ANATOMY AND PHYSIOLOGY (N3)
1st Semester AY 2023-2024
STUDY GUIDE

DIGESTIVE SYSTEM AND METABOLISM

Introduction

Hello students! This session explores the structure and function of the digestive system. It is important that nurses understand and can apply how the digestive system works and its role in maintaining health. The study guide describes the gastrointestinal tract's gross structure and relevant physiology.

The gastrointestinal system is one of the largest endocrine organs in the body. The main function of the gastrointestinal system is to supply the body's cells with nutrients. The GI system (another name for the gastrointestinal system) is important to assess because it is responsible for nutrition, digestion, absorption, hydration, and defecation. You may also have heard it referred to as the digestive system. As a nurse, your assessment of the GI system provides information about how the system is functioning and potential cues that require nursing and medical action.

I hope you enjoy this topic, and advance congratulations on completing the course.

Topic outline

I. Introduction
   - A. Functions of the Digestive System
   - B. Gastrointestinal Processes and Control
   - C. Digestive Structures and Functions
   - D. Organs of the Alimentary Canal
   - E. Accessory Digestive Organs
   - F. Nutrition and Metabolism

Learning outcomes

After going through this topic, you should be able to:

1. Explain the functions of the digestive system and its role in maintaining homeostasis
2. Describe the structures and functions of the organs and accessory organs of the digestive system
3. Discuss the processes and control of ingestion, propulsion, mechanical digestion,
4. Describe the processes involved in anabolic and catabolic reactions
5. Describe the steps necessary for carbohydrate, lipid, and protein metabolism

Please read the main reference below to understand the topic better.

1. Tortora GJ & Derrickson B. (2014). Chapter 24-25 An Introduction to the Human Body. *Principles of Anatomy and Physiology.* John Wiley & Sons, Inc. 14 edition. Pp 898-890.

The GI tract is a continuous tube that starts from the mouth down to the pharynx, esophagus, stomach, small intestine, and large intestine. It contains food from when it is eaten until it is digested and absorbed or eliminated. The food is physically broken down through the muscular contractions in the wall of the GI tract and is propelled along the tract from the esophagus to the anus. The said contractions also help dissolve foods by mixing them with fluids secreted into the tract.

Another component is the Accessory digestive organs. We have teeth and the tongue, which aid in the physical breakdown of food and aids in chewing and swallowing, respectively. The other accessory organs are the salivary glands, the liver, the gallbladder, and the pancreas. These organs don't have direct contact with food, but they produce or store enzymes that break down the food chemically.

Functions of the Digestive System

The functions of the digestive system are:

1. Ingestion. Food must be placed into the mouth before it can be acted on; this is an active, voluntary process called ingestion.
2. Propulsion. If foods are to be processed by more than one digestive organ, they must be propelled from one organ to the next; swallowing is one example of food movement that depends largely on the propulsive process called peristalsis (involuntary, alternating waves of contraction and relaxation of the muscles in the organ wall).
3. Food breakdown: mechanical digestion. Mechanical digestion prepares food for further degradation by enzymes by physically fragmenting the food into smaller pieces. And examples of mechanical digestion are the mixing of food in the mouth by the tongue, churning of food in the stomach, and segmentation in the small intestine.
4. Food breakdown: chemical digestion. The sequence of steps in which the large food molecules are broken down into their building blocks by enzymes is called chemical digestion.
5. Absorption. Transport of digested end products from the lumen of the GI tract to the blood or lymph is absorption, and for absorption to happen, the digested foods must first enter the mucosal cells by active or passive transport processes.
6. Defecation. Defecation is the elimination of indigestible residues from the GI tract via the anus in the form of feces.

Layers of the Alimentary Canal

Mucosa

The inner lining of the GI tract is the Mucosa. It is a mucous membrane that is composed of three layers of tissues. The first is of (1) a layer of epithelium that has direct contact with the contents of the GI tract, the second layer of connective tissue called the lamina propria, and the last layer is a thin layer of smooth muscle (muscularis mucosae).

The second layer is the Lamina propria. This connective tissue contains many blood and lymphatic vessels that aid in the dispersion of nutrients absorbed into the GI tract to other body tissues.
Lamina propria also contains most of the cells of the mucosa-associated lymphatic tissue (MALT).

Lastly, we have the muscularis mucosae. It is a thin layer of smooth muscle fibers found in the stomach and small intestines, which increase the surface area for digestion and absorption. Movements of the muscularis mucosae ensure that all absorptive cells are fully exposed to the contents of the GI tract.

Submucosa

The submucosa consists of areolar connective tissue that binds the mucosa to the muscularis. This layer contains many blood and lymphatic vessels that receive absorbed food molecules. Located in the submucosa is an extensive network of neurons known as the submucosal plexus. The submucosa may also contain glands and lymphatic tissue.

Muscularis Mucosae

The muscularis of the mouth, pharynx, and superior and middle parts of the esophagus contain skeletal muscle that produces voluntary swallowing. Skeletal muscle also forms the external anal sphincter, which permits defecation. Involuntary contractions of the smooth muscle help break down food, mix it with digestive secretions, and propel it along the tract. Between the layers of the muscularis is a second plexus of neurons—the myenteric plexus.

