UNIT
2

DIGESTION

Dr. Ivan Pavlov

The Nobel Prize in Physiology or Medicine (1904) was awarded to Ivan Petrovich Pavlov in recognition of his work on the physiology of digestion. He was a pioneer who has carried out research in understanding the various processes of digestion, by surgical methods in dogs. He studied the conditional reflexes and the involvement of nervous system in the intestinal movements as well as secretion of gastric juice and other secretions. He also explored the significance of psychic factors in activating secretion of gastric juice.

MF982P

Learning Objectives

After studying this unit the students will be able to

- recognise the anatomy of digestive system
- understand the digestive glands and their secretions
- Deliberate the mechanical and chemical aspects of digestion
- explain the role of digestive enzymes in digestion of macromolecules
- describe different modes of absorption and assimilation of nutrients
- recognise the role of gastro-intestinal hormones in digestion

INTRODUCTION

Food is vital for sustenance of life for all organisms. However, the billions and trillions of cells in our body cannot utilize the complex constituents present in the food we eat like lip smacking pizzas or burgers and idlies or dosas, directly. Hence, these complex molecules should be broken down into simpler forms for the cells to assimilate and use them. The process by which the complex food is broken down mechanically (i.e. physically, in mouth and stomach), as well as chemically to smaller macromolecules that can be utilized by the cells of our body is called as digestion. Digestion is unique to heterotrophs, as autotrophs like plants are capable of synthesizing their own food. The process of conversion of food to fuel that could be used by cells is aided by the digestive system and it is a unique anatomical feature of the animal kingdom.

2.1 DIGESTIVE SYSTEM:

The digestive system is made up of a tubular gastro -intestinal tract (GI tract), extending from mouth till anus, and secretory organs (Figure 2.1). The organs of the GI tract include the oral cavity, pharynx, stomach, small intestine, large intestine, rectum and anus. The accessory digestive organs include the salivary glands, oxyntic and parietal glands of the stomach, duodenal glands, liver, gall bladder and pancreas.

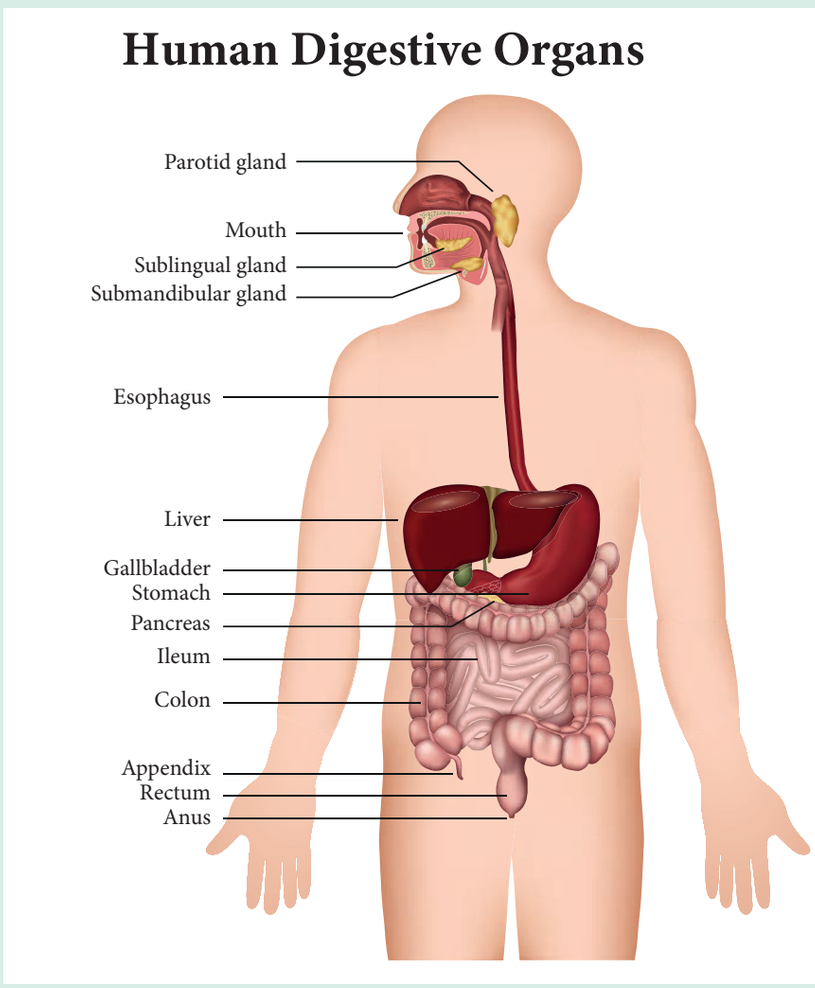

Figure 2.1 Digestive system of human

2.1.1 Gastrointestinal Tract:

2.1.1.1 Oral Cavity

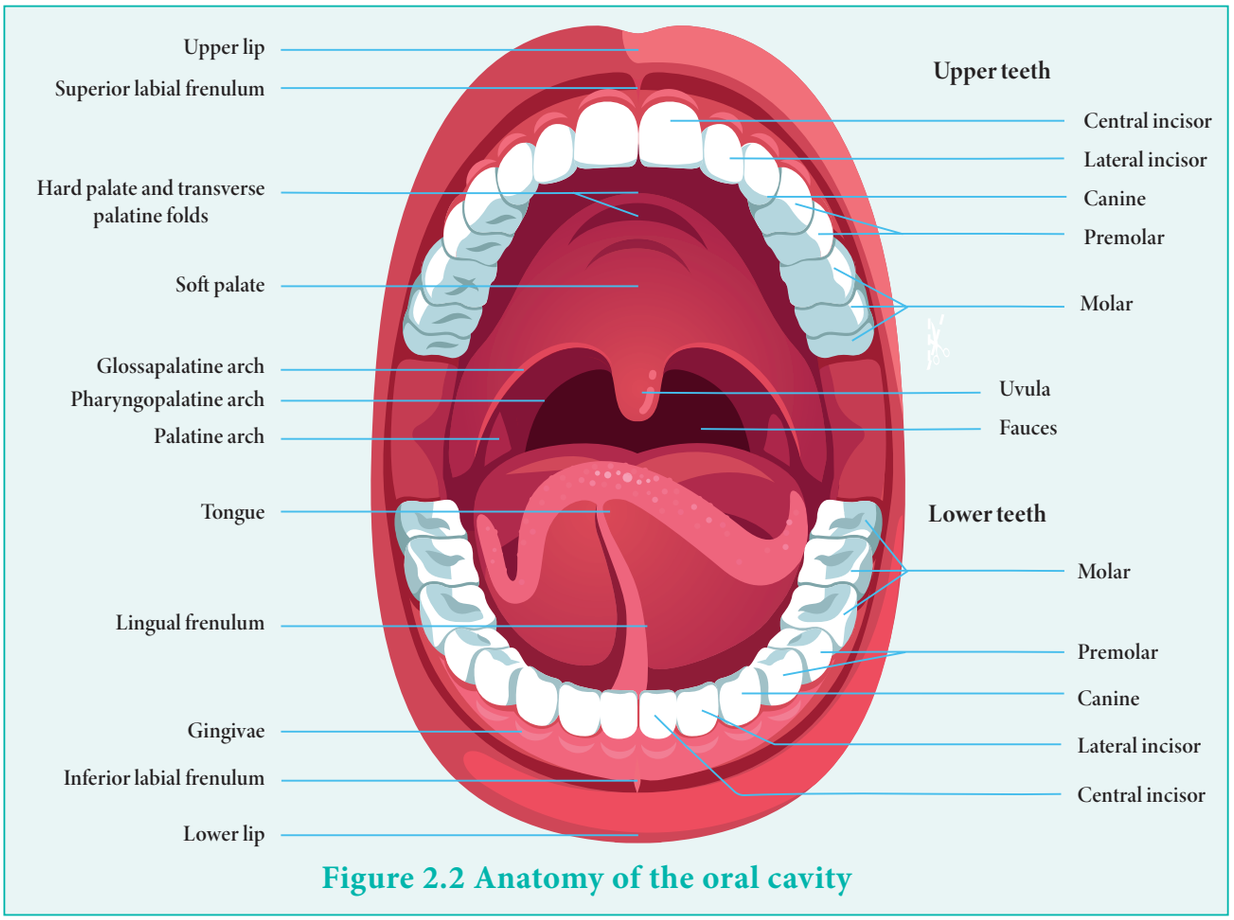

Figure 2.2 Anatomy of the oral cavity

The mouth or the oral or buccal cavity is made up of cheeks, hard and soft palates and the tongue along with the teeth embedded in the upper and lower jaws (Figure 2.2). The cheeks form the lateral walls of the oral cavity. The palate is the septum or the wall which separates the oral from the nasal cavity. The hard palate in the front is bony in structure, while the soft palate at the back is muscular in nature and separates the oropharynx from the nasopharynx. The soft palate accommodates a hanging muscular organ called uvula, meaning little grape. The tongue is a muscular organ attached by the frenulum to the floor of the buccal cavity and free in the front. It is involved in mastication of food, swallowing and also bears the taste buds. The tongue and uvula are responsible for the swallowing action. There are four types of teeth – incisors for cutting, canine for holding and tearing, premolars and molars for grinding the food. Human teeth are thecodont (embedded in socket of jaw bones), diphyodont (temporary and permanent sets of teeth) and heterodont in nature. The dental formula for each half of the upper and lower jaw of an adult is 2123/2123.

2.1.1.2 Pharynx

The pharynx is a funnel shaped structure that connects the oral and nasal cavity to oesophagus and trachea. The function of pharynx is to help in swallowing the bolus (masticated food). The whole of the pharyngeal stage of swallowing usually occurs within

6 seconds. During this period, the swallowing center inhibits the respiratory center of the medulla, halting respiration, thereby allowing swallowing to proceed.

2.1.1.3 Oesophagus

The bolus passes from the pharynx into the oesophagus. Epiglottis (a cartilageneous flap) prevents the entry of food into the glottis, while the food is being swallowed. Tonsils, the lymphoid organs are present on either side of the pharynx. Oesophagus is the muscular tube located behind the trachea in the thorax, which connects the pharynx to the stomach. The function of oesophagus is to transport the bolus into the stomach. At the end of the esophagus, near the juncture with the stomach, there is a circular muscle called the gastroesophageal sphincter or cardiac sphincter. The gastric secretions are highly acidic and contain many proteolytic enzymes. The oesophageal mucosa, except in the lower one eighth of the oesophagus, is not capable of resisting the action of gastric secretions. The oesophageal sphincter helps to prevent significant reflux of stomach contents into the oesophagus. Gastro esophageal Reflux Disease (GERD) is a condition, which is associated with gastric reflux of acid into the oesophagus resulting in heartburn.

2.1.1.4 Stomach

The stomach is a J shaped enlargement of the GI tract that is divided anatomically into cardia, fundus, body, and pyloric part (Figure 2.3).

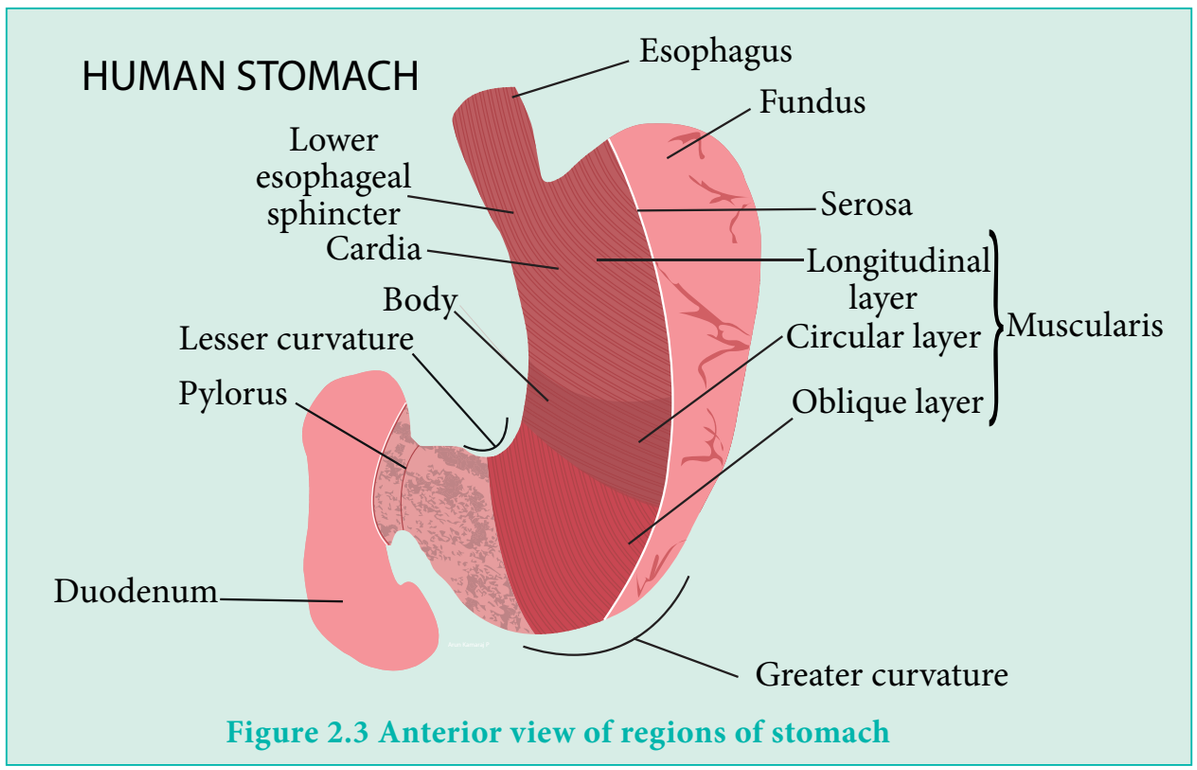

Figure 2.3 Anterior view of regions of stomach

The functions of the stomach are:

1. It mixes the semi-solid bolus with the gastric secretions to form a liquid called as chyme.

2. Digestion cannot occur at the rate at which we eat food. Stomach acts as a storage organ and releases it into the duodenum at regulated intervals.
3. Certain vitamins like B12 are absorbed in the stomach.
4. It secretes gastric juice, which contains HCl that kills bacteria and denatures protein, pepsin that digests proteins and gastric lipase that aids in the digestion of triglycerides.
5. It also secretes gastrin into blood, which aids in gastric motility (movement).

