCl in our stomach affect food digestion?
8. How the stomach does protect itself from the damaging effect of HCl?
9. Why there are villi in the intestine and not in stomach?
10. Trypsin acts at alkaline pH. What provides the alkalinity?
11. What would happen to the activity of the intestinal enzymes if the pH in the small intestine remained at 2?
12. How does the absorption of fat differ from absorption of glucose?
13. Describe defaecation reflex in infants.
14. Describe defaecation reflex in adults.
15. Bile juice contains no digestive enzymes, yet it is important for digestion. Why?
16. What is the role of hormone gastrin in digestion?
17. What is the role of hormone secretin in digestion?
18. Describe the storage role of liver.
19. What is gall bladder? Write its function.
20. Write the differences between:
    (a) pharynx and larynx
    (b) pepsinogen and pepsin

Section III: Extensive Answer Questions

1. Describe the process of swallowing in man.
2. Describe the human stomach with diagram.
3. Describe the structure of human small intestine.
4. Explain the absorption of digested products from the small intestine lumen to the blood capillaries and lacteals of the villi.
5. Describe the large intestine of man. What are the functions of large intestine?
6. What is bile? Describe the composition of bile. What is the role of constituents of bile?
7. How secretion of bile is related to the secretion of hormone secretin?
8. Write the functions of liver of man.
9. What is the structure of pancreas? Explain the functions of pancreas as an exocrine gland.

Chapter 2

BLOOD CIRCULATORY SYSTEM OF MAN

Students' learning outcomes
After studying this chapter, students will be able to:

1. [B-12-R-36] State the location of heart in the body and define the role of pericardium.
2. [B-12-R-37] Describe the structure of the walls of heart and rationalize the thickness of the walls of each chamber.
3. [B-12-R-38] Trace the flow of blood through the heart as regulated by the valve.
4. [B-12-R-39] State the phases of heartbeat.
5. [B-12-R-40] Explain the roles of A node, AV node and Purkinje fibers in controlling the heartbeat.
6. [B-12-R-41] List the principles and uses of Electrocardiogram.
7. [B-12-R-42] Describe the detailed structure of arteries, veins and capillaries.
8. [B-12-R-43] Describe the role of arterioles in vasoconstriction and vasodilation.
9. [B-12-R-44] Describe the role of pre-capillary sphincters in regulating the flow of blood through the capillaries.
10. [B-12-R-45] Trace the path of the blood through the pulmonary and systemic circulation (coronary, hepatic-portal and renal circulation).
11. [B-12-R-46] Compare the rate of blood flow through arteries, arterioles capillaries, venules and veins.
12. [B-12-R-47] Define blood pressure and explain its periods of systolic and diastolic pressure.
13. [B-12-R-48] State the role of baroreceptors and volume receptor in regulating the blood pressure.
14. [B-12-R-49] Define the term thrombus and differentiate between thrombus and embolus.
15. [B-12-R-50] Identify the factors causing atherosclerosis and arteriosclerosis.
16. [B-12-R-51] Categorize Angina pectoris, heart attack, and heart failure as the stages of cardiovascular disease development.
17. [B-12-R-52] State the congenital heart problem related to the malfunction of cardiac valves.
18. [B-12-R-53] Describe the principles of angiography.
19. [B-12-R-54] Outline the main principle of coronary bypass, angioplasty and open-heart surgery.
20. [B-12-R-55] Define hypertension and describe the factor that regulate blood pressure and lead to hypertension and hypotension.
21. [B-12-R-56] List the changes in lifestyles that can protect man from hypertension and cardiac problems.
22. [B-12-R-57] Describe the formation, composition and function of intercellular fluid.
23. [B-12-R-58] Compare the composition of intercellular fluid with that of lymph.
24. [B-12-R-59] State the structure and role of lymph capillaries, lymph vessels and lymph trunks.
25. [B-12-R-60] Describe the functions of lymph nodes and state the role of spleen as containing lymphoid tissue.

Why do we need a transport system? You have read in the previous chapter that what is digestion? In chapter 1 you have read what are cells? All the cells of our body need food from small intestine and oxygen from the lungs. Carbon dioxide and waste chemicals have to be removed from the lungs and kidneys respectively. 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 oxygen and carbon dioxide, distributes nutrients to the body cells and conveys the waste products of metabolism to specific site for disposal. The cardiovascular system consists of a strong muscular heart, three kinds of blood vessels: arteries, capillaries, veins and blood. The study of the diseases of cardiovascular system is called **angiology**.

2.1 HUMAN HEART

Location: Although the size of heart varies with the body size, the heart of an average adult is about 14 cm long and 9 cm wide. The heart is within the mediastinum, which is bordered laterally by the lungs, posteriorly by the backbone, and anteriorly by the sternum. It base lies beneath the second rib. It distal end extend downward and to the left, terminating as bluntly pointed apex at the level of the fifth intercostal space.

Role of pericardium

The pericardium is a closed sac that surrounds heart. The inelastic nature of the pericardium as a whole prevents the heart from being overstretched or overfilled with blood. The pericardium is a fibre membrane found as an external covering around the heart. It protects the heart by producing a serous fluid, which serves to lubricate the heart and prevent friction between the surrounding organs. Apart from the lubrication, the pericardium also helps by holding the heart in its position and by maintaining a hollow space for the heart to expand itself when it is full. The pericardium consists of two parts, the outer part and inner part. **Visceral Layer** is directly covers the outside of the heart. **Parietal Layer** forms a sac around the outer region of the heart that contains the fluid in the pericardial cavity.

2.2 STRUCTURE OF WALLS OF HEART

The heart consists of four chambers: two atria (meaning, entrance chamber) and two ventricles (meaning, belly). The atria lie above the ventricles. The heart wall is composed of the three layers of tissue: The epicardium, the myocardium, and the endocardium. The **epicardium** is a thin serous membrane comprising of the smooth outer surface of the heart. The thick middle layer of the heart, the **myocardium**, is composed of cardiac muscle cells. The smooth inner surface of the heart chambers is the **endocardium**, which consists of simple squamous epithelium over a layer of connective tissue. The heart valves are formed by a fold of the endocardium, making a double layer of endocardium with connective tissue in between.

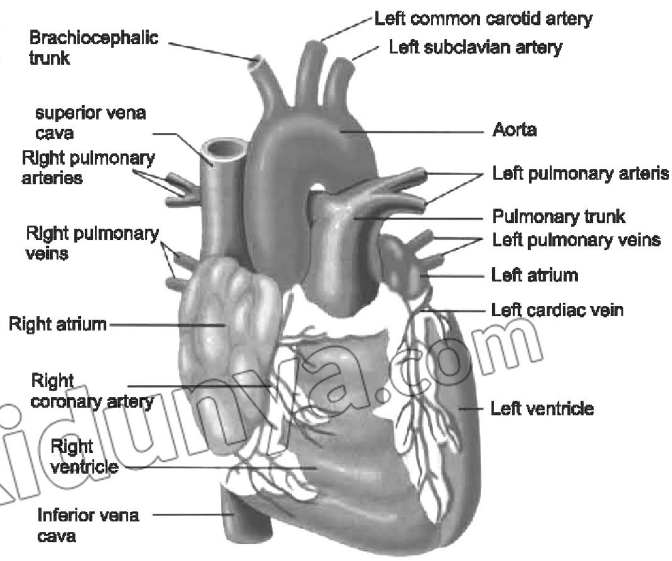


Fig. 2.1: Human heart, external view

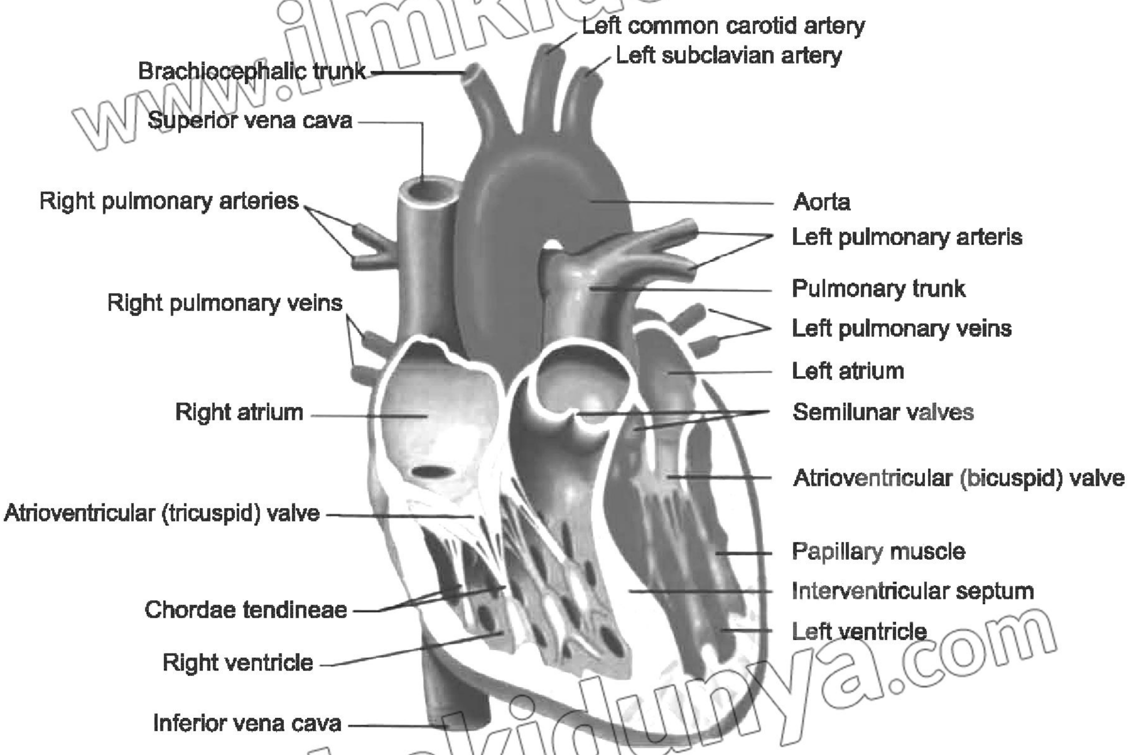


Fig. 2.2: Dissection of a human heart, as seen from the front, with the ventral part of both atria and both ventricles removed

The thickness of the walls of each chamber is different: The atria have comparatively thin walls as they only 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 walls 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 **right atrium** receives the superior vena cava, the inferior vena cava, and the coronary sinus. The **left atrium** receives the four pulmonary veins. The two atria are separated from each other by the **interatrial septum.**

The atria open into the ventricles through **atrioventricular canals.** The **right ventricle** opens into the pulmonary trunk, and the **left ventricle** opens into the aorta. The two ventricles are separated from each other by the **interventricular septum.**

An **atrioventricular valve** is on each atrioventricular canal and is composed of **cusps**, or flaps. The atrioventricular valve between the right atrium and the right ventricle has three cusps and is called the **tricuspid valve**. The atrioventricular valve between the left atrium and left ventricle has two cusps and is therefore called the **bicuspid or mitral valve.** Each ventricle contains cone-shaped muscular pillars called **papillary muscles.** These muscles are attached by thin, strong connective tissue strings called **chordae tendineae** to the cusps of the atrioventricular valves. The papillary muscles contract when the ventricles contract and prevent the valves from opening into the atria by pulling on the chordae tendineae attached to the valve cusps. The aorta and pulmonary trunk possess **aortic** and **pulmonary semilunar valves.**

2.3 FLOW OF BLOOD THROUGH THE HEART

The superior vena cava and the inferior vena cava, both carrying deoxygenated blood, enter the right atrium. The right atrium sends blood through the tricuspid valve to the right ventricle. The right ventricle sends blood through the pulmonary semilunar valve into the pulmonary trunk and the two pulmonary arteries to the lungs. Four pulmonary veins, carrying oxygenated blood from the lungs, enter the left atrium. The left atrium sends blood through the bicuspid valve to the left ventricle.

The left ventricle sends blood through the aortic semilunar valve into the aorta to the body proper. The heart is a double pump because the right ventricle of the heart sends blood to the lungs, and the left ventricle sends blood throughout the body.

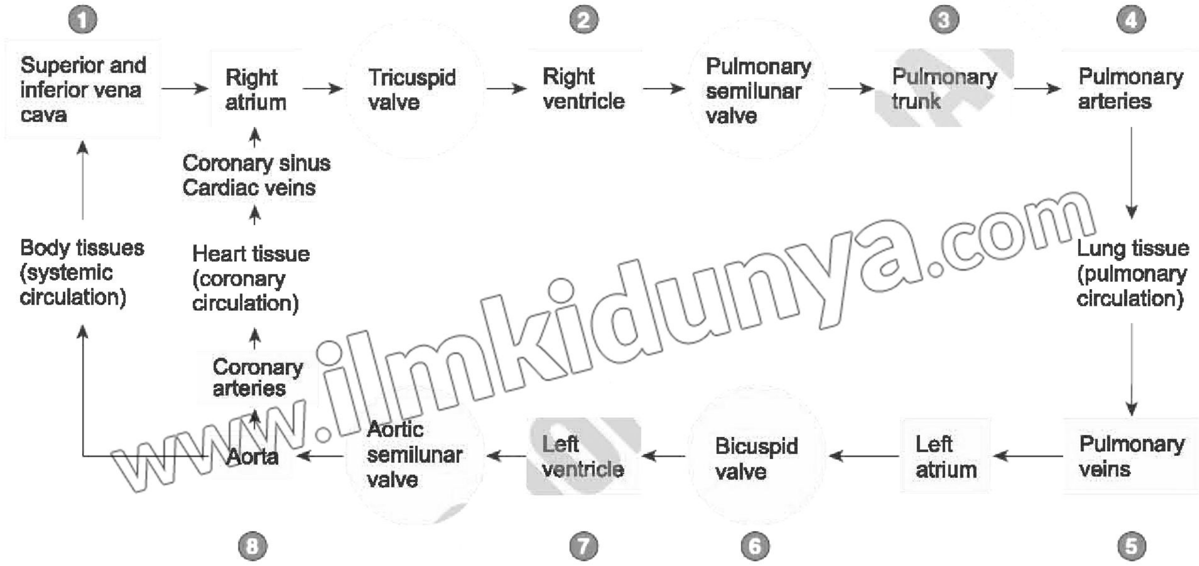


Fig. 2.3: Passage of blood through heart

2.4 PHASES OF HEARTBEAT

In a continuous, rhythmic cycle heart is passively filled with blood from the large veins and then the heart actively contracts, propelling the blood throughout the body. Its alternating relaxations and contractions make up the **cardiac cycle**. The cardiac cycle is a sequence of one heartbeat.

Phases of heartbeat

The term **systole** means to contract and **diastole** means to dilate. Atrial systole is contraction of the atrial myocardium and atrial diastole is relaxation of the atrial myocardium. Similarly ventricular systole is contraction of the ventricular myocardium and ventricular diastole is the relaxation of the ventricular myocardium. When the word "systole" and "diastole" are used without reference to specific chambers, they mean ventricular systole or diastole.

In **atrial diastole** blood enters the right atrium from the body through the vena cavae. At first the bicuspid and tricuspid valves are closed, but as the atria fill with blood, pressure in them rises. Eventually it becomes greater than that in the relaxed ventricles and the valves are pushed opens. In atrial systole the two atria contract simultaneously and blood is pushed through the atrio-ventricular valve into the still relaxed ventricles.

At this phase semilunar valve is closed, tricuspid and bicuspid valves are open.

In **ventricular systole** almost immediately the ventricles contract. When this occurs the pressure in the ventricles rises and closes the atrioventricular valves, preventing blood from returning to the atria. This pressure forces, open semilunar valves of the aorta and the pulmonary artery and blood enters these vessels. In this phase the tricuspid and bicuspid valves are closed.

In **ventricular diastole** the high pressure developed in the aorta and pulmonary artery tends to force some blood back towards the ventricles and close the semilunar valves of the aorta and pulmonary artery. Hence back flow in the heart is prevented. In this phase bicuspid valve and tricuspid valve are open, aortic semilunar valve, and pulmonary semilunar valve are closed. The normal cardiac cycle is of 0.7 to 0.8 second depending on the capability of cardiac muscle to contract. The heart muscle rests 0.1 to 0.3 second between the beats.