1. Skeletal muscle — VOLUNTARY: this includes mouth, pharynx, superior and middle parts of the esophagus, external anal sphincter –for defecation.
2. Smooth muscle – involuntary contractions of smooth muscles that help break down food.

Serosa

The serosa is a serous membrane composed of areolar connective tissue and simple squamous epithelium (mesothelium). The serosa is also called the visceral peritoneum because it forms a portion of the peritoneum, The esophagus lacks a serosa; instead, only a single layer of areolar connective tissue called the adventitia forms the superficial layer of this organ.

Peritoneum

The abdominal cavity, where the abdominal organs lie, is covered and lined by the peritoneum.
The peritoneum is the largest serous membrane of the body; it consists of a layer of simple squamous epithelium (mesothelium) with an underlying supporting layer of areolar connective tissue. The peritoneum is divided into the **parietal peritoneum**, which lines the wall of the abdominal cavity, and the **visceral peritoneum**, which covers some of the organs in the cavity and is their serosa.
The peritoneal cavity is the slim space containing lubricating serous fluid between the parietal and visceral portions of the peritoneum. In certain diseases, the peritoneal cavity may become distended by accumulating several liters of fluid, a condition called ascites.

5 Major peritoneal folds

Greater Omentum

The **greater omentum** is the largest peritoneal fold, drapes over the transverse colon, and coils of the small intestine like a “fatty apron”. It contains adipose tissue, which expands with weight gain and contributes to the “beer belly” of overweight individuals. It also contains lymph nodes that contribute macrophages and antibody-producing plasma cells that help combat and have GI tract infections.
The **falciform ligament** attaches the liver to the anterior abdominal wall and diaphragm

Lesser omentum: > suspends stomach and duodenum from liver.

- ➢ pathway for blood vessels entering the liver and contains the hepatic portal vein, common hepatic artery, common bile duct along with some lymph nodes

The lesser omentum arises as an anterior fold in the serosa of the stomach and duodenum, and it suspends the stomach and duodenum from the liver.

Mesentery:

>A fan-shaped fold of the peritoneum, called the mesentery,
> binds the jejunum and ileum of the small intestine to the posterior abdominal wall.

Mesocolon

Mesocolon binds the transverse and sigmoid colon (sigmoid mesocolon) of the large intestine to the posterior abdominal wall. It carries blood and lymphatic vessels to the intestines colon) and sigmoid colon (sigmoid mesocolon)

The organs of the digestive system can be separated into two main groups: those forming the alimentary canal and the accessory digestive organs.

Organs of the Alimentary Canal
The alimentary canal, also called the gastrointestinal tract, is a continuous, hollow muscular tube that winds through the ventral body cavity and is open at both ends. Its organs include the following:

Mouth
Also referred to as the oral or buccal cavity

Food enters the digestive tract through the mouth, or oral cavity, a mucous membrane-lined cavity.

- Lips. The lips (labia) protect its anterior opening.
- Cheeks. The cheeks form its lateral walls.
- Palate. The hard palate forms its anterior roof, and the soft palate forms its posterior roof.
- Uvula. The uvula is a fleshy finger-like projection of the soft palate, which extends inferiorly from the posterior edge of the soft palate.
- Vestibule. The space between the lips and the cheeks externally and the teeth and gums internally is the vestibule.
- Oral cavity proper. The area contained by the teeth is the oral cavity proper.
- Tongue. The muscular tongue occupies the floor of the mouth and has several bony attachments- two of these are to the hyoid bone and the styloid processes of the skull.
- Lingual frenulum. The lingual frenulum, a fold of mucous membrane, secures the tongue to the floor of the mouth and limits its posterior movements.
- Palatine tonsils. At the posterior end of the oral cavity are paired masses of lymphatic tissue, the palatine tonsils.
- Lingual tonsil. The lingual tonsils cover the base of the tongue just beyond.

* The Salivary gland is a gland that releases a secretion called saliva into the oral cavity
Saliva lubricates and dissolves foods and begins the chemical breakdown of carbohydrates and lipids .

Normally, parasympathetic stimulation promotes continuous secretion of a moderate amount of saliva. Facial (VII) and glossopharyngeal (IX) nerves stimulate secretion of saliva. Saliva continues to be secreted heavily after food is swallowed; this saliva flow washes out the mouth and dilutes and buffers the remnants of irritating chemicals such as that tasty (but hot!) salsa. The smell, sight, sound, or thought of food may also stimulate secretion of saliva.

Eventually, most components of saliva are reabsorbed, which prevents fluid loss. Sympathetic stimulation dominates during stress, resulting in dryness of the mouth. If the body becomes dehydrated, the salivary glands stop secreting saliva to conserve water; the resulting dryness in the mouth contributes to the sensation of thirst. Drinking not only restores the homeostasis of body water but also moistens the mouth
Chemicals in the food stimulate receptors in taste buds on the tongue, and impulses are conveyed from the taste buds to two salivary nuclei in the brain stem superior and inferior salivatory nuclei.

Pharynx

From the mouth, food passes posteriorly into the oropharynx and laryngopharynx.

- Oropharynx. The oropharynx is posterior to the oral cavity.
- Laryngopharynx. The laryngopharynx is continuous with the esophagus below; both of which are common passageways for food, fluids, and air.

The nasopharynx functions only in respiration, but both the oropharynx and laryngopharynx have digestive as well as respiratory functions. Swallowed food passes from the mouth into the oropharynx and laryngopharynx; the muscular contractions of these areas help propel food into the esophagus and then into the stomach.

