ANATOMY AND PHYSIOLOGY OF THE DIGESTIVE SYSTEM

ANATOMY OF THE DIGESTIVE SYSTEM

INTRODUCTION:

Food is Essential to Life: Food is necessary for the chemical reactions that take place in everybody cell; for example, formation of new enzymes, cell structures, bone, and all other parts of the body that give the energy to supply the body's needs. Most of the foods we eat are just too large to pass through the plasma membranes of the cells. The process of breaking down food molecules for the body's cells to use is called digestion, and the organs which work together to perform this function are termed the digestive system.

Regulation of Food Intake: How much food we eat is regulated by two sensations--hunger and appetite. When we crave food in general, we are experiencing hunger, and when we want a specific food, the correct term is appetite. The stronger of the two sensations is hunger which is accompanied by a stronger feeling of discomfort. The hypothalamus is the control center for food intake. There are a cluster of nerve cells in the lateral hypothalamus (the appetite center) which send impulses causing a person to want to eat. Another cluster of nerve cells tell the person he has had enough. These cells are located in the medial hypothalamus and called the satiety center. A person's food intake must be regulated to prevent the digestive tract from becoming too full. The upper digestive tract expands to let food enter the tract. Receptors in the walls of the digestive tract are stimulated and send signals to the satiety center, signals that tell the person he is full. He stops taking in food, and the contents of the digestive tract are digested.

a. **Digestive Processes.** Five basic activities help the digestive system prepare for use by the cells. These activities are ingestion, peristalsis, digestion, absorption, and defecation.

(1) Ingestion. Taking into the body of food, drink, or medicines by mouth.

(2) Peristalsis. Alternating contraction and relaxation of the walls of a tubular structure by which food is move along the digestive tract.

(3) Digestion. The processes by which food is broken down chemically and mechanically for the body's use. In chemical digestion, catabolic reactions break down protein, lipid, and large carbohydrate molecules we have eaten into smaller molecules which can be used by the body's cells. Mechanical digestion refers to the various movements which aid chemical digestion. Examples of such movements are the chewing of food by teeth and the churning of food by the smooth muscles of the stomach and the small intestine.

