Selected Key Terms

The following terms and other boldface terms in the chapter are defined in the Glossary

absorption
bile
chyle
chyme
defecation
deglutition
digestion
duodenum
emulsify
enzyme
esophagus
gallbladder
hydrolysis
intestine
lacteal
liver
mastication
pancreas
peristalsis
peritoneum
saliva
stomach
ulcer
villi

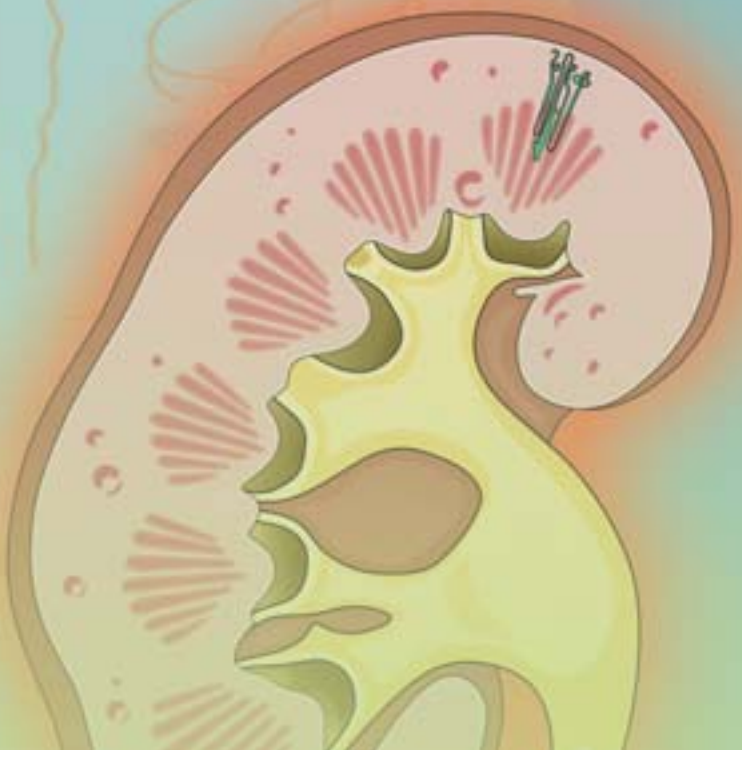
Learning Outcomes

After careful study of this chapter, you should be able to:

1. Name the three main functions of the digestive system
2. Describe the four layers of the digestive tract wall
3. Differentiate between the two layers of the peritoneum
4. Name and locate the different types of teeth
5. Name and describe the functions of the organs of the digestive tract
6. Name and describe the functions of the accessory organs of digestion
7. Describe how bile functions in digestion
8. Name and locate the ducts that carry bile from the liver into the digestive tract
9. Explain the role of enzymes in digestion and give examples of enzymes
10. Name the digestion products of fats, proteins, and carbohydrates
11. Define *absorption*
12. Define *villi* and state how villi function in absorption
13. Explain the use of feedback in regulating digestion and give several examples
14. List several hormones involved in regulating digestion
15. Describe common disorders of the digestive tract and the accessory organs
16. Show how word parts are used to build words related to digestion (see Word Anatomy at the end of the chapter)

chapter 19

Digestion



Function and Design of the Digestive System

Every body cell needs a constant supply of nutrients. The energy contained in these nutrients is used to do cell work. In addition, the cell rearranges the chemical building blocks of the nutrients to manufacture cellular materials for metabolism, growth, and repair. Food as we take it in, however, is too large to enter the cells. It must first be broken down into particles small enough to pass through the cells' plasma membrane. This breakdown process is known as **digestion.**

After digestion, the circulation must carry nutrients to the cells in every part of the body. The transfer of nutrients into the circulation is called **absorption**. Finally, undigested waste material must be eliminated from the body. Digestion, absorption, and elimination are the three chief functions of the digestive system.

For our purposes, the digestive system may be divided into two groups of organs:

- The **digestive tract,** a continuous passageway beginning at the mouth, where food is taken in, and terminating at the anus, where the solid waste products of digestion are expelled from the body.
- The **accessory organs,** which are necessary for the digestive process but are not a direct part of the digestive tract. They release substances into the digestive tract through ducts. These organs are the salivary glands, liver, gallbladder, and pancreas.

Checkpoint 19-1 Why does food have to be digested before cells can use it?

Before describing the individual organs of the digestive tract, we will pause to discuss the general structure of these organs. We will also describe the large membrane (peritoneum) that lines the abdominopelvic cavity, which contains most of the digestive organs.

The Wall of the Digestive Tract

Although modified for specific tasks in different organs, the wall of the digestive tract, from the esophagus to the anus, is similar in structure throughout. The general pattern consists of four layers:

- Mucous membrane
- Submucosa
- Smooth muscle
- Serous membrane

Refer to the diagram of the small intestine in Figure 19-1 as we describe the layers of this wall from the innermost to the outermost surface.

First is the **mucous membrane,** or **mucosa**, so called because its epithelial layer contains many mucus-secreting cells. From the mouth through the esophagus, and also in the anus, the epithelium consists of multiple layers of squamous (flat) cells, which help to protect deeper tissues. Throughout the remainder of the digestive tract, the type of epithelium in the mucosa is simple columnar.

