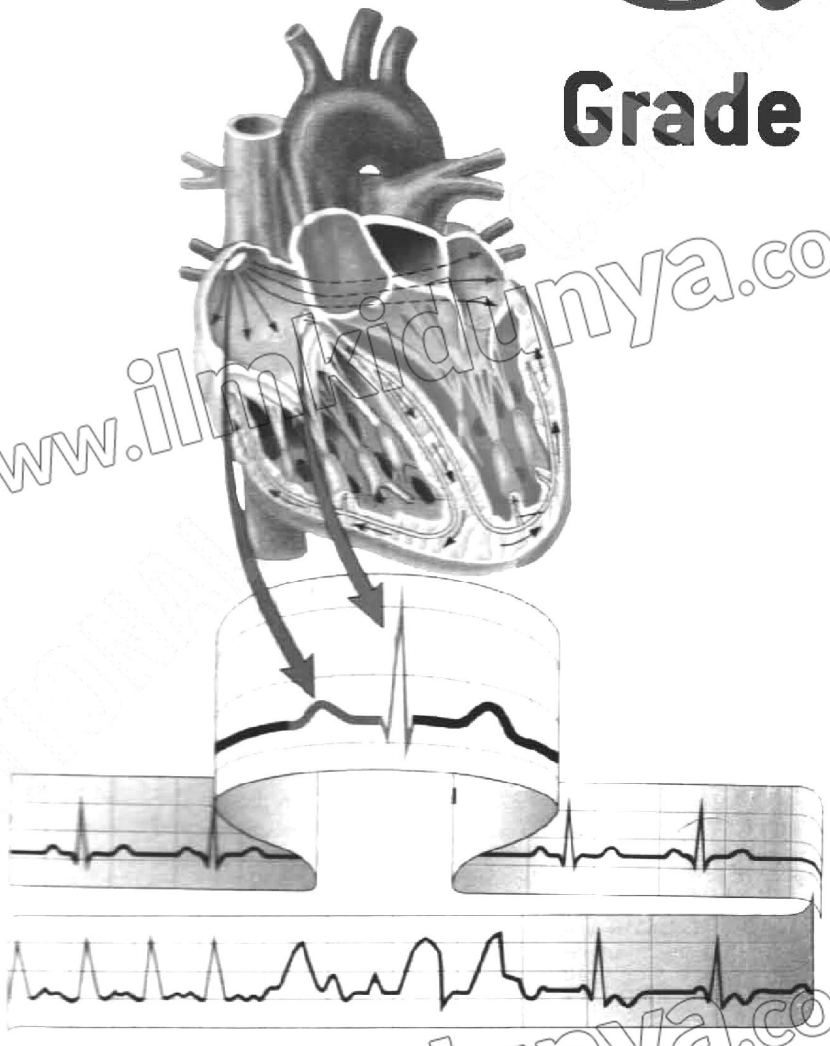
Based on National Curriculum of Pakistan 2022-23

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.

