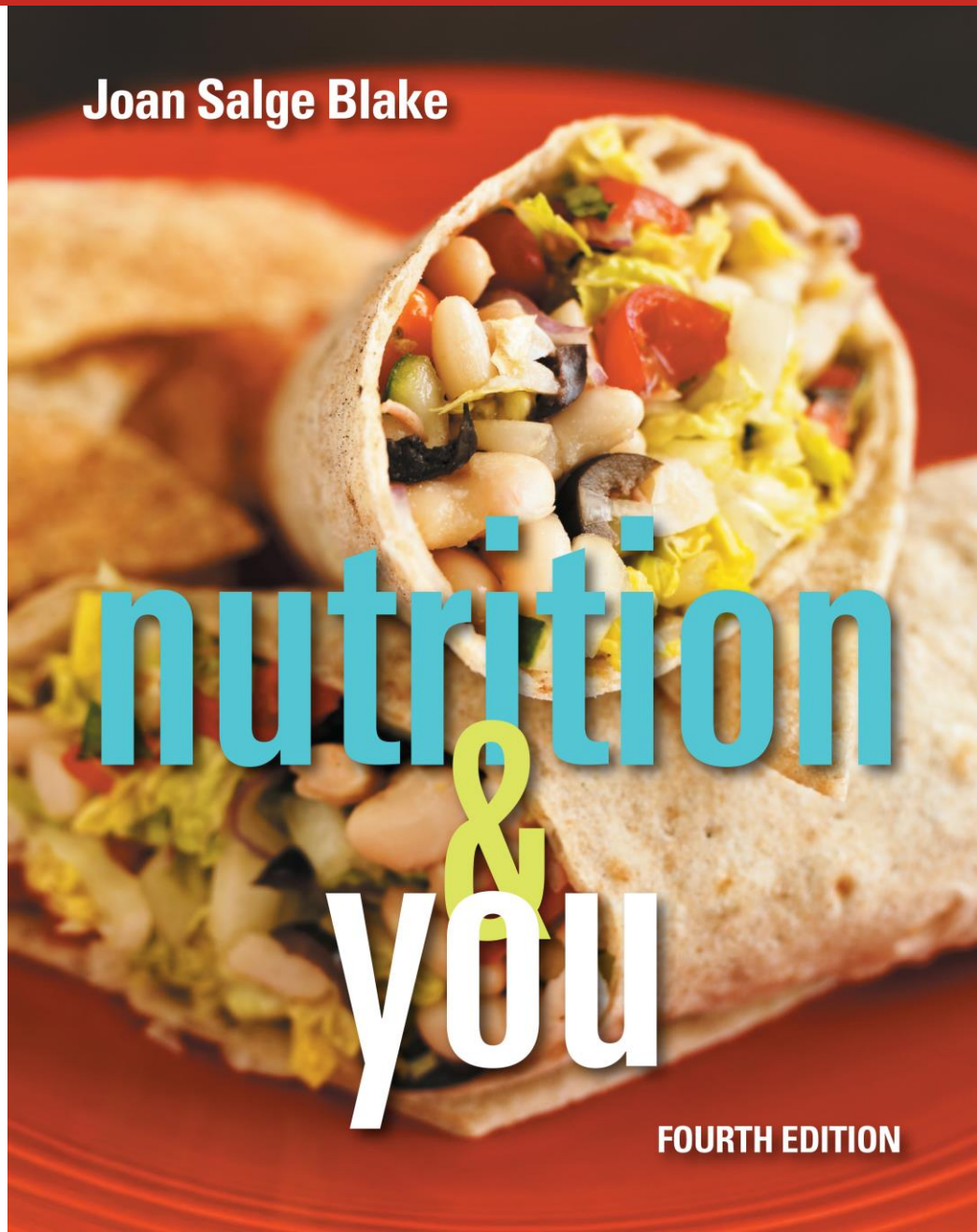
Chapter 3: The Basics of Digestion



Objectives for Chapter 3

- Define digestion and the processes involved in preparing food for absorption.
- Describe the organs involved in digestion and their primary functions.
- Explain the function of enzymes, hormones, and bile in digestion, including their primary action and their source of origin.
- Describe the process of absorption.
- Explain how the circulatory and lymphatic systems transport absorbed nutrients throughout the body.
- Describe the role of the nervous system and the endocrine system in keeping your body nourished.
- Describe the symptoms and causes of the most common digestive disorders.

What Is Digestion and Why Is It Important?

- **Digestion:** a multi-step process of breaking down foods into absorbable components using mechanical and chemical means in the gastrointestinal (GI) tract
- Gastrointestinal tract consists of:
  - Mouth
  - Esophagus
  - Stomach
  - Small and large intestines
  - Accessory organs: pancreas, liver, gallbladder

What Is Digestion and Why Is It Important?, Continued

- Main roles of the GI tract are to:
  - Break down food into smallest components
  - Absorb nutrients
  - Prevent microorganisms or other harmful compounds in food from entering tissues of the body
- GI tract is nearly 30 feet long with extensive surface area for nutrient absorption
  - Cells lining GI tract are shed into the **lumen** (interior of the intestinal tract) and replaced with new, healthy cells every 3 to 5 days

Overview of Digestion and Absorption

Basic Absorption Mechanisms

Digestion Is Mechanical and Chemical

- **Mechanical digestion:** chewing, grinding food to aid swallowing
- **Chemical digestion:** digestive juices and enzymes break down food into absorbable nutrients

Digestion Is Mechanical and Chemical, Continued

- Mechanical and chemical digestion occur throughout GI tract, especially in small intestine
  - **Peristalsis:** the forward, rhythmic motion that moves chyme through digestive system
  - **Segmentation** ("sloshing motion") mixes chyme with chemical secretions; increases time food comes into contact with intestinal walls
  - **Pendular movement** (constrictive wave) enhances nutrient absorption in small intestine
- Actions move chyme at 1 centimeter per minute
- Total contact time in small intestine: 3 to 6 hours, depending on amount and type of food

