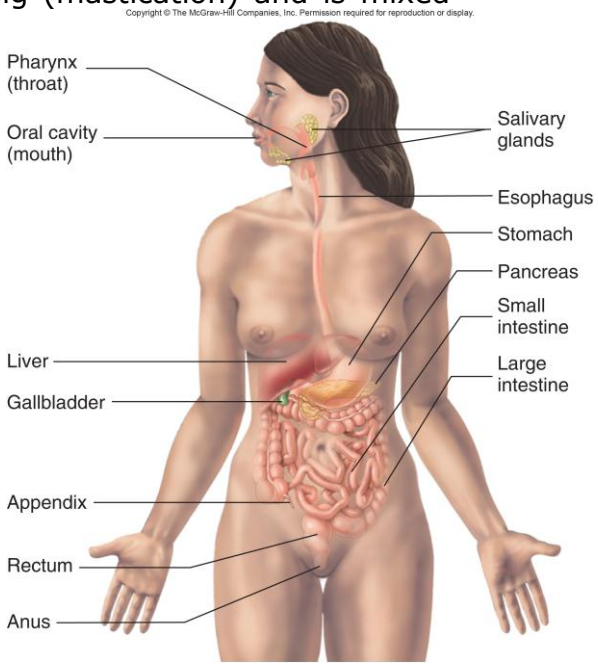
Unit 3 Lecture 9

THE DIGESTIVE SYSTEM

The main function of the digestive system is to break down organic nutrients so that they can be absorbed into the body. The organic nutrients that are absorbed can be carbohydrates, proteins, fats, water, vitamins, and minerals. The basic functions of the organs of the digestive system are

- In the mouth, food is broken up by chewing (mastication) and is mixed with saliva which is produced in the salivary glands and moistens and begins digesting some food particles.
- The food passes through the esophagus is a straight muscular tube that connects the mouth and pharynx to the stomach.
- The stomach stores, mixes, and digests some food and delivers food to the small intestine.
- The liver has many functions, but for digestion it produces and secretes bile.
- The gallbladder stores and concentrates bile.
- The pancreas secretes digestive enzymes, hormones, and bicarbonate.
- The small intestine allows digestion and absorption of most food particles.
- The large intestine stores and concentrates undigested material and absorbs salt and water.
- The rectum is the site where the defecation reflex is triggered.



Overall Digestive Processes

The basic processes of the digestive system include the following:

1. Secretion involves the release of digestive fluids into the lumen of the digestive tract. This fluid may include about 9 liters/day of water, mucus, acid, electrolytes, enzymes, bile salts, and digestive enzymes.
2. Digestion is the process whereby food is broken down into smaller molecules by the digestive enzymes so they can be taken up by the body.
3. Absorption is the process whereby these small molecules are taken up by the circulatory system and are distributed throughout the body. This can be an active or passive process.
4. Motility is the movement of the "food" through the digestive system by the contraction of smooth muscle that lines the walls of the tract.
5. Excretion is the removal of the unwanted waste products from the body after almost all of the wanted material is absorbed.

Layers of the GI Tract

The layers of the GI tract are the mucosa, submucosa, muscular, and serosa. The mucosa is the inner lining of the lumen and a mucous membrane. It has three layers: the epithelium (a protective layer of cells, the inner lining of GI tract), the lamina propria which contains blood, lymph nodes and vessels, and the muscular layer (a thin layer of smooth muscle). The submucosa layer contains blood vessels and connective tissue. A portion of the submucosal plexus controls secretions of GI tract. The muscularis layer contains some skeletal muscle at each end of GI tract but is mostly smooth muscle. There are two sheets of muscle fibers (circular and longitudinal). Involuntary contractions of the smooth musculature help breakdown food, mix it with digestive juices and propel (peristalsis) the food along. The myenteric plexus (of Auerbach) controls GI tract mobility. The serosa, outermost layer, is also called the visceral peritoneum (below the diaphragm).

Peritoneum
The peritoneum is the largest serous membrane in the body. The parietal peritoneum lines the wall of the abdominal cavity whereas the visceral peritoneum covers some of the internal organs. The space between is the peritoneal cavity and it contains peritoneal fluid (ascites). The retroperitoneal organs are covered by peritoneum on the anterior surface only. The mesentery binds small intestine to the posterior abdominal wall. The mesocolon binds large intestine to posterior abdominal wall and carries blood and lymph vessels to the intestine. The falciform ligament attaches the liver to anterior wall and diaphragm. The lesser omentum suspends the stomach and duodenum from the liver and the greater omentum covers the transverse colon and coils of the small intestine. It also contains large quantities of fatty tissue and many lymph nodes.

