

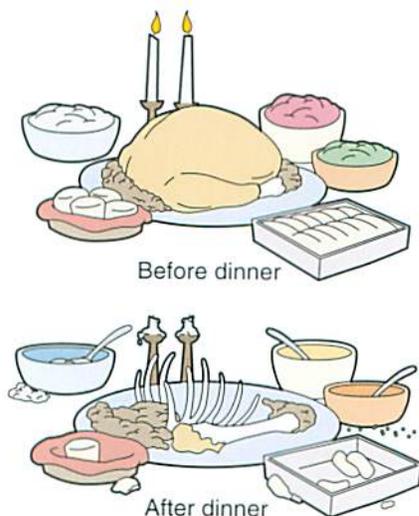
## Key Terms

**absorption** (p. 429)**amylase** (p. 448)**appendix** (p. 438)**bile** (p. 443)**biliary tree** (p. 445)**cecum** (p. 438)**chyle** (p. 438)**chyme** (p. 434)**colon** (p. 438)**common bile duct** (p. 445)**digestion** (p. 429)**duodenum** (p. 437)**emulsification** (p. 449)**esophagus** (p. 434)**gallbladder** (p. 445)**ileum** (p. 438)**jejunum** (p. 438)**lipase** (p. 449)**liver lobule** (p. 443)**minerals** (p. 452)**pancreas** (p. 445)**peristalsis** (p. 430)**protease** (p. 449)**stomach** (p. 434)**villus** (p. 438)**vitamins** (p. 451)

## Objectives

1. Discuss the basic anatomy and physiology of the digestive system, including:
  - List four functions of the digestive system.
  - Explain the processes of digestion and absorption.
  - Describe the four layers, nerves, and membranes of the digestive tract.
2. Describe the structure and functions of the organs and accessory organs of the digestive tract.
3. Explain the physiology of digestion and absorption, including:
  - Describe the effects of amylases, proteases, and lipases.
  - Describe the role of bile in the digestion of fats.
4. Discuss nutrition concepts, including:
  - Describe five categories of nutrients.
  - Discuss the importance of a balanced diet.
  - Explain how energy is measured, balanced, and expended in the body.

Most of us have no difficulty in eating our way through the Thanksgiving holiday turkey dinner, although the hours after the feeding frenzy can be a digestive challenge. Our digestive systems work very efficiently to digest and absorb as much of the food as possible. Before the holiday is over, the turkey dinner will be a part of every cell in your body.



Cells require a constant supply of nutrients and energy. Food is their source. The purpose of the digestive system is to break down or digest the food into particles that are small and simple enough to be absorbed. Thus, the digestive system ingests food, digests it, absorbs the end products of digestion, and eliminates the waste. The study of the digestive tract is called *gastroenterology*.

## OVERVIEW OF THE DIGESTIVE SYSTEM

The digestive tract and the accessory organs of digestion make up the digestive system. The digestive tract, also called the *alimentary canal* or the *gastrointestinal (GI) tract*, is a hollow tube extending from the mouth to the anus (Figure 23-1). The structures of the digestive or GI tract include the mouth, pharynx, esophagus, stomach, small intestine, large intestine, rectum, and anus.

The accessory organs of digestion include the salivary glands, teeth, liver, gallbladder, and pancreas. The salivary glands empty their secretions into the mouth; the liver, gallbladder, and pancreas empty their secretions into the small intestine.

**7. According to Figure 22-8**

- a. Air moves into the lungs when thoracic volume decreases.
- b. Air moves out of the lungs when thoracic volume increases.
- c. Air moves out of the lungs when the diaphragm and intercostal muscles contract.
- d. Intrapulmonic pressure decreases when the diaphragm contracts.

**8. According to Figure 22-9**

- a. Tissue  $pO_2$  is 95 mm Hg.
- b. Venous  $pO_2$  is 95 mm Hg whereas  $pCO_2$  is 45 mm Hg.
- c. Aortic blood  $pO_2$  and  $pCO_2$  are both 95 mm Hg.
- d. Arterial  $pO_2$  is higher than tissue  $pO_2$ .

**9. According to Figure 22-10**

- a. Tidal volume and vital capacity equals the total lung capacity.
- b. Vital capacity is equal to the sum of the resting tidal volume and expiratory reserve volume.
- c. Vital capacity is equal to the tidal volume, inspiratory reserve volume, and expiratory reserve volume.
- d. Expiratory reserve volume is the same as residual volume.

**10. According to Figure 22-11**

- a. Inspiratory and expiratory neurons are located within the respiratory control center of the medulla oblongata.
- b. All respiratory control is located within the brain stem.
- c. All respiratory control is voluntary.
- d. The medulla oblongata is the only brain stem structure that affects respirations.

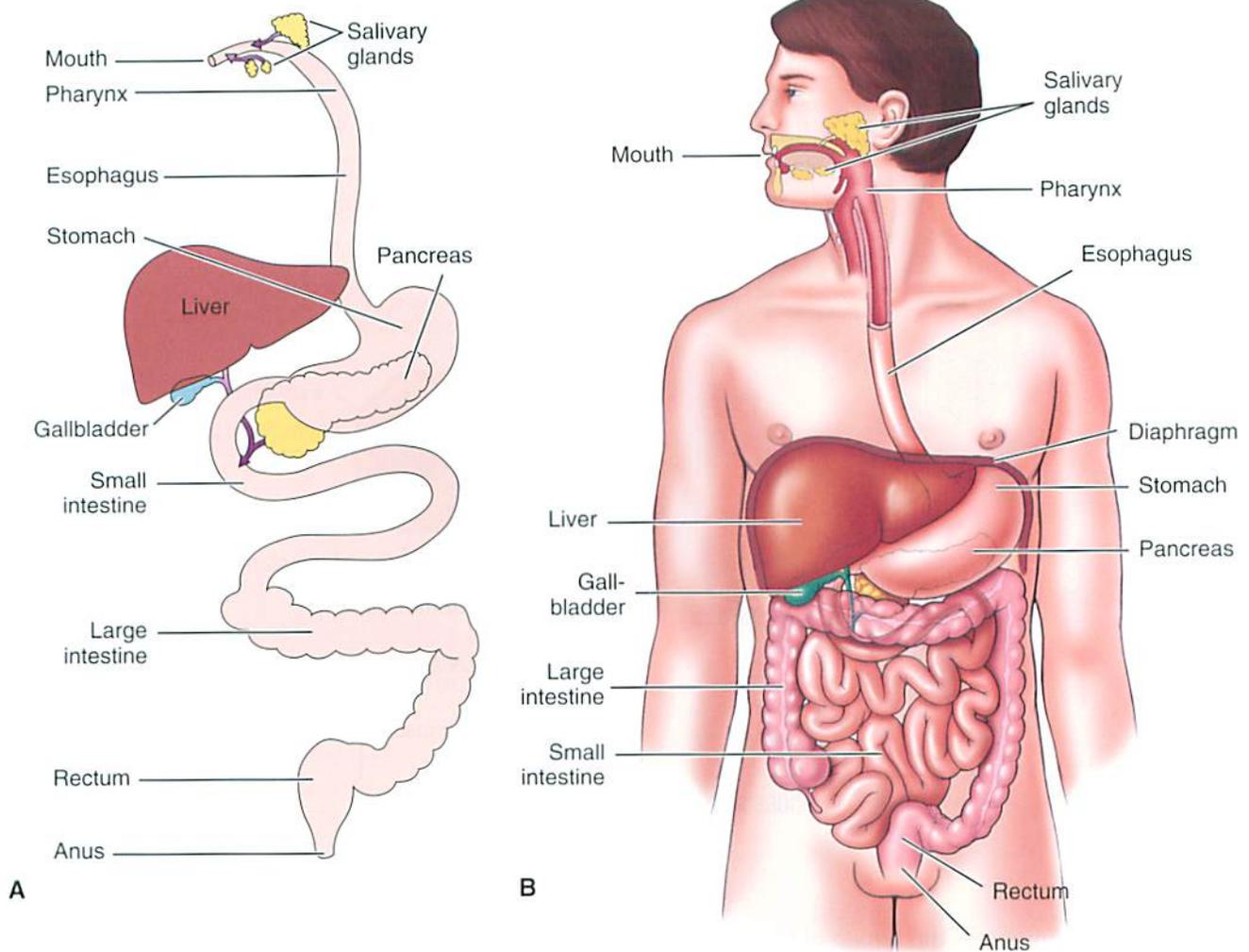


FIGURE 23-1 The digestive system. **A**, Hollow tube. **B**, Anatomical arrangement.

## DIGESTION AND ABSORPTION

**Digestion** is the process by which food is broken down into smaller particles suitable for absorption. Digestion takes place within the digestive tract. **Absorption** is the process whereby the end products of digestion move across the walls of the digestive tract into the blood for distribution throughout the body.

The two forms of digestion are mechanical and chemical. Mechanical digestion is the breakdown of large food particles into smaller pieces by physical means. This process is usually achieved by chewing and by the mashing, or squishing, actions of the muscles in the digestive tract. Chemical digestion is the chemical alteration of food. For example, a protein changes chemically into amino acids. Chemical substances such as digestive enzymes, acid, and bile accomplish chemical digestion.

The end products of digestion are absorbed by moving across the lining of the digestive tract into the blood. Digested nutrients eventually reach every

cell in the body. The food that cannot be digested and absorbed is eliminated from the body as feces. Elimination of waste products is the last stage of the digestive process.

### ? Re-Think

1. Differentiate between digestion and absorption.
2. Differentiate between mechanical and chemical digestion.

## LAYERS, NERVES, AND MEMBRANES

Although modified for specific functions in different organs, the wall of the digestive tract has a similar structure throughout its length (Figure 23-2). The wall of the digestive tract has four layers: the mucosa, the submucosa, the muscle layer, and the serosa.

### MUCOSA

The innermost layer of the digestive tract, the mucosa, consists of the mucous membrane. Glands secrete mucus, digestive enzymes, and hormones. Ducts from

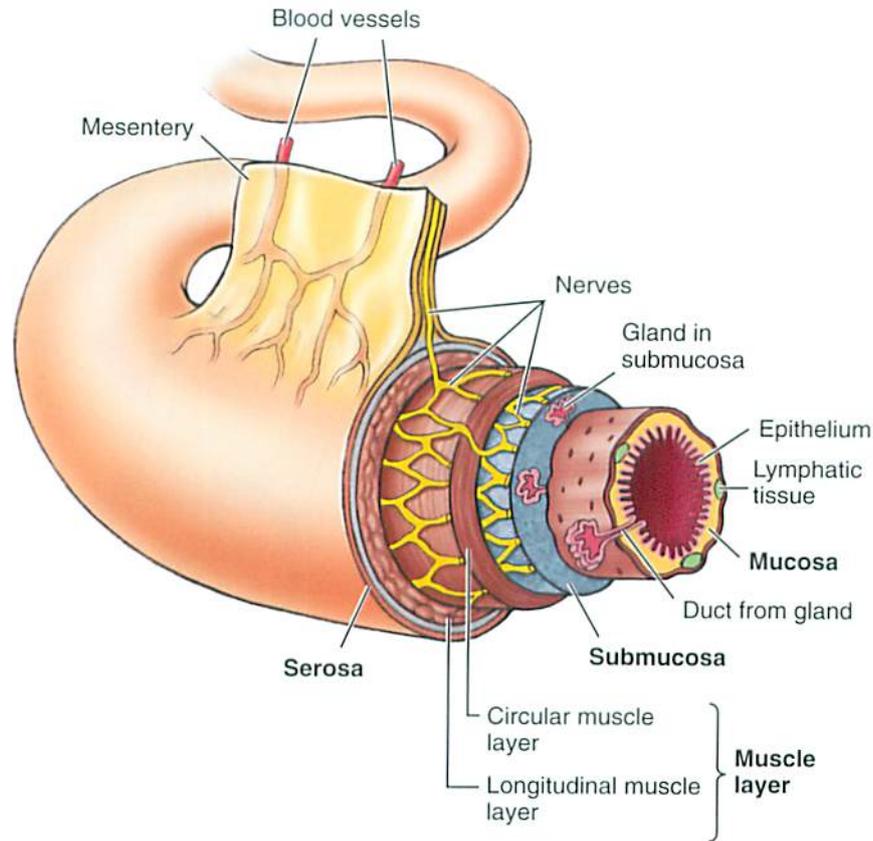


FIGURE 23-2 Layers of the digestive tract.

exocrine glands empty into the lumen of the digestive tract.

### SUBMUCOSA

A thick layer of loose connective tissue, the submucosa, lies beneath the mucosa. The submucosa contains blood vessels, nerves, glands, and lymphatic vessels.

### MUSCLE LAYER

The third layer of the digestive tract is the muscle layer. Two layers of smooth muscles are an inner circular layer and an outer longitudinal layer. The muscle layer is responsible for several types of movements in the digestive tract. Repeated contraction and relaxation of the stomach muscles digest the food mechanically and mix the particles with digestive juices.

A second type of muscle movement is **peristalsis** (pair-i-STAL-sis), a rhythmic alternating contraction and relaxation of the muscles. Peristalsis pushes the food in a forward direction through the digestive tract. It's a gutsy move! Peristalsis moves food in the same way that toothpaste squirts from a tube, as illustrated here by G.I. Joe. The toothpaste squirts in a forward direction because the bottom of the tube is squeezed. Peristaltic waves squeeze the food from behind and push it forward. Peristaltic waves are stimulated by the presence of food.



What happens if peristalsis stops? After surgery, intestinal peristalsis is often sluggish and may actually cease. This condition is called *paralytic ileus*. When this happens, food, gas, and liquid accumulate within the digestive tract, creating a life-threatening situation that demands immediate intervention.

Muscle activity is also responsible for other types of movement, such as swallowing and defecation (the elimination of waste from the digestive tract).

### SEROSA

The outermost lining of the digestive tract is the serosa. The serosa extends as peritoneal membranes.

### INNERVATION

The digestive tract has a unique nervous network called the *enteric nervous system* (ENS). The ENS regulates gastrointestinal (gut) motility and secretion; its activity is modulated by autonomic nerves, especially

the parasympathetic (vagal) fibers. Some refer to the gut as a second brain. Why? Because so many of the neurotransmitters that affect the brain also affect the gut. Ever have a “gut” feeling that something is wrong? Your gut might be telling you something!

## PERITONEAL MEMBRANES

The peritoneal membranes in the abdominal cavity are extensions of the serosa. These form large flat and folded structures that perform several important functions. They help anchor the digestive organs in place; carry blood vessels, lymph vessels, and nerves to the abdominal organs; and help restrict the spread of infection in the abdominal cavity.

The peritoneal membranes, located behind the digestive organs, are called the *mesentery* and *mesocolon*. When located in front of the organs, they are called the *greater* and *lesser omentum*. The greater omentum is a double layer of peritoneum that contains a considerable amount of fat and resembles an apron draped over the abdominal organs.

### 2+2 Sum It Up!

The digestive system is made up of a hollow tube that extends from the mouth to the anus and the accessory organs of digestion. The digestive system has four functions: ingestion, digestion, absorption, and elimination. The wall of the digestive tract has four layers: mucosa, submucosa, muscle layer, and serosa. The muscle layer enables the digestive tract to mix, mash, and move food through the tract; the forward movement of food is caused by peristalsis. The enteric nervous system regulates gastrointestinal (gut) motility and secretion; its activity is modulated by autonomic nerves, especially the parasympathetic (vagal) fibers. Large, flat peritoneal membranes in the abdominal cavity help anchor the digestive organs in place.

## STRUCTURES AND ORGANS

### MOUTH

The digestive tract begins with the mouth, also known as the *oral cavity*. The mouth contains structures that assist in the digestive process. These include the teeth, tongue, salivary glands, and several other structures. The buccal cavity, as part of the oral cavity, refers to the area between the gums and the cheek or lips.

### TEETH

The purpose of the teeth is to chew food and to begin mechanical digestion. During the process of chewing, or mastication (mass-ti-KAY-shun), the teeth break down large pieces of food into smaller pieces. Once moistened by the secretions in the mouth, the small pieces of food are easily swallowed.

During a lifetime, a person will have two sets of teeth: deciduous and permanent. The deciduous (deh-SID-yoo-us) teeth are also called *baby teeth* or *milk teeth*. There are 20 deciduous teeth. They begin to appear at

the age of 6 months and are generally in place by the age of 2½ years. Between the ages of 6 and 12 years, these teeth are pushed out and replaced by the permanent teeth. There are 32 permanent teeth (Figure 23-3, A).

Note the positions and names of the teeth: the incisors, cuspids (canines), premolars (bicuspid), and molars, including wisdom teeth. The shape and location of each tooth determines its function. For example, the sharp, chisel-shaped incisors and cone-shaped cuspids are front teeth used to tear or grasp food. The larger flatter molars, the back teeth, are more suited for grinding food.