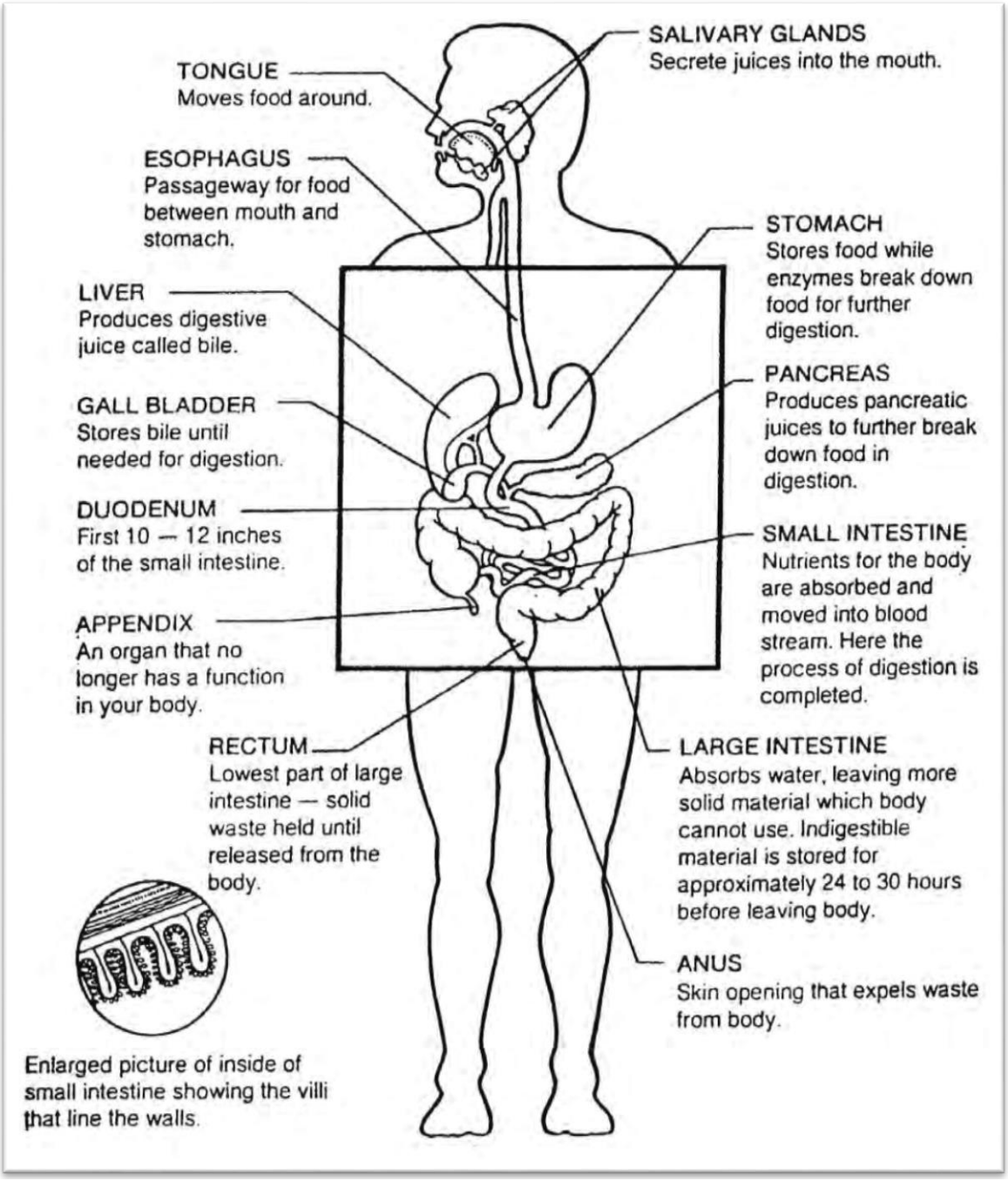

Figure 1-1. The digestive system.

(4) Absorption. The taking up of digested food from the digestive tract into the cardiovascular and lymphatic systems for distribution to the body's cells.

(5) Defecation. The discharge of indigestible substances from the body.

b. **Organization of Digestive Organs.** The digestive organs are commonly divided into two main groups: the gastrointestinal (GI) tract (also called the alimentary canal) and the accessory structures.

(1) The gastrointestinal (GI) tract. The gastrointestinal tract is a continuous tube which extends from the mouth to the anus and which runs through the ventral body cavity. The tube is about 30 feet long in a cadaver and a little shorter in a living person because the tube's wall muscles are toned. From the time food is eaten until it is digested and eliminated, it is in the gastrointestinal tract. Muscular contractions in the walls of the GI tract churn the food breaking it into usable molecules. The organs which make up the gastrointestinal tract are the mouth, pharynx, esophagus, stomach, small intestine, and large intestine. These organs are sometimes referred to as the primary organs of the digestive system.

(2) Accessory structures. These structures include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas. Except for the teeth and the tongue, all the structures lie outside the continuous tube which is the gastrointestinal tract. Secretions that aid in the chemical breakdown of food are produced and stored by these structures. Eventually, such secretions are released into the GI tract through ducts in the body.

(3) General histology (structure of tissues). The gastrointestinal wall has the same basic tissue arrangement from the mouth to the anus. There are four coats (also called tunics): the mucosa, submucosa, muscularis, and serosa (adventitia). The mucosa, the inner tissue layer, contains blood and lymph vessels which carry nutrients to other tissues and also protects the rest of the body against disease. The submucosa is made up of loose connective tissue and binds the mucosa to the next layer which is the muscularis. Skeletal muscle in the muscularis of the mouth, pharynx, and esophagus produce voluntary swallowing. The outer layer of tissue is the serosa.

A. MOUTH--PRIMARY ORGAN

a. The mouth is also referred to as the oral cavity or the buccal cavity. This organ is formed by the cheeks, the hard palate, the soft palate, and the tongue. The lips and the teeth are also considered part of the mouth.

b. The lips, fleshy folds surrounding the opening of the mouth, are covered on the outside by skin and on the inside by a mucous membrane. Cheeks, forming the lateral boundaries of the mouth, are muscular structures covered on the outside by skin and lined with squamous epithelium. The hard palate consists of portions of the two maxillae bones and the two palatine bones. The soft palate is fashioned by muscle and contains the uvula (the cone-shaped, fleshy mass of tissue hanging from the soft palate above the back of the tongue). The tongue is a solid mass of skeletal muscle that contains the sensations of taste. The teeth are the organs of mastication (the process of chewing food). Refer to figure 1-1 for position of the mouth.

B. PHARYNX (THROAT)--PRIMARY ORGAN

a. The pharynx, more commonly called the throat, is a funnel-shaped tube which starts at the internal nares and runs about five inches down the neck. It lies just behind the nasal cavity and oral cavity and just in front of the cervical vertebrae. Skeletal muscles make up the wall of the pharynx along with a mucous membrane.