Mouth (Oral or Buccal cavity)

The structure of the mouth consists of the cheeks (muscles on the side of the mouth), the lips (labia), a vermilion (transition zone between lips and mouth), a labial frenulum (midline fold that attaches inner surface of lips to gum), the vestibule (space between lips/cheeks and gums/teeth), hard palate/soft palate (roof of mouth), the uvula (muscular process hanging from soft palate), and tonsils (palatine and lingual). The tongue is an accessory structure of digestive system. The musculature is skeletal for voluntary action. Extrinsic muscles originate outside of the tongue and insert into the tongue. Their function is side-to-side movement of food in mouth. Intrinsic muscles originate inside tongue and they alter the shape and size of the tongue to aid in speech and swallowing. A lingual frenulum limits movement of tongue to the posterior. Teeth are accessory structures located in the alveolar process of the jaw bones and are covered by the gums. The sockets are lined by periodontal ligaments which anchor teeth into position and serves as a shock absorber during chewing. The tooth consists of a crown, neck and root. Dentin makes up most of the tooth and is covered by an

enamel crown. The pulp cavity lies in the crown of tooth and is filled with pulp (connective tissue containing blood and lymph vessels. Humans have two sets of teeth; a deciduous set consisting of twenty teeth and a permanent set of 32 teeth

Physiology of digestion in the mouth

Mechanical chewing (mastication) allows food to be mixed with saliva to form a bolus. From a chemical point, salivary amylase initiates breakdown of starch into monoglycerides and lingual lipase digests triglycerides into fatty acids. Swallowing (deglutition) moves food from the mouth to the stomach by voluntary (mouth to oropharynx) and involuntary (pharynx through esophagus to stomach) mechanisms.

Salivary glands

Most of work is done by three pair of glands (parotid located beneath and in front of ears), submandibular found beneath tongue, and sublingual which are located superior to submandibular glands. Ducts from each gland carry saliva to mouth. Saliva is 99.5% water, 0.5% sodium, potassium, chloride, bicarbonate ions, phosphates and enzymes. The function of saliva is based on the constituents: water is medium for dissolving food; bicarbonates and phosphates buffer acidic foods; chloride activates salivary amylase; and lysozyme kills bacteria. About 1000 - 1500 ml/day of saliva is secreted.

Esophagus
The esophagus contains 4 layers: mucosa, submucosa, muscularis and adventitia. Cells secrete mucous to aid in transport of food. The upper esophageal sphincter relaxes to allow food to enter, peristalsis moves the food along the esophagus, and the lower esophageal (gastroesophageal) sphincter relaxes and allows bolus to enter the stomach. Achalasia occurs when the sphincter fails to relax allowing food to remain in esophagus causing chest pains. Heart burn occurs when the sphincter fails to close allowing stomach contents to irritate the esophageal wall causing a burning sensation.

Stomach

The stomach is a J-shaped enlargement of GI tract located below diaphragm. It is composed of three muscle layers in muscularis. Parts of the stomach are the cardia (surrounds the superior opening of the stomach), the fundus (rounded area to left of cardia for food storage), the body (main portion of stomach where mixing occurs), and the pylorus (attaches to duodenum: pyloric antrum and canal). Rugae are folds in the mucosa of an empty stomach. They allow the stomach to stretch. The pyloric sphincter is a valve that connects stomach to small intestine. The mucosa contains channels called gastric pits. Gastric glands at bottom of pits contain four types of secretory cells that secrete 2000-3000 ml of gastric juice per day. Chief cells

secrete pepsinogen and gastric lipase. Parietal (oxyntic) cells secrete HCl and intrinsic factor. The mucous cells secrete mucous that protects the stomach wall. G-cells secrete gastrin into the blood.

Physiology of Digestion in the stomach

Motility are the muscular contractions of the stomach and intestine that mix the food and propel it through the digestive tract. It is very important to regulate this process in order for digestion and absorption to be completed. The digestion and absorption of fats is a long and complex process. If too much fatty food is released from the stomach into the intestine, then the fats and lipids may not be completely digested. Therefore, it is very important that the chyme be released by the stomach in discrete amounts in order to maximize the digestive and absorptive processes. Peristaltic movements called mixing waves mix food with gastric secretions to form chyme. Chyme is moved forward and backward in stomach to further mix. Some chyme is forced through pyloric sphincter but some is left for more mixing.

HCl denature proteins and stimulates secretion of hormones that promote flow of bile and pancreatic juice. Enzymatic digestion of proteins begins in stomach by pepsin. Amino acids are broken down into peptides. Gastric lipase secreted by chief cells produce limited breakdown of triglycerides.

Whereas the processes of digestion and absorption are unregulated, regulation of gastric secretions and motility is under control of nervous and hormonal mechanisms. In the **cephalic phase**, which is initiated by sensory receptors in brain, parasympathetic impulse promotes peristalsis and stimulate the gastric glands to secrete pepsinogen, HCl, and mucous into stomach and gastrin into blood. During the **gastric phase**, stretch receptors detect distention of stomach; chemoreceptors detect decreased pH of gastric juice which stimulate peristalsis and secretion of gastric juices. Peristalsis shoots 10-15 ml through pyloric sphincter. Gastrin secreted in pyloric region of stomach, is absorbed into blood where it travels to target cells (gastric glands) which secrete gastric juice. Gastrin's primary function is to cause the secretion of hydrochloric acid (HCl) that will, in turn, convert pepsinogen to the active enzyme pepsin. Pepsin will then begin to digest proteins.

