

Chapter 15 – Digestive System and Nutrition

15.1 Introduction (Fig. 15.1)

- A. Digestion refers to the mechanical and chemical breakdown of foods so that nutrients can be absorbed by cells.
- B. The digestive system carries out the process of digestion.
- C. The digestive system consists of the alimentary canal, leading from mouth to anus, and several accessory organs whose secretions aid the processes of digestion.

15.2 General Characteristics of the Alimentary Canal (Fig. 15.2)

- A. The alimentary canal is a muscular tube about 9 meters long that passes through the body's ventral cavity.
- B. Structure of the Wall (Fig. 15.3)
 - 1. The wall of the alimentary canal consists of the same four layers throughout its length, with only slight variations according to the functions of specific sections of the canal.
 - a. The inner layer is the mucosa, which is lined with epithelium attached to connective tissue; it protects tissues of the canal and carries on secretion and absorption.
 - b. The next layer is the submucosa, which is made up of loose connective tissue containing blood and lymph vessels and nerves; it nourishes the surrounding layers of the canal.
 - c. The muscular layer consists of inner circular fibers and outer longitudinal fibers that propel food through the canal.
 - d. The outer layer, or serosa, is composed of visceral peritoneum that protects underlying tissues and secretes serous fluid to keep the canal from sticking to other tissues in the abdominal cavity.
- C. Movements of the Tube (Fig. 15.4)
 - 1. The motor functions of the alimentary canal are of two types — mixing movements and propelling movements.
 - 2. Mixing movements occur when smooth muscles contract rhythmically in small sections of the tube.
 - 3. Propelling movements include a wavelike motion called peristalsis, which is caused by contraction behind a mass of food as relaxation allows the mass to enter the next segment of the tube.

15.3 Mouth (Fig. 15.5)

- A. The mouth is the first portion of the alimentary canal; it functions to receive food and begins mechanical digestion by mastication.
- B. Cheeks and Lips
 - 1. Cheeks form the lateral walls of the mouth.
 - 2. The lips are highly mobile structures that surround the mouth opening.
 - 3. The lips have sensory receptors to help to judge the temperature and texture of food.
- C. Tongue (Fig. 15.6)
 - 1. The tongue is a thick, muscular organ covered by mucous membrane with taste buds within papillae; it is attached to the floor of the mouth by the frenulum.
 - 2. The papillae also provide friction for moving food around in the mouth.
 - 3. Lingual tonsils are lymphatic tissues located at the root of the tongue.
- D. Palate (Figs. 15.5-15.6)
 - 1. The palate forms the roof of the oral cavity and has an anterior hard palate and posterior soft palate.
 - 2. The soft palate and uvula function to close off the nasal cavity during swallowing.
 - 3. Associated with the palate in the back of the mouth are palatine tonsils, which,

because they are lymphatic tissue, help to protect the body against infection.

4. Another lymphatic tissue mass, pharyngeal tonsils (adenoids), is located on the posterior wall of the pharynx, above the border of the soft palate.
- E. Teeth (Figs. 15.7-15.9; Table 15.1)
1. Two sets of teeth develop in sockets within the alveolar processes of the maxillary and mandibular bones.
 2. The 20 primary teeth are shed in the order they appeared and are replaced by 32 secondary teeth.
 3. Through the actions of chewing, teeth break food into smaller pieces, beginning the process of mechanical digestion.
 4. Different teeth are adapted to handle food in different ways, and include incisors, cuspids, bicuspid, and molars.
 5. Each tooth consists of a crown and a root, and is made of enamel, dentin, pulp, cementum, nerves, and blood vessels.
 6. A tooth is held tight in its socket by a periodontal ligament.

15.4 Salivary Glands

- A. The salivary glands secrete saliva, which moistens and dissolves food particles, binds them together, allows tasting, helps to cleanse the mouth and teeth, and begins carbohydrate digestion.
- B. Salivary Secretions
1. Salivary glands contain serous cells that produce a watery fluid with amylase, and mucous cells that produce lubricating and binding mucus.
 2. Salivary glands receive parasympathetic stimulation that triggers the production of a large volume of saliva at the sight or smell of food.
- C. Major Salivary Glands (Fig. 15.10)
1. The parotid glands, lying in front of the ear, are the largest of the major salivary glands; they secrete a clear, watery fluid rich in amylase.
 2. The submandibular glands, located on the floor of the mouth, secrete a more viscous fluid.
 3. The sublingual glands, inferior to the tongue, are the smallest of the major salivary glands and secrete a saliva that is thick and stringy.