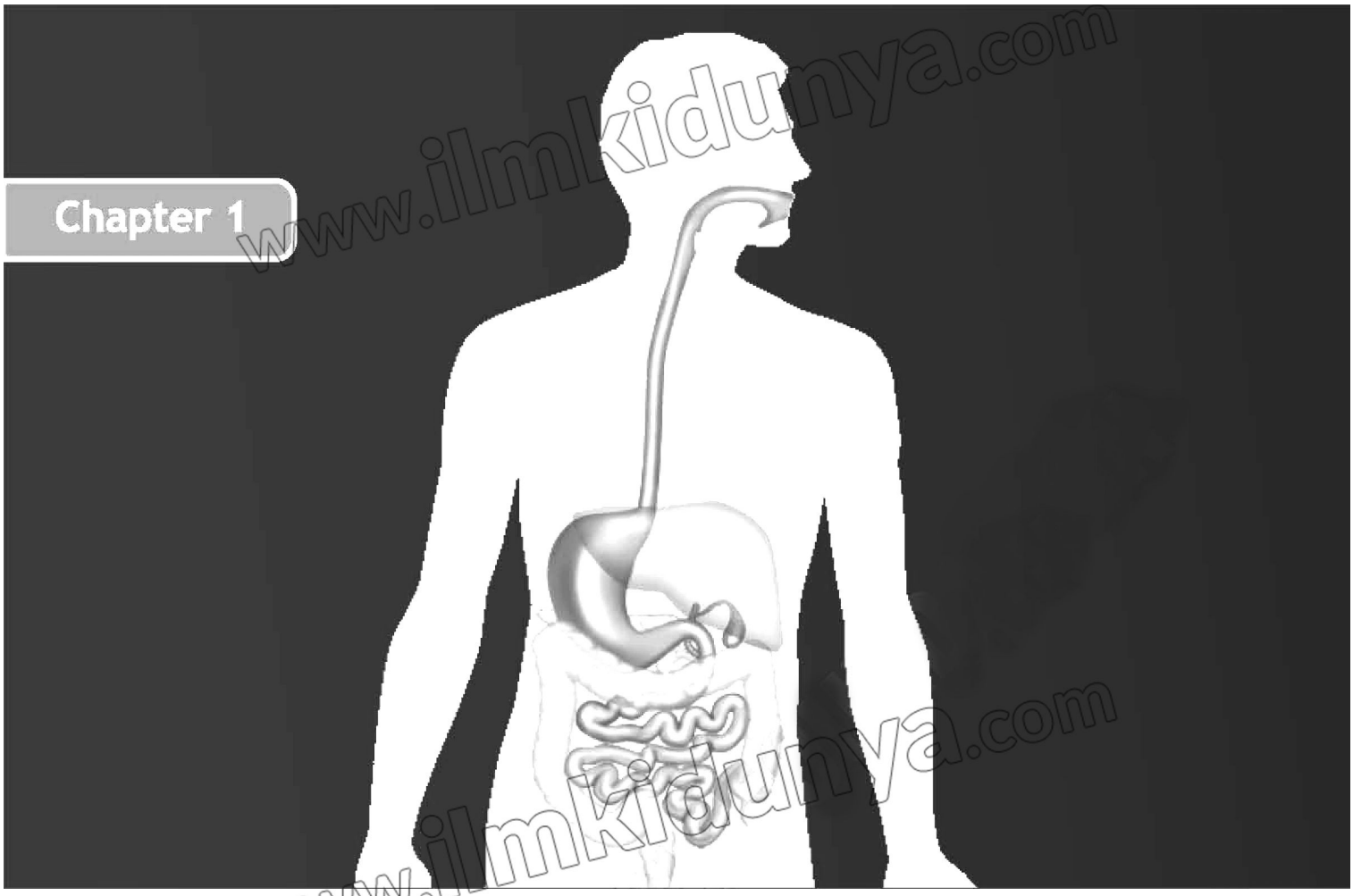
    Knowledge about ocean acidification and the role of carbon dioxide absorption can drive personal actions like supporting reforestation and using renewable energy sources. People can also contribute to reducing climate impacts by supporting renewable energy projects, minimizing plastic use to protect 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.

