Chapter 09

HUMAN DIGESTIVE SYSTEM

Student Learning Outcomes (SLOs)

After studying this chapter, the students will be able to:

- Describe the mechanical and chemical digestion in the oral cavity
- Explain swallowing and peristalsis.
- Illustrate with a diagram the structure of the stomach and relate each component with the mechanical and chemical digestion in the stomach.
- Identify the role of the nervous system and gastrin hormone on the secretion of gastric juice.
- Describe the major actions carried out on food in the three regions of the small intestine.
- Trace the absorption of digested products from the small intestine lumen to the blood capillaries and lacteals of the villi.
- Describe the component parts of large intestine with their respective roles.
- Correlate the involuntary reflex for egestion in infants and the voluntary control in adults.
- Explain the storage and metabolic role of the liver.
- Describe composition of bile and relate the constituents with respective roles.
- Outline the structure of pancreas and explain its function as an exocrine gland.
- Relate the secretion of bile and pancreatic juice with the secretin hormone.

- **Digestion:** It is the process by which the body breaks down food into **smaller, absorbable** components.
- Digestion is crucial for converting food into energy and raw materials required for **growth, repair** and maintenance of **body functions**.
- **Importance:** It supports the immune system, provides essential nutrients and ensures overall health.
- Efficient digestion prevents nutrient deficiencies, supports metabolism and maintains energy levels, making it vital for sustaining life.

ANATOMY & PHYSIOLOGY OF DIGESTIVE SYSTEM

Q. Explain the complete process of digestion, starting from ingestion in the mouth to egestion in the large intestine. Include the roles of mechanical and chemical digestion at each stage. (Exercise L.Q.1)

➢ **Components of Human Digestive System:**

- **The human digestive system is composed of:**
  (1) Gastrointestinal (GI) Tract **(2) Accessory Digestive Organs**

(1) Gastrointestinal Tract: The GI tract is a continuous tube that extends from mouth to anus:
(a) Oral cavity (b) Pharynx (c) Oesophagus (d) Stomach
(e) Small intestine (f) Large intestine.

(2) Accessory Digestive Organs:
(a) Salivary glands (b) Liver (c) Gallbladder (d) Pancreas

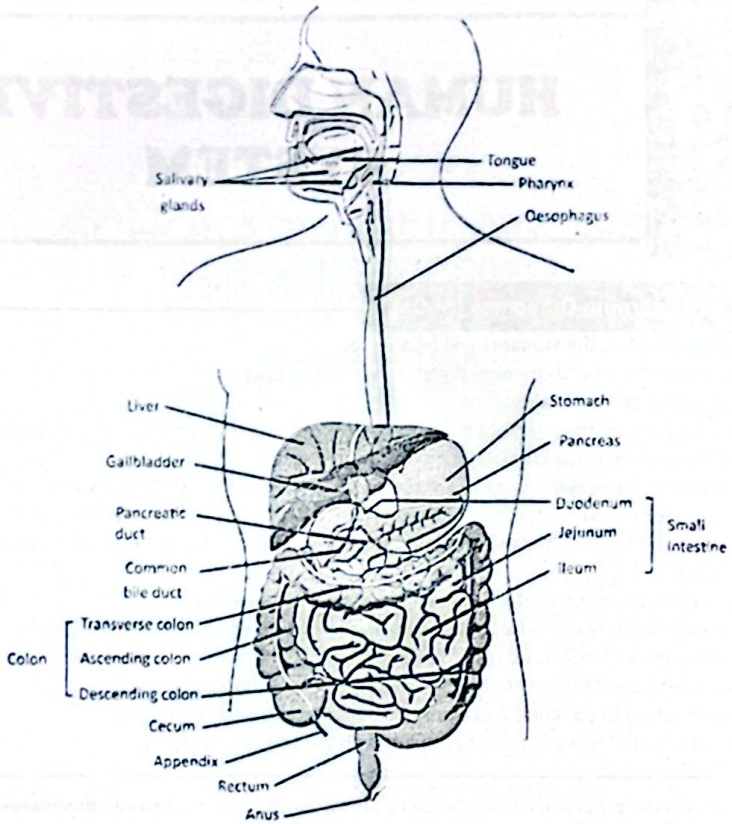

Figure: Human digestive system

Components of Gastrointestinal (GI) Tract:

(a) Oral Cavity:

- It is a cavity immediately after the opening of mouth.
- **Lips & Their Role:** Lips are made of highly vascularized, skeletal muscle tissue with many sensory **nerve endings.** Lips help to retain food as it is being chewed. They also play a role in phonation (the modification of sound).

Check Understanding!

1. **Which of the following is NOT a function of the oral cavity?**
   A. Speech production
   B. Mechanical digestion
   C. Absorption of nutrients
   D. Taste perception

Functions of Oral Cavity:

The important functions performed by oral cavity are as follows:

(i) Selection of Food:

- The muscular tongue plays role in the selection of food through its **taste buds.**
- When food enters the oral cavity, it is tasted and physically felt.
- If the **taste** or smell is unpleasant or if hard objects like bone or dirt are present in the food, it is rejected.
- The senses of smell and sight also play role in the selection of food.

(ii) Mechanical Digestion of Food:

- **Mastication:** The ingested food is physically broken down by the teeth through a process called mastication (chewing).
- Chewing reduces food into smaller and more manageable pieces, increasing the surface area for enzymatic action.

(iii) Chemical Digestion of Food:

- As the chewing of food goes on, the salivary glands pour their secretion, saliva into oral cavity.
- Palate, tongue and cheeks help in the mixing of chewed food with saliva.

Types of Salivary Glands:

- There are three pairs of salivary glands which pour saliva into **oral cavity.**
- These three pairs are:
  - **(a) Sublingual Glands:** Which are situated below tongue.
  - **(b) Submaxillary Glands:** Which are located behind jaws.
  - **(c) Parotid Glands:** Which are located in front of ears.

Check Understanding!

2. **What is the pharynx and what is its function?**

Composition of Saliva:

- **Water + Mucus:** Saliva contains **water** and **mucus** that moisten and lubricate the food. Saliva also contains **bicarbonate ions**, which buffer chemicals in the oral cavity, and thiocyanate ions, which kill microorganisms.
- **pH of Fresh Saliva:** Fresh saliva is alkaline **(pH : 8)** but it quickly loses CO_2 and **gets pH 6.**
- **Enzymes in Saliva:** Saliva also contains an **enzyme, salivary amylase,** which partially digests the polysaccharides (starch and glycogen) to **disaccharides** (maltose). After the mechanical and chemical digestive processes in the oral cavity, food mass is in the form of a small moist mass called a bolus.

$$\text{Polysaccharide} \xrightarrow{\text{Amylase}} \text{Maltose}$$

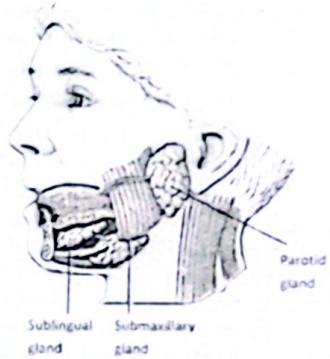

Figure: Location of salivary glands

(b) Pharynx:

- The pharynx is a cavity behind the **mouth.** It is the common passageway for both the digestive and respiratory tracts. The bolus is **pushed to the back** of the mouth and is swallowed through the pharynx.