Peristalsis

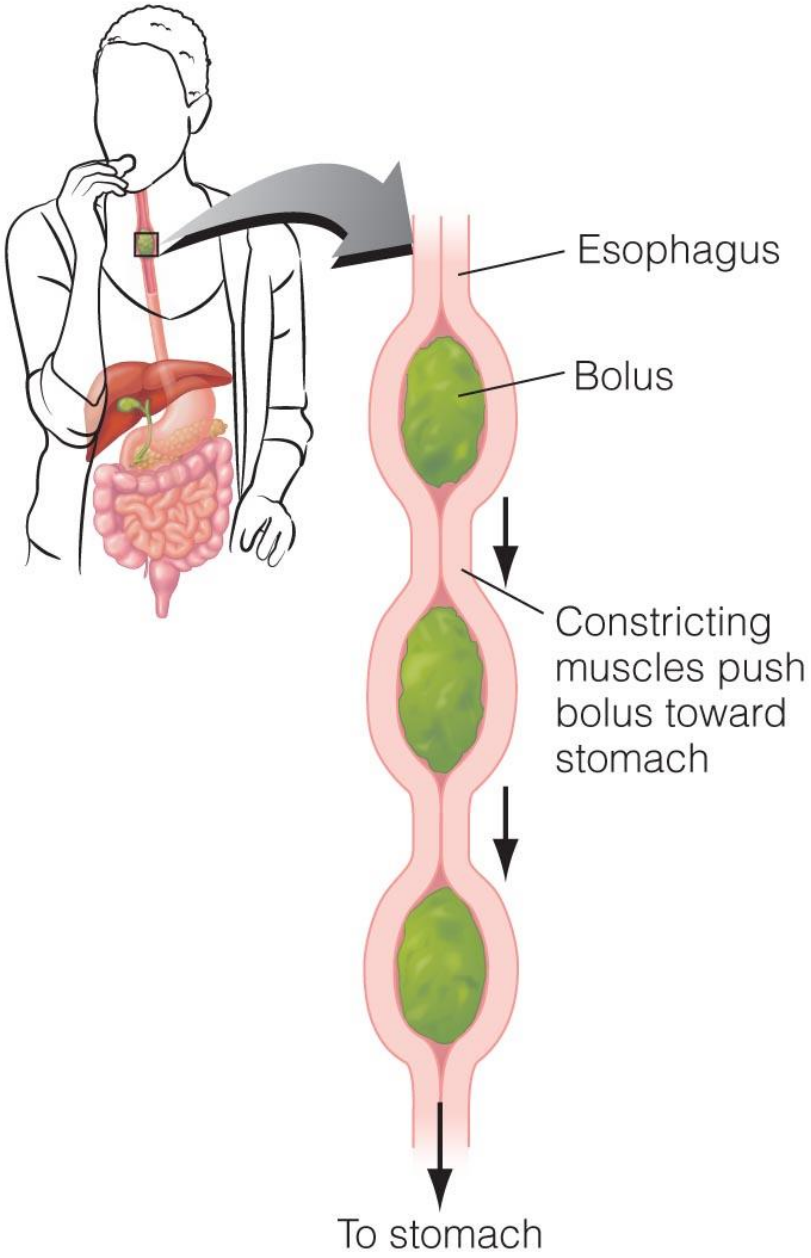


Figure 3.1

From Cells to Organs and Organ Systems

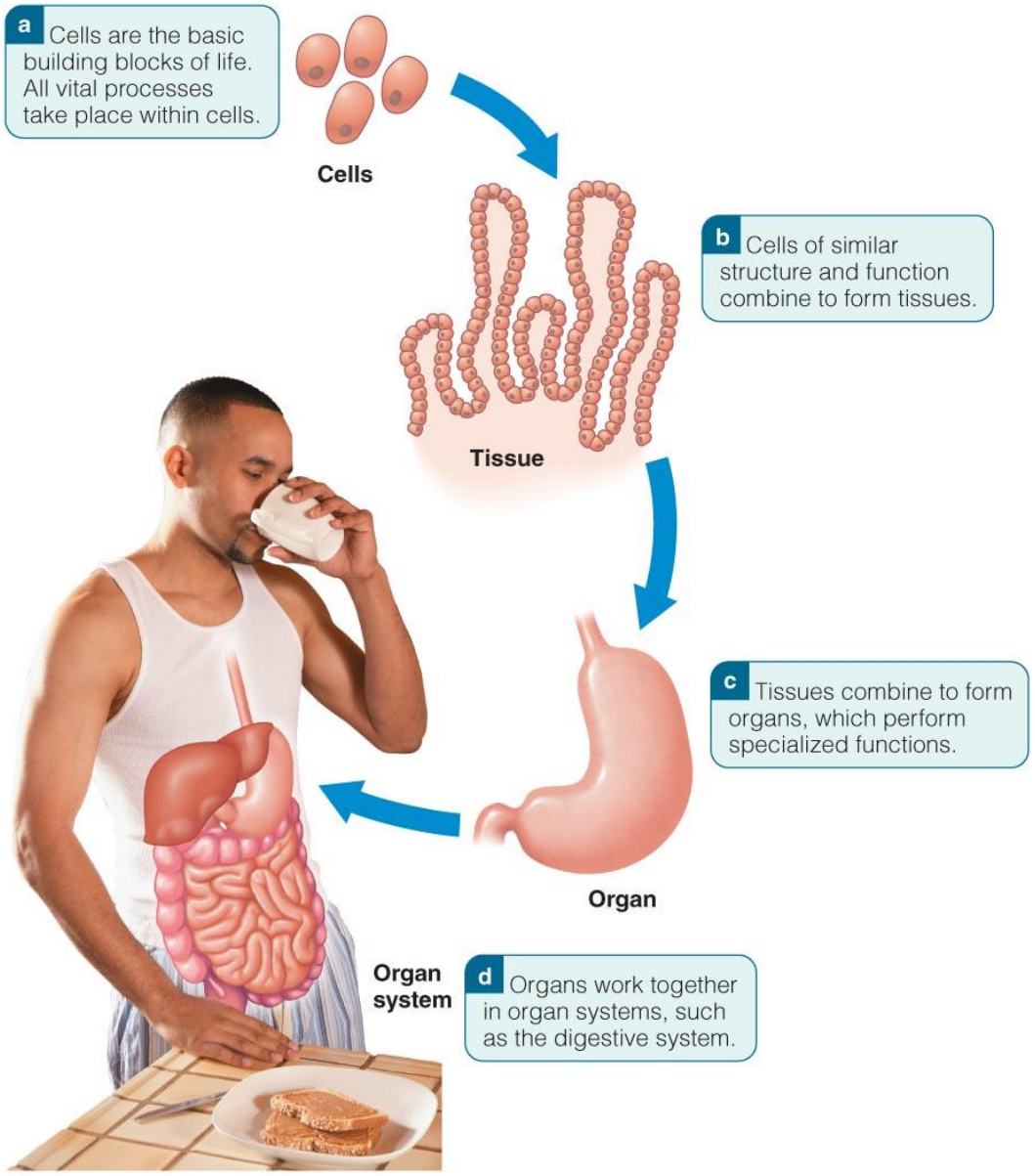


Figure 3.2

Tinkering with your Body's Digestive Process

- Many people consider using weight loss aids
- Alli is a popular aid in drugstores
  - First FDA-approved, over-the-counter drug containing orlistat
  - Blocks the absorption of about 25 percent of the fat in a meal by preventing lipase enzyme from breaking down dietary fat
  - Can experience unpleasant side effects – bathroom urgency, fatty/oily stools, frequent bowel movements
    - Symptoms are less present with lower fat meals
  - Need for vitamin supplement with the fat-soluble vitamins A,D,E,K and the antioxidant beta-carotene

Digestive System

The human digestive system consists of the organs of the gastrointestinal (GI) tract and associated accessory organs. The processing of food in the GI tract involves ingestion, mechanical digestion, chemical digestion, propulsion, absorption, and elimination.

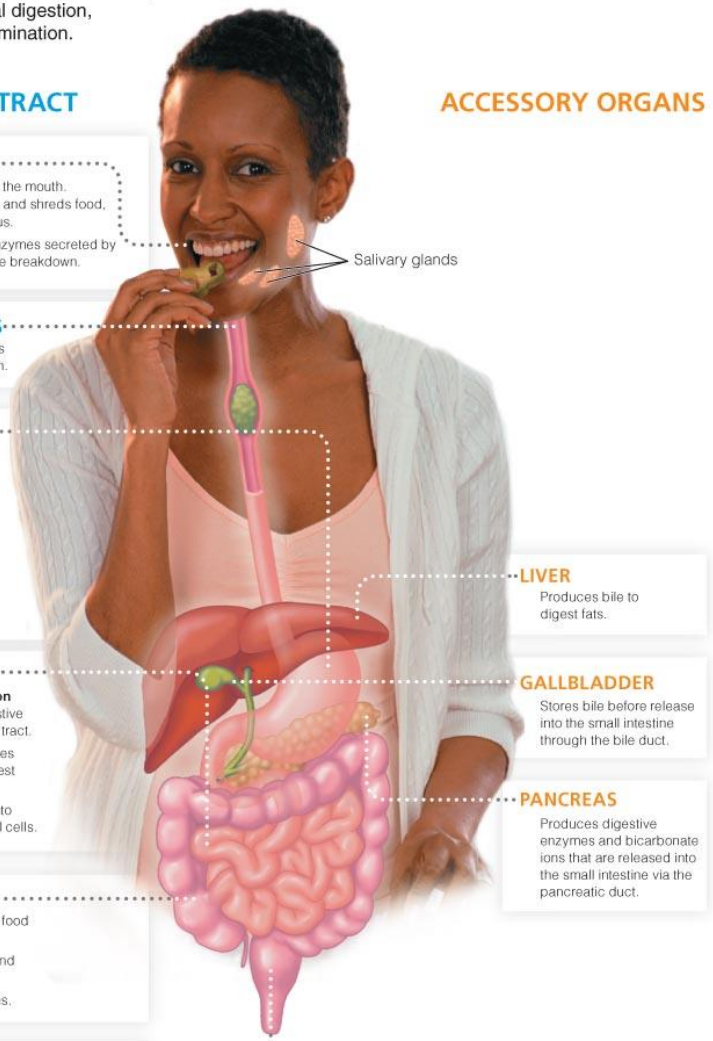


Figure 3.3

What Are the Organs of the GI Tract and Why Are They Important?