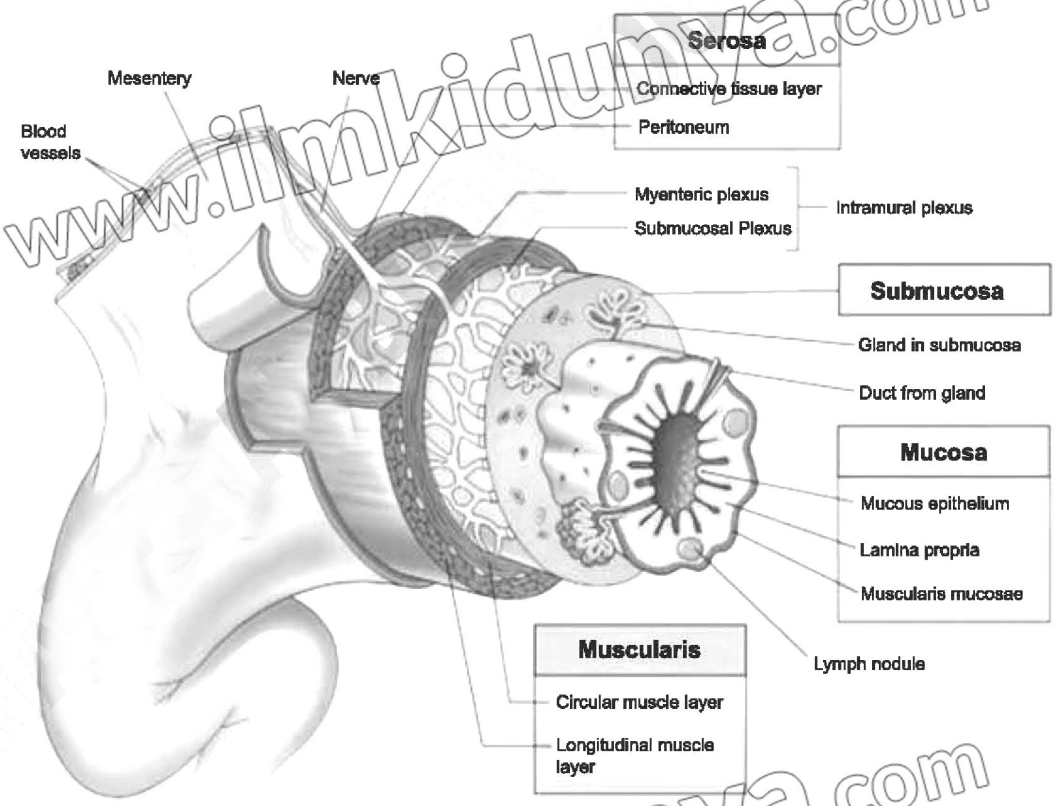


Fig. 1.1: Histological layers of the digestive tract

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.

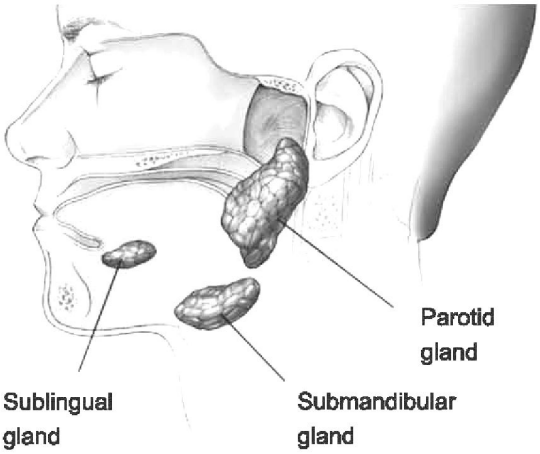


Fig. 1.2: Human salivary glands

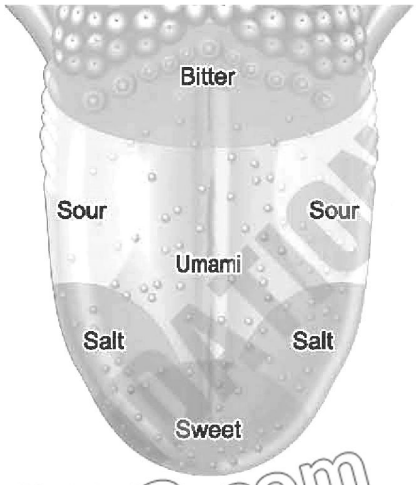


Fig. 1.3: Human taste buds map

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.

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.

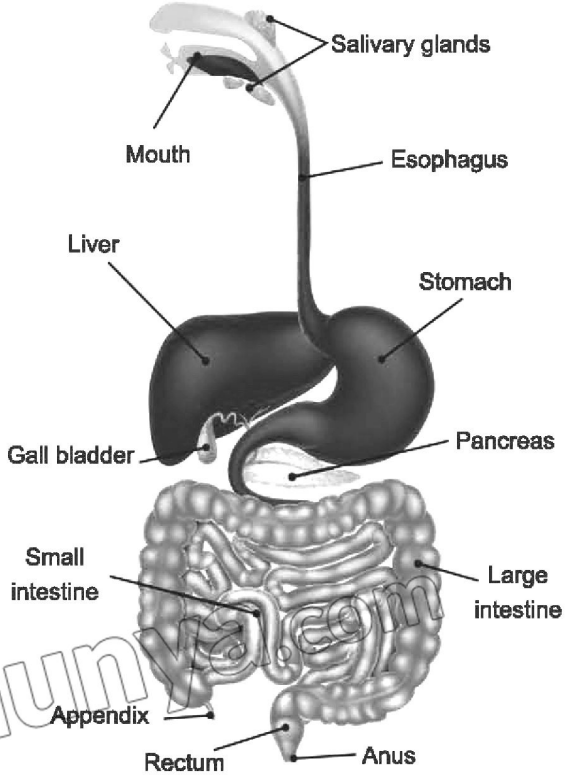


Fig. 1.4: Human digestive system

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.