- The beginning of the **swallowing** action is voluntary, but once the food reaches the back of the mouth, swallowing becomes automatic.

- **Mechanism of Swallowing of Food:**
  - **Movement of Tongue:** During **swallowing,** the tongue moves **upwards** and backwards against the roof of the mouth.
  - **Soft Plate Raises:** Due to movement of tongue the bolus is forced to the back of oral cavity. The soft palate is also raised against the back wall of pharynx. These movements close the passage between **nasal cavity and pharynx.** At the same time, the larynx moves upward and it lowers the epiglottis (a flap of cartilage) and closes the **opening of trachea.**
- In this way, the bolus passes over the trachea and enters oesophagus.

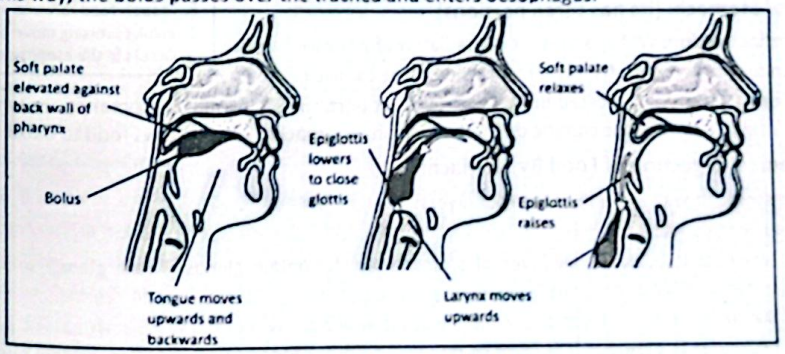

Figure: Swallowing of food

(c) Oesophagus:

- After being swallowed, the food enters the tube called oesophagus. It connects the pharynx to the stomach. The previous digestive actions of saliva continue in **oesophagus**.
- **Length of Oesophagus:** In adult human, the oesophagus is **about 25 cm long** and its lower end opens in stomach.
- Food moves down through the **oesophagus** to the stomach by **peristalsis**.
- The exit of food from the oesophagus to the stomach is **controlled** by the lower oesophageal **sphincter or cardiac sphincter** which opens in response to the pressure exerted by food. It also prevents the backflow of stomach contents into the oesophagus.

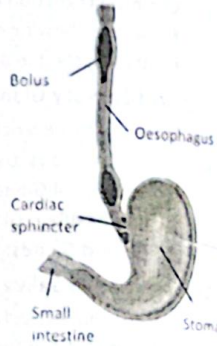

Figure: Oesophagusand its connections

➢ Motility of Alimentary Canal:

The following **two types** of movements occur in alimentary canal.

- **Peristalsis:** It is the rhythmic **sequence** of waves of contraction in the smooth-muscles of the walls of alimentary canal. Peristalsis squeezes the food **down along** oesophagus and other parts of the alimentary canal.
- **Segmentation:** The small and **large intestines** also have rings of smooth-muscles, which contract and relax repeatedly. These contractions and relaxations create a **back-and-forth** movement in the same place, called **segmentation.** This movement mixes the food with digestive secretions and increases the efficiency of absorption.
- **Antiperistalsis:** Occasionally, the **peristaltic** movements may **reverse in a process** called **antiperistalsis** pushing food from the **intestines back into** the stomach and oral cavity, leading to vomiting.
- **Hunger Pang:** Hunger contractions are peristaltic movements triggered by low blood glucose levels, creating the uncomfortable sensation known as hunger pangs.

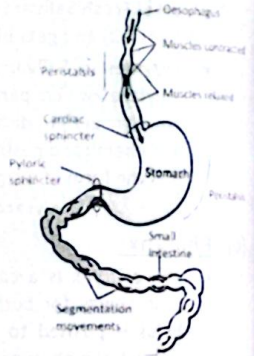

Figure: Peristalsis and Segmentation

Q. Describe the structure and function of the stomach in digestion. (Exercise Q.2)

(d) The Stomach:

- The stomach is an **elastic muscular bag** (J-shaped) situated after oesophagus and before duodenum.
- **Location:** It is located in the left side in abdominal cavity, right below the diaphragm.

Check Understanding!

3. **Which of the following is a characteristic of segmentation rather than peristalsis?**
   A. Moves food in one direction
   B. Propels food forward
   C. Involves mixing movements
   D. Occurs in the esophagus

➢ Parts of Stomach: (Its has three portions)

(i) Cardiac Portion: Which is present immediately after oesophagus.
(ii) Fundus Portion: Which is present **on a side** of the cardiac portion.
(iii) Pyloric Portion: It is located beneath the **cardiac portion.** The cardiac sphincter **opens** when a wave of peristaltic contractions coming down the **oesophagus reaches** it and allows food to enter the stomach.

➢ Mechanical Digestion of Food By Stomach:

- The stomach wall is made of the four layers:
- **Layers of Stomach:**
  (a) Mucosa: It is the inner layer of stomach which contain glands. These glands secrete digestive enzymes, HCℓ and mucus.
  (b) Submucosa: It is a layer of connective tissue which contain blood vessels, lymphatic and nerves.
  (c) Muscular is externa: It is layer of muscle i.e., outer longitudinal muscles, middle circular muscles and the inner oblique muscles.

(d) Serosa: It is an outermost thin layer that forms part of peritoneum and provides protection.
The inner two layers are **submucosa** and **mucosa.**

- **Stomach Walls Help in Churning:** The muscular walls of stomach contract and vigorously and help in churning of food (mechanical digestion) and mixing the food with stomach secretions. These contractions also generate enough heat that melts the solid fats.
- **Chemical Digestion of Food By Stomach:**
  - The **mucosa** inner most layer of stomach possesses numerous tubular gastric glands.
  - **Gastric Pits:** The glands open in the mucosa wall through **deep depressions,** called **gastric pits** Each gastric gland contains epithelial cells and **three secretory cells:**
    i. Mucous Cells: The **mucous** cells which secrete mucus- a **thick secretion** that covers the inside of the stomach and protects it from HCl and digestive enzymes.
    ii. Parietal Cells: The **parietal** (oxyntic) cells which secrete Hydrochloric acid. It adjusts the pH of stomach contents to about **2 – 3.** HCℓ also softens the food, activates the pepsinogen and kills microorganisms.
    iii. Chief Cell: The chief cells which secrete enzyme, **pepsinogen**, inactive form of pepsin.