SCIENCE TITBITS

When a stethoscope is used to listen to the heart sounds, distinct sounds normally are heard. The first heart sound is a low-pitched sound, often described as a "lub" sound. It is caused by vibration of the atrioventricular valves which close near the beginning of ventricular systole. The second heart sound is a higher pitched sound often described as a "dub" sound. It results from closure of the aortic and pulmonary samilunar valves, near the end of systole. 'lub' is also written as 'lubb' and 'dub' as 'dupp'.

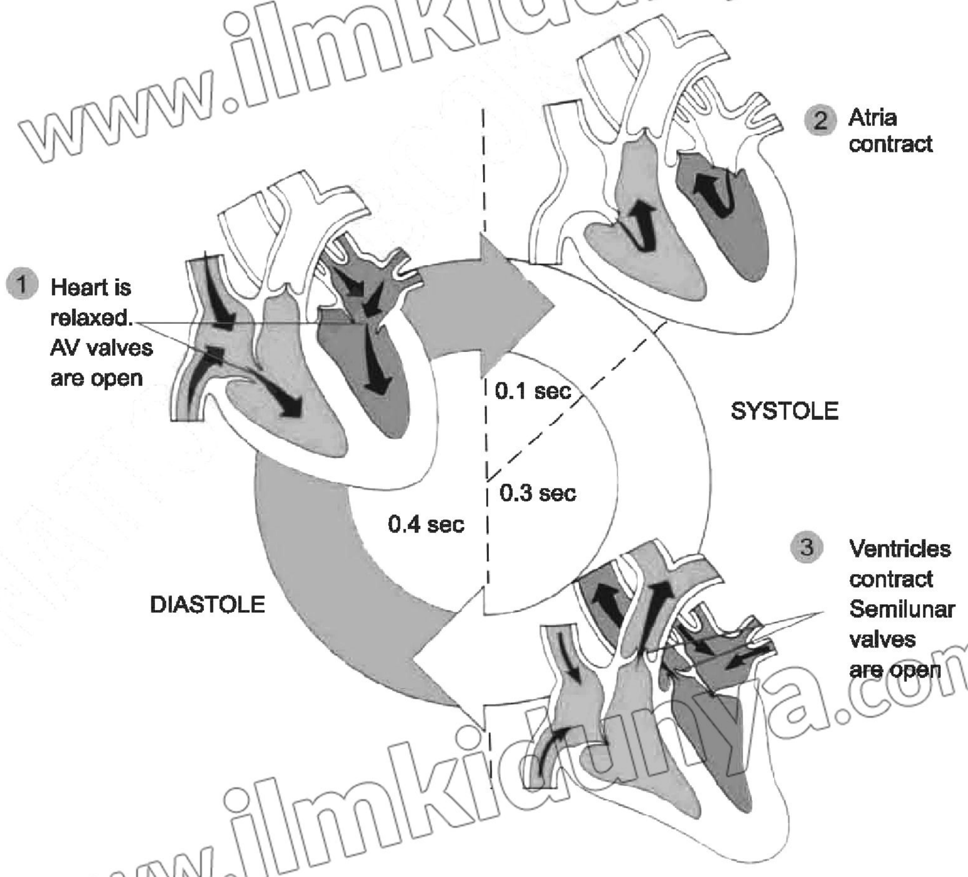


Fig. 2.4: Cardiac cycle

2.5 CONDUCTING SYSTEM OF THE HEART

The heart will go on beating after it has been cut right out of the body. Cardiac muscles are **myogenic** i.e., its rhythmic contraction arise from within the muscle itself. Cardiac muscle has an intrinsic rhythmicity that allows the heartbeat to originate in and be conducted through the heart without extrinsic stimulation. Specialized strands of interconnecting cardiac muscle tissue that coordinate cardiac contraction constitute the **conduction system**. The conduction system constitutes the cardiac cycle. The components of the conduction system are the (a) Sinoatrial node, (b) Atrioventricular node, (c) Atrioventricular bundle (d) Conducting myofibrils.

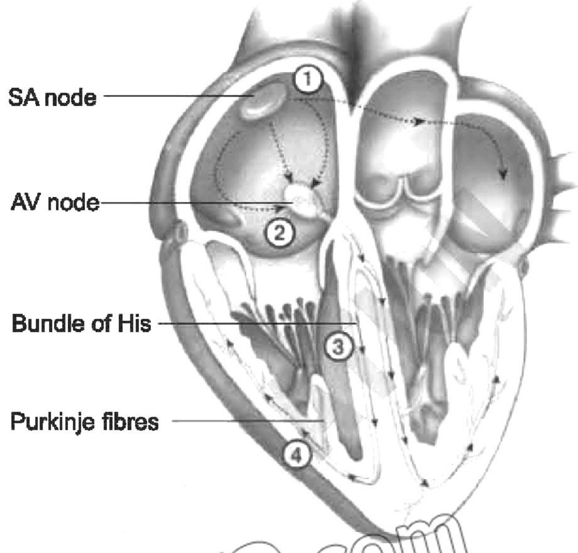


Fig. 2.5: Conducting system of the heart
1. Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium (arrows) from the SA node to the atrioventricular (AV) node.
2. Action potentials pass through the AV node and along the atrioventricular (AV) bundle, which extends from the AV node, through the fibrous skeleton, into the interventricular septum.
3. The AV bundle divides into right and left bundle branches, and action potentials descend to the apex of each ventricle along the bundle branches.
4. Action potentials are carried by the Purkinje fibres from the bundle branches to the ventricular walls.

Sinoatrial node in short is called **SA node**. It consists of specialized plexus of cardiac muscles embedded in the upper wall of the right atrium. It is close to where vena cavae enter the atrium. The SA node has been developed from the sinus venosus and has become a part of the atrium, so it is called sinoatrial node. There is another specialized group of cardiac muscle fibres called **atrioventricular node**. In short it is called **AV node**. It is present near the junction of right atrium and right ventricle.

AV node is connected to a strand of specialized muscles (in the ventricular septum) known as **atrioventricular bundle or bundle of His**. This bundle passes through a small opening in the fibrous skeleton to reach the interventricular septum, where it divides to form right and left bundle branches, which extend beneath the endocardium on either side of the interventricular septum to the apices of the right and left ventricles respectively. The inferior, terminal branches of the bundle branches are called **Purkinje fibres**, which are large-diameter cardiac muscle fibres. They have fewer myofibrils than most cardiac muscle cells and do not contract forcefully. **Intercalated disks** are well developed between the Purkinje fibres and contain numerous gap junctions. As a result of these structural modifications, action potentials travel along the Purkinje fibres much more rapidly than through other cardiac muscle tissue. Cardiac muscle cells have the capacity to generate spontaneous action potentials, but cells of the SA node do so at a greater frequency. As a result, the SA node is called the **pacemaker** of the heart. When the heart beats under resting conditions, approximately 0.04 second is required for action potentials to travel from the SA node to the AV node. Within the AV node action potentials are propagated slowly compared with the remainder of the conducting system. As a consequence, there is a delay of 0.11 second from the time action potentials reach the AV node until they pass to the AV bundle. The total delay of 0.15 second allows completion of the atrial contraction before ventricular contraction begins.

Science, Technology and Society Connections

- **Rationalize the use of artificial pacemaker in patients of cardiac arrhythmias.**

A **cardiac arrhythmia** is a disturbance in electrical rhythm of heart. It may be **bradycardia** (heart beat less than 40 beats per minute) or **tachycardia** (heart beat more than 100 beats per minute). Pacemaker supplies electrical initiation to myocardial contraction. The pacemaker is put surgically under the skin where it may be programmed. It generates electrical rhythm at a set rate, so in this way arryhthmia are controlled.

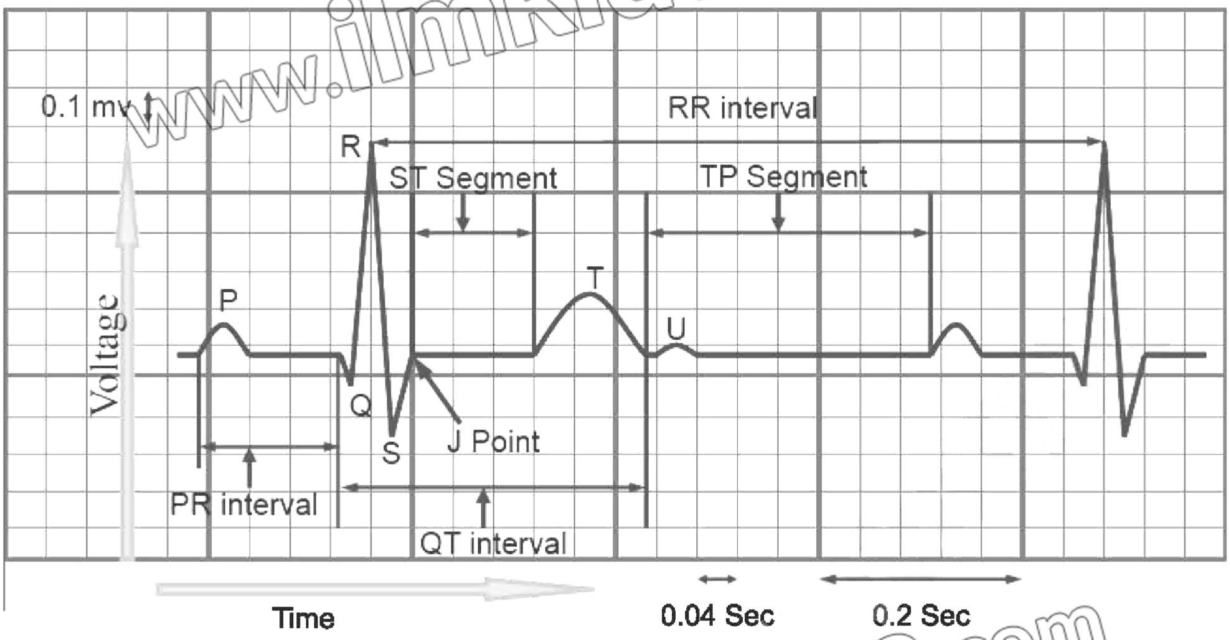
2.6 ELECTROCARDIOGRAM

The electrical impulses that pass through the conduction system of the heart during the cardiac cycle can be recorded as an electrocardiogram (ECG). The electrical changes result from depolarization and repolarization of cardiac muscle fibres and can be detected on the surface of the skin using an instrument called the **electrocardiograph**. The principal aspects of an ECG are shown in the given figure. The wave deflections, designated P, QRS, and T, are produced as specific events of the cardiac cycle occur.

Depolarization of the atrial fibres of the SA node produces the **P wave**. The ventricles of the heart are in diastole during the expression of the P wave. On the ECG recording, the **P-R interval** is the period of time from the start of the P wave to the beginning of the QRS complex. This interval indicates the amount of time required for the SA depolarization to reach the ventricles. The **QRS complex** begins as a short downward deflection (Q), continues as a sharp upward spike (R), and ends as a downward deflection (S). The QRS complex indicates the depolarization of the ventricles. During this interval, the ventricles are in systole and blood is being ejected from the heart. The time duration known as the **S-T segment** represents the period between the completion of ventricular depolarization and initiation of repolarization. The **T wave** is produced by ventricular repolarization. A normal ECG indicates that the heart is functioning properly. The P wave represents excitation and occurs just prior to contraction of the atria. The second wave, or the QRS complex, occurs just prior to ventricular contraction. The third, or T, wave occurs just before the ventricles relax. The J (junction) point in the junction between termination of the QRS complex and the beginning of the ST segment.

Uses of electrocardiogram

An ECG is a painless test that measures heart electrical activity to show whether or not it is working normally. ECG can detect arrhythmias (irregular heartbeat), conduction defects, size and position of heart chambers, damage to heart muscle, impaired blood flow to heart muscle, the effect of cardiac medicines and function of artificial pacemakers.



• PR interval	0.12 - 0.20 sec	• QT interval	0.4 - 0.43 sec
• QRS duration	0.08 - 0.10 sec	• RR interval	0.6 - 1.0 sec

Fig. 2.6: Electrocardiogram (ECG)

2.7 BLOOD VESESLS

There are three types of blood vessels, the **arteries** (and arterioles), which carry blood away from the heart, the **veins**, which return blood to the heart, and **capillaries**, which permit exchange of materials with the tissues.

2.7.1 Arteries

Arteries carry blood away from the heart. Arteries are pink in colour and are situated within the muscles. Arteries vary in size.

Arteries branch into **arterioles** and **capillaries.** The lumens of arteries have no valves. The wall of an artery consists of three coats or tunics: tunica adventitia, tunica media and tunica intima.

The outermost layer is called **tunica adventitia.** It is composed of white fibrous connective tissue. The middle layer is called **tunica media**, and has variable amount of elastic fibres. It is many layered in thickness. It consists of one or two layers of circular smooth muscle cells.

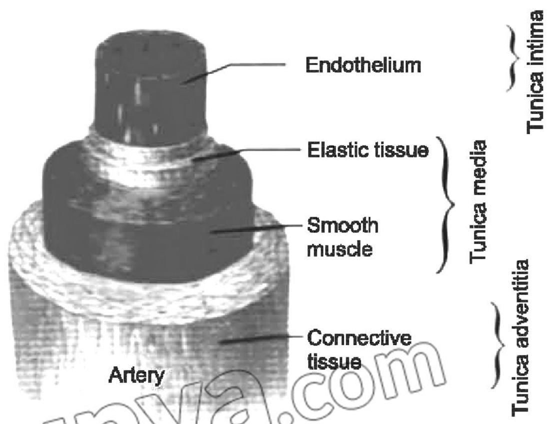


Fig. 2.7: Artery

The innermost layer of the artery is called **tunica intima.** It is composed of simple squamous epithelium and elastic fibres composed of elastin. Arterioles transport blood from small arteries to capillaries. Aorta is approximately 23 mm and arterioles are about 0.2 mm in diameter.

2.7.2 Capillaries

The capillary wall consists primarily of endothelial cells. Most capillaries range from 7 to 9 μm in diameter, and thus branch without a change in their diameter. Capillaries are approximately 1 mm long. Red blood cells flow through most of capillaries in a single file.

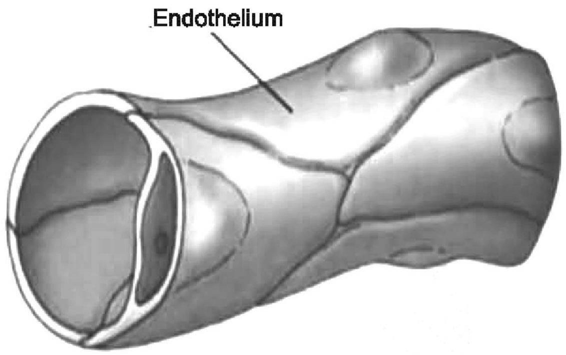


Fig. 2.8: Capillary

2.7.3 Veins

The blood vessels that bring blood back to the heart are called veins. Veins are relatively not deep in the muscles. Veins can be seen as blue vessels under the skin. A vein also consists of **tunica adventitia**, tunica media and tunica intima. Tunica adventia is composed of collagenous connective tissue. **Tunica media** is composed of a thin layer of circularly arranged smooth muscle cells, collagen fibres and a few sparsely distributed elastic fibres. **Tunica intima** is a smooth muscle and consists of endothelial cells, thin layer of elastic fibres. **Venules** with a diameter of 40 to 50 μm are tubes composed of endothelium. The venules collect blood from the capillaries and transport it to the small veins.