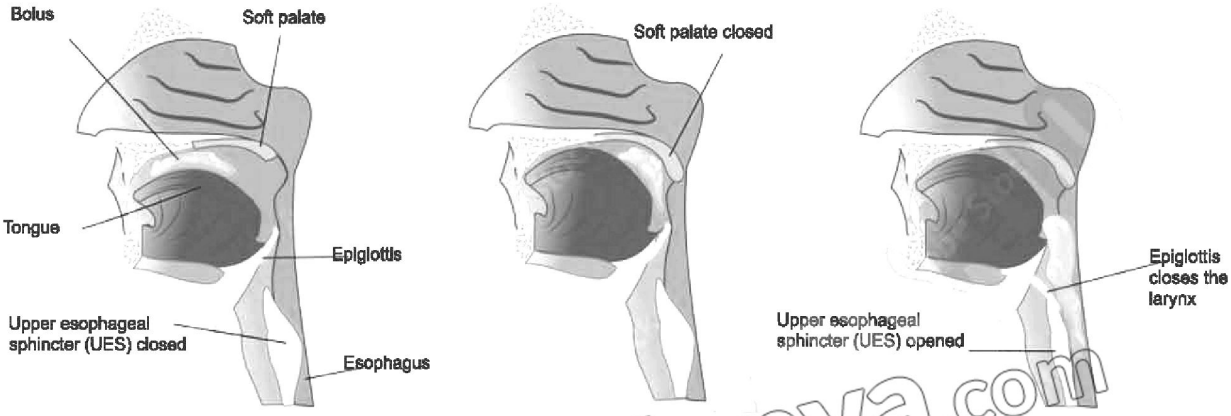


Fig. 1.5: Process of swallowing

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.

Functions of Peristalsis

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

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.

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.

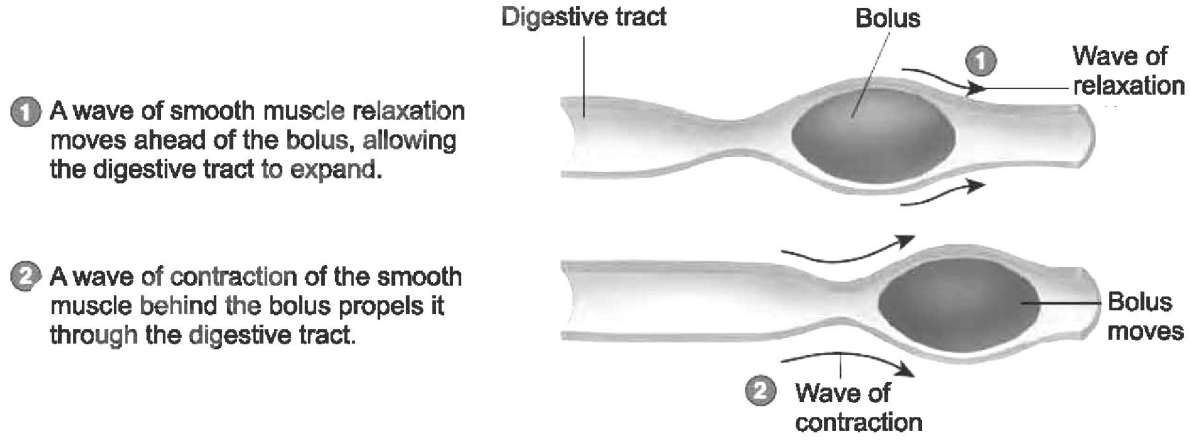


Fig. 1.6: Peristalsis

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.

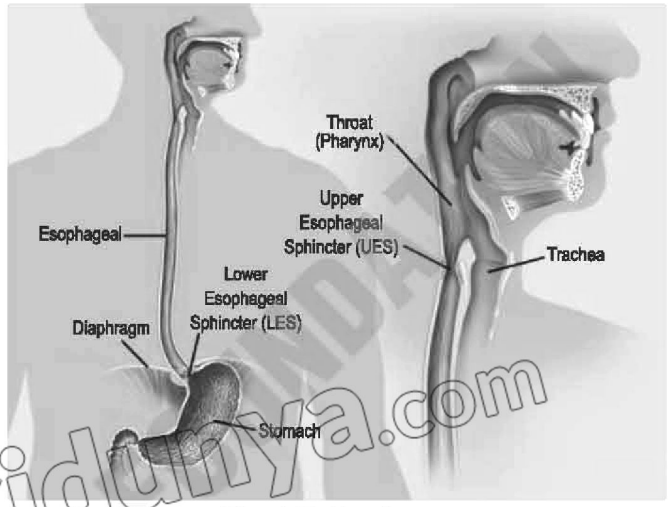


Fig. 1.7: Esophagus

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**.