Pyrosis/Heartburn

- Sometimes there is a back flush of acidic chyme from stomach into the oesophagus.
- It causes a **painful burning** sensation in the chest and this condition is known as **pyrosisor heartburn.**

Check Understanding!

4. **What is the function of mucous, parietal, and chief cells?**

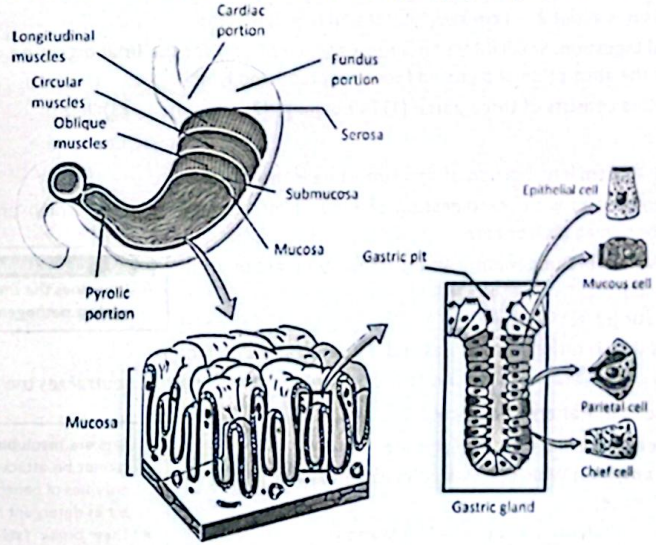

Figure: Stomach; external and internal structure

- **Gastric Juice:** All the secretions of gastric glands are collectively called **gastric juice**. When the bolus enters the stomach, the gastric glands secrete **gastric juice.**

➢ Activation of Depsin:

- The H^+ **Ions** of the HCℓ activate pepsinogen into pepsin. Pepsin catalyses the breakdown of **proteins to yield polypeptides** and peptides.
- **Chyme (Kime):** About three to **four hours** after a meal, the stomach contents have been sufficiently mixed and are **semi-liquid acidic** mass called chyme. The pyloric sphincter regulates the release of the chyme into the small intestine.

Check Understanding!

5. **Which part of the small intestine is primarily responsible for the absorption of iron?**
   A) Duodenum B) Jejunum
   C) Ileum D) Colon

➢ **Regulation of Secretion of Gastric Juice:**

- The secretion of **gastric juice** is regulated by both the **nervous system** and **hormonal mechanisms**. In reaction to the smell, sight, or thought of food, the medulla of brain sends message to the gastric glands to secrete **small amounts of gastric juice**.
- When food arrives in stomach, the distension of stomach and decrease in the **pH of the gastric** contents stimulate more secretion and powerful contractions.
- **Stimulation of Gastrin:** The presence of proteins in food stimulate special endocrine cells present in the mucosa of stomach to release a hormone called **gastrin.**
- **Gastric Stimulates Gastric Juice:** Gastrin is carried by blood to the gastric glands where it stimulates them to produce and **secrete more** gastric juice.
- When food moves from stomach to small intestine, a hormone called **somatostatin stops** the release of **hydrochloric acid**.

- The mucosa of **stomach** is susceptible to damage from acid and pepsin. If it had no protection.
- Protection of the mucosa is provided in two ways: viscous mucous and bicarbonate, which neutralizes acid.

Q. Explain the absorption of food from the small intestine? (Multan Board)

(e) The Small Intestine

- It is the **longest part** of alimentary canal. It starts after the stomach and ends at the large intestine.
- In adult man it is about **2 – 3 cm** in diameter and 6 m in length.
- **Site of Final Digestion:** Small intestine is responsible not only for the **final digestion** of all kinds of food but also for the absorption of digested food into blood and lymph.
- **Small intestine consists of three parts: (1)** Duodenum **(2)** Jejunum **(3)** Ileum

(1) Duodenum:

- The first **20 – 25 cm** long portion of small intestine is the duodenum.
- **Use:** It is concerned with the **digestion of food**. It also contains glands, which produce an alkaline secretion containing bicarbonate.
- **Secretion Poured in Duodenum:** Two main secretions are poured into duodenum.

Check Understanding!
6. How does the small intestine defend against pathogens?

(a) Pancreatic juice:

- It is the secretion of pancreas and is poured into duodenum.
- It is slightly alkaline (pH 8) due to the presence of bicarbonate. It neutralizes the acidity of chyme.

➢ **Enzymes Present in Pancreatic Juice:**

The important enzymes in pancreatic juice are:

- **Fats are insoluble in water.** So, they cannot be attacked readily by lipase enzymes of pancreatic juice. Bile salts act as detergent molecules.
- They break fats into droplets and keep them separate from one another.

(i) Pancreatic amylase: Which digests polysaccharides into maltose and even glucose)

$$\text{Polysaccharide} \xrightarrow{\text{Amylase}} \text{Maltose}$$

(ii) Trypsinogen: Which is in inactive form. Another enzyme **enterokinase** (secreted by the walls of duodenum) activates trypsinogen into trypsin, which digests proteins into polypeptides.

$$\text{Proteins} \xrightarrow{\text{Trypsin}} \text{Polypeptide}$$

(iii) Chymotrypsin and Carboxypeptidase: Which digest proteins into smaller peptides and then into amino acids.

$$\text{Proteins} \longrightarrow \text{Peptides} \longrightarrow \text{Amino Acids}$$

(iv) Pancreatic Lipase: Which digests lipids to glycerol and fatty acids.

$$\text{Lipids} \longrightarrow \text{Glycerol} + \text{Fatty Acids}$$

(v) Pancreatic Nucleases: Which digest DNA and RNA into nucleotides.

$$\text{DNA/RNA} \rightarrow \text{Nucleotides}$$

(b) Bile: It is the secretion of liver. Before its release, it is stored in gallbladder.

- It contains salts which emulsify fats and break them into small droplets (emulsion).
- These droplets provide large surface areas for effective action of lipids-digesting enzymes.

- If bile pigments are prevented from leaving digestive tract, they may accumulate in blood, causing a condition known as jaundice.

(2) Jejunum and Ileum

- **Jejunum is 2.4 meters** long part of small intestine, next to duodenum.
- **Ileum is the last three fifth** i.e., about **3.5 metres long part of small intestine.**
- These parts carry out the rest of digestion and absorption of food.
- The walls of jejunum and ileum contain glands which secrete intestinal juice. It contains various enzymes.
- **Examples:** Aminopeptidase digests polypeptides into dipeptides.
  - **Erypsin** digests dipeptides into amino acids.
  - **Lipase** digests fats into fatty acids and glycerol.
  - **Maltase** digests maltose into glucose,
  - **Sucrase** digests sucrose into glucose and fructose
  - **Lactase** digests lactose into glucose and galactose.
- **Chyle (Kile):** After the action of **enzymes** of intestinal juice, the chyme is converted into an alkaline emulsion, called chyle.

