

## Chapter 14: Digestive system and body metabolism

- I. The digestive system functions
  - A. Ingestion - taking in food
  - B. Digestion - breaking food down both physically and chemically
  - C. Absorption - movement of nutrients into the bloodstream
  - D. Defecation- rids the body of indigestible waste
- II. Organs of the digestive system
  - A. Two main groups
    1. Alimentary canal (gastrointestinal GI tract) continuous coiled hollow tube
    2. Accessory digestive organs
  - B. Organs of the alimentary canal
    1. Mouth
      - a. Lips (labia) protect the anterior opening
      - b. Cheeks- form lateral walls
      - c. Hard palate- forms the anterior roof
      - d. Soft palate- forms the posterior roof
      - e. Uvula- fleshy projection of the soft palate
      - f. Vestibule- space between lips externally and teeth and gums internally
      - g. Oral cavity proper- area contained by the teeth
      - h. Tongue- attached at hyoid bone and styloid processes of the skull, and by the lingual frenulum to the floor of the mouth
      - i. Tonsils
        - 1) Palatine
        - 2) Lingual
      - j. Mouth physiology
        - 1) Mastication (chewing) of food
        - 2) Mixing masticated food with saliva
        - 3) Initiation of swallowing by the tongue
        - 4) Allows for the sense of taste
    2. Pharynx
      - a. Nasopharynx- not part of the digestive system
      - b. Oropharynx- posterior to oral cavity
      - c. Laryngopharynx- below the oropharynx and connected to the esophagus
      - d. Pharynx physiology
        - 1) Serves as a passageway for air and food
        - 2) Food is propelled to the esophagus by two muscle layers
          - a. Longitudinal inner layer
          - b. Circular outer layer
        - 3) Food movement is by alternating contractions of the muscle layers (peristalsis)

### 3. Esophagus

#### a. Anatomy

- 1) About 10 inches long
- 2) Runs from pharynx to stomach through the diaphragm

#### b. Physiology

- 1) Conducts food by peristalsis (slow rhythmic squeezing)
- 2) Passageway for food only (respiratory system branches off after the pharynx)

### 4. Stomach

#### a. Stomach anatomy

- 1) Located on the left side of the abdominal cavity
- 2) Food enters at the cardioesophageal sphincter
- 3) Food empties into the small intestine at the pyloric sphincter (valve)
- 4) Regions of the stomach
  - a) Cardiac region- near the heart
  - b) Fundus- expanded portion lateral to the cardiac region
  - c) Body- midportion
  - d) Pylorus- funnel-shaped terminal end
- 5) Rugae- internal folds of the mucosa
- 6) External regions
  - a) Lesser curvature- concave medial surface
  - b) Greater curvature- convex later surface
- 7) Layers of peritoneum attached to the stomach
  - a) Lesser omentum- attaches the liver to the lesser curvature
  - b) Greater omentum- attaches the greater curvature to the posterior body wall
    - i. Contains fat to insulate, cushion, and protect abdominal organs
    - ii. Has lymph nodules containing macrophages

#### b. Stomach physiology

- 1) Temporary storage tank for food
- 2) Site of food breakdown
- 3) Chemical breakdown of protein begins
- 4) Delivers chyme (processed food) to the small intestine

#### c. Structure of the stomach mucosa

- 1) Mucosa is simple columnar epithelium
- 2) Mucous neck cells- produce a sticky alkaline mucus
- 3) Gastric glands- produce protein-digesting enzymes (pepsinogens)
- 4) Parietal cells- produce hydrochloric acid

5) Enteroendocrine cells- produce gastrin

5. Small intestine

- a. The body's major digestive organ
- b. Site of nutrient absorption into the blood
- c. Muscular tube extending from the pyloric sphincter to the ileocecal valve
- d. Suspended from the posterior abdominal wall by the mesentery
- e. Subdivisions of the small intestine
  - 1) Duodenum
    - a) Attached to the stomach
    - b) Curves around the head of the pancreas
  - 2) Jejunum
    - a) Attaches anteriorly to the duodenum
  - 3) Ileum
    - a) Extends from jejunum to large intestine
- f. Chemical digestion in the small intestine
  - 1) Chemical digestion begins at the small intestine
    - a) Enzymes are produced by
      - i. Intestinal cells
      - ii. Pancreas- pancreatic ducts carry enzymes to the small intestine
  - 2) Bile, formed by the liver, enters via the bile duct
- g. Small intestine anatomy
  - 1) Three structural modifications that increase surface area
    - a) Microbilli- tiny projections of the plasma membrane (create a brush border appearance)
    - b) Villi- fingerlike structures formed by the mucosa
    - c) Circular folds (plicae circulares)- deep folds of mucosa and submucosa

6. Large intestine

- a. Larger in diameter, but shorter in length, than the small intestine
- b. Frames the internal abdomen
- c. Large intestine anatomy
  - 1) Cecum- saclike first part of the large intestine
  - 2) Appendix
    - a) Accumulation of lymphatic tissue that sometimes becomes inflamed (appendicitis)
    - b) Hangs from the cecum
  - 3) Colon
    - a) Ascending- travels up right side of abdomen
    - b) Transverse- travels across the abdominal cavity
    - c) Descending- travels down the left side

- d) Sigmoid- enters the pelvis
      - i. Rectum and anal canal- also in pelvis
    - d. No villi present
    - e. Goblet cells produce alkaline mucus which lubricates the passage for feces
    - f. Muscularis externa layer is reduced to three bands of muscle called teniae coli
    - g. These bands cause the wall to pucker into haustra (pocketlike sacs)
  - 7. Anus- opening of the large intestine
    - a. External anal sphincter- formed by skeletal muscle and under voluntary control
    - b. Internal involuntary sphincter- formed by smooth muscle
    - c. These sphincters are normally closed except during defecation
- C. Layers of alimentary canal organs
  - 1. Four layers
    - a. Mucosa
      - 1) Innermost, moist membrane consisting of:
        - a) Surface epithelium
        - b) Small amount of connective tissue (lamina propria)
        - c) Small smooth muscle layer
    - b. Submucosa
      - 1) Just beneath the mucosa
      - 2) Soft connective tissue with blood vessels, nerve endings, and lymphatics
    - c. Muscularis externa- smooth muscle
      - 1) Inner circular layer
      - 2) Outer longitudinal layer
    - d. Serosa- outermost layer of the wall
      - 1) Visceral peritoneum- outermost layer that is continuous with the innermost layer
      - 2) Parietal peritoneum- innermost layer that lines the abdominopelvic cavity
- D. Alimentary canal nerve plexuses
  - 1. Two important nerve plexuses serve the alimentary canal
  - 2. Both are part of the autonomic nervous system
    - a. Submucosal nerve plexus
    - b. Myenteric nerve plexus
  - 3. Function is to regulate motility and secretory activity of the GI tract organs
- E. Accessory digestive organs
  - 1. Teeth
    - a. Function to masticate (chew) food
    - b. Humans have two sets of teeth

- 1) Deciduous (baby or "milk") teeth
  - 2) 20 teeth are fully formed by age 2
  - c. Permanent teeth
    - 1) Replace deciduous teeth between ages of 6-12
    - 2) A full set is 32 teeth, but some people do not have wisdom teeth (third molars)
    - 3) If they do emerge, the wisdom teeth appear between ages of 17-25
  - d. Classification of teeth
    - 1) Incisors- cutting
    - 2) Canines- tearing or piercing
    - 3) Premolars- grinding
    - 4) Molars- grinding
  - e. Regions of a tooth
    - 1) Crown- exposed part
      - a) Enamel- hardest substance in the body
      - b) Dentin- found deep to the enamel and forms the bulk of the tooth
      - c) Pulp cavity- contains connective tissue, blood vessels, and nerve fibers
      - d) Root canal- where the pulp cavity extends to the root
    - 2) Neck
      - a) Region in contact with the gum
      - b) Connects crown to root
    - 3) Root
      - a) Cementum- covers outer surface and attaches the tooth to the periodontal membrane
2. Salivary glands
- a. Three pairs of salivary glands empty secretions into the mouth
    - 1) Parotid glands
    - 2) Submandibular glands
    - 3) Sublingual glands
  - b. Saliva
    - 1) Mixture of mucus and serous fluids
    - 2) Helps to form a food bolus
    - 3) Contains salivary amylase to begin starch digestion
    - 4) Dissolves chemicals so they can be tasted
3. Pancreas
- a. Found posterior to the parietal peritoneum
  - b. Extends across the abdomen from spleen to duodenum
  - c. Produces a wide spectrum of digestive enzymes that break down all categories of food

- d. Enzymes are secreted into the duodenum
- e. Alkaline fluid introduced with enzymes neutralizes acidic chyme coming from stomach
- f. Hormones produced by the pancreas
  - 1) Insulin
  - 2) Glucagon

#### 4. Liver

- a. Largest gland in the body
- b. Located on the right side of the body under the diaphragm
- c. Consists of four lobes suspended from the diaphragm and abdominal wall by the falciform ligament
- d. Connected to the gallbladder via the common hepatic duct
- e. Bile
  - 1) Produced by cells in the liver
  - 2) Composition is:
    - a) Bile salts
    - b) Bile pigments (mostly bilirubin from the breakdown of hemoglobin)
    - c) Cholesterol
    - d) Phospholipids
    - e) Electrolytes
  - 3) Function- emulsify fats by physically breaking large fat globules into smaller ones

#### 5. Gallbladder

- a. Sac found in hollow fossa of liver
- b. When no digestion is occurring, bile backs up the cystic duct for storage in the gallbladder
- c. When digestion of fatty food is occurring, bile is introduced into the duodenum from the gallbladder
- d. Gallstones are crystallized cholesterol which can cause blockages

#### F. Functions of the digestive system

- 1. Ingestion- getting food into the mouth
- 2. Propulsion- moving foods from one region of the digestive system to another
  - a. Peristalsis- alternating waves of contraction and relaxation that squeezes food along the GI tract
  - b. Segmentation- moving materials back and forth to aid with mixing in the small intestine
- 3. Food breakdown as mechanical digestion
  - a. Examples:
    - 1) Mixing food in the mouth by the tongue
    - 2) Churning food in the stomach
    - 3) Segmentation in the small intestine

- b. Mechanical digestion prepares food for further degradation by enzymes
  - 4. Food breakdown as chemical digestion
    - a. Enzymes breakdown food molecules into their building blocks
    - b. Each major food group uses different enzymes
      - 1) Carbohydrates are broken to simple sugars
      - 2) Proteins are broken to amino acids
      - 3) Fats are broken to fatty acids and alcohols
  - 5. Absorption
    - a. End products of digestion are absorbed in the blood or lymph
    - b. Food must enter mucosal cells and then into blood or lymph capillaries
  - 6. Defecation
    - a. Elimination of indigestible substances from the GI tract in the form of feces
- G. Control of digestive activity
  - 1. Mostly controlled by reflexes via the parasympathetic division
  - 2. Chemical and mechanical receptors are located in organ walls that trigger reflexes
  - 3. Stimuli include
    - a. Stretch of the organ
    - b. pH of the contents
    - c. Presence of breakdown products
  - 4. Reflexes include
    - a. Activation or inhibition of glandular secretions
    - b. Smooth muscle activity
- H. Digestive activities of the mouth
  - 1. Mechanical breakdown
    - a. Food is physically broken down by chewing
  - 2. Chemical digestion
    - a. Food is mixed with saliva
    - b. Starch is broken down into maltose by salivary amylase
- I. Activities of the pharynx and esophagus
  - 1. These organs have no digestive function
  - 2. Serve as passageways to the stomach
- J. Deglutition (swallowing)
  - 1. Buccal phase
    - a. Voluntary
    - b. Occurs in the mouth
    - c. Food is formed into a bolus
    - d. The bolus is forced into the pharynx by the tongue
  - 2. Pharyngeal- esophageal phase
    - a. Involuntary transport of the bolus
    - b. All passageways except to the stomach are blocked

- 1) Tongue blocks off the mouth
  - 2) Soft palate (uvula) blocks the nasopharynx
  - 3) Epiglottis blocks the larynx
  - c. Peristalsis moves the bolus toward the stomach
  - d. The cardioesophageal sphincter is opened when food presses against it
- K. Food breakdown in the stomach
1. Gastric juice is regulated by neural and hormonal factors
  2. Presence of food or rising pH causes the release of the hormone gastrin
  3. Gastrin causes stomach glands to produce
    - a. Protein-digesting enzymes
    - b. Mucus
    - c. Hydrochloric acid
  4. Hydrochloric acid makes the stomach contents very acidic
    - a. Acidic pH
      - 1) Activates pepsinogen to pepsin for protein digestion
      - 2) Provides a hostile environment for microorganisms
- L. Digestion and absorption in the stomach
1. Protein digestion enzymes
    - a. Pepsin- an active protein-digesting enzyme
    - b. Rennin- works on digesting milk protein in infants, not adults
  2. Alcohol and aspirin are the only items absorbed in the stomach
- M. Propulsion in the stomach
1. Food must first be well mixed
  2. Rippling peristalsis occurs in the lower stomach
  3. The pylorus meters out chyme into the small intestine (30 mL at a time)
  4. The stomach empties in 4-6 hours
- N. Digestion in the small intestine
1. Enzymes from the brush border function to
    - a. Break double sugars into simple sugars
    - b. Complete some protein digestion
  2. Pancreatic enzymes play the major digestive function
    - a. Help complete digestion of starch (pancreatic amylase)
    - b. Carry out about half of all protein digestion
    - c. Digest fats using lipases from the pancreas
    - d. Digest nucleic acids using nucleases
  3. Alkaline content neutralizes acidic chyme
- O. Regulation of pancreatic juice secretion
1. Release of pancreatic juice into the duodenum is stimulated by
    - a. Vagus nerve
    - b. Local hormones
      - 1) Hormones travel the blood to stimulate the pancreas to release enzyme- and bicarbonate-rich product

- 2) Secretin- causes the liver to increase bile output
- 3) Cholecystokinin (CCK) causes the gallbladder to release stored bile
  - a) Bile is necessary for fat absorption of fat-soluble vitamins (K, D, A)

P. Absorption in the small intestine

1. Water is absorbed along the length of the small intestine
2. End products of digestion
  - a. Most substances are absorbed by active transport through cell membranes
  - b. Lipids are absorbed by diffusion
3. Substances are transported to the liver by the hepatic portal vein or lymph

Q. Propulsion in the small intestine

1. Peristalsis is the major means of moving food
2. Segmental movements
  - a. Mix chyme with digestive juices
  - b. Aid in propelling food

R. Food breakdown and absorption in the large intestine

1. No digestive enzymes are produced
2. Resident bacteria digest remaining nutrients
  - a. Produce some vitamin K and B
  - b. Release gases
3. Water and vitamins K and B are absorbed
4. Remaining materials are eliminated via feces
5. Feces contains
  - a. Undigested food residues
  - b. Mucus
  - c. Bacteria
  - d. Water

S. Propulsion in the large intestine

1. Sluggish peristalsis
2. Mass movements
  - a. Slow, powerful movements
  - b. Occur three to four times per day
3. Presence of feces in the rectum causes defecation reflex
  - a. Internal anal sphincter is relaxed
  - b. Defecation occurs with relaxation of the voluntary (external) anal sphincter

III. Nutrition

- A. Nutrient- substance used by the body for growth, maintenance, and repair
- B. Major nutrients
  1. Carbohydrates

2. Lipids
3. Proteins
4. Water
- C. Minor nutrients
  1. Minerals
  2. Vitamins
- D. Five basic food groups and some of their major nutrients
  1. Dietary sources of major nutrients
    - a. Carbohydrates
      - 1) Most are derived from plants
      - 2) Exceptions: lactose from milk and small amounts of glycogens from meats
    - b. Lipids
      - 1) Saturated fats from animal products
      - 2) Unsaturated fats from nuts, seeds, and vegetable oils
      - 3) Cholesterol from egg yolk, meats, and milk products
    - c. Proteins
      - 1) Complete proteins- contain all essential amino acids
        - a) Most are from animal products
      - 2) Legumes and beans also have proteins, but are incomplete
    - d. Vitamins
      - 1) Most vitamins are used as coenzymes
      - 2) Found in all major food groups
    - e. Minerals
      - 1) Play many roles in the body
      - 2) Most mineral-rich foods are vegetables, legumes, milk and some meats

#### IV. Metabolism

- A. Chemical reactions necessary to maintain life
  1. Catabolism- substances are broken down into simpler substances; energy is released
  2. Anabolism- larger molecules are built from smaller ones
- B. Carbohydrate metabolism
  1. Carbohydrates are the body's preferred source to produce cellular energy (ATP)
  2. Glucose (blood sugar) is the major breakdown product and fuel to make ATP
- C. Cellular respiration
  1. Oxygen-using events take place within the cell to create ATP from ADP
  2. Carbon leaves cells as carbon dioxide (CO<sub>2</sub>)
  3. Hydrogen atoms are combined with oxygen to form water
  4. Energy produced by these reactions adds a phosphorus to ADP to produce ATP
  5. ATP can be broken down to release energy for cellular use
- D. Metabolic pathways involved in cellular respiration

1. Glycolysis- energizes a glucose molecule so it can be split into two pyruvic acid molecules and yield ATP
  2. Krebs cycle
    - a. Produces virtually all the carbon dioxide and water resulting from cellular respiration
    - b. Yields a small amount of ATP
  3. Electron transport chain
    - a. Hydrogen atoms removed during glycolysis and the Krebs cycle are delivered to protein carriers
    - b. Hydrogen is split into hydrogen ions and electrons in the mitochondria
    - c. Electrons give off energy in a series of steps to enable the production of ATP
- E. Metabolism of carbohydrates
1. Hyperglycemia- excessively high levels of glucose in the blood
    - a. Excess glucose is stored in body cells as glycogen
    - b. If blood glucose levels are still too high, excesses are converted to fat
  2. Hypoglycemia- low levels of glucose in the blood
    - a. Liver breaks down stored glycogen and releases glucose into the blood
- F. Fat metabolism
1. Handled mostly by the liver
    - a. Uses some fats to make ATP
    - b. Synthesizes lipoproteins, thromboplastin, and cholesterol
    - c. Releases breakdown products to the blood
  2. Body cells remove fat and cholesterol to build membranes and steroid hormones
  3. Fats must first be broken down to acetic acid
  4. Within mitochondria, acetic acid is completely oxidized to produce water, carbon dioxide, and ATP
  5. Acidosis (ketoacidosis) results from incomplete fat oxidation in which acetoacetic acid and acetone accumulate in the blood
    - a. Breath has a fruity odor
    - b. Common with:
      - 1) "No carbohydrate" diets
      - 2) Uncontrolled diabetes mellitus
      - 3) Starvation
- G. Protein metabolism
1. Proteins are conserved by body cells because they are used for most cellular structures
  2. Ingested proteins are broken down to amino acids
  3. Cells remove amino acids to build proteins
    - a. Synthesized proteins are actively transported across cell membranes

4. Amino acids are used to make ATP only when proteins are overabundant or there is a shortage of other sources
  5. Production of ATP from protein
    - a. Amine groups are removed from proteins as ammonia
    - b. The rest of the protein molecule enters the Krebs cycle in mitochondria
    - c. The liver converts harmful ammonia to urea which can be eliminated in urine
- H. Role of the liver in metabolism
1. Several roles in digestion
    - a. Manufacture bile
    - b. Detoxifies drugs and alcohol
    - c. Degrades hormones
    - d. Produces cholesterol, blood proteins (albumin and clotting proteins)
    - e. Plays a central role in metabolism
  2. Can regenerate if part of it is damaged or removed
  3. Metabolic functions of the liver
    - a. Glycogenesis- "glycogen formation"
      - 1) Glucose molecules are converted into glycogen
      - 2) Glycogen molecules are stored in the liver
    - b. Glycogenolysis- "glucose splitting"
      - 1) Glucose is released from the liver after conversion from glycogen
    - c. Gluconeogenesis- "formation of new sugar"
      - 1) Glucose is produced from fats and proteins
    - d. Fats and fatty acids are picked up by the liver
      - 1) Some are oxidized to provide energy for liver cells
      - 2) The rest are broken down into simpler compounds and released into the blood
    - e. Cholesterol metabolism
      - 1) Cholesterol is not used to make ATP
      - 2) Functions of cholesterol
        - a) Serves as a structural basis of steroid hormones and vitamin D
        - b) Is a major building block of plasma membranes
      - 3) Most cholesterol is produced in the liver (85%) and is not from diet (15%)
    - f. Cholesterol transport
      - 1) Cholesterol and fatty acids cannot freely circulate in the bloodstream
      - 2) They are transported by lipoproteins (lipid-protein complexes)
      - 3) Low-density lipoproteins (LDLs) transport to body cells
      - 4) Rated "bad lipoproteins" since they can lead to atherosclerosis

5) High-density lipoproteins (HDLs) transport from body cells to the liver

- I. Body energy balance
  - 1. Energy intake = total energy output
    - a. (heat + work + energy storage)
  - 2. Energy intake is liberated during food oxidation
  - 3. Energy output
    - a. Heat is usually about 60%
    - b. Storage energy is in the form of fat or glycogen
- J. Regulation of food intake
  - 1. Body weight is usually relatively stable
    - a. Energy intake and output remain about equal
  - 2. Mechanisms that may regulate food intake
    - a. Levels of nutrients in the blood
    - b. Hormones
    - c. Body temperature
    - d. Psychological factors
- K. Metabolic rate and body heat production
  - 1. Basic metabolic rate (BMR)- amount of heat produced by the body per unit of time at rest
  - 2. Average BMR is about 60-72 kcal/hour
  - 3. Kilocalorie (kcal) is the unit of measure for the energy value of foods and the amount of energy used by the body
- L. Metabolic rate and body heat production
  - 1. Factors that influence BMR
    - a. Surface area- a small body usually has a higher BMR
    - b. Gender- males tend to have higher BMR's
    - c. Age- children and adolescents have higher BMR's
    - d. The amount of thyroxine produced is the most important control factor
      - 1) More thyroxine means a higher metabolic rate
  - 2. Factors determining BMR
  - 3. Total metabolic rate (TMR)
    - a. Total amount of kilocalories the body must consume to fuel ongoing activities
    - b. TMR increases with an increase in body activity
    - c. TMR must equal calories consumed to maintain homeostasis and maintain a constant weight
- M. Body temperature regulation
  - 1. Most energy is released as foods are oxidized
  - 2. Most energy escapes as heat
  - 3. The body has a narrow range of homeostatic temperature
    - a. Must remain between 35.6°C to 37.8°C (96°F to 100°F)

- b. The body's thermostat is in the hypothalamus
          - 1) Initiated heat-loss or heat-promoting mechanisms
  - 4. Heat-promoting mechanisms
    - a. Vasoconstriction of blood vessels
      - 1) Blood is rerouted to deeper, more vital body organs
    - b. Shivering- contraction of muscles produces heat
  - 5. Heat-loss mechanisms
    - a. Heat loss from the skin via radiation and evaporation
      - 1) Skin blood vessels and capillaries are flushed with warm blood
      - 2) Evaporation of perspiration cools the skin
  - 6. Fever- controlled hyperthermia
    - a. Results from infection, cancer, allergic reactions, CNS injuries
    - b. If the body thermostat is set too high, body proteins may be denatured and permanent brain damage may occur
- N. Developmental aspects of the digestive system
  - 1. The alimentary canal is a continuous tube by the fifth week of development
  - 2. Digestive glands bud from the mucosa of the alimentary tube
  - 3. The developing fetus receives all nutrients through the placenta
  - 4. In newborns, feeding must be frequent, peristalsis is inefficient, and vomiting is common
- V. Developmental aspects of the digestive system
  - A. Newborn reflexes
    - 1. Rooting reflex helps the infant find the nipple
    - 2. Sucking reflex helps the infant hold onto the nipple and swallow
  - B. Teething begins around 6 months of age
  - C. Problems of the digestive system
    - 1. Gastroenteritis- inflammation of the gastrointestinal tract
    - 2. Appendicitis- inflammation of the appendix
  - D. Metabolism decreases with old age
  - E. Middle-age digestive problems
    - 1. Ulcers
    - 2. Gallbladder problems
  - F. Activity of digestive tract in old age
    - 1. Fewer digestive juices
    - 2. Peristalsis slows
    - 3. Diverticulosis and cancer are more common