A tooth has three parts: the crown, the neck, and the root (see Figure 23-3, B). The crown of the tooth is above the level of the gum, or gingiva (JIN-ji-vah), and is covered with hard brittle enamel. The neck connects the crown with the root of the tooth. The root is that part of the tooth embedded in the jawbone. The outer surface of the root is anchored to the periodontal membrane by cementum. The bulk of the tooth consists of a bonelike material called *dentin*. Nerves, blood vessels, and connective tissue, called *pulp*, penetrate the dentin through the pulp cavity and supply the tooth with sensation and nutrients. As the pulp cavity extends into the root, it is called the *root canal*. The *periodontium* is the name given to the tissues that surround the teeth and include the gums, soft tissue, and bone. Gingivitis and stomatitis are mouth conditions that are often drug induced. Both cause considerable discomfort and interfere with nutrition. Gingivitis is inflammation of the gums. Stomatitis refers to inflammation or ulcers of the oral mucosa of the mouth area.



### Do You Know...

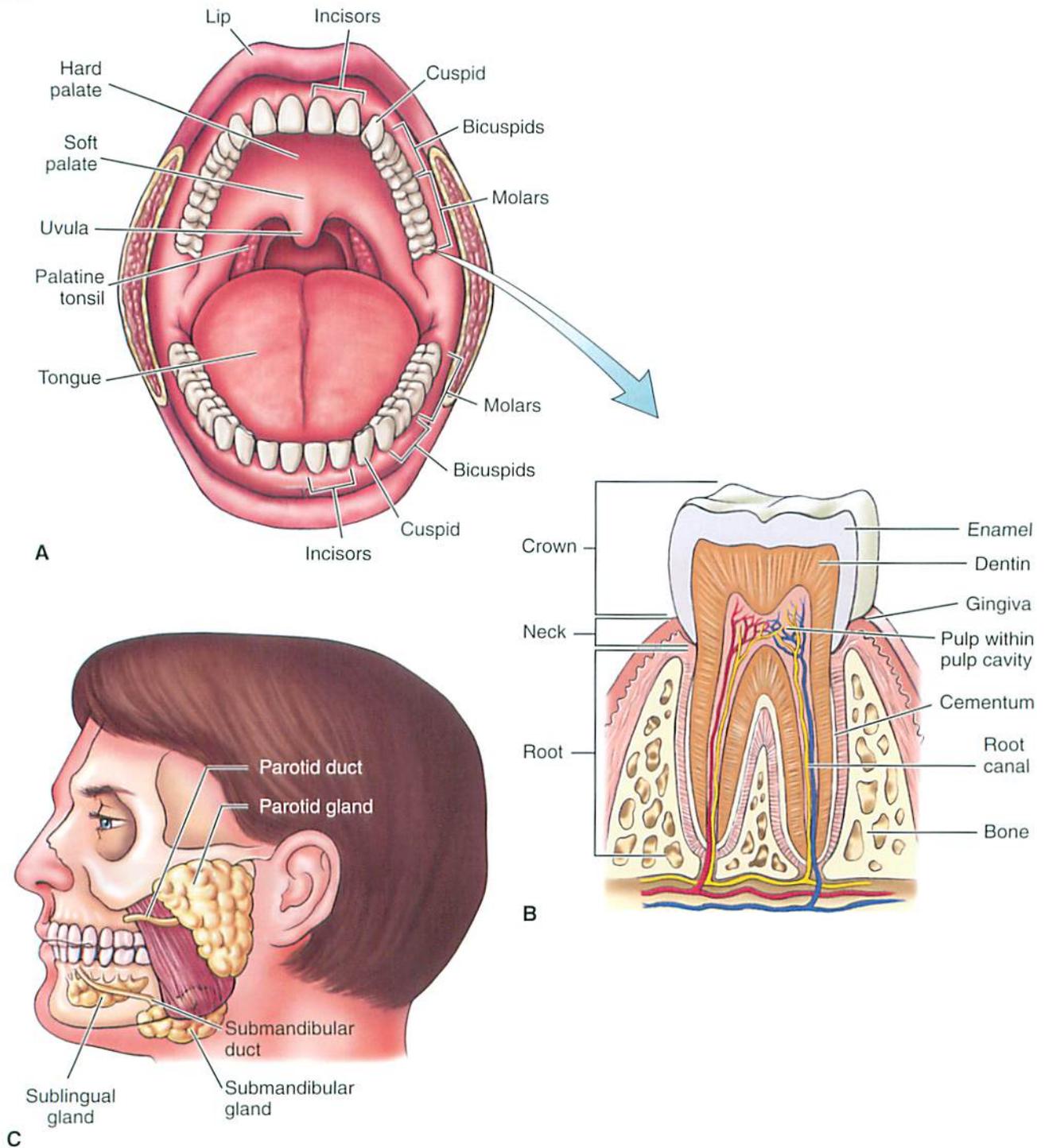
#### The Meaning of These Tooth Words?

Four back molars can appear later in life (at 17 to 25 years of age, when you have “become wiser”) and are therefore called *wisdom teeth*. In many individuals, the wisdom teeth remain embedded in the jawbone and are said to be impacted. Because impacted teeth serve no function and are often a source of infection, they are frequently removed.

Lacking some naming creativity, the canine teeth are commonly called *eyeteeth* because they are positioned under the eyes. To be “long in the tooth” is a not-too-flattering reference to advanced age; the gums recede with aging, thereby exposing more of the tooth.

### TONGUE

The tongue is a muscular organ that occupies the floor of the mouth and serves two major roles in the digestive process. First, it facilitates chewing and swallowing by continuously repositioning the food in the mouth. As swallowing begins, the tongue pushes the food, which it has molded into a ball-like mass called a *bolus*, toward the pharynx. Second, the tongue contains the taste buds and allows us to taste food.



**FIGURE 23-3** Oral cavity. **A**, Structures in the mouth. **B**, Longitudinal view of a tooth. **C**, Location of the salivary glands.

If you look under your tongue in the mirror, you will notice two structures. One is a small piece of mucous membrane called the *frenulum*, which anchors the tongue to the floor of the mouth. The second structure is an extensive capillary network that provides the sublingual (under the tongue) area with a rich supply of blood. Because the blood supply is so good, medications are absorbed rapidly when administered sublingually.

### ? Re-Think

1. What is peristalsis? What causes it? What does it do?
2. A patient is taking three medications: one by the oral route, the second by the buccal route, and the third to be administered sublingually. Explain the difference between the three routes of administration.

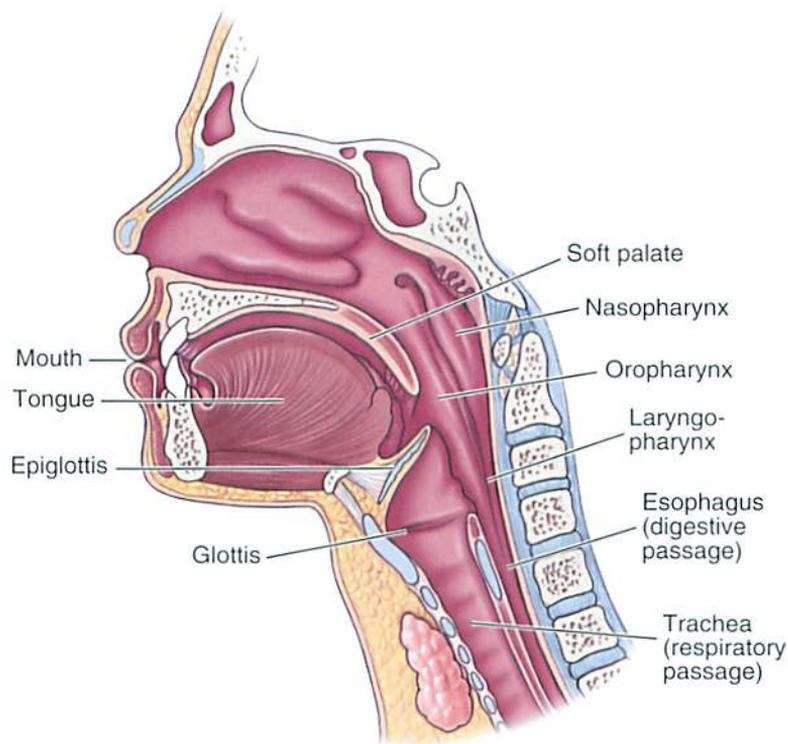


FIGURE 23-4 Eating and swallowing structures: from mouth to pharynx to esophagus.

## SALIVARY GLANDS

Three pairs of salivary glands secrete their contents into the mouth: the parotid glands, the submandibular glands, and the sublingual glands (see Figure 23-3, C). The parotid glands are the largest of the three glands and lie below and anterior to the ears. These are the glands infected by the mumps virus, which results in a chipmunk-like appearance. The submandibular glands are located on the floor of the mouth. The sublingual glands are located under the tongue and are the smallest of the salivary glands. The salivary glands are exocrine glands that secrete saliva (from a Greek word meaning “spittle”), a watery fluid that contains mucus and one digestive enzyme called *salivary amylase*, or *ptyalin*. Approximately 1 L of saliva is secreted each day. Saliva reaches the mouth by way of tiny ducts. The most important function of saliva is to soften and moisten food and thereby facilitate swallowing.

What does one do with 1 L of saliva? Normally, the saliva is swallowed. If someone is unable to swallow, however, the saliva must be suctioned so that it is not aspirated into the lungs. This problem occurs in patients who experience inflammation, tumors, or surgery of structures of the upper digestive tract.

Occasionally, one of the salivary ducts becomes obstructed by a stone. The condition is called *sialolithiasis* (si-ah-lo-li-THI-ah-sis) and is characterized by intense pain on eating when the salivary juices start to flow.

## OTHER STRUCTURES WITHIN THE MOUTH

The hard and soft palates form the roof of the mouth (see Figure 23-3, A). The anterior hard palate separates the oral cavity from the nasal passages, and the posterior soft palate separates the oral cavity from the nasopharynx. The soft palate extends toward the back of the oral cavity as the uvula (YOO-vyoo-lah), the V-shaped piece of soft tissue that hangs down from the upper back region of the mouth. The uvula plays a role in swallowing. The palatine tonsils are masses of lymphoid tissue located along the sides of the posterior oral cavity. These play a role in the body’s defense against infection (further explained in Chapter 21).

## PHARYNX

The tongue pushes the food from the mouth into the pharynx (throat). The pharynx is involved in swallowing (deglutition). The three parts of the pharynx are the nasopharynx, the oropharynx, and the laryngopharynx (Figure 23-4). Only the oropharynx and laryngopharynx are part of the digestive system.

The pharynx communicates with the nasal, respiratory, and digestive passages. The act of swallowing normally directs food from the throat into the esophagus, a long tube that empties into the stomach. Food does not normally enter the nasal or respiratory passages because swallowing temporarily closes off the openings to both. For example, during swallowing, the soft palate moves toward the opening to the

nasopharynx. Similarly, the laryngeal opening is closed when the trachea moves upward and allows the epiglottis to cover the entrance to the respiratory passages. You can see this process as the up-and-down movement of the Adam's apple, part of the larynx or voice box.

### Re-Think

1. List the three salivary glands.
2. Explain how food or water can be aspirated into the respiratory tract.

## ESOPHAGUS

The **esophagus** (eh-SOF-ah-gus) is the food tube that carries food from the pharynx to the stomach (see Figure 23-1). The esophagus, which is approximately 10 inches (25 cm) in length, descends through the chest cavity and penetrates the diaphragm. The act of swallowing pushes the bolus of food into the esophagus. The presence of food in the esophagus stimulates peristaltic activity and causes the food to move through the esophagus into the stomach. Glands within the mucosa of the esophagus secrete mucus, which lubricates the bolus and facilitates its passage along the esophagus.

The two esophageal sphincters are the pharyngo-esophageal sphincter located at the top of the esophagus, and the gastroesophageal, or lower esophageal sphincter (LES), located at the base of the esophagus (Figure 23-5). Swallowing pushes food past the pharyngo-esophageal sphincter into the esophagus. Relaxation of the LES keeps the base of the esophagus open, thereby allowing the passage of food into the stomach. When contracted, however, the LES closes the base of the esophagus, thereby preventing reflux, or regurgitation, of acidic stomach contents back into the esophagus.

In some persons a poorly functioning LES allows for reflux of stomach contents into the esophagus. The condition is called *gastroesophageal reflux disease* (GERD) and is characterized by a burning sensation called *heartburn* or *pyrosis*. The burning sensation is a result of the high acidity of stomach contents. (Note that the word *pyrosis* is related to the word *pyromaniac*, a person who loves to set fires, and to the word *pyretic*, referring to fever.)

## STOMACH

### WHAT IT DOES

The **stomach** is a pouchlike organ that lies in the upper part of the abdominal cavity under the diaphragm (see Figure 23-1). It performs five important digestive functions:

- Secretion of gastric (stomach) juice, which includes digestive enzymes, hydrochloric acid, and intrinsic factor.
- Secretion of gastric hormones.

- Regulation of the rate at which the partially digested food is delivered to the small intestine. This is the most important function of the stomach.
- Digestion of food. The stomach plays an important role in the mechanical digestion (mixing and mashing) of food. Chemical digestion is limited.
- Absorption of small quantities of water and dissolved substances. The stomach is not well suited for an absorptive role. It can, however, absorb alcohol efficiently. Therefore, the consumption of alcoholic beverages on an empty stomach can quickly increase blood levels of alcohol.

## REGIONS OF THE STOMACH

The major regions of the stomach include the fundus, the body, and the pylorus (see Figure 23-5, *A*). The pylorus, which literally means “gatekeeper,” continues as the pyloric canal. A pyloric sphincter is located at the end of the pyloric canal and helps regulate the rate at which gastric contents are delivered to the small intestine. Other landmarks of the stomach include the greater curvature and the lesser curvature.

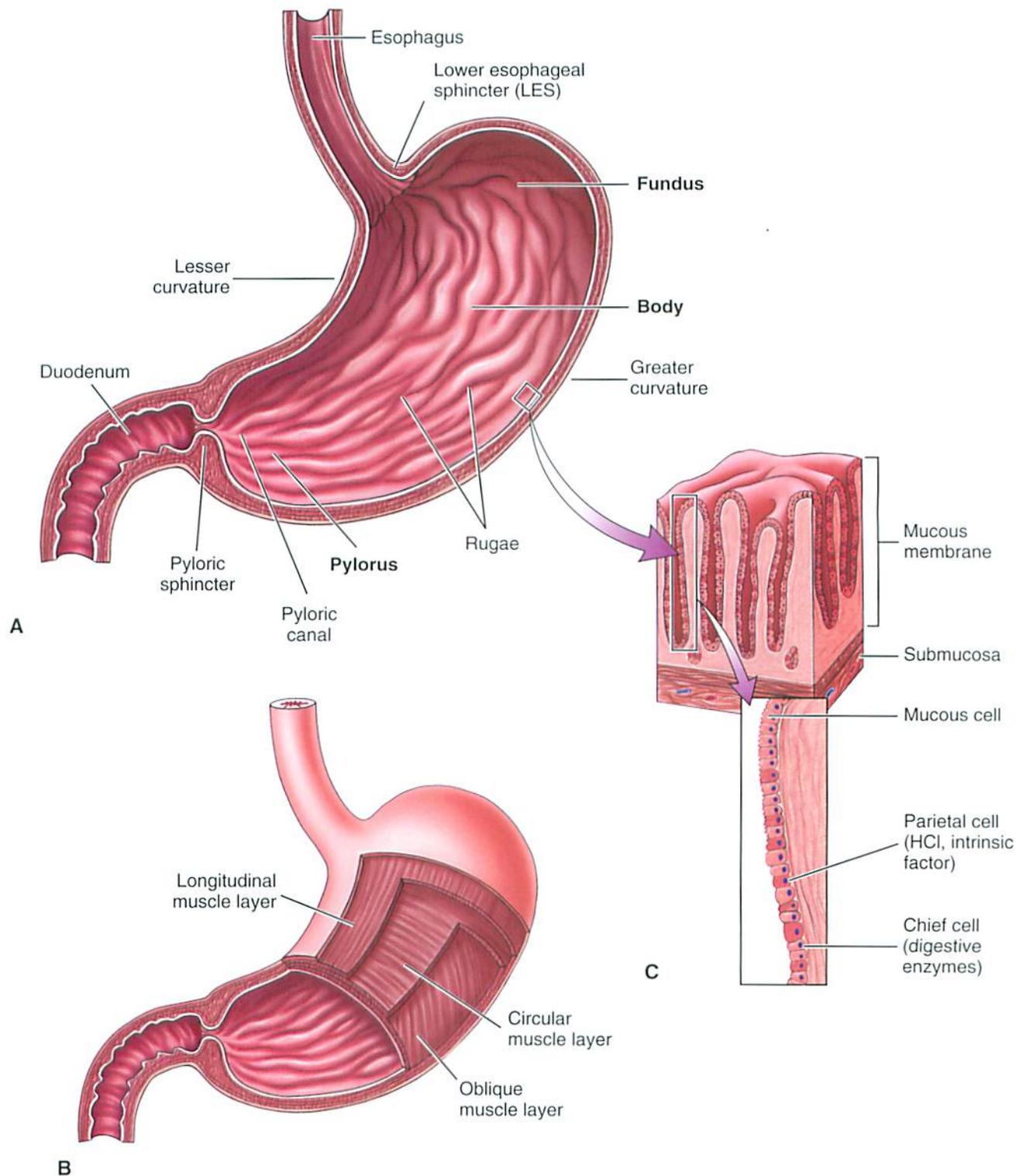
How big can your stomach get? The empty stomach lies in thick accordion-like folds called *rugae* (ROO-gay). The rugae allow the stomach to expand. For example, when the stomach is empty, it is the size and shape of a sausage. Following a large meal, however, the stomach may expand to approximately 1 L. Think of your turkey dinner sitting in your very expanded stomach—it feels like you are going to pop! Sadly, the stomach can keep stretching in response to continued overeating.