(f) Absorption of Digested Food and Water:

- Due to the presence of folds and numerous villi, the internal surface of jejunum and ileum **appears velvety.**

- The absorption of **digested food, water,** and dissolved minerals occurs in jejunum and ileum.
- **Villi: The inner wall of jejunum** and ileum contains large circular folds. These folds have numerous finger-like projections called villi.
- **Lacteals:** Each villus is richly supplied with blood **capillaries** and a vessel of lymphatic system, called lacteal. The **blood capillaries** and lacteal are covered by a single-cell thick epithelium.
- **Microvilli: The epithelial cells of villi have countless cytoplasmic projections**, called microvilli. The total surface area of absorption becomes extraordinarily large due to **villi and microvilli.**

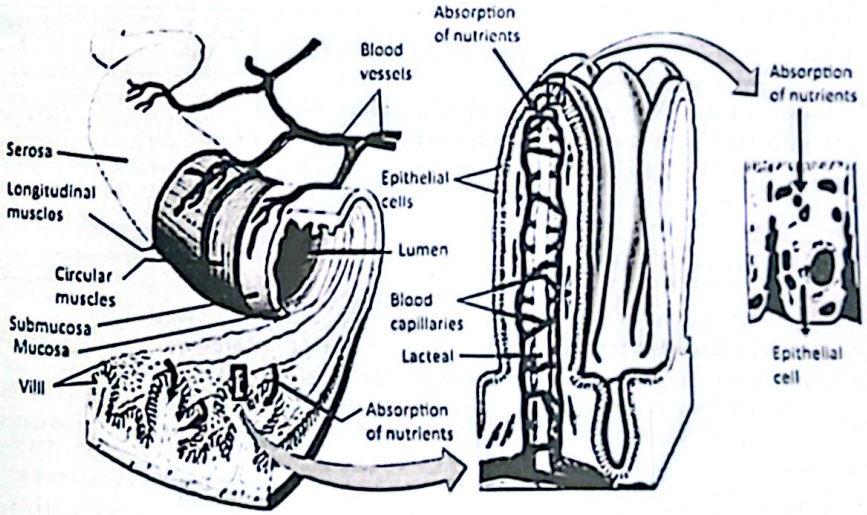

Figure: Intestinal wall and detailed structure of villi

- **Absorption of Simple Sugars and Amino Acids:**
  - **Absorption by Diffusion or Active Transport:** Simple sugars (e.g., glucose) and amino acids are absorbed by diffusion or active transport into the epithelial cells of villi. From cells of villi these molecules enter the blood **capillaries of villi**. Blood capillaries of villi join to form **hepatic portal** vein which carries sugars and amino acids to liver.
  - **Storage of Sugars and Amino Acids:** Liver stores **extra glucose** and **amino acids** in the form glycogen and proteins respectively.
  - From liver, the required amounts of these products pass to heart **via hepatic vein.**
- **Absorption of Fatty Acids and Glycerol:**
  - **Absorption by Passive Transport:** The products of fat digestion i.e., **fatty acids** and glycerol are absorbed by **passive transport** into the epithelial cells of villi.
  - **Formation of Chylomicrons:** Inside villi, they combine to form triglycerides. The triglycerides are coated with proteins. In this way small droplets, called chylomicrons are formed. The **chylomicrons** enter the lacteals of villi. From the lacteals, the **chylomicrons** move into thoracic lymphatic duct, from where they enter in bloodstream.
  - **Breakdown of Chylomicrons:** Blood plasma has enzymes which hydrolyse chylomicrons back into **fats and proteins.**
  - **Fats are ultimately** hydrolysed into **fatty acids** and glycerol and enter body cells.

Check Understanding!

7. Glucose and amino acids are absorbed into the bloodstream through:

A. Diffusion into lacteals
B. Capillaries in the villi
C. Parietal cells
D. Chief cells

Q. Compare and contrast the roles of the small intestine and large intestine in digestion. Exercise L.O.5

(g) The Large Intestine:

- It is the last part of the **alimentary canal**. It is much shorter than **small intestine**, occupying about the last metre of the intestinal tract.
- **Importance:** It is involved in the absorption of **water** and **salts** and **vitamin 'K'** from the lumen of intestine into the blood.
- The large intestine is not convoluted and its inner surface area does not possess villi.

Parts of Large Intestine:

- It consists of three parts.

(i) Cecum:

- It is a **blind sac** that projects from the area of large intestine between **ileum** and **colon**.
- **Appendix:** From the blind end of caecum there arises a **finger-like** process called **vermiform appendix.**
- In human digestive system, appendix performs no function so is vestigial.

Appendicitis

- **Appendicitis** is the inflammation of the appendix. It is usually due to bacterial infection.
- The infected appendix must be removed surgically otherwise it may burst and the inflammation may spread in the entire lining of the abdomen.
- The surgical removal of appendix is called **appendicectomy.**

(ii) Colon:

- Next to cecum is the colon.
- **Parts of Colon:**

(i) Ascending Colon (ii) Transverse Colon (iii) Descending Colon

- **Functions Absorption of Water:** The main function of colon is to absorb water from the **alimentary canal**.
- **Formation of Faeces:** As the water is absorbed, the remaining material becomes more solid. These wastes products, called faeces, consist of a large number of bacteria, indigestible plant fibres (e.g. cellulose), other undigested food stuff, sloughed off mucosal cells, bile pigments and water.

(iii) Rectum:

- It is the last part of **large intestine** where faeces are temporarily stored.
- At its distal end, the rectum opens out through anus.

- Anus is surrounded by **two sphincters**; the internal sphincter is made of smooth muscles and the outer is made of striated muscles.
- Under normal conditions when the rectum is filled up with faeces, it gives rise to a defecation reflex.
- The defecation reflex is consciously inhibited in adults but in infants it is controlled involuntarily.
- During growth, the child learns to bring this reflex under **voluntary control.**

Importance of Bacteria Present in Colon:

- Many bacteria, for example **E. coli**, live and actively divide **within** colon. During their metabolism, they produce amino acids and **vitamin K.** Vitamin K is necessary for man for the coagulation of blood. It is absorbed from the large intestine into the blood.

Check Understanding!

8. What is the role of cholecystokinin (CCK) in digestion?

- **Control of Egestion:**
  - **Egestion:** The process of removal of undigested waste is called **egestion.**
  - The involuntary reflex for **egestion** in infants and the **voluntary** control in adults represent two stages of neurological and muscular development.
  - **In Infants.** The egestion is an **involuntary reflex** mediated by the spinal cord, where rectal distension triggers automatic relaxation of the internal anal sphincter and expulsion of waste. This occurs because the higher brain centres responsible for voluntary control are not yet fully developed.
  - **In Adults:** The egestion becomes voluntary as the cerebral cortex matures, allowing conscious regulation of the external anal sphincter to **delay or initiate defecation.**
  - This transition reflects the **integration** of reflex pathways with **cognitive control**, adapting to social and environmental demands.