15.5 Pharynx and Esophagus

- A. The pharynx is a cavity lying behind the mouth, and the esophagus is a muscular tube leading to the stomach.
1. The pharynx functions in both the digestive and respiratory systems.
- B. Structure of the Pharynx (Fig. 15.6)
1. The pharynx connects the nasal and oral cavities with the larynx and esophagus and is divided into a nasopharynx (top portion), oropharynx (middle portion), and laryngopharynx (bottom portion).
- C. Swallowing Mechanism
1. Swallowing reflexes can be divided into three stages.
 - a. Food is mixed with saliva and voluntarily forced into the pharynx with the tongue.
 - b. Sensory receptors in the pharynx sense food, which triggers swallowing reflexes.
 - c. In the third stage of swallowing, peristalsis transports the food in the esophagus to the stomach.
- D. Esophagus (Figs. 15.6, 15.11)
1. The esophagus is a straight, collapsible passageway leading to the stomach.
 2. Mucous glands are scattered throughout the submucosa of the esophagus and produce mucus to moisten and lubricate the inner lining of the tube.

3. The lower esophageal sphincter helps to prevent regurgitation of the stomach contents into the esophagus.

15.6 Stomach

- A. The stomach is a J-shaped muscular organ that receives and mixes food with digestive juices, and propels food to the small intestine.
- B. Parts of the Stomach (Figs. 15.1,15.11)
 1. The stomach is divided into cardiac, fundic, body, and pyloric regions and a pyloric canal.
 2. A pyloric sphincter controls release of food from the stomach into the small intestine.
- C. Gastric Secretions (Fig. 15.12; Table 15.2)
 1. Gastric glands within the mucosa of the stomach open as gastric pits.
 2. Gastric glands generally contain three types of secretory cells.
 - a. Mucous cells produce mucus that protects the stomach lining.
 - b. Chief cells secrete pepsin (to digest protein) as inactive pepsinogen, which is activated when it comes in contact with hydrochloric acid.
 - c. Parietal cells secrete hydrochloric acid.
 - d. Other components of gastric juice include intrinsic factor, required for vitamin B₁₂ absorption from the small intestine.
- D. Regulation of Gastric Secretions (Fig. 15.13)
 1. Gastric secretions are enhanced by parasympathetic impulses and the hormone gastrin, which is released from gastric glands.
 2. As more food enters the small intestine, secretion of gastric juice from the stomach wall is reflexly inhibited.
 - a. Presence of fats and proteins in the upper small intestine causes the release of cholecystokinin from the intestinal wall, which also decreases gastric mobility.
- E. Gastric Absorption
 1. The stomach absorbs only small quantities of water and certain salts, alcohol, and some lipid-soluble drugs.
- F. Mixing and Emptying Actions
 1. Following a meal, mixing actions of the stomach turn the food into chyme and pass it toward the pyloric region using peristaltic waves.
 2. The rate at which the stomach empties depends on the fluidity of the chyme and the type of food.
 3. As chyme fills the duodenum, stretching of its wall triggers the enterogastric reflex, which inhibits peristalsis and slows the rate at which chyme enters the small intestine.

15.7 Pancreas

- A. The pancreas has an exocrine function of producing pancreatic juice that aids digestion.
- B. Structure of the Pancreas (Figs. 15.1,15.14)
 1. The pancreas is closely associated with the small intestine.
 2. The cells that produce pancreatic juice, called pancreatic acinar cells, make up the bulk of the pancreas.
 3. Pancreatic acinar cells cluster around tiny tubes that merge to form larger ones, and then give rise to the pancreatic duct.
 4. The pancreatic and bile ducts join and empty into the small intestine, which is surrounded by the hepatopancreatic sphincter.
- C. Pancreatic Juice
 1. Pancreatic juice contains enzymes that digest carbohydrates, fats, proteins, and nucleic acids.

2. Pancreatic enzymes include pancreatic amylase, pancreatic lipase, trypsin, chymotrypsin, carboxypeptidase, and two nucleases.
 3. Protein-digesting enzymes are released in an inactive form and are activated upon reaching the small intestine.
- D. Regulation of Pancreatic Secretion (Fig. 15.15)
1. The nervous and endocrine systems regulate release of pancreatic juice.
 2. Secretin from the duodenum stimulates the release of pancreatic juice with a high bicarbonate ion concentration but few digestive enzymes.
 3. Cholecystokinin from the wall of the small intestine stimulates the release of pancreatic juice with abundant digestive enzymes.