Esophagus

The esophagus or gullet, runs from the pharynx through the diaphragm to the stomach.

- Size and function. About 25 cm (10 inches) long, it is essentially a passageway that conducts food by peristalsis to the stomach
- Structure. The walls of the alimentary canal organs from the esophagus to the large intestine are made up of the same four basic tissue layers or tunics.
- Mucosa. The mucosa is the innermost layer, a moist membrane that lines the cavity, or lumen, of the organ; it consists primarily of a surface epithelium, plus a small amount of connective tissue (lamina propria) and a scanty smooth muscle layer.
- Submucosa. The submucosa is found just beneath the mucosa; it is a soft connective tissue layer containing blood vessels, nerve endings, lymph nodules, and lymphatic vessels.
- Muscularis externa. The muscularis externa is a muscle layer typically made up of an inner circular layer and an outer longitudinal layer of smooth muscle cells.
- Serosa. The serosa is the outermost layer of the wall that consists of a single layer of flat serous fluid-producing cells, the visceral peritoneum.
- Intrinsic nerve plexuses. The alimentary canal wall contains two important intrinsic nerve plexuses-the submucosal nerve plexus and the myenteric nerve plexus, both of which are networks of nerve fibers that are actually part of the autonomic nervous system and help regulate the mobility and secretory activity of the GI tract organs.

The esophagus secretes mucus and transports food into the stomach. It does not produce digestive enzymes, and it does not carry on absorption.

Stomach

Different regions of the stomach have been named, and they include the following:

- Location. The C-shaped stomach is on the left side of the abdominal cavity, nearly hidden by the liver and the diaphragm.
- Function. The stomach acts as a temporary “storage tank” for food as well as a site for food breakdown.
- Cardiac region. The cardiac region surrounds the cardioesophageal sphincter, through which food enters the stomach from the esophagus.
- Fundus. The fundus is the expanded part of the stomach lateral to the cardiac region.
- Body. The body is the midportion, and as it narrows inferiorly, it becomes the pyloric antrum, and then the funnel-shaped pylorus.
- Pylorus. The pylorus is the terminal part of the stomach and it is continuous with the small intestine through the pyloric sphincter or valve.
- Size. The stomach varies from 15 to 25 cm in length, but its diameter and volume depend on how much food it contains; when it is full, it can hold about 4 liters (1 gallon) of food, but when it is empty it collapses inward on itself.
- Rugae. The mucosa of the stomach is thrown into large folds called rugae when it is empty.
- Greater curvature. The convex lateral surface of the stomach is the greater curvature.

- Lesser curvature. The concave medial surface is the lesser curvature.
- Lesser omentum. The lesser omentum, a double layer of peritoneum, extends from the liver to the greater curvature.
- Greater omentum. The greater omentum, another extension of the peritoneum, drapes downward and covers the abdominal organs like a lacy apron before attaching to the posterior body wall, and is riddled with fat, which helps to insulate, cushion, and protect the abdominal organs.
- Stomach mucosa. The mucosa of the stomach is a simple columnar epithelium composed entirely of mucous cells that produce a protective layer of bicarbonate-rich alkaline mucus that clings to the stomach mucosa and protects the stomach wall from being damaged by acid and digested by enzymes.
- Gastric glands. This otherwise smooth lining is dotted with millions of deep gastric pits, which lead into gastric glands that secrete the solution called gastric juice.
- Intrinsic factor. Some stomach cells produce intrinsic factor, a substance needed for the absorption of vitamin b12 from the small intestine.
- Chief cells. The chief cells produce protein-digesting enzymes, mostly pepsinogens.
- Parietal cells. The parietal cells produce corrosive hydrochloric acid, which makes the stomach contents acidic and activates the enzymes.
- Enteroendocrine cells. The enteroendocrine cells produce local hormones such as gastrin, that are important to the digestive activities of the stomach.
- Chyme. After food has been processed, it resembles heavy cream and is called chyme.

The gastric glands contain three types of exocrine gland cells that secrete their products into the stomach lumen: mucous neck cells, chief cells and parietal cells.

Surface mucous and Mucous neck cells = mucus

* parietal cells: produce Intrinsic factor which is important in absorption of Vit B12 and also produces HCl acid

- Chief cells: secrete pepsinogen and gastric lipase
- * Enteroendocrine cell: called G cell: and secretes the **hormone gastrin** in the blood stream

Gastric juice is the combined secretions of mucous cells, parietal cells, and chief cells

Only a small amount of nutrients are absorbed in the stomach because its epithelial cells are impermeable to most materials. However, mucous cells of the stomach absorb some water, ions, short-chain fatty acids, certain drugs (especially aspirin), and alcohol.

Small Intestine

- Location. The small intestine is a muscular tube extending from the pyloric sphincter to the large intestine.
- Size. It is the longest section of the alimentary tube, with an average length of 2.5 to 7 m (8 to 20 feet) in a living person.
- Subdivisions. The small intestine has three subdivisions: the duodenum, the jejunum, and the ileum, which contribute 5 percent, nearly 40 percent, and almost 60 percent of the small intestine, respectively.
- Ileocecal valve. The ileum meets the large intestine at the ileocecal valve, which joins the large and small intestine.
- Hepatopancreatic ampulla. The main pancreatic and bile ducts join at the duodenum to form the flasklike hepatopancreatic ampulla, literally, the ” liver-pancreatic-enlargement”.
- Duodenal papilla. From there, the bile and pancreatic juice travel through the duodenal papilla and enter the duodenum together.
- Microvilli. Microvilli are tiny projections of the plasma membrane of the mucosa cells that give the cell surface a fuzzy appearance, sometimes referred to as the brush border; the plasma membranes

bear enzymes (brush border enzymes) that complete the digestion of proteins and carbohydrates in the small intestine.

- Villi. Villi are fingerlike projections of the mucosa that give it a velvety appearance and feel, much like the soft nap of a towel.
- Lacteal. Within each villus is a rich capillary bed and a modified lymphatic capillary called a lacteal.
- Circular folds. Circular folds, also called plicae circulares, are deep folds of both mucosa and submucosa layers, and they do not disappear when food fills the small intestine.
- Peyer's patches. In contrast, local collections of lymphatic tissue found in the submucosa increase in number toward the end of the small intestine.

Large Intestine
The large intestine is much larger in diameter than the small intestine but shorter in length.

- Size. About 1.5 m (5 feet) long, it extends from the ileocecal valve to the anus.
- Functions. Its major functions are to dry out indigestible food residue by absorbing water and to eliminate these residues from the body as feces.
- Subdivisions. It frames the small intestines on three sides and has the following subdivisions: cecum, appendix, colon, rectum, and anal canal.
- Cecum. The saclike cecum is the first part of the large intestine.
- Appendix. Hanging from the cecum is the wormlike appendix, a potential trouble spot because it is an ideal location for bacteria to accumulate and multiply.
- Ascending colon. The ascending colon travels up the right side of the abdominal cavity and makes a turn, the right colic (or hepatic) flexure, to travel across the abdominal cavity.
- Transverse colon. The ascending colon makes a turn and continuous to be the transverse colon as it travels across the abdominal cavity.
- Descending colon. It then turns again at the left colic (or splenic) flexure, and continues down the left side as the descending colon.
- Sigmoid colon. The intestine then enters the pelvis, where it becomes the S-shaped sigmoid colon.
- Anal canal. The anal canal ends at the anus which opens to the exterior.
- External anal sphincter. The anal canal has an external voluntary sphincter, the external anal sphincter, composed of skeletal muscle.
- Internal involuntary sphincter. The internal involuntary sphincter is formed by smooth muscles.

Accessory Digestive Organs
Other than the intestines and the stomach, the following are also part of the digestive system:

Teeth
The role the teeth play in food processing needs little introduction; we masticate, or chew, by opening and closing our jaws and moving them from side to side while continuously using our tongue to move the food between our teeth.

- Function. The teeth tear and grind the food, breaking it down into smaller fragments.
- Deciduous teeth. The first set of teeth is the deciduous teeth, also called baby teeth or milk teeth, and they begin to erupt around 6 months, and a baby has a full set (20 teeth) by the age of 2 years.
- Permanent teeth. As the second set of teeth, the deeper permanent teeth, enlarge and develop, the roots of the milk teeth are reabsorbed, and between the ages of 6 to 12 years they loosen and fall out.
- Incisors. The chisel-shaped incisors are adapted for cutting.
- Canines. The fang like canines are for tearing and piercing.
- Premolars and molars. Premolars (bicuspids) and molars have broad crowns with round cusps (tips) and are best suited for grinding
- Crown. The enamel-covered crown is the exposed part of the tooth above the gingiva or gum
- Enamel. Enamel is the hardest substance in the body and is fairly brittle because it is heavily mineralized with calcium salts.

- Root. The outer surface of the root is covered by a substance called cementum, which attaches the tooth to the periodontal membrane (ligament).
- Dentin. Dentin, a bonelike material, underlies the enamel and forms the bulk of the tooth.
- Pulp cavity. It surrounds a central pulp cavity, which contains several structures (connective tissue, blood vessels, and nerve fibers) collectively called the pulp.
- Root canal. Where the pulp cavity extends into the root, it becomes the root canal, which provides a route for blood vessels, nerves, and other pulp structures to enter the pulp cavity of the tooth.

Tongue
The tongue is an accessory digestive organ of skeletal muscle covered with mucous membrane. Together with its associated muscles, it forms the oral cavity floor.

The tongue's upper surface and lateral surfaces are covered with papillae projections of the lamina propria covered with stratified squamous. Many papillae contain taste buds, the receptors for gustation (taste). Some papillae lack taste buds, but they contain receptors for touch and increase friction between the tongue and food, making it easier for the tongue to move food in the oral cavity.

Salivary Glands
The salivary gland is a gland that releases a secretion called saliva into the oral cavity. Saliva lubricates and dissolves foods and begins the chemical breakdown of carbohydrates and lipids.

Three pairs of salivary glands empty their secretions into the mouth.

- Parotid glands. The large parotid glands lie anterior to the ears and empty their secretions into the mouth.
- Submandibular and sublingual glands. The submandibular and sublingual glands empty their secretions into the floor of the mouth through tiny ducts
- Saliva. The product of the salivary glands, saliva, is a mixture of mucus and serous fluids.
- Salivary amylase. The clear serous portion contains an enzyme, salivary amylase, in a bicarbonate-rich juice that begins the process of starch digestion in the mouth.

Normally, parasympathetic stimulation promotes continuous secretion of a moderate amount of saliva. Facial (VII) and glossopharyngeal (IX) nerves stimulate the secretion of saliva. Saliva continues to be secreted heavily for some time after food is swallowed.

Pancreas
Only the pancreas produces enzymes that break down all categories of digestible foods.

- Location. The pancreas is a soft, pink triangular gland that extends across the abdomen from the spleen to the duodenum; but most of the pancreas lies posterior to the parietal peritoneum, hence its location is referred to as retroperitoneal.
- Pancreatic enzymes. The pancreatic enzymes are secreted into the duodenum in an alkaline fluid that neutralizes the acidic chyme coming in from the stomach.
- Endocrine function. The pancreas also has an endocrine function; it produces hormones insulin and glucagon.

Liver
The liver is the largest gland in the body.

- Location. Located under the diaphragm, more to the right side of the body, it overlies and almost completely covers the stomach.
- Falciform ligament. The liver has four lobes and is suspended from the diaphragm and abdominal wall by a delicate mesentery cord, the falciform ligament.

- Function. The liver's digestive function is to produce bile.
- Bile. Bile is a yellow-to-green, watery solution containing bile salts, bile pigments, cholesterol, phospholipids, and various electrolytes.
- Bile salts. Bile does not contain enzymes, but its bile salts emulsify fats by physically breaking large fat globules into smaller ones, thus providing more surface area for the fat-digesting enzymes to work on.
- Hepatocytes are major functional cells of the liver and perform a wide array of metabolic, secretory, and endocrine functions.
- Hepatocytes form complex three-dimensional arrangements called hepatic laminae.
- It is bordered on either side by the endothelial-lined vascular spaces called hepatic sinusoids.

Gallbladder

While in the gallbladder, bile is concentrated by the removal of water.

- Location. The gallbladder is a small, thin-walled green sac that snuggles in a shallow fossa in the inferior surface of the liver.
- Cystic duct. When food digestion is not occurring, bile backs up the cystic duct and enters the gallbladder to be stored.

Major Functions of the Liver and the Gallbladder

Carbohydrate metabolism -The liver is especially important in maintaining a **normal blood glucose level**

- blood glucose is low→ liver breakdown glycogen to glucose.
- blood glucose is high→ liver converts glucose to glycogen and triglycerides for storage.

Lipid metabolism

- Hepatocytes store some triglycerides; break down fatty acids to generate ATP; synthesize lipoproteins, which transport fatty acids, triglycerides, and cholesterol to and from body cells; synthesize cholesterol; and use cholesterol to make bile salts.

Protein metabolism

- Hepatocytes deaminate remove the amino group, NH2, from amino acids so that the amino acids. can then be used for ATP production or converted to carbohydrates or fats. The resulting toxic ammonia (NH3) is then converted into the much less toxic urea, excreted in urine. Processing of drugs and hormones

Processing of drugs and hormones

- The liver can detoxify substances such as alcohol and excrete drugs such as penicillin, erythromycin, and sulfonamides into bile. It can also chemically alter or excrete thyroid hormones and steroid hormones such as estrogens and aldosterone.

Excretion of bilirubin

- Bilirubin derived from the heme of the aged RBC → is absorbed by the liver from the blood and secreted into bile. Most of the bilirubin in bile is metabolized in the small intestine by bacteria and eliminated in feces.

Synthesis of bile salts

- Bile salts are used in the small intestine to emulsify and absorb lipids.

Storage.

- The liver is a prime storage site for certain vitamins (A, B,12,, D, E, and K) and minerals (iron and copper), which are released from the liver when needed elsewhere in the body.

Phagocytosis

- The stellate reticuloendothelial (Kupffer) cells of the liver phagocytize aged red blood cells, white blood cells, and some bacteria and some bacteria

Activation of vitamin D. The skin, liver, and kidneys participate in synthesizing the active form of vitamin D

Physiology of the Digestive System

Specifically, the digestive system takes in food (ingests it), breaks it down physically and chemically into nutrient molecules (digests it), and absorbs the nutrients into the bloodstream, then, it rids the body of indigestible remains (defecates).

Activities Occurring in the Mouth, Pharynx, and Esophagus

1. The activities that occur in the mouth, pharynx, and esophagus are food ingestion, food breakdown, and food propulsion.
2. Food Ingestion and Breakdown
   Once food is placed in the mouth, both mechanical and chemical digestion begin.

   - Physical breakdown. First, the food is physically broken down into smaller particles by chewing.
   - Chemical breakdown. Then, as the food is mixed with saliva, salivary amylase begins the chemical digestion of starch, breaking it down into maltose.
   - Stimulation of saliva. When food enters the mouth, much larger amounts of saliva pour out; however, the simple pressure of anything put into the mouth and chewed will also stimulate the release of saliva.
   - Passageways. The pharynx and the esophagus have no digestive function; they simply provide passageways to carry food to the next processing site, the stomach.

Food Propulsion – Swallowing and Peristalsis
For food to be sent on its way to the mouth, it must first be swallowed.

- Deglutition. Deglutition, or swallowing, is a complex process that involves the coordinated activity of several structures (tongue, soft palate, pharynx, and esophagus).
- Buccal phase of deglutition. The first phase, the voluntary buccal phase, occurs in the mouth; once the food has been chewed and well mixed with saliva, the bolus (food mass) is forced into the pharynx by the tongue.
- Pharyngeal-esophageal phase. The second phase, the involuntary pharyngeal-esophageal phase, transports food through the pharynx and esophagus; the parasympathetic division of the autonomic nervous system controls this phase and promotes the mobility of the digestive organs from this point on.
- Food routes. All routes that the food may take, except the desired route distal into the digestive tract, are blocked off; the tongue blocks off the mouth; the soft palate closes off the nasal passages; the larynx rises so that its opening is covered by the flaplike epiglottis.
- Stomach entrance. Once food reaches the distal end of the esophagus, it presses against the cardioesophageal sphincter, causing it to open, and food enters the stomach.

Activities of the Stomach

The activities of the stomach involve food breakdown and food propulsion.

1. Food Breakdown
   The sight, smell, and taste of food stimulate parasympathetic nervous system reflexes, which increase the secretion of gastric juice by the stomach glands
   - Gastric juice. Secretion of gastric juice is regulated by both neural and hormonal factors.
   - Gastrin. The presence of food and a rising pH in the stomach stimulate the stomach cells to release the hormone gastrin, which prods the stomach glands to produce still more of the protein-digesting enzymes (pepsinogen), mucus, and hydrochloric acid.
   - Pepsinogen. The extremely acidic environment that hydrochloric acid provides is necessary, because it activates pepsinogen to pepsin, the active protein-digesting enzyme.
   - Rennin. Rennin, the second protein-digesting enzyme produced by the stomach, works primarily on milk protein and converts it to a substance that looks like sour milk.
   - Food entry. As food enters and fills the stomach, its wall begins to stretch (at the same time as the gastric juices are being secreted).
   - Stomach wall activation. Then the three muscle layers of the stomach wall become active; they compress and pummel the food, breaking it apart physically, all the while continuously mixing the food with the enzyme-containing gastric juice so that the semifluid chyme is formed.

Food Propulsion
Peristalsis is responsible for the movement of food towards the digestive site until the intestines.

- Peristalsis. Once the food has been well mixed, a rippling peristalsis begins in the upper half of the stomach, and the contractions increase in force as the food approaches the pyloric valve.
- Pyloric passage. The pylorus of the stomach, which holds about 30 ml of chyme, acts like a meter that allows only liquids and very small particles to pass through the pyloric sphincter; and because the pyloric sphincter barely opens, each contraction of the stomach muscle squirts 3 ml or less of chyme into the small intestine.
- Enterogastric reflex. When the duodenum is filled with chyme and its wall is stretched, a nervous reflex, the enterogastric reflex, occurs; this reflex “puts the brakes on” gastric activity and slows the emptying of the stomach by inhibiting the vagus nerves and tightening the pyloric sphincter, thus allowing time for intestinal processing to catch up.

Activities of the Small Intestine
The activities of the small intestine are food breakdown and absorption and food propulsion.

1. Food Breakdown and Absorption
   Food reaching the small intestine is only partially digested.
   - Digestion. Food reaching the small intestine is only partially digested; carbohydrate and protein digestion has begun, but virtually no fats have been digested up to this point.
   - Brush border enzymes. The microvilli of small intestine cells bears a few important enzymes, the so-called brush border enzymes, that break down double sugars into simple sugars and complete protein digestion.
   - Pancreatic juice. Foods entering the small intestine are literally deluged with enzyme-rich pancreatic juice ducted in from the pancreas, as well as bile from the liver; pancreatic juice contains enzymes that, along with brush border enzymes, complete the digestion of starch, carry out about half of the protein digestion, and are totally responsible for fat digestion and digestion of nucleic acids.
   - Chyme stimulation. When chyme enters the small intestine, it stimulates the mucosa cells to produce several hormones; two of these are secretin and cholecystokinin which influence the release of pancreatic juice and bile.
   - Absorption. Absorption of water and of the end products of digestion occurs all along the length of the small intestine; most substances are absorbed through the intestinal cell plasma membranes by the process of active transport.

- Diffusion. Lipids or fats are absorbed passively by the process of diffusion.
- Debris. At the end of the ileum, all that remains are some water, indigestible food materials, and large amounts of bacteria; this debris enters the large intestine through the ileocecal valve.

2. Food Propulsion
   Peristalsis is the major means of propelling food through the digestive tract.
   - Peristalsis. The net effect is that the food is moved through the small intestine in much the same way that toothpaste is squeezed from the tube.
   - Constrictions. Rhythmic segmental movements produce local constrictions of the intestine that mix the chyme with the digestive juices, and help to propel food through the intestine.

Activities of the Large Intestine
The activities of the large intestine are food breakdown and absorption and defecation.

1. Food Breakdown and Absorption
   What is finally delivered to the large intestine contains few nutrients, but that residue still has 12 to 24 hours more to spend there.
   - Metabolism. The “resident” bacteria that live in its lumen metabolize some of the remaining nutrients, releasing gases (methane and hydrogen sulfide) that contribute to the odor of feces.
   - Flatus. About 50 ml of gas (flatus) is produced each day, much more when certain carbohydrate-rich foods are eaten.
   - Absorption. Absorption by the large intestine is limited to the absorption of vitamin K, some B vitamins, some ions, and most of the remaining water.
   - Feces. Feces, the more or less solid product delivered to the rectum, contains undigested food residues, mucus, millions of bacteria, and just enough water to allow their smooth passage.

2. Propulsion of the Residue and Defecation
   When presented with residue, the colon becomes mobile, but its contractions are sluggish or short-lived.
   - Haustral contractions. The movements most seen in the colon are haustral contractions, slow segmenting movements lasting about one minute that occur every 30 minutes or so.
   - Propulsion. As the haustrum fills with food residue, the distension stimulates its muscle to contract, which propels the luminal contents into the next haustrum.
   - Mass movements. Mass movements are long, slow-moving, but powerful contractile waves that move over large areas of the colon three or four times daily and force the contents toward the rectum.
   - Rectum. The rectum is generally empty, but when feces are forced into it by mass movements and its wall is stretched, the defecation reflex is initiated.
   - Defecation reflex. The defecation reflex is a spinal (sacral region) reflex that causes the walls of the sigmoid colon and the rectum to contract and anal sphincters to relax.
   - Impulses. As the feces is forced into the anal canal, messages reach the brain giving us time to make a decision as to whether the external voluntary sphincter should remain open or be constricted to stop passage of feces.
   - Relaxation. Within a few seconds, the reflex contractions end and rectal walls relax; with the next mass movement, the defecation reflex is initiated again

NUTRITION AND METABOLISM

In terms of Transport Processes involved:

1. most nutrients are absorbed by active transport eg. glucose amino acids some minerals
2. some lipids are absorbed by diffusion to lacteals eg. fats fat soluble vitamins
3. water is absorbed by osmosis
4. large molecules are absorbed by pinocytosis eg. a few large fats and proteins passed to lacteals

CARBOHYDRATES DIGESTION AND ABSORPTION

Glucose, galactose, and fructose are the three monosaccharides that are commonly consumed and are readily absorbed. Your digestive system is also able to break down the disaccharide sucrose (regular table sugar: glucose + fructose), lactose (milk sugar: glucose + galactose), and maltose (grain sugar: glucose + glucose), and the polysaccharides glycogen and starch (chains of monosaccharides). Your bodies do not produce enzymes that can break down most fibrous polysaccharides, such as cellulose.

When it comes to absorption, all carbohydrates are absorbed in the form of monosaccharides. The small intestine is highly efficient at this, absorbing monosaccharides at an estimated rate of 120 grams per hour. All normally digested dietary carbohydrates are absorbed; indigestible fibers are eliminated in the feces. The monosaccharides glucose and galactose are transported into the epithelial cells by common protein carriers via secondary active transport (that is, co-transport with sodium ions). The monosaccharides leave these cells via facilitated diffusion and enter the capillaries through intercellular clefts. The monosaccharide fructose (which is in fruit) is absorbed and transported by facilitated diffusion alone. The monosaccharides combine with the transport proteins immediately after the disaccharides are broken down.

PROTEIN DIGESTION AND ABSORPTION

Proteins are polymers composed of amino acids linked by peptide bonds to form long chains. Digestion reduces them to their constituent amino acids. You usually consume about 15 to 20 percent of your total calorie intake as protein. The digestion of protein starts in the stomach, where HCl and pepsin break proteins into smaller polypeptides, which then travel to the small intestine. Chemical digestion in the small intestine is continued by pancreatic enzymes, including chymotrypsin and trypsin, which act on specific bonds in amino acid sequences. At the same time, the brush border cells secrete enzymes such as aminopeptidase and dipeptidase, which further break down peptide chains. This results in molecules small enough to enter the bloodstream.

Absorption of most proteins uses active transport mechanisms, primarily in the duodenum and jejunum, as their breakdown products, amino acids. Almost all (95 to 98 percent) protein is digested and absorbed in the small intestine. The type of carrier that transports an amino acid varies. Most carriers are linked to the active transport of sodium. Short chains of two amino acids (dipeptides) or three amino acids (tripeptides) are also transported actively. However, after they enter the absorptive epithelial cells, they are broken down into their amino acids before leaving the cell and entering the capillary blood via diffusion.

LIPID DIGESTION AND ABSORPTION

A healthy diet limits lipid intake to 35 percent of total calorie intake. The most common dietary lipids are triglycerides, which are made up of a glycerol molecule bound to three fatty acid chains. Small amounts of dietary cholesterol and phospholipids are also consumed. The three lipases responsible for lipid digestion are lingual lipase, gastric lipase, and pancreatic lipase.

However, because the pancreas is the only consequential source of lipase, virtually all lipid digestion occurs in the small intestine. Pancreatic lipase breaks down each triglyceride into two free fatty acids and a monoglyceride. The fatty acids include both short-chain (less than 10 to 12 carbons) and long-chain fatty acids.

About 95 percent of lipids are absorbed in the small intestine. Bile salts not only speed up lipid digestion, they are also essential to the absorption of the end products of lipid digestion. Short-chain fatty acids are relatively water soluble and can enter the absorptive cells (enterocytes) directly. The small size of short-chain fatty acids enables them to be absorbed by enterocytes via simple diffusion and then take the same path as monosaccharides and amino acids into the blood capillary of a villus. The large and hydrophobic long-chain fatty acids and monoacylglycerides are not so easily suspended in the watery intestinal chyme. However, bile salts and lecithin resolve this issue by enclosing them in a micelle, which is a tiny sphere with polar (hydrophilic) ends facing the watery environment and hydrophobic tails turned to the interior, creating a receptive environment for the long-chain fatty acids. The core also includes cholesterol and fat-soluble vitamins. Without micelles, lipids would sit on the surface of chyme and never come in contact with the absorptive surfaces of the epithelial cells. Micelles can easily squeeze between microvilli and get very near the luminal cell surface. At this point, lipid substances exit the micelle and are absorbed via simple diffusion. The free fatty acids and monoacylglycerides that enter the epithelial cells are reincorporated into triglycerides. The triglycerides are mixed with phospholipids and cholesterol, and surrounded with a protein coat. This new complex, called a chylomicron, is a water-soluble lipoprotein. After being processed by the Golgi apparatus, chylomicrons are released from the cell. Too big to pass through the basement membranes of blood capillaries, chylomicrons instead enter the large pores of lacteals. The lacteals come together to form the lymphatic vessels. The chylomicrons are transported in the lymphatic vessels and empty through the thoracic duct into the subclavian vein of the circulatory system. Once in the bloodstream, the enzyme lipoprotein lipase breaks down the triglycerides of the chylomicrons into free fatty acids and glycerol. These breakdown products then pass through capillary walls to be used for energy by cells or stored in adipose tissue as fat. Liver cells combine the remaining chylomicron remnants with proteins, forming lipoproteins that transport cholesterol in the blood.

METABOLISM

The sum of all of the chemical reactions that are involved in catabolism and anabolism - reactions governing the breakdown of food to obtain energy are called catabolic reactions, while anabolic reactions use the energy produced by catabolic reactions to synthesize larger molecules from smaller ones, such as when the body forms proteins by stringing together amino acids.

Both sets of reactions are critical to maintaining life. Because catabolic reactions produce energy and anabolic reactions use energy, ideally, energy usage would balance the energy produced. If the net energy change is positive (catabolic reactions release more energy than the anabolic reactions use), then the body stores the excess energy by building fat molecules for long-term storage. On the other hand, if the net energy change is negative (catabolic reactions release less energy than anabolic reactions use), the body uses stored energy to compensate for the deficiency of energy released by catabolism.

During Catabolic Reactions, ATP is created and energy is stored until needed during anabolic reactions. The energy from ATP drives all bodily functions, such as contracting muscles, maintaining the electrical potential of nerve cells, and absorbing food in the gastrointestinal tract. The metabolic reactions that produce ATP come from various sources. During these reactions, proteins are broken down into amino acids, lipids are broken down into fatty acids, and polysaccharides are broken down into monosaccharides. These building blocks are then used for the synthesis of molecules in anabolic reactions.

Of the macronutrients or macromolecular groups (carbohydrates, lipids, proteins, and nucleic acids), carbohydrates are considered the most common source of energy to fuel the body.
They take the form of either complex carbohydrates, polysaccharides like starch and glycogen, or simple sugars (monosaccharides) like glucose and fructose. Sugar catabolism breaks polysaccharides down into their individual monosaccharides. Among the monosaccharides, glucose is the most common fuel for ATP production in cells, and as such, there are a number of endocrine control mechanisms to regulate glucose concentration in the bloodstream. Excess glucose is either stored as an energy reserve in the liver and skeletal muscles as the complex polymer glycogen, or it is converted into fat (triglyceride) in adipose cells (adipocytes). Among the lipids (fats), triglycerides are most often used for energy via a metabolic process called β-oxidation. About onehalf of excess fat is stored in adipocytes that accumulate in the subcutaneous tissue under the skin, whereas the rest is stored in adipocytes in other tissues and organs. Proteins, which are polymers, can be broken down into their monomers, individual amino acids. Amino acids can be used as building blocks of new proteins or broken down further for the production of ATP. When one is chronically starving, this use of amino acids for energy production can lead to a wasting away of the body, as more and more proteins are broken down. Nucleic acids are present in most of the foods you eat. During digestion, nucleic acids including DNA and various RNAs are broken down into their constituent nucleotides. These nucleotides are readily absorbed and transported throughout the body to be used by individual cells during nucleic acid metabolism.

In contrast to catabolic reactions, **anabolic reactions or anabolism** involve the joining of smaller molecules into larger ones. Anabolic reactions combine monosaccharides to form polysaccharides, fatty acids to form triglycerides, amino acids to form proteins, and nucleotides to form nucleic acids. These processes require energy in the form of ATP molecules generated by catabolic reactions. Anabolic reactions, also called biosynthesis reactions, create new molecules that form new cells and tissues, and revitalize organs.

Activity 1. The Food Journey 1. Watch the short video on what happens to the food once it enters the mouth and goes to your intestines. Click this link for the video. 2. Answer the following questions in the discussion forum: a. How the food changes consistency and form? b. How could the body absorb the nutrients from the foods we eat? Choose one of the following to answer the question a. Carbohydrates digestion and absorption b. Protein digestion and absorption c. Lipid Digestion and absorption Short video: https://www.youtube.com/watch?v=Oh_Pt_UrtEE

Activity 2. Laboratory Activity To supplement your learning from the resources above, please answer the laboratory worksheets on DIGESTIVE SYSTEM and submit it in the designated submission bin.

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