Q. Discuss accessory organs (liver, gallbladder and pancreas) and their contributions in digestion. Exercise L.O.5

Accessory Digestive Organs:

(1) Liver:

- The liver plays a **vital role** in digestion by producing bile, which is essential for fat digestion.
- Bile emulsifies **fats,** making them easier to digest.
- Liver also processes nutrients absorbed from the **small intestine, detoxifies harmful substances,** synthesizes proteins and stores glycogen for energy.

- Cholesterol, secreted by the liver, may precipitate in the gall bladder to produce gall stones, which may block **release of bile.**

(2) Gallbladder:

- The gallbladder **stores** and concentrates bile produced by the liver. When food enters the small intestine, the gallbladder releases bile through the bile duct.

(3) Pancreas (Double Gland):

- **Location:** Pancreas is a **large gland** situated just ventral to the stomach. It has **exocrine** and **endocrine** portions.
- **Exocrine Function:** The exocrine (ducted) portion secretes its secretion i.e., pancreatic juice into pancreatic duct. The pancreatic duct joins with the common bile duct from the liver and enters the duodenum. Pancreatic juice contains enzymes for the digestion of all groups of food.

Check Understanding!

9. Which of the following substances is stored in the liver?

A. Urea B. Glycogen
C. Pepsin D. Bile salts

- **Major Enzymes in Pancreatic Juice:** Its major enzymes include trypsin, chymotrypsin, lipases, amylases, nucleases etc.
- **Endocrine Function:** The endocrine (ductless) portion of pancreas secretes its secretion i.e., insulin and **glucagon** hormones into extracellular fluid from where they diffuse into nearby capillaries.

Q. Describe the hormonal and nervous regulation of gastric acid secretion. Exercise Q.01

Hormonal Control of the Secretions of Pancreas and Liver:

- The gastric secretions are controlled through nervous system and hormones.
- The release of secretions from pancreas and liver is also controlled by hormones.
- When **chyme enters duodenum from stomach, its acidity stimulates duodenal** walls to release a hormone, secretin.
- Similarly, the **partially digested proteins and fats** present in chyme stimulate the duodenal walls to secrete another hormone, **cholecystokinin (CCK). Both these hormones stimulate pancreas** to release pancreatic juice, and gallbladder to release bile.

Check Understanding!
10. Name two substances the liver stores and explain their significance.

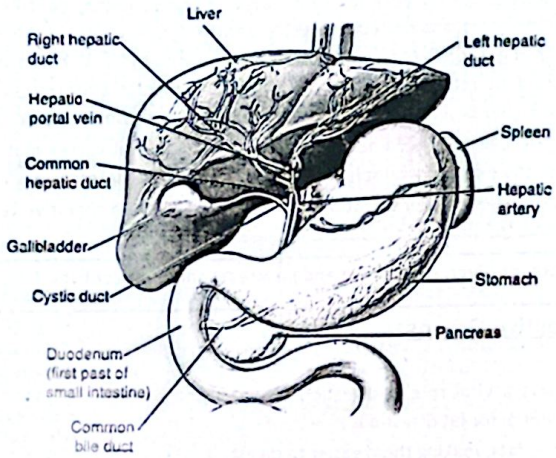

Figure: Accessory Digestive Organs

Storage and Metabolic Role of the Liver:

- The liver performs many important functions, especially in storing nutrients and regulating metabolism.
- Stores Nutrients: It stores excess nutrients from the food and releases them when the body needs energy or building materials. These nutrients stored in the liver include glucose (stored as glycogen), vitamins (like A, D, B12, and K), minerals (e.g., iron and copper), and fats and fat-soluble substances. It also plays a central role in metabolism. It helps in breaking down, building up, and converting substances in the body. For example, it converts excess glucose into **glycogen and back** when needed.
- **Helps in Metabolism:** It also breaks down fats to produce energy and forms cholesterol and lipoproteins. It converts amino acids and removes harmful ammonia by turning it into urea, which is excreted in urine.
- **Remove Toxins from Blood:** It breaks down and removes toxins, drugs, and alcohol from the blood.
- **Help in Regulating Hormones:** The liver also helps in breaking down and regulating hormones.

Check Understanding (Solutions)

Sr. #	Option	Explanation
1.	C	• The oral cavity performs functions such as mastication (chewing), taste, and speech, but nutrient absorption primarily occurs in the small intestine, not in the mouth.
2.	S.Q	• The pharynx is a muscular tube that connects the mouth and nasal cavity to the esophagus and larynx. It functions as a shared pathway for food and air, ensuring safe.
3.	C	• Segmentation is a type of non-propulsive movement seen mainly in the small intestine. It helps in mixing food with digestive enzymes, not in pushing it forward.
4.	S.Q	• Mucous cells secrete mucus to protect the stomach lining, • Parietal cells secrete HCl, and • Chief cells secrete pepsinogen, which digests proteins.
5.	A	• Iron is mainly absorbed in the duodenum, which is the first part of the small intestine where initial digestion and absorption occur.
6.	S.Q	• The ileum contains Peyer's patches—immune structures that detect harmful microbes and trigger an immune response, helping protect the body.
7.	B	• Glucose and amino acids are water-soluble and are absorbed into the blood capillaries in the villi through active and facilitated transport.
8.	S.Q	• CCK is released in response to fats and proteins. It triggers the pancreas to release enzyme-rich juice and causes the gallbladder to contract, releasing bile into the duodenum.
9.	B	• The liver stores glycogen, a polysaccharide that acts as a glucose reserve. When blood sugar levels fall, glycogen is broken down into glucose and released into the bloodstream.
10.	S.Q	• The liver stores glycogen, which maintains blood sugar levels, and vitamin B12, essential for red blood cell formation. It also stores fat-soluble vitamins like A, D, E, and K for various physiological functions.