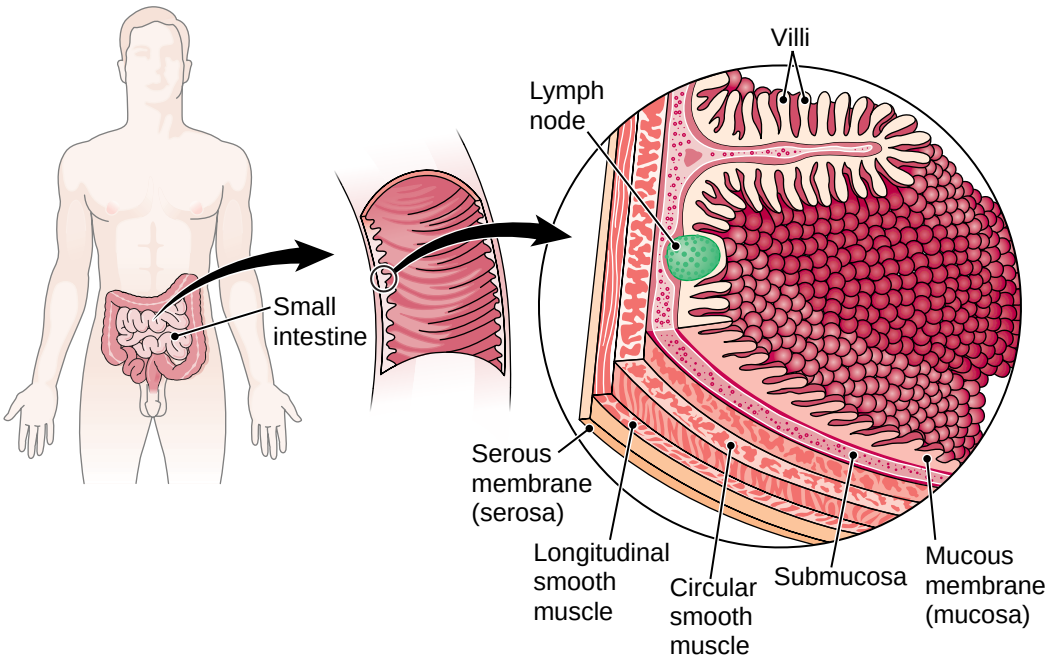


Figure 19-1 Wall of the digestive tract. The mucous membrane of the small intestine shown here has numerous projections called villi. *ZOOMING IN ✦ What type of tissue is between the submucosa and the serous membrane in the digestive tract wall?*

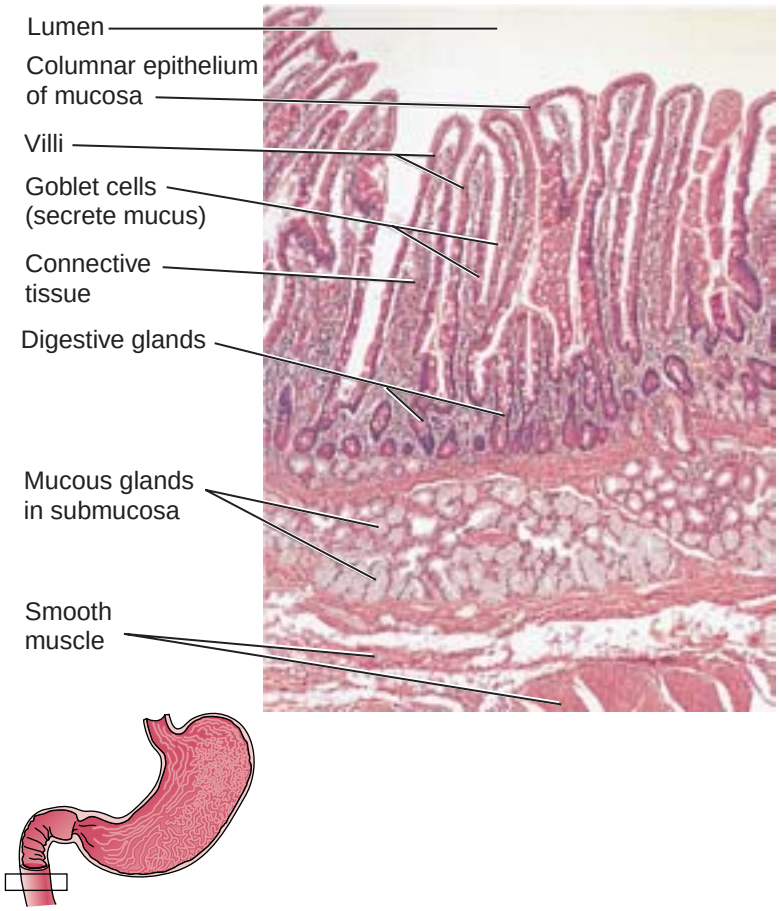


Figure 19-2 **Microscopic view of small intestine.** The layers of the intestinal wall are visible (except for the serous membrane). (Micrograph reprinted with permission from Cormack DH. Essential Histology. 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2001.)

Many of the cells that secrete digestive juices are located in the mucosa. Figure 19-2 is a microscopic view of a representative section of the digestive tract taken from the small intestine. Mucus-secreting cells (goblet cells) appear as clear areas between epithelial cells. Note that the small intestine's lining has fingerlike extensions (villi) that aid in the absorption of nutrients, as will be described later.