Emptying of the stomach is regulated by neural and hormonal reflexes. It is stimulated by distention of stomach and by gastrin and inhibited by GIP, CCK and enterogastric reflex of small intestine. Carbohydrates spend least amount of time in stomach, triglycerides spend the most. Absorption of some water, electrolytes, some drugs and alcohol occurs but the stomach is mostly impermeable to most substances.

There are three phases of gastric acid secretion: the cephalic phase, the gastric phase, and the **intestinal phase**. The increased gastric acid secretion during the cephalic phase is initiated in response to the sight, smell, taste, and chewing of the food. This is an anticipatory response to the act of eating

and involves the activation of the enteric nervous system through the long loop reflex. The sight, smell, and taste of the food trigger the parasympathetic nervous system. It, in turn, activates the enteric nervous system, causing the parietal cells to release HCl and the G cells to release gastrin. In addition, the motility of the stomach will also increase. In other words, just thinking about food starts the system.

Once the food is swallowed, the gastric phase of acid secretion begins. The stimulus in this phase is the presence of the food in the stomach that distends the walls (mechanical stimulus) and the presence of amino acids (chemical stimulus) from the breakdown of proteins. These stimuli trigger a short loop reflex involving the enteric nervous system, which will cause the release of HCl, gastrin, and pepsinogen and will increase gastric motility. The intestinal phase will be covered in the small intestine section.

Pancreas

An important part of the digestive system is the pancreas. From a structural point of view, the pancreas has a head, tail, body, and two ducts. The larger duct is the pancreatic duct that joins the common bile duct to form the hepatopancreatic duct which empties into the duodenum through the hepatopancreatic ampulla. The smaller one is the accessory duct which also empties into the duodenum. The pancreas lies just below the stomach and has either digestive (or exocrine) and endocrine functions. The exocrine products of the pancreas are secreted into a long pancreatic duct. There are two cell types found in the pancreas. The pancreatic islets secrete hormones (endocrine portion) and the acini (exocrine portion) are enzyme secreting cells that secrete pancreatic juice. Pancreatic juices are secreted into the duodenum of the small intestine.

Pancreatic juice contains enzymes that digest starch (pancreatic amylase), proteins (trypsin, chymotrypsin and carboxypeptidases), triglycerides (pancreatic lipase) and nucleic acids (ribo- and deoxyribonucleases). About 1200 - 1500 ml/day is produced. The pancreatic juice buffers the acidity of gastric juice making it slightly alkaline which prevents duodenal ulcers. Secretion of the juice is regulated by nervous and hormonal mechanisms. Exocrine secretions are necessary for normal digestion and absorption of dietary nutrients.

Liver

The liver is the heaviest gland in the body. It contains two lobes (the right lobe includes quadrate and caudate lobes). The right and left lobes are separated by falciform ligament. The liver is made up of lobules which are the functional units of the liver. The lobules contain hepatocytes (liver cells) arranged around a central vein. Kupffer's cells are reticuloendothelial cells that phagocytize worn out RBC/WBC. The liver possesses sinusoids instead of capillaries. Hepatocytes produce bile which emulsifies triglycerides during digestion. About 800-1000 ml of bile is secreted daily. Bile is partially an excretory product and partially a digestive secretion (emulsifies fats).

Nervous and hormonal factors regulate bile secretion. Bile goes to the gallbladder via the cystic duct where it is stored until it is released into the small intestine.

About 1400 ml of blood passes through the liver each minute (1000 ml from portal circulation and 400 ml via the hepatic artery). The vascular function of liver is storage and filtration.

Functions of the Liver

- Carbohydrate metabolism maintains normal glucose levels by storing glucose as glycogen when blood glucose levels are high and breakdown of glycogen to glucose when blood glucose is low.
- Lipid metabolism stores triglycerides, breaks down fatty acids, synthesizes cholesterol and uses it to make bile salts.
- Protein metabolism is a very important function. The liver deaminates amino groups to be used for ATP production, converts ammonia to urea for excretion, synthesizes plasma proteins such as fibrinogen and prothrombin, and performs transamination which converts one amino acid into another which may be needed by the body.
- Removal of drugs and hormones by detoxification.
- Excretion of bile.
- Synthesis of bile salts that used to emulsify and absorb fats.
- Storage of certain vitamins and minerals.
- Phagocytosis of worn out RBC, WBC, and bacteria.
- Activation of Vitamin D.

Gallbladder

The function of the gallbladder is to store and concentrate bile. When bile is needed in the small intestine, bile is forced into the cystic duct, through the common bile duct, through the hepatopancreatic ampulla and into the duodenum where it is used in the emulsification of large lipid globules into smaller lipid globules.