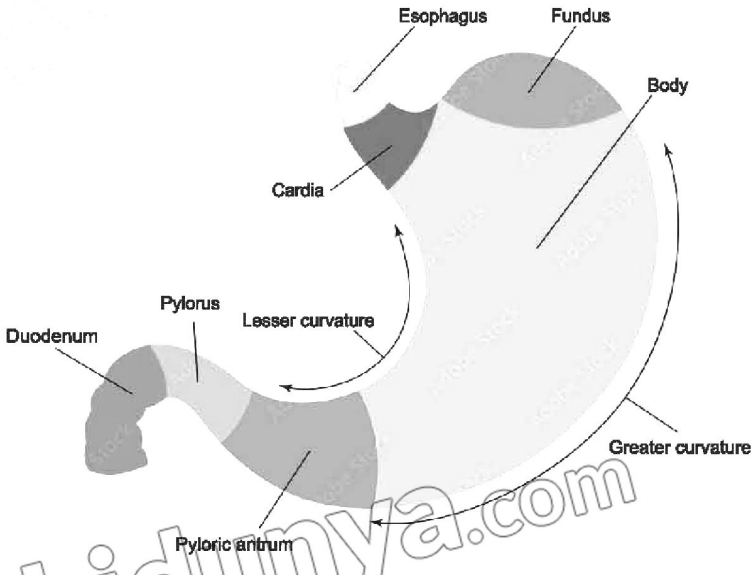


Fig. 1.8: Division of the stomach

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.

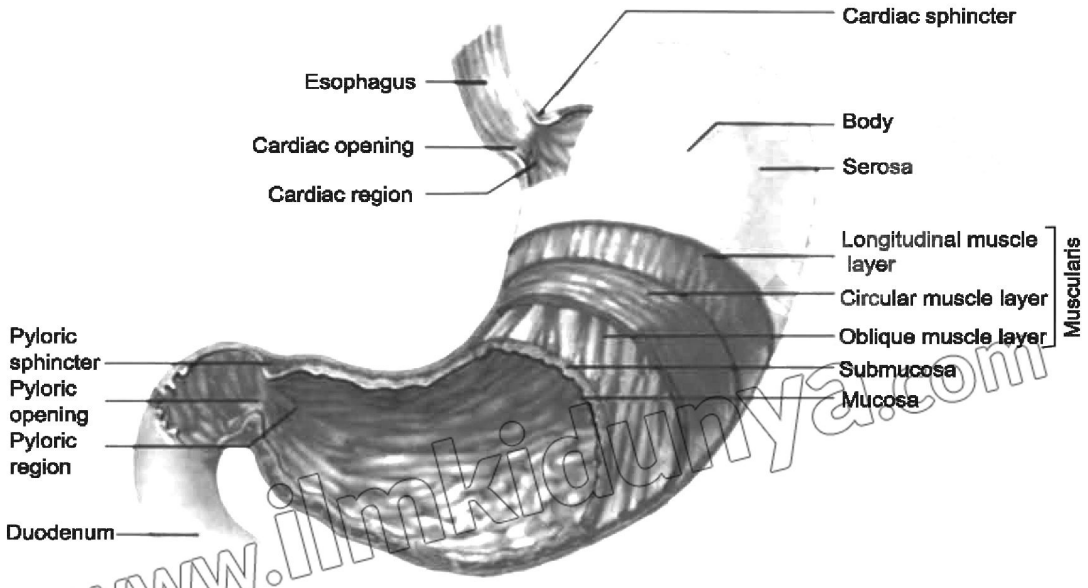


Fig. 1.9: Cutaway section of the stomach reveals muscular layers and internal anatomy