- Both mechanical and chemical digestion begin in the mouth
  - Saliva released: contains water, electrolytes, mucus, and a few enzymes
    - Softens, lubricates, dissolves food particles
  - Bolus (food mass) moves into pharynx, is swallowed, and enters the esophagus
  - Epiglottis closes off trachea during swallowing to prevent food from lodging in the windpipe

The Epiglottis

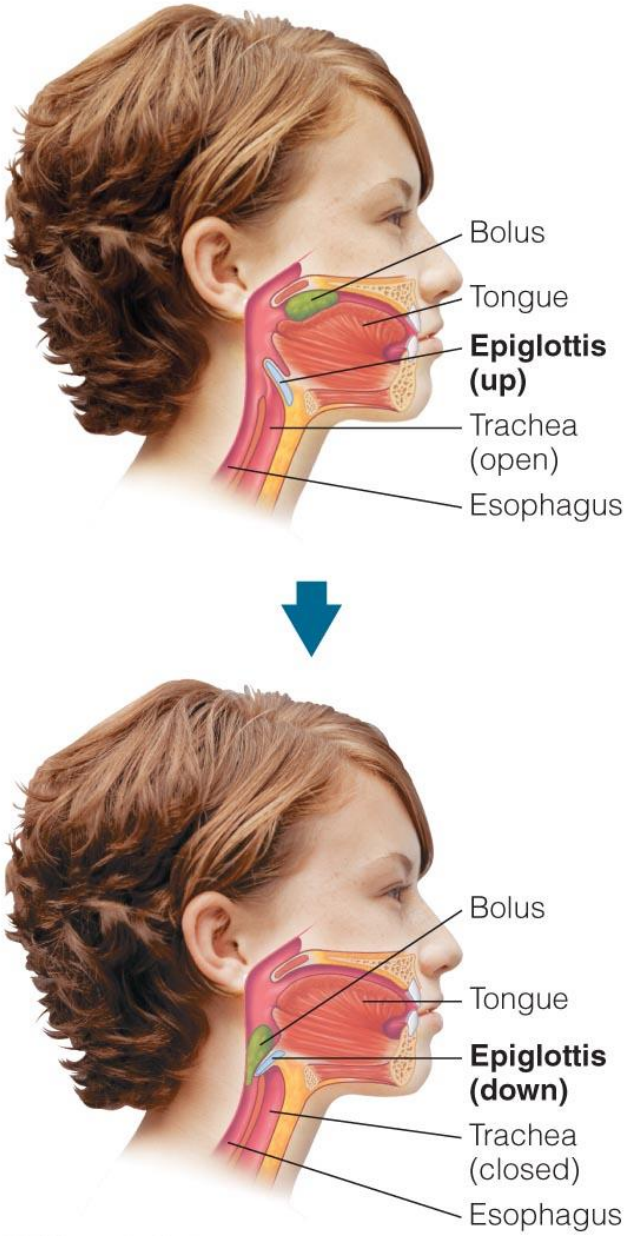


Figure 3.4

What Are the Organs of the GI Tract and Why Are They Important? Continued

- Once swallowed, a bolus is pushed down esophagus by *peristalsis* into the stomach
- **Lower esophageal sphincter (LES)**: at bottom of esophagus relaxes and allows food into stomach
- LES then closes to prevent backflow of hydrochloric acid (HCl) from stomach
  - "Reflux" of stomach acid causes "heartburn" (irritation of esophagus lining)

The Stomach Stores, Mixes, and Prepares Food for Digestion

- The **stomach** is a muscular organ that continues mechanical digestions by churning and contracting to mix food with digestive juices for several hours
- Stomach produces powerful digestive secretions:
  - **HCl**: activates enzyme **pepsin**, enhances absorption of minerals, breaks down connective tissue of meat
    - Mucus protects stomach lining from damage
  - Digestive enzymes, intrinsic factor (for vitamin B_{12} absorption), stomach hormone **gastrin**
- Bolus becomes **chyme**, semiliquid substance of partially digested food and digestive juices

Anatomy of the Stomach

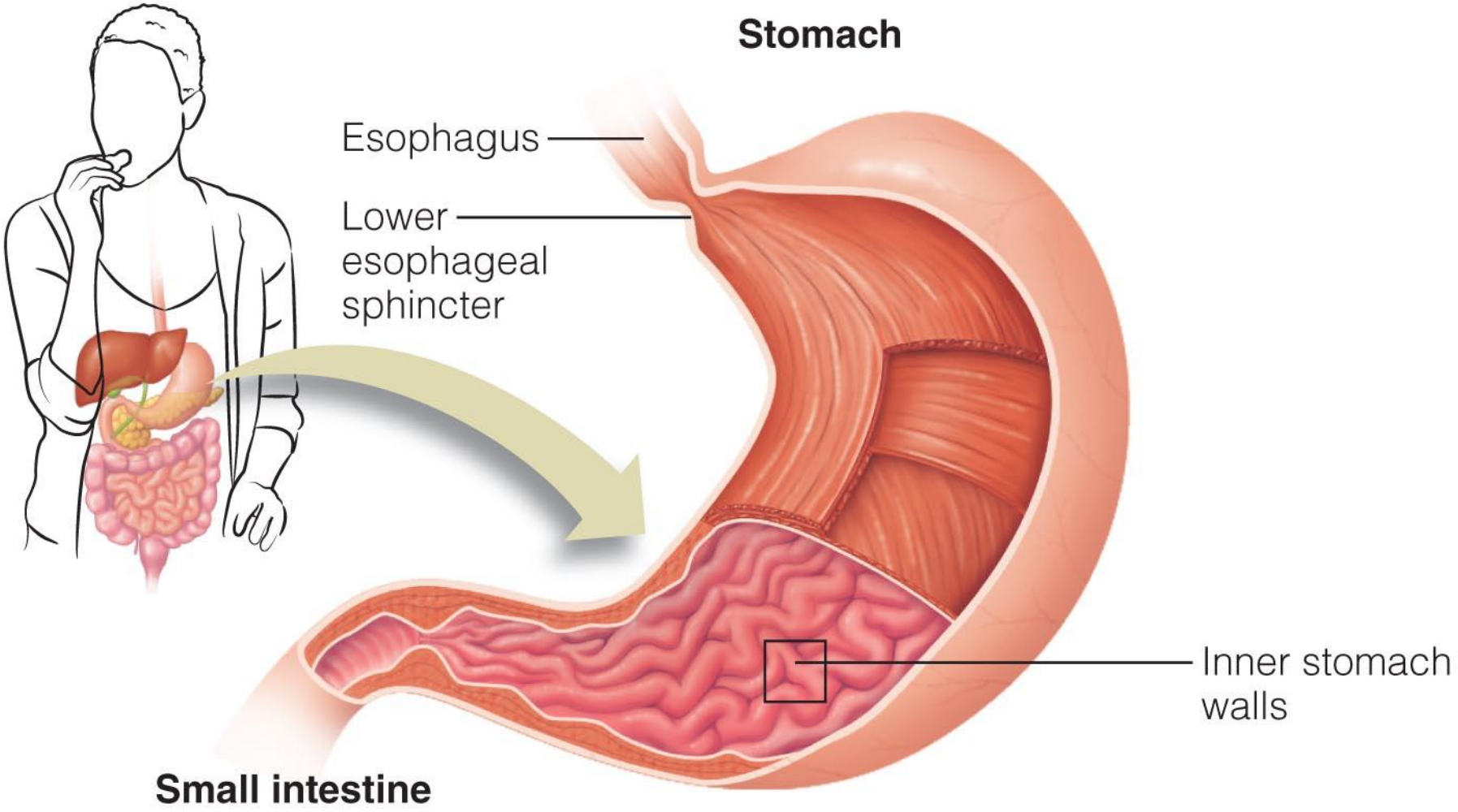


Figure 3.5

The Stomach Stores, Mixes, and Prepares Food for Digestion, Continued

- **Gastrin:** hormone stimulates digestive activities and increases gastric motility and emptying
- Liquids, carbohydrates, low-fiber, and low-calorie foods exit stomach faster
- High-fiber, high-fat, and high-protein foods exit slower, keep you feeling full longer
- **Pyloric sphincter:** located between the stomach and small intestine; allows about 1 tsp of chyme to enter the small intestine every 30 seconds
  - Prevents backflow of intestinal contents