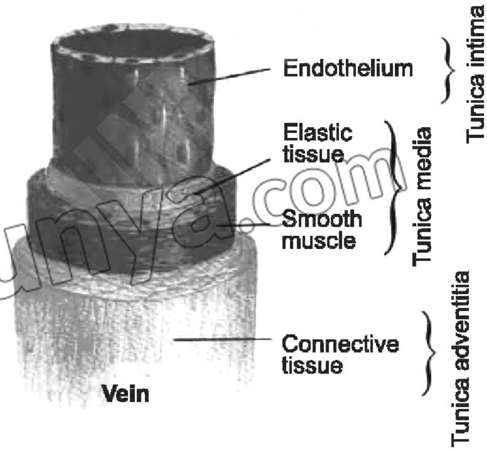


Fig. 2.9: Vein

Valves in veins

Veins having diameters greater than 2mm contain valves that allow blood flow toward the heart but not in the opposite direction. Valves are present only in the lower part of the body especially in the abdomen and hind limbs. In the upper region above the heart there is no valve. As the blood pressure in the veins is comparatively low, so the flow of blood in the veins is helped by gravity, semilunar valve and muscular contraction.

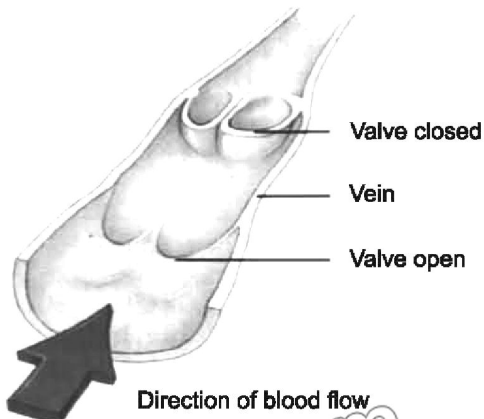


Fig. 2.10: Valves in veins

2.8 ROLE OF ARTERIOLES IN VASO-CONSTRICTION AND VASODILATION

The amount of blood flowing through a blood vessel can be regulated by contraction or relaxation of smooth muscle in the tunica media. A decrease in blood flow results from **vasoconstriction**, a decrease in blood vessels diameter caused by smooth muscle contraction whereas an increase in blood flow is produced by **vasodilation** an increase in blood vessel diameter because of smooth muscle relaxation. Blood circulation is also controlled by hormones (vasoconstriction agents) acting on arterioles. Norepinephrine is an especially powerful vasoconstriction hormone, and epinephrine is less.

Several substances called kinins (vasodilator agents) can cause powerful vasodilation are formed in the blood and tissue fluids of some organs. e.g., histamine. Most of the prostaglandins are vasodilator agents though some of the prostaglandins are vasoconstrictor.

- **Justify how Vasodilation and Vasoconstriction is Reflective of Emotions?**

During emotional rage such as apprehension and rage vasodilation occurs due to secretion of epinephrine. It is a hormone that is responsible for fear, flight and fright conditions. The sympathetic vasodilator fibres are part of a regulatory system that originates in cerebral cortex and ends at postganglionic neurons in blood vessels on skeletal muscles, activate them to release acetylcholine, and vasodilation occurs. Blood discharge through thoroughfare channels rather than capillaries so heat loss occurs and the skin becomes hot and red. While in vasoconstriction blood supply becomes less to skin, so heat is preserved and the skin becomes cold. Situations such as shock, hypotension and tachycardia occur by stimulation of arterial stretch receptors and production of hypertension and bradycardia (slowness of the heart) occur by increased intracranial pressure.

2.9 ROLE OF PRE-CAPILLARY SPHINCTERS

Arterioles supply blood to each capillary network, blood then flows through the capillary network and into the venules. Blood flows from arterioles through metarterioles. From a metarteriole blood flows into a thoroughfare channel. Several capillaries branch from the thoroughfare channels. Flow in these capillaries is regulated by smooth muscle cells called precapillary sphincter, which are located at the origin of the branches. This sphincter can open and close the entrance to the capillary. Precapillary sphincters are normally either completely open or completely closed, and the degree of constriction of the metarteriole also varies. The precapillary sphincters and metarterioles often open and close cyclically several times per minute, with the duration of the open phases being about proportional to the metabolic needs of the tissue. The cyclic opening and closing is called vasomotion.

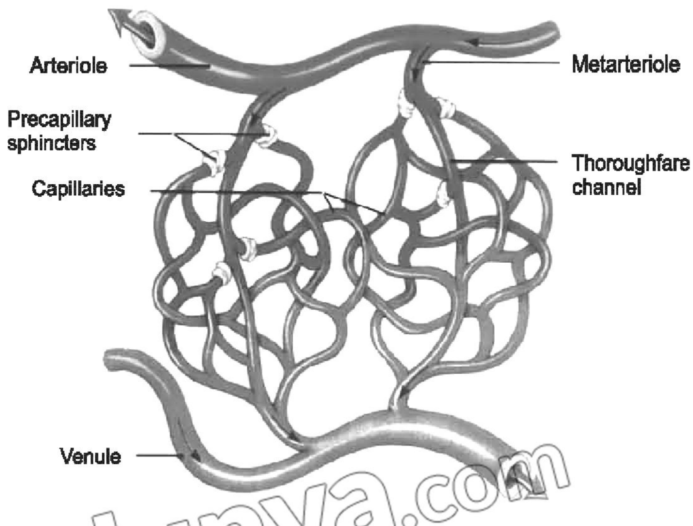


Fig. 2.11: Capillary network

2.10 PATH OF BLOOD THROUGH THE PULMONARY AND SYSTEMIC CIRCULATION

We will discuss here the path of blood through the pulmonary and systemic circulation.

Pulmonary circulation

The left atrium receives oxygenated blood from the lungs through a pair of **pulmonary veins**, which open by common aperture into it. From left atrium the blood flows into the left ventricle. The superior and inferior vena cavae bring deoxygenated blood and open into the right atrium. From right atrium blood flows into the lungs for oxygenation by a **pulmonary arch** or **trunk** which divides into two **pulmonary arteries**, each going to the lung of its own side. This part of circulation is called **pulmonary circulation** or **circuit.** The pulmonary arteries carry deoxygenated blood and pulmonary veins carry oxygenated blood.

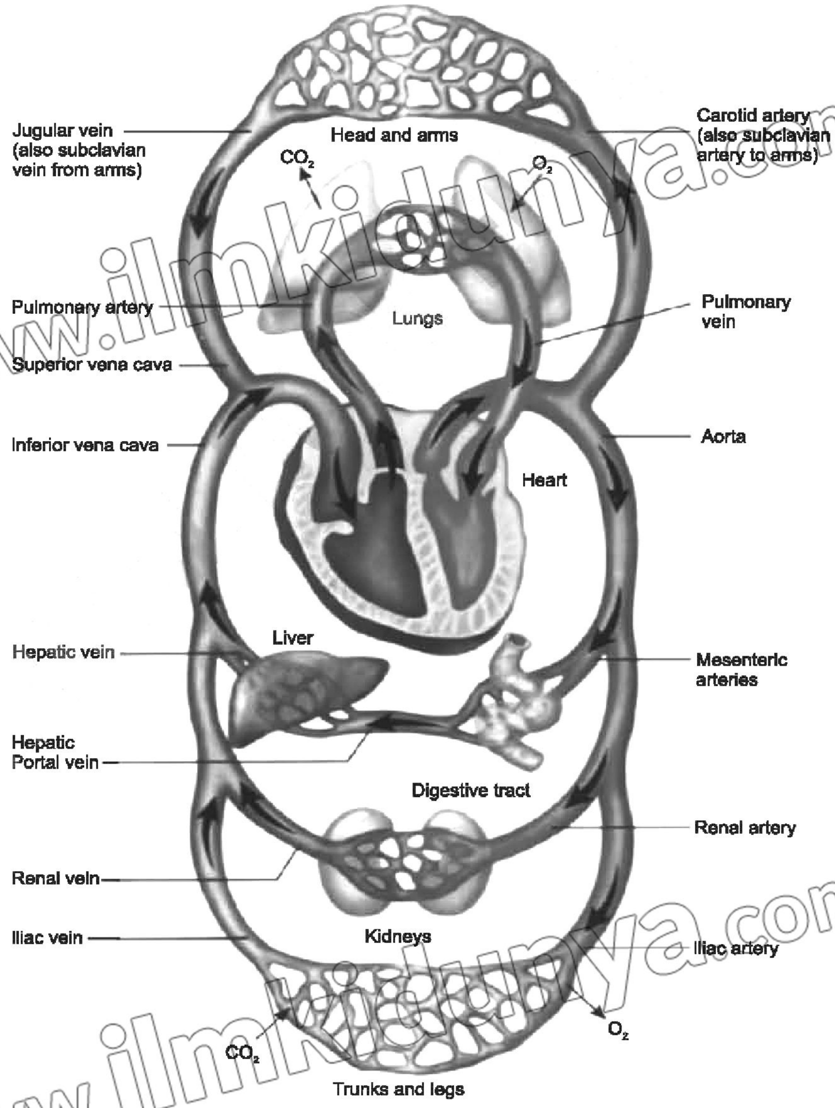


Fig. 2.12: Cardiovascular system

Systemic circulation

The systemic circuit includes all the **arteries** and **veins** other than involved in pulmonary circuit. The largest artery in the systemic circuit is the **aorta**. The largest veins are the **superior** and **inferior venae cava**. The path of systemic blood to any organ in the body begins in the **left ventricle** which pumps blood in the aorta. Branches from aorta go to the organs and major body regions. The **superior vena cava** collects blood from the head, the chest and the arms. The **inferior vena cava** collects blood from the lower body regions. Both enter the right atrium. The aorta and the vena cavae are the major pathways in the systemic circuit. In most instances the artery and the vein that serve the same organ are given the same name.

Coronary circulation

The wall of the heart has its own supply of blood vessels to meet its vital needs. The myocardium is supplied with blood by the **right** and **left coronary arteries**. From the capillaries in the myocardium, the blood enters the **cardiac veins**. The course of these vessels parallels that of the coronary arteries. These cardiac veins converge to form the **coronary sinus channel** on the posterior surface of the heart. The coronary venous blood then enters the heart through an opening into the right atrium.

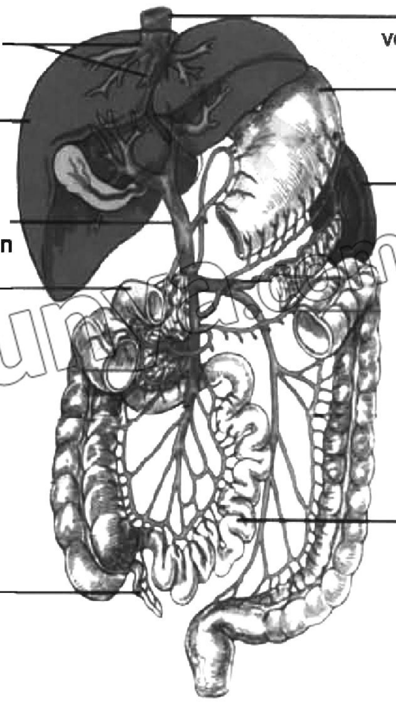


Fig. 2.13: Hepatic portal system

Hepatic portal system

A **portal** system is vascular system that begins and ends with capillary beds and has no pumping mechanism such as the heart. The **portal system** that begins with capillaries in the viscera and ends with the capillaries in the liver is the hepatic portal system. The **hepatic portal vein**, the largest vein of the system, is formed by the union of all the veins coming from digestive system. Within the liver the blood flows through a series of dilated capillaries which empty into hepatic veins. The **hepatic veins** join the inferior vena cava.

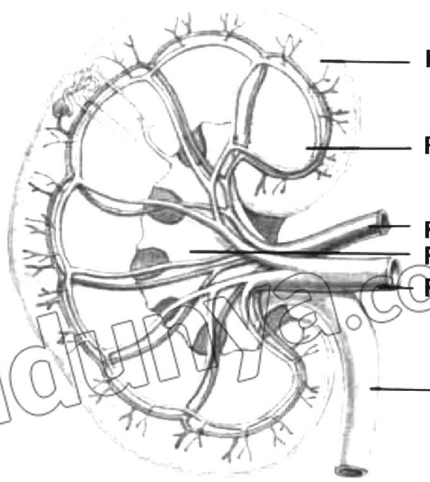


Fig. 2.14: Principal arteries and veins of kidney

Renal circulation

Renal artery enters into kidney and gives branches which pass through medulla. In cortex they give rise to afferent

glomerular arterioles From here blood enters the **peritubular capillaries** and **vasa recta**. From these capillary networks the blood is drained through veins and leave the kidney as a single renal vein that empties into the inferior vena cava.

2.11 RATE OF BLOOD FLOW IN BLOOD VESSELS

Blood flow means simply the quantity of blood that passes through a given point in the circulation in a given period. The overall blood flow in the circulation of an adult at rest is about 5000 ml/min. This is called **cardiac output**. It is the amount of blood pumped by the heart in a unit period.

Comparison of the rate of blood flow through arteries, arterioles, capillaries, venules and veins

Blood travels over a thousand times faster in the aorta, i.e., about 30cm/sec on average than in capillaries i.e., about 0.26 cm/sec. You might think that blood should travel faster through capillaries than through arteries, because the diameter of capillaries is very small. However, it is the total cross-sectional area of capillaries that determines flow rate. Each artery conveys blood to such an enormous number of capillaries that the total cross-sectional area is much greater in capillary beds than in any other part of the circulatory system. For this reason the blood slows substantially as it enters the arterioles from arteries and slows further still in the capillary beds. As blood leaves the capillaries and enters the venules and veins it speeds up again as a result of the reduction in total cross-sectional area. The carotid sinus and aortic arch baroreceptor reflexes are important in regulating blood pressure moment to moment.

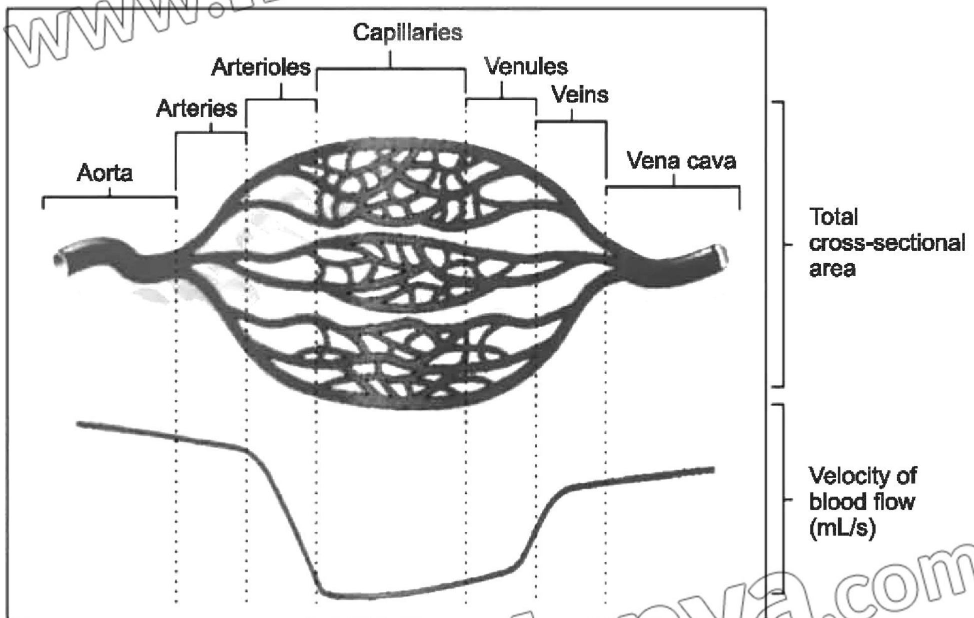


Fig. 2.15: Blood vessel types and velocity of blood flow: Total cross-sectional area for each of the major blood vessel types is the space through which blood flows, measured in square centimeters. The cross-sectional area of the aorta is about 2.5 cm^2. The crosssectional area of each capillary is much smaller, but there are so many that the total cross-sectional area is more than that of the aorta. The line at the bottom of the graph shows that blood velocity drops dramatically in arterioles, capillaries, and venules. As the total cross-sectional area increases the velocity of blood flow decreases

2.12 BLOOD PRESSURE

Blood pressure is the force exerted by the blood against any unit area on the inner walls of the blood vessel. The standard reference for the blood pressure is the mercury (Hg) manometer, which measures pressure in millimetres of mercury (mm Hg). If the blood pressure is 100 mm Hg the pressure is great enough to lift a column of mercury 100 mm. When the ventricles of the heart contract the arterial blood pressure is the highest. It is called **systolic pressure**. When the ventricles of the heart relax, the arterial blood pressure is the lowest. It is called **diastolic pressure**.