## MUSCLES OF THE STOMACH

The stomach has three layers of muscles that lie in three directions: longitudinal, oblique, and circular (see Figure 23-5, *B*). This arrangement allows the stomach to churn and mix the food with gastric juice to create a thick, pastelike mixture called **chyme** (kime). The stomach is your personal organ grinder. The muscles of the stomach also generate peristaltic waves that squeeze the food toward the pylorus.

## GLANDS OF THE STOMACH

The mucous membranes of the stomach contain gastric glands (see Figure 23-5, *C*). These glands contain three types of secretory cells: (1) the mucous cells, which secrete mucus; (2) the chief cells, which secrete digestive enzymes; and (3) the parietal cells, which secrete hydrochloric acid (HCl) and intrinsic factor. The secretions of the gastric glands are called *gastric juice*. An interesting note: the HCl in gastric juice is strong enough to eat the varnish off furniture. In addition to the gastric juice, other cells secrete thicker mucus and bicarbonate that adheres closely to the stomach lining. This secretion forms a protective coating for the stomach lining and prevents the acidic gastric juices from digesting the stomach itself.



**FIGURE 23-5** Stomach. **A**, Regions of the stomach: fundus, body, and pylorus. **B**, Three muscle layers of the stomach. **C**, Mucosa of the stomach, showing the mucus, parietal, and chief cells.

### ? Re-Think

1. Locate the following structures: LES, fundus of the stomach, pyloric sphincter, and the greater and lesser curvatures.
2. What is the most important function of the stomach?
3. What "burns" the base of the esophagus in patients with GERD?

### VOMITING

Vomiting, or emesis, is and is not a stomach event. It is a stomach event in that the stomach is emptied on vomiting. However, vomiting is not a stomach event in terms of mechanism. Vomiting is part of the emetic reflex controlled by the medulla oblongata. In response to stimuli sent to the medullary vomiting center, the

LES relaxes and the diaphragm and abdominal muscles contract, thereby compressing the stomach and ejecting its contents. You should become a keen observer of vomited stomach contents and its surrounding events. For example, you will want to know if the vomiting was preceded by nausea or vertigo (dizziness), or related to food or drug intake. Record the frequency—is it an isolated event or more frequent? Record the amount and contents, including drugs, and note the color and any evidence of blood (blood that is changed because of the stomach acid can have a bright red or coffee grounds–like appearance). A lot of clinically valuable information can be obtained through your observations. Don't rush to flush!

### WHEN THE STOMACH IS NOT WORKING RIGHT

The stomach gets a lot of attention clinically. Note how it is shown in Figure 23-6:

- *Ulcer* (see Figure 23-6, A). A healthy digestive tract has an intact inner mucous membrane. The stomach lining may erode, or break down, thereby creating a lesion called an *ulcer*. Some ulcers are caused by the *Helicobacter pylori* microorganism and are painful and prone to bleeding. An antiulcer drug plan for this type of ulcer includes an antibiotic in addition to drugs that decrease or neutralize acid.
- *Hiatal hernia* (see Figure 23-6, B). The stomach is located in the upper abdominal cavity immediately

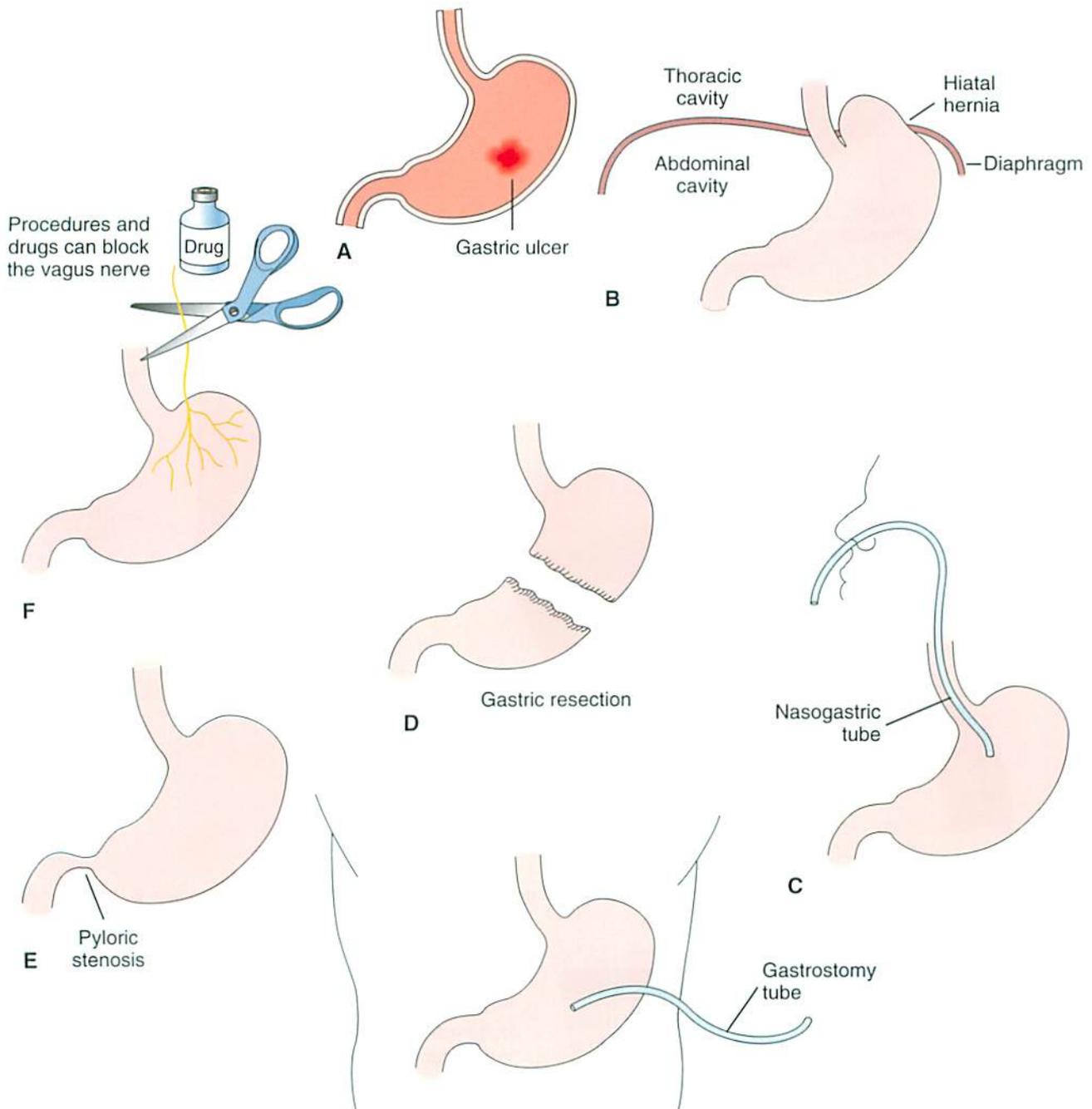


FIGURE 23-6 Some clinical conditions that involve the stomach. The labeled parts of this figure are described in the text.

below the diaphragm. The esophagus enters the abdominal cavity through an opening in the diaphragm. If that opening is weakened or enlarged, the stomach may protrude, or herniate, from the abdominal cavity into the thoracic cavity. This condition is called a *hiatal hernia*.

- **Nasogastric tube** (see Figure 23-6, C). Many conditions require that a nasogastric (NG) tube be inserted through the nasal passages into the stomach. Usually, the NG tube is used to empty the stomach to prevent vomiting. When a person cannot eat normally, a tube may be surgically inserted through the abdominal wall into the stomach. Food is introduced directly into the stomach through this tube. This procedure is called a *gastrostomy*.
- **Gastric resection** (see Figure 23-6, D). An important function of the stomach is to regulate the rate at which chyme is delivered to the duodenum. A person with cancer of the stomach may require a surgical procedure that removes the stomach, or part of it. The procedure is called a *gastric resection*, or *gastrectomy*. A serious consequence of gastric resection is the inability to regulate the rate at which chyme is delivered to the duodenum. Because food (chyme) is literally dumped into the duodenum, since there is no stomach, a condition called *dumping syndrome* develops. The person experiencing dumping syndrome looks and acts “shocky,” with severe nausea, perspiration, dizziness, and tachycardia.
- **Pyloric stenosis** (see Figure 23-6, E). The digestive tract is a hollow tube that must remain open. Occasionally, during infancy, the pylorus is too narrow and impedes the movement of food out of the stomach. This condition is pyloric stenosis (narrowing). Pyloric stenosis is characterized by projectile vomiting immediately after feeding. Interestingly, pyloric stenosis is more common in male infants than in female infants. Fortunately, a simple surgical procedure corrects the defect.
- **Gastric hyperactivity** (see Figure 23-6, F). Stimulation of the vagus nerve increases gastric secretion and motility. Certain drugs block the effects of the vagus nerve, thereby decreasing gastric secretion and motility. The administration of a vagolytic drug is like cutting the vagus nerve (vagotomy).
- **Autonomic translation**. Stimulation of the vagus nerve activates muscarinic receptors. Drugs that activate muscarinic receptors stimulate gut motility and secretion and are used to treat “slow” gut conditions such as gastroparesis. Anticholinergic or antimuscarinic (atropine) drugs block muscarinic receptors, thus slowing gut motility and decreasing gastric secretions.

## Re-Think

What functions are lost in the patient who has a total gastrectomy?

## 2+2 Sum It Up!

The mouth begins the process of mechanical and chemical digestion. The bolus of food is swallowed and moves from the mouth, through the pharynx and esophagus, and into the stomach. The stomach continues the digestive process by mashing the food into chyme. Gastric juice minimally helps to break down food chemically. The stomach delivers chyme to the duodenum (small intestine) at the proper rate.

## SMALL INTESTINE

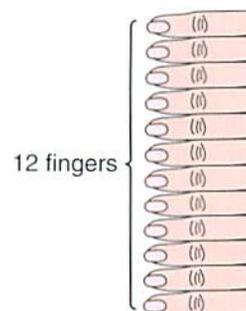
### LOCATION AND PARTS

An acidic chyme is ejected by the stomach into the small intestine (see Figure 23-1). The small intestine is called “small” because its diameter is smaller than the diameter of the large intestine. However, the word “small” does not refer to the length of the small intestine; it is considerably longer (about 20 feet [6 m]) than the large intestine (5 feet [1.5 m]). The small intestine is located in the central and lower abdominal cavity and is held in place by the mesentery. The small intestine is concerned primarily with chemical digestion and the absorption of digested food. It consists of three parts: the duodenum, the jejunum, and the ileum. Although the stock market can make your guts churn, it can also help you remember the parts of the small intestine:

Dow	Duodenum
Jones	Jejunum
Industrials	Ileum

### SEGMENTS OF THE SMALL INTESTINE

The **duodenum** (doo-oh-DEE-num) is the first segment of the small intestine. The word *duodenum* literally means “twelve” (*duo* means “two”; *denum* means “ten”). In this case, the reference is to the width of 12 fingers. Thus, the length of the duodenum is 12 finger-breadths or approximately 10 inches (25 cm).



Why is the duodenum considered the meeting point for digestion? In addition to receiving chyme from the stomach, the duodenum also receives secretions from several accessory organs of digestion such as the liver, gallbladder, and pancreas (see Figure 23-1). These

secretions, in addition to those from the mouth, stomach, and duodenum, are responsible for the digestion of all food. Most digestion and absorption occur in the duodenum and the first third of the jejunum, the next segment. *To repeat: Most digestion and absorption occur in the duodenum and first third of the jejunum.*

The **jejunum** (jeh-JOO-num) is the second segment of the small intestine. It is approximately 8 feet (2.4 m) in length. Digestion and absorption of food occurs in the first third of the jejunum.



### Do You Know...

#### What Borborygmus Is?

"Gurgle, gurgle," growls your guts. How embarrassing is this as you look around the room! This gurgling sound that eminently emanates from your intestines is caused by the rapid movement of gas and liquid through the intestines. The sounds are louder and more noticeable when you are hungry because you tend to salivate more and swallow more air. "Gurgle, gurgle" is called *borborygmus* (bor-bor-IG-mus) and comes from the Greek word meaning "to rumble." Despite this long and ugly name, borborygmus is normal. Its only purpose? To embarrass you.

The **ileum** (IL-ee-um) is the third segment of the small intestine and is approximately 12 feet (3.6 m) in length. It extends from the jejunum to the ileocecal valve. The ileocecal valve prevents the reflux of contents from the cecum (first part of the large intestine) back into the ileum. The function of the ileum is to complete the process of absorption of digestive end products, vitamin B<sub>12</sub>, and bile salts. The lining of the ileum contains numerous patches of lymphoid tissue called *Peyer's patches*. Peyer's patches diminish the bacterial content in the digestive system. The ileum performs another important role as an "ileal brake." Through a reflex mechanism, the presence of fatty acids in the ileum slows gut motility. What you eat affects gut motility and secretions.

### FUNCTIONS OF THE SMALL INTESTINE

What is so special about the wall of the small intestine? The wall of the small intestine forms circular folds with fingerlike projections called *villi* (sing., **villus**) (Figure 23-7). The epithelial cells of each villus form extensions called *microvilli*. The large number of villi and microvilli increases the amount of digested food that can be absorbed.

What is a villus? Each villus consists of a layer of epithelial tissue that surrounds a network of blood capillaries and a lymphatic capillary called a *lacteal* (see Figure 23-7, B). The villus absorbs the end products of digestion from the duodenum into the blood capillaries or the lacteal. The capillary blood within the villus drains into the hepatic portal system and then into the liver. Thus, the end products of carbohydrate and protein digestion first go to the liver for processing before being distributed throughout the body. The

end products of fat digestion enter the lacteal, forming a milky-white lymph called **chyle** (kile). The chyle empties directly into the lymphatic system. (Do not confuse the words *chyle* and *chyme*.)

In addition to forming a site for absorption, the cells of the intestinal wall also secrete several digestive enzymes and two important hormones: secretin and cholecystokinin (CCK). Table 23-1 lists the major intestinal enzymes and hormones.

### Peristalsis and Absorption in the Small Intestine

Like other parts of the digestive tract, peristalsis moves its digestive contents through the small intestines. The peristalsis in the small intestine, however, is unique. Instead of merely pushing the digestive contents forward, the peristalsis also generates a swishing and swaying motion. This motion continually washes the nutrient-rich digestive contents across the villi, thereby increasing absorption. That which is not absorbed is moved forward by peristaltic waves toward the large intestine.



### Re-Think

1. List the three segments of the small intestine.
2. Where does most digestion and absorption take place?

## LARGE INTESTINE

The large intestine is approximately 5 feet (1.5 m) long and extends from the ileocecal valve to the anus (Figure 23-8). The cecum, colon, rectum, and anal canal are parts of the large intestine.

### SEGMENTS OF THE LARGE INTESTINE

The first part of the large intestine is the **cecum**. The cecum is located in the right lower quadrant and ascends on the right side as the ascending **colon**. Attached to the cecum is the **appendix**, a wormlike structure that contains lymphocytes and is a source of immune cells.

Occasionally, the appendix becomes inflamed, causing appendicitis, and must be surgically removed through an appendectomy. Failure to remove an inflamed appendix causes it to rupture. The discharge of fecal material into the peritoneal cavity causes a life-threatening infection called *peritonitis*. RLQ pain? Think appendicitis and get thee to a doctor.