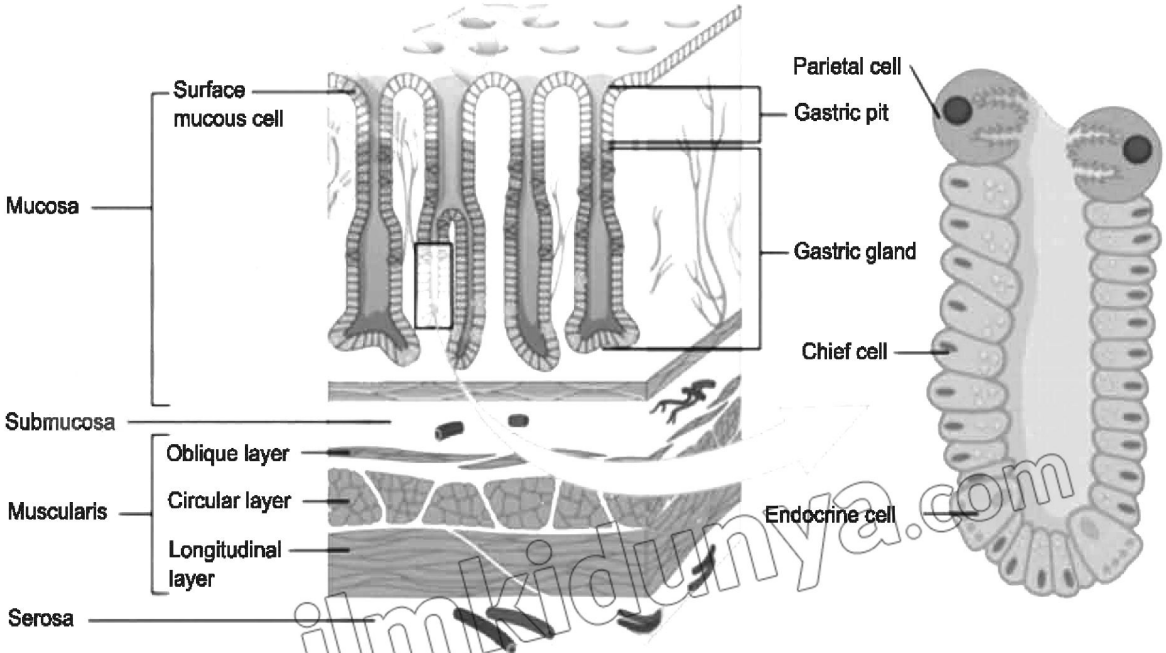


Fig. 1.10: A section of stomach wall that illustrates its histology, including several gastric pits and glands

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.

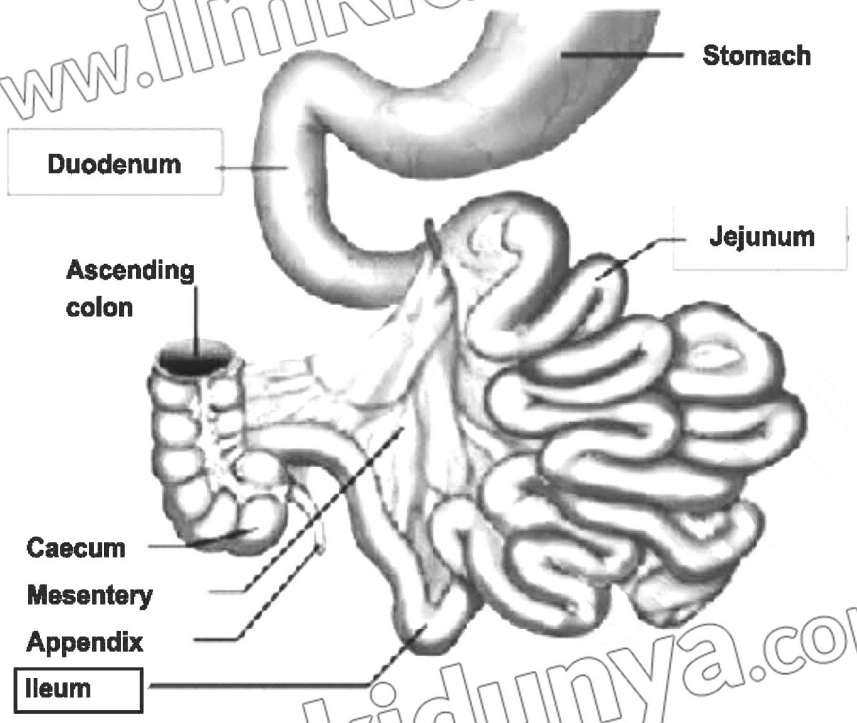


Fig. 1.11: Small intestine

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.