Most Digestion and Absorption Occurs in the Small Intestine

- **Small intestine:** long, narrow, coiled
  - Three segments:
    - Duodenum (shortest segment)
    - Jejunum
    - Ileum (longest segment)
  - In total the small intestine accounts for about 20 feet of the GI tract
  - Interior surface area tremendously increased by villi, microvilli, circular folds

Anatomy of the Small Intestine

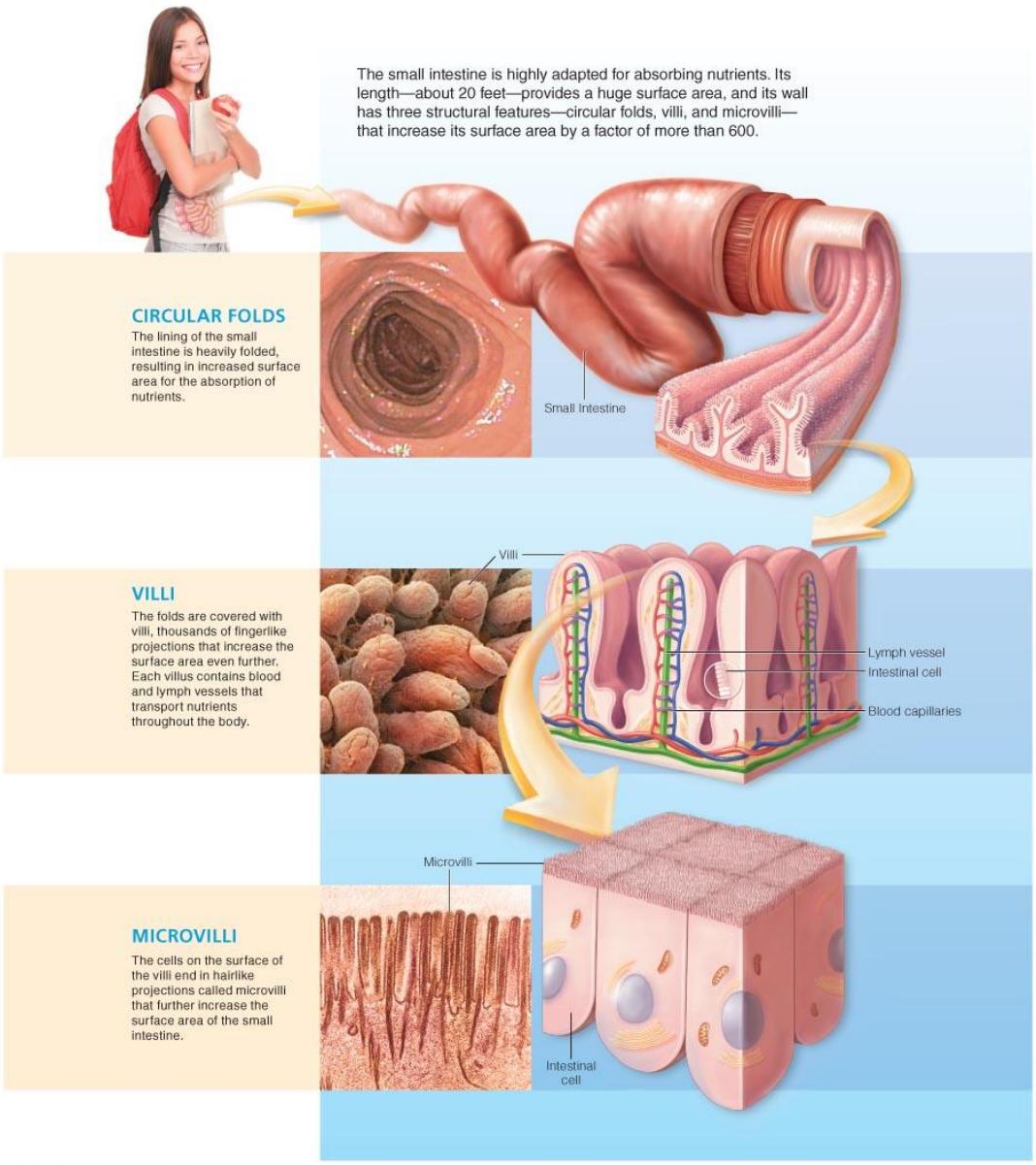


Figure 3.6

Large Intestine Eliminates Waste and Absorbs Water and Some Nutrients

- **Ileocecal sphincter:** prevents backflow of fecal matter into ileum
- Most nutrients in chyme have been absorbed when it reaches large intestine
- Large intestine has three sections: cecum, colon, rectum
  - About 5 feet long, 2.5 inches in diameter (twice the diameter of the small intestine)
  - Absorbs water and electrolytes
  - No digestive enzymes; chemical digestion done by bacteria

Large Intestine Eliminates Waste and Absorbs Water and Some Nutrients, Continued

- Intestinal matter passes through colon in 12 to 24 hours depending on age, health, diet, fiber intake
  - Bacteria in colon produce vitamin K and biotin and break down fiber and undigested carbohydrates, producing methane, carbon dioxide, hydrogen gas, and other compounds
- Stool stored in rectum
- Anus controlled by two sphincters: internal and external
  - Final stage of defecation is under voluntary control