The ascending colon ascends on the right side and curves acutely near the liver at the hepatic flexure. As it crosses the upper abdomen, it is known as the *transverse colon*. The colon then bends near the spleen at the splenic flexure to become the descending colon. The descending colon descends on the left side of the abdomen into an S-shaped segment called the *sigmoid colon*. Structures distal to the sigmoid colon include the rectum, anal canal, and anus. The anal canal ends at the anus, a structure composed primarily of two sphincter muscles (an involuntary internal sphincter

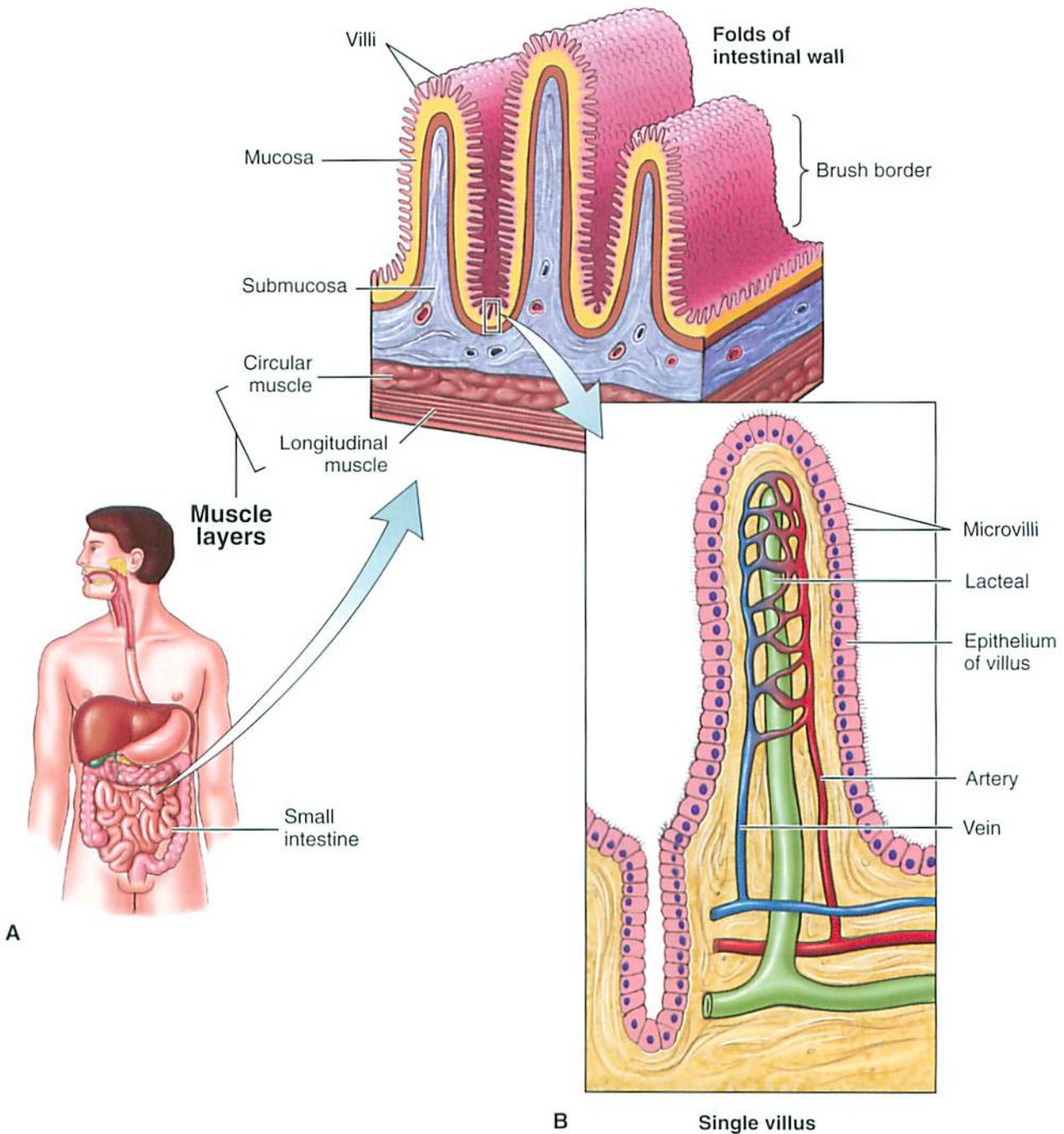


FIGURE 23-7 Small intestine. **A**, Folds of the intestinal wall. **B**, Single villus showing the blood capillaries and the lacteal.

and a voluntary external sphincter). The sphincters are closed except during the expulsion of the feces. Feces (FEE-seez) is waste composed primarily of nondigestible food residue; it forms the stool, or bowel movement (BM). Expulsion of feces is called *defecation*.

#### FUNCTIONS OF THE LARGE INTESTINE

The four functions of the large intestine are as follows:

- Absorption of water and electrolytes
- Synthesis of certain vitamins by the intestinal bacteria (especially vitamin K and some B vitamins)
- Temporary storage site of waste (feces)
- Elimination of waste from the body (defecation)

#### Peristalsis and Absorption

Intermittent and well-spaced peristaltic waves move the fecal material from the cecum through the colon. As the fecal material moves through the colon, water is continuously reabsorbed from the feces, across the intestinal wall, into the capillaries. Consequently, as the feces enter the rectum, it has changed from a watery consistency to a semisolid mass. Feces that remain in the large intestine for an extended period lose excess water, and the person experiences constipation. Rapid movement through the intestine allows insufficient time for water reabsorption, causing diarrhea.

**Table 23-1** Major Secretions of the Digestive System

NAME	SOURCE	DIGESTIVE FUNCTION
<b>Enzymes</b>		
Salivary Enzyme • Amylase (ptyalin)	Salivary glands	Begins carbohydrate digestion to disaccharides
Gastric Enzyme • Pepsin	Gastric glands	Begins digestion of protein
Pancreatic Enzymes • Amylase • Lipase • Proteases Trypsin Chymotrypsin	Pancreas Pancreas Pancreas	Digests polysaccharides to disaccharides Digests fats to fatty acids and glycerol Digests proteins to peptides and amino acids
Intestinal Enzymes • Peptidases • Disaccharidases Sucrase Lactase Maltase • Lipase • Enterokinase	Intestine Intestine Intestine Intestine	Digests peptides to amino acids Digests disaccharides to monosaccharides Digests fats to fatty acids and glycerol Activates trypsinogen to trypsin
<b>Digestive Aids</b>		
Hydrochloric acid	Stomach	Helps unravel proteins; kills microorganisms that are ingested in food
Intrinsic factor	Stomach	Assists in the absorption of vitamin B <sub>12</sub>
Bile	Liver	Emulsifies fats; aids in the absorption of fatty acids and the fat-soluble vitamins (A, D, E, K)
Mucus	Entire digestive tract	Softens food; lubricates food and eases its passage through the digestive tract
<b>Hormones</b>		
Gastrin	Stomach	Stimulates gastric glands to secrete gastric juice
Cholecystokinin	Duodenum	Stimulates the gallbladder to contract and release bile; stimulates release of pancreatic digestive enzymes; slows gastric emptying
Secretin	Duodenum	Stimulates the pancreas to secrete sodium bicarbonate; called "nature's own antacid"; makes chyme alkaline



### Do You Know...

#### Why Hirschsprung's Disease Is Also Called Megacolon?

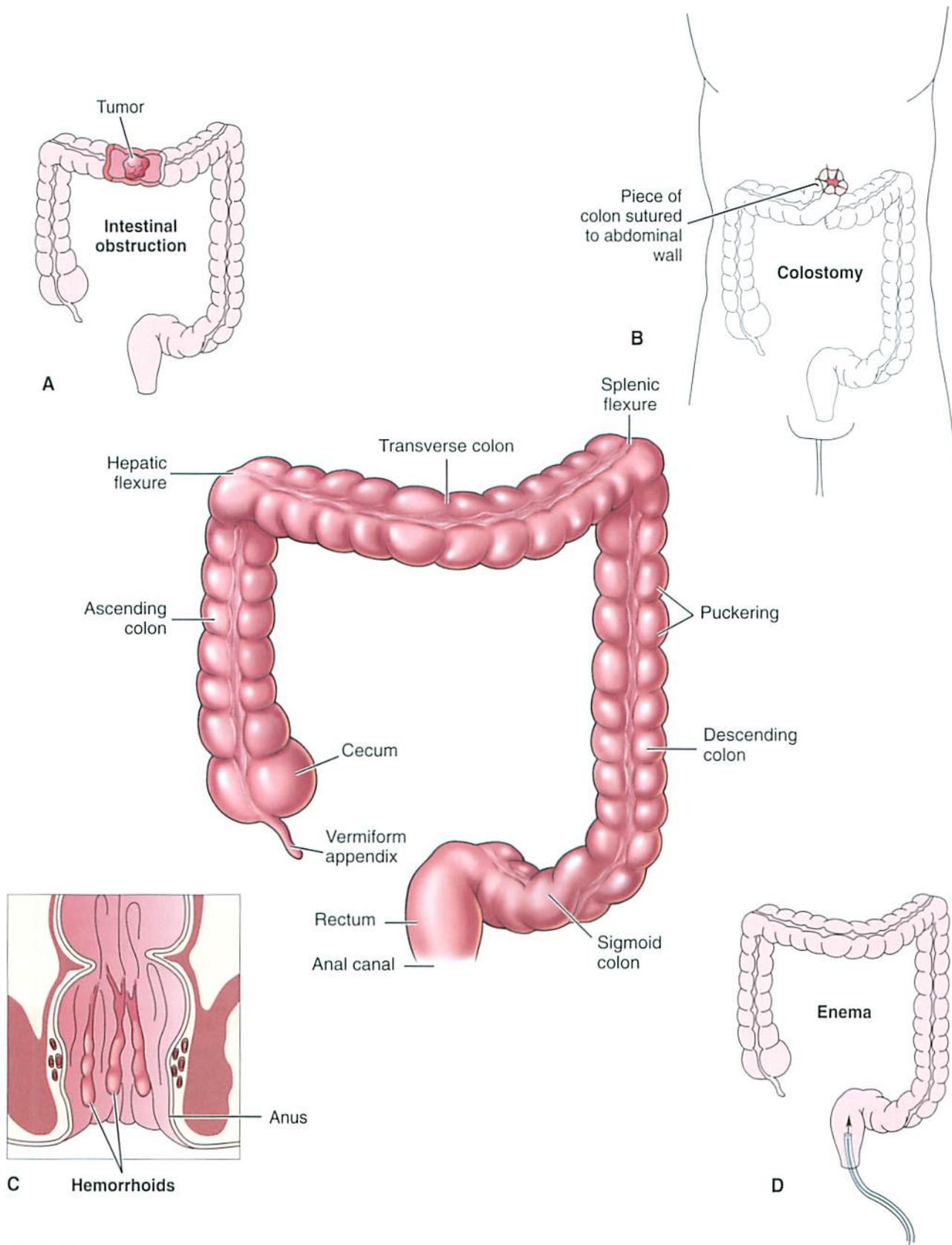
Hirschsprung's disease is a congenital disorder characterized by a lack of the enteric nerve network (no ganglia) in the distal colon near the rectum. The aganglionic colon "feels" no urge to defecate and enlarges in response to accumulated feces (earning its alternative name, *megacolon*, or *congenital aganglionosis*). When the megacolon finally produces a stool, it is huge and noteworthy! This condition attests to the role of the enteric nerves in "moving things along."

Drugs may be administered to increase or decrease the motility of the large intestine. For example, a person with diarrhea may take a drug that slows motility. Slower motility allows for more water reabsorption and the formation of a drier stool. In contrast, a person

with constipation requires an increase in motility, so as to prevent additional water reabsorption. Thus, a laxative, which increases motility, is often prescribed to relieve constipation.

#### Bacterial Action

What do bacteria do in the large intestine? The bacterial content in the feces is normally high, accounting for an impressive 30% of the fecal content. (The presence of bacteria in the intestinal tract is normal and is called the *normal flora*.) Some of these bacteria, *Escherichia coli* for example, synthesize vitamins. Although *E. coli* is normal and beneficial in the intestinal tract, it can cause serious medical conditions in urine and blood. Bacteria are also responsible for the formation of malodorous molecules that provide stools with their characteristic aroma.



**FIGURE 23-8** Large intestine (*center*) and some clinical conditions that affect the large intestine. The labeled parts of this figure are described in the text.

**Do You Know...****About the Clinical Concern for *Clostridium Difficile*?**

*Clostridium difficile*, a gram-positive bacillus, is a part of the intestinal normal flora; it normally causes no problems. If the intestinal flora is disrupted, as may occur with antibiotic therapy, the number of *C. difficile* increases, causing a serious antibiotic-associated colitis. The combination of antibiotic therapy and severe diarrhea should send up a red flag: the possibility of superinfection with *C. difficile*. How did *C. difficile* get its name? From its uncooperative nature; it is difficult to grow in the lab.

**Intestinal Gas**

We have our own natural gas line! The average person expels about 500 mL of gas/day (always a crowd pleaser). The expelled gas is called *flatus* (FLAY-tus), and the process is called *flatulence* (FLATCH-yoo-lints). From a Ms. Manners perspective, most episodes of flatulence can be controlled, a much appreciated act of kindness. Gas is normally produced from air that is swallowed and as a byproduct of digestion, especially of gassy foods. Conditions such as lactose intolerance produce excess gas, causing severe cramping and discomfort. You will often hear surgeons ask patients if they have been “passing gas.” A barely audible and embarrassed “yes” indicates that peristaltic activity, which often diminishes during surgery, has resumed. Passing gas after surgery is very good. The intestinal gases include methane and hydrogen gas, both of which are flammable. This is a concern in the operating room, where the use of electrical equipment (cautery) can cause the intestinal gas to explode. Not good. This just in—dinosaurs may have done themselves in through the expulsion of ginormous amounts of gas; the gas produced a toxic environment unsuitable for baby dinos.

**Re-Think**

1. List the parts of the large intestine.
2. Why is it important to assess your patient's bowel sounds postoperatively?

**WHEN THE LARGE INTESTINE IS NOT WORKING RIGHT**

The large intestine is a common site of clinical disorders and discomfort. Some clinical conditions and procedures involving the large intestine are illustrated in Figure 23-8.

Because the digestive tract is a hollow tube that extends from the mouth to the anus, it occasionally becomes blocked, or occluded (see Figure 23-8, A). For example, a tumor may grow large enough to block a segment of the large intestine completely. Or, the bowel may become twisted on itself, causing a *volvulus*, and may occlude the lumen of the bowel. Both conditions result in intestinal obstruction, whereby the movement of feces is impaired.

In case of an intestinal obstruction, a surgical procedure may be performed to relieve the obstruction (see Figure 23-8, B). An incision into the colon and the rerouting of the colon onto the surface of the abdomen (colostomy) allows the feces to bypass the obstruction. Because of insufficient water reabsorption, a colostomy performed on the ascending colon is characterized by the drainage of liquid feces. Because of adequate water reabsorption along the length of the large intestine, however, a colostomy performed on the sigmoid colon is characterized by a well-formed stool.

All organs receive a supply of oxygen-rich blood from the arteries and are drained by veins. The walls of the veins are thin and may become damaged by excessive pressure. Sometimes, the veins that drain the anal region become stretched and distorted, causing varicosities. These varicosities are called *hemorrhoids* (see Figure 23-8, C).

For several reasons (e.g., constipation, preparation for x-ray examination), cleansing of the rectum or colon may be necessary. This procedure is accomplished by an enema, which infuses water through a tube inserted into the rectum (see Figure 23-8, D). The water stimulates the contraction of the muscle of the bowel, causing evacuation of its contents. Once the bowel is cleansed of fecal material, barium may be infused into the lower bowel (a procedure called a *barium enema*). The white translucent barium appears on the x-ray and outlines any tumor or other abnormality.

**Do You Know...****That the “Shepherd of the Anus” Was a High-Profile “Ca-rear”?**

Ancient Egyptian medicine was divided into many specialties. Each area of the body had its own physician, or shepherd. The physician of the rectal area, comparable to today's proctologist, was called the “shepherd of the anus.” Given the ancients' preoccupation with bowel irregularity and the popularity of emetics and purges, this shepherd was a very busy person—not too different from today if you note the staggering numbers of over-the-counter gastrointestinal drugs.

**Sum It Up!**

Chyme is discharged from the stomach into the small intestine: duodenum, jejunum, and ileum. Most digestion and absorption occur in the duodenum and first third of the jejunum. The end products of digestion are absorbed across the duodenal and jejunal walls into the villi of the small intestine. Glucose and amino acids are absorbed into the capillaries of the villi. The fats and fat-soluble vitamins are absorbed into the lacteals. Water and electrolytes are absorbed as the contents move through the small and large intestines (cecum, colon, and rectum). Digestive waste is eliminated as feces.

**Re-Think**

List the structures through which food would pass on a mouth-to-anus travelogue.

## ACCESSORY DIGESTIVE ORGANS

Three important organs—the liver, the gallbladder, and the pancreas—empty their secretions into the duodenum (Figure 23-9). These secretions are necessary for the digestion of food.

## LIVER

The liver is a large reddish-brown organ located in the mid and right upper abdominal cavity (see Figure 23-9, A). It lies immediately below the diaphragm; much of the liver is tucked up under the right rib cage. The liver is the largest gland in the body and has two main lobes: a larger right lobe and a smaller left lobe separated by a ligament. This ligament secures the liver to surrounding structures. The liver is surrounded by a fibrous membrane called a *capsule*. The word *hepatic* refers to liver.

## WHAT THE LIVER DOES

The liver is essential for life and performs many vital functions:

- *Synthesis of bile salts and secretion of bile.* Bile salts play an important role in fat digestion and in the absorption of fat-soluble vitamins. Bile secretion is the main digestive function of the liver.
- *Synthesis of plasma proteins.* The plasma proteins play an important role in maintaining blood volume and controlling blood coagulation.
- *Storage.* The liver stores many substances: glucose in the form of glycogen, the fat-soluble vitamins (A, D, E, and K), and vitamin B<sub>12</sub>.
- *Detoxification.* The liver plays an important role in the detoxification of drugs and other harmful substances. The liver changes these toxic substances into substances that can be more easily eliminated from the body by the kidneys. The liver is the most important organ in the biotransformation of drugs!
- *Excretion.* The liver excretes many substances, including bilirubin, cholesterol, and drugs.
- *Metabolism of carbohydrates.* The liver plays an important role in the regulation of blood glucose levels. If blood glucose levels rise above normal, the liver removes glucose from the blood, converts it to glycogen, and then stores it for future use. If the blood glucose levels decline below normal, the liver makes glucose from glycogen and nonglucose substances (gluconeogenesis) and releases it into the blood.
- *Metabolism of protein.* The liver can make a variety of different amino acids. Also, because only the liver contains the urea cycle enzymes, nitrogen (from ammonia) is converted to urea in the liver for eventual excretion by the kidneys. Free ammonia in the blood is toxic to humans.
- *Metabolism of fats.* The liver can break down fatty acids, synthesize cholesterol and phospholipids,

and convert excess dietary protein and carbohydrates to fat.

- *Phagocytosis.* The Kupffer cells are hepatic macrophages and can phagocytose bacteria and other substances.

## ? Re-Think

1. Explain how the liver helps to regulate blood glucose.
2. Explain why a person with poor hepatic function requires a smaller dose of a drug.
3. Explain the role of Kupffer cells.

## BLOOD SUPPLY TO THE LIVER

### Blood Supply and the Hepatic Portal System

The liver has a unique arrangement of blood vessels called the *hepatic portal system* (see Figure 18-7). The liver receives a lot of blood, approximately 1.5 L/min, from two sources: the portal vein, which provides most of the blood, and the hepatic artery. The portal vein drains blood from all of the organs of digestion and brings blood rich in digestive end products to the liver. The hepatic artery delivers oxygen-rich blood from the aorta to the liver. Blood leaves the liver through the hepatic veins and empties into the inferior vena cava, where it is returned to the heart for recirculation.

## ? Re-Think

1. Why does the liver require a blood supply from both the hepatic artery and the portal vein?
2. Why is portal blood flow to the liver much greater than the arterial flow?
3. Identify the blood vessels that carry the blood from the liver to the vena cava.

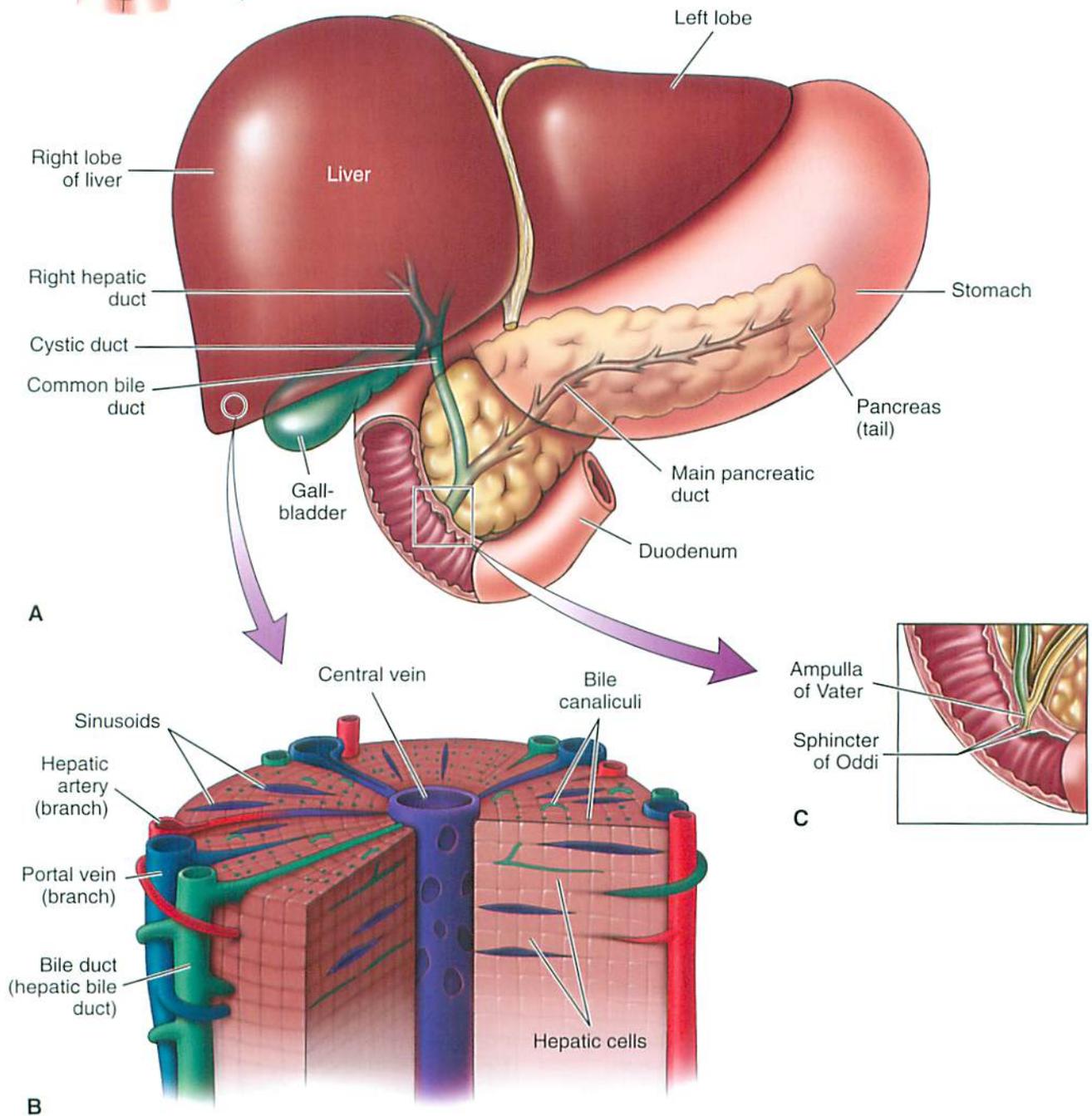
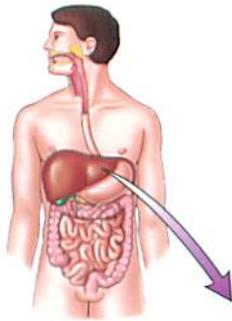
## LIVER LOBULES

The liver contains thousands of **liver lobules**, the functional unit of the liver (see Figure 23-9, B). The liver lobules consist of a special arrangement of blood vessels and hepatic cells (hepatocytes). Note the central vein and the rows of hepatic cells that radiate away from the central vein. These cells are bathed by blood that enters the lobule from both the hepatic artery and the portal vein.

Blood from these two blood vessels mixes in the liver in spaces called *sinusoids* (SINE-u-soids), or large pore capillaries. The hepatic cells extract water and dissolved substances from the sinusoidal blood. Hepatic cells then secrete a greenish-yellow substance called *bile* into tiny canals called *canaliculi* (kan-ah-LIK-yoo-lye). These tiny bile canals merge with canals from other lobules to form larger hepatic bile ducts. Bile exits from the liver through two hepatic bile ducts.

## BILE

**Bile** is a greenish-yellow secretion produced by the liver and stored in the gallbladder. Bile is composed



**FIGURE 23-9** A, Liver, gallbladder, bile ducts, and pancreas. B, Liver lobule. C, The entrance of the common bile duct into the duodenum.

primarily of water, electrolytes, cholesterol, bile pigments, and bile salts. The bile pigments bilirubin and biliverdin are formed from the hemoglobin of worn-out red blood cells. The bile salts are the most abundant constituents of the bile. Only the bile salts have a digestive function; they play an important role in fat digestion and in the absorption of fat-soluble vitamins. Between 800 and 1000 mL of bile is secreted per day.

Bile pigments, especially urobilinogen (yoo-roh-bil-IN-oh-jen) (a breakdown product of bilirubin), also give the stool a brownish color. With gallbladder disease, a gallstone sometimes becomes lodged in the common bile duct, blocks the flow of bile into the duodenum, and deprives the stools of brown pigments. Common bile duct obstruction is therefore characterized by colorless, gray, or clay-colored stools.

Bile salts are made from cholesterol by the liver. If the liver is stimulated to make additional bile salts, more cholesterol is used up, thereby lowering the amount of cholesterol in the blood. The statins, popular cholesterol-lowering drugs, stimulate the hepatic synthesis of bile salts and are therefore useful in lowering cholesterol and preventing coronary artery disease.

### BILIARY TREE

The ducts that connect the liver, gallbladder, and duodenum are called the **biliary tree** (see Figure 23-9, A). This network of ducts, the “bile aisle,” includes the hepatic bile ducts, cystic duct, and common bile duct. The hepatic bile ducts receive bile from the canaliculi in the liver lobules. The hepatic ducts merge with the cystic duct to form the **common bile duct**, which carries bile from the hepatic ducts (liver) and the cystic duct (gallbladder) to the duodenum.

The base of the common bile duct swells to form the hepatopancreatic ampulla (ampulla of Vater; see Figure 23-9, C). The main pancreatic duct joins the common bile duct at this point. The hepatopancreatic sphincter (sphincter of Oddi) encircles the base of the ampulla, where it enters the duodenum. This sphincter helps regulate the delivery of bile to the duodenum and is sensitive to nervous, hormonal, and pharmacological control. (Do not confuse the ducts of the biliary tree with the hepatic blood vessels.)

### Do You Know...

#### With No Hepatic Cells—Everything Swells?

The liver is a very busy organ. One of its functions is to make plasma proteins such as albumin. Plasma proteins help hold water in the blood vessels. In severe liver disease, insufficient protein is made, causing water to leak out of the blood vessels into the surrounding tissue. The waterlogged tissue is called *edema*. “Take care of that liver,” says Sir Osis, who has cirrhosis. “And remember, too many drinks, liver shrinks. Too much nog, ‘ammonia fog.’ No hepatic cells, everything swells.” Need those hepatic cells!

## GALLBLADDER

The **gallbladder** is a pear-shaped sac attached to the underside of the liver (see Figure 23-9, A). The cystic duct connects the gallbladder with the common bile duct. Bile, produced in the liver, flows through the hepatic ducts and into the cystic duct and gallbladder. The function of the gallbladder is to concentrate and store bile. The gallbladder concentrates about 1200 mL of bile/day.

The presence of dietary fat in the duodenum stimulates the release of a hormone, cholecystokinin (koh-lee-sis-toh-KYE-nin) (CCK). This hormone enters the bloodstream and circulates to the gallbladder, where it causes the smooth muscle of the gallbladder to contract. When the gallbladder contracts, the bile is ejected into the cystic duct and then into the common bile duct and duodenum.

For unknown reasons, bile components often form stones. The larger stones remain in the gallbladder. However, the smaller stones can be pushed out of the gallbladder when bile is ejected. The stones then lodge in the common bile duct. Bile that backs up behind the stones causes jaundice and impairs hepatic function. The stagnant bile can also be forced into the main pancreatic duct, causing a life-threatening pancreatitis. The presence of stones in the gallbladder often causes an inflammation called *cholecystitis*. The presence of stones in the common bile duct is called *choledocholithiasis*. Both conditions may cause biliary colic (mid-epigastric pain that often radiates to the right subscapular area) and other digestive symptoms, such as nausea, vomiting, and pain.

How can a fatty meal trigger biliary colic in a person with cholecystitis? When the fat enters the duodenum, it causes the release of CCK. The CCK travels via the blood to the gallbladder and stimulates the inflamed gallbladder to contract. Ouch!

### Re-Think

1. Trace the flow of bile from its source to its point of excretion.
2. Explain the difference in function between the hepatic portal system and the hepatobiliary system.

## PANCREAS

The **pancreas** is an accessory organ of digestion located just below the stomach (see Figure 23-9, A). The head of the pancreas rests in the curve of the duodenum, and the tail lies near the spleen in the left upper quadrant of the abdominal cavity. The main pancreatic duct, which travels the length of the pancreas, joins with the common bile duct at the ampulla of Vater. The pancreatic duct carries digestive enzymes from the pancreas to the duodenum—the meeting point for digestion.

The pancreas secretes both endocrine and exocrine substances. The exocrine secretions include the digestive enzymes and an alkaline secretion. These secretions form the pancreatic juice; the pancreas secretes about 1400 mL/day. *Note: The pancreatic enzymes are the most important of all the digestive enzymes.* Acinar cells secrete the pancreatic enzymes in their inactive form. The enzymes travel through the main pancreatic duct to the duodenum and are activated in the duodenum.

In addition to the digestive enzymes, the pancreas also secretes an alkaline juice rich in bicarbonate. The bicarbonate neutralizes the highly acidic chyme coming from the stomach into the duodenum. This neutralization is important because the digestive enzymes in the duodenum work best in an alkaline environment.

The secretion of the digestive enzymes and bicarbonate is under nervous (vagus) and hormonal control. The presence of food in the stomach and duodenum is the stimulus for the nervous and hormonal responses. For example, the presence of chyme in the duodenum stimulates the release of the hormone CCK from the duodenal walls. CCK travels by way of the blood to the pancreas, stimulating the release of pancreatic digestive enzymes. Note that CCK affects both the gallbladder and pancreas (see Table 23-1). The acid in the duodenum stimulates the release of a second hormone, secretin, from the duodenal walls. Secretin travels by way of the blood to the pancreas, stimulating release of the bicarbonate-rich juice. Bicarbonate neutralizes the gastric acid.

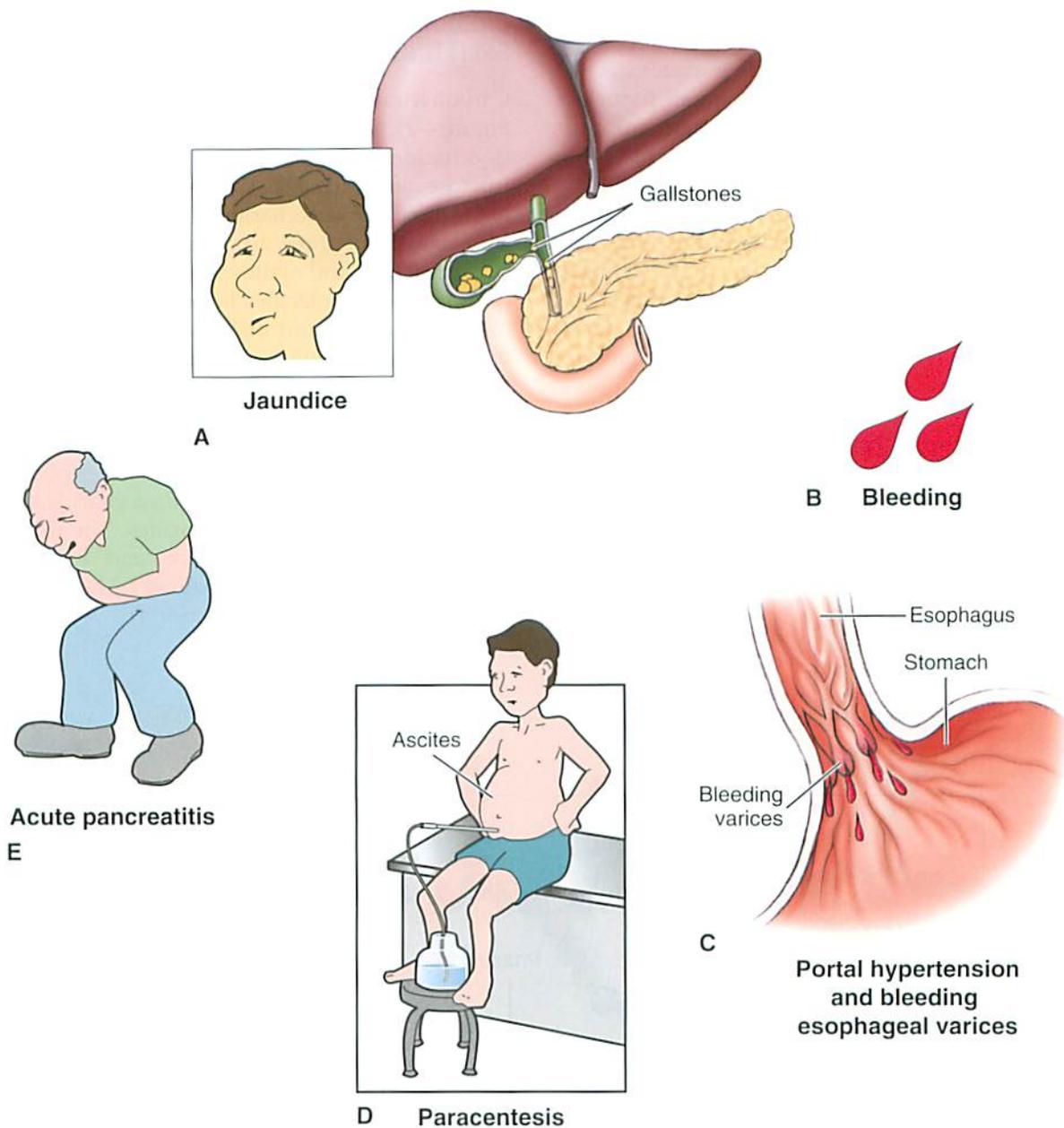
### Re-Think

1. What are the stimuli for the release of CCK and secretin? What are the effects of CCK and secretin?
2. How does the gallbladder “know” when to release bile into the common bile duct?

### WHEN ACCESSORY DIGESTIVE ORGANS ARE NOT WORKING RIGHT

Disorders involving the liver, gallbladder, biliary tree, and pancreas are common. Some clinical conditions are shown in Figure 23-10.

- *Jaundice* (see Figure 23-10, A). The liver secretes bile, which is stored in the gallbladder for future use in the duodenum. When needed, bile travels through bile ducts to the duodenum. If the common bile duct becomes blocked with stones, the flow of bile stops. The bile backs up into the liver. The bile pigments, especially bilirubin, accumulate in the blood and are eventually carried throughout the body, where they are deposited in the skin. The skin turns yellow, and the person is described as being jaundiced. Because the jaundice is caused by an obstruction, it is called *obstructive jaundice* (in contrast to hemolytic jaundice, which is caused by the rapid breakdown of red blood cells; see Chapter 15). Jaundice can also occur in response to liver disease (hepatitis). A person with hepatitis may become jaundiced because the inflamed hepatic tissue causes the bile canaliculi to swell and close. This closure diminishes the excretion of bile from the liver and causes backup of bilirubin in the blood. In addition, the hepatocytes are too damaged to metabolize bilirubin.
- *Bleeding* (see Figure 23-10, B). The liver synthesizes clotting factors such as prothrombin. What can make a person hypoprothrombinemic? A gallstone lodged in the common bile duct may cause hypoprothrombinemia. Because bile is necessary for the absorption of fat-soluble vitamins, bile duct obstruction causes diminished absorption of vitamin K. Vitamin K is necessary for the hepatic synthesis of a number of clotting factors, including prothrombin. Thus, common bile duct obstruction diminishes the hepatic synthesis of prothrombin, causing hypoprothrombinemia, a prolonged prothrombin time, and bleeding. Damaged hepatocytes are another hepatic cause of hypoprothrombinemia; they are simply too damaged to make prothrombin.
- *Portal hypertension and hemorrhage* (see Figure 23-10, C). The liver receives a large flow of blood from the portal vein. Normally, the blood passes through the liver quickly and easily. In alcoholic cirrhosis, however, the liver is so damaged that the flow of portal blood through the liver is greatly impeded. The blood backs up in the portal vein, elevating the pressure in the vein and causing portal hypertension. The increased portal pressure is felt not only by the portal vein, but also by all the veins that drain into the portal vein, including the small veins at the base of the esophagus. Over time, the small veins become stretched and damaged (varicose veins). If the portal pressure becomes too great, the weak varicose veins (esophageal varices) at the base of the esophagus may rupture, causing a massive hemorrhage (ruptured esophageal varices). The elevated portal pressure also causes some portal blood to bypass the liver, thereby allowing toxic amounts of ammonia (nitrogen) to enter the general circulation. This causes a type of disorientation called “ammonia fog”; the toxic effects of ammonia eventually causes hepatic encephalopathy (en-sef-ah-LOP-ath-ee).
- *Portal hypertension and ascites* (see Figure 23-10, D). In alcoholic cirrhosis, the portal hypertension may also cause fluid to seep across the blood vessels into the peritoneal cavity. The collection of fluid in the peritoneal cavity is called *ascites* (ah-SYE-tees). The ascites may be so severe that the accumulated fluid pushes up on the diaphragm and interferes with breathing. The fluid may be siphoned off by



**FIGURE 23-10** Some clinical conditions that affect the liver, gallbladder, and pancreas. The labeled parts of this figure are described in the text.

the insertion of a tube into the peritoneal cavity. This procedure is called *paracentesis* (pair-ah-sin-TEE-siss).

- **Pancreatitis** (see Figure 23-10, E). The pancreas secretes potent proteolytic enzymes in their inactive forms. These inactive enzymes normally flow through the main pancreatic duct into the duodenum, where the enzymes are activated. Sometimes, the enzymes become activated within the pancreas and digest the pancreatic tissue, causing severe inflammation in the form of acute pancreatitis.

### 2+2 Sum It Up!

The accessory digestive organs include the liver, gallbladder, and pancreas. These organs secrete substances that are eventually emptied into the duodenum, the meeting place for digestion. The liver performs many functions. The liver's primary digestive role is the secretion of bile. Bile is concentrated and stored in the gallbladder; it is released into the bile ducts in response to cholecystokinin. The pancreatic acinar cells secrete the most potent digestive enzymes (amylase, lipase, proteases). The pancreatic enzymes empty into the duodenum. In addition to the digestive enzymes, bicarbonate-rich pancreatic secretions assist the digestive process.

## DIGESTION AND ABSORPTION

The primary purpose of the digestive system is to break down large pieces of food into small particles suitable for absorption. Food is digested mechanically and chemically. Mechanical digestion is the physical breakdown of food into small pieces. It is achieved by the chewing activity of the mouth and by the mixing and churning activities of the muscles of the digestive organs. Chemical digestion is the chemical change occurring primarily in response to the digestive enzymes. Whereas mechanical digestion refers to a breakdown in the size of the piece of food, chemical digestion refers to a change in the chemical composition of the food molecule.

Food is made up of carbohydrates, proteins, and fats. Digestive enzymes and several digestive agents (mucus, hydrochloric acid, and bile) play key roles in chemical digestion. Specific enzymes digest each type of food (see Table 23-1). (Review the structures of carbohydrates, protein, and fat in Chapter 4.)

## CARBOHYDRATES AND CARBOHYDRATE-SPLITTING ENZYMES

Carbohydrates are classified according to size (see Figure 4-2). Monosaccharides are single (mono) sugars (saccharides). The three monosaccharides are glucose, fructose, and galactose. Glucose is the most important of the three monosaccharides. Disaccharides are double (di) sugars. The three disaccharides are sucrose (table sugar), lactose, and maltose. Polysaccharides are many (poly) glucose molecules linked together. The shorter monosaccharides and disaccharides are called *sugars*; the longer-chain polysaccharides are *starches*.

A polysaccharide is digested in two stages (Figure 23-11, A). First, enzymes called **amylases** (AM-eh-lays-ez) break the polysaccharide into disaccharides. The two amylases are salivary amylase (ptyalin) and pancreatic amylase. Second, disaccharidases break disaccharides into monosaccharides. The three disaccharidases are sucrase, lactase, and maltase. (The ending *-ase* indicates an enzyme.) The cells of the

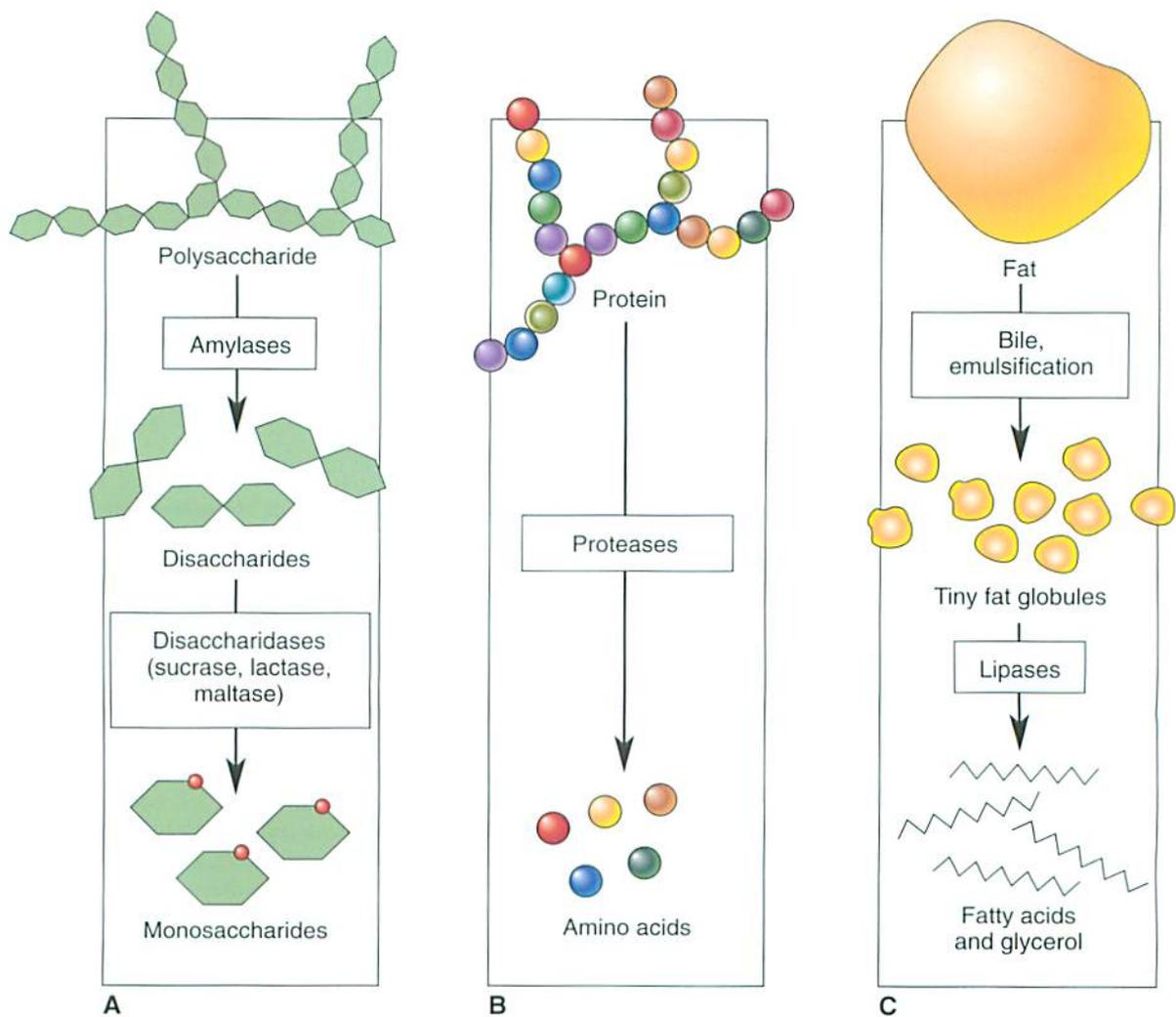


FIGURE 23-11 Chemical digestion. A, Carbohydrate digestion. B, Protein digestion. C, Fat emulsification and digestion.

intestinal villi contain disaccharidases. Disaccharides therefore are split into monosaccharides in the duodenum at the surface of the villi. They are immediately absorbed across the villus into the blood capillaries.

Certain carbohydrates, such as cellulose, cannot be digested and therefore remain in the lumen of the digestive system. Although providing no direct nourishment, dietary cellulose is beneficial in that it provides fiber and bulk to the stool.

Many persons suffer from a deficiency of the enzyme lactase. They are unable to digest the sugar found in milk (lactose) and are said to be lactose intolerant. This enzyme deficiency prevents lactose-intolerant people from digesting milk and many milk products. An interesting note: Most people worldwide are lactose intolerant!

## PROTEINS AND PROTEIN-SPLITTING ENZYMES

The building blocks of proteins are amino acids. Several amino acids linked together form a peptide. Many amino acids linked together form a polypeptide. Proteins are very long polypeptide chains; some proteins contain more than one polypeptide chain (see Figure 23-11, *B*). To be absorbed across the wall of the digestive tract, these chains must be uncoiled and broken down into small peptides and amino acids.

Enzymes called **proteases**, or proteolytic enzymes, digest proteins. Proteases are secreted by three organs: the stomach secretes pepsin, the intestinal cells secrete enterokinase, and the pancreas secretes several proteases, including trypsin and chymotrypsin. The pancreatic proteases are the most potent proteases. Proteins are broken down into small peptides and amino acids and are absorbed across the intestinal villi into the blood capillaries. (Interesting fact: Because it was thought to aid digestion, Pepsi was named after the enzyme pepsin.)

Although not an enzyme, HCl aids protein digestion. First, the HCl unravels the strands of protein, making the protein fragments more sensitive to the proteases. Second, the HCl activates a gastric proteolytic enzyme, pepsinogen, into pepsin. Pepsin then facilitates breaking protein into small peptides.

## FATS, BILE, AND FAT-SPLITTING ENZYMES

Fats are long-chain molecules. Enzymes called **lipases** (LYE-pays-ez) digest fats. The most important is pancreatic lipase (see Figure 23-11, *C*). The end products of fat digestion are fatty acids and glycerol; fat is absorbed into the lacteals of the villi.

Why is bile necessary for fat digestion (see Figure 23-11, *C*)? Fats, unlike carbohydrates or proteins, are not soluble in water; they tend to clump together into large fat globules when added to water. If, for example, oil and water are placed in a test tube, the oil and water separate; the oil rises to the surface, and the water

settles at the bottom. Oil and water simply do not mix. The same separation occurs in the digestive tract. Dietary fat tends to form large fat globules. The lipase cannot readily digest the fat; it can attack only the outside surface of the fat globule.

Bile solves the large fat globule problem. Bile can split the large fat globule into thousands of tiny fat globules. This process is **emulsification** (ee-MULL-seh-feh-KAY-shun). Because of emulsification, the lipases can work on the surfaces of all the tiny fat globules, thereby digesting more fat. Bile performs two other important roles. Bile salts prevent the fatty acids (end products of fat digestion) from reforming large fat globules in the intestine before they can be absorbed across the intestinal villi. Bile salts also help the absorption of the fat-soluble vitamins A, D, E, and K.

## ? Re-Think

1. List the enzymes needed for carbohydrate, protein, and fat digestion.
2. Why does fat digestion require bile whereas carbohydrate and protein digestion do not?
3. Why may a high-fat meal “bother” a person with cholecystitis (inflammation of the gallbladder)?

## 2+2 Sum It Up!

How is a turkey dinner digested and absorbed (Figure 23-12)?

1. In the mouth, food is chewed into tiny pieces and mixed with saliva.
2. The smaller pieces of food are transported through the esophagus to the stomach, where they are mixed, mashed, and churned into chyme.
3. The partially digested food (chyme) squirts into the duodenum, where it mixes with bile and the pancreatic and intestinal enzymes. Pancreatic amylase and the disaccharidases digest the polysaccharides to monosaccharides. The pancreatic proteases (trypsin and chymotrypsin) and the intestinal proteases digest the proteins to amino acids. A pendulum-like peristaltic motion washes the digested food across each villus, thereby enhancing absorption.
4. The simple sugars and the amino acids are absorbed into the blood capillaries of the villi. These capillaries eventually empty into the portal vein for transport to the liver. Bile emulsifies the fats, and the pancreatic and intestinal lipases digest them. The end products of fat digestion are fatty acids and glycerol. The fat products are absorbed into the lacteals of the villi. Most of the digestion and absorption occurs in the duodenum and the proximal jejunum.
5. The unabsorbed food material continues along the jejunum and ileum and into the large intestine.
6. A large volume of water and certain electrolytes are absorbed along this route, and a semisolid stool is formed.
7. The presence of the fecal material in the rectum gives rise to an urge to defecate.

## NUTRITION: CONCEPTS TO KNOW

Nutrition is the science that studies the relationship of food to the functioning of the body. Food consists of

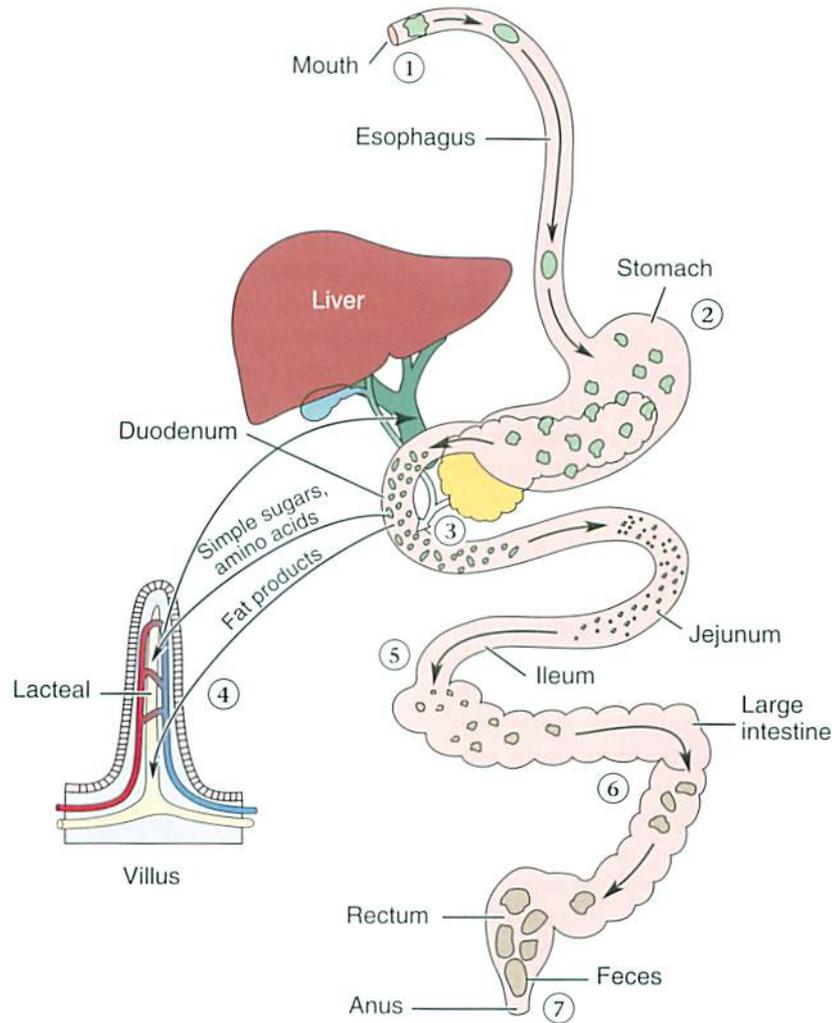


FIGURE 23-12 Summary: digestion and absorption of the turkey meal.

nutrients, substances the body uses to promote normal growth, maintenance, and repair. The five categories of nutrients are carbohydrates, proteins, lipids, vitamins, and minerals.

## CARBOHYDRATES

Dietary carbohydrates are classified as simple sugars and complex carbohydrates. A simple sugar is composed of monosaccharides and disaccharides. Glucose, the simplest carbohydrate, is the major fuel used to make ATP in most body cells. Most of the carbohydrates come from plants. The sugars are derived primarily from fruit, sugar cane, and milk.

The complex carbohydrates are larger sugar molecules (polysaccharides) and consist primarily of starch and fiber. Starch is found in cereal grains (wheat, oats, corn, barley), legumes (peas, beans), and root vegetables, such as potatoes. Fiber, or cellulose, is found primarily in vegetables.

Most dietary carbohydrate should be in the form of complex carbohydrates for two reasons. First, complex carbohydrates usually provide other nutrients, whereas simple sugars provide “empty calories” (nothing but

calories). Second, complex carbohydrates are absorbed at a slower rate than sugars, thereby preventing a sudden spike in blood glucose. The spiking of blood glucose has been linked to an oversecretion of insulin, impaired cellular uptake of glucose, and hypertension. Our excessive intake of corn syrup is fattening us up and raising our blood pressures. Is it also creating a nation of diabetics?

## PROTEINS

Dietary proteins supply the body with amino acids. Because the body cannot store amino acids, a daily supply is necessary. Amino acids are classified as essential and nonessential. An essential amino acid cannot be synthesized by the body and must therefore be consumed in the diet. A nonessential amino acid can be synthesized by the body. It is not essential that these amino acids be consumed in the diet. Of the 20 amino acids, 9 are essential.

Proteins are classified as complete or incomplete. A complete protein contains all essential amino acids. Complete proteins are found in animal sources such as meat, eggs, and dairy products. Incomplete proteins

do not contain all of the essential amino acids, and these proteins include vegetable proteins such as nuts, grains, and legumes. Vegetable proteins, if eaten in combinations, can supply a complete complement of amino acids. For example, a favorite Mexican dish containing rice and beans is complete in that it supplies all the essential amino acids, even though both the rice and the beans are incomplete proteins.

## FATS (LIPIDS)

Most dietary lipids are triglycerides, or molecules that contain glycerol and fatty acids. Fatty acids are classified as saturated or unsaturated. A saturated fatty acid (e.g., butter, lard), which come primarily from animal sources, is solid at room temperature. Also included in this group are artificially hardened, or hydrogenated, fats such as vegetable shortening and margarine. An unsaturated fat is liquid at room temperature and is called an *oil*.

The body can synthesize all fatty acids, with one exception: linoleic acid, an important component of cell membranes. Because the body cannot synthesize it, linoleic acid is an essential fatty acid and therefore must be included in the diet.

Foods high in fat come from both animal and plant sources. Animal sources, however, tend to contain more saturated fat. They include meat, eggs, butter, and whole-milk products such as cheese. Plant sources

include coconut oil and palm oil. Hydrogenated vegetable oils in shortening and margarine are also high in saturated fat. In addition to the fat content, these foods also tend to be high in cholesterol.

## ? Re-Think

1. What is the difference between an essential amino acid and a nonessential amino acid?
2. What is the difference between a complete and incomplete protein?

## VITAMINS

**Vitamins** are small organic molecules that help regulate cell metabolism (Table 23-2). Vitamins are parts of enzymes or other organic substances essential for normal cell function and are classified as fat soluble or water soluble. The fat-soluble vitamins include vitamins A, D, E, and K. Because the body stores fat-soluble vitamins, excess intake may result in symptoms of toxicity (hypervitaminosis).

The water-soluble vitamins include vitamins B and C. These vitamins, for the most part, are not stored by the body. Excess water-soluble vitamins are generally excreted in the urine. Excretion, however, does not rule out the possibility of toxicity in response to megadosing with water-soluble vitamins.

**Table 23-2** Selected Vitamins

VITAMIN	FUNCTION	DEFICIENCY
<b>Fat-Soluble Vitamins</b>		
Vitamin A	Necessary for skin, mucous membranes, and night vision	Night blindness; dry, scaly skin; disorders of mucous membranes
Vitamin D (calciferol)	Necessary for the absorption of calcium and phosphorus	Rickets in children; osteomalacia in adults
Vitamin E	Necessary for health of cell membrane	None defined
Vitamin K	Needed for the synthesis of prothrombin and other clotting factors	Bleeding
<b>Water-Soluble Vitamins</b>		
Thiamine (vitamin B <sub>1</sub> )	Helps release energy from carbohydrates and amino acids; needed for growth	Beriberi; alcohol-induced Wernicke's syndrome
Riboflavin (vitamin B <sub>2</sub> )	Essential for growth	Skin and tongue disorders; dermatitis
Niacin (vitamin B <sub>3</sub> )	Helps release energy from nutrients	Pellagra with dermatitis, diarrhea, mental disorders
Pyridoxine (vitamin B <sub>6</sub> )	Participates in the metabolism of amino acids and proteins	Nervous system and skin disorders
Vitamin B <sub>12</sub>	Helps form red blood cells and deoxyribonucleic acid (DNA)	Anemias, particularly pernicious anemia
Folic acid	Participates in the formation of hemoglobin and DNA	Anemia; neural tube defects in embryo
Ascorbic acid (vitamin C)	Necessary for synthesis of collagen; helps maintain capillaries; aids in the absorption of iron	Scurvy; poor bone and wound healing

You can best appreciate the roles vitamins play by observing the effects of specific vitamin deficiencies. For example, vitamin A is necessary for healthy skin and night vision. Vitamin A deficiency is characterized by various skin lesions and by night blindness, or the inability to see in a darkened room. Vitamin D is necessary for the absorption of calcium and the development and formation of strong bones. Vitamin D deficiency causes rickets in children, a condition in which the bones are soft and often bow in response to weight bearing. Because the skin can synthesize vitamin D in response to exposure to ultraviolet radiation, the incidence of rickets is higher in places with little sunlight. Vitamin D deficiency in adults results in a bone-softening condition called *osteomalacia*.

Vitamin K plays a crucial role in hemostasis. It is necessary for the synthesis of prothrombin and several other hepatic clotting factors. A deficiency of vitamin K causes hypoprothrombinemia and a tendency to bleed excessively.

Finally, vitamin C is necessary for the integrity of the skin and mucous membranes. A deficiency of vitamin C causes scurvy, a condition involving skin lesions and inability of the tissues to heal. Historically, scurvy was common on ships that were at sea for months at a time. Having determined that limes prevented scurvy, the British sailors traveled around the world sipping lime juice. In response to this habit, they

were dubbed “limeys.” Other vitamin deficiencies are included in Table 23-2.

## MINERALS

**Minerals** are inorganic substances necessary for normal body function (Table 23-3). Minerals have numerous functions, ranging from regulation of plasma volume (sodium, chloride) to bone growth (calcium) to oxygen transport (iron) to the regulation of metabolic rate (iodine).

Mineral deficiencies can cause serious health problems. For example, because iodine is necessary for the synthesis of the thyroid hormone thyroxine, iodine deficiency can cause an enlarged thyroid gland (goiter) and hypothyroidism. Because iron is necessary for the synthesis of hemoglobin, iron deficiency can cause anemia. This anemic state is characterized by fatigue and, depending on its severity, a diminished ability to transport oxygen around the body.

## HEALTH AND A BALANCED DIET

### A BALANCED DIET

A balanced diet contains all the essential nutrients and includes a variety of foods. The balanced diet is often displayed in the form of a food pyramid. The newest food pyramid “personalizes” food intake because it

**Table 23-3** Selected Minerals

MINERAL	FUNCTION	DEFICIENCY
Potassium (K)	Nerve and muscle activity	Nerve and muscle disorders
Sodium (Na)	Water balance; nerve impulse conduction	Weakness, cramps, diarrhea, dehydration, confusion
Calcium (Ca)	Component of bones and teeth, nerve conduction, muscle contraction, blood clotting	Rickets, tetany, bone softening
Phosphorus (P)	Component of bones and teeth; component of ATP, nucleic acids, and cell membranes	Bone demineralization
Iron (Fe)	Component of hemoglobin (red blood cells)	Anemia, dry skin
Iodine (I)	Necessary for synthesis of thyroid hormones	Hypothyroidism; iodine-deficient goiter
Magnesium (Mg)	Component of some enzymes; important in carbohydrate metabolism	Muscle spasm, dysrhythmias, vasodilation
Fluorine (F)	Component of bones and teeth	Dental caries
Trace minerals	Small amounts required for certain specific functions	Nerve and muscle disorders
• Zinc (Zn)	Nerve and muscle activity	Weakness, cramps, diarrhea, dehydration, confusion
• Copper (Cu)	Activates many enzymes	Loss of structural support resulting from a deficiency of connective tissues in many organs and blood vessels
• Manganese (Mn)	Component of bones and teeth; nerve conduction, muscle contraction, blood clotting	Bone demineralization
• Selenium (Se)	Not determined, plays a significant role in many enzymes, thereby affecting metabolism	Cardiomyopathy; other conditions not yet identified

also considers body build and level of activity. Exercise is a crucial part of the newest pyramid.

### POORLY BALANCED DIET AND DISEASE

Many health problems are thought to originate in poor dietary choices. For example, a diet high in cholesterol or fat, or both, has been implicated in coronary artery disease, stroke, diabetes, and cancer.

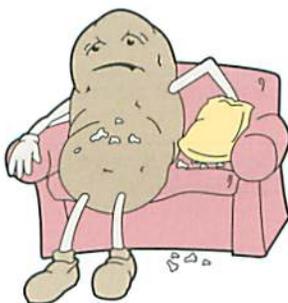
Although overeating and obesity have been linked with health problems, a number of health problems are also related to a deficiency of certain foods. For example, infants who are fed fat-poor diets (skim milk) may become deficient in fats essential for the development of nervous tissue. Fat deficiency may cause nerve damage and developmental delay. In poverty-stricken areas of the world, protein deficiency diseases are common. Kwashiorkor, for example, is a protein-deficient state in which protein intake is inadequate to synthesize plasma proteins, muscle protein, and proteins necessary for healthy skin.

### Do You Know...

#### That Kwashiorkor Refers to a “Displaced” Child?

Kwashiorkor is a condition of severe protein deficiency resulting in emaciation, edema formation, and ascites. The African word *kwashiorkor* (displaced or deposed) indicates the cause of the condition. A breast-fed infant is prematurely weaned from breast milk and placed on a protein-poor cereal diet. Why the premature weaning? To make room for baby brother. The 9-month-old infant is displaced or deposed by the newborn.

Malnutrition usually refers to starvation or a profound weight loss caused by a calorie deficiency. Although malnutrition certainly takes this form in countries with limited food supplies, in the United States malnutrition appears most often in the overfed. The American diet and sedentary lifestyle have contributed to obesity, a national health problem. The magnitude of the problem is evident in the numbers of weight-reduction diets. The problem is so common that we now have a common term, *couch potato*, to describe a snack-prone sedentary person, someone who may well be obese.



One form of extreme wasting common in the United States is called *cachexia* (kah-KEK-see-ah). It is most often seen in patients who are terminally ill with cancer and other chronic diseases. The severe anorexia

and altered metabolism cause depletion of fat and protein stores, resulting in dramatic weight loss and starvation.

### APPETITE CONTROL AND THE COUCH POTATO

What makes us eat and stop eating? Don't know. We know that the hypothalamus plays an important role. There is an area of the lateral hypothalamus called the *feeding center*. When destroyed, it leads to anorexia and starvation. Another hypothalamic area is called the *satiety center*; damage to it causes overeating and morbid obesity. There are numerous theories about what satisfies (satiety) and therefore suppresses appetite. The glucostat hypothesis states that the satiety center contains neurons called *glucostats* that absorb glucose and send inhibitory information to the feeding center. In response, appetite diminishes. The lipostat hypothesis states that adipocytes (fat cells) secrete an appetite-suppressing hormone called *leptin*. Alas! Couch Potato keeps eating, apparently ignoring the “stop eating” signals from his blitzed hypothalamus.

### ? Re-Think

List four fat-soluble vitamins and provide a function of each.

### BODY ENERGY

Energy is essential for two reasons: (1) it provides the body with the power to do its work, and (2) it maintains body temperature.

### MEASUREMENT OF ENERGY

Energy is measured in units called *kilocalories* (kcal), meaning “the large calorie.” (A capital “C” means a large calorie.) One Calorie is the amount of energy required to raise the temperature of 1 kilogram (kg) of water by 1° Celsius (C). The energy yield of the three food groups—carbohydrates, proteins, and fats—is expressed in calories.

Carbohydrate, 1 g, yields 4 Cal/g  
Protein, 1 g, yields 4 Cal/g  
Fat, 1 g, yields 9 Cal/g

NOTE: The metabolism of 1 g of fat yields about twice as many calories as the metabolism of 1 g of carbohydrate or protein.

### ENERGY BALANCE

Energy balance occurs when the input of energy (food) equals the output of energy (energy expenditure). Energy balance is not always achieved. If food intake exceeds energy expenditure, the excess energy is converted to and stored as fat, causing weight gain. Conversely, if food intake is less than the energy expended, weight loss occurs. Weight management programs therefore encourage both dietary restriction and exercise regimens.

## ENERGY EXPENDITURE

Energy expenditure differs depending on whether the body is in a resting or nonresting state. The amount of energy the body requires per unit of time to perform essential activities at rest is the basal metabolic rate (BMR). These activities include breathing, kidney function, cardiac muscle contraction, and whatever minimal functions the body must perform to remain alive.

Several factors affect BMR. These include gender, age, body surface area, emotional state, overall health status, and several hormones. Men have a higher BMR than women. An adolescent has a higher BMR than an older person. A tiny bird has a higher BMR than an elephant. A person livid with rage has a higher metabolism than a peaceful person. A patient with an infection has a higher BMR than an infection-free person. The thyroid hormone thyroxine exerts the most profound effect on BMR. The hyperthyroid patient has a higher BMR than a euthyroid (normal thyroid) person. The metabolism of a hyperthyroid patient can be so high that the patient can consume in excess of 6000 Cal/day and still lose weight. In contrast, the hypothyroid patient has a lower than normal BMR and often consults a physician because of loss of energy and weight gain.

The body needs a certain amount of energy to maintain minimal function but requires additional energy when the person engages in activity above and beyond the resting state. In general, the more active the person is, the higher the metabolic rate and the greater the expenditure of energy.

## 2+2 Sum It Up!

The body uses food for energy, repair, and maintenance. A balanced diet contains specific amounts and types of nutrients: carbohydrates, proteins, fats, vitamins, and minerals. Failure to ingest certain nutrients causes malnutrition, deficiency states, and illness.

## As You Age

1. The muscular wall of the digestive tract loses tone, causing constipation because of a slowing of peristalsis.
2. Secretion of saliva and digestive enzymes decreases, thereby decreasing digestion. The decrease in secretions also impairs the absorption of vitamins (vitamin B<sub>12</sub>) and minerals (iron and calcium).
3. The sensations of taste and smell diminish with age. Consequently, food tastes different, and appetite may be affected.
4. The loss of teeth and an inability to chew food effectively makes eating difficult. The loss of teeth may also affect the choice of food, causing the older person to select a less nutritious diet such as tea and toast.
5. Peristalsis in the esophagus is no longer triggered with each swallow, and the lower esophageal sphincter relaxes more slowly. These changes hamper swallowing and cause an early feeling of fullness.
6. A weakened gag reflex increases the risk of aspiration.
7. The liver shrinks and receives a smaller supply of blood. The rate of drug detoxification by the liver declines, thereby prolonging the effects of drugs and predisposing the person to a drug overdose. (Remember that the liver is the chief organ of drug inactivation or biotransformation.)



## MEDICAL TERMINOLOGY AND DISORDERS Disorders of the Digestive System

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
<b>Words</b>			
amylase	amyl/o- -ase	starch enzyme	An <b>amylase</b> is an enzyme that digests starch, a carbohydrate. A <b>lipase</b> (lip/o- = fat) is an enzyme that digests fat. A <b>protease</b> is an enzyme that digests protein.
buccal	bucc/o- -al	cheek pertaining to	The <b>buccal</b> cavity is located between the teeth and cheeks.
colonoscopy	colon/o- -scopy	colon, large intestine examination	A <b>colonoscopy</b> is the visual examination of the colon using a scope.
dyspepsia	dys- -pepsia	difficult or faulty digestion	<b>Dyspepsia</b> is difficult or disturbed digestion.
gastroenterology	gastr/o- -enter/o- -logy	stomach intestines study	<b>Gastroenterology</b> is the study of the digestive tract, made up largely of the stomach and intestines.
hematemesis	hemat/o- -emesis	blood vomiting	<b>Hematemesis</b> means the vomiting of blood.
melena	melan/o-	black	<b>Melena</b> refers to dark-colored stools and is an indication of bleeding within the gastrointestinal tract.
oral	or/o- -al	mouth pertaining to	The <b>oral</b> cavity is the mouth. Many drugs are administered orally.



## MEDICAL TERMINOLOGY AND DISORDERS

## Disorders of the Digestive System—cont'd

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
postprandial	post- -prand(ium)- -al	after From a Latin word meaning “meal” pertaining to	<b>Postprandial</b> means <i>after a meal</i> , whereas <b>preprandial</b> means <i>before a meal</i> .
stomatitis	stomat/o- -itis	mouth inflammation	<b>Stomatitis</b> means <i>inflammation of the oral mucosa (mouth)</i> .
sublingual	sub- -lingul/o-	underneath tongue	Means <i>underneath the tongue or hypoglossal</i> . Some drugs are administered <b>sublingually</b> .
<b>Disorders</b>			
diverticulitis	diverticul/o- -itis	diverticulum inflammation	A <b>diverticulum</b> is a <i>sac formed by mucous membrane that herniates through a weakened muscular wall of the colon, especially the sigmoid colon</i> . <b>Diverticulitis</b> refers to <i>inflammation of the diverticula and surrounding tissue</i> . <b>Diverticulosis</b> refers to <i>the condition of having diverticula in the colon</i> .
dysentery	dys- -enter/o- -ery	difficult or abnormal intestine pertaining to	<b>Dysentery</b> is a <i>group of disorders characterized by inflammation of the intestines, especially the large intestine; it is characterized by cramping and the passage of bloody diarrhea</i> .
gastroenteritis	gastr/o- -enter/o- -itis	stomach intestine inflammation	<i>Inflammation of the stomach and the intestine</i> . It can be caused by a variety of pathogens, including viruses, bacteria, and parasites.
gastroparesis	gastr/o- -paresis	stomach paralysis	<b>Gastroparesis</b> is <i>paralysis of the stomach causing slow gastric emptying and esophageal reflux</i> .
gastroesophageal reflux disease (GERD)	gastr/o- -esophagi/o-	stomach esophagus	<b>GERD</b> refers to the <i>backflow (reflux) of stomach contents into the esophagus</i> . Relaxation of the lower esophageal sphincter (LES) commonly occurs with GERD and is thought to be the chief cause of the reflux and heartburn, also known as <b>pyrosis</b> (pyr/o- = fire, burning).
gingivitis	gingiv/o- -itis	gums inflammation	<i>Inflammation of the gums surrounding the teeth</i> . Gingivitis is a <b>periodontal disease</b> .
hernia	hernia	Related to two Latin words meaning “rupture” and “intestine”	A <i>protrusion of an organ or part of an organ out of the cavity in which it is normally contained</i> . A hernia may be described as <b>incarcerated</b> (the herniated intestine swells and becomes trapped), <b>strangulated</b> (the herniated intestine is trapped, swollen, and necrotic because its blood supply has been cut off), <b>reducible</b> (the herniated intestine can be pushed back into its proper cavity), or <b>irreducible</b> (the herniated intestine is not able to be pushed back into place). Hernias develop in many different locations. An <b>inguinal hernia</b> refers to the herniation of the intestine in the groin area. A <b>femoral hernia</b> is the herniation of intestine along a path used by the femoral artery as it leaves the abdomen and enters the thigh. An <b>umbilical hernia</b> is a herniation of intestine through the abdominal wall surrounding the umbilicus (belly button). An <b>incisional hernia</b> is the herniation of intestine through a surgically induced weakened abdominal wall. Organs other than the intestine can herniate. A <b>hiatal hernia</b> refers to the herniation of a part of the stomach into the thoracic cavity. Surgical repair of a hernia is called a <b>herniorrhaphy</b> .

Continued

## MEDICAL TERMINOLOGY AND DISORDERS

## Disorders of the Digestive System—cont'd

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
inflammatory bowel disease			Abbreviated as <b>IBD</b> , but also known as <b>ileitis</b> and <b>enteritis</b> . The two most common types of IBD are Crohn's disease and ulcerative colitis. <b>Crohn's disease</b> is an inflammatory condition that can affect any part of the GI tract, most commonly the ileum. <b>Ulcerative colitis</b> is a chronic inflammatory condition that usually affects the inner lining of the colon and rectum. <b>Irritable bowel syndrome (IBS)</b> refers to periodic episodes of altered bowel function, diarrhea or constipation, and abdominal pain.
intestinal obstruction			Also called a <b>bowel obstruction</b> . It is a partial or complete blockage of the intestines that prevents the passage of food or fluid. The obstruction may be mechanical, meaning that something is in the way. The obstruction may also be due to <b>paralytic ileus</b> , whereby the intestinal or bowel muscles do not contract effectively to propel its contents forward. There are many causes of intestinal obstruction: tumors, twisting, telescoping, hernias, and adhesions. Other conditions include <b>volvulus</b> , a twisted intestine (like a twisted garden hose); an <b>intussusception</b> , a telescoped intestine; <b>hernias</b> , "trapped" intestines; and <b>adhesions</b> , bands of connective tissue that wrap around intestinal organs, such as the intestines, causing occlusion.
peptic ulcer disease (PUD)			<b>Peptic ulcer disease (PUD)</b> refers to a mucosal erosion (ulcer) in an area of the gastrointestinal tract that has acidic contents. Most often the cause of PUD is due to <i>Helicobacter pylori</i> ; the ulcers develop within the duodenum (duodenal ulcer) and/or stomach (gastric ulcer).
<b>Liver, Gallbladder, Pancreas</b>			
cholecystitis	chol/e- -cyst/o- -itis	bile bladder inflammation	Inflammation of the gallbladder; characterized by nausea, vomiting, and severe RUQ pain that radiates to the right subscapular region. The pain is called <b>biliary colic</b> . <b>Cholecystitis</b> is most often caused by gallstones in the gallbladder, a condition called <b>cholelithiasis</b> (chol/e- = bile; -lith/o- = stone). Sometimes the small gallstones escape from the gallbladder and become lodged in the common bile duct, called <b>choledocholithiasis</b> (chol/e- = bile; -doch/o- = duct; -lith/o- = stone), causing inflammation of the bile ducts, or <b>cholangitis</b> (chol/e- = bile; -angio- = vessel; -itis = inflammation), biliary obstruction, hyperbilirubinemia, and jaundice.
cirrhosis of the liver	cirrh- -osis	From the Greek word <i>kirrhos</i> , meaning "tawny" condition	Scarring of the liver in response to repeated destruction and regeneration of the liver cells. Despite hepatic regeneration, the architecture of the liver is altered so as to impair hepatic function and blood flow. Because of the obstruction of blood flow, blood bypasses the liver, eventually causing <b>hepatic encephalopathy</b> . Obstruction of blood flow also increases portal vein pressure, causing <b>portal vein hypertension</b> , which in turn causes ascites and esophageal varices.
hepatitis	hepat/o- -itis	liver inflammation	An inflammation of the liver, usually caused by viral infection. (There are nonviral causes of hepatitis.) There are five main types: A, B, C, D, and E. Hepatitis X is hepatitis caused by an unidentified virus. Hepatitis A and E are commonly transmitted by contaminated food or water. Hepatitis B and D are transmitted by contact with body fluids. Hepatitis C is transmitted by contact with contaminated blood and increases the patient's risk for cancer of the liver.
pancreatitis	pancreat/o- -itis	pancreas inflammation	<b>Pancreatitis</b> is inflammation of the pancreas. Approximately 70% of cases are caused by excess alcohol ingestion. <b>Acute pancreatitis</b> is an emergency condition with severe abdominal pain as the most common symptom. <b>Chronic pancreatitis</b> may persist for many years.

## Get Ready for Exams!

### Summary Outline

#### I. Overview of the Digestive System

- A. Functions of the digestive system
  1. Ingestion (eating)
  2. Digestion
  3. Absorption
  4. Elimination
- B. The wall of the digestive tract and membranes
  1. Four layers: mucosa, submucosa, muscle, and serosa
  2. Peritoneal membranes: mesentery, mesocolon, and greater and lesser omentum

#### II. Structures and Organs of the Digestive System

- A. Mouth
  1. Teeth and tongue
  2. Salivary glands
    - a. Parotid, submandibular, and sublingual glands
    - b. Secretes saliva
- B. Pharynx (oropharynx and laryngopharynx)
- C. Esophagus
  1. The esophagus is a long tube that connects the pharynx to the stomach.
  2. There are two sphincters: pharyngoesophageal and LES.
- D. Stomach
  1. The three parts of the stomach are the fundus, body, and pylorus.
  2. The stomach functions in digestion; its most important role is to regulate the rate at which chyme is delivered to the small intestine.
  3. It secretes hormones, few digestive enzymes, HCl, and intrinsic factor.
- E. Small intestine
  1. The three segments of the small intestine are the duodenum, jejunum, and ileum.
  2. Most of the digestion and absorption occurs within the duodenum and first third of the jejunum.
  3. The end products of digestion are absorbed into villi (capillaries and lacteal).
  4. The common bile duct enters the small intestine at the duodenum.
- F. Large intestine
  1. The large intestine consists of the cecum, ascending colon, transverse colon, descending colon, sigmoid colon, rectum, and anus.
  2. The large intestine functions in absorption of water and electrolytes.

#### III. Accessory Digestive Organs

- A. Liver
  1. The liver has many functions; its most important digestive function is the secretion of bile.
  2. The liver receives most of its blood from the portal vein; portal blood is rich in digestive end products.
  3. The arterial blood is delivered by the hepatic artery (from the celiac trunk).
- B. Biliary tree
  1. The biliary tree is composed of the bile ducts that connect the liver, gallbladder, and duodenum.

2. The bile ducts are the hepatic ducts, cystic duct, and common bile duct.
3. The common bile duct empties into the duodenum.

#### C. Gallbladder

1. The gallbladder functions to store and concentrate bile.
2. The gallbladder contracts and releases bile into the bile ducts in response to the hormone cholecystokinin (CCK).

#### D. Pancreas

1. The pancreas secretes the most important digestive enzymes.
2. The pancreatic enzymes empty into the base of the common bile duct and then into the duodenum.
3. The pancreas is responsive to both cholecystokinin and secretin.

#### IV. Digestion and Absorption

##### A. Carbohydrate digestion

1. To be absorbed, carbohydrates must be broken down into monosaccharides, especially glucose.
2. Carbohydrates are digested by enzymes called *amylases* and *disaccharidases*.

##### B. Protein digestion

1. To be absorbed, proteins must be broken down into small peptides and amino acids.
2. Proteins are broken down by proteolytic enzymes or proteases.

##### C. Fat digestion

1. To be absorbed, fats must be broken down into fatty acids and glycerol.
2. Fats are emulsified by bile and then digested by enzymes called *lipases*.

#### V. Nutrition and Body Energy

##### A. Carbohydrates

1. Carbohydrates are simple or complex.
2. Glucose, the simplest carbohydrate, is the major fuel used by the body for energy.

##### B. Protein

1. The body needs essential amino acids, which it cannot synthesize, and nonessential amino acids, which it can synthesize.
2. Dietary proteins are complete or incomplete.

##### C. Fats (lipids)

1. Most dietary lipids are triglycerides.
2. Fats are saturated fats (like butter) or unsaturated fats (like oils).

##### D. Vitamins

1. Vitamins are small organic molecules that help regulate cell metabolism. Dietary vitamin deficiencies give rise to many diseases (see Table 23-2).
2. Vitamins are water soluble (vitamins B and C) or fat soluble (vitamins A, D, E, and K).

##### E. Minerals

1. Minerals are inorganic substances necessary for normal body function.
2. Mineral deficiencies can cause serious health problems (see Table 23-3).

- F. Body Energy
- The body needs energy to do its work and maintain body temperature.
  - The basal metabolic rate (BMR) is the amount of energy the body requires per unit of time to perform essential activities at rest.
  - Metabolism is determined by many factors, including age, gender, surface area, emotional state, overall health status, and hormones, especially thyroxine.

### Review Your Knowledge

#### Matching: Structures: Making the Connections

Directions: Match the following words with their description below.

- |                     |  |
|---------------------|--|
| a. ileum            | 1. ___ Connects the duodenum to the ileum                    |
| b. sigmoid colon    | 2. ___ Connects the cystic and hepatic ducts to the duodenum |
| c. jejunum          | 3. ___ Connects the rectum to the descending colon           |
| d. common bile duct | 4. ___ Connects the ascending colon to the descending colon  |
| e. transverse colon | 5. ___ Connects the esophagus to the duodenum                |
| f. duodenum         | 6. ___ Connects the pharynx to the stomach                   |
| g. esophagus        | 7. ___ Connects the stomach to the jejunum                   |
| h. stomach          | 8. ___ Connects the jejunum to the cecum                     |

#### Matching: Enzymes, Hormones, and Digestive Aids

Directions: Match the following words with their description below. Some words may be used more than once.

- |                          |   |
|--------------------------|---|
| a. amylases              | 1. ___ Classification of trypsin and chymotrypsin                                   |
| b. hydrochloric acid     | 2. ___ Secreted by the parietal cells of the stomach; lowers gastric pH             |
| c. disaccharidases       | 3. ___ Digests sucrose, maltose, and lactose  |
| d. secretin              | 4. ___ An emulsifying agent   |
| e. bile                  | 5. ___ Digests fats to fatty acids and glycerol                                     |
| f. proteases             | 6. ___ Hormone secreted by the duodenum in response to the presence of fat          |
| g. cholecystokinin (CCK) | 7. ___ Digest starch and polysaccharides to disaccharides                           |
| h. intrinsic factor      | 8. ___ Hormone that stimulates the pancreas to secrete a bicarbonate-rich secretion |
| i. lipase                |   |

- |   |
|---|
| 9. ___ Hormone that stimulates the gallbladder to contract      |
| 10. ___ Digests protein to small peptides and amino acids       |
| 11. ___ Secreted by the liver and stored in the gallbladder     |
| 12. ___ Necessary for the absorption of vitamin B <sub>12</sub> |
| 13. ___ Classification of sucrase, maltase, and lactase         |

#### Multiple Choice

- The esophagus
  - secretes potent proteolytic enzymes.
  - secretes intrinsic factor that is necessary for the absorption of vitamin B<sub>12</sub>.
  - is a hollow tube that carries food from the pharynx to the stomach.
  - is the primary site of digestion and absorption.
- Which of the following is true regarding the stomach?
  - Its most important function is the digestion of fat.
  - It is lined with microvilli to maximize absorption.
  - It is attached distally to the jejunum and proximally to the esophagus.
  - Its most important function is to deliver chyme to the duodenum at the proper rate.
- Which of the following is not descriptive of bile?
  - Aids in fat digestion
  - Is an emulsifying agent
  - Is classified as a lipase
  - Is stored by the gallbladder
- Lipases, proteases, and amylases are
  - gastric hormones.
  - synthesized by the liver and stored in the gallbladder.
  - digestive enzymes.
  - bile-dependent digestive enzymes.
- Which of the following is not a function of the liver?
  - Makes blood-clotting factors such as prothrombin
  - Makes bile
  - Secretes cholecystokinin and secretin
  - Stores fat-soluble vitamins
- Which of the following best describes emulsification?
  - A fat is chemically digested to fatty acids and glycerol.
  - The fatty acids are absorbed into the lacteal, becoming chyle.
  - A large fat globule is mechanically broken into smaller fat globules.
  - A large protein forms ammonia.
- The pancreas
  - secretes the most potent digestive enzymes.
  - secretes CCK and secretin.
  - is only important because of its endocrine (insulin) function.
  - empties its digestive enzymes into the appendix.
- The duodenum is most concerned with
  - the secretion of intrinsic factor and the absorption of vitamin B<sub>12</sub>.
  - digestion and absorption.
  - the synthesis of clotting factors and plasma proteins.
  - the synthesis of bile and emulsification.