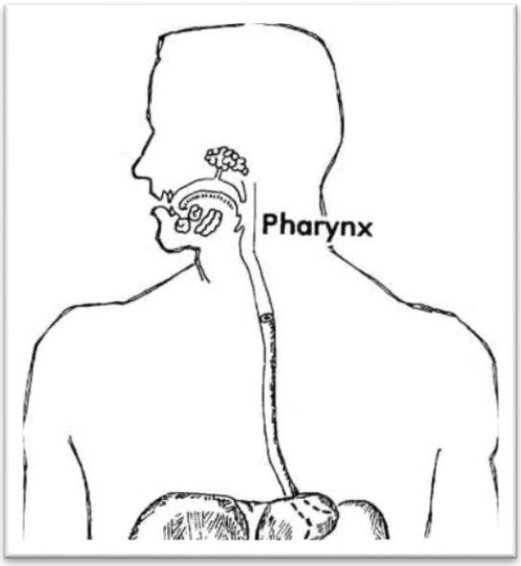

Figure 1-2. The pharynx.

b. The pharynx has three anatomical divisions: The nasopharynx, the oropharynx, and the laryngopharynx. This organ is a common passageway for both the respiratory and digestive systems.

C. ESOPHAGUS--PRIMARY ORGAN

a. The esophagus is a muscular, collapsible tube which is about ten inches long. It lies behind the trachea and extends from the pharynx to the stomach. See figure 1-1 for position of the esophagus.

b. The esophagus can be divided into thirds according to its composition. The upper third of the esophagus is made up of striated (striped) muscle. The middle third has striated and smooth muscle, and the lower third has smooth muscle.

D. STOMACH--PRIMARY ORGAN

The stomach is a musculomembranous, J-shaped enlargement of the alimentary canal and is located between the esophagus and the duodenum. See figure 1-1 for the position of the stomach. The stomach is divided into three parts: the fundus, the body, and the pylorus. The fundus is the upper rounded portion of the stomach located above and to the left of the cardia. The body of the stomach is the large central portion which is located below the fundus. The pylorus is the narrow, inferior region of the stomach. In every person, the

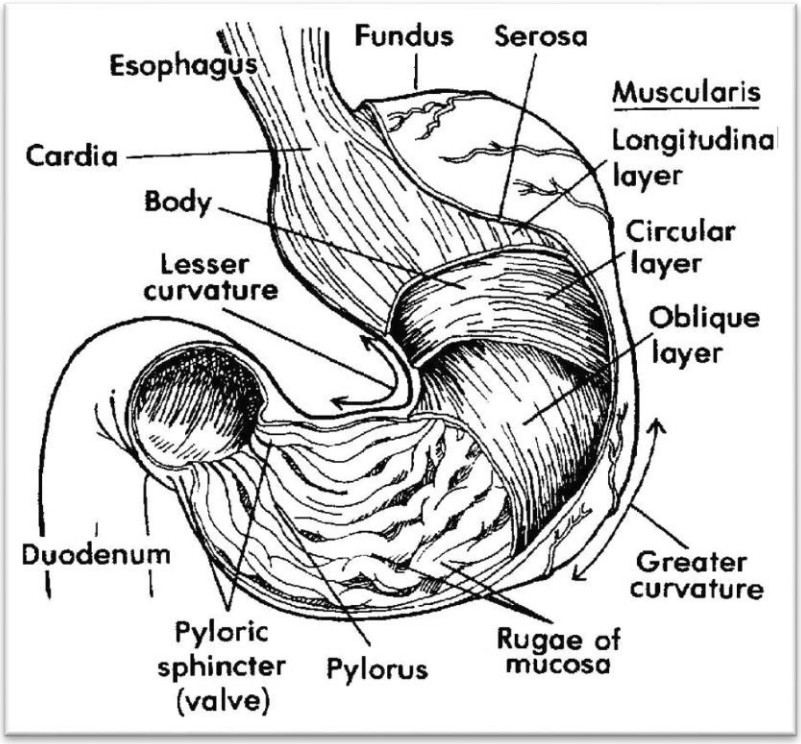

Figure 1-3. Stomach.

position and size of the stomach vary continually. For example, the diaphragm pushes the stomach down each time a person breathes in and pulls the stomach up each time a person breathes out. When the stomach is empty, it is about the size of a large sausage, but when an individual eats a large amount of food, the stomach stretches as necessary and may become very large.

a. The cardiac sphincter muscle guards the opening between the esophagus and the stomach. The pyloric sphincter muscle guards the opening between the stomach and the small intestine. The stomach contains glands called gastri pits which are lined with secreting cells. The zymogenic cells (the chief cells) secrete the substance pepsinogen. During the digestive process, pepsinogen comes in contact with hydrochloric acid (produced by the stomach parietal cells) creating the principal gastric enzyme pepsin.

NOTE: The cardiac sphincter cannot perform its functions when an individual is intubated.