When empty, the inner mucosal layers of the stomach fold into invaginations called rugae that unfold on intake of large meals. The pylorus of the stomach leads to duodenum of the small intestine via a smooth muscle sphincter called the pyloric sphincter.

2.1.1.5 The Small Intestine

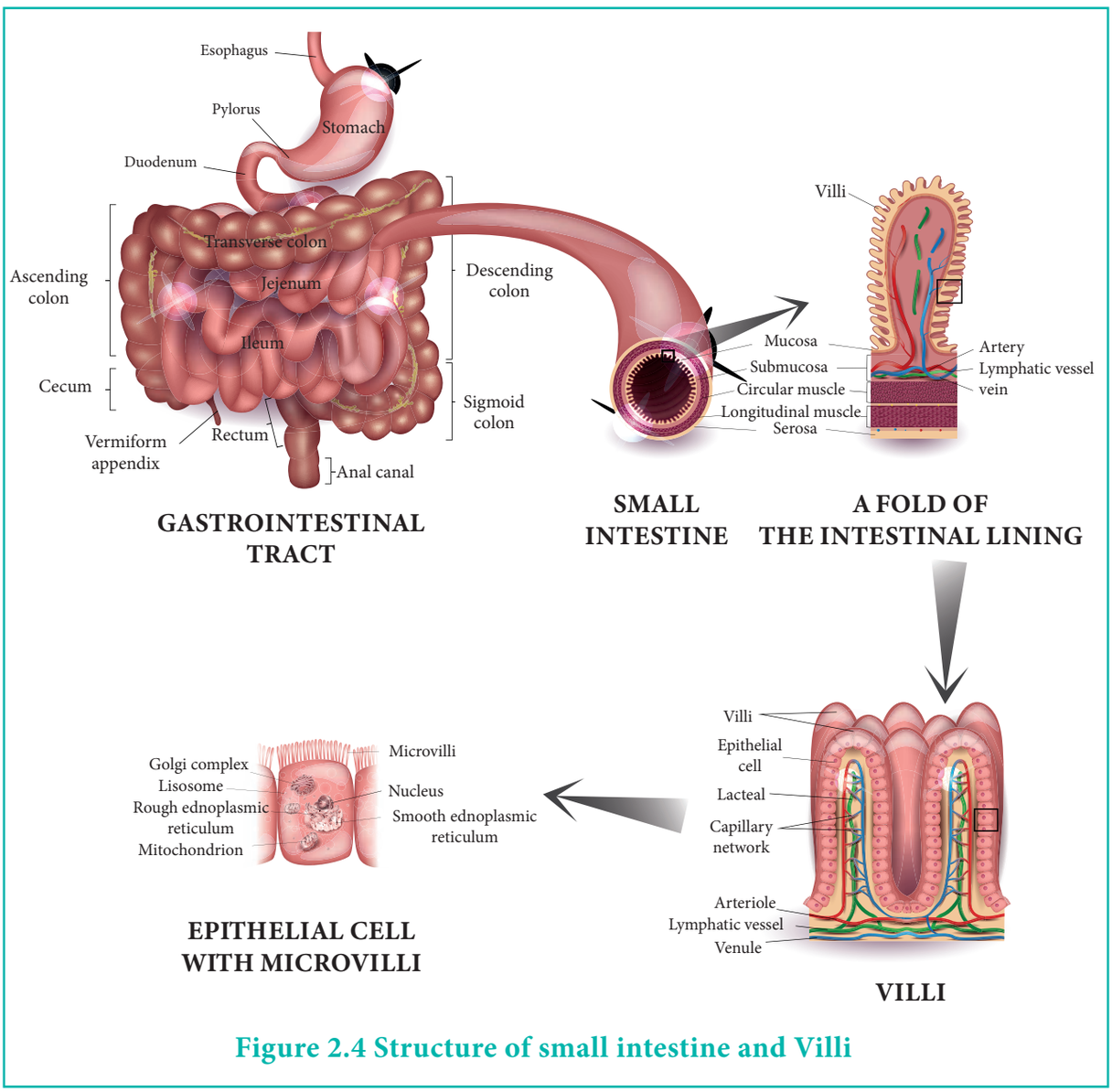

Figure 2.4 Structure of small intestine and Villi

The small intestine starts from the pyloric sphincter and opens into the large intestine. It has a diameter of about 2.5 cm and is 10 feet long in a living person. It is the region in the

gastro intestinal tract where most of the digestion and absorption occurs. The small intestine has a large surface area due to the presence of villi or microvilli to aid absorption of nutrients.

The small intestine is divided into three regions: The duodenum, a C shaped tube, which starts at the pyloric sphincter that extends about 25 cm (10 inches) and merges with the jejunum. The jejunum is about 1 m (3 ft) long and extends to the ileum, the final and longest region of the small intestine, measuring about 2 m (6 ft); ileum joins the large intestine at a smooth muscle sphincter called the ileocecal sphincter (valve) (Figure 2.4).

Structure of Villi

An intestinal villus is a small finger like projection that extends into the lumen of the small intestine (Figure 2.5). Each villus has many microvilli projecting from its epithelial surface, collectively forming a brush border. The structure of villi aids in absorption of nutrients by providing large surface area and also have thin wall that reduces the distance for the nutrients to move across the intestine by a process called diffusion. Between the villi there are crypts, called crypts of Lieberkuhn, which are short glands. The Gut associated lymphoid tissue or the Peyer's patches are present in the small intestine and protect the intestine from the foreign pathogens.

Each villus consists of one cell thick thin epithelium surrounding the blood capillary and tiny lymphatic vessels called lacteals.

2.1.1.6 The Large Intestine

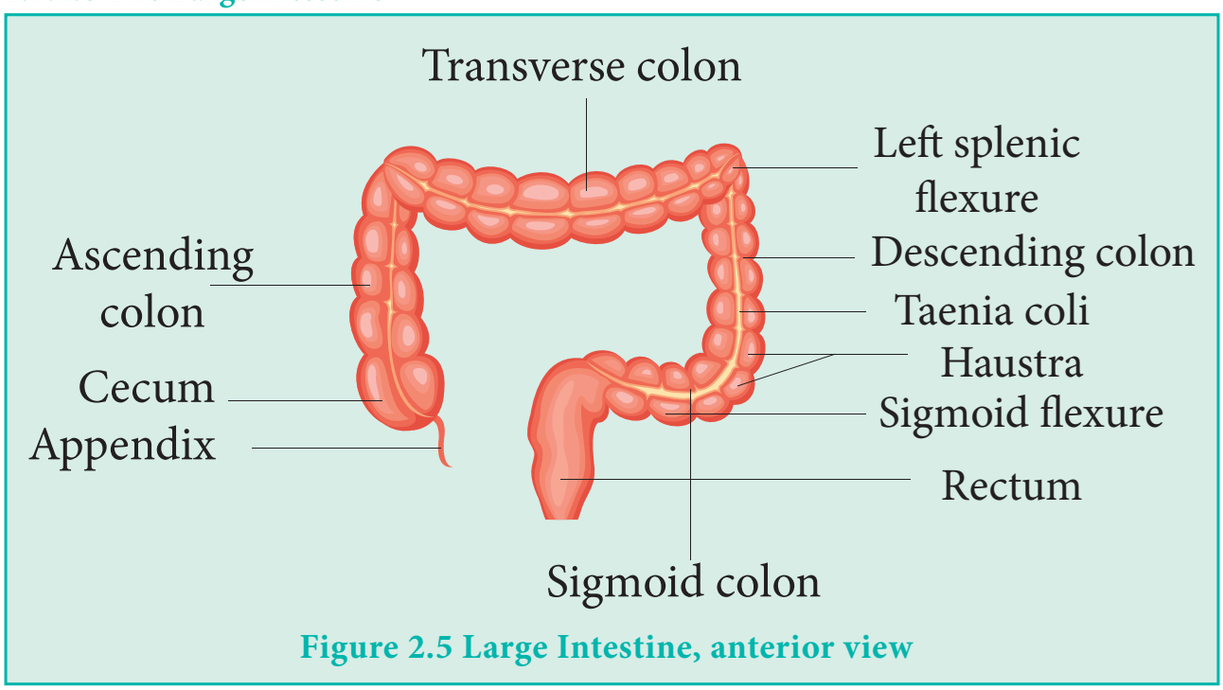

Figure 2.5 Large Intestine, anterior view

The large intestine includes the cecum, colon, rectum and the anal canal (Figure 2.5). It is larger in diameter than the small intestine (6.5 cm compared to 2.5 cm), but it is shorter in length. The large intestine absorbs water, salts, and some vitamins. The indigestible material is stored in the large intestine till it is eliminated via the anus. The cecum has a small projection called the vermiform appendix (vermiform -wormlike). The

colon is divided into the ascending colon, which goes up in the right side of the abdomen to the level of the liver; the transverse colon that crosses the abdominal cavity below the liver and descending colon, that descends in the left side of the body; and the S shaped sigmoid colon, which enters the rectum, where feces is stored. When sufficient amount of feces is collected, the rectum opens at the anus, where defecation occurs. The internal and external anal sphincters help to keep the orifice closed. Getting rid of indigestible remains is the means by which the large intestine helps to maintain homeostasis.

2.1.2 Secretory Organs

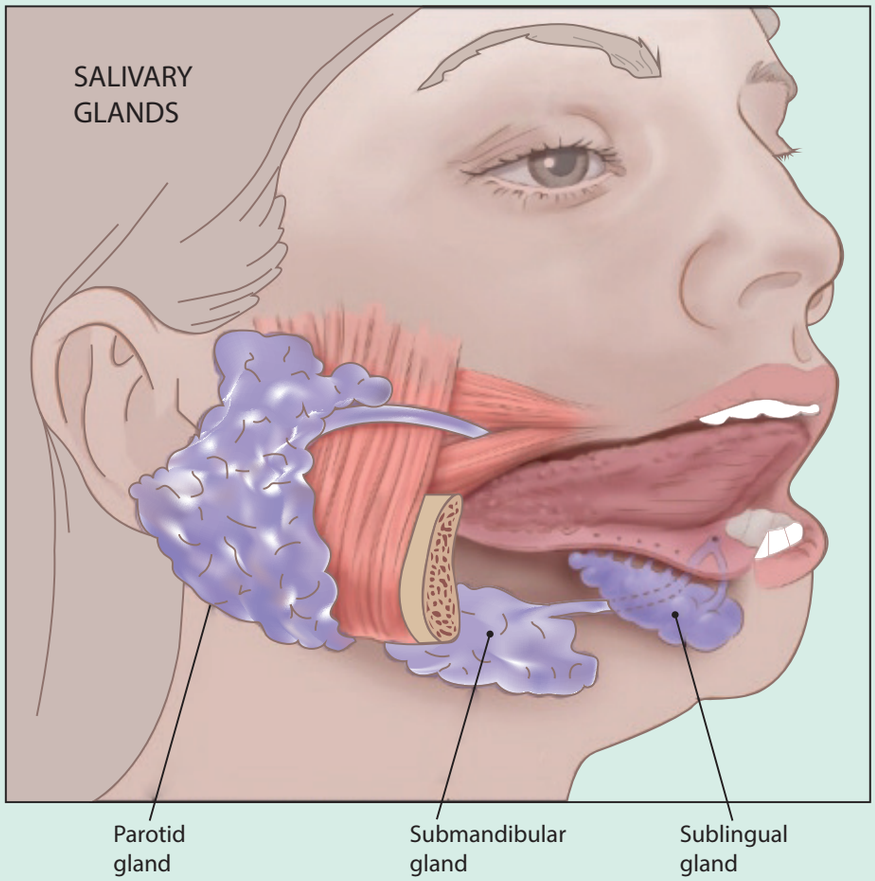

Figure 2.6 location of salivary gland

2.1.2.1 Salivary Glands

There are three pairs of major salivary glands namely, the parotid glands present inferior and anterior to the ears, the submandibular glands located in the floor of the mouth and the sublingual glands beneath the tongue and few minor salivary glands that are present in the cheeks, lips and palate (Figure 2.6). The secretion called saliva from the major salivary glands reaches the mouth by Stenson's duct, Wharton's duct and Bartholin's duct. Approximately, an average man secretes about 1 to 1.5 liters of saliva per day. Saliva is 99.5% water and the remaining is mucus, electrolytes, anti-microbial agents and enzymes. The water helps in dissolving the food and thereby stimulates the taste

receptors (gustatory receptors), while the chloride ions activate amylase to digest starch. The IgA in the saliva acts against the microbes. The saliva helps in rolling the food into a ball so that it can be swallowed.