2.13 BARORECEPTORS AND VOLUME RECEPTORS

Baroreceptors can be divided into two categories based on the type of blood vessel in which they are located: high-pressure arterial baroreceptors and low-pressure baroreceptors or volume receptors

High-pressure arterial baroreceptors

These are mechanoreceptors located in the walls of the aorta and carotid sinus in the carotid arteries. They sense the blood pressure and relay the information to the brain, so that a proper blood pressure can be maintained. Stimulation of parasympathetic nerves in these areas caused by cardiac output, produces vasodilatation throughout the body and consequent reduction in blood pressure as well as a slowing the heart rate. The opposite occurs when blood pressure is low. In this case, a fall in blood pressure increases nerve impulse transmission along sympathetic nerves. This causes body-wide vasoconstriction and a rise in blood pressure. Baroreceptors act immediately as part of a negative feedback system called the **baroreflex**.

Low-pressure baroreceptors or volume receptors

Low-pressure baroreceptors or volume receptors are found in the atria of the heart and carotid arteries. When these receptors detect a blood volume decrease in the atria, a signal is transmitted from the receptors to the hypothalamus in the brain. The hypothalamus, in turn, increases the production of antidiuretic hormone (ADH) which will cause water retention in kidney. This increases the blood volume, resulting in the increase of blood pressure.

2.14 CARDIOVASCULAR DISORDERS

Cardiovascular disorders or diseases (CVD) are the diseases of the heart and blood vessels. The CVD are the leading cause of untimely death.

2.14.1 Thrombosis and Embolism

The formation of a clotted mass of blood within a vessel or the heart during life is called **thrombosis**. The clotted mass of blood within a vessel or the heart during life is called **thrombus**. The occlusion (a closing of an opening) of some part of the cardiovascular system by any mass transported to the site through the blood stream is called embolism. **Embolus** (plural: emboli) is a detached intravascular solid, liquid or gaseous mass that is carried to a site distant from its point of origin. About 99% emboli arise from dislodgement of thrombi and are therefore called **thromboemboli**. Thrombus and embolus cause death.

2.15 HEART PROBLEMS

In this section we will discuss cardiovascular diseases, such as: atherosclerosis and arteriosclerosis.

2.15.1 Atherosclerosis and arteriosclerosis

Atherosclerosis is the plaque deposition of cholesterol in the arteries resulting in the narrowing of the arteries lumen. Later, fibres are deposited in the cholesterol and these often start to calcify and become hard, a process known as **arteriosclerosis**. The plaque first forms thrombus and may detach to form embolus. The major factors that cause atherosclerosis and arteriosclerosis are: Hypercholesterolemia, (hyperlipidemia), Hypertension, Cigarette smoking, Diabetes mellitus, the other minor risk factors are: (a) Increasing age, (b) Lack of exercise, (c) Stressful competitive life, (d) Obesity.

2.16 STAGES OF CARDIOVASCULAR DISEASE DEVELOPMENT

In this section we will discuss cardiovascular diseases, such as: angina pectoris, heart attack, heart failure.

2.16.1 Angina pectoris

Due to atherosclerosis a person may feel occasional chest pain, a condition known as angina pectoris. Angina is most likely to occur when the heart is labouring hard because of physical or emotional stress. Angina is a signal that part of the heart is not receiving a sufficient supply of oxygen and that part of the heart attack could occur in future.

2.16.2 Heart attack

Many heart attacks occur without warning. A blood clot may completely block a coronary artery, or atherosclerosis may reach a critical level causing massive damage to the heart muscle. All of a sudden, the person feels a heavy squeezing ache or discomfort in the centre of the chest. The pain may radiate to shoulder, arm neck or jaw. Other symptoms may include sweating, nausea, shortness of breath and dizziness or fainting. The whole process is called **myocardial** (heart muscle) **infarction** (death due to lack of oxygen). When heart muscles die, they are not replaced because cardiac muscles do not divide. When a person survives a heart attack scar tissue (a type of connective tissue) grows into the areas where the heart muscles have died. The scar tissue cannot contract as cardiac muscle. As a result the damaged heart is permanently weakened.

2.16.3 Heart failure

Congestive heart failure is inability of heart to pump all the blood coming to it. The cardiac output is unable to keep pace with the venous return.

2.16.4 Congenital heart problem

Congenital heart problems result from abnormalities in the embryonic development. It can be related to the malfunctioning of cardiac valves e.g., **Valvular stenosis.**

2.17 DIAGNOSIS OF CARDIOVASCULAR DISORDERS

Modern research efforts have resulted in improved diagnosis of CVD, their treatment and preventions.

a. Principles of angiography

Cardiac catheterization is a technique in which specially designed catheter is inserted into a vein or artery and advanced into the heart under radiographic fluoroscopic guidance. This allows the operator to obtain angiograms by injecting contrast media into an area of interest. It is used to evaluate disease of the mitral valve, aortic valve and aorta, to determine the size and function of the left ventricle.Coronary angiography is used to detect stenosis (narrowing of a tube) and guide revascularisation procedures such as balloon angiography and stenting.

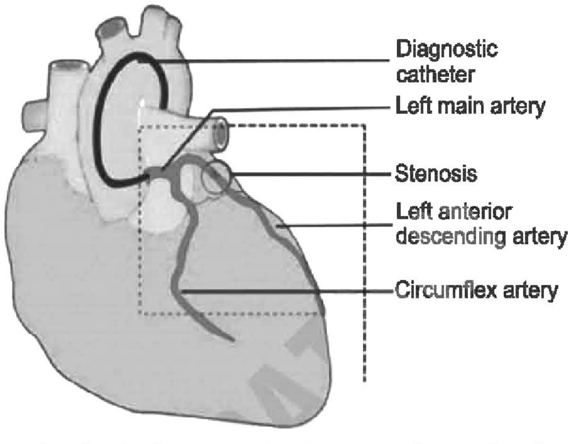


Fig. 2.16: Coronary angiogram-schematic of the vessels and branches

b. Coronary bypass

A coronary bypass is a surgical procedure that relieves the effects of obstruction in the coronary arteries. The technique involves taking healthy segments of blood vessel from other parts of the patient's body usually a vein from the leg or an artery of thorax to bypass obstructions in the coronary arteries.

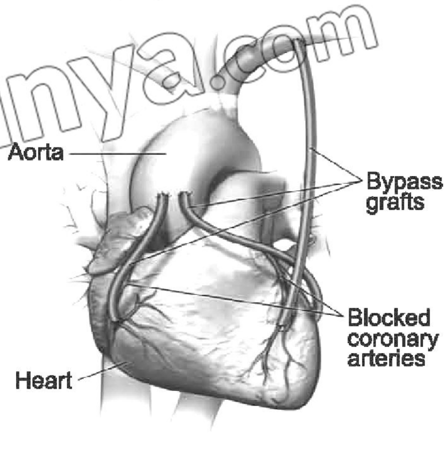


Fig. 2.17: Coronary artery bypass graft.

c. Angioplasty

In angioplasty a cardiologist threads a plastic tube into an artery of an arm or a leg and guides it through a major blood vessel toward the heart. When the tube reaches the region of plaque in a coronary artery a balloon is attached to the end of the tube is inflated forcing the vessel open. However, the artery may not remain open, so slotted tubes called **stents** are expanded inside the artery to keep the artery open. Stents are coated with heparin to prevent blood clotting and chemicals to prevent arterial closing.

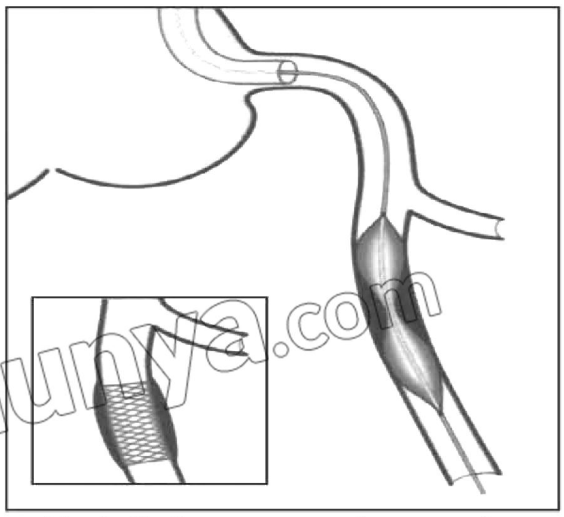


Fig. 2.18: Coronary artery bypass graft.

d. Open heart surgery

This is a surgery in which the patient's chest is opened. The surgery is performed on the heart. The term "open" refers to the chest, not to the heart itself. The heart may or may not be opened depending on the particular type of surgery. Heart surgery is used to correct heart problems in children and adults. An incision is made through the breastbone (sternum) while the patient is under general anesthesia. Tubes are used to re-route the blood through a special pump called a heart-lung bypass machine. This machine adds oxygen to the blood and keeps the blood warm and moving through the rest of the body while the surgeon is repairing the heart. Using the machine allows the heart to be stopped. Stopping the heart makes it possible to repair the heart muscle itself, the heart valves, or the blood vessels outside the heart. After the repair is done, the heart is started again, and the machine is removed. The breastbone and the skin incision are then closed.

2.18 HYPERTENSION AND HYPOTENSION

Hypertension

Blood pressure (BP) is the measurement of the pressure or force of blood pushing against blood vessel walls. The BP reading has two numbers. The top number is the **systolic blood pressure**, which measures the pressure on the artery walls when the heart beats or contracts. The bottom number is the **diastolic blood pressure**. This measures the pressure on the artery walls between beats when the heart is relaxing. The physicians' measure blood pressure in millimeters of mercury (mmHg).Your blood pressure may be different at different times of the day. High blood pressure is also called **hypertension**. When the blood pushes harder against the walls, your blood pressure goes up.

Definition: Hypertension is defined as blood pressure higher than 140/90 mmHg.

A diagnosis of hypertension may be made when one or both readings are high. 120/80 mmHg is normal blood pressure

2.18.1 Factors regulating blood pressure

Blood pressure is influenced by various factors. These factors can be broadly categorized into controllable and uncontrollable risk factors.

Controllable Factors

a. Diet: High sodium intake, a diet low in potassium, and excess saturated fat can elevate blood pressure.
b. Physical Activity: Lack of regular exercise is a significant risk factor.
c. Weight: Being overweight or obese increases the risk of high blood pressure.
d. Stress: High stress levels can lead to temporary increases in blood pressure.
e. Sleep: Insufficient or poor quality sleep can affect blood pressure regulation.
f. Medications: Some medications, including cough and cold medicines, can interfere with blood pressure control.

Uncontrollable Factors

a. Age: The risk of high blood pressure increases with age.
b. Genetics: Family history of hypertension can increase your predisposition.

c. Medical Conditions: Conditions like kidney disease, thyroid problems, and obstructive sleep apnea (Sleep apnea is a common condition that occurs when you're breathing stops and restarts many times while you sleep) can affect blood pressure.

Other Factors

Baroreceptors: These are sensory receptors in blood vessels that monitor blood pressure and send signals to the brain to adjust heart rate and blood vessel constriction.

a. **Cardiac Output:** This refers to the amount of blood pumped by the heart with each beat, and it is influenced by heart rate and stroke volume.

b. **Total Peripheral Resistance:** This is the resistance to blood flow in the blood vessels, and it is affected by factors like blood vessel diameter and blood viscosity.

c. **Blood Volume:** The amount of blood in the circulatory system also impacts blood pressure.

d. **Blood Viscosity:** The thickness of blood can affect its flow and pressure.

2.18.2 Hypotension

Low blood pressure is a condition in which the force of the blood pushing against the artery walls is too low. It's also called hypotension. Blood pressure is measured in millimeters of mercury (mm Hg). In general, low blood pressure is a reading lower than 90/60 mm Hg.

2.18.3 Protection from hypertension and cardiac problem

To protect yourself from hypertension and cardiac problems, make significant lifestyle changes. Look at these changes:

1. Heart-Healthy Diet

a. Focus on fruits, vegetables, whole grains, and lean protein: These foods are rich in nutrients and fiber, which can help lower blood pressure and cholesterol.

b. Limit saturated and Tran's fats: These fats can raise LDL cholesterol, increasing the risk of heart disease.

c. Reduce sodium intake: High sodium levels can contribute to high blood pressure.

d. Choose anti-inflammatory foods: Foods like dark green leafy vegetables, orange-colored vegetables, and legumes can help reduce inflammation, which is linked to heart disease.

2. Regular Physical Activity

a. Aim for at least 150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous activity per week: This could include walking, running, swimming, or dancing.

b. Incorporate strength training exercises: These help build muscle, which can improve overall metabolism and help manage weight.

3. Maintain a Healthy Weight

a. Calculate your Body Mass Index (BMI) to determine if you're at a healthy weight: Being overweight or obese increases the risk of hypertension and heart disease.

b. Combine a healthy diet with regular physical activity to lose weight and maintain it: This helps lower blood pressure and cholesterol levels.

4. Quit Smoking

a. Smoking damages blood vessels and increases the risk of heart attack and stroke: Quitting smoking is one of the most important steps you can take to improve your heart health.

5. Manage Stress

a. Find healthy ways to manage stress, such as exercise, yoga, meditation, or spending time with loved ones: Chronic stress can contribute to high blood pressure and other health problems.
b. Get enough sleep: Aim for 7-9 hours of quality sleep per night to allow your body to recover and manage stress.

2.19 INTERCELLULAR FLUID AND LYMPH

The lymphatic system includes lymph, lymphocytes, lymphatic vessels, lymph nodes, tonsils, spleen and thymus gland. About one sixth of the body consists of spaces between the cells, which collectively are called the **interstitium**. The fluid in these spaces is the **interstitial fluid** or **intercellular fluid**.

2.19.1 Interstitial fluid

Formation: The fluid in the interstitium is derived by filtration and diffusion from the capillaries.

Composition: Interstitial fluid contains almost the same constituents as plasma except for much lower concentrations of proteins because proteins do not pass outward through the walls of the capillaries with ease.

Function: The interstitial fluid allows rapid transport of water molecules electrolytes, nutrients, cellular excreta, oxygen, carbon dioxide etc. Materials are exchanged between the blood and interstitial fluid and between the interstitial fluid and the body cells. In other words, to get from the blood to body cells or vice versa, materials must pass through the interstitial fluid.

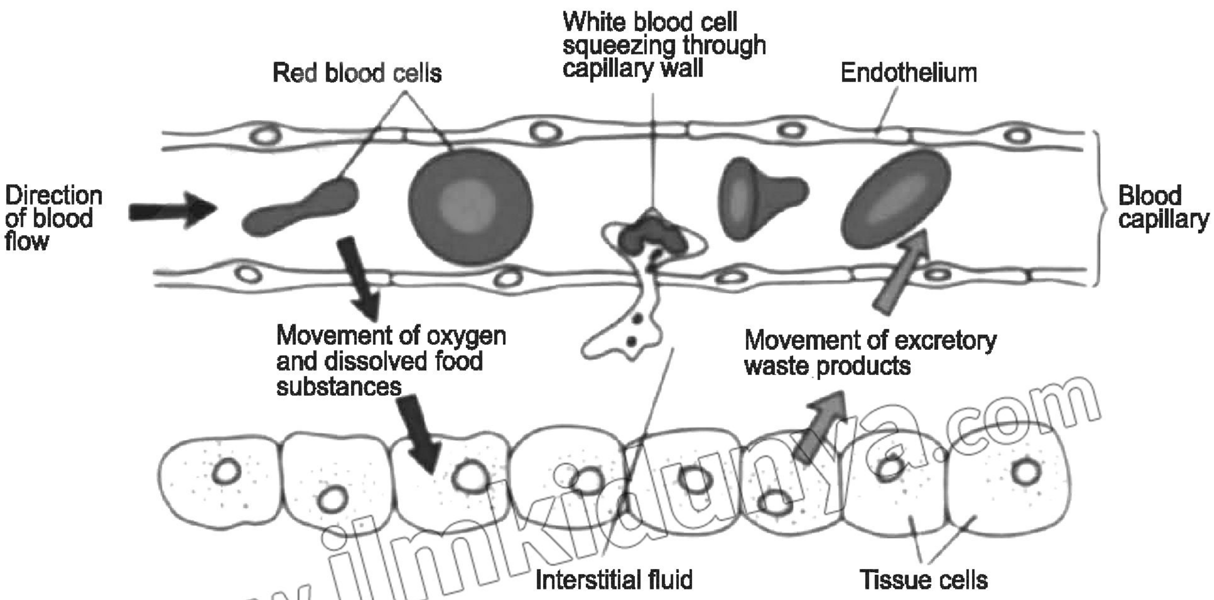


Fig. 2.19: Relationship between a blood capillary, interstitial fluid and tissue cells

2.19.2 Comparison of the composition of interstitial fluid and lymph

The composition of intercellular fluid is primarily water. along with electrolytes sugars, salts, acids, hormones, neuro-transmitters and cell wall products. The tissue fluid that had entered the lymphatic capillaries is called **lymph** and passes through the lymphatic vessels back to the blood. In addition to water lymph contains solutes such as ions, nutrients, gases and some proteins, hormones, enzymes and waste products. As lymph moves through the lymphatic system it accumulates more white blood cells (lymphocytes) proteins.