E. SMALL INTESTINE--PRIMARY ORGAN

a. The major parts of the process of digestion and absorption take place in the small intestine. This organ is a tube about one inch in diameter and 20 feet long. Refer to figure 1-1 for position of the small intestine.

b. There are three major divisions in this organ: the duodenum, the jejunum, and the ileum. The duodenum, about ten inches long, is the upper-most part of the small intestine and is attached to the pyloric end of the stomach. The jejunum, about eight feet long, begins at the point where the small intestine turns abruptly forward and downward. The ileum, the third part of the small intestine, is about 12 feet long. Villi,

finger-like projections from the membrane covering the inside of the small intestine, increase the surface area of the intestinal wall. This allows larger amounts of digested nutrients to move into the wall of the small intestine.

F. LARGE INTESTINE--PRIMARY ORGAN

a. The large intestine is the broad, shorter part of the intestines. This tube-shaped organ has a diameter of about two and one half inches and is about five to six feet long. The large intestine extends from the ileum to the anus. See figure 1-1 for position of the large intestine.

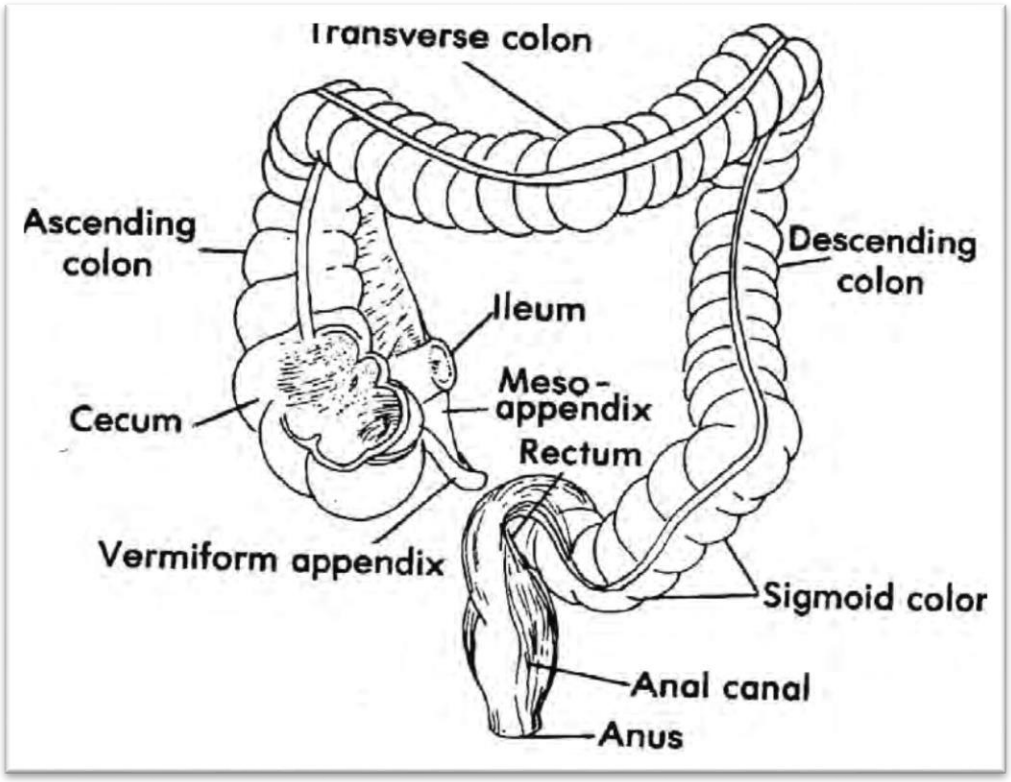

Figure 1-4. Large intestine.

b. The large intestine consists of three divisions: the cecum, the colon, and the rectum. The cecum is the first two or three inches of this organ. The colon begins at the open end of the cecum and is further divided into four parts: the ascending colon, the transverse colon, the descending colon, and the sigmoid colon. The ascending colon comes down on the right side of the abdomen, reaches the undersurface of the liver, and turns abruptly to the left. As the large intestine continues across the abdomen to the left side, it becomes the transverse colon. The intestine then curves beneath the lower end of the spleen on the left side and is called the descending colon. The sigmoid colon is the intestine continuing and projecting inward to the midline of the body and ending as the rectum at about the level of the third sacral vertebra. The rectum is about the last seven or eight inches of the large intestine. The last one inch of the rectum is the anal canal. The opening of the anal canal is guarded by an internal sphincter of smooth muscle and an eternal sphincter of skeletal muscle. The anal canal's opening to the outside is called the anus, an opening usually closed except during the elimination

of the wastes of digestion.