2.1.2.2 Gastric glands

Gastric juice is secreted by the different types of exocrine cells present in the gastric glands lining the stomach. These glandular cells empty their secretions into the gastric pit. There are three types of exocrine cells: Intrinsic factor and HCl secreting parietal cells, chief cells that secrete pepsinogen and gastric lipase, and mucous secreting mucosal cells. The secretions of the mucous, parietal, and chief cells form gastric juice, which amounts to 2 – 3 liters per day. The G cells, which are entero-endocrine (endocrine cells of the GI tract) in nature located mainly in the pyloric antrum secrete gastrin into the bloodstream.

2.1.2.3 Liver

The liver is the largest organ in the human body and it lies in the upper right section of the abdomen, just below the diaphragm. The liver has two main lobes, the bigger right lobe and the smaller left lobe, which are further divided into lobules that serve as the structural and functional units of liver (Figure 2.7). A lobule consists of hepatic cells arranged in groups that radiate from a central vein. Hepatic sinusoids separate these groups of cells from each other. Kupffer cells, which are phagocytic in nature are attached to the lining of the hepatic sinusoids (Figure 2.9).

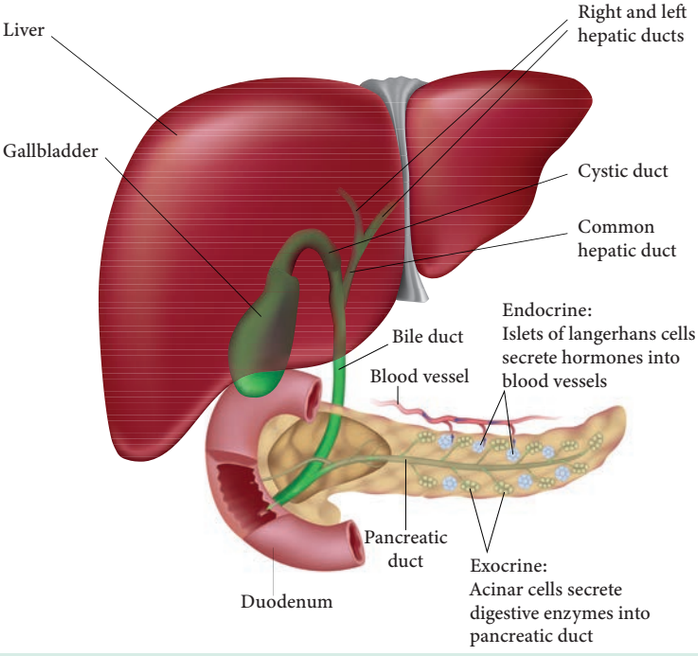

Figure 2.7 Anterior view of Liver

Every day, the hepatocytes secrete about 1 liter of bile, a yellow, olive-green or brown liquid with a pH of 7.6 – 8.6. Components of bile include bile salts, cholesterol, lecithin, bile pigments, and several ions.

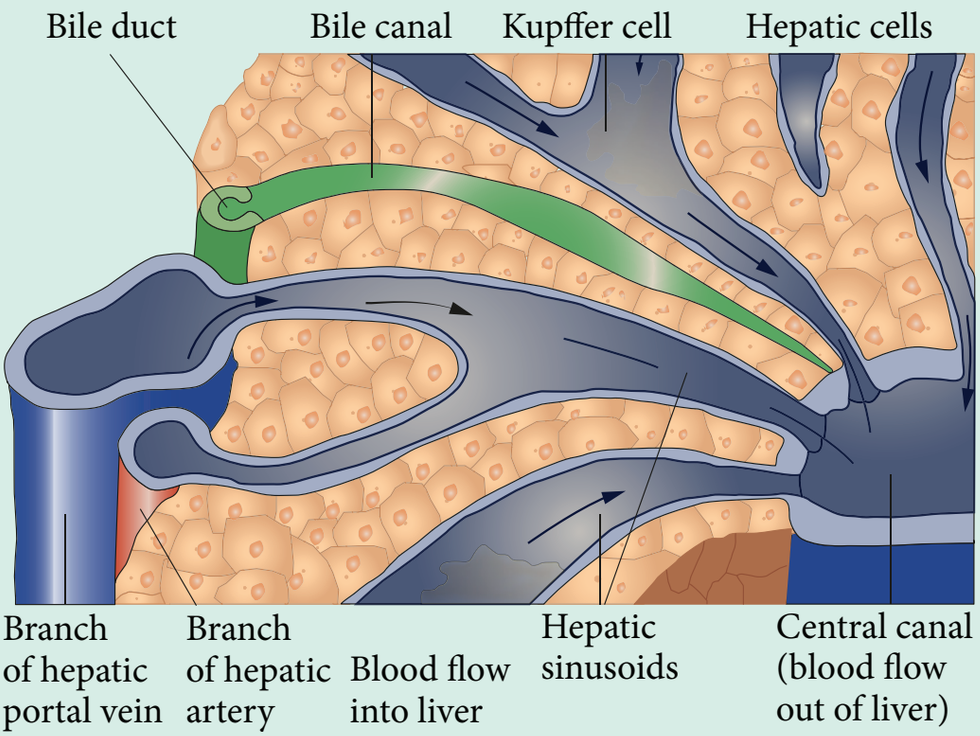

Figure 2.8 Lobules of liver

Functions of liver are:

Synthetic function

- Synthesis, storage and release of bile for emulsification of fats
- Synthesis of plasma proteins

Storage function

- Stores fat-soluble vitamins and iron
- Stores glucose as glycogen and converts to fats and packages into lipoproteins to be stored in adipose tissue

Homeostatic function

Helps in maintenance of blood glucose

- Helps in cholesterol homeostasis by converting some amount of cholesterol to bile salts

Detoxification function

- Detoxifies ammonia to urea
- Helps in detoxification by removing poisonous substances
- Phagocytosis of worn out red and white blood cells

2.1.2.4 Gall bladder

The gallbladder is a pear-shaped sac, muscular in nature that is located in a depression on the inferior surface of the liver. Excess of bile is stored in the gallbladder. Water is reabsorbed from bile in the gallbladder making bile to become thick, mucus like material. The cystic duct from the gall bladder and the common hepatic duct join to form the

common bile duct and enter into the duodenum. The cholesterol content of bile can crystallize and grow in size, leading to formation of gallstones. Sometimes, the stones might block the common bile duct and cause obstructive jaundice, in which case, the gallbladder is removed.

2.1.2.5 Pancreas

The pancreas lies deep in the abdominal cavity, behind the stomach in the upper left abdomen resting on the posterior abdominal wall. The broad portion of the pancreas is called as the head and it fills the loop formed by the duodenum. The narrow portion is called the tail. The pancreas has both endocrine (as it secretes glucagon and insulin into the blood stream) and exocrine function (by way of secreting pancreatic juice). Pancreatic acinar cells produce pancreatic juice, which is secreted into tiny tubes that merge forming a single pancreatic duct that extends the length of the pancreas. This pancreatic duct joins the common bile duct to form the hepatopancreatic duct Ampulla of Vater that is guarded by the Sphincter of Oddi.

Glands of Lieberkuhn

These are tubular glands that lie between the villi of the inner surface of the small intestine.

2.1.2.6 Brunner's glands

The submucosa of the duodenum above the Oddi of Sphincter contains duodenal glands, also called Brunner's glands, which secrete alkaline mucus into the intestinal lumen. The functions of the mucus are:

- To neutralize the acid in the chyme
- To provide an alkaline pH enabling the intestinal enzymes to act
- To protect the intestinal walls

The secretions of the Brunner's gland and Glands of Lieberkuhn together contribute to intestinal juice. About 1 -2 liters of intestinal juice is secreted every day.

2.2. DIGESTION

GASTROINTESTINAL TRACT	SECRETORY GLANDS
Oral cavity	Salivary glands
Pharynx	Gastric glands
Oesophagus	Liver and Gall bladder
Stomach	Pancreas
Small Intestine	Duodenal glands (Brunner's glands)
Large Intestine	
Rectum	
Anus	

2.2.1 MECHANICAL DIGESTION

The mechanical processes involved in digestion are:

1. Ingestion refers to intake of food by the mouth. The amount of food taken by an individual is dependent on hunger and appetite. Hunger is the need for food and appetite is the preferential desire for food.
2. Mastication is the process of chewing the food. It ensures that the food taken is broken down into smaller pieces and ground well. The mouth is equipped with teeth which are well designed for chewing. The incisors provide a strong cutting action and the molars a grinding action. All the jaw muscles when working together can close the teeth with a force as great as 55 pounds on the incisors and 200 pounds on the molars.
3. Deglutition is the act of swallowing which involves the voluntary squeezing or rolling action which pushes the food into the pharynx and the involuntary pharyngeal action that pushes the food into oesophagus.
4. Peristalsis is the wave like motion of the esophagus that propels the food into the stomach (Figure 2.9).
5. Mixing and propulsion - Alternating contractions and relaxations of smooth muscle in the walls of the GI tract mix the food with the secretions of the GI tract and propel them forward. This action of the intestine is called as motility.

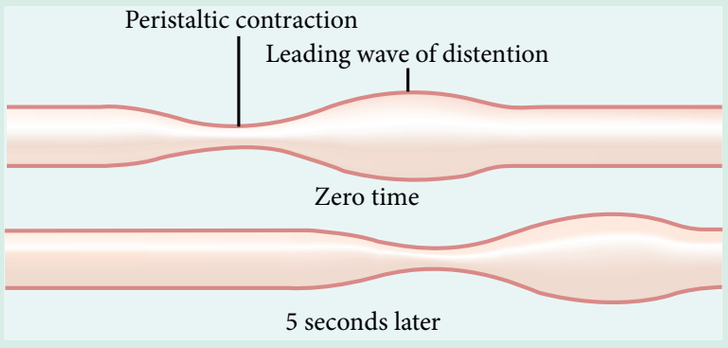

Figure 2.9 Peristaltic Movements

6. Defecation- Digested constituents that were not absorbed in the digestive tract and undigested waste leave the body through the anus in a process called defecation. The eliminated material is termed as feces or stool.

2.2.2 CHEMICAL DIGESTION

2.2.2.1 Digestion and absorption of carbohydrates

The food we eat contains abundant carbohydrates as they provide a major share of daily caloric requirement. Dietary carbohydrates consist of both digestible compounds such as starch, glycogen, lactose, maltose and sucrose and indigestible fibers such as cellulose and hemi-cellulose (Figure 2.10).

Digestion of carbohydrates takes place briefly in the mouth and largely in the n intestine. The polysaccharides get hydrated during cooking, which is essential for efficient digestion.

Two types of enzymes are required for digestion of carbohydrates – Amylases and Disaccharidases. Amylases are present in saliva and pancreatic juice, while disaccharidases are present in the brush border membrane of the intestine (Figure 2.11).