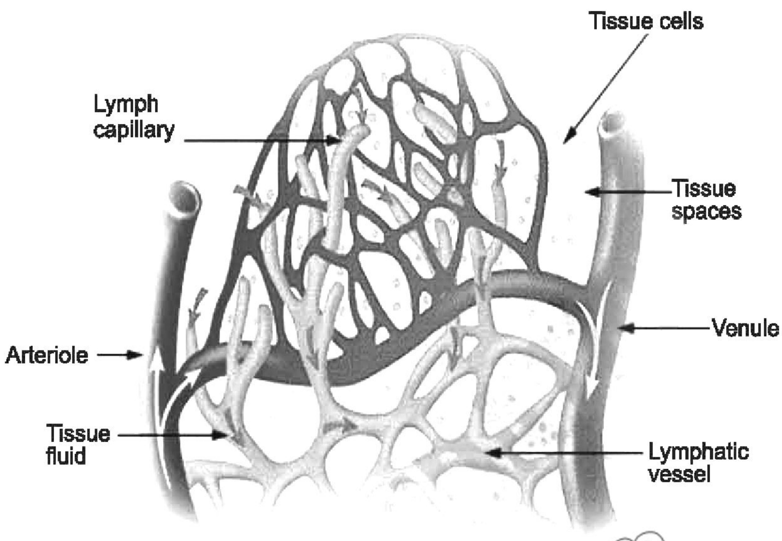


Fig. 2.20: Lymphatic vessels

Table 2.1 Differences between composition of intercellular fluid and lymph

Feature	Intercellular Fluid	Lymph
Major Electrolytes	High potassium, high phosphate, moderate magnesium, low sodium	High sodium, high chloride, moderate potassium, moderate phosphate
Proteins	Higher concentration of proteins	Lower concentration of proteins than plasma
White Blood Cells	–	Significantly higher, particularly lymphocytes
Red Blood Cells	–	Absent normally
Water	High water content	High water content
Fats	–	Can be high in lymph from the digestive system (chyle)
Origin	Fluid inside cells	Derived from blood plasma and interstitial fluid

2.20 LYMPHATIC SYSTEM OF MAN

The lymphatic system includes lymph, lymphocytes, lymphatic vessels, lymph nodes, tonsils, spleen and thymus gland.

2.20.1 Lymph vessels

Lymphatic pathways begin as lymphatic capillaries. These tiny tubes emerge to form larger lymphatic vessels, which in turn lead to the collecting ducts that unite with the veins in the thorax.

a. Lymphatic Capillaries

Lymph capillaries are microscopic, closed-ended tube. See the figure given (Fig: 2.21). They extend into the spaces within interstitial spaces, forming complex networks that parallel the networks of blood capillaries. The walls of the lymphatic capillaries, like those of blood capillaries, consist of a single layer of squamous epithelial cells. This thin wall makes it possible for interstitial fluid from interstitial spaces to enter the lymphatic capillary. Once the fluid is inside a lymphatic capillary, it is called **lymph**. Each villus contains a lymph capillary called **lacteal**. The lacteal absorbs fats and other substances from digestive tract.

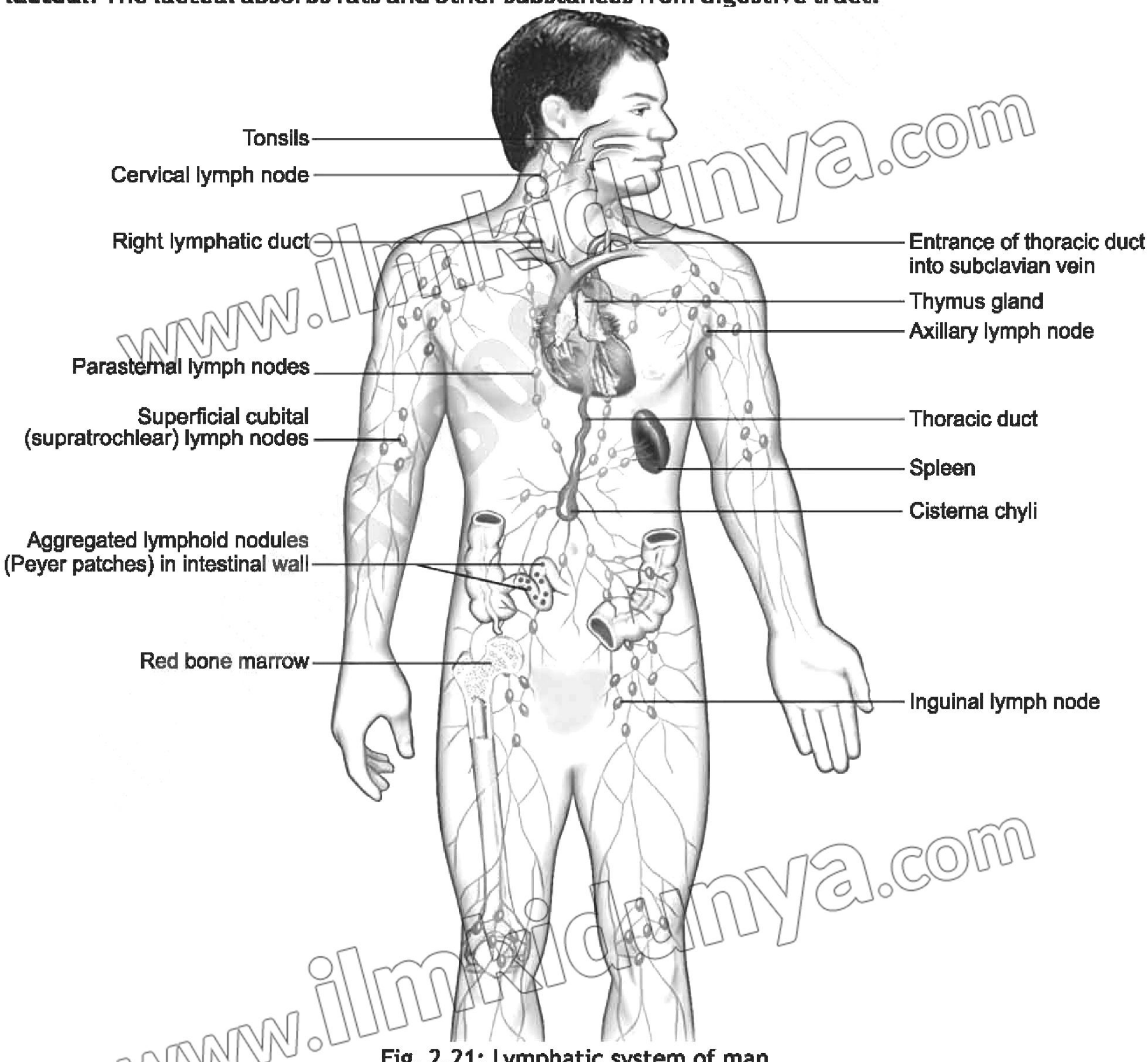


Fig. 2.21: Lymphatic system of man

b. Lymphatic Vessels

Lymphatic vessels are formed by merging of lymphatic capillaries, have walls similar to those of veins. Also like veins, lymphatic vessels have flap like valves, which help to prevent the backflow of lymph. Typically, the lymphatic vessels lead to specialized organs called **lymph nodes**. After leaving these structures, the vessels merge to form still larger lymphatic trunks.

c. Lymphatic Trunks

Lymphatic trunks, the drain lymph from relatively larger portions of the body, are named for the region they serve. The lymphatic trunks then join one of two collecting ducts, the thoracic duct or the right lymphatic duct. The **thoracic duct** is the larger and longer of the two collecting ducts. It receives lymph from the lower body regions, left side, and left side of the head and neck, and empties into the left subclavian vein near the junction of the left jugular vein. The **right lymphatic duct** receives lymph from the right side of the head and the neck, right arm and right thorax. It empties into the subclavian vein near the junction of the right and jugular vein.

2.20.2 Lymph nodes and spleen

a. Lymph nodes

The **lymph nodes** are structures located along the lymphatic pathways.

Functions of lymph nodes: The lymph nodes contain a large number of lymphocytes. The lymph nodes act against foreign particles, such as bacteria and viruses. The lymph nodes also contain macrophages, which engulf and destroy foreign substances, damaged cells and cellular debris.

b. Spleen

The spleen helps get rid of germs. It contains white blood cells called lymphocytes and macrophages. These cells work to attack and destroy germs and remove them from the blood that passes through the spleen. Filters blood by removing cellular waste and getting rid of old or damaged blood cells. It stores blood and iron for future use. It makes white blood cells and antibodies that help to fight infection. It maintains the levels of fluid in your body.

STEAM ACTIVITY 2.1

When we are active, the heart pumps faster to help blood move around our bodies more quickly. As the heart beats and pumps blood around your body, you can feel a slight throbbing or thumping in some parts where an artery (blood vessel carrying blood from the heart around the body) comes close to the surface of your skin. This is called your pulse. Your pulse tells you how fast your heart is beating; this is called your heart rate. The heart rate is measured in beats per minute, sometimes shortened to BPM.

There are few places pulse can be felt but the two main places where the pulse can be felt; the neck and the wrist

Neck: Put two fingers of your left hand onto the side of the windpipe in your throat. Push down gently and you will find your pulse which feels like a small 'thump' (you can feel it going up and down). It can be a bit tricky to find, so you may have to try moving your fingers around to find the right spot.

Wrist: Using the pointer and middle fingers of your right hand, slide from the base of your left thumb (the squishy part of your palm) to where your hand meets your wrist. You might need to move the fingers around until you find the right spot. When you have found the pulse, count how many times you feel it while timing 30 seconds. Multiply this number by 2 to calculate your heart rate in beats per minute (BPM).

Pulse Experiment
Material required: A stopwatch, timer or clock with a second hand, Pencil Record sheet.

on the wrist

on the neck

Step 1: Begin by finding your resting heart rate by taking your pulse. This is how fast your heart is beating each minute when not doing physical activity. Set a timer for one minute. Sit down and relax, taking slow deep breaths.
Step 2: Then set a timer for 30 seconds and take your pulse on the wrist or neck. Record this number in the table below and multiply it by 2 to calculate your resting heart rate in beats per minute.
Step 3: Jog on the spot for 30 seconds. Set your timer and take your pulse again for 30 seconds. Record and calculate beats per minute.
Step 4: Rest for one minute to allow your heart rate to slow down again.
Step 5: Continue doing the activities named on the record sheet for 30 seconds, taking your pulse after each to find BPM. Ensure you take one minute of rest after each time you take your pulse

Record Sheet

Name of the activity	Length of the activity	Beats counted in 30 seconds	Heart rate .BMP, Multiply by 2 to calculate beats in 60 seconds
Sitting	60 seconds		X2 = ---------- BPM
Jogging on the spot	30 seconds		X2 = ---------- BPM
Stretching	30 seconds		X2 = ---------- BPM
Running as fast as on the spot	30 seconds		X2 = ---------- BPM

EXERCISE

Section I: Multiple Choice Questions
Select the correct answer:

1. Which one of the following has the thickest wall?
   A. right ventricle B. left ventricle C. right atrium D. left atrium
2. The reason why tricuspid and bicuspid valves are closed is
   A. ventricular relaxation B. ventricular filling
   C. atrial systole D. attempted backflow of blood into the atria
3. Tricuspid valve is present between
   A. ventricle and pulmonary artery
   B. ventricle and aorta
   C. left auricle and left ventricle
   D. right auricle and right ventricle
4. From where does the aorta originate?
   A. Right ventricle B. Left atrium C. Right atrium D. Left ventricle
5. How many aortic valves are present?
   A. 1 B. 2 C. 3 D. 4
6. The epicardium:
   A. Is also known as the parietal pericardium.
   B. Is a layer of cardiac muscle.
   C. Is the visceral pericardium.
   D. Lines the heart chambers.
7. The tissue which forms a loose-fitting sac around the heart is the:
   A. Visceral pericardium. B. Parietal pericardium.
   C. Myocardium. D. Epicardium.
8. The valve between the left ventricle and the blood vessel leaving the left ventricle is the:
   A. Bicuspid valve B. Tricuspid valve
   C. Pulmonary semilunar valve D. Aortic semilunar valve
9. During the period of ejection in the cardiac cycle, the atrioventricular valves are .... and the semilunar valves are.................
   A. closed, closed B. closed, open
   C. open, closed D. open, open

10. The second heart sound, described as "dupp" is actually the sound of the
   A. Atria contracting
   B. Ventricles contracting
   C. Atrioventricular valves closing
   D. Semilunar valves closing

11. Cardiac output is determined by:
   A. heart rate   B. stroke volume
   C. blood flow   D. heart rate and stroke volume

12. Which one is the definition of cardiac cycle?
   A. The contraction of the atria.
   B. Circulation of blood in the heart.
   C. The contraction and relaxation of the ventricles.
   D. It is sequence of events that occurs during a complete heartbeat.

13. For how long is the cardiac cycle, if the heart rate is 75 beats/min?
   A. 0.7 sec   B. 0.8 sec   C. 0.5 sec   D. 0.4 sec

14. The fluid that passes through the lymphatic vessels
   A. flows toward the lungs
   B. passes from the lymphatic vessels into the arteries
   C. enters the left ventricle of the heart through the right thoracic duct
   D. moves in a single direction toward the heart

15. Lymph nodes may be located in the human body in the tissues of the
   A. stomach and brain   B. groin and neck
   C. ventricle and atrium   D. thyroid gland and adrenal gland

16. A red blood cell, entering the right side of the heart, passes by or through the following structures:
   1. atrioventricular valve 2. semilunar valve 3. right atrium 4. right ventricle
   5. Pulmonary trunk
   In which order will the red blood cell passes the structures?
   A. 2 → 3 → 1 → 4 → 5
   B. 3 → 1 → 4 → 2 → 5
   C. 3 → 5 → 1 → 2 → 4
   D. 5 → 3 → 1 → 4 → 2

17. The rhythmic beating of cardiac muscle in the mammalian heart is initiated by the.
   A. atrio-ventricular node   B. parasympathetic nervous system
   C. Purkinje tissue   D. sino-atrial node

18. What produces systolic blood pressure?

A. contraction of the right atrium B. contraction of the right ventricle

C. contraction of the left atrium D. contraction of the left ventricle

19. Human heart is

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

20. 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 left atrium

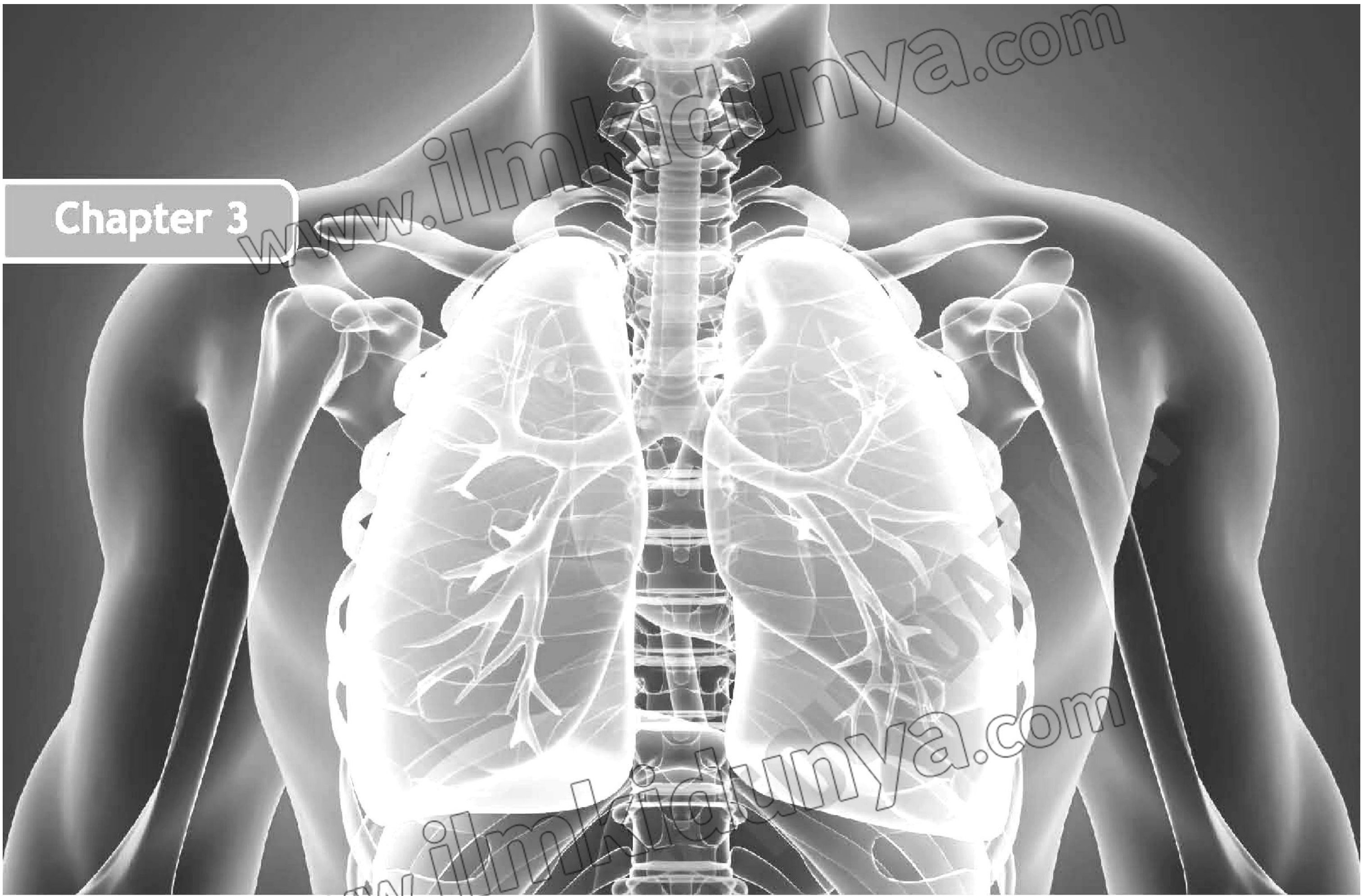
Section II: Short Answer Questions

1. Why do we have a circulatory system?
2. What are the contraction and relaxation of human heart called?
3. Where is SA node, AV node, Purkinje fibre, Bundle of His located?
4. Why action potentials travel along the Purkinje fibres more rapidly than through other muscle fibres?
5. Name the artery supplying blood to the heart.
6. What is blood pressure?
7. Why SA node is called pacemaker of the heart?
8. What is a cardiac cycle?
9. What is an arterial pulse? What is the normal human pulse rate?
10. Why is AV node essential for the conduction of cardiac impulse?
11. What are the risks associated with atherosclerosis?
12. Why can you feel your pulse in arteries but not in veins? If there is no pulse in your veins what pushes the blood in veins back to the heart?
13. Define the term thrombus and differentiate between thrombus and embolus.
14. Identify the factors causing atherosclerosis and arteriosclerosis.
15. List the advantages and disadvantages of coronary bypass.
16. List the changes in the life styles that can protect man from hypertension and cardiac problems.
17. What is the major feature of human lymphatic system?
18. Justify why blood circulatory system is dependent on the lymphatic system.
19. Interpret why the swelling of the lymph node is cause of concern.
20. Write the differences between:
    (a) bicuspid valve and tricuspid valve
    (b) systole and diastole
    (c) SA node and AV node
    (d) P-wave and T-wave of ECG
    (e) blood capillaries and lymph capillaries
    (f) baroreceptor and volume receptor

Section III: Extensive Answer Questions

1. Draw, label and describe the external structure of human heart.
2. Describe the flow of blood through human heart as regulated by the valves.
3. State the phases of heartbeat in man.
4. Describe the conducting system of human heart.
5. Explain electrocardiogram with the help of diagram.
6. Describe the structure of blood vessels in man.
7. What is the role of precapillary sphincter?
8. Describe pulmonary circulation and systemic circulation.
9. Describe hepatic portal system
10. Give an account of blood pressure in man.
11. Compare the rate of blood flow through arteries, arterioles, capillaries, venules and veins.
12. Explain the following:
    a. Principle of angiography
    b. Coronary bypass
    c. Angioplasty
    d. Open heart surgery
13. Explain hypertension and hypotension. What are the factors that regulate blood pressure?
14. Describe the lymphatic system of man.

Chapter 3



RESPIRATORY SYSTEM OF MAN

Students' learning outcomes
After studying this chapter, students will be able to:

1. [B-12-R-01] Define the respiratory surface and list its properties.
2. [B-12-R-02] Describe the main structural features and functions of human respiratory system.
3. [B-12-R-03] Explain the ventilation mechanism in humans.
4. [B-12-R-04] Discuss the transport of oxygen and carbon dioxide through blood.
5. [B-12-R-05] Outline the role of respiratory pigments.
6. [B-12-R-06] State the causes, symptoms and treatment of upper respiratory tract infections (sinusitis, otitis media) and lower respiratory infections (pneumonia, pulmonary tuberculosis).
7. [B-12-R-07] Describe the disorders of lungs (emphysema and COPD)
8. [B-12-R-08] List the effects of smoking on respiratory system.

Like other life processes, the respiration process also occurs at cellular level and organismic level. The process of respiration that occurs at cellular level is also called **internal respiration** which is a catabolic process. It involves the breakdown of complex organic compounds into simpler molecules with the release of energy. On the other hand, the process of respiration that occurs at organismic level is also called **external respiration**. It involves the inhaling of oxygen and exhaling of carbon dioxide. Both the processes are interlinked as the oxygen, required for cellular respiration, is inhaled from environment while the carbon dioxide which is produced in cellular respiration, is exhaled into the environment. This chapter deals with various aspects of respiration.

3.1 PROPERTIES OF RESPIRATORY SURFACE

The area where gaseous exchange with the environment actually takes place is called the **respiratory surface**. The respiratory surface must have the following properties so that diffusion can occur effectively:

- It must be moist and permeable so that gases can pass through.
- It must be thin, because diffusion is only efficient over distance of 1 mm or less.
- It should possess a large surface area so that sufficient amount of gases can be exchanged according to the organism's need.
- It should possess a good blood supply.
- There should be a good ventilation mechanism to maintain a steep diffusion gradient across the respiratory surface.

3.2 RESPIRATORY SYSTEM OF MAN

The body system which is responsible for the exchange of gases between body fluid and outer environment is called **respiratory system**.

The human respiratory system can be divided into two regions, upper respiratory tract and lower respiratory tract.

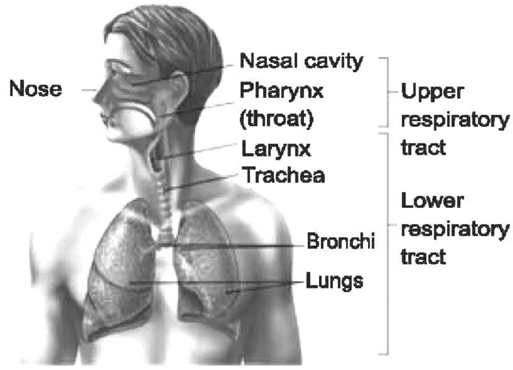


Fig. 3.1: Human respiratory tract

3.2.1 Upper Respiratory Tract

The upper respiratory tract includes nostrils, nasal cavity and pharynx.

Nose

The nose is only externally visible part of the respiratory system. Human nose is composed of bones, cartilage and fatty tissues. The external openings of nose are called **nostrils** and the inner hollow spaces are called **nasal cavities**. There are two nasal cavities which are partitioned by means of nasal septum (the part of nasal bone). The anterior parts of nasal cavities near the nostrils are called **vestibules** which contain hair. Both the nostrils and nasal cavities are lined by ciliated mucous membranes.

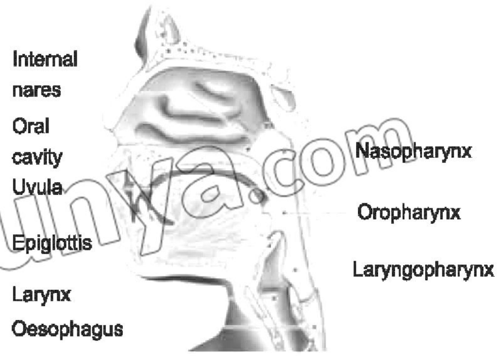


Fig. 3.2: Human respiratory tract

Nose hair, mucus and cilia serve as a defence mechanism against the harmful pathogens and particulate matter present in the air. The mucus and cilia filter the air and prevent the entry of foreign particles such as microorganisms, dust and particulate matter inside the respiratory system. The mucus also helps in moistening the air. Cilia move the trapped substances to the pharynx for their removal. Underneath the mucous membrane, there are blood capillaries that help to warm the air to about 30°C, depending upon the external temperature.

Pharynx

Pharynx is cone-shaped passageway leading from the oral and nasal cavities to the esophagus and larynx. The pharynx is part of the digestive system and also the respiratory system. The human pharynx is conventionally divided into three sections: the nasopharynx, the oropharynx, and the laryngopharynx

3.2.2 Lower Respiratory Tract

The lower respiratory tract includes the larynx, trachea, bronchi and lungs.

Larynx

The larynx is an enlargement in the airway at the top of the trachea and below the pharynx. The larynx is composed primarily of muscles and cartilages. One of the cartilages is the **epiglottis.** This structure usually stands upright and allows air to enter the larynx. During swallowing, however larynx is raised and the epiglottis is pressed downward. As a result, the epiglottis partially covers the opening into the larynx and helps to prevent foods and liquids from entering the air passages. The opening of the larynx is called **glottis**. It is also lined with mucus membrane. Inside the larynx, there are two vocal cords which are responsible for vocalization.

Trachea

The trachea or windpipe is a membranous tube. It consists of dense regular tissue and smooth muscle reinforced with 15-20 C-shaped pieces of cartilage.

Bronchi and bronchioles

The trachea divides to form two smaller tubes called **primary bronchi**.

SCIENCE TITBITS

The alveoli of human lungs are lined with a **surfactant**, a film of lipoprotein that lowers the surface tension and prevents them from closing. Surfactant also speeds up the transport of oxygen and carbon dioxide between the air and liquid lining the alveolus and helps to kill any bacteria, which reach the alveoli. Surfactant is constantly being secreted and reabsorbed in a healthy lung.

The primary bronchi divide into **secondary bronchi** within each lung. There are two secondary bronchi in the left lung and three in the right lung. The secondary bronchi, in turn, give rise to **tertiary bronchi**. The bronchi continue to branch, finally giving rise to **bronchioles** which are less than 1mm in diameter. The bronchioles also subdivide several times to become even smaller **terminal bronchioles**. In the secondary bronchi, the C-shaped cartilages are replaced with cartilage plates but the bronchioles and their terminal branches have no cartilage structures.

Alveolar ducts and alveoli

The terminal bronchioles divide to form **alveolar ducts**. These alveolar ducts end at tiny air filled chambers called **alveoli** which are the sites of gas exchange between the air and the blood. There are over 700 million alveoli present in the lungs.

The wall of each alveolus is only 0.1 μm thick. On its outsides is a dense network of blood capillaries. Lining each alveolus is moist squamous epithelium. This consists of very thin, flattened cells, reducing the distance over which diffusion must occur. Collagen and elastin proteins are also present in their walls which allow the alveoli to expand and recoil easily during breathing.

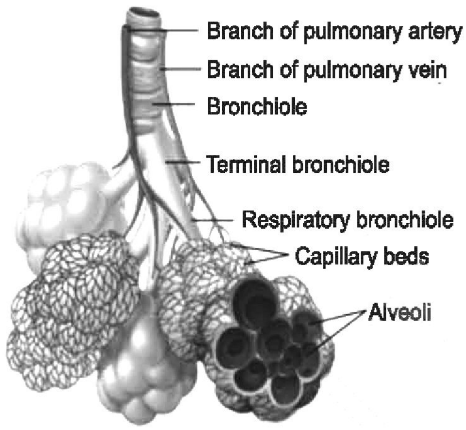


Fig. 3.3: Alveoli

External structure of lungs

The lungs are the principal organs of respiration. Each lung is conical in shape, with its base resting on the diaphragm and its apex extends to a point just above the clavicle. The right and left lungs are separated medially by the heart and **mediastinum**, which is the area between the lungs.
The left lung has two lobes, **superior lobe** and **inferior lobe**. The left lung shares space with the heart. The right lung has three lobes. The **hilum** is a triangular shaped depression of both the lungs where the blood vessels and airways pass into the lungs. The lungs are spongy due to presence of alveoli.

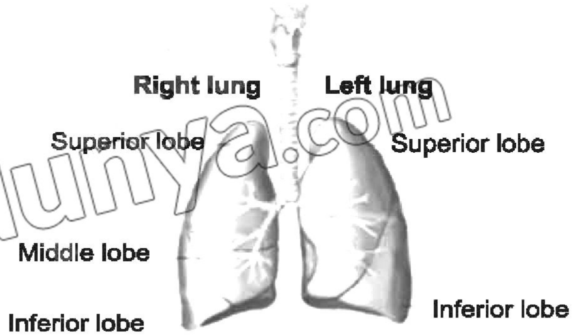


Fig. 3.4: Human lungs

3.3 MECHANISM OF VENTILATION (BREATHING)

The lungs themselves neither draw in air nor push it out. The diaphragm and the intercostal muscles accomplish the expansion and contraction of the lungs. The **diaphragm** is a large dome of skeletal muscle that separates the thoracic cavity from abdominal cavity. There are two sets of **intercostal muscles** between each pair of ribs: the external intercostal and the internal intercostal. The muscle fibres run diagonally but in opposite direction in the two sets of muscles. Breathing takes place in two phases i.e., inspiration and expiration.

Inspiration: It is taking in of air; it is the active phase of breathing. During inspiration contraction of the diaphragm causes its dome shape to flatten or less dome shape whereas contraction of the external intercostal and relaxation of the internal intercostal causes the rib cage to move upward and forward. Both these events result in increase of inner space of thoracic cavity. Consequently, the pressure in the thorax and hence in the lungs, is reduced to less than atmospheric pressure. Air therefore enters the lungs and alveoli become inflated.

Expiration: It is the removal of air out of the lungs; it is the passive phase of breathing. During expiration relaxation of the diaphragm causes it to become more dome shape whereas relaxation of the external intercostal and contraction of the internal intercostal cause the rib cage to move downward and backward. Both these events result in decrease of inner space of thoracic cavity. Consequently, the pressure in the thorax and hence in the lungs, is increased to more than atmospheric pressure, therefore, air is forced to expelled from the lungs.

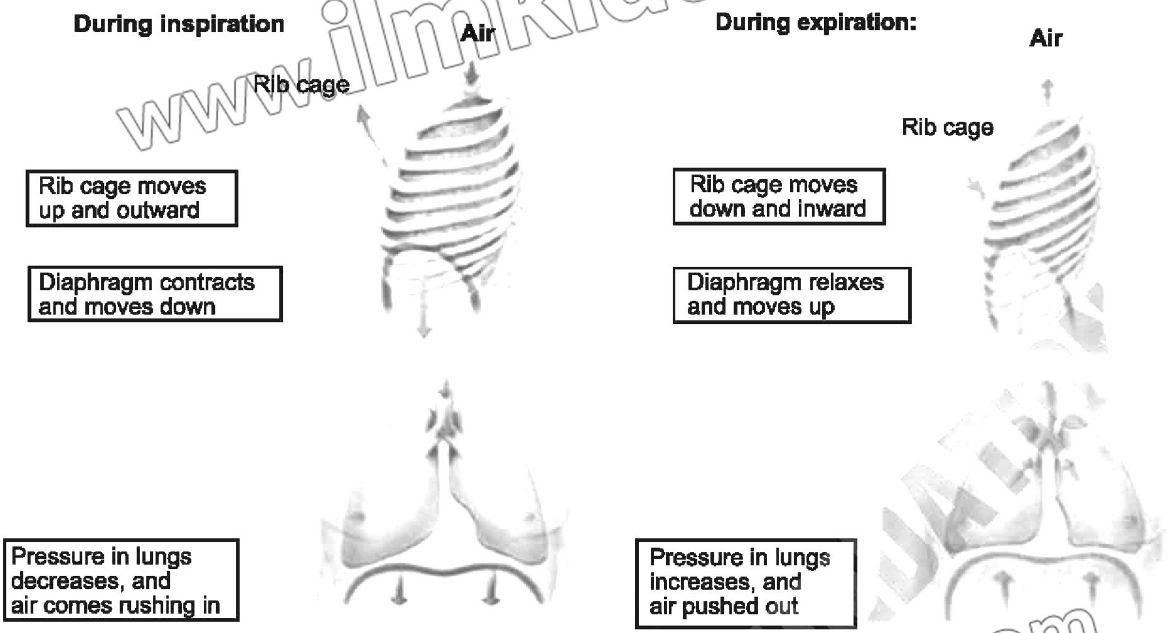


Fig. 3.5: Mechanism of breathing in human

3.3.1 Control of Breathing (Ventilation)

Normally we are not conscious of our breathing because it is controlled involuntarily. A **breathing centre** located in the **medulla** of the brain carries out involuntary control of breathing. The ventral portion of the breathing centre acts to increase the rate and depth of inspiration and is called **inspiratory centre**. The dorsal and lateral portions inhibit inspiration and stimulate expiration. These regions form the **expiratory centre**.

Through the **cerebral cortex** it is possible to consciously or unconsciously increase or decrease the rate and depth of the respiratory movement. A person may also stop breathing voluntarily. Occasionally people are able to hold their breath until the blood partial pressure of oxygen declines to a level low enough that they lose consciousness. After consciousness is lost, the respiratory centre resumes its normal function in automatically controlling respiration. Emotions acting through the **limbic system** of the brain can also affect the respiratory centre.

3.4 TRANSPORT OF GASES

Like other materials, respiratory gases are also transported in various regions of the body by means of blood. The blood transports oxygen from the lungs to different tissues and carbon dioxide from tissues to the lungs.

3.4.1 Transport of Oxygen in Blood

Approximately 97% of oxygen is carried by the red blood cells as **oxyhaemoglobin**, while 3% is transported as dissolved oxygen in the **plasma**. At its high partial pressure oxygen binds with haemoglobin.

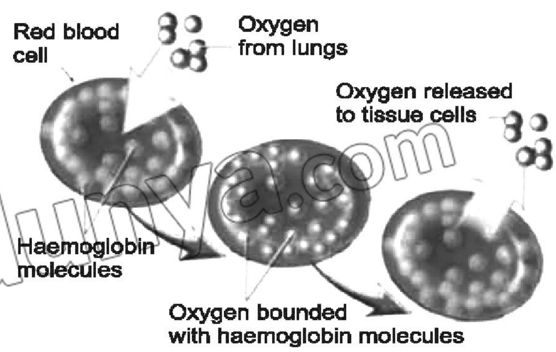


Fig. 3.6: Human lungs

This binding is reversible that occurs in the lungs in the presence of enzyme carbonic anhydrase. Each molecule of haemoglobin can bind with four molecules of oxygen to form oxyhaemoglobin.

$$Hb + 4O_2 \xrightarrow{\text{Carbonic anhydrase}} Hb4O_2$$

The ability of haemoglobin to bind with oxygen is called **oxygen carrying capacity** of blood.

SCIENCE TITBITS

The oxygen carrying capacity of blood is directly proportional to the partial pressure of oxygen (PO_2). Maximum oxygen carrying capacity of arterial blood is 20 ml/100 ml of blood (100% saturated) which is achieved at 100 mmHg Po_2. The 5 ml of O_2 is released to the tissues by each 100 ml blood. Oxygen carrying capacity is sensitive to a variety of environmental conditions like rise in body temperature, drop in pH of blood and partial pressures of carbon dioxide and oxygen.

SCIENCE TITBITS

The amount of haemoglobin is 15 gms/100 ml of blood. Since 1gm Hb can combine with 1.34 ml of O_2, therefore 100 ml blood combines with 20 ml O_2 (100% saturated). Normally each 100 ml of arterial blood contains 19.4 ml O_2 (i.e., it is 97% saturated; PO_2 is 95 mmHg), while 100 ml of venous blood contains 14.4 ml O_2 (i.e., it is 75% saturated; Po_2 is 40 mmHg).

3.4.2 Transport of Carbon dioxide in Blood

Carbon dioxide is transported in the blood in three main ways: (i) In the form of bicarbonate ions. (ii) In the form of carboxyhaemoglobin. (iii) Dissolved in plasma.

(I) As bicarbonate ions

Approximately 70% of carbon dioxide is carried in the blood as bicarbonate ions. Carbon dioxide diffuses into the blood, enters the red blood cells and combines with water to form carbonic acid in the presence of enzyme carbonic anhydrase. The chemical reaction can be depicted as follows:

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3$$

Carbonic acid, H_2CO_3 is an unstable compound and dissociates to form hydrogen ions and bicarbonate ions.

$$H_2CO_3 \xrightleftharpoons{\text{Carbonic anhydrase}} H^+ + HCO_3^-$$

Accumulation of H^+ ions increases acidity in the blood, i.e., it leads to the decrease in pH. This does not occur since haemoglobin buffers the hydrogen formed. The hydrogen ion readily associates with oxyhaemoglobin ($Hb4O_2$) to form haemoglobinic acid (HHb) and oxygen is released to the tissue.

$$Hb4O_2 + H^+ \longrightarrow HHb + 4O_2$$

From inside of the erythrocytes negatively charged HCO_3^- ions diffuse to the plasma. This is balanced by the diffusion of chloride ions, (Cl^-), in the opposite direction. This is achieved by special bicarbonate-chloride carrier proteins that exist in the RBC membrane. This protein moves the two ions in opposite directions, maintaining the balance of ions on either side. This is called the **chloride shift or Hamburger' phenomenon**.

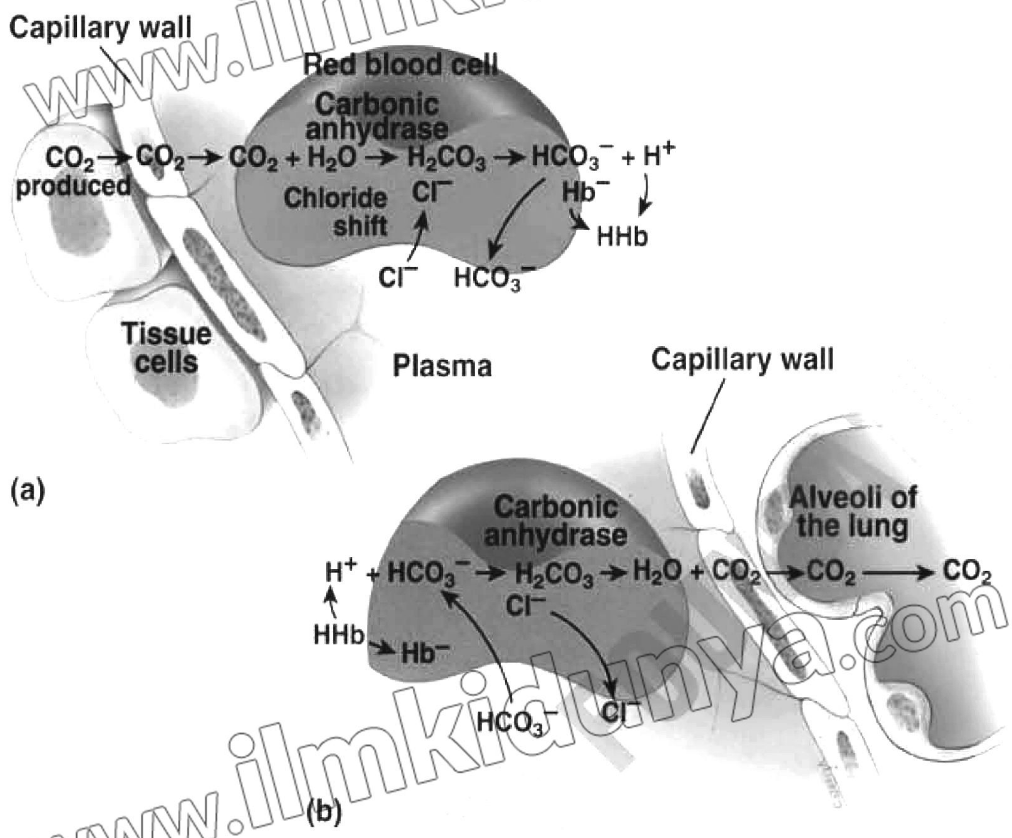


Fig. 3.7: Transport of CO_2 as bicarbonate ions (a) Transfer of CO_2 from tissues to blood (b) Transfer of CO_2 from blood to lungs.

The chloride ions that enter the RBC combine with potassium (K+) to form potassium chloride, whereas bicarbonate ions in the blood plasma combine with Na+ to form sodium bicarbonates. The blood pH is thus maintained at approximately 7.4 by the buffer mechanism that exists in blood.

Transport of CO_2 depends on the partial pressure of CO_2. The partial pressure of Co_2 is higher in tissues than blood so it diffuses into blood here it react with water and transported to the lungs as bicarbonate ion. In lungs process reverses and bicarbonate ions combine with hydrogen ion to release carbon dioxide and water.

(II) As carboxyhaemoglobin

About 23% of carbon dioxide is carried as carboxyhaemoglobin. CO_2 combines with the globin part of haemoglobin. The reaction depends upon the partial pressure of CO_2. When the PCO_2 is higher in the tissues than blood, formation of carboxyhaemoglobin occurs. When the PCO_2 is higher in the blood than tissues as in case of lungs, carboxyhaemoglobin releases its CO_2.

(iii) As dissolved CO_2 in plasma

Only 7% of carbon dioxide is carried this way. This is rather inefficient way to carry carbon dioxide, but it does occur.

3.5 ROLL OF RESPIRATORY PIGMENTS

Respiratory pigments are coloured molecules, which act as oxygen carriers by binding reversibly to oxygen. All known respiratory pigments contain a coloured non-protein portion e.g., **haem** in the haemoglobin. The two well-known respiratory pigments are haemoglobin and myoglobin.

Haemoglobin

It contains four globin protein chains, each associated with haem, an iron-containing group. Iron combines loosely with oxygen and in this way oxygen is carried in the blood. At high oxygen concentrations, the pigment combines with oxygen, whereas at low oxygen concentrations the oxygen is quickly released.

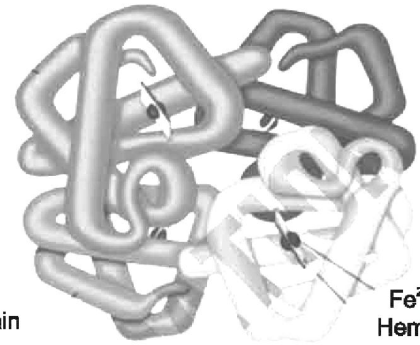


Fig. 3.8: Haemoglobin

Myoglobin

It consists of one polypeptide chain. This chain is associated with an iron containing ring structure. This iron can bind with one molecule of oxygen. It is found in skeletal muscles and is the main reason why meat appears red. It serves as an intermediate compound for the transfer of oxygen from haemoglobin to aerobic metabolic processes of the muscle cells. Myoglobin releases oxygen when the partial pressure of oxygen is below 20 mmHg. In this way it stores oxygen in resting muscle, only releasing it when supplies of oxyhaemoglobin have been exhausted.

Fig. 3.9: Myoglobin

Table 3.1 Differences between haemoglobin and myoglobin

Haemoglobin	Myoglobin
It consists of four polypeptide chains.	It consists of one polypeptide chain.
Each molecule possesses four iron containing haem groups.	Each molecule possesses one iron containing haem group.
Four oxygen molecules can bind to each haemoglobin molecule.	Only one oxygen molecule can bind to each myoglobin molecule.
It is found in RBCs.	It is found in muscles.
It transports oxygen.	It stores oxygen.
It has less affinity with oxygen.	It has more affinity with oxygen.
It loses oxygen at PO_2 60 mmHg.	It loses oxygen at PO_2 20 mmHg.

Science, Technology and Society Connections

Describe the carbon monoxide poisoning (caused by gas heaters left on overnight in closed environments).

Gases that have undergone incomplete combustion produce CO and toxic fumes (hydrogen cyanide). In carbon monoxide poisoning caused by gas heaters, left on overnight in closed environments, CO binds to haemoglobin preventing the uptake of oxygen by haemoglobin. The symptoms of CO poisoning are nausea, vomiting, headache, mental status changes, and cherry-red lips. CO binds to haemoglobin with affinity 249 times greater than that of oxygen. CO poisoning also decreases ability of haemoglobin to release oxygen to tissue.

3.6 RESPIRATORY DISORDERS

Respiratory tract infections are infections of parts of the body involved in breathing such as sinuses, throat, airways and lungs. The causes of respiratory tract infections can be bacterial, viral and fungal infections. Factors that increase susceptibility included weakened immune systems, smoking, air pollution and close contact with the infected individuals. Infections can affect the upper respiratory tract or the lower respiratory tract.

3.6.1 Upper Respiratory Tract Infection

The infections of the upper respiratory tract include sinusitis, etc.

Sinusitis

Sinusitis is an inflammation of the nasal sinuses that may be acute (symptoms last 2 - 8 weeks) or chronic (symptoms last much longer). The sinuses are holes in the skull between the facial bones.

Cause: Sinusitis is generally caused by cold and wet climate. Atmospheric pollution, smoke, dust, overcrowding, dental infections, viral infections etc., also cause sinusitis.

Symptoms: Fever, nasal obstruction, raspy voice, pus-like nasal discharge, loss of sense of smell, facial pain or headache that is sometimes aggravated by bending over.

Treatment: If a bacterial infection is present, antibiotics or sulpha drugs are usually prescribed. Beside it the physician may also prescribe nebulization which can be useful in reducing inflammation in the sinuses and nose and to accelerate recovery.

Otitis media

Otitis media is inflammation or infection located in the middle ear.

Causes: Middle ear infections are usually a result of a malfunction of the eustachian tube. When this tube is not working properly, it prevents normal drainage of fluid from the middle ear, causing a buildup of fluid behind the eardrum. When this fluid cannot drain, it allows for the growth of bacteria and viruses in the ear that can lead to acute otitis media. The following are some of the reasons: (i) A cold or allergy which can lead to swelling and congestion of the lining of the nose, throat, and eustachian tube (this swelling prevents the normal drainage of fluids from the ear) (ii) A malformation of the eustachian tube.