15.8 Liver

- A. The reddish-brown liver, located in the upper right quadrant of the abdominal cavity, is the body's largest internal organ.
- B. Liver Structure (Figs. 15.1,15.16-15.18)
1. The liver is divided into right and left lobes, and is enclosed by a fibrous capsule.
 2. Each lobe is separated into hepatic lobules consisting of hepatic cells radiating from a central vein.
 3. Hepatic sinusoids separate groups of hepatic cells.
 4. Blood from the hepatic portal vein carries blood rich in nutrients to the liver.
 5. Kupffer cells carry on phagocytosis in the liver.
 6. Secretions from hepatic cells are collected in bile canals that converge to become hepatic ducts and finally form the common hepatic duct.
- C. Liver Functions (Table 15.3)
1. The liver carries on many diverse functions for the body.
 2. The liver is responsible for many metabolic activities, such as the metabolism of carbohydrates, lipids, and proteins.
 3. The liver also stores glycogen, vitamins A, D, and B₁₂, iron, and blood.
 4. The liver filters the blood, removing damaged red blood cells and foreign substances, and removes toxins.
 5. The liver's role in digestion is to secrete bile.
- D. Composition of Bile
1. Bile is a yellowish-green liquid that hepatic cells secrete; it includes water, bile salts, bile pigments, cholesterol, and electrolytes.
 2. Bile pigments are breakdown products from red blood cells.
 3. Only the bile salts have a digestive function.
- E. Gallbladder (Figs. 15.1,15.14,15.19)
1. The gallbladder is a pear-shaped sac lying on the interior surface of the liver.
 2. It is connected to the cystic duct, which joins the hepatic duct; these two ducts merge to form the common bile duct leading to the duodenum.
 3. A sphincter muscle controls the release of bile from the common bile duct.
- F. Regulation of Bile Release (Fig. 15.19; Table 15.4)
1. Bile does not normally enter the duodenum until cholecystokinin stimulates the gallbladder to contract.
 2. The hepatopancreatic sphincter remains contracted unless a peristaltic wave approaches it, at which time it relaxes and a squirt of bile enters the duodenum.
- G. Functions of Bile Salts
1. Bile salts emulsify fats into smaller droplets and aid in the absorption of fatty acids, cholesterol, and certain vitamins.

15.9 Small Intestine (Fig. 15.1)

- A. The lengthy small intestine receives secretions from the pancreas and liver, completes digestion of the nutrients in chyme, absorbs the products of digestion, and transports the

- remaining residues to the large intestine.
- B. Parts of the Small Intestine (Figs. 15.21-15.23)
1. The small intestine consists of the duodenum, jejunum, and ileum.
 2. The duodenum is the shortest and most fixed portion of the small intestine; the rest is mobile and lies free in the peritoneal cavity.
 3. The small intestine is suspended from the posterior abdominal wall by a double-layered fold of peritoneum called mesentery.
- C. Structure of the Small Intestinal Wall (Figs. 15.3,15.24-15.25)
1. The inner wall of the small intestine is lined with finger-like intestinal villi, which greatly increase the surface area available for absorption and aid in mixing actions.
 2. Each villus contains a core of connective tissue housing blood capillaries and a lymphatic capillary called a lacteal.
 3. Between the bases of adjacent villi are tubular intestinal glands.
- D. Secretions of the Small Intestine (Table 15.5)
1. Cells that secrete mucus in the small intestine include goblet cells, which are abundant throughout the mucosa, and mucus-secreting glands located in the submucosa of the duodenum.
 2. Intestinal glands at the bases of the villi secrete large amounts of watery fluid that carry digestive products into the villi.
 3. Epithelial cells of the mucosa have embedded digestive enzymes on their microvilli, including peptidases, sucrase, maltase, and lactase, and intestinal lipase.
- E. Regulation of Small Intestinal Secretions
1. Mechanical and chemical stimulation from chyme causes goblet cells to secrete mucus.
 2. Distention of the intestinal wall stimulates parasympathetic reflexes that stimulate secretions from the small intestine.
- F. Absorption in the Small Intestine (Fig. 15.26; Table 15.6)
1. The small intestine is the major site of absorption within the alimentary canal.
 2. Monosaccharides are absorbed by the villi through active transport or facilitated diffusion and enter blood capillaries.
 3. Amino acids are absorbed into the villi by active transport and are carried away in the blood.
 4. Fatty acids are absorbed and transported differently than the other nutrients.
 - a. Fatty acid molecules dissolve into the cell membranes of the villi.
 - b. The endoplasmic reticula of the cells reconstruct the lipids.
 - c. These lipids collect in clusters that become encased in protein (chylomicrons).
 - d. Chylomicrons are carried away in lymphatic lacteals until they eventually join the bloodstream.
 5. The intestinal villi also absorb water (by osmosis) and electrolytes (by active transport).
- G. Movements of the Small Intestine (15.27)
1. The small intestine carries on segmentation and peristaltic waves.
 2. The ileocecal sphincter at the junction of the small and large intestines usually remains closed unless a gastroileal reflex is elicited after a meal.