The layer of connective tissue beneath the mucosa is the **submucosa**, which contains blood vessels and some of the nerves that help regulate digestive activity. In the small intestine, the submucosa has many glands that produce mucus to protect that organ from the highly acidic material it receives from the stomach.

The next layer is composed of **smooth muscle**. Most of the digestive organs have two layers of smooth muscle: an inner layer of circular fibers, and an outer layer of longitudinal fibers. When a section of the circular muscle contracts, the lumen of the organ narrows; when the longitudinal muscle contracts, a section of the wall shortens and the lumen becomes wider. These alternating muscular contractions create the wavelike movement, called **peristalsis** (per-ih-STAL-sis), that propels food through the digestive tract and mixes it with digestive juices.

The esophagus differs slightly from this pattern in having striated muscle in its upper portion, and the stomach has an additional third layer of smooth muscle in its wall to add strength for churning food.

The digestive organs in the abdominopelvic cavity have an outermost layer of **serous membrane**, or **serosa**, a thin, moist tissue composed of simple squamous epithelium and loose connective tissue. This membrane forms part of the peritoneum (per-ih-to-NE-um). The esophagus above the diaphragm has instead an outer layer composed of fibrous connective tissue.

Checkpoint 19-2 The digestive tract has a wall that is basically similar throughout its length and is composed of four layers. What are the typical four layers of this wall?

The Peritoneum

The abdominopelvic cavity (Fig. 19-3) is lined with a thin, shiny serous membrane that also folds back to cover most of the organs contained within the cavity. The outer portion of this membrane, the layer that lines the cavity, is called the **parietal peritoneum**; that covering the organs is called the **visceral peritoneum**. This slippery membrane allows the organs to slide over each other as they function. The peritoneum also carries blood vessels, lymphatic vessels, and nerves. In some places, it supports the organs and binds them to each other. Subdivisions of the peritoneum around the various organs have special names.

Subdivisions of the Peritoneum

The **mesentery** (MES-en-ter-e) is a double-layered portion of the peritoneum shaped somewhat like a fan. The handle portion is attached to the posterior abdominal wall, and the expanded long edge is attached to the small intestine. Between the two membranous layers of the mesentery are the vessels and nerves that supply the intestine. The section of the peritoneum that extends from the colon to the posterior abdominal wall is the **mesocolon** (mes-o-KO-lon).

A large double layer of the peritoneum containing much fat hangs like an apron over the front of the intestine. This **greater omentum** (o-MEN-tum) extends from

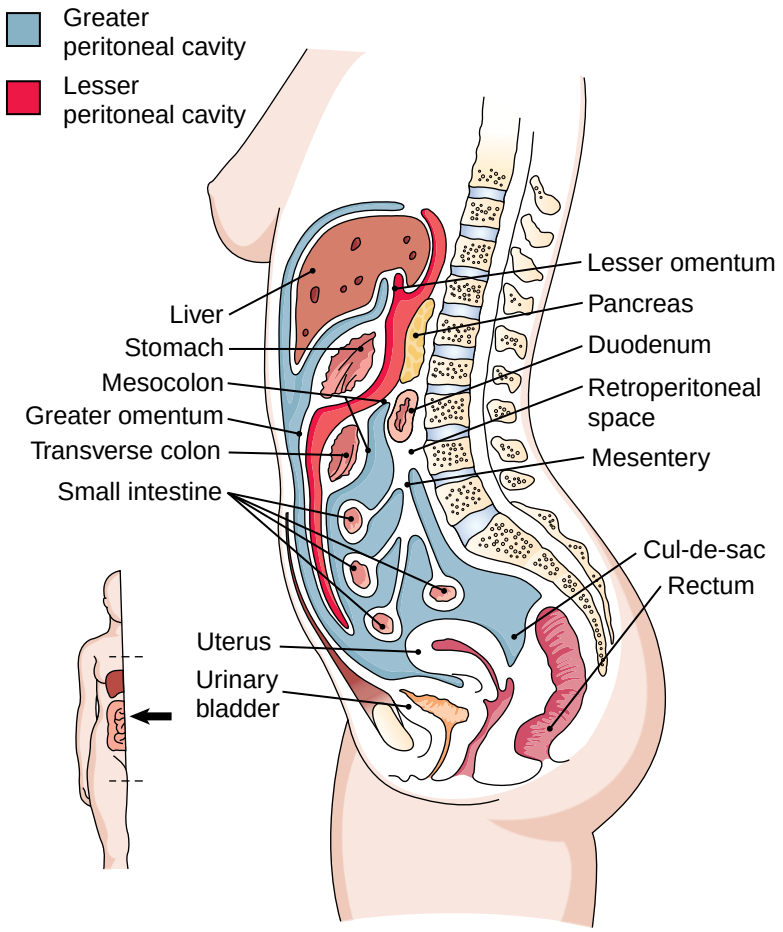


Figure 19-3 The abdominopelvic cavity. Subdivisions of the peritoneum fold over, supporting and separating individual organs. *ZOOMING IN ✦ What part of the peritoneum is around the small intestine?*

the lower border of the stomach into the pelvic part of the abdomen and then loops back up to the transverse colon. A smaller membrane, called the **lesser omentum**, extends between the stomach and the liver.

Checkpoint 19-3 What is the name of the large serous membrane that lines the abdominopelvic cavity and covers the organs it contains?