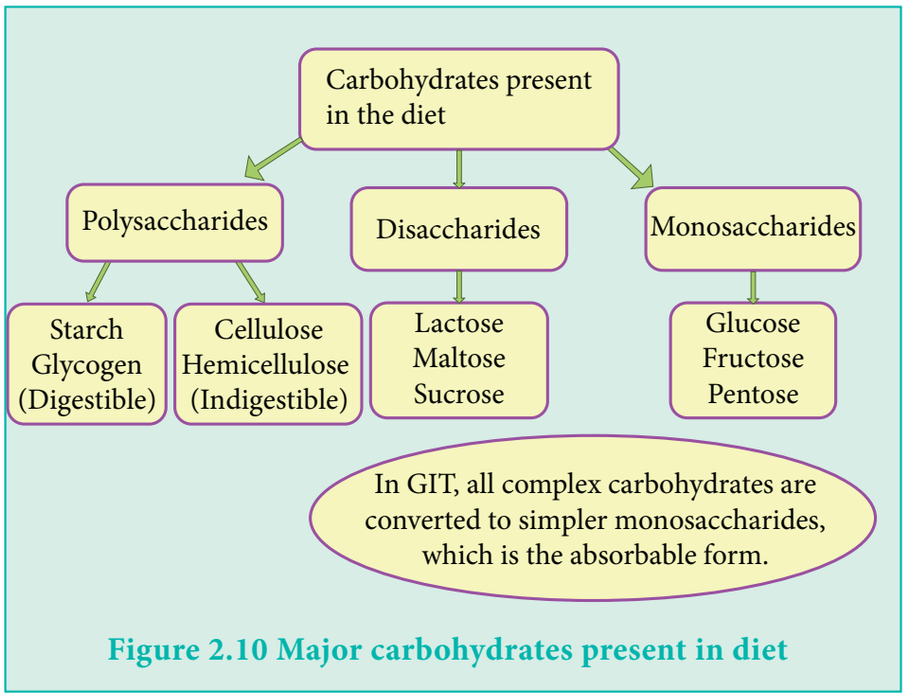

Figure 2.10 Major carbohydrates present in diet

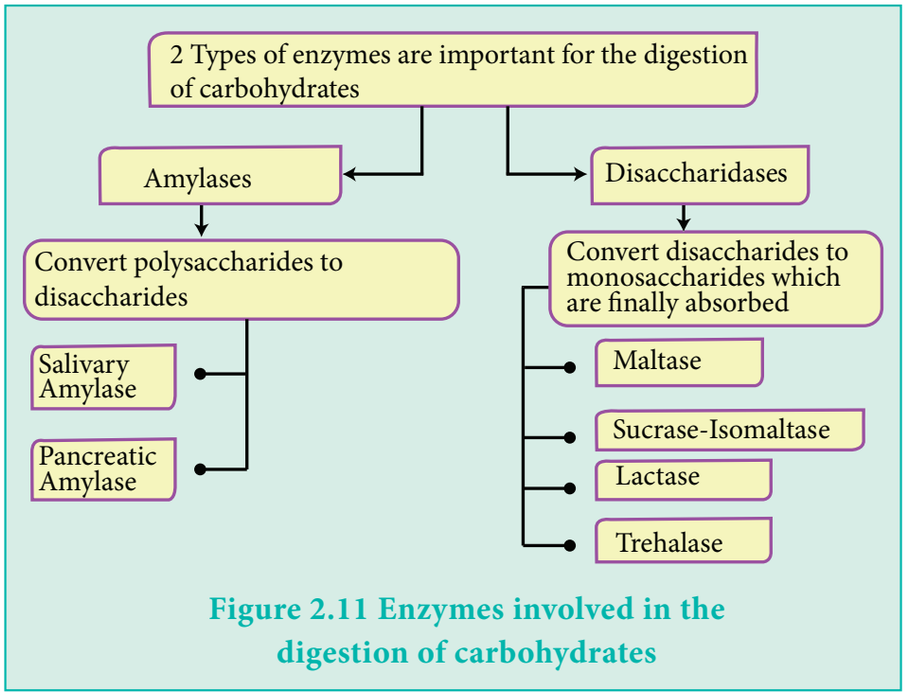

Figure 2.11 Enzymes involved in the digestion of carbohydrates

Digestion in mouth

Simpler carbohydrates and carbohydrates present in milk and juices escape digestion in mouth. The digestion of the digestible polysaccharides like starch and glycogen begins in mouth in humans by action of the salivary enzyme, Ptyalin, also called as α-amylase. This enzyme with an optimum pH of 6.8, hydrolyzes the α1→4 glycosidic bonds to release smaller oligosaccharide fragments and a highly branched limit dextrin (as the inner α1→4 linkages are inaccessible to the salivary amylase) (Figure 2.12). However, the digestion of carbohydrates by salivary amylase is limited because of its lower residual time in the mouth and oesophagus. As soon as the bolus reaches the stomach, the salivary amylase is inactivated because of the prevailing low pH.

Digestion in stomach

There are no enzymes present in the stomach to digest carbohydrates, despite the evidences citing the presence of gastric amylase, which is of lesser significance. Further, the low pH of stomach inactivates salivary amylase. The major digestive action of stomach on carbohydrates is that it helps in the cleavage of the glycosidic bonds present in sucrose. No further digestion of carbohydrates occurs in the stomach and the chyme passes into the duodenum.

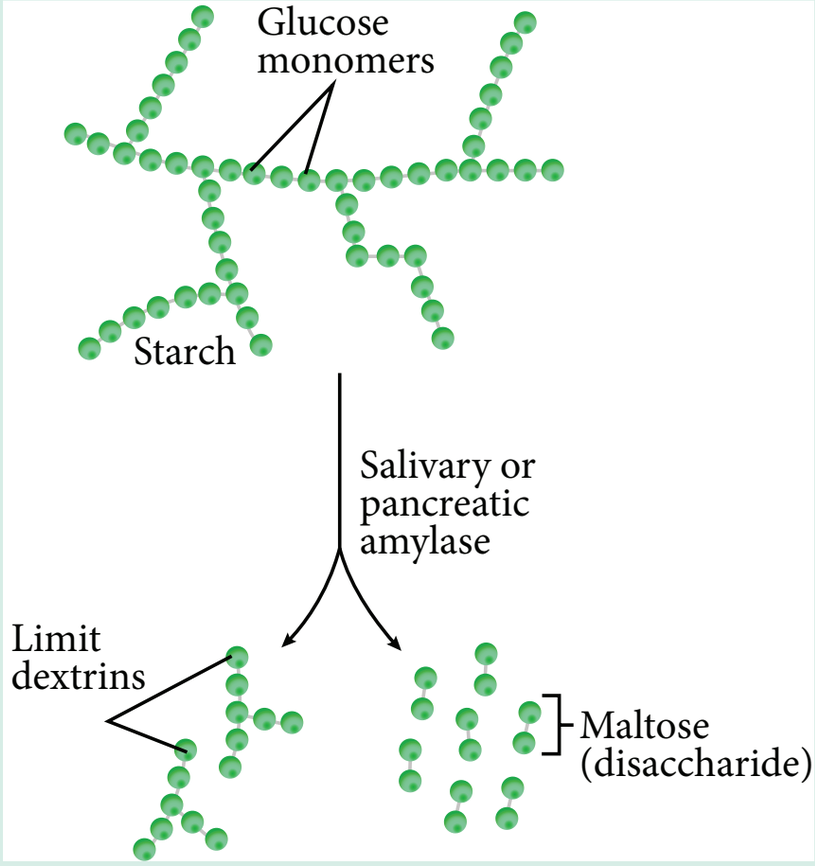

Figure 2.12 Action of amylases

Digestion in duodenum

The chyme on reaching the duodenum, gets mixed up with the bile juice and pancreatic juice that contains bicarbonate and gets neutralized. The pancreatic amylase, which is similar to the salivary amylase in enzymatic action, with optimum pH 6.9 to 7.1, acts upon the polysaccharides and breaks down the starch and glycogen to disaccharides like maltose and isomaltose (which contains α1→6 linkage)

Digestion in small intestine

Pancreatic amylase also requires chloride ion for its action and acts on the complex and partially digested carbohydrates. Pancreatic amylase completes the digestion of polysaccharides in the intestine because of

- its ability to break the interior linkages of complex carbohydrates
- the longer residual time of food in the duodenum and intestine

Moreover, pancreas secrete ten times more of pancreatic amylase into the intestinal lumen than that required to digest the carbohydrates in the diet.

Disaccharidases

There are four important disaccharidases in the human intestinal brush border membrane to hydrolyse the disaccharides (Table 2.1). They are:

Sucrase: Sucrase which acts upon sucrose to cleave it into equimolar quantities of glucose and fructose has an optimum pH of 6.

Isomaltase: Isomaltase co-elutes with Sucrase on purification and therefore Sucrase/ isomaltase is a complex protein. Isomaltase acts on the α1→6 linkage and cleaves it into two molecules of glucose.

$$\textit{Isomall}\text{tose} \xrightarrow{\text{Isomaltase}} \text{Glucose+ Glucose}$$

Lactase: The β 1→4 glycosidic linkage of lactose is acted upon by Lactase and cleaves it into equimolar quantities of glucose and galactose. The optimum pH for *sucrase* is the optimal pH for *lactase* which is around 6, but it can function in an acidic environment ranging between a pH of 2 to 7.

$$\text{lactose} \xrightarrow{\text{Lactase}} \text{Glucose + Galactose}$$

Maltase: Maltose, the end product of polysaccharide digestion by amylases is cleaved into two glucose molecules by cleavage of α1→4 linkage by maltase to liberate glucose into the lumen. It also has an optimum pH around 6 (Figure 2.13).

$$\textit{Mal}\text{tose} \xrightarrow{\text{Maltase}} \text{Glucose+ Glucose}$$

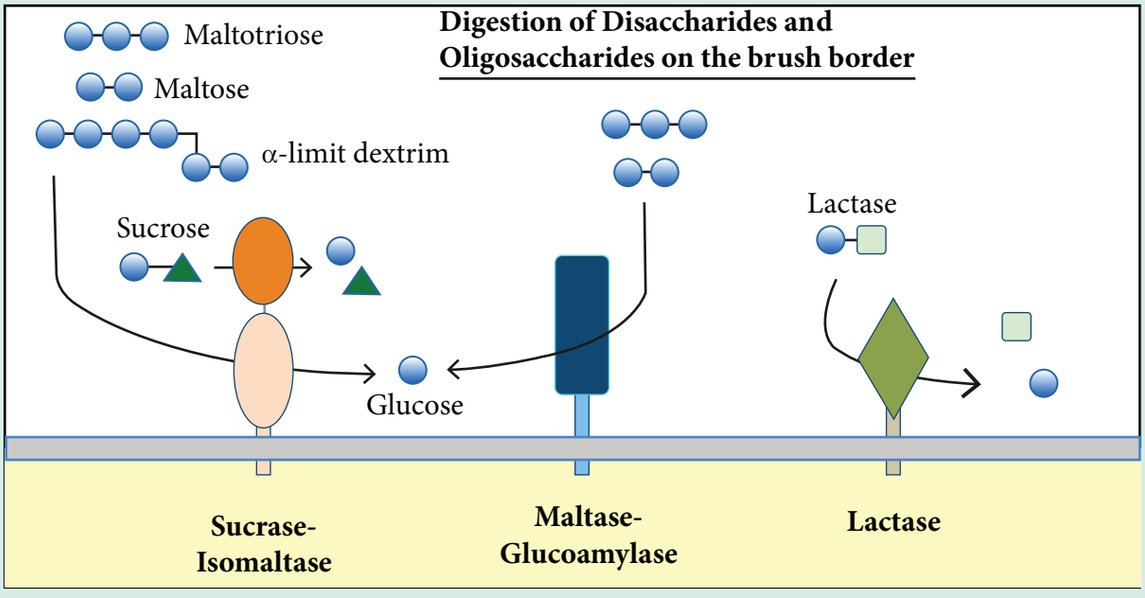

Figure 2.13 Digestion of disaccharides on the brush border

Cerebrosidases : Cerebrosidases are a group of minor enzymes that hydrolyse the gluco and galactocerebrosides present in glycolipids.

Table 2.1 Disaccharidases and oligosaccharidases of the intestinal brush border

Enzyme	Cleavage Specificity
Maltase	Maltose, maltotriose; also acts as exoglycosidase on $\alpha(1 \rightarrow 4)$ bonds at the non-reducing end of starch and starch – derived oligosaccharides
Lactase*	Lactose; also cellobiose#
Cerebrosidase*	Gluco – and galactocerebroside
Sucrase	Sucrose; also maltose and maltotriose
Isomaltase	$\alpha(1 \rightarrow 6)$ bonds in isomaltose and α –limit dextrins
Trehalase	• Trehalose

* The lactase and cerebrosidase activities reside in two different globular domains of the same polypeptide.
# Cellobiose is a disaccharide of two glucose residues in $\beta(1 \rightarrow 4)$ glycosidic linkage.
• Trehalose is a disaccharide with a structure of ∝-D-glucopyranosy l -∝ -D-glucopyranoside (in 1,1 glycosidic linkage); common only in mushrooms.

Absorption of carbohydrates

- Only monosaccharides can be absorbed by the villi. However, few disaccharides are taken up by pinocytosis and later hydrolysed to monosaccharides.
- The principal monosaccharides that are present in the diet or formed as end products of digestion are glucose (80%), galactose, fructose and pentoses like ribose, xylulose and arabinose.
- The absorption of monosaccharides mainly takes place in the duodenum and the upper part of the small intestine.
- The order of absorption of important monosaccharides are :
  Galactose > Glucose > Fructose > Mannose > Pentoses
- Monosaccharides are absorbed by both passive diffusion as well as active transport. Different monosaccharides are absorbed in different ways. Glucose and Galactose are the prime monosaccharides that are absorbed actively, while fructose and pentoses are absorbed passively by facilitated diffusion.

Facilitated diffusion

Initially, when the glucose concentration in the digested food is very high, facilitated diffusion plays a major role in absorption. Since glucose is a highly polar molecule, glucose is absorbed passively by a transporter, GLUT2 (Glucose Transporter 2). Fructose is absorbed by GLUT5 transporter in a passive manner.