Anatomy of the Large Intestine

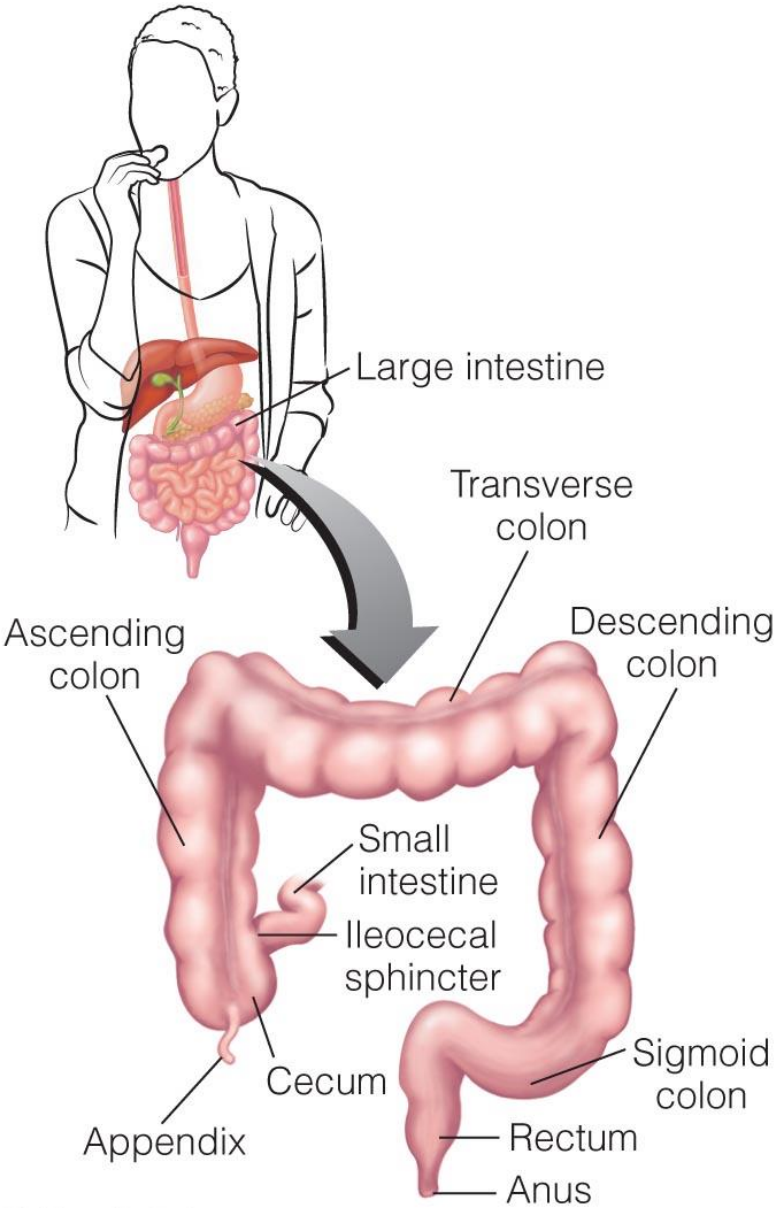


Figure 3.7

The Liver, Gallbladder, and Pancreas Are Accessory Organs

- **Liver:** largest internal organ of the body
  - Produces bile needed for fat digestion
  - Metabolism of carbohydrates, fats, and protein
  - Stores nutrients: vitamins A, D, B_{12}, E; copper; iron; glycogen (glucose storage form)
  - Detoxifies alcohol
- **Gallbladder:** concentrates and stores bile
  - Released into GI tract when fat is ingested

The Liver, Gallbladder, and Pancreas Are Accessory Organs, Continued

- **Pancreas**
  - Produces hormones: insulin and glucagon regulate blood glucose
  - Produces and secretes digestive enzymes and bicarbonate
    - Bicarbonate neutralizes acidic chyme, protects enzymes from inactivation by acid

The Accessory Organs

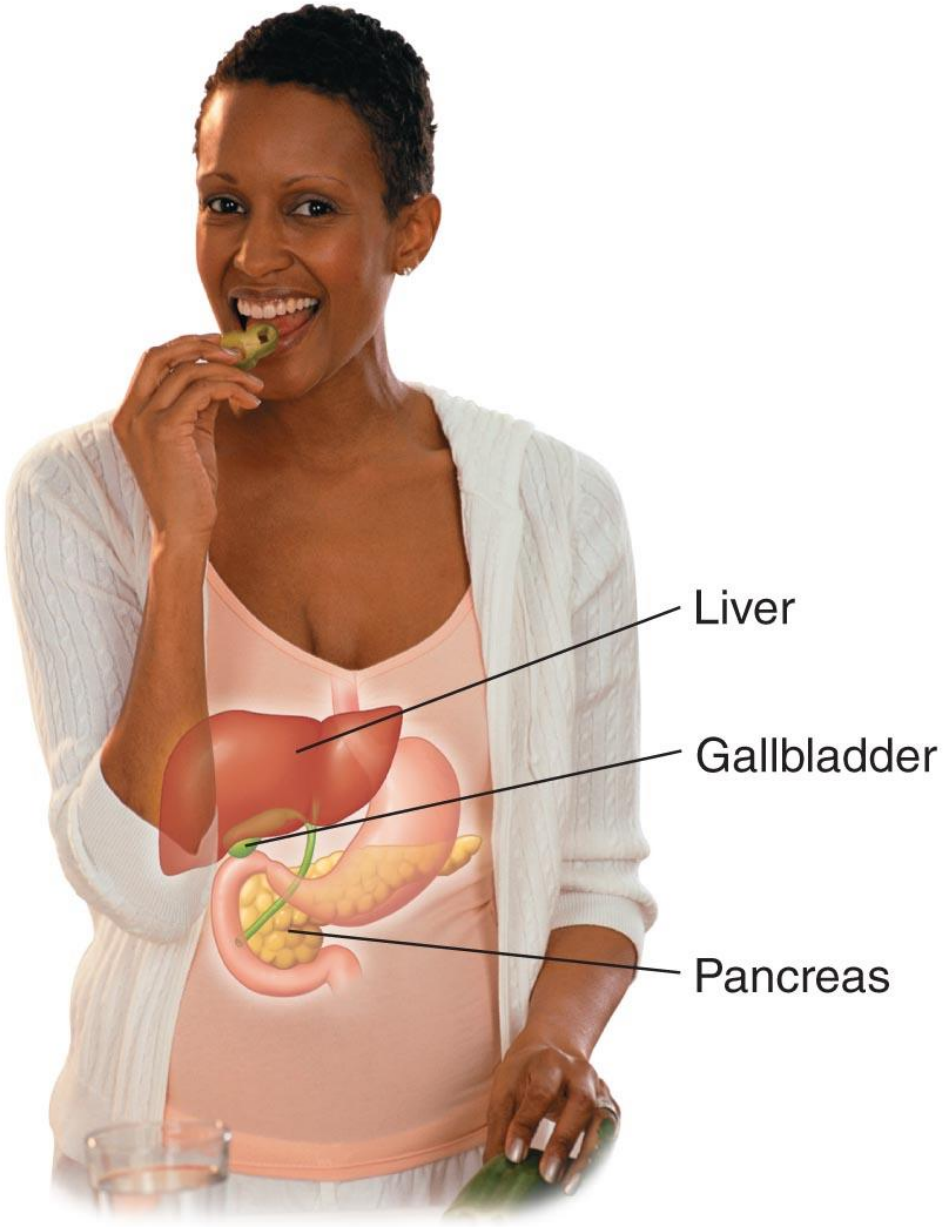


Figure 3.8

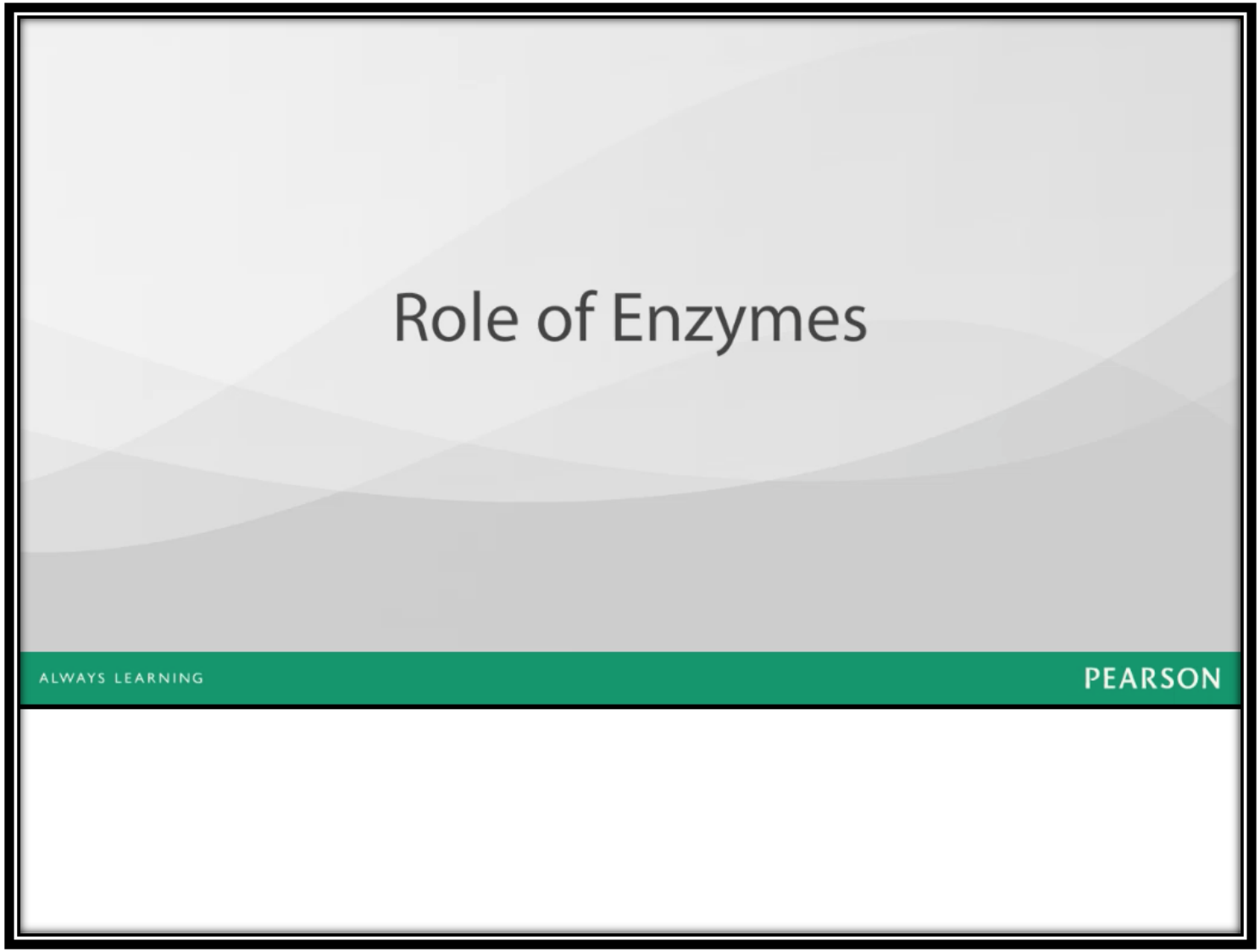
How Do Hormones, Enzymes, and Bile Aid Digestion?