Exercise

Exercise — MULTIPLE CHOICE QUESTIONS (MCQs) — Section 01

1. **Where does chemical digestion of carbohydrates begin?**
   (a) Stomach (b) Oesophagus (c) Small intestine (d) Mouth
2. **Which enzyme in saliva starts breaking down starch?**
   (a) Lipase (b) Amylase (Ptyalin) (c) Trypsin (d) Pepsin
3. **What prevents food from entering the trachea during swallowing?**
   (a) Epiglottis (b) Oesophageal sphincter (c) Uvula (d) Tongue
4. **Why does the enzyme activity drops in the stomach when pH rises?**
   (a) Acid blocks food entry (b) Enzymes denature in low pH
   (c) Enzymes need acidic pH to work (d) Saliva dilutes gastric juice
5. **Which change would most affect protein digestion?**
   (a) Blocking bile release (b) Inhibiting salivary glands
   (c) Inhibiting pepsin production (d) Slowing peristalsis
6. **Why is lipase not active in the stomach?**
   (a) It is destroyed by acid (b) It needs alkaline pH to work
   (c) It is secreted by the liver (d) It digests only proteins
7. **Which stomach secretion activates pepsin and kills bacteria?**
   (a) Bile (b) Hydrochloric acid (HCl)
   (c) Sodium bicarbonate (d) Mucus

8. Why is segmentation important in the small intestine?
(a) It absorbs bile (b) It breaks down enzymes
(c) It mixes food with digestive juices (d) It pushes food to the rectum

9. What is the function of villi and microvilli in the small intestine?
(a) Produce enzymes (b) Increase surface area for absorption
(c) Store bile (d) Neutralize stomach acid

10. Which best explains the liver's role in digestion?
(a) It produces insulin (b) It stores undigested food
(c) It produces bile for fat digestion (d) It secretes enzymes into the colon

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(d)	Mouth	• Chemical digestion of carbohydrates starts in the mouth with the enzyme amylase
2.	(b)	Amylase (Ptyalin)	• Amylase is the enzyme in saliva that breaks down starch into simpler sugars.
3.	(a)	Epiglottis	• The epiglottis is a flap-like structure that covers the entrance to the trachea during swallowing, preventing food from entering the airway.
4.	(b)	Enzymes denature in low pH	• Most enzymes are sensitive to pH changes; some denature in low pH, but the correct interpretation here is that enzymes like pepsin work best in acidic conditions, and others may denature if the pH becomes too high or too low for their optimal function.
5.	(c)	Inhibiting pepsin production	• Pepsin is a key enzyme for protein digestion in the stomach; inhibiting its production would significantly impact protein digestion.
6.	(a)	It is destroyed by acid	• Gastric lipase is present but not very active; the main reason lipase is not active in the stomach is due to the acidic environment which can denature enzymes.
7.	(b)	Hydrochloric acid (HCl)	• HCl activates pepsinogen to pepsin and creates an acidic environment that kills ingested bacteria.
8.	(c)	It mixes food with digestive juices	• Segmentation movements mix the intestinal contents with digestive enzymes, enhancing nutrient absorption.
9.	(b)	Increase surface area for absorption	• Villi and microvilli increase the surface area available for the absorption of nutrients.
10.	(c)	It produces bile for fat digestion	• The liver produces bile, which emulsifies fats, aiding in their digestion and absorption.

Exercise — SHORT ANSWER QUESTIONS — Section 02

Q.1 What is the main function of the digestive system?

Ans. Main Function of the Digestive System:

- **Breakdown:** Converts food into absorbable nutrients.
- **Absorption:** Transports nutrients into the bloodstream.
- **Elimination:** Expels indigestible waste as feces.

Q.2 What is the mode of action of saliva in mouth?

Ans. Mode of Action of Saliva in Mouth:

- **Enzymatic Action:** Salivary amylase begins carbohydrate digestion.
- **Moistening:** Lubricates food for easier swallowing.
- **Protection:** Contains lysozymes to inhibit bacterial growth.

Q.3 What is role of tongue in the mouth?

Ans. Role of Tongue in the Mouth:

- **Mechanical Digestion:** Manipulates food during chewing.
- **Taste Sensation:** Detects flavors via taste buds.
- **Bolus Formation:** Shapes food into a soft mass for swallowing.

Q.4 What role does the epiglottis play during swallowing?

Ans. Role of Epiglottis Play during Swallowing:

- **Protection:** Covers the trachea to prevent food entry into the lungs.
- **Direction:** Guides food toward the esophagus.

Q.5 What is the composition of gastric juice?

Ans. Composition of Gastric Juice:

- **Hydrochloric Acid (HCl):** Creates acidic pH.
- **Pepsinogen:** Activated to pepsin (digests proteins).
- **Mucus:** Protects the stomach lining from acid.
- **Gastric Lipase:** Begins fat digestion (minor role).

Q.6 Why is hydrochloric acid (HCl) important in the stomach?

Ans. Importance of Hydrochloric Acid in the Stomach:

- **Pathogen Destruction:** Kills ingested bacteria.
- **Enzyme Activation:** Converts pepsinogen to pepsin.
- **Optimal pH:** Maintains acidic environment for enzymatic activity.

Q.7 What is the difference between bolus and chyme?

Ans.

Bolus	Chyme
• Chewed food mixed with saliva (formed in the mouth).	• Semi-liquid mixture of partially digested food and gastric juice (formed in the stomach).

Q.8 Which organ produces bile, and what is its function?

Ans. Bile Production:

- **Produced By:** Liver (stored in the gallbladder).
- **Function:** Emulsifies fats, neutralizes stomach acid, and aids lipid digestion.

Q.9 Differentiate between physical and chemical digestion.

Ans.

Physical	Chemical
• Mechanical breakdown (e.g., chewing, peristalsis).	• Enzymatic breakdown (e.g., amylase, pepsin, lipase)

Q.10 What do you understand by emulsification of fats?

Ans. Emulsification of Fats:

- **Process:** Bile salts break large fat globules into smaller droplets.
- **Purpose:** Increases surface area for lipase enzyme action.

Q.11 What is role of the pyloric sphincter in digestion?

Ans. Role of the Pyloric Sphincter in Digestion:

- **Regulation:** Controls the release of chyme from the stomach to the duodenum.
- **Prevents Overload:** Ensures gradual entry into the small intestine.

Q.12 How do villi and microvilli help in nutrient absorption?

Ans. Villi and Microvilli help in Nutrient Absorption:

- **Villi:** Finger-like projections in the small intestine that increase surface area.
- **Microvilli:** Hair-like structures on villi ("brush border") further enhance nutrient absorption.

Q.13 What are the main functions of the large intestine?

Ans. Main Functions of the Large Intestine:

- **Water Absorption:** Reabsorbs water and electrolytes.
- **Feces Formation:** Compacts undigested waste.
- **Bacterial Activity:** Gut flora synthesizes vitamins (e.g., vitamin K).

Q.14 What causes jaundice in the digestive system?

Ans. Causes of Jaundice in the Digestive System:

- **Liver Dysfunction:** Hepatitis, cirrhosis, or bile duct obstruction.
- **Bilirubin Buildup:** Excess bilirubin in blood due to impaired processing or excretion.

Q.15 How does stress negatively impact digestion?

Ans. Stress of Negative Impact on Digestion:

- **Reduced Blood Flow:** Diverts energy to muscles and brain.
- **Delayed Motility:** Slows digestion, causing bloating or constipation.
- **Acid Imbalance:** May trigger acid reflux or ulcers.
- **Gut Microbiome Disruption:** Alters bacterial balance, affecting nutrient absorption.

Exercise — LONG ANSWER QUESTIONS — Section 03

Q.1 Explain the complete process of digestion, starting from ingestion in the mouth to egestion in the large intestine. Include the roles of mechanical and chemical digestion at each stage.

Ans. See Page No. (267)

Q.2 Describe the structure and function of the stomach in digestion.

Ans. See Page No. (270)

Q.3 Compare and contrast the roles of the small intestine and large intestine in digestion.

Ans. See Page No. (274)

Q.4 Explain the absorption of food from the small intestine?

Ans. See Page No. (272)

Q.5 Discuss accessory organs (liver, gallbladder and pancreas) and their contributions in digestion.

Ans. See Page No. (275)

Q.6 Describe the hormonal and nervous regulation of gastric acid secretion.

Ans. See Page No. (276)

Exercise — INQUISITIVE ANSWER QUESTIONS

Q.1 Why does the small intestine need both peristalsis and segmentation?

Ans. i. Peristalsis – Propelling the Food Forward

- Peristalsis consists of wave-like muscle contractions that move food (chyme) along the small intestine.
- It ensures that digested food progresses from the duodenum to the ileum for further absorption and eventual entry into the large intestine.

ii. Segmentation – Mixing and Absorption

- Segmentation involves rhythmic contractions of circular muscles that mix chyme with digestive juices.
- It increases contact with intestinal walls, improving nutrient absorption.

iii. Coordinated Action

- Both processes are essential: segmentation for mixing, peristalsis for movement.
- Their coordination ensures efficient digestion and nutrient absorption throughout the small intestine.

Q.2 How does the liver help digestion without using enzymes?

Ans. i. Bile Production for Fat Emulsification

- The liver produces bile, a fluid containing bile salts.
- Bile emulsifies fats, breaking them into smaller droplets, which increases the surface area for lipase (a fat-digesting enzyme) to act more efficiently.

ii. Storage and Release of Nutrients

- The liver stores glucose as glycogen and releases it when needed to maintain energy balance.
- It also stores vitamins and minerals essential for various metabolic processes.

iii. Detoxification of Harmful Substances

- The liver detoxifies drugs, alcohol, and metabolic waste (like ammonia into urea), keeping the body environment stable for digestion and metabolism.

iv. Regulation of Blood Composition

- The liver regulates the levels of glucose, amino acids, and lipids in the blood.
- This ensures that digested nutrients are properly processed and made available to the body.

v. Hormonal Support for Digestion

- The liver responds to digestive hormones like secretin, which stimulates bile production, helping fat digestion indirectly.

Q.3 Why do we need bile if we already have enzymes for fat digestion?

Ans. i. Emulsification of Fats

- Bile breaks large fat globules into tiny droplets (emulsification).
- This increases the surface area for lipase to act on fats effectively.

ii. No Digestive Action by Bile Itself

- Bile does not contain enzymes, so it doesn't digest fats directly.
- It prepares fats for digestion by lipase, which needs smaller droplets to function properly.

iii. Efficient Fat Digestion

- Without bile, lipase would be less effective, and fat digestion would be slow and incomplete.
- Bile ensures fast and complete digestion and absorption of dietary fats.

Q.4 How does the pancreas "know" when to release its enzymes?

Ans.
- The presence of acidic chyme and fats in the small intestine triggers the release of two hormones secretin and cholecystokinin (CCK).
- Secretin stimulates the pancreas to release bicarbonate-rich fluid, while CCK signals it to release enzyme-rich pancreatic juice.
- These hormones ensure enzymes are released only when needed for digestion.

Q.5 Why are pancreatic secretions alkaline, not acidic?

Ans. Pancreatic Secretions Alkaline:
- Pancreatic secretions are alkaline due to their high bicarbonate (HCO_3^-) content.
- This alkalinity helps neutralize the acidic chyme coming from the stomach into the small intestine.
- It creates an optimal pH environment (around 7.5–8) for pancreatic enzymes to function effectively.

ADDITIONAL MCQs

1. **Which salivary gland is the largest and located near the ear?**
   A. Sublingual B. Submandibular C. Parotid D. Buccal
2. **Which component of saliva helps prevent bacterial infection?**
   A. Amylase B. Mucin C. Lysozyme D. Water
3. **Which part of the pharynx leads into the esophagus?**
   A. Nasopharynx B. Oropharynx C. Laryngopharynx D. Epiglottis
4. **What is anti-peristalsis?**
   A. Movement of food towards the rectum B. Forward movement of bile
   C. Reversal of peristaltic movement D. Mixing movement in the stomach
5. **What causes hunger pangs in the human body?**
   A. High blood sugar B. Full stomach
   C. Strong stomach contractions D. Saliva secretion
6. **The parietal cells of the stomach secrete:**
   A. Pepsinogen B. Mucus C. Hydrochloric acid (HCl) D. Gastrin
7. **Which structure increases the surface area in the small intestine the most?**
   A. Rugae B. Microvilli C. Haustra D. Plicae circulares
8. **Which of the following enzymes is secreted by the small intestine?**
   A. Pepsin B. Trypsin C. Enterokinase D. Amylase
9. **Which hormone stimulates the pancreas to release digestive enzymes in response to chyme in the duodenum?**
   A. Insulin B. Secretin C. CCK (Cholecystokinin) D. Gastrin
10. **Peyer's patches are mostly found in:**
    A. Duodenum B. Jejunum C. Ileum D. Colon
11. **Which structures in the small intestine increase surface area for absorption?**
    A. Crypts B. Rugae C. Villi and microvilli D. Lacteals
12. **The main function of the large intestine is:**
    A. Digestion of proteins B. Absorption of nutrients
    C. Absorption of water and minerals D. Production of bile
13. **The caecum is located at the junction of the:**
    A. Colon and rectum B. Ileum and large intestine
    C. Duodenum and jejunum D. Esophagus and stomach

14. **The main function of the gallbladder is to:**
    A. Produce digestive enzymes B. Absorb nutrients
    C. Store and concentrate bile D. Neutralize stomach acid
15. **Which organ produces both digestive enzymes and hormones?**
    A. Liver B. Gallbladder C. Pancreas D. Stomach
16. **Which hormone stimulates the liver to secrete more bile?**
    A. Gastrin B. Secretin C. Insulin D. Cholecystokinin
17. **Which hormone stimulates the pancreas to release enzyme-rich pancreatic juice?**
    A. Gastrin B. Secretin C. Cholecystokinin (CCK) D. Somatostatin
18. **The liver converts excess glucose into:**
    A. Fructose B. Urea C. Glycogen D. Lactic acid

ANSWER KEY

1. C	2. C	3. C	4. C	5. C	6. C	7. B	8. C	9. C	10. C	11. C	12. C
13. B	14. C	15. C	16. B	17. C	18. C						

ADDITIONAL SHORT ANSWER QUESTIONS

Q.1 How does the oral cavity help in the selection of food?

Ans. Oral Cavity help in the Selection of Food:
- Taste buds on the tongue detect sweet, sour, salty, bitter, and umami flavors.
- This sensory input helps humans accept nutritious food and reject harmful substances, aiding in food selection.

Q.2 Name the three major salivary glands and their locations.

Ans. Three Major Salivary Glands And Their Locations:
- The parotid glands are near the ears, submandibular glands are beneath the lower jaw, and sublingual glands are under the tongue.
- All produce saliva that aids digestion and lubrication.

Q.3 What is the function of the esophagus?

Ans. Esophagus:
- The esophagus is a muscular tube that transports food from the pharynx to the stomach using peristaltic movements.
- It does not play a role in digestion but ensures the safe passage of food.

Q.4 What is segmentation and where does it occur?

Ans. Segmentation:
- Segmentation is a mixing movement seen mainly in the small intestine.
- It helps thoroughly blend food with digestive juices and improves nutrient absorption by exposing more surface area.

Q.5 Define hunger pangs and their physiological basis.

Ans. Hunger Pangs:
- Hunger pangs are painful contractions of the empty stomach, typically occurring several hours after eating.
- They are triggered by the hypothalamus and indicate the body's need for food.

Q.6 What is chyme, and how is it formed?

Ans. Chime: (Kime)
- Chyme is a semi-liquid mass of partially digested food formed in the stomach by the mechanical mixing of food with gastric juice.
- It moves from the stomach to the small intestine for further digestion.

Q.7 How do villi and microvilli help in absorption?

Ans. Role of Villi and Microvilli:

- Villi and microvilli increase the surface area of the intestinal lining, allowing more efficient absorption of nutrients into the bloodstream.

Q.8 Where does water absorption occur in the digestive system?

Ans. Water Absorption Occur in the Digestive System:

- Most water absorption takes place in the small intestine, but the large intestine also absorbs residual water, helping to form solid feces and maintain body fluid balance.

Q.9 What role does the colon play in digestion?

Ans. Role does the Colon Play in Digestion:

- The colon absorbs water, salts, and vitamins from undigested food.
- It also compacts the waste into feces for elimination and houses beneficial bacteria that produce vitamin K.

Q.10 How is vitamin K produced in the large intestine?

Ans. Production of Vitamin K in large Intestine:

- Gut microbiota, especially E. coli, ferment undigested residues and produce vitamin K, which is absorbed into the bloodstream and helps in blood coagulation.

Q.11 What is the function of the caecum in the large intestine?

Ans. Function of Caecum:

- The caecum receives material from the small intestine and begins compaction.
- In herbivores, it may assist in cellulose digestion, while in humans, its function is minor.

Q.12 How does defecation differ in infants compared to adults?

Ans. Difference of defecation in infants than Adults:

- In infants, the control of the anal sphincter is involuntary due to the immaturity of the nervous system, causing reflexive defecation.
- Adults have voluntary control, allowing conscious regulation of bowel movements.

Q.13 What is the role of the liver in digestion?

Ans. Role of the Liver in Digestion:

- The liver produces bile, which emulsifies fats to aid in digestion.
- It also detoxifies substances, processes nutrients, and stores glycogen and fat-soluble vitamins like A, D, E, and K.

Q.14 What are the exocrine and endocrine roles of the pancreas?

Ans. Exocrine and Endocrine Roles of Pancreas:

- The exocrine part of the pancreas secretes digestive enzymes into the duodenum, while the endocrine part (islets of Langerhans) releases hormones like insulin and glucagon to regulate blood sugar.

Q.15 Why is pancreatic juice important in digestion?

Ans. Important of Pancreatic Juice in Digestion:

- Pancreatic juice contains enzymes that digest all major macronutrients: amylase for carbs, trypsin for proteins, and lipase for fats.
- It also contains bicarbonates to neutralize acidic chyme.

Q.16 How does the pancreas respond to hormonal stimulation during digestion?

Ans. Response of Pancreas to Hormonal Stimulation:

- In the presence of food, the duodenum releases secretin and CCK, which stimulate the pancreas to secrete alkaline fluids and digestive enzymes, helping to digest food and neutralize acids.

Q.17 How is bile secretion and release hormonally controlled?

Ans. Control of Bile Secretion:

- Secretin promotes continuous bile production by the liver, while CCK causes the gallbladder to contract and release stored bile into the small intestine to emulsify fats.

Q.18 What is the liver's role in carbohydrate metabolism?

Ans. Role of Liver in Metabolism of Carbohydrates:

- The liver helps regulate blood glucose levels by converting excess glucose into glycogen (glycogenesis) for storage and later converting glycogen back into glucose (glycogenolysis) when needed.

Q.19 How does the liver contribute to protein metabolism?

Ans. Contribution of Liver in Protein Metabolism:

- The liver performs deamination, removing the amino group from amino acids and converting the remaining molecule into compounds used for energy.
- The ammonia formed is converted into urea for excretion.

SELF-ASSESSMENT Chapter # 09

Total Mark: 30

Q.1 Encircle the correct option. **(1 x 6 = 06)**

i. **Which of the following is NOT a component of the stomach's mechanical digestion?**
(a) Gastric contractions (b) Peristalsis (c) Segmentation (d) Mastication

ii. **Which region of the small intestine is responsible for the majority of nutrient absorption?**
(a) Duodenum (b) Jejunum
(c) Ileum (d) All regions absorb equal amounts of nutrients

iii. **Which of the following is a function of the large intestine?**
(a) Absorption of nutrients (b) Secretion of digestive enzymes
(c) Storage of bile (d) Water absorption and feces formation

iv. **What is the primary function of peristalsis in the digestive system?**
(a) To mix food with digestive enzymes (b) To propel food through the digestive tract
(c) To absorb nutrients into the bloodstream (d) To secrete digestive enzymes

v. **Where does chemical digestion of carbohydrates begin?**
(a) Stomach (b) Oesophagus (c) Small intestine (d) Mouth

vi. **Which change would most affect protein digestion?**
(a) Blocking bile release (b) Inhibiting salivary glands
(c) Inhibiting pepsin production (d) Slowing peristalsis

Q.2 Write short answers of the following questions. **(2 x 8 = 16)**

i. What is the mode of action of saliva in mouth?
ii. What is the composition of gastric juice?
iii. What is the difference between bolus and chyme?
iv. How does peristalsis aid in the movement of food through the digestive tract?
v. What is the function of bile in digestion?
vi. How does the structure of the pancreas support its function?
vii. What is the function of the caecum in the large intestine?
viii. How does the pancreas respond to hormonal stimulation during digestion?

Q.3 Extensive Questions. **(4 x 2 = 8)**

(a) Describe the structure and function of the stomach in digestion.
(b) Describe the hormonal and nervous regulation of gastric acid secretion.