G. SALIVARY GLANDS--ACCESSORY ORGANS

a. The salivary glands are accessory structures that lie outside the mouth. These glands secrete the major portion of saliva, the fluid that keeps the membranes of the mouth moist. Saliva glands empty the saliva into ducts that let their contents flow into the mouth. Refer to figure 1-1 for general position of the salivary glands.

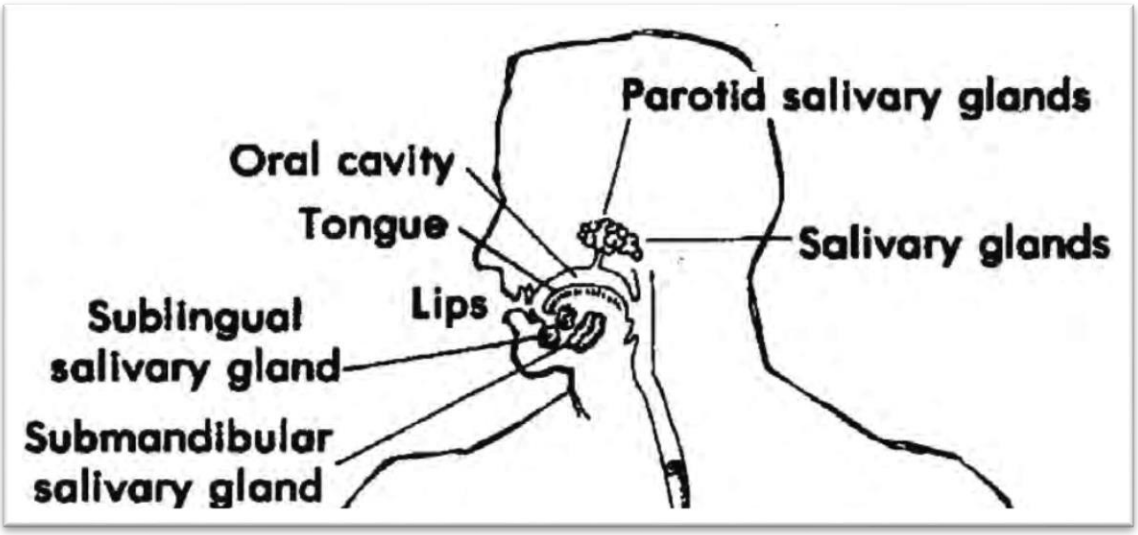

Figure 1-5. Salivary glands.

b. These glands appear in pairs in three locations. The largest pair of salivary glands are the parotid glands which are located below each external ear. The submandibular glands are each located toward the back under the mucous membrane which covers the floor of the mouth under the tongue. The sublingual glands, the smallest of the salivary glands, are located toward the front of the mouth from the submandibular glands.

H. LIVER--ACCESSORY ORGAN

a. The liver is the largest gland in the body. It weighs three to four pounds. There are two principal lobes in the liver: the left lobe and the right lobe. The left lobe forms one-sixth of the liver mass. The right lobe has several subdivisions: the right lobe proper and two small lobes associated with it. Those smaller lobes are the caudate lobe and the quadrate lobe.

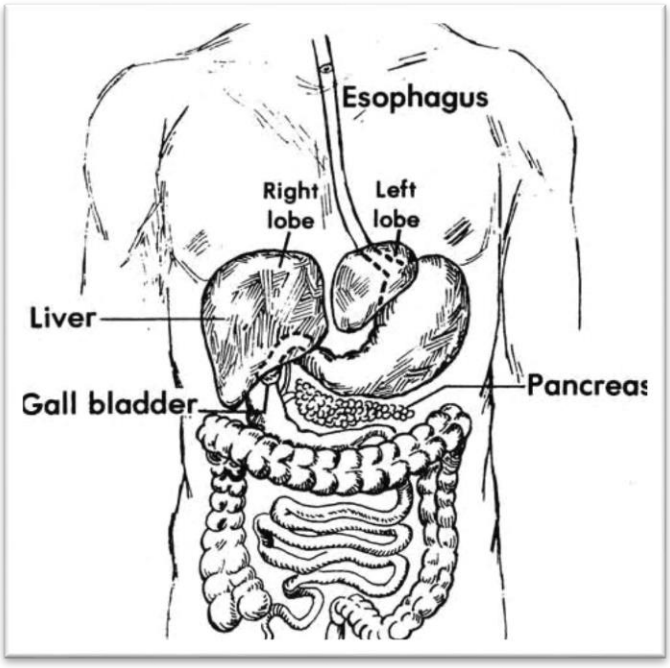

Figure 1-6. The liver.

b. The liver is connected to the small intestine by a series of ducts which are important passageways. The right and left hepatic ducts come from under the surface of the liver to form the common hepatic duct. The common hepatic duct joins with the cystic duct of the gallbladder to form the common bile duct which empties into the duodenum.