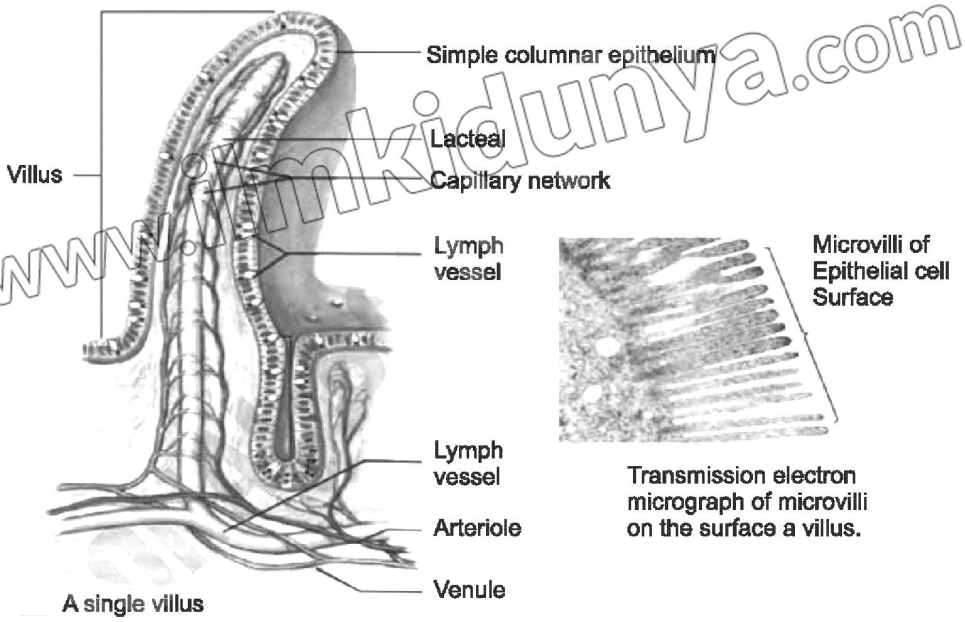


Fig. 1.12: Structure of villus

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.

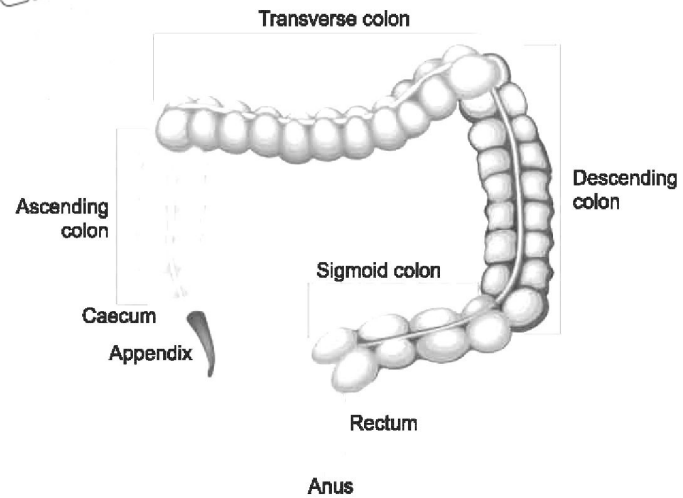


Fig. 1.13: Large intestine

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

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.

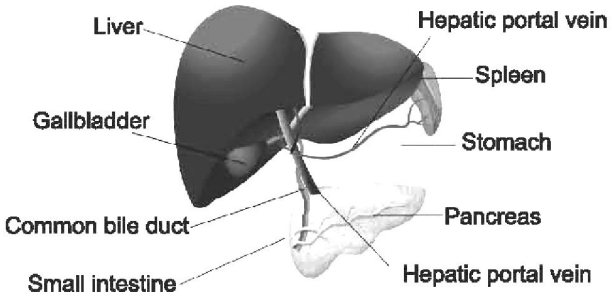


Fig. 1.14: Liver

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).

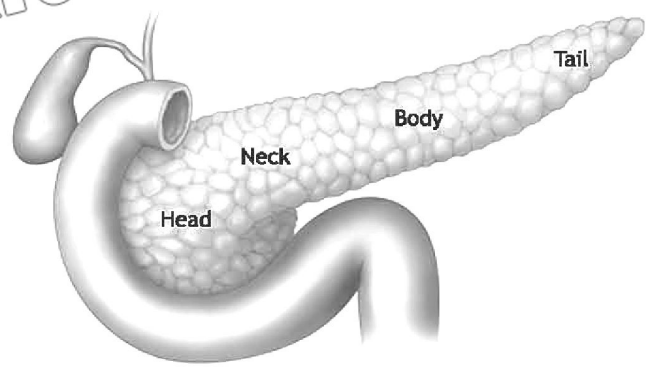


Fig. 1.15: Structure of pancreas

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.