Organs of the Digestive Tract

As we study the organs of the digestive system, locate each in Figure 19-4.

The digestive tract is a muscular tube extending through the body. It is composed of several parts: the **mouth**, **pharynx**, **esophagus**, **stomach**, **small intestine**, and **large intestine**. The digestive tract is sometimes called the **alimentary tract**, from the word *aliment*, meaning "food." It is more commonly referred to as the **gastrointestinal (GI) tract** because of the major importance of the stomach and intestine in the process of digestion.

The next section describes the structure and function of each digestive organ. These descriptions are followed by an overview of how the organs work together in the digestive process.

The Mouth

The **mouth**, also called the **oral cavity**, is where a substance begins its travels through the digestive tract (Fig. 19-5). The mouth has the following digestive functions:

- It receives food, a process called **ingestion.**
- It breaks food into small portions. This is done mainly by the teeth in the process of chewing or **mastication** (mas-tih-KA-shun), but the tongue, cheeks, and lips are also used.
- It mixes the food with **saliva** (sah-LI-vah), which is produced by the salivary glands and secreted into the mouth. Saliva lubricates the food and has a digestive enzyme called *salivary amylase*, which begins starch digestion. The salivary glands will be described with the other accessory organs.
- It moves proper amounts of food toward the throat to be swallowed, a process called **deglutition** (deg-lu-TISH-un).

The tongue, a muscular organ that projects into the mouth, is used as an aid in chewing and swallowing, and is one of the principal organs of speech. The tongue has a number of special organs on its surface, called *taste buds*, which can differentiate taste sensations (bitter, sweet, sour, or salty) (see Chapter 11).

The Teeth

The oral cavity also contains the teeth (see Fig. 19-5). A child between 2 and 6 years of age has 20 teeth, known as the baby teeth or **deciduous** (de-SID-u-us) teeth. (The word deciduous means "falling off at a certain time," such as the leaves that fall off the trees in autumn.) A complete set of adult permanent teeth numbers 32. The cutting teeth, or **incisors** (in-SI-sors), occupy the anterior part of the oral cavity. The **cuspids** (KUS-pids), commonly called the *canines* (KA-nines) or *eyeteeth*, are lateral to the incisors. They are pointed teeth with deep roots that are used for more forceful gripping and tearing of food. The **molars** (MO-lars), the larger grinding teeth, are posterior. There are two premolars and three molars. In an adult, each quadrant (quarter) of the mouth, moving from

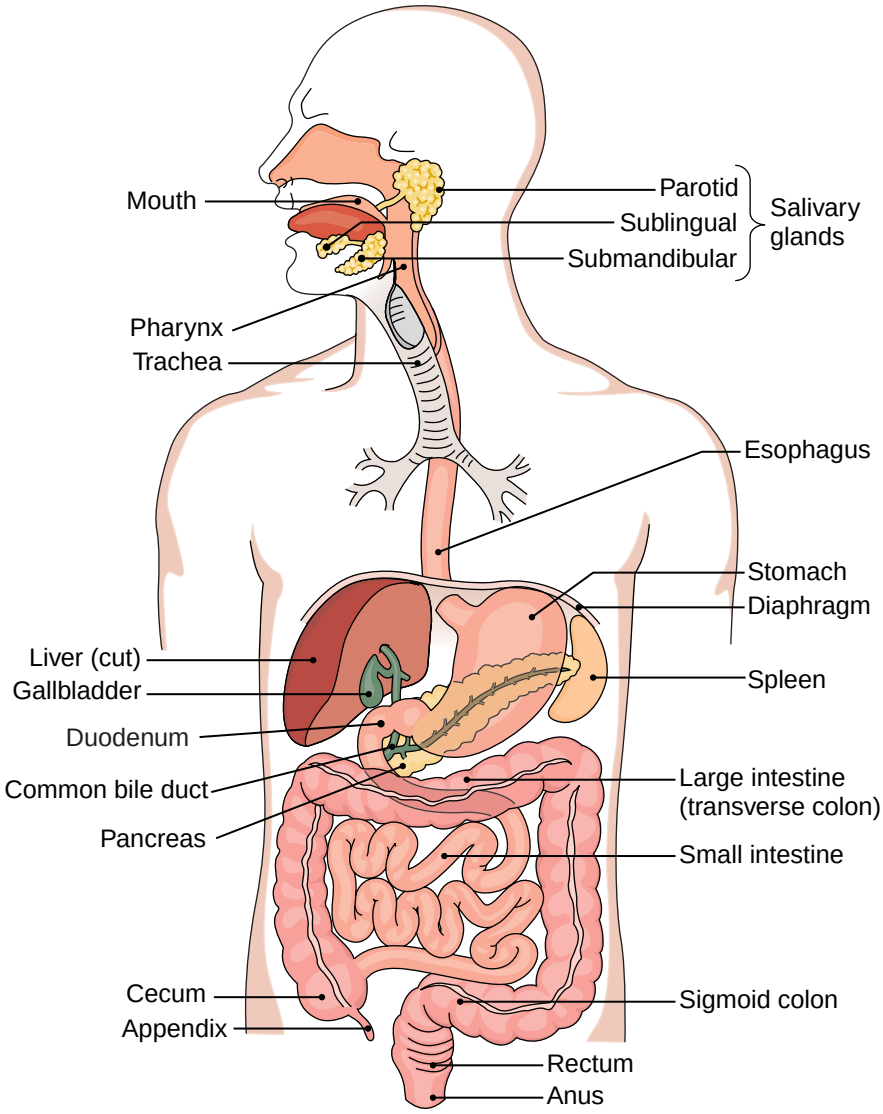


Figure 19-4 **The digestive system.** *ZOOMING IN ✦ What accessory organs of digestion secrete into the mouth?*

anterior to posterior, has two incisors, one cuspid and five molars.