Active Transport

Active transport is mediated by a protein called as SGLT1 (Sodium Glucose Transporter 1) in the luminal side and GLUT 2 on the basolateral side (Figure 2.14). The events involved in the transport are:

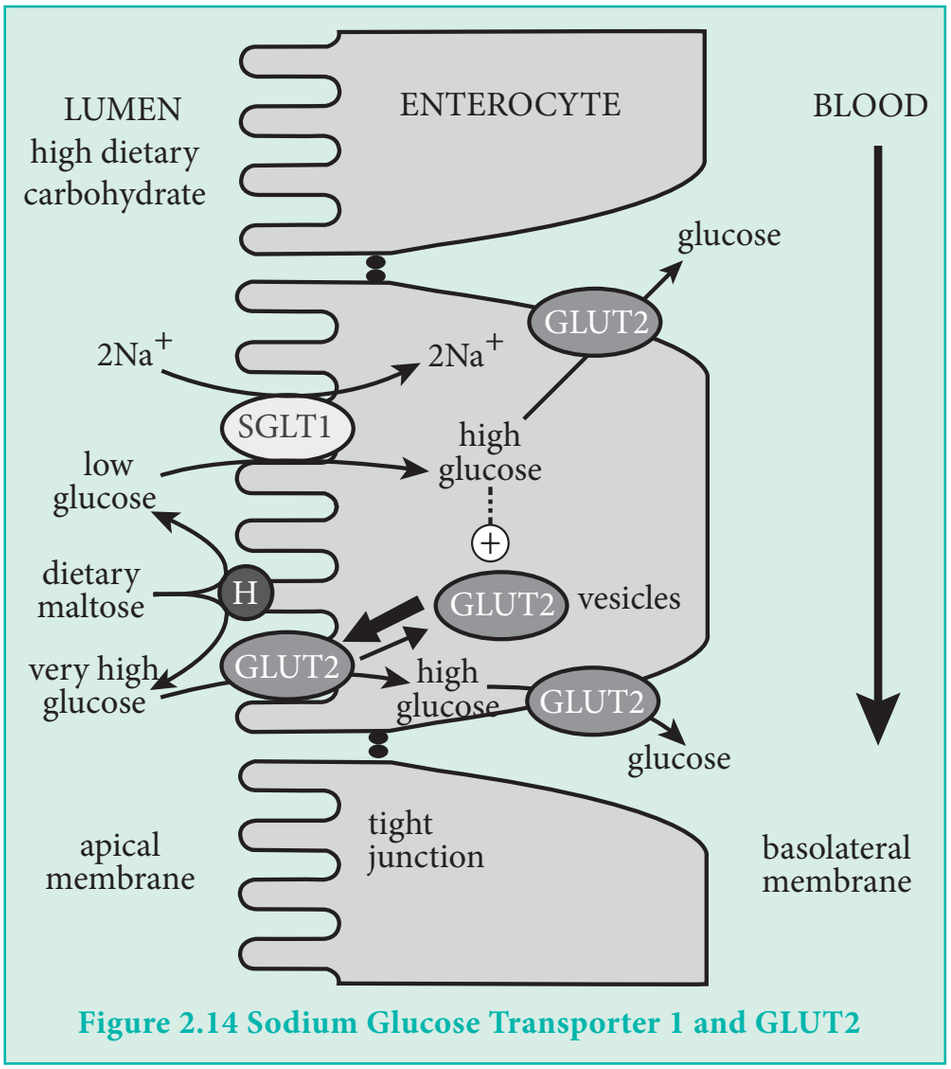

Figure 2.14 Sodium Glucose Transporter 1 and GLUT2

1. A high concentration of K^+ and low concentration of Na^+ is maintained inside the intestinal brush border membrane enterocytes with the help of Na^+-K^+ ATPases, which utilize ATP for its pumping action.
2. SGLT1 is a symporter, which can bind Na^+ and glucose from the gut lumen. With the energy obtained by downhill transport of sodium, glucose is transported in a uphill manner, ie.against the concentration gradient, resulting in high concentrations of glucose inside the enterocyte. The steps involved in this transport are :

- The transporter is initially facing the lumen and oriented such that it can bind sodium and not glucose.
- After the binding of sodium, a conformational change is induced that opens the glucose-binding pocket
- Glucose binding induces a conformational change so that the transporter now faces the cytosol.
- Sodium and glucose dissociate into the cytoplasm
- After delivering the cargo, the transporter reorients back to the luminal side.

3. GLUT2 on the basolateral membrane, by facilitated diffusion, transports the glucose from the enterocytes into the blood circulation.

- Glucose and galactose are absorbed by the enterocyte by cotransport with sodium using the same transporter.
- Thus, the sodium dependent SGLT1 and sodium independent GLUT2 play major role in absorption of glucose.

Carbohydrates that are not digested and absorbed in the digestive tract so far will reach the large intestine where they are broken down by intestinal bacteria. Indigestible fibers and other carbohydrates are excreted with feces.

Factors affecting absorption

- Absorption is high with intact mucosa. Any damage to the intestinal mucosa in the form of infections and congenital disorders reduce the rate of absorption.
- Hormones such as thyroid hormones, pituitary hormones and mineralocorticoids increase the absorption, while insulin has no effect on absorption of carbohydrates.
- Vitamin B6, B12 and pantothenic acid deficiencies decrease the absorption of monosaccharides.
- Advancing age decreases the absorption.
- Inhibitors of carbohydrate digestive enzymes and SGLT1 inhibitors like phlorizin decrease the absorption.

2.2.2.2 Digestion and absorption of proteins

Proteins have to be broken down to it's constituent amino acids for absorption into the gut. The digestion and absorption of proteins is very effective in a healthy human. The major contribution of the protein is from diets rich in protein like milk, meat, egg, pulses, soybean, nuts, etc. and minor contribution is from the proteins present in the digestive juices and worn out intestinal epithelial cells that are shed into the lumen.

Digestion in mouth

Proteolytic enzymes are not present in saliva and therefore, no digestion of proteins takes place in the mouth. However, chewing the protein-rich foods especially the harder ones like meat increases the surface area of the food particles and thereby allows digestion to occur more quickly.

Digestion in stomach

In the stomach the proteins are converted into: Protein → Metaprotein → Proteone → Peptone → Peptide

HCl: The partially denatured proteins (denaturation occurring due to cooking process) or the non-denatured proteins present in the raw foods are further denatured by the highly acidic environment present in the stomach, which unveils the sites for action of the peptidases. HCl also initiates the conversion of inactive pepsinogen to active enzyme pepsin.

Pepsin: Pepsin is secreted in the form of inactive pepsinogen, a protein with a molecular weight of 42 kD. Pepsinogen is cleaved into active pepsin of 34 kD, initially by the acidic medium, and then autocatalytically.

Pepsin

- is an endopeptidase (an enzyme that acts in the interior of the protein)
- has a broad range of specificity
- acts on the peptide linkages contributed by the carboxyl group of aromatic amino acids / acidic amino acids, to a lesser extent.
- breaks down proteins to peptones.
- works optimally at pH 2.0. Hence, any factor that reduces acidity of the stomach like achlorhydria or antacid intake that neutralizes stomach acid or proton pump inhibitors reduces the activity of pepsin.

Rennin: Rennin, also called as chymosin is an enzyme that is responsible for curdling of milk and is present only in infants and children. It is responsible for conversion of milk protein into Paracaseinate.

Gelatinase: Gelatinase helps in the digestion of gelatin and type IV and V collagen, which are proteoglycans present in meat. Gastricsin is another enzyme present in the gastric juice that digests proteins.

Digestion in duodenum

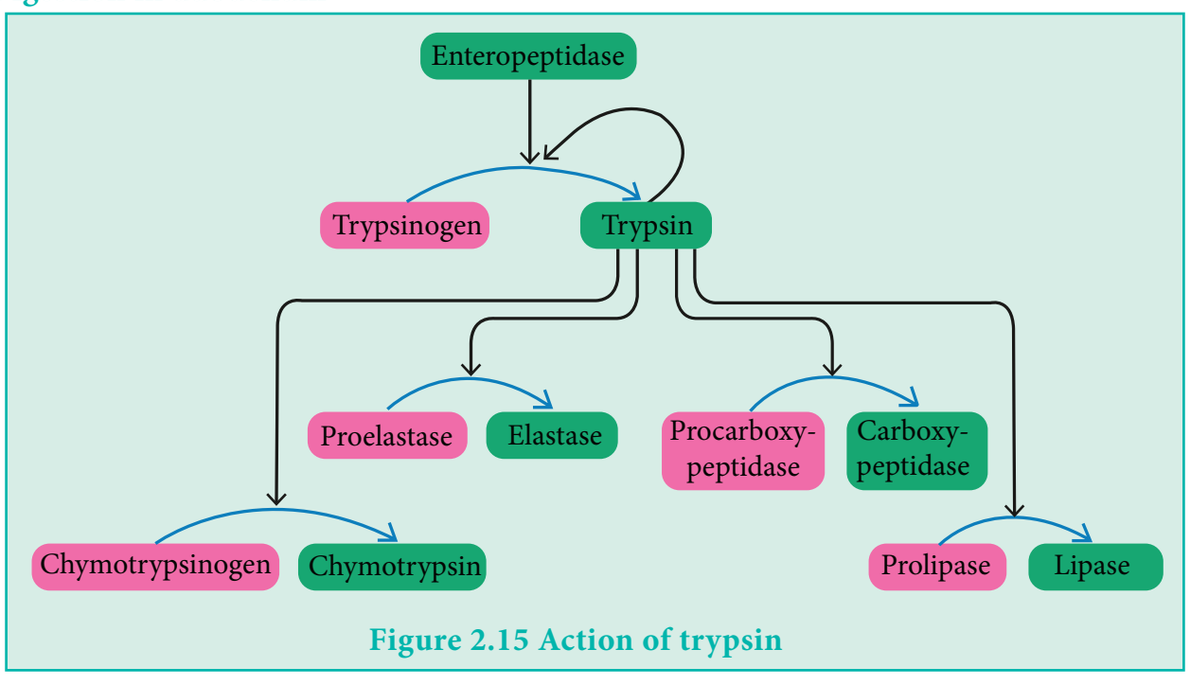

Figure 2.15 Action of trypsin

Enteropeptidase: Enteropeptidase or Enterokinase is a transmembrane protein expressed by the epithelial cells of the jejunum and the duodenum. It has a substrate specificity of Lys-Lys or Arg-Lys and is involved in activation of trypsin.

Human pancreatic juice contains zymogens of proteolytic enzymes like trypsinogen, chymotrypsinogen, procarboxypeptidases A and B, pro-elastase along with trypsin inhibitor.

Trypsin: Trypsinogen in the pancreatic juice is activated to trypsin by enterokinase and subsequently stabilized by calcium. Trypsin also converts chymotrypsinogen to chymotrypsin, proelastase to elastase and procarboxypeptidases to carboxypeptidases (Figure 2.15). It acts upon the peptide linkages contributed by carboxyl group of Lys and Arg (Figure 2.16). It is ineffective in hydrolyzing the peptide linkages formed by proline. It has an optimum pH of 8-9. Trypsin-inhibitor present in the pancreatic juice prevents the action of trypsin in small intestine and pancreas.

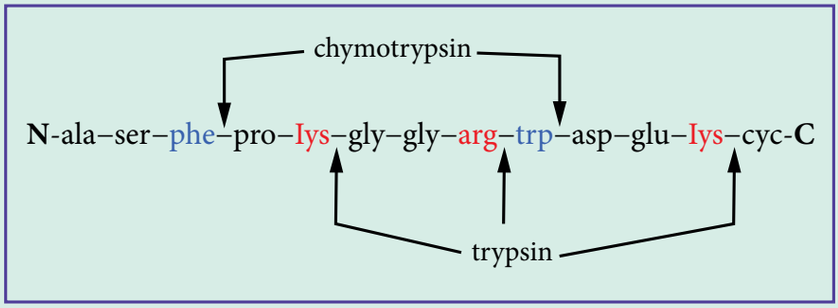

Figure 2.16 Site of action of chymotrypsin and trypsin

Chymotrypsin

Chymotrypsin is also an endopeptidase secreted in the form of its zymogen, chymotrypsinogen, by the pancreas. Its optimum pH is around 8.0. Chymotrypsin catalyzes the hydrolysis of peptide bonds involving the carboxyl group of hydrophobic amino acids like phenylalanine, and tryptophan (Figure 2.17).

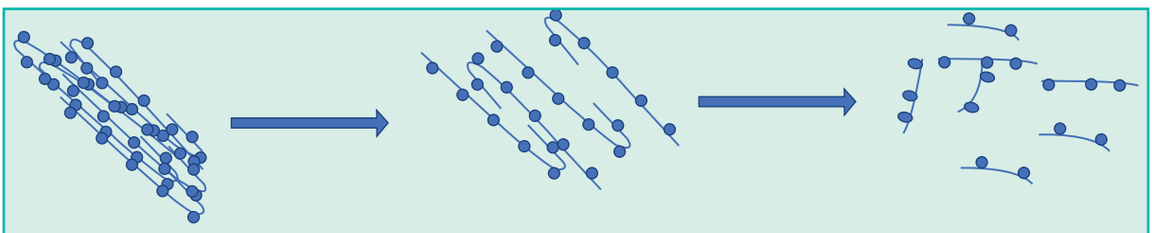

Figure 2.17 Hydrolysis of peptide bond by chymotrypsin

Carboxypeptidases

Carboxypeptidases A and B are zinc containing metallo-enzymes that cleave the peptide bond at the carboxyl or C-terminal end of peptides with a greater preference for aromatic and branched chain amino acids by Carboxypeptidase A and for basic amino acids by Carboxypeptidase B. Elastases and Gelatinases also contribute to the digestion of the proteins. Many dipeptides and tripeptides along with free amino acids are formed in the lumen by the combined action of pancreatic peptidases.