- **Hormones** are released from endocrine glands and regulate digestion
- They control digestive secretions and regulate enzymes
  - Gastrin stimulates stomach to release HCl and enzyme gastric lipase
  - Ghrelin stimulates hunger
  - Secretin causes pancreas to release bicarbonate to neutralize HCl
  - Cholecystokinin stimulates pancreas to secrete digestive enzymes, controls pace of digestion

How Do Hormones, Enzymes, and Bile Aid Digestion? Continued

- **Enzymes** drive process of digestion
  - Speed up chemical reactions that break down food into absorbable nutrient components
  - Secreted by salivary glands, stomach, pancreas, and small intestine
  - Enzymes from pancreas are responsible for large portion of digested nutrients
    - Amylase: digests carbohydrate
    - Lipase: digests fats
    - Trypsin, chymotrypsin, and carboxypeptidase: digest protein

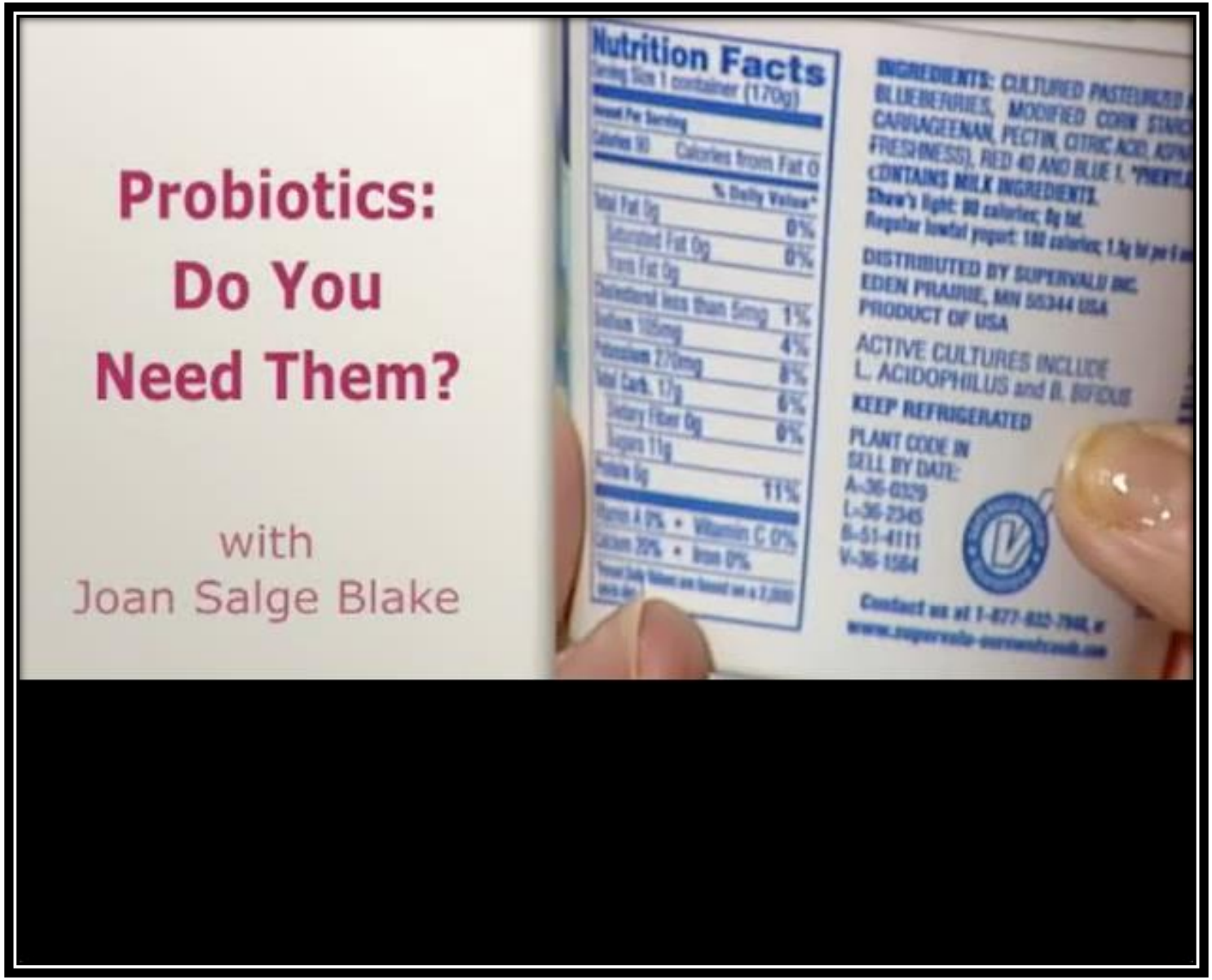
Role of Enzymes



How Do Hormones, Enzymes, and Bile Aid Digestion?, Continued-1

- **Bile** helps digest fat
  - Yellowish-green substance made in liver and stored in gallbladder
  - Breaks down large fat globules into smaller fat droplets
  - Can be reused by recycling through liver

Practical Nutrition Tips Video: Probiotics



Functions of Digestive Secretions

Table 3.1 Functions of Digestive Secretions

Secretion	Secreted from	Function
Saliva	Glands in the mouth	Moistens food, eases swallowing, contains the enzyme salivary amylase
Mucus	Stomach, small and large intestines	Lubrication and coating of the internal mucosa to protect it from chemical or mechanical damage
Hydrochloric acid (HCl)	Stomach	Activation of enzymes that begin protein digestion
Bile	Liver (stored in the gallbladder)	Emulsifies fat in the small intestine
Bicarbonate	Pancreas	Raises pH and neutralizes stomach acid
Enzymes (amylases, proteases, and lipases)	Stomach, small intestine, pancreas	Chemicals that break down food into nutrient components that can be absorbed
Hormones (gastrin, secretin, cholecystokinin, and ghrelin)	Stomach, small intestine	Chemicals that regulate digestive activity, increase or decrease peristalsis, and stimulate various digestive secretions