The first eight deciduous (baby) teeth to appear through the gums are the incisors. Later, the cuspids and molars appear. Usually, the 20 baby teeth all have appeared by the time a child has reached the age of 2 to 3 years. During the first 2 years, the permanent teeth develop within the upper jaw (maxilla) and lower jaw (mandible) from buds that are present at birth. The first permanent teeth to appear are the four 6-year molars, which come in before any baby teeth are lost. Because decay and infection of deciduous molars may spread to new, permanent teeth, deciduous teeth need proper care.

As a child grows, the jawbones grow, making space for additional teeth. After the 6-year molars have appeared, the baby incisors loosen and are replaced by permanent incisors. Next, the baby canines (cuspids) are replaced by permanent canines, and finally, the baby molars are replaced by the permanent bicuspids (premolars).

At this point, the larger jawbones are ready for the appearance of the 12-year, or second, permanent molar teeth. During or after the late teens, the third molars, or so-called *wisdom teeth,* may appear. In some cases, the jaw is not large enough for these teeth, or there are other abnormalities, so that the third molars may not erupt or may have to be removed. Figure 19-6 shows the parts of a molar.

The main substance of the tooth is **dentin**, a calcified substance harder than bone. Within the tooth is a soft pulp containing blood vessels and nerves. The tooth's crown projects above the gum, the **gingiva** (JIN-jih-vah), and is covered with **enamel**, the hardest substance in the body. The roots of the tooth, below the gum line in a bony socket, are covered with a rigid connective tissue (cementum) that helps to hold the tooth in place. Each root has a canal containing extensions of the pulp.

Checkpoint 19-4 How many baby teeth are there and what is the scientific name for the baby teeth?

The Pharynx

The **pharynx** (FAR-inks) is commonly referred to as the throat (see Fig. 19-5). The oral part of the pharynx, the oropharynx, is visible when you look into an open mouth and depress the tongue. The palatine tonsils may be seen at either side of the oropharynx. The pharynx also extends upward to the nasal cavity, where it is referred to as the nasopharynx and downward to the larynx, where it is called the laryngeal pharynx. The **soft palate** is tissue that forms the posterior roof of the oral cavity. From it hangs a soft, fleshy, V-shaped mass called the **uvula** (U-vu-lah).

In swallowing, the tongue pushes a **bolus** (BO-lus) of food, a small portion of chewed food mixed with saliva, into the pharynx. Once the food reaches the pharynx, swallowing occurs rapidly by an involuntary reflex action. At the same time, the soft palate and uvula are raised to prevent food and liquid from entering the nasal cavity, and the tongue is raised to seal the back of the oral cavity. The entrance of the trachea is guarded during swallowing by a leaf-shaped cartilage, the **epiglottis**, which

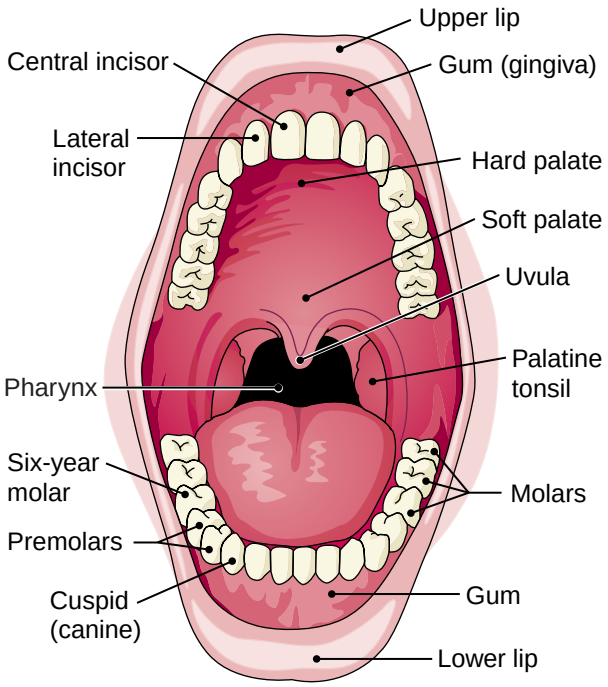


Figure 19-5 **The mouth.** The teeth and tonsils are visible in this view.

covers the opening of the larynx. The swallowed food is then moved into the esophagus.

The Esophagus

The **esophagus** (eh-SOF-ah-gus) is a muscular tube about 25 cm (10 inches) long. In the esophagus, food is lubricated with mucus and moved by peristalsis into the stomach. No additional digestion occurs in the esophagus.