Digestion in small intestine

Digestion at the Brush Border

The di and tripeptides formed by the pancreatic enzymes are finally digested by the amino-peptidases and di and tripeptidases present on the luminal side of the intestinal brush border membrane. Leucine aminopeptidase that releases the N-terminal leucine residue and Proline amino peptidase specific for proline at the end of polypeptides, along with the other brush border membrane enzymes, will bring about the complete digestion of proteins.

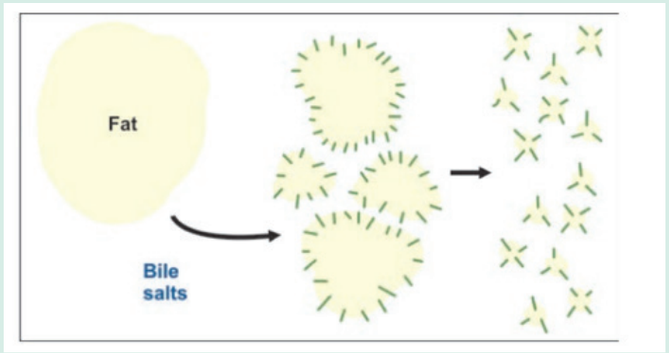

Figure 2.18 Digestion in small intestine

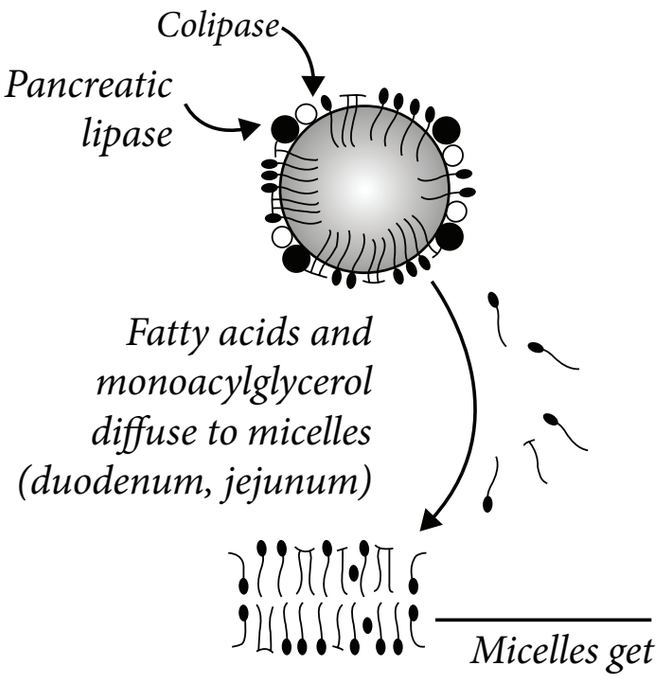

Figure 2.19 Action of pancreatic lipase

Absorption of amino acids

1. At physiologic temperature, the amino acids and to some extent, the di and tripeptides are absorbed actively by sodium dependent transporters present in the villi. D amino acids produced by bacteria are absorbed passively, while L amino acids are absorbed actively.

At least five brush border transporters exist - Neutral amino acids (uncharged aliphatic and aromatic), basic amino acids (Lys, Arg, Cys, Cys-Cys), acidic amino acids (Asp, Glu), imino acids (Pro, Hydroxyproline) and di- and tripeptides.

Meister Cycle (Gamma Glutamyl Cycle)

Absorption of neutral amino acids is facilitated by the gamma glutamyl cycle. Glutathione (GSH-gamma glutamyl cysteinyl glycine), a tripeptide is involved in this cycle (Figure 2.18) The steps involved in the reaction are:

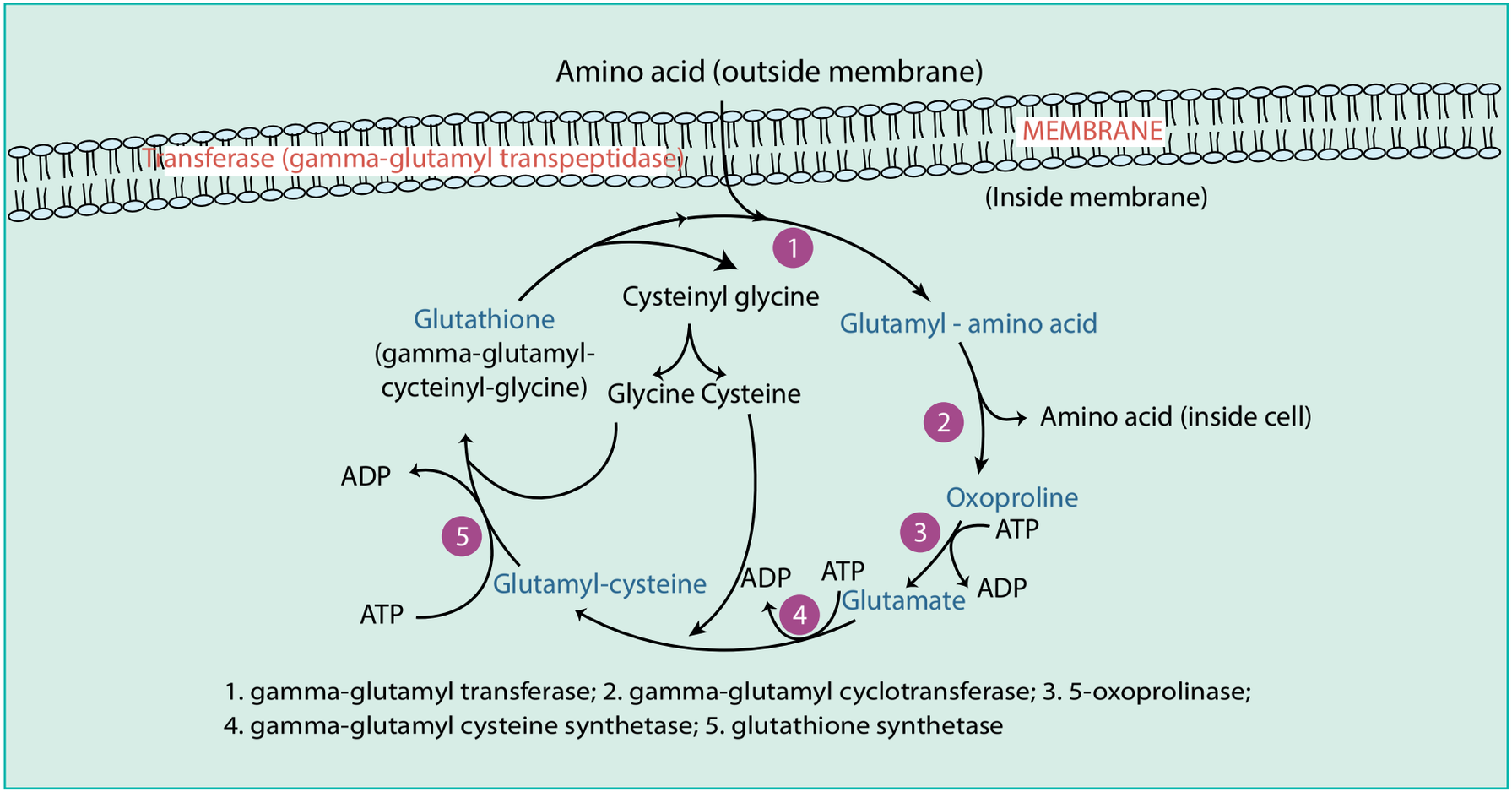

Figure 2.20 Gamma gutamyl cycle (Meister cycle)

1. Gamma glutamyl transferase catalyses the reaction of glutathione (inside the cell) with the neutral amino acid (in the lumen) to form gamma glutamyl amino acid and cysteinyl glycine in the cytoplasm of the brush border membrane cell.
2. The glutamyl amino acid is then cleaved to give the free amino acid and oxo-proline inside the cytosol. The net result is the transfer of an amino acid across the membrane.
3. Oxo-proline is converted to glutamate. Cysteinyl glycine is cleaved into cysteine and glycine.
4. Glutathione is regenerated from the three amino acids.
5. The transport of one molecule of any amino acid along with regeneration of GSH requires 3 molecules of ATP.

After release into the cytosol, the amino acids are released into the blood stream and are transported to the liver by the entero-hepatic circulation.

Some oligopeptides, larger peptides or proteins can cross the brush border membrane by a process called transcytosis. This particularly happens in infants whereby the imunoglobulins in mother's milk can be transferred to the child. The enterocytes located in the Crypts of Lieberkuhn are generally involved in this process. However, this mechanism operates only to a lesser extent in adults.

Factors affecting absorption

- Glutathione is required for absorption of amino acids and its regeneration should be effective for good absorption.
- Amino acids transported by the same transporter compete with each other for absorption. Therefore, high concentrations of one particular amino acid will have an influence on the other.
- Salicylates decrease the intestinal absorption of amino acids, particularly that of tryptophan
- Dinitrophenol and indomethacin also inhibit the absorption of amino acids.

2.2.2.3 Digestion and absorption of lipids

The major difficulty in digestion of fats is that all the enzymes that digest fats are hydrophilic in nature, while fats are insoluble in water. This problem is circumvented by a process called emulsification. During emulsification, the fat is dispersed into smaller droplets, and their surface tension is reduced; and surface area is increased.

This process is facilitated by :

- the Detergent action of the Bile salts.
- Mechanical mixing i.e. chewing and peristalsis, where the surface area is increased.
- Presence of Phospholipids for micelle formation.

Digestion in mouth

The digestion of fat starts in the mouth by the action of Lingual lipase, which has an optimum pH between 4.5 and 5.4. It acts on short chain triglycerides that are typically present in milk, butter and ghee. The action of lingual lipase is more important for new born infants and children (Table 2.2).

Table 2.2 Various lipases and the site of action

Lipase	Site of action	Preferred substrate	Products (s)
Lingual/acid - stable lipase	Mouth, stomach	TAGs with medium / short chain FAs	FFA+DAG
Pancreatic lipase + co-lipase	Small intestine	TAGs with long - chain FAs	2 FFA+MAG
Intestinal lipase with bile acids	Small intestine	TAGs with medium chain FAs	3 FFA+ glycerol
Phospho-lipase A_2 + bile acids	Small intestine	PLs with unsat. FA on position 2	Unsat FFA + lysolecithin

Digestion in stomach

Gastric lipase with an optimum pH of 4 -5 is secreted into the stomach by the chief cells. This also acts on breaking down fat. However, the gastric lipase digests the fat to a minimal extent because of the prevailing high acidic pH and absence of emulsification. But, unlike pepsin, it is not dependent on an acid pH, and therefore remains active in the small intestine, and constitutes about 30% of the total lipase secreted over a 3-hour period. Gastric lipase is not essential in fat digestion, but resulting fatty acids and peptides formed by pepsin help to coordinate gastric emptying and pancreatic secretion.

Satiety: Fats have a very high satiety value (fullness of the stomach), by inhibiting the gastric motility (movement of the chyme from stomach to duodenum). This effect of dietary lipids is mediated by the hormone enterogastrone.

Digestion in duodenum

The bile (pH 7.7) entering the duodenum serves to neutralize the acid chyme from the stomach and provides a pH favorable for the action of pancreatic enzymes and small intestine (Figure 2.19).

The hydrophobic regions of bile salts intercalate into the lipid aggregates, such that the hydrophilic domains face the surface resulting in the breakdown of larger aggregates into small droplets. This increases the surface area for action of lipase.

The lipolytic enzymes present in the pancreatic secretions are:

1. Pancreatic lipase with Co-lipase

Pancreatic lipase can hydrolyse the ester linkages at the 1st and 3rd carbon atoms of glycerol forming 2-monoacylglycerol. The fatty acid in the second position is shifted to 1st position by an isomerase, the resulting 1 monoacylglycerol is then hydrolysed by the lipase to form glycerol and fatty acid. Co-lipase is a protein that binds to the triacylglycerol molecules at the interface, and this is essential for the action of lipase. The co-lipase is also secreted by the pancreas as zymogen, which is activated by trypsin (Figure 2.20).

Cholesterol esters are hydrolysed to free cholesterol and fatty acid by cholesterol esterase.