Symptoms: The following are the most common symptoms of otitis media. However, each child may experience symptoms differently. Symptoms may include: (a) unusual irritability

(b) Difficulty sleeping or staying asleep (c) Tugging or pulling at one or both ears. (d) Fever, especially in infants and younger children (e) Fluid draining from ear(s) (f) Loss of balance (g) Hearing difficulties (h) Ear pain.

Treatment: It may include: (a) Antibiotic medication by mouth or ear drops (b) Medication (for pain and fever) (d) A combination of the above.

3.6.2 Lower Respiratory Tract Infection

The infections of lower respiratory tract include, pulmonary tuberculosis etc.

Pneumonia

Pneumonia is an infection that inflames the air sacs in one or both lungs. The air sacs may fill with fluid or pus, causing cough with phlegm or pus, fever, chills, and difficulty breathing.

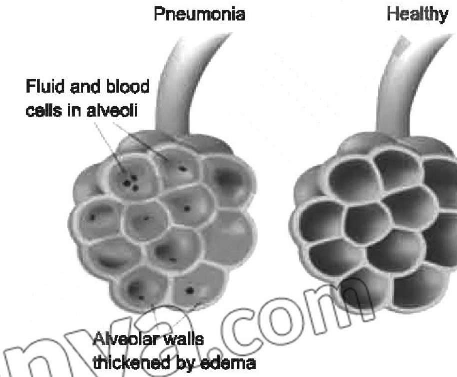


Fig. 3.10: Pneumonia

Causes: A variety of organisms, including bacteria, viruses and fungi, can cause pneumonia.

Symptoms: These may include: (a) Chest pain when you breathe or cough (b) Confusion or changes in mental awareness (in adults age 65 and older (c) Cough, which may produce phlegm (d) Fatigue (e) Fever, sweating and shaking chills. (f) Lower than normal body temperature (in adults older than age 65 and people with weak immune systems) (g) Nausea, vomiting or diarrhea (h) Shortness of breath.

Treatment: Some treatments may include:

1. **Antibiotics:** Pneumonia caused by bacteria is treated with an antibiotic.
2. **Antifungal medications:** Antifungal can treat pneumonia caused by a fungal infection.
3. **Antiviral medications:** Viral pneumonia usually isn't treated with medication and can go away on its own.
4. **Draining of fluids:** If you have a lot of fluid between your lungs and chest wall (pleural effusion), a physician may drain it. This is done with a catheter or surgery.

Pulmonary Tuberculosis

Pulmonary Tuberculosis (TB) is a highly contagious chronic bacterial infection of lungs. When people have pulmonary tuberculosis, the alveoli burst and are replaced by inelastic connective tissue. The cells of the lung tissue build a protective capsule around the bacilli and isolate them from rest of the body. This tiny capsule is called **tubercle**. The tubercles can rupture, releasing bacteria that infect other parts of the lung.

Cause: Pulmonary tuberculosis is caused by *Mycobacterium tuberculosis*.

Symptoms: There is a low-grade intermittent fever usually in the evening, night sweats, weight loss, anorexia, depression, weakness and dry cough with sputum, dull ache in the chest due to Inflammation of the pleura of the lungs.

Treatment: Taking medicines for 9 months regularly can cure T.B disease. This is called **Daily Observed Treatment Short Course (DOTS)**. This treatment is given to patients under supervision to ensure that the "medicines intake" completely cures the patient.

SCIENCE TITBITS

The spread of pulmonary TB can be controlled by some preventive measures like:

1. Living room should be well ventilated and bright.
2. Always cover the mouth with cloth during coughing and sneezing.
3. Avoid spitting openly.
4. Always burry or burn the sputum of patient.
5. The patients should spit in a utensil with lime powder to prevent the spread of disease.
6. The use of masks and other respiratory isolation procedures to prevent spread to medical personal is also important.

3.6.3 Disorders of lungs

There are many disorders that affect lungs. Emphysema and COPD are two common examples of disorders of lungs.

Emphysema

Emphysema is a lung disease that results from damage to the walls of the alveoli in the lungs. A blockage (obstruction) may develop, which traps air inside the lungs. With fewer alveoli, less oxygen moves into your bloodstream.

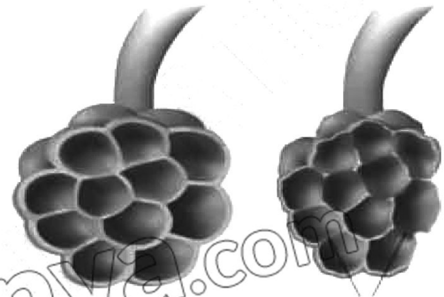


Fig. 3.11: Emphysema

Causes: Smoking is the main cause of emphysema. There are other causes. These include: (a) Marijuana (b) Vaping and e-cigarettes (c) Cigar smoke. (d) Air pollution. (e) Dust.
Symptoms: These include: (a) Long-term coughing (smoker's cough). (b) Wheezing. (c) Shortness of breath, especially during light exercise like climbing steps. (d) Constant feeling of not being able to get enough air. (e) Tightness in the chest. (f) Increased mucus production. (g) Abnormal mucus color (yellow or green). (h) Ongoing fatigue. (i) Heart problems.
Treatment: Treatment options may include: (a) Quitting smoking. (b) Bronchodilators (c) Inhaled and oral corticosteroids (d) Antibiotics (e) Anti-inflammatory medications.

Chronic obstructive pulmonary disease (COPD)

Chronic obstructive pulmonary disease (COPD) is the name for a group of lung conditions that cause breathing difficulties. It includes: (a) emphysema - damage to the air sacs in the lungs (b) chronic bronchitis - long-term inflammation of the airways
Causes: COPD happens when the lungs become inflamed, damaged and narrowed. The main cause is smoking. Some cases of COPD are caused by long-term exposure to harmful fumes or dust. Others are the result of a rare genetic problem that makes the lungs more vulnerable to damage.

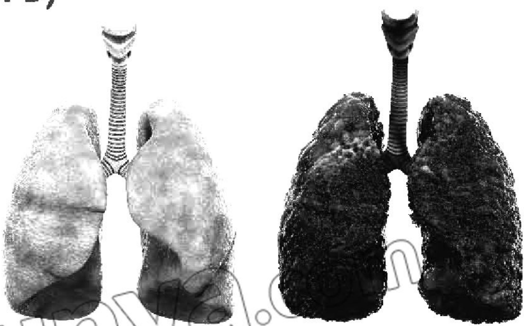


Fig. 3.12: Effects of smoking on lungs

Symptoms: The main symptoms of COPD are: (a) shortness of breath, (b) a persistent chesty cough, with phlegm (c) frequent chest infections (d) persistent wheezing

Treatment: Treatments include: (a) stopping smoking (b) inhalers and medicines - to help make breathing easier (c) pulmonary rehabilitation -a specialized programmed of exercise and education (d) surgery or a lung transplant- although this is only an option for a very small number of people.

3.6.4 Effects of smoking

The effects of smoking on respiratory system are:

1. Cigarette smoking causes about 87% of lung cancer.
2. Besides lung cancer, cigarette smoking is also a major cause of cancer of the mouth, larynx and esophagus.
3. Cigarette smoking causes other lung diseases e.g., chronic bronchitis, emphysema.
4. Cigarette smokes contain chemicals which irritate the air passages and lungs, causing early morning cough.
5. Smokers are likely to get pneumonia because damaged or destroyed cilia cannot protect lungs from bacteria and viruses that float in the air.
6. Almost immediately, smoking can make it hard to breathe. Within a short time, it can also worsen asthma and allergies.

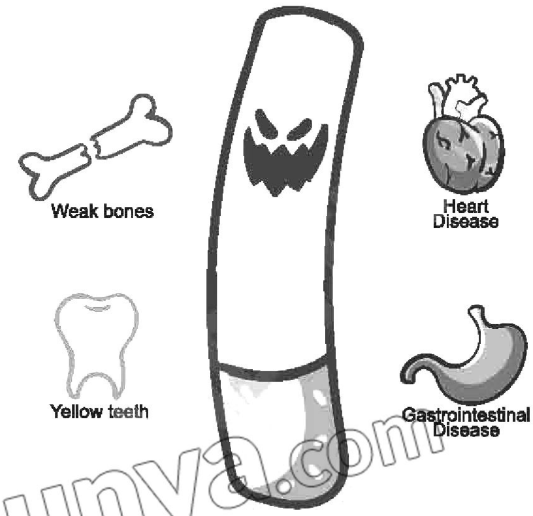
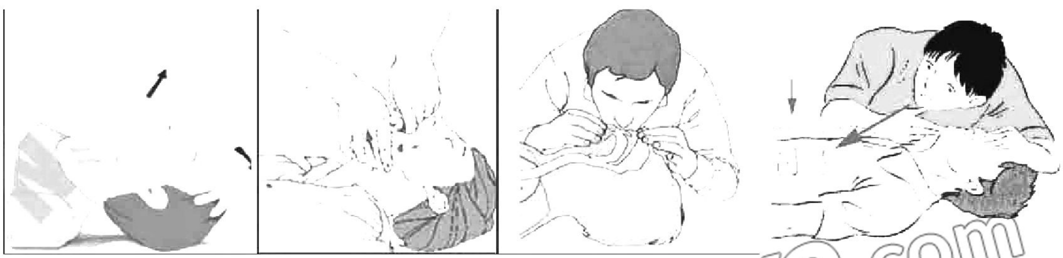


Fig. 3.13: Effects of smoking

Science, Technology and Society Connections

Mouth to mouth artificial respiration. (Cardiopulmonary Resuscitation (CPR)

Mouth to mouth artificial respiration is called resuscitation. It is a technique used to recover a person who has stopped breathing. In this technique, the rescuer presses his or her mouth against the mouth of the victim and allowing for passive inhalation, forces air into the lungs at intervals of several seconds.



What to do:

1. Stretch out victim on his back and kneel close to his side. Loosen any tight clothing around his neck or chest.
2. Remove foreign objects if present from victim's mouth and throat by finger sweeping.
3. Lift up chin and tilt head back as far as possible. If the head is not tilted, the tongue may block the throat.

4. Begin the resuscitation immediately. Pinch the nostrils together with the thumb and index finger of the hand that is pressing on the victim's forehead. This prevents the loss of air through the nose during resuscitation.
5. Inhale deeply.
6. Place your mouth tightly around the victim's mouth (over mouth and nose of small children) and blow into the air passage with brief intervals. Continue this activity so long as there is any pulse or heartbeat.
7. Watch the victim's chest. When you see it rise, stop blowing, raise your mouth, turn your head to the side and listen for exhalation.
8. If patient is revived, keep him warm and do not move him until the doctor arrives, or at least for half or one hour.

STEAM ACTIVITY 3.1

a. How to measure your respiratory rate

Your respiratory rate is also known as your breathing rate. This is the number of breaths you take per minute.

You can measure your breathing rate by counting the number of breaths you take over the course of one minute while you are at rest.

To get an accurate measurement:

1. Sit down and try to relax.
2. It's best to take your respiratory rate while sitting up in a chair or in bed.
3. Measure your breathing rate by counting the number of times your chest or abdomen rises over the course of one minute.
4. Record this number.

EXERCISE

Section I: Multiple Choice Questions
Select the correct answer:

1. When blood leaves the capillary bed most of the carbon dioxide is in the form of
   A. carbonate ions B. bicarbonate ions
   C. hydrogen ions D. hydroxyl ions
2. 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
3. With which other system do specialised respiratory systems most closely interface in exchanging gases between the cells and the environment?
   A. the skin B. the excretory system
   C. the circulatory system D. the muscular system
4. Which of the following is the respiratory surface in human respiratory system:
   A. larynx B. trachea
   C. bronchi D. alveoli

5. How is most of the oxygen transported in the blood?

A. dissolved in plasma
B. bound to haemogloibin
C. as bicarbonate
D. dissolved in water

6. The lateral walls of the chest cavity of man are composed of the:

A. ribs
B. intercostal muscles
C. ribs and intercostal muscles
D. ribs, intercostal muscles and diaphragm

7. Which of the following factors is the most effective in accelerating the rate of breathing in man?

A. a lack of oxygen in the blood
B. a lack of oxygen in the tissues
C. an excess of carbon dioxide in the lungs
D. an excess of carbon dioxide in the blood

8. Which of the following changes will increase the body's rate of carbon dioxide excretion into the alveoli?

A. holding the breath
B. the breakdown of alveolar tissue as a result of disease
C. a decrease in the partial pressure of carbon dioxide in the alveolar air
D. a decrease in the pulmonary circulation

9. Breathing is an example of

A. counter current exchange
B. cellular respiration
C. ventilation
D. diffusion

10. Which sequence most accurately describes the sequence of airflow in the human respiratory system?

1. pharynx 2. bronchus 3.trachea 4.larynx 5.alveolus 6.bronchiole

A. 4, 1, 3, 2, 5, 6
B. 1, 4, 3, 2, 5, 6
C. 4, 1, 3, 2, 6, 5
D. 1, 4, 3, 2, 6, 5

11. Which one of the following changes takes place during inspiration?

A. Decrease in thoracic cavity
B. Relaxation in diaphragm
C. Relaxation in external intercostal muscles
D. Sternum moves towards ventral and anterior direction

12. The volume of air that can be exhaled after normal exhalation is the

A. tidal volume
B. residual volume
C. inspiratory reserve volume
D. expiratory reserve volume

13. Hemoglobin

A. combine reversely with only oxygen
C. attach to the alveolar wall
B. all have four heme group
D. none of them

14. The maximum volume of air contained in the lung by a full forced inhalation is called __________.

A. Tidal volume
B. Vital capacity
C. Ventilation rate
D. Total lung capacity

15. Dissociation of O_2 from oxyhaemoglobin is facilutated by:

A. decreased temperature
B. decreases H^+
C. decreased PO_2
D. exercise

16. Which of these correctly orders the structures through which air passes during inhalation?

A. pharynx → trachea → larynx → bronchi

B. pharynx → larynx → trachea → bronchi

C. larynx → pharynx → bronchi → trachea

D. larynx → pharynx → trachea → bronchi

17. The pharynx is also known as the:

A. windpipe
B. trachea
C. voice box
D. throat

18. What is the correct path air takes when it enters the trachea on its way to the lungs?

A. bronchi /bronchioles /pulmonary capillaries/ alveoli

B. bronchioles/ bronchi/ alveoli/ pulmonary capillaries

C. bronchi / pulmonary capillaries/alveoli/ bronchioles

D. bronchi /bronchioles/alveoli / pulmonary capillaries

19. Which of the following is correct for the partial pressure of oxygen in alveoli?

A. less than carbon dioxide

B. less than the blood

C. more than the blood

D. equal to that of the blood

20. Which of the following is the respiratory surface in human respiratory system:

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

Section II: Short Answer Questions

1. What is respiratory surface? Write the properties of respiratory surface.
2. What organs constitute the respiratory system?
3. How nose and nasal cavity function in filtering the incoming air?
4. What is the role of 'pharynx' in human respiration?
5. Describe function of human larynx.
6. Describe the structure and function of alveoli.
7. How the contraction and relaxation of human lungs take place?
8. What is chloride shift?
9. What are the advantages of having millions of alveoli rather than a pair of simple balloon like lungs?
10. Write the differences between:
    (a) Internal and external respiration
    (b) Upper and lower respiratory tract
    (c) Bronchi and bronchioles

(d) Oxyhaemoglobin and carboxyhaemoglobin
(e) Haemoglobin and myoglobin

11. List the effects of smoking.

Section III: Extensive Answer Questions

1. Describe the human upper respiratory tract.
2. Describe the human lower respiratory tract.
3. Describe the mechanism of breathing in man.
4. How the control of breathing takes place?
5. Explain the transport of oxygen in blood.
6. Explain the transport of carbon dioxide in blood.
7. What is the role of respiratory pigments in man?
8. Describe the cause, symptoms and treatments of:
   (a) Sinusitis
   (b) Otitis media
   (c) Pneumonia
   (d) Pulmonary tuberculosis
   (e) Emphysema
   (f) Chronic obstructive pulmonary disease (COPD)

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