15.10 Large Intestine

- A. The large intestine absorbs water and electrolytes and forms and stores feces.
- B. Parts of the Large Intestine (Figs. 15.1,15.27-15.29)
1. The large intestine consists of the cecum (pouch at the beginning of the large intestine), colon (ascending, transverse, descending, and sigmoid regions), the rectum, and the anal canal.

2. The anal canal opens to the outside as the anus; it is guarded by an involuntary internal anal sphincter and a voluntary external anal sphincter muscle.
- C. Structure of the Large Intestinal Wall (Fig 15.27)
 1. The large intestinal wall has the same four layers found in other areas of the alimentary canal, but lacks many of the features of the small intestinal mucosa such as villi.
 2. Fibers of longitudinal muscle are arranged in teniae coli that extend the entire length of the colon, creating a series of pouches (haustra).
- D. Functions of the Large Intestine (Fig. 15.30)
 1. The large intestine does not digest or absorb nutrients, but it does secrete mucus.
 2. The large intestine absorbs electrolytes and water.
 3. The large intestine contains important bacteria that synthesize vitamins and use cellulose.
- E. Movements of the Large Intestine
 1. The movements of the large intestine are similar to those of the small intestine.
 2. Peristaltic waves happen only two or three times during the day.
 3. Defecation is stimulated by a defecation reflex that forces feces into the rectum where they can be expelled.
- F. Feces
 1. Feces are composed of undigested material, water, electrolytes, mucus, and bacteria.
 2. Both the color of feces and its odor is due to the action of bacteria.

15.11 Nutrition and Nutrients

- A. Nutrition is the process by which the body takes in and uses nutrients.
- B. Essential nutrients are those that cannot be synthesized by human cells.
- C. Carbohydrates, such as sugars and starches, are organic compounds used for sources of energy in the diet.
 1. Carbohydrate Sources
 - a. Carbohydrates are ingested in a variety of forms: starch from grains, glycogen from meat, and disaccharide and monosaccharide sugars from fruits and vegetables.
 - b. During digestion, complex carbohydrates are broken down into monosaccharides, which can be absorbed by the body.
 - c. Cellulose is a complex carbohydrate that cannot be digested, but provides bulk (fiber), facilitating the movement of food through the intestine.
 2. Carbohydrate Use
 - a. The monosaccharides that are absorbed in the small intestine are fructose, galactose, and glucose; the liver converts the first two into glucose.
 - b. Excess glucose is stored as glycogen in the liver or is converted into fat and stored in adipose tissue.
 - c. Certain body cells (neurons) need a continuous supply of glucose to survive; if glucose is scarce, amino acids may be converted to glucose.
 3. Carbohydrate Requirements
 - a. The need for carbohydrates varies with a person's energy requirements; the minimum requirement is unknown.
 - b. An estimated intake of 125-175 grams of carbohydrate is needed daily to avoid protein breakdown.
- D. Lipids are organic substances that supply energy for cellular processes and to build structures. The most common dietary lipids are triglycerides.
 1. Lipid Sources
 - a. Lipids include fats, phospholipids, and cholesterol.
 - b. Triglycerides are found in plant- and animal-based foods.

- i. Saturated fats are found in foods of animal origin.
 - ii. Unsaturated fats are found in foods of plant origin.
 - iii. Cholesterol is found only in foods of animal origin.
 - 2. Lipid Use
 - a. Digestion breaks down triglycerides into fatty acids and glycerol.
 - b. The liver and adipose tissue control triglyceride metabolism which has many steps.
 - c. The liver can convert fatty acids from one form to another, but it cannot synthesize the essential fatty acids that must be obtained from the diet.
 - d. The liver controls circulating lipids and cholesterol.
 - e. Excessive lipids are stored in adipose tissue.
 - 3. Lipid Requirements
 - a. Human diets vary widely in their lipid content.
 - b. A typical diet consisting of a variety of foods usually provides adequate fats.
- E. Proteins
 - 1. Proteins are polymers of amino acids with a wide variety of functions in cells and in the body (enzymes, hormones, antibodies, clotting factors, and so forth).
 - 2. Amino acids are also potential sources of energy.
 - 3. Protein Sources
 - a. Animal sources of protein contain complete proteins, which contain all essential amino acids.
 - b. Plant sources of protein are missing one or more essential amino acids making them incomplete proteins that should be consumed in combinations.
 - 4. Protein Use
 - a. Proteins include enzymes that control metabolic rates, clotting factors, the keratin of skin & hair, elastin and collagen of connective tissue, plasma proteins that regulate water balance, the muscle components actin and myosin, hormones, and the antibodies that protect against infection.
 - b. They may also supply energy after digestion breaks them down.
 - 5. Protein Requirements
 - a. Protein requirements vary according to body size, metabolic rate, and nitrogen requirements.
 - b. For the average adult, nutritionists recommend 0.8 grams of protein per day per kilogram of body weight; pregnant and nursing women need more.
- G. Vitamins
 - 1. Vitamins are organic compounds required in small amounts for normal metabolic processes, and are not produced by cells in adequate amounts.
 - a. Vitamins are classified as fat-soluble (vitamins A, D, E, and K) or water-soluble (B vitamins and vitamin C).
 - 2. Fat-Soluble Vitamins (Table 15.8)
 - a. Fat-soluble vitamins dissolve in fats and are influenced by some of the factors that influence lipid absorption.
 - b. Fat-soluble vitamins are stored in moderate quantities in the body and are usually not destroyed by cooking or processing foods.
 - c. Table 15.8 lists the characteristics, functions, sources, and recommended daily allowances (RDA) for adults for the fat-soluble vitamins.
 - 3. Water-Soluble Vitamins (Table 15.9)
 - a. Water-soluble vitamins, including the B vitamins and vitamin C, are necessary for normal cellular metabolism in the oxidation of carbohydrates,

- lipids, and proteins.
- b. Vitamin C (ascorbic acid) is needed for the production of collagen, the metabolism of certain amino acids, and the conversion of folacin into folic acid.
- c. Table 15.9 lists the characteristics, functions, sources and RDAs for adults of the water-soluble vitamins.

H. Minerals

1. Dietary minerals are derived from the soil and are essential in human metabolism.
2. Characteristics of Minerals
 - a. Minerals are responsible for 4% of body weight, and are concentrated in the bones and teeth.
 - b. Minerals may be incorporated into organic molecules or inorganic compounds, while others are free ions.
 - c. Minerals comprise parts of the structural materials in all body cells, where they may also be portions of enzymes; they contribute to the osmotic pressure of body fluids and play roles in conduction of nerve impulses, muscle contraction, coagulation of blood, and maintenance of pH.
3. Major Minerals (Table 15.10)
 - a. Calcium and phosphorus account for 75% by weight of the minerals, and are thus called major minerals.
 - b. Other major minerals include potassium, sulfur, sodium, chlorine, and magnesium.
 - c. Table 15.10 lists the distribution, functions, sources, and RDAs for adults of the major minerals.
4. Trace Elements (Table 15.11)
 - a. Trace elements are essential nutrients needed only in minute amounts, each making up less than 0.005% of adult body weight.
 - b. They include iron, manganese, copper, iodine, cobalt, zinc, fluorine, selenium, and chromium.
 - c. Table 15.11 lists the distribution, functions, sources, and RDAs for adults of the minor minerals.

I. Adequate Diets (Fig. 15.33, 15.34)

1. An adequate diet provides sufficient energy as well as adequate supplies of essential nutrients to support growth, repair, and maintenance of tissues.
2. Malnutrition is poor nutrition that results either from a lack of essential nutrients or a failure to utilize them; malnutrition may result from undernutrition or overnutrition.
3. A BMI is used to determine whether a person is of adequate weight, overweight, or obese.