Table 3.1

Organs of Digestion and Their Functions

Table 3.2 Organs of Digestion and Their Functions

Organ or Tissue	Function	How They Work Together to Digest a Peanut Butter Sandwich
Mouth	Begins breaking down food into components through chewing	Saliva moistens the sandwich as your teeth grind the food. Amylase begins to break down the carbohydrate in the bread.
Esophagus	Transfers food from the mouth to the stomach	Bolus of sandwich moves through the esophagus to the stomach.
Stomach	Mixes food with digestive juices; breaks down some nutrients into smaller components	The HCl activates pepsin to begin digesting the protein in the sandwich. Gastric lipase starts breaking down the triglycerides in the peanut butter.
Small intestine	Completes digestion of food and absorbs nutrients through its walls	The carbohydrates, proteins, and fat are broken down further with the help of bile and enzymes so they can be absorbed.
Large intestine	Absorbs water and some nutrients; passes waste products out of the body	The fiber in the bread leaves the body in the stool.
Accessory organs	Release enzymes, bile, and bicarbonate ions	
liver		The liver produces the bile and regulates the metabolism of the absorbed nutrients.
gallbladder		The gallbladder releases stored bile into the small intestine to emulsify the fat in the peanut butter sandwich.
pancreas		The pancreas produces bicarbonate ions to neutralize the chyme, and the enzymes amylase, lipase, and protease to digest the sandwich.

Table 3.2

How Are Digested Nutrients Absorbed?

- After digestion, nutrients are absorbed through the walls of the intestines into the body's two transport systems:
  - Circulatory system (blood)
  - Lymphatic system
- Sent to the liver for processing before delivery to the body's cells
- GI tract is highly efficient: 92 to 97 percent of nutrients from food are digested and absorbed

How Are Digested Nutrients Absorbed?, Continued

- Nutrients absorbed by three methods:
  - **Passive diffusion:** due to concentration gradient
    - When concentration in GI tract exceeds that of intestinal cell, nutrient is forced across cell membrane
  - **Facilitated diffusion:** similar to passive method, but requires specialized protein to carry nutrients
  - **Active transport:** differs from other two methods
    - Nutrients absorbed from low to high concentration, requiring both carrier and energy

Absorption Methods in the Small Intestine

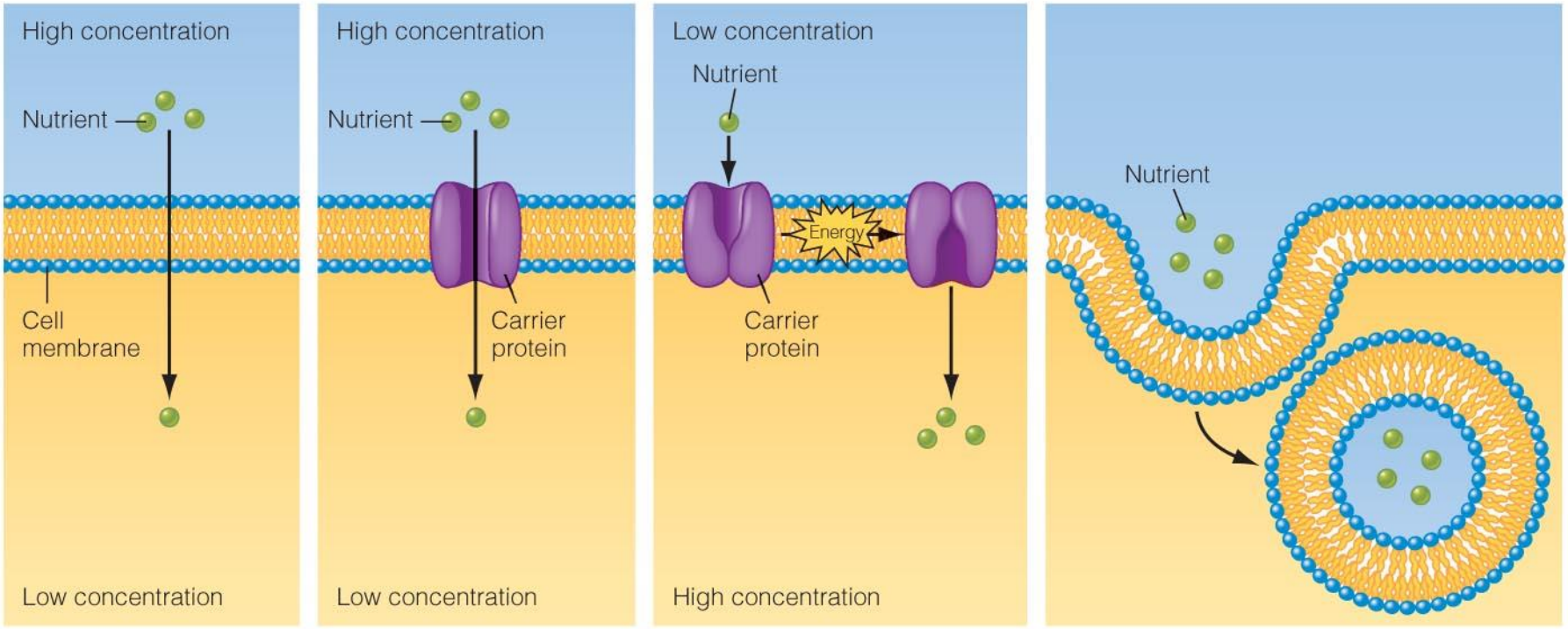


Figure 3.9

What Happens to Nutrients after They Are Absorbed?

- Circulatory system distributes nutrients through your blood
- Lymphatic system distributes some nutrients through your lymph vessels
- Your body can store some surplus nutrients
- Excretory system passes waste out of the body

The Circulatory and Lymphatic Systems

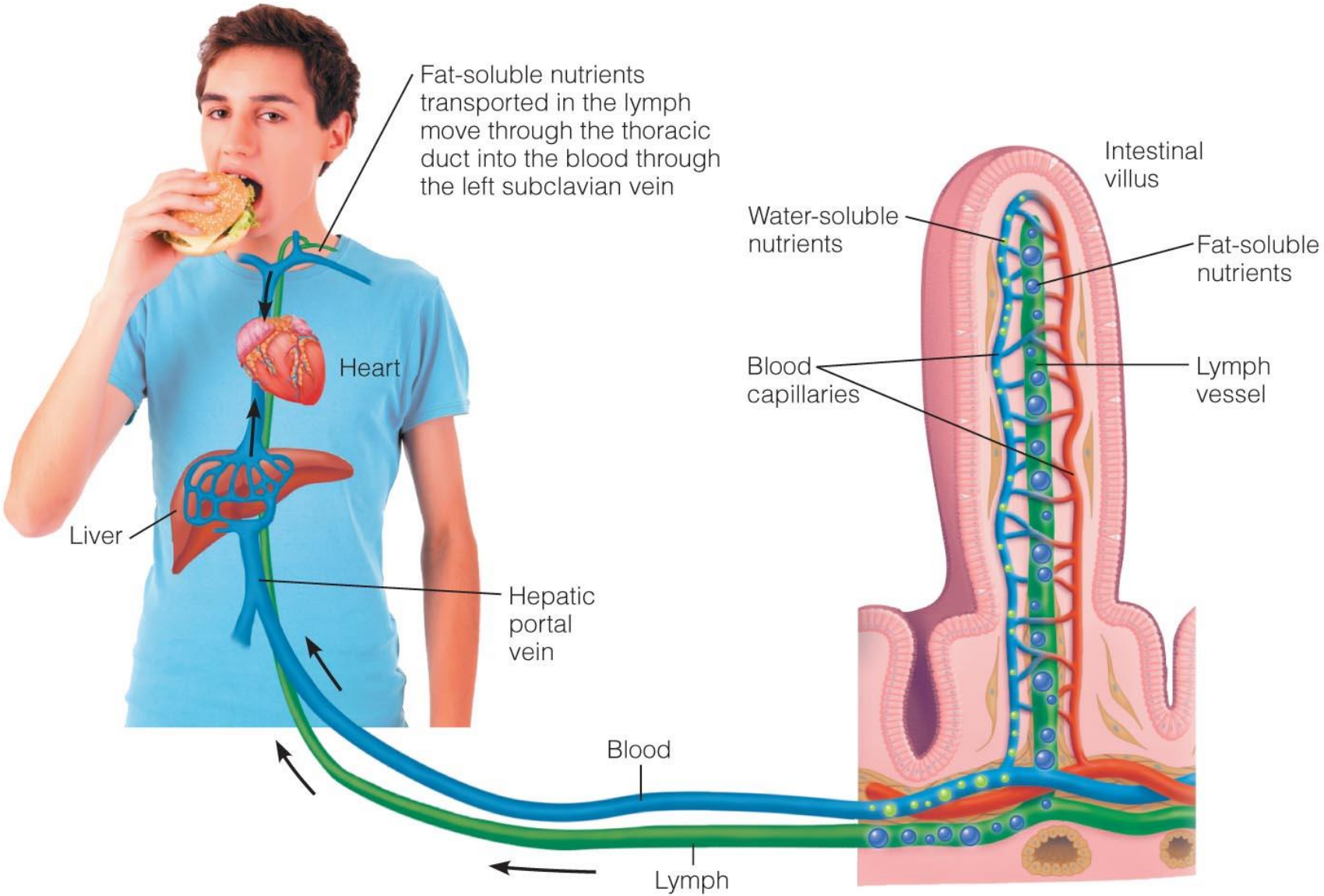


Figure 3.10

The Excretory System

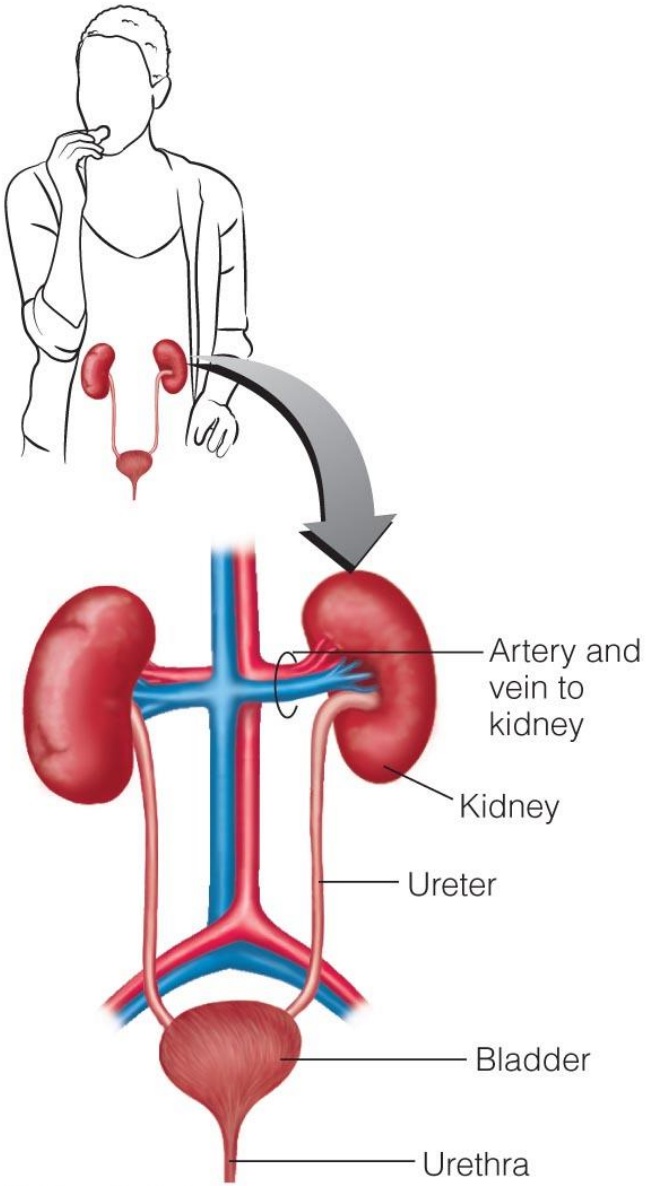


Figure 3.11

What Other Body Systems Affect Your Use of Nutrients?

- Nervous system stimulates your appetite
  - Hormone ghrelin signals your brain to eat
- Endocrine system releases hormones that help regulate the use of absorbed nutrients
  - Insulin and glucagon help regulate blood levels of glucose

What Are Some Common Digestive Disorders?

- Disorders of the mouth and esophagus:
  - Gingivitis and periodontal disease
  - Swallowing problems: dysphagia
  - Esophageal problems
    - Heartburn (acid reflux) may be caused by weak lower esophageal sphincter (LES)
      - Chronic heartburn can be a symptom of **gastroesophageal disease (GERD)**
      - Certain foods and behaviors (smoking, drinking alcohol, reclining after eating, large evening meals) may worsen condition

What Are Some Common Digestive Disorders? Continued

- Disorders of the stomach:
  - Gastroenteritis: stomach flu, caused by virus or bacteria
  - Peptic ulcers: sore or erosion caused by drugs, alcohol, or bacteria
- Gallbladder disease:
  - Gallstones: small, hard, crystalline structures
    - May require surgery

What Are Some Common Digestive Disorders? Continued-1

- Disorders of the intestines:
  - Flatulence: release of intestinal gas from the rectum
  - Constipation and diarrhea
    - Constipation often due to insufficient fiber or water intake
    - Diarrhea causes loss of fluids and electrolytes; serious if lasting for extended period
  - Hemorrhoids: swelling and inflammation in veins of rectum and anus

What Are Some Common Digestive Disorders? Continued-2

- More serious intestinal disorders:
  - Irritable bowel syndrome (IBS): functional disorder involving changes in colon rhythm
  - Celiac disease: autoimmune, genetic disorder related to gluten consumption
  - Crohn's disease: inflammatory bowel disease of several types
  - Colon cancer: one of the leading forms of cancer, but curable if detected early

Common Digestive Disorders

Table 3.3 Common Digestive Disorders

Site	Disorder	Symptoms	Causes	Treatment
Esophagus and Stomach	Gastrointestinal reflux disease (GERD)	Sore throat, burning sensation in the chest (heartburn)	Poor eating habits; overeating; other lifestyle choices	Eat smaller meals; eat more slowly; decrease fat and/or alcohol intake; quit smoking
Stomach or small intestine	Gastric and duodenal Ulcers	Bleeding, pain, vomiting, fatigue, weakness	Multiple causes	Prescription drugs and an as-tolerated diet
Gallbladder	Gallstones	Cramps, bloating, intense abdominal pain, diarrhea	The concentration of high cholesterol-containing bile that crystallizes and forms stones in the duct	Gallbladder removal, medication, or shock-wave therapy
Small intestine	Celiac disease	Malabsorption	Error of gluten metabolism	Gluten-free diet
Small intestine	Crohn's disease	Pain, diarrhea, rectal bleeding, weight loss, anemia	Swelling of the intestines	Medication, nutritional or dietary supplements, surgery
Large intestine	Constipation	Cramping, bloated uncomfortable feeling in abdomen	Too little water or too little fiber; inactivity	More water, fiber, and exercise
Large intestine	Diarrhea	Too-frequent, loose bowel movements	Multiple causes	Water and electrolyte replacement
Large intestine	Irritable bowel syndrome (IBS)	Diarrhea and constipation in alternating sequence; pain	Unknown cause(s); stress worsens the condition	Self-management with fiber therapy, stress relief, and good sleep habits
Large intestine	Colon cancer	Symptoms are often silent; may include weight loss, internal bleeding, iron-deficiency anemia, fatigue	Multiple causes (genetics, various colon diseases, smoking, exposure to dietary carcinogens)	Radiation therapy, chemotherapy, surgery

Table 3.3