Before joining the stomach, the esophagus must pass through the diaphragm. It travels through a space in the diaphragm called the **esophageal hiatus** (eh-sof-ah-JE-al hi-A-tus). If there is a weakness in the diaphragm at this point, a portion of the stomach or other abdominal organ may protrude through the space, a condition called *hiatal hernia.*

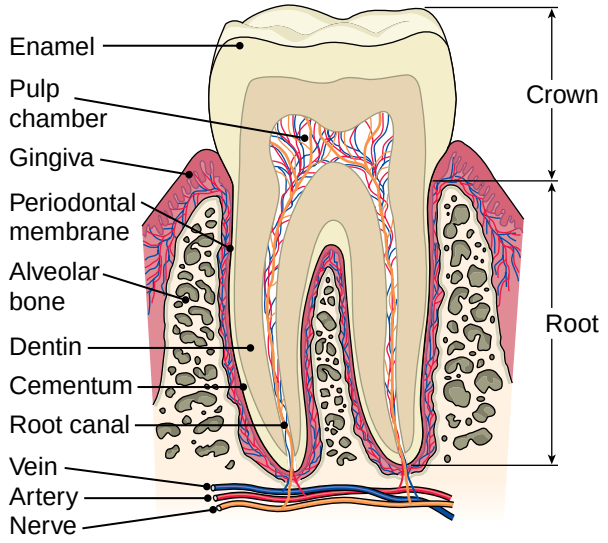


Figure 19-6 **A molar tooth.**

The Stomach

The stomach is an expanded J-shaped organ in the upper left region of the abdominal cavity (Fig. 19-7). In addition to the two muscle layers already described, it has a third, inner oblique (angled) layer that aids in grinding food and mixing it with digestive juices. The left-facing arch of the stomach is the **greater curvature**, whereas the right surface forms the **lesser curvature**. The superior rounded portion under the left side of the diaphragm is the stomach's **fundus**.

Sphincters A **sphincter** (SFINK-ter) is a muscular ring that regulates the size of an opening. There are two sphincters that separate the stomach from the organs above and below.

Between the esophagus and the stomach is the **lower esophageal sphincter (LES).** This muscle has also been called the **cardiac sphincter** because it separates the esophagus from the region of the stomach that is close to the heart. We are sometimes aware of the existence of this sphincter when it does not relax as it should, producing a feeling of being unable to swallow past that point.

Between the distal, or far, end of the stomach and the small intestine is the **pyloric** (pi-LOR-ik) **sphincter**. The region of the stomach leading into this sphincter, the **pylorus** (pi-LOR-us), is important in regulating how rapidly food moves into the small intestine.

Functions of the Stomach The stomach serves as a storage pouch, digestive organ, and churn. When the stomach is empty, the lining forms many folds called **rugae** (RU-je). These folds disappear as the stomach expands. (The stomach can stretch to hold one half of a gallon of food and liquid.) Special cells in the lining of the stomach secrete substances that mix together to form **gastric juice**. Some of the cells secrete a great amount of mucus to protect the stomach lining from digestive secretions. Other cells produce the active components of the gastric juice, which are:

- Hydrochloric acid (HCl), a strong acid that helps break down protein and destroys foreign organisms
- Pepsin, a protein-digesting enzyme produced in an inactive form and activated only when food enters the stomach and HCl is produced

Chyme (*kime*), from a Greek word meaning "juice," is the highly acidic, semiliquid mixture of gastric juice and food that leaves the stomach to enter the small intestine.

Checkpoint 19-5 What type of food is digested in the stomach?

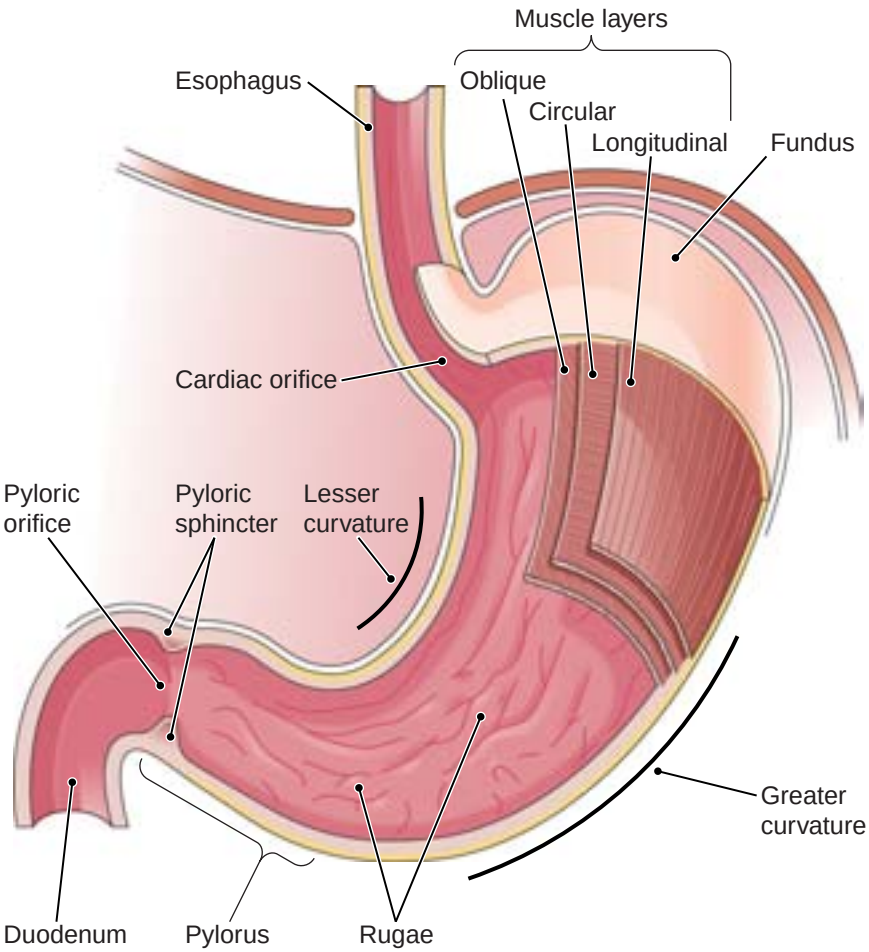


Figure 19-7 **Longitudinal section of the stomach.** The stomach's interior is visible, along with a portion of the esophagus and the duodenum. *ZOOMING IN ✦ What additional muscle layer is in the wall of the stomach that is not found in the rest of the digestive tract?*

The Small Intestine

The small intestine is the longest part of the digestive tract (Fig. 19-8). It is known as the small intestine because, although it is longer than the large intestine, it is smaller in diameter, with an average width of approximately 2.5 cm (1 inch). After death, when relaxed to its full length, the small intestine is approximately 6 m (20 feet) long. In life, the small intestine averages 3 m (10 feet) in length. The first 25 cm (10 inches) or so of the small intestine make up the **duodenum** (du-o-DE-num) (named for the Latin word for "twelve," based on its length of twelve finger widths). Beyond the duodenum are two more divisions: the **jejunum** (je-JU-num), which forms the next two-fifths of the small intestine, and the **ileum** (IL-e-um), which constitutes the remaining portion.

Functions of the Small Intestine The duodenal mucosa and submucosa contain glands that secrete large amounts of mucus to protect the small intestine from the strongly acidic chyme entering from the stomach. Mucosal cells of the small intestine also secrete enzymes that digest proteins and carbohydrates. In addition, digestive juices from the liver and pancreas enter the small intestine through a small opening in the duodenum. Most of the digestive process takes place in the small intestine under the effects of these juices.

Most absorption of digested food, water, and minerals also occurs through the walls of the small intestine. To increase the organ's surface area for this purpose, the mucosa is formed into millions of tiny, fingerlike projections, called **villi** (VIL-li) (Fig. 19-9), which give the inner surface a velvety appearance (see also Figs. 19-1 and 19-2). The epithelial cells of the villi also have small projecting folds of the plasma membrane known as **microvilli.** These create a remarkable increase in the total surface area available in the small intestine for absorption.

Each villus contains blood vessels through which most digestion products are absorbed into the blood. Each one also contains a specialized lymphatic capillary called a **lacteal** (LAK-tele) through which fats are absorbed into the lymph. Box 19-1 provides more information on the relationship of surface area to absorption.

Checkpoint 19-6 What are the three divisions of the small intestine?

Checkpoint 19-7 How does the small intestine function in the digestive process?

The Large Intestine

The large intestine is approximately 6.5 cm (2.5 inches) in diameter and approximately 1.5 m (5 feet) long (see Fig. 19-8). It is named for its wide diameter, rather than its length. The outer longitudinal muscle fibers in its wall form three separate surface bands (see Fig. 19-8). These bands, known as **teniae** (TEN-e-e) **coli** draw up the organ's wall to give it its distinctive puckered appearance. (Spelling is also *taeniae*; the singular is *tenia* or *taenia*).

Subdivisions of the Large Intestine The large intestine begins in the lower right region of the abdomen. The first part is a small pouch called the **cecum** (SE-kum). Between the ileum of the small intestine and the cecum is a sphincter, the **ileocecal** (il-e-o-SE-kal) **valve,** that prevents food from traveling backward into the small

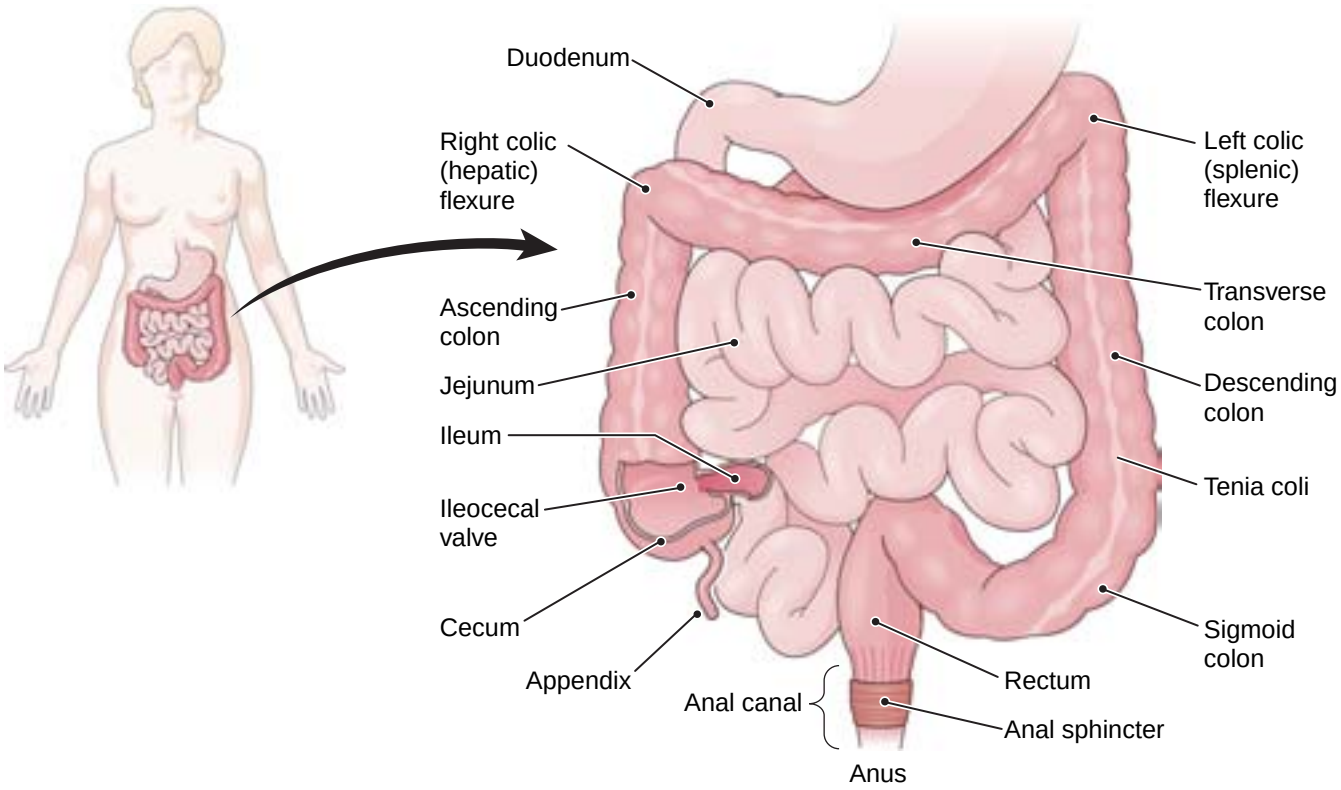


Figure 19-8 **The small and large intestines.** *ZOOMING IN ✦ What part of the small intestine joins the cecum?*

intestine. Attached to the cecum is a small, blind tube containing lymphoid tissue; its full name is **vermiform** (VER-mih-form) **appendix** (*vermiform* means "worm-like"), but usually just "appendix" is used.

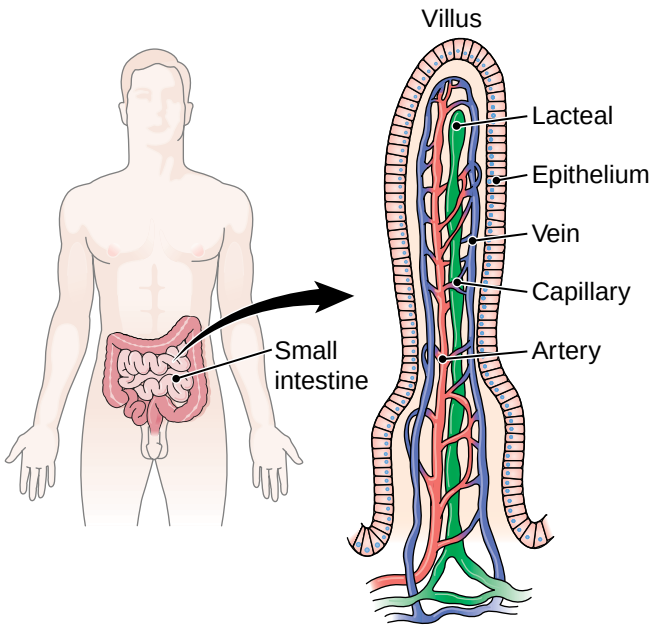


Figure 19-9 **A villus of the small intestine.** Each villus has blood vessels and a lacteal (lymphatic capillary) for absorption of nutrients.

The second portion, the **ascending colon**, extends upward along the right side of the abdomen toward the liver. It bends near the liver at the right colic (hepatic) flexure and extends across the abdomen as the **transverse colon**. It bends again sharply at the left colic (splenic) flexure and extends downward on the left side of the abdomen into the pelvis, forming the **descending colon**. The distal part of the colon bends backward into an S shape forming the **sigmoid colon** (named for the Greek letter *sigma*), which continues downward to empty into the **rectum**, a temporary storage area for indigestible or nonabsorbable food residue (see Fig. 19-8). The narrow portion of the distal large intestine is the **anal canal**, which leads to the outside of the body through an opening called the **anus** (A-nus).

Functions of the Large Intestine

The large intestine secretes a great quantity of mucus, but no enzymes. Food is not digested in this organ, but some water is reabsorbed, and undigested food is stored, formed into solid waste material, called **feces** (FE-seze) or stool, and then eliminated.

At intervals, usually after meals, the involuntary muscles within the walls of the large intestine propel solid waste toward the rectum. Stretching of the rectum stimulates contraction of smooth muscle in the rectal wall. Aided by voluntary contractions of the diaphragm and the abdominal muscles, the feces are eliminated from the body in a process called **defecation** (def-e-KA-shun). An

Box 19-1 A Closer Look

The Folded Intestine: More Absorption With Less Length

Whenever materials pass from one system to another, they must travel through a cellular membrane. A major factor in how much transport can occur per unit time is the total surface area of the membrane; the greater the surface area, the higher the rate of transport. The problem of packing a large amount of surface into a small space is solved in the body by folding the membranes. We do the same thing in everyday life. Imagine trying to store a bed sheet in the closet without folding it!

In the small intestine, where digested food must absorb into the bloodstream, there is folding of membranