CHAPTER

3

The Human Body: Are We Really What We Eat?

Chapter Summary

There are a number of factors that stimulate us to eat, such as our senses of sight, smell, and taste. Appetite is a psychological desire to consume. Hunger is considered a more basic physiological drive that prompts us to eat. Several factors affect hunger and satiation, including the hypothalamus, hormones, and the amount and type of food we eat. Foods with fiber, water, and protein have the highest satiety value. The primary goal of digestion is to break food into molecules small enough to be transported throughout the body. When we eat, the food we consume is digested, the useful nutrients absorbed into the bloodstream, and the waste products eliminated. Digestion begins in the mouth with mechanical breakdown of food by chewing and the beginning of carbohydrate digestion. Food travels to the stomach through the esophagus via peristalsis. Protein and a small amount of fat digestion begin in the stomach as the food is mixed with gastric juices. The partially digested food, known as chyme, is periodically released by the stomach into the small intestine. Most digestion and absorption occurs in the small intestine. The large intestine digests any remaining food particles, absorbs water and chemicals, and moves feces to the rectum for elimination. Enzymes, synthesized by the pancreas and small intestines, guide the digestion of food. Gastrin, secretin, cholecystokinin, and gastric inhibitory peptide are the primary hormones that regulate digestion. The gallbladder stores and secretes bile, which aids in fat digestion. The pancreas synthesizes and secretes digestive enzymes and the hormones insulin and glucagon. The liver processes absorbed nutrients, alcohol, and drugs, synthesizes bile, and regulates energy metabolism. The large surface area of the small intestine maximizes the four types of absorption. The neuromuscular system involves coordination of the muscles, the central nervous system, and the enteric nervous system to move food along the GI tract and to control all aspects of digestion, absorption, and elimination.

A number of disorders can affect the GI tract. Heartburn or gastroesophageal reflux disease can occur when hydrochloric acid (HCl) flows back into the esophagus. An ulcer is an area of the GI tract that has been eroded away by a combination of HCl and pepsin. This results in a burning pain in the abdominal area and is typically caused by the bacteria *Heliobacter pylori.* A food intolerance is gastrointestinal discomfort caused by foods, but that is not a result of an immune system reaction. Food allergies caused by an immune reaction can cause serious localized or systemic symptoms. People with celiac disease cannot eat foods containing gluten, as it results in an immune reaction that damages the lining of the small intestine, leading to malabsorption. Gastrointestinal infection, certain drugs, and other factors can cause acute vomiting. Chronic vomiting can be caused by cyclic vomiting syndrome. Crohn's disease and ulcerative colitis have similar symptoms, and both damage the lining of the GI tract, but ulcerative colitis is limited to the colon, and Crohn's is more common in the small intestine.

Diarrhea and constipation can be symptoms of many digestive problems, including irritable bowel syndrome. Cancer can develop in any part of the gastrointestinal system, but colorectal cancer is the most common GI cancer.

Nutrition Myth or Fact addresses the question: Should you grow your microbiome?

Learning Objectives

After studying this chapter, the student should be able to:

1. Distinguish between appetite and hunger, describing the physiologic mechanisms and other influences behind both conditions (pp. 72–76).
2. Describe the contribution of each organ of the gastrointestinal tract to the digestion, absorption, and elimination of food (pp. 76-81).
3. Explain how the pH of the stomach's internal environment contributes to the stomach's role in digestion (pp. 82-85).
4. Identify the primary role of enzymes and hormones in accomplishing chemical digestion (pp. 87-88).
5. Discuss the roles of the gallbladder, pancreas, and liver in accomplishing chemical digestion (pp. 88–90).
6. Explain how the anatomy of the small intestine's lining contributes to its absorptive function (pp. 90–91).
7. List and describe the four types of absorption that occur in the small intestine (pp. 90-92).
8. Identify three gastrointestinal tract movements and three divisions of the nervous system that contribute to gastrointestinal function (pp. 94-95).
9. Describe the causes, symptoms, and treatments of gastroesophageal reflux disease, peptic ulcers, food allergies, celiac disease, vomiting, inflammatory bowel diseases, and functional gastrointestinal disorders (pp. 96-98).
10. Compare the incidence of colorectal cancer with that of other cancers of the gastrointestinal system, and explain the role of screening in reducing colorectal cancer deaths (p. 104).

Key Terms

absorption
active transport
accessory organs of di gestation
appetite
bile
bolus
brush border
celiac disease
cephalic phase
chyme
constipation
Crohn's disease
diarrhea
digestion
elimination
endocytosis
enteric nervous system
enterocytes
enzymes
esophagus
facilitated diffusion
food allergy
food intolerance
gallbladder
gastric juice
gastroesophageal reflux disease
gastrointestinal (GI) system
gastrointestinal (GI) tract
haustration
heartburn
hormone
hunger
hydrolysis
hypothalamus

irritable bowel syndrome
lacteal
large intestine
liver
mass movement
pancreas
passive diffusion
peptic ulcer
peristalsis
portal venous system
probiotics
saliva
salivary glands
segmentation
small intestine
sphincter
stomach
ulcerative colitis
vomiting

Chapter Outline

I. Why Do We Want to Eat What We Want to Eat?

A. The mechanisms hunger and appetite prompt us to seek food.

1. Hunger is a physiological drive that prompts us to eat nonspecific foods.

2. Appetite is a psychological desire to consume specific foods that is aroused by environmental stimuli.

a. People commonly experience appetite in the absence of hunger.

3. Anorexia, a physiological need for food with no appetite, occurs for a variety of reasons, including illness and medication.

4. Ideally, appetite prompts an individual to eat specific foods to satisfy hunger.

B. The hypothalamus prompts hunger in response to various signals.

1. The hypothalamus, located in the brain, triggers feelings of hunger and satiation.

2. Nerve cells in the stomach and small intestine sense changes in pressure or fullness and send signals to the hypothalamus.

3. Chemicals called hormones affect hunger and satiation.

a. The hypothalamus receives messages about blood sugar levels as a result of changes in the hormones insulin and glucagon.

b. The hormone ghrelin is released by the stomach triggering the hypothalamus to induce us to eat as.

c. The hormone cholecystokinin, produced by the small intestine in response to food entry, stimulates the satiety center.

d. Leptin is produced by fat cells and acts on the hypothalamus to suppress food intake over time; the obese appear to be leptin-resistant.

4. The amount and type of food we eat can affect hunger and satiation.

a. Foods containing protein have the highest satiety value, and fat is more satiating than carbohydrates.

b. Bulky meals provide satiety by stretching the stomach and small intestine.

c. Beverages tend to be less satisfying than foods.

C. Environmental cues trigger appetite.

1. Foods stimulate our senses and contribute to the flavor and appeal.

2. Social and cultural events stimulate associations with appetite.

3. Desire for certain foods may be triggered by external events or emotions.

4. Food choices are often learned responses to the environment, but food preferences can change as people learn new things about food.

Key Terms: gastrointestinal (GI) system, hunger, appetite, hypothalamus, hormone

Figures:

Figure 3.1: The hypothalamus triggers hunger

Figure 3.2: Appetite is the drive to consume specific foods

II. What Happens to the Food We Eat?

A. Digestion is the process by which foods are broken down into molecules, either mechanically or chemically.

B. Absorption is the process in which the products of digestion move through the wall of the intestine.

C. Elimination is the process by which undigested food and waste products are excreted from the body.

D. These processes occur in the gastrointestinal (GI) tract with the aid of accessory organs.

1. The flow of food between the organs of the digestive tract is controlled by sphincters, which are tight rings of muscle that open when a nerve signal indicates that food is ready to pass into the next section.

E. Digestion begins in the mouth.

1. The cephalic phase is the earliest phase of digestion in which the brain thinks about and prepares the digestive organs for the consumption of food.

a. The nervous system stimulates the release of digestive juices in preparation.

2. Chewing moistens food and mechanically breaks it down.

3. Saliva, secreted from the salivary glands, initiates chemical digestion.

a. Chemicals dissolved in saliva bind to taste receptors in taste buds enabling us to taste.

b. Amylase, an enzyme, catalyzes chemical reactions to break down carbohydrates.

c. Bicarbonate neutralizes acids.

d. Mucus moistens food and the oral cavity.

e. Antibodies and lysozyme defend the mouth against bacterial damage.

F. The esophagus propels food into the stomach.

1. The food, which has been chewed and moistened, is known as a bolus.

2. When food is swallowed, the soft palate and epiglottis close the airways and the esophagus opens.

3. Peristalsis refers to rhythmic waves of muscular contraction that move food in one direction through the length of the GI tract.

4. Food passes into the stomach when the gastroesophageal sphincter relaxes.

G. The stomach mixes, digests, and stores food.

1. Gastric glands are lined with parietal cells and chief cells that secrete components of gastric juice.

2. The parietal cells secrete:

a. HCl, which keeps the stomach interior acidic.

b. Intrinsic factor, which is critical to B_{12} absorption.

3. The chief cells secrete:

a. Pepsin, which begins to digest protein.

b. Gastric lipase, which begins to break apart lipids.

4. The stomach mechanically digests food by mixing it with gastric juice until it becomes a liquid called chyme.

5. Mucus protects the stomach lining from eroding.

6. Water, fluoride, some lipids, and some drugs can be absorbed through the walls of the stomach.

7. Chyme remains in the stomach for about two hours and is periodically released into the small intestine through the pyloric sphincter.

H. Most of digestion and absorption occurs in the small intestine.

1. The small intestine is composed of the duodenum, jejunum, and ileum.

a. It connects to the large intestine at a sphincter called the ileocecal valve.

2. Food is broken down into molecules for absorption.

3. The action of enzymes, accessory organs, and unique features allow food to be digested and absorbed.

a. Once digestion and absorption are complete, the residue is passed into the large intestine.

I. The large intestine stores food waste until it is excreted.

1. The indigestible food material enters the large intestine.

2. Bacteria, the GI flora, finish digesting some nutrients and ferment fibrous waste.

a. GI flora are also referred to as probiotics because they are thought to stimulate the immune system, inhibit the growth of harmful bacteria, and reduce the risk for diarrhea.

3. The digestive mass is stored for 12 to 24 hours.

4. Nutrients and water are absorbed, leaving a semisolid mass called feces, which is then eliminated from the body.

Key Terms: digestion, absorption, elimination, gastrointestinal (GI) tract, sphincter, accessory organs of digestion, cephalic phase, saliva, salivary glands, enzymes, bolus, esophagus, peristalsis, stomach, gastric juice, chyme, small intestine, large intestine, probiotics

Figures:

Figure 3.3: Digestion Overview

Figure 3.4: Where your food is now: the mouth.

Figure 3.5: Enzymes speed up the body's chemical reactions.

Figure 3.6: Chewing and swallowing are complex processes.

Figure 3.7: Where you food is now: the esophagus.

Figure 3.8: Where your food is now: the stomach.

Figure 3.9: The pH scale identifies the levels of acidity or alkalinity of various substances.

Figure 3.10: The stomach is protected from the acidity of gastric juices by a layer of mucus.

Figure 3.11: Where your food is now: the small intestine.

Figure 3.12: Where your food is now: the large intestine.

III. How Does the Body Accomplish Chemical Digestion?

A. Enzymes and hormones play roles in digestion.

1. Enzymes speed up digestion via hydrolysis.

a. Hydrolysis is a chemical reaction that breaks down substances by the addition of water.

b. Most digestive enzymes are produced by the pancreas and small intestine.

2. Hormones assist in regulating digestion.

a. There are more than 80 hormones and hormonelike substances that regulate the digestive system.

b. The four most important hormones are gastrin, secretin, cholecystokinin (CCK), and gastric inhibitory peptide (GIP).

B. Accessory organs produce, store, and secrete chemicals that aid in digestion.

1. The gallbladder stores bile.

a. CCK signals the gallbladder to contract sending bile into the duodenum.

b. Bile emulsifies lipids so they are more accessible to digestive enzymes.

2. The pancreas produces enzymes, hormones, and bicarbonate.

a. The pancreas holds and secretes inactive enzymes that are activated in the small intestine.

b. Pancreatic amylase, pancreatic lipase, and proteases, which catalyze the digestion of carbohydrates, lipids, and proteins, are secreted by the pancreas.

c. Insulin and glucagon are produced by the pancreas, and are important in regulating the amount of glucose in the blood.

d. The pancreas secretes bicarbonate into the duodenum to neutralize the acidic chyme.

3. The liver produces bile and regulates blood nutrients.

a. The liver performs more than 500 functions, including digestive and regulatory functions.

b. The liver synthesizes chemicals, such as bile, which aid in digestion.

c. The liver receives the products of digestion via the portal vein and processes them for storage.

d. The liver releases nutrients into the bloodstream as they are needed by the body.

e. The liver filters the blood, removing wastes and toxins including alcohol.

Key Terms: hydrolysis, gallbladder, bile, pancreas, liver, portal venous system

Figures and Tables:

Table 3.1: Digestive Enzymes Produced in the Gastrointestinal Tract and Their Actions

Table 3.2: Hormones Involved in the Regulation of Digestion

Figure 3.13: The portal venous system is a group of digestive veins.

IV. How Does the Body Absorb and Transport Digested Nutrients?

A. A specialized lining enables the small intestine to absorb food.

1. The surface area of the small intestine is increased by heavy folding, villi, and microvilli.

2. Villi are composed of specialized absorptive cells called enterocytes.

3. The capillaries and lacteals of the villi absorb some of the by-products of digestion.

a. Hair-like projections on enterocytes known as microvilli are collectively called the brush border.

B. Four types of absorption occur in the small intestine.

1. Passive diffusion occurs when nutrients are absorbed without a carrier protein or use of energy.

2. Facilitated diffusion occurs when nutrients require a carrier protein for absorption.

3. Active transport requires both a carrier protein and energy.

4. Endocytosis occurs when the enterocyte's cell membrane engulfs the nutrient, incorporating it into the cell.

C. Blood and lymph transport nutrients and wastes.

1. Blood in the capillaries picks up water and water-soluble nutrients in the enterocytes.

a. Blood is transported from the GI system via the portal venous system to the liver.

b. Waste products are excreted by the kidneys and carbon dioxide exhaled by the lungs.

2. The lacteals pick up lipids and fat-soluble vitamins, transporting them in lymph, which returns to the bloodstream.

Key Terms: enterocytes, lacteal, brush border, passive diffusion, facilitated diffusion, active transport, endocytosis

Figures:

Figure 3.14: Small Intestine Structure/Function

Figure 3.15: The four types of absorption that occur in the small intestine.

Figure 3.16: Blood travels through the cardiovascular system to transport nutrients and fluids and pick up waste products.

V. How Does the Neuromuscular System Support the Gastrointestinal System?

A. The muscles of the gastrointestinal tract mix and move food.

1. During peristalsis, the muscles of the GI tract contract and relax causing constriction, which pushes contents from one area to the next.

2. The muscles of the stomach mix and liquefy the food, the pyloric sphincter opens, allowing some of the chyme into the small intestine.

3. Segmentation in the small intestine squeezes and mixes chyme.

4. In the colon, haustration moves waste toward the sigmoid colon, and mass movements push waste toward the rectum.

5. Both voluntary and involuntary muscles are involved in digestion.

B. Three types of nerves control the contractions and secretions of the gastrointestinal tract.

1. The enteric nervous system (ENS) is localized in the wall of the GI tract and is part of the autonomic nervous system.

a. Enteric nerves can respond independently to signals from the GI tract controlling peristalsis and segmentation and regulating digestive secretions.

b. Enteric nerves also collaborate with the central nervous system (CNS) and the parasympathetic nervous system (PNS).

2. Other branches of the autonomic nervous system outside the GI tract.

3. The central nervous system (CNS), which includes the brain and spinal cord.

a. A variety of stimuli can trigger a CNS response, without enteric involvement.

Key Terms: segmentation, haustration, mass movement, enteric nervous system (ENS)

Figures:

Figure 3.17: Peristalsis and segmentation.

Figure 3.18: The stomach has longitudinal, circular, and diagonal muscles.

VI. What Disorders Are Related to Digestion, Absorption, and Elimination?

A. Belching and flatulence are caused primarily by swallowing air and eating gas-forming foods.

1. The primary cause of belching is swallowing air.

2. Flatus is composed of several gases, of which only sulfur produces odor.

3. Foods made with the fat substitute olestra, sugar alcohols, and the meat substitute Quorn may cause gas, cramps, and diarrhea.

4. Many gas-forming foods are considered healthy, and there are methods of reducing flatus without eliminating these foods.

B. Heartburn and gastroesophageal reflux disease (GERD) are caused by reflux of gastric juice.

1. Gastroesophageal reflux (GER) is caused when gastric juices back up into the lower esophagus.

a. The painful sensation behind the sternum that it causes is known as heartburn.

b. OTC antacids and swallowing can neutralize acid and relieve heartburn.

2. Gastroesophageal reflux disease (GERD) is a chronic disease in which episodes of GER cause heartburn or other symptoms more than twice per week.

a. The exact cause of GERD is unknown, but there are many ways to reduce its symptoms.

b. GERD, left untreated, can cause damage to the esophagus as well as serious health effects.

C. A peptic ulcer is an area of erosion in the GI tract.

1. A peptic ulcer is an area of the GI tract that has been eroded away by a combination of hydrochloric acid and the enzyme pepsin.

2. The bacteria *Heliobacter pylori* (*H. pylori*) plays a key role in development of most pep tic ulcers and must be treated with antibiotics.

3. Prolonged use of nonsteroidal anti-inflammatory drugs can also cause ulcers.

D. Some people experience disorders related to specific foods.

1. Food intolerance is a cluster of GI symptoms caused by foods without any role of the immune system.

2. A food allergy is a hypersensitivity reaction of the immune system to a particular component (usually a protein) in a food.

a. Food allergies are much less common than food intolerances.

b. Food allergies can cause local symptoms or severe, widespread inflammation, resulting in anaphylactic shock.

3. Celiac disease is a genetic disorder characterized by the inability to absorb a compound found in gluten.

a. When wheat, barley, or rye products are eaten, an immune response destroys the lining of the small intestine.

b. As the villi are destroyed, malabsorption of nutrients occurs, resulting in malnutrition.

c. Celiac is frequently misdiagnosed because its symptoms mimic other diseases, not all of which are associated with the digestive tract.

d. Eliminating gluten from the diet is the only treatment.

4. There is increasing evidence for a disorder called nonceliac gluten sensitivity (NCGS).

a. Signs and symptoms vary, but the common factor is that patients improve on a gluten-free diet.

E. Vomiting is the involuntary expulsion of the contents of the stomach and duodenum from the mouth, and it can be acute or chronic.

1. Cyclic vomiting syndrome (CVS) is a chronic condition characterized by recurring cycles of severe nausea and vomiting that can last for hours or days, alternating with symptom-free periods.

F. Crohn's disease and colitis are inflammatory bowel diseases.

1. Crohn's disease causes inflammation in the small intestine resulting in diarrhea, abdominal pain, rectal bleeding, weight loss, and fever.

a. Crohn's disease is treated with medication, nutrition, and sometimes surgery.

2. Ulcerative colitis is a chronic disease characterized by inflammation and ulceration of the innermost lining of the colon.

a. Symptoms include diarrhea, urgent need to have a bowel movement, weight loss, anemia, nausea, fever, and fatigue.

G. Diarrhea, constipation, and irritable bowel syndrome are functional disorders.

1. Diarrhea is the frequent (more than three times in one day) elimination of loose, watery stools.

a. Acute diarrhea is usually the result of an infection.

b. Chronic diarrhea is often due to an underlying disorder of the GI tract.

c. Diarrhea should be treated promptly to avoid dehydration.

d. Traveler's diarrhea has become a common problem for global travelers.

2. Constipation is a condition characterized by the absence of bowel movements for at least 2 days or a time period that is significantly longer than normal for the individual, resulting in small, hard stools that are difficult to pass.

a. Disorders affecting the nervous system often cause constipation.

b. Temporary constipation has a variety of causes, including schedule and dietary changes, as well as medications.

c. Increasing fiber, fluid, and exercise aid in the prevention of constipation.

3. Irritable bowel syndrome (IBS) is a disorder that interferes with normal functions of the colon.

a. Symptoms include abdominal cramps, bloating, and constipation or diarrhea.

b. The causes of IBS are not well understood, but the normal movement of the colon appears to be disrupted.

c. Treatment includes medication, stress management, and regular physical activity.

H. Cancer can develop in any part of the gastrointestinal system.

1. The most common GI cancer is colorectal cancer.

a. Symptoms include changes in bowel habits, rectal bleeding, unexplained weight loss, and abdominal pain or discomfort.

b. Screening includes a stool sample and colonoscopy.

Key Terms: heartburn, gastroesophageal reflux disease (GERD), peptic ulcer, food intolerance, food allergy, celiac disease, vomiting, Crohn's disease, ulcerative colitis (UC), diarrhea, constipation, irritable bowel syndrome (IBS)

Figures and Table:

Figure 3.19: The mechanism of heartburn and gastroesophageal reflux disease is the same.

Figure 3.20: A peptic ulcer.

Table 3.3: Signs and Symptoms of Dehydration in Adults and Children

Activities

1. Bring in pictures of foods that you feel will stimulate some reaction from the students. (Better yet, microwave a bag of butter-flavored popcorn and bring it to class still steaming.) Have students discuss how the sight, smell, taste, and texture of food affect their appetite and food choices. Some questions to stimulate discussion include:

a. Which pictures make you hungry? Which evoke negative feelings? Which neither affect you positively or negatively? Explain why.

b. What foods stimulate hunger for you personally? Note the differences between group members.

c. What foods do you choose most often when you are hungry? What factors make these foods preferable?

2. At the class meeting prior to the lecture on digestion, give each student an index card with the name of a digestive system segment (stomach, duodenum, jejunum, ileum), an accessory organ, enzyme, or hormone involved in digestion and absorption of food. Instruct students to know the following about their card for the next class:

Organs or segments:	Where is it located in relationship to the digestive tract?
	What role/role(s) does it have in the digestive process?
Enzymes or hormones:	Where is it produced and stored in the body?
	Where is it secreted into the digestive system (enzymes only)?
	What role/role(s) does it have in the digestive process?

During the lecture on digestion, ask students with organ/segment cards to arrange themselves in the order they would be found in the digestive system, with accessory organs to the side of the segment they would adjoin. Have the students tell what organ/segment they represent so the class may determine any alterations that must be made in their arrangement. Now have the enzymes/hormones stand near the organ that produces each one. Again, have students reveal their identity to confirm their positions. At this point, you (the instructor) become the food. Ask the students which of them would become active at the sight of food, instructing enzymes to move to the proper place. Then, move down the line of students, starting with the mouth, and have each student explain his or

her role in the process of digestion. As you move along, explain your transformation from food to bolus, to chyme, and so on. With a few comments along your path, you will have completed the lecture by the time you reach the end of the line and are "excreted."

Note: This assignment can be modified easily for various class sizes by using more terms for larger classes or designating only certain class members for the assignment and, for smaller classes, combining terms.

3. As a class, develop a list of common digestive disorders and over-the-counter products (including herbal remedies) to treat these disorders. Eliminate all disorders that require immediate medical attention. Have students research the various products available. The class can develop a chart listing simple digestive disorders, home treatment options, effects of those treatments, side effects and contraindications, timing of treatment for best effects, and dietary changes that might improve the effects of the product.
4. Give students a list of foods and ingredients that contain gluten (a good list can be found at www.celiac.com). Have them keep track of everything they consume for one day that contains gluten. If they are unsure of a food but believe it could contain gluten, they should also record that food. Students can bring their list to class and discuss how difficult it would be to give up foods containing gluten.

Diet Analysis Activity

5. The health of the GI tract largely depends on the foods we eat. Using the nutritional assessment previously completed, students should review the information provided by their diet analysis software and note the following:
   - **a.** Do you meet recommendations for fiber intake?
   - **b.** Do you meet recommendations for water intake?
   - **c.** If you have any GI difficulties, can you correlate them with any of the foods you consume?
   - **d.** What changes could you make in your diet to improve the health of your GI tract?

Nutrition Debate Activity

6. Probiotics have become so popular in treatment and prevention of digestive disorders that they are now being added to a variety of foods and marketed for a variety of positive health effects. Have students collect a variety of advertisements for foods and supplements with probiotics. Students should research the various claims in the advertisements and then debate:
   - **a.** Is there enough evidence to make the claim about probiotics?
   - **b.** Do the products contain enough probiotics per serving to meet the claims?
   - **c.** Can promoting foods with probiotics have harmful effects?

Web Resources

National Digestive Diseases Information Clearinghouse
www.digestive.niddk.nih.gov

Health Finder
www.healthfinder.gov

Food Allergy & Anaphylaxis Network
www.foodallergy.org

Celiac Sprue Association/National Celiac Disease Support Group
www.csaceliacs.org

Crohn's & Colitis Foundation of America
www.ccfa.org