I. GALLBLADDER--ACCESSORY ORGAN

a. The gallbladder is a pear-shaped sac which is about three to four inches long. This organ is located under the liver. Bile pours into and comes out of the liver by way of the cystic duct. The gallbladder serves as a storage sac for excess bile which is concentrated five to ten times normal strength while in this organ. See figure 1-1 for position of the gallbladder.

b. The wall of the gallbladder is made up of an inner muscular layer, a middle, muscular coat, and an outer coat. The inner muscular layer consists of mucous membranes arranged in large folds similar to the empty stomach lining. The middle muscular coat is made up of smooth muscle fibers, and the outer coat is the visceral peritoneum (the outer covering for internal organs of the body).

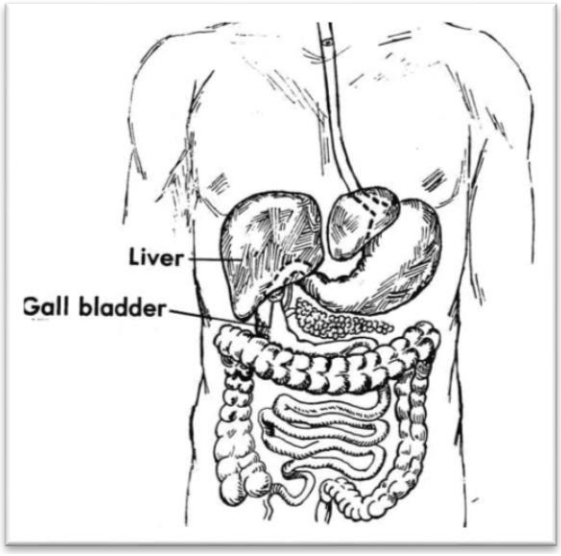

Figure 1-7. The gallbladder.

J. PANCREAS--ACCESSORY ORGAN

a. The pancreas lies behind the greater curve of the stomach and is connected by a duct or two ducts to the duodenum. This organ is soft and oblong, about six inches long and one inch thick. See figure 1-1 for position of the pancreas.

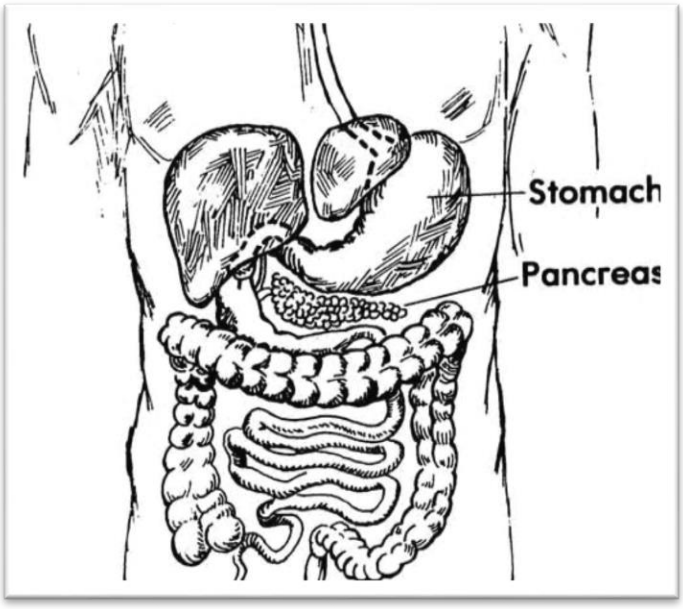

Figure 1-8. The pancreas.

b. The pancreas, linked to the small intestine by a series of small ducts, is made up of exocrine cells and endocrine cells. Exocrine cells empty their products into the pancreas duct network. Endocrine cells distribute their products into the circulatory system. Another name for endocrine cells is islands or islets of Langerhans. Endocrine cells make up about two percent of the total pancreas mass and are made up of alpha, beta, and delta cells that secrete hormones.

K. APPENDIX--ACCESSORY STRUCTURE

The appendix is attached to the cecum of the large intestine. This organ is a worm-like structure that has no functional importance in the digestive process. See figure 1-1 for position of the appendix.

FUNCTIONS AND STAGES OF THE DIGESTIVE PROCESS

1. MECHANICAL AND CHEMICAL DIGESTION:

There are two major types of digestion: mechanical digestion and chemical digestion. Mechanical digestion refers to the various movements that help food move through the digestive system. Chemical digestion refers to the series of catabolic reactions (here, the breakdown of bonds of food molecules to release energy) that break down large carbohydrate, lipid, and protein molecules which are in the food we have eaten. The broken down molecules are used by the cells of the body to produce energy.

a. **Mouth.** Both mechanical digestion and chemical digestion take place in the mouth.

(1) Mechanical digestion. The first step in mechanical digestion in the mouth is mastication, more commonly called chewing. The tongue moves food around in the mouth, the teeth chew the food, and food is mixed with saliva during this process. The result is that food is reduced to a soft, flexible mass called a bolus. The second mechanical function that occurs in the mouth is deglutition, also called swallowing. In swallowing, the tongue moves the bolus upward and backward against the palate forcing the bolus to the back of the mouth cavity and into the oropharynx (a voluntary stage of swallowing). Next, the involuntary pharyngeal stage of swallowing takes place, and the bolus passes through the pharynx and enters the esophagus. Note that the tongue is important in both mastication and deglutition.

(2) Chemical digestion. Only one chemical digestive process occurs in the mouth. The enzyme salivary amylase begins the breakdown of starch. The function of this enzyme is to aid in the breakdown of carbohydrates. Most food is swallowed too quickly for it to be broken down to substances which the body can use. The enzyme salivary amylase continues to act on starches in the food for 15 to 20 minutes while the

food is in the stomach.

b. **Pharynx.** The pharynx contributes to the digestive process by deglutition. The wall of the pharynx contains three pharyngeal constrictor muscles. By wave-like contractions, these muscles force the food mass (the bolus) down into the beginning of the esophagus.

c. **Esophagus.** Two processes contribute to digestion in the esophagus: mechanical digestion and peristalsis. The functions of the esophagus are to secrete mucus and transport food to the stomach. The process of deglutition continues as the bolus continues on its way to the stomach. The involuntary muscular movements of peristalsis which are wave-like movements squeeze food downward; through the esophagus. This is the process of esophageal peristalsis:

(1) The circular muscles just above the bolus contract causing the esophagus to become narrower thus pushing the bolus down the esophagus.

(2) The section of the esophagus just below the bolus adjust to make the esophagus under the bolus widen to accept this food mass.

(3) These muscles continue in waves to contract continually pushing the food mass toward the stomach.

(4) At the same time, glands in the esophagus secrete mucus which also helps the food mass move through the esophagus.

NOTE: Solid or semisolid food usually moves from the mouth to the stomach in from four to eight seconds. Very soft foods and liquids pass from the mouth to the stomach in about one second.

d. **Stomach.** Both mechanical digestion and chemical digestion take place in the stomach.

(1) Mechanical digestion. The food mass enters the stomach, and several minutes later mixing waves pass over the stomach. These are gentle, rippling peristaltic movements which pass over the stomach every 15 to 25 seconds when there is food in the stomach. The movement of these waves mixes the food with the secretions of the gastric glands, softening the food mass, and reducing it to a thin liquid called chyme (pronounced kim). The fundus portion of the stomach is mainly a storage area, and few mixing waves take place there. Foods may be stored is the fundus for an hour or more without becoming mixed with gastric juice. During this storage time, salivary digestion continues. The food progresses through the stomach from the fundus to the body where the mixing waves become stronger and even stronger as the food reaches the pylorus. At the pylorus, each mixing wave forces a small amount of the stomach contents into the duodenum. Most of the food is forced back into the body of the

stomach where further chemical digestion takes place. Another mixing wave pushes another small amount of the contents of the stomach into the duodenum. This continuous forward and backward movement of the stomach contents results in a thorough mixing of the food with the secretions of the gastric glands.

(2) Chemical digestion. The main chemical activity of the stomach is to begin the digestion of proteins. Gastrin, a hormone produced by the stomach, stimulate the secretion of gastric juices, primarily hydrochloric acid. Hydrochloric acid activates the production of pepsinogen which in turn becomes pepsin. Pepsin starts a chemical breakdown of proteins.

e. **Small Intestine.** Mechanical digestion and chemical digestion take place in the small intestine. In fact, the major part of digestion and absorption occurs in the small intestine.

(1) Mechanical digestion. The two main mechanical digestive processes which take place in the small intestine are segmentation and peristalsis. Segmentation is a forward and backward movement of food within a particular segment of the small intestine. The food is not being moved forward but is being thoroughly mixed with digestive juices and intestinal mucosa. (The intestinal mucosa makes absorption easier.) Peristalsis, the second mechanical process, propels the chyme onward through the intestinal tract. Peristaltic contractions in the small intestine are much weaker than those in the esophagus or stomach. Chyme remains in the small intestine for from three to five hours because chyme moves through this organ at a slow rate of one centimeter per minute.

(2) Chemical digestion. When fats, carbohydrates, and acids pass through the pyloric sphincter, the chemical digestive process in the small intestine begins. The chyme which enters the small intestine is made up of partly digested carbohydrates, partially digested proteins, and largely undigested lipids (a group of fat and fat-like substances which are a source of the body's fuel). These carbohydrates, proteins, and lipids finish the process of digestion in the small intestine. Fats, carbohydrates, and acids passing through the pyloric sphincter trigger the release of hormones from the intestinal mucosa. One of these hormones inhibits gastric secretions produced by the liver and also inhibits motility. Two other hormones stimulate the flow of bile and pancreatic juices that help in the emulsifying of fats and the chemical breakdown of carbohydrates.

f. **Large Intestine.** The chief functions of the large intestine are to finish the job of absorption, make certain vitamins, form feces, and expel feces from the body. Both mechanical digestion and chemical digestion work to perform these functions.

(1) Mechanical digestion. Remember that the large intestine is composed of the cecum, the colon, and the rectum. After an individual eats a meal, the peristaltic wave-like motions in the ileum (the lower part of the small intestine) become stronger forcing chyme from the ileum into the cecum (the first part of the large intestine). Chyme continues its journey filling the cecum and then moving into the colon. In the colon, mass peristalsis, a stronger peristaltic wave, drives the contents of the colon into the rectum. When the rectum is full, pressure receptors in its walls activate the defecation reflex which causes the contents of the rectum to be eliminated.

(2) Chemical digestion. Bacterial action rather than the action of enzymes completes the last stage of digestion, a stage which is completed in the large intestine. Glands in the large

intestine secrete mucus, and bacteria prepare the undigested remainder of chyme for eventual elimination. Bacteria causes any remaining carbohydrates to ferment releasing hydrogen, carbon dioxide, and methane gas in the fermentation process. These gases contribute to gas in the colon. Bacteria also act on any proteins which remain changing them to amino acids and breaking down amino acids into simpler substances. Some of these simpler substances are carried off in the feces and contribute to fecal odor. The brown color of feces is the result of bacteria decomposing bilirubin (an orange pigment) to a simpler pigment. Several vitamins necessary for normal metabolism including some B vitamins and vitamin K are the result of bacterial actions in the large intestine.

2. ABSORPTION

a. **General**. Absorption is the passage of substances (water, salts, vitamins, carbohydrates, proteins, and fats) through the intestinal mucosa of the villi into the blood or lymph. The chemical and mechanical phases of digestion are focused on changing food into forms that can go through the epithelial cells which line the mucosa and into the blood and lymph vessels underneath. Most absorption takes place in the small intestine; actually, 90 percent of nutrients are absorbed in the small intestine. The other 10 percent of absorption takes place in the stomach and the large intestine.

b. **Proteins.** Most proteins are absorbed in the form of amino acids, and absorption takes place mainly in the duodenum and the jejunum. As amino acids, proteins move into the epithelial cells of the villi. Amino acids move out of these cells and enter the bloodstream.

c. **Carbohydrates.** Most carbohydrates are absorbed as simple sugars (monosaccharides). They move into the epithelial cells of the villi, then to the capillaries of the villi, next to the bloodstream and into the liver, through the heart, and into general circulation in the body.

d. **Water.** Each day about nine quarts of water enter the small intestine. This fluid is composed of liquid intake and various gastrointestinal secretions. The small intestine absorbs roughly eight quarts of this water. The remainder of the water passes into the large intestine where most of the water is absorbed. The small intestine absorbs water by osmosis through epithelial cells and into the blood capillaries of the villi (small hair-like projections from the surface of mucous membranes). Water is normally absorbed at the rate of 200 to 400 ml/hour.

e. **Electrolytes.** The small intestine absorbs electrolytes which are parts of gastrointestinal secretions. This organ also absorbs electrolytes from ingested foods and liquids. Absorption again takes place through the villi in the small intestine.

f. **Salts.** Salts are absorbed by the villi in the large intestine.

g. **Vitamins.** The small intestine absorbs fat-soluble vitamins such as vitamins A, D, E, and K. The majority of water-soluble vitamins are absorbed by diffusion.

3. ELIMINATION

Certain parts of food resist digestion and are eliminated from the intestines in the feces. These residues of digestion include cellulose from carbohydrates, undigested connective tissue,

and toxins from meat proteins and undigested fats. Additionally, feces contain bacteria, pigments, water, and mucus.

CONCLUSION:

The feeding of each tissue is critical to growth and maintenance of the body. When this system is disrupted, the body cannot maintain itself. The understanding of the anatomy and physiology of this system will help you develop the concepts necessary to anticipate the problems disease or trauma may cause.