The phospholipid phosphatidyl choline is the second most abundant lipid in the intestinal lumen, after triglyceride. Phosphatidyl choline and cholesterol enter the gut via bile and it contributes about three fourths of the gut lipid content. Lingual and gastric lipases are ineffective in hydrolyzing phosphatidyl choline. Pancreatic phospholipase A2 (PLA2) and other lipases secreted act upon the phospholipids. The action of phospholipase A2 produces lysophospholipid and a fatty acid.

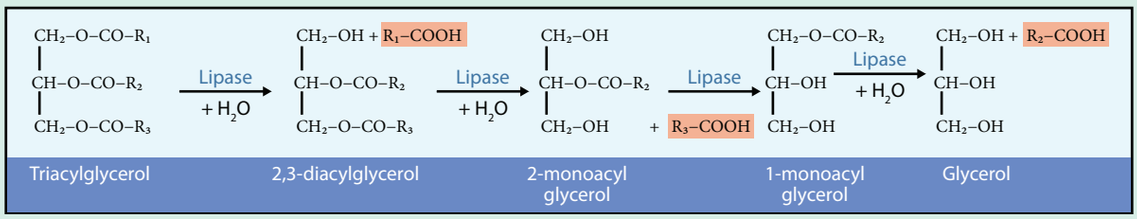

Figure 2.21 Complete hydrolysis of triglycerides

Absorption of lipids

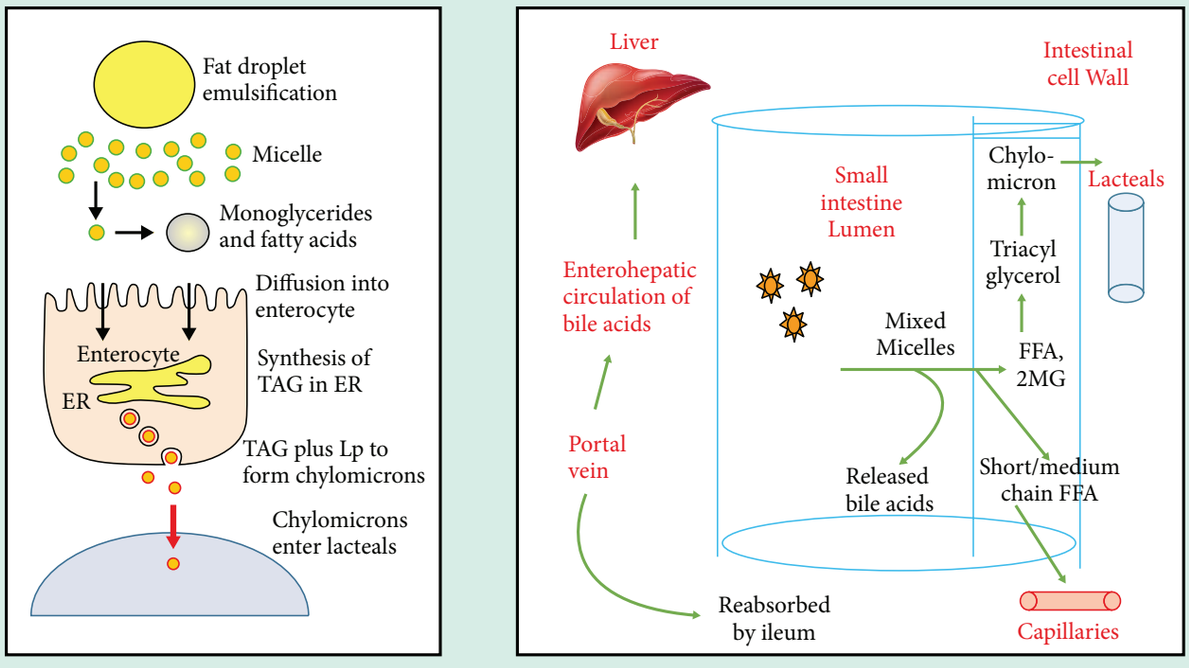

Figure 2.22 Absorption of fat as a chylomicron

Fats are absorbed by passive diffusion mainly in the proximal jejunum (Figure 2.22).

"Mixed micelle" formation: The fatty acids, mono and diglycerides and cholesterol, the enzymatic hydrolytic products of lipid digestion along with bile salts, together, form water-soluble molecular aggregates called as mixed "micelles of size 0.1 to 0.5 μm in diameter and are absorbed mainly from duodenum and jejunum. Micelles can also accommodate some fat soluble substances like carotene and vitamins.

- Micellar complexes get destabilized when they come near the brush border of enterocytes and liberates its contents.
- This is followed by passive diffusion of the digested fats across the luminal cell membrane.
- Only few fatty acids like oleic acid and linoleic acid enter the enterocyte by facilitated diffusion.
- In the endoplasmic reticulum of the enterocyte, triacylglycerols and cholesterol esters are re-synthesized
- These resynthesized lipids, together with small quantities of phospholipids and apolipoprotein B-48, form the chylomicrons.
- The chylomicrons cross the other side of the cell membrane and enter into the lymphatic vessels.
- The triacylglycerols of short chain fatty acids and few short chain free fatty acids of chain length (6–10 carbon atoms) can directly enter the portal circulation.

Bile salts of the "micelles" are not absorbed initially, while they are reabsorbed in the lower part of the small intestine and returned to the liver through the portal vein for re-secretion into the bile. Such a process is known as entero-hepatic circulation of bile salts.

Factors affecting absorption

- Short chain fatty acids enter the circulation at a faster rate than the long chain fatty acids.
- Certain plant sterols like stigmasterol and sitosterol inhibit cholesterol absorption. Drugs like statins and certain phytochemicals present in green tea decrease the absorption of fats.
- Bile salts enhance the digestion and absorption of fats. Presence of unsaturated free fatty acids enhances the absorption of cholesterol.
- Certain conditions like obstructive jaundice/ pancreatic disorders reduce the digestion and absorption of fats.

2.2.2.4 Digestion and absorption of nucleic acids

Digestion in mouth: No digestion of nucleic acid has been reported in the mouth.

Digestion in stomach: Nucleoproteins are denaturated and nucleotides are released by the acidic environment in the stomach. Recent reports suggest that the cleavage of nucleic acids is also facilitated by pepsin in the stomach.

Digestion in duodenum and small intestine: The nucleic acids are hydrolysed to a mixture of nucleotides by ribonucleases and deoxyribonucleases (both endo and exonucleases) present in pancreatic and intestinal secretions. The nucleotides thus formed liberate the phosphate and form nucleosides by the action of nucleotidases. The resulting nucleosides are either absorbed or hydrolyzed by nucleosidases to purine and pyrimidine bases and pentose sugars (Figure 2.23). Some of the unabsorbed purines are metabolized by the intestinal bacteria.

Absorption of nucleic acids: The nucleic acid bases are absorbed by active transport in the small intestine and the pentoses are absorbed with the other sugars.

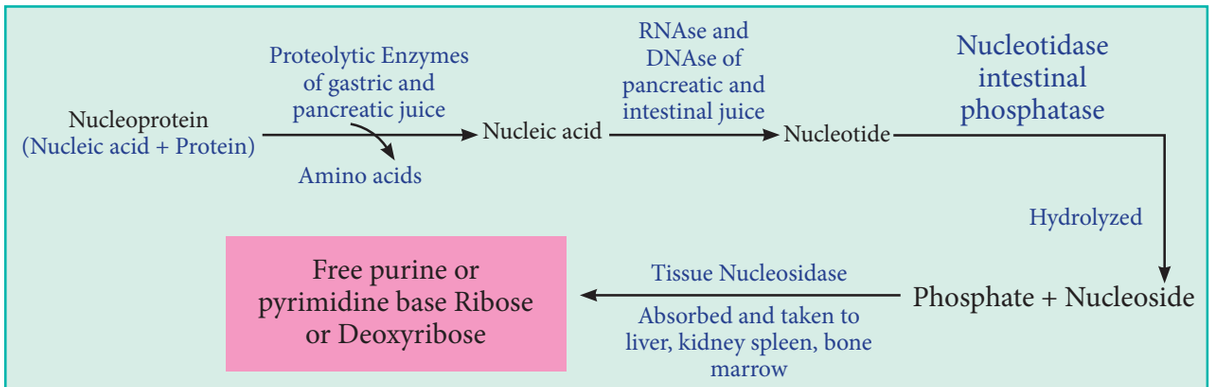

Figure 2.23 Digestion and absorption of nucleic acids

2.3. Gastrointestinal hormones

Table 2.3 Gastrointestinal hormone actions, Stimuli for secretion and site of secretion

Hormone	Stimuli for Secretion	Site of Secretion	Actions
Gastrin	Protein, Distention (Acid inhibits release)	G cells of the antrum, duodenum, and jejunum	Stimulates Gastric acid secretion Mucosal growth
Cholecystokinin	Protein Fat Acid	I cells of the duodenum, jejunum, and ileum	Stimulates Pancreatic enzyme secretion Pancreatic bicarbonate secretion Gallbladder contraction Growth of exocrine pancreas

Secretin	Acid Fat	S cells of the duodenum, jejunum, and ileum	Stimulates Pepsin secretion Pancreatic Bicarbonate secretion Biliary bicarbonate secretion Growth of exocrine pancreas Inhibits Gastric acid secretion
Gastric inhibitory peptide	Protein Fat Carbohydrate	K cells of the duodenum and jejunum	Stimulates Insulin release Inhibits Gastric acid secretion
Motilin	Fat Acid Nerve	M cells of the duodenum and jejunum	Stimulates Gastric motility Intestinal motility

There are five major hormones that help in digestion. They are

1. Gastrin is secreted by the G cells of the gastric pits and it stimulates the gastric glands to secrete pepsinogen and HCl. The stimulation for gastrin secretion is food in the stomach and it is inhibited by low pH. Gastrin also stimulates the growth of the mucosa.
2. The presence of acidic chyme in the duodenum stimulates the secretion of a hormone called Secretin, which in turn stimulates the pancreas to secrete a bicarbonate rich fluid. It also stimulates the secretion of bile in the liver.
3. Cholecystokinin (CCK) is another hormone in the duodenum that stimulates the release of digestive enzymes from the pancreas and also it is involved in the emptying of bile in the gallbladder. This hormone is secreted in response to the abundance of fat in chyme.
4. Enterogastrone and Gastric inhibitory peptide (GIP) released from the duodenum decreases the churning action of stomach and slows the emptying of the stomach. It also induces insulin secretion.
5. Motilin is a duodenal hormone that regulates gastrointestinal motility and stimulates the production of pepsin.
6. Others: Hepatocrinin stimulates bile formation with lesser bile salts. Enterocrinin is involved in the stimulation of the secretion of enzymes by the intestinal mucosa. Chymodenin stimulates the secretion of chymotrypsin from pancreas.

Appetite-Regulating Hormones

Ghrelin, a hormone which is released by the stomach targets the pituitary gland, signaling to eat. The action of Ghrelin is countered by PYY released by the small intestine signals that you have eaten enough and helps to suppress your appetite.

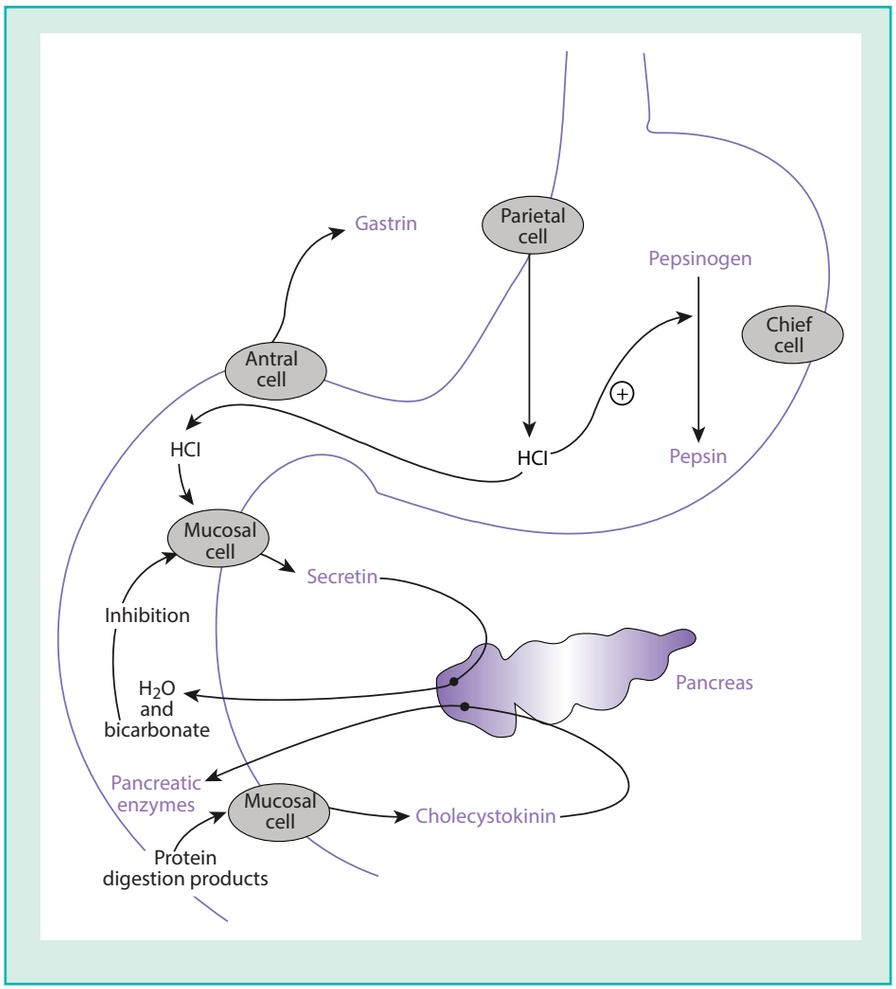

Figure 2.24. Release and action of intestinal hormones

Summary

- The digestive system is made up of a tubular gastro -intestinal tract (GI tract) and secretory organs.
- GI tract includes the oral cavity, pharynx, stomach, small intestine, large intestine, rectum and anus.
- The accessory digestive organs include the salivary glands, glands of the stomach, duodenal glands, liver, gall bladder and pancreas.
- The stomach, a J shaped enlargement is involved in mechanical grinding of food and secretes HCl, gastric lipase and pepsin.
- The small intestine constituted by duodenum, ileum and jejunum has a large surface area due to the presence of villi that aid in absorption of nutrients.
- The large intestine includes the cecum, colon, rectum and the anal canal. The

indigestible material is stored in the large intestine till it is eliminated via the anus.

- Salivary glands, gastric glands, liver, pancreas, glands of Lieberkuhn and Brunner's glands contribute to the secretions of the GI tract.
- The mechanical processes involved in digestion are ingestion, mastication, deglutition, peristalsis, mixing and propulsion and defecation.

Digestion and absorption of carbohydrates

- Digestion of carbohydrates takes place briefly in the mouth and largely in the intestine. Amylases present in saliva and pancreatic juice and disaccharidases present in the brush border membrane of the intestine such as sucrase, lactase, maltase and isomaltase are responsible for digestion of carbohydrates.
- Monosaccharides are absorbed by both passive diffusion as well as active transport. Glucose is absorbed passively by a transporter, GLUT2 (Glucose Transporter 2). Active transport is mediated by a protein called as SGLT1 (Sodium Glucose transporter 1) in the luminal side and GLUT2 on the baso-lateral side.

Digestion and absorption of proteins

- In the stomach, HCl denatures the proteins and exposes the sites for action of the peptidases.
- Pepsin, Rennin, Gelatinase and Gastricsin in the stomach, enteropeptidase, trypsin, chymotrypsin, carboxypeptidases, elastases and gelatinases along with amino peptidases and carboxy peptidases contribute to the digestion of proteins.
- D-amino acids produced by bacteria are absorbed passively, while L amino acids are absorbed actively. Few di and tripeptides are also absorbed.
- Gamma glutamyl cycle is involved in the absorption of neutral amino acids.

Digestion and absorption of fats

- Fat digestion is facilitated by the detergent action of the Bile salts and micelle formation. Pancreatic lipase, cholesterol esterase and phospholipase A2 are the enzymes that complete lipid digestion. Fat is responsible for the satiety value of foods.
- Fats are absorbed by passive diffusion mainly in the proximal jejunum.

Digestion and absorption of nucleic acids

- No digestion of nucleic acids has been reported in the stomach.
- The nucleic acids are hydrolyzed to a mixture of nucleotides by ribonucleases and deoxy ribonucleases (both endo and exonucleases) present in pancreatic and intestinal secretions.

Gastrointestinal hormones

- Gastrin, Cholecystokinin, enterogastrone, secretin and motilin are the five major hormones that help in digestion.

Mumps is a viral infection accompanied by inflammation and enlargement of the parotid glands presented with moderate fever, malaise (general discomfort), and extreme pain in the throat while swallowing. Swelling occurs on one or both sides of the face, just anterior to the ramus of the mandible. In about 30% of males past puberty, the testes may also become inflamed, however, sterility rarely occurs because of unilateral testicular involvement.

- Hemorrhoids are "cushions" of tissue filled with blood vessels, found at the end of the rectum, just inside the anus. Along with the anal sphincters, they close off the bowel, preventing stool from leaving the body. Enlarged hemorrhoids also known as "piles" can cause unpleasant symptoms.
- -Hartnup Disease is a genetic defect in the neutral amino acid transporter.

  -Symptoms: dermatitis due to tryptophan malabsorption ("niacin" flush)

  -Consequences: Not serious, di- and tripeptide absorption supply minimal amounts of dietary essential neutral amino acids.
- Immediately after birth, the small intestine of infants can absorb intact proteins and polypeptides by a process known as endocytosis or pinocytosis. This is very important for the transfer of maternal immunoglobulins to the child. Colostrum (the first secreted milk after child birth) is rich in immunoglobulins.
- Certain drugs are absorbed by the sublingual area of the oral cavity (i.e. the floor of the mouth). Glyceryl trinitrate, a potent coronary vasodilator used for the rapid symptomatic relief of angina is one of the best known drugs used regularly with great success.

Activity

1. Testing for salivary amylase

Take two test tubes labeled as A and B. Add 5 ml of 1% starch solution to both the tubes and add 2 ml of saliva to the test tube labeled as B. Incubate it for 15 minutes. Add iodine solution to both the tubes. Observe the color change. Discuss the reason for it in the laboratory.

Preparation of chart

- Prepare a chart with the involvement of various enzymes in digestion of carbohydrates, lipids and proteins.

Preparation of model

- Prepare a model for the human digestive system and explain.

Preparation of assignment

- Try to prepare an assignment with the diseases that are involved with mutations associated with digestion.

EVALUATION

I Multiple choice questions

1. The tongue is a muscular organ attached by the _____ to the floor of the buccal cavity.

   a. Frenulum b. Uvula

   c. Oropharynx d. nasopharynx

2. _____ teeth are responsible for holding and tearing food.

   a. Incisors canine b. Canine

   c. Premolar d. Molar

3. Thecodont means _____

   a. Embedded in socket of jaw bones b. Temporary set of teeth

   c. Permanent set of teeth d. same in structure

4. Dental formula for each half of the upper and lower jaw of an adult is

   a. 2323/2121 b. 2123/2123

   c. 2321/2321 d. 2322/2322

5. Which prevents the entry of food into the lung?

   a. Epigottis b. Tonsil

   c. Trachea d. Pharynx

6. _____ protect the intestine from the foreign microorganism.

   a. Microvilli b. The Peyer's patches

   c. Crypts of Lieberkuhn d. HCl

7. The length of the small intestine is about

   a. 9 feet b. 10 feet

   c. 12 feet d. 15 feet

8. _____ has a small projection called the vermiform appendix.

   a. Cecum b. Colon

   c. Rectum d. Anal canal

9. HCl is secreted by

   a. Chief cells b. G cells

   c. Parietal cells d. Mucosal cells

10. Which cells are phagocytic in nature?

a. Kupffer cells
b. Sinusoids
c. Mucosal cells
d. G-cells

11. _____is required for the absorption of aminoacid.

a. Glutathione
b. Lipid
c. Nucleic acid
d. Catecholamines

12. Gall stones are made up of___

a. Uric acid
b.Cholesterol
c. Calcium oxalate
d. Glycine

13. The organ that functions as both exocrine and endocrine

a. Stomach
b. Liver
c. Gall bladder
d. Pancreas

14. The tubular glands that lie between the villi of the inner surface of the small intestine

a. Glands of Lieberkuhn
b. Brunner's glands
c. Adrenal gland
d. Thyroid gland

15. _____ is an example for indigestible fiber present in the dietary carbohydrates

a. amylopectin
b. Glycogen
c. starch
d. Hemi-cellulose

16. _____ is responsible for the conversion of milk protein to Paracaseinate.

a. Gastricsin
b. Renin
c. Gelatinase
d. Promelanin

17. The inner mucosal layer of stomach fold into invagination called_____.

a. Rugae
b. Frenulum
c. Villi
d. Uvula

18. The duodenal gland are also called as_____.

a. Adrenal gland
b. Brunner's gland
c. Thyroid gland
d. Glands of Lieberkuhn

19. _____ in the saliva acts against the microbes.

a. Salivary amylase

b. Solutes

c. IgA

d. IgG

20. Which is a symporter?

a. GLUT 1

b. GLUT 2

c. SGLT 1

d. GLUT 4

21. Pick the add one out.

a. Pepsin

b. Renin

c. Trypsin

d. Gelatinase

22. Find the exopeptidase.

a. Trypsin

b. Chymotrypsin

c. Carboxy peptidase

d. Pepsin

23. Cholecystokinin is a hormone secreted by the.

a. G cells of gastric pits

b. S cells of duodenum

c. I cells of duodenum

d. C cells of duodenum

24. _____ is a hormone responsible for signaling to eat.

a. Ghrelin

b. PYY

c. Enterogastrone

d. Motilin

25. Gall bladder is a _____ shaped sac

a. Pear
b. Globular
c. Oval
d. Tubular

II Give short answer for the following

1) What is digestion? Why it is needed?
2) Mention the different types of salivary glands along with its location.
3) Give the composition and functions of saliva.
4) Discuss about the different secretory cells of the gastric glands.
5) What do you meant by motility?
6) Why is pancreatic amylase superior to salivary amylase in digesting carbohydrates?
7) Give the specificity of pepsin and enteropeptidase.
8) What do you meant by transcytosis?
9) What are chylomicrons?
10) How are mixed micelles formed?
11) Define the term satiety.
12) Write shortly on gastrin.
13) Comment on digestion of fats in mouth.
14) List the enzymes that digest protein in stomach.
15) Brief a note on the specificity and optimum pH of trypsin.

III Give short answer for the following

1) What is mastication? How is food masticated in the mouth?
2) What are disaccharidases? List the disaccharidases in the small intestine.
3) Brief a note on the anatomy of gall bladder.
4) Write any 3 functions of mucous present in duodenal secretions.
5) What is facilitated diffusion?
6) Enumerate the duodenal enzymes that act upon proteins.
7) Write any 3 factors that affect absorption of amino acids.
8) Bring out the role of bile in digestion of fats.
9) Is there any role for mouth in digestion of protein?
10) Comment on the impact of age on digestion of macromolecules present in milk.

IV Answer the following

1) Discuss the anatomy of mouth.

2) Outline the structure and function of oesophagus.

3) List the functions of stomach.

4) Draw and explain the structure of villi.

5) Discuss about the different secretory cells of the gastric glands.

6) Bring out the role of large intestine in digestion.

7) Enumerate the functions of the liver.

8) Explain the mechanical process involved in digestion.

9) Detail on the secretory glands of the digestive system.

10) With a neat diagram, explain the anatomy of the gastro intestinal tract.

11) Discuss about the digestion of carbohydrates in mouth.

12) Outline the digestion of carbohydrates.

13) Illustrate the active transport of glucose across the intestinal brush border membrane.

14) List down the factors that affect the absorption of carbohydrates.

15) Tabulate the enzymes that are involved in digestion of proteins.

16) Write in detail about the absorption of proteins by Gamma Glutamyl Cycle and the factors affecting the absorption.

17) Brief a note on digestion on proteins in stomach.

18) Write the action of gastric lipase on lipids.

V Analyze the table and match the following:

Organ	Enzyme	Macromolecules
Saliva	Pancreatic amylase	Di/Tripeptide
Pancreas	Gelatinase	Starch
Intestine	Salivary amylase	Type IV Collagen
Stomach	Trypsin	Dextrin
Duodenum	Leucine amino peptidase	Chymotrypsinogen

Answer Table:

Organ	Enzyme	Macromolecules
Saliva	Salivary amylase	Starch
Pancreas	Pancreatic amylase	Dextrin
Intestine	Leucine amino peptidase	Di/Tripeptide
Stomach	Gelatinase	Type IV Collagen
Duodenum	Trypsin	Chymotrypsinogen

II. Assertion and Reason:

Direction: In each of the following questions a statement of assertion (A) is given and a corresponding statement of reason (R) is given just below it. Mark the correct statement as.

a) If both A and R are true and R is correct explanation of A

b) If both A and R are true but R is not the correct explanation of A

c) If A is true but R is false

d) If both A and R are false.

1. **Assertion** : Phlorizin decreases the absorption of carbohydrates.
   Reason : Phlorizin is an inhibitor of GLUT 2.
2. **Assertion** : Liver is responsible for cholesterol homeostasis.
   Reason : Liver converts some amount of cholesterol to bile salts.
3. **Assertion** : The secretion of Brunner's gland inactivates the intestinal enzymes.
   Reason : The G-cells of Brunner's gland secrete HCl.
4. **Assertion** : Rennin helps in the digestion of milk.
   Reason : Rennin is present only in Infants and children.
5. **Assertion** : Digestion of fats starts in the mouth.
   Reason : Lingual lipase can act on long chain fatty acid containing Triglycerides.

Answer:

1. c) A is true but R is false
2. a) Both A and R are true and R is correct explanation of A
3. d) Both A and R are false
4. b) Both A and R are true but R is the correct explanation of A
5. c) A is true but R is false

CONCEPT MAP

Digestion