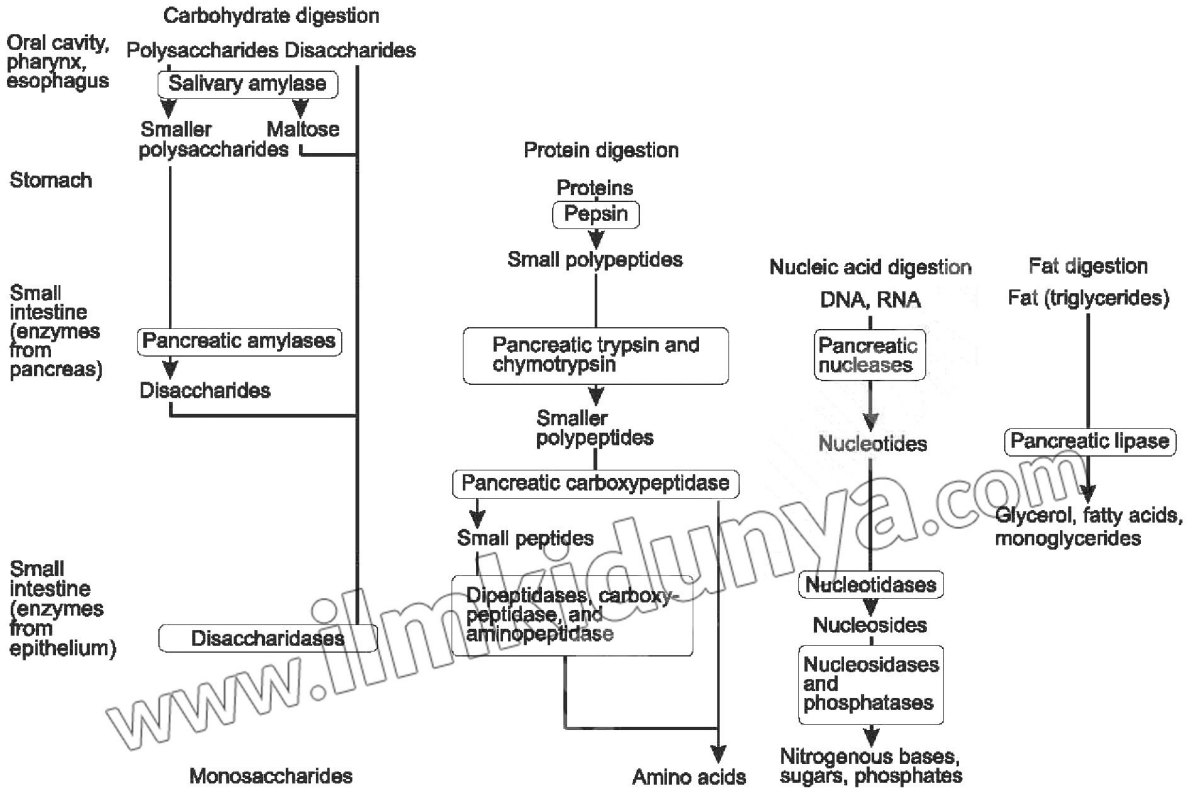


Fig. 1.16: Flow chart showing action of enzymes in GIT from mouth to small intestine

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

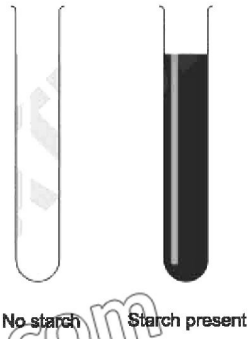
Procedure

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

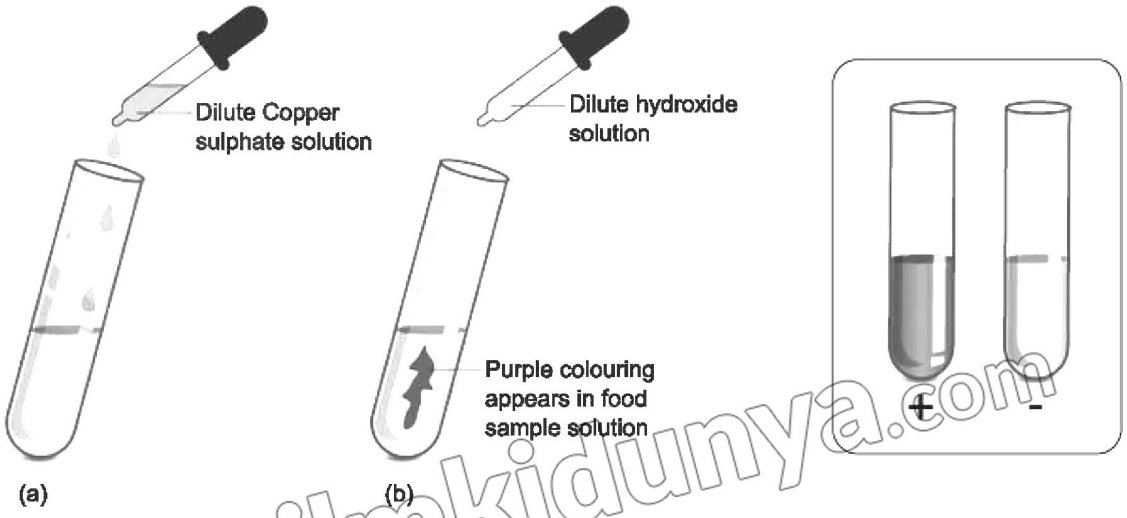
1. Dissolve a sample of food such as yogurt and egg in water.
2. Add a few drops of sodium hydroxide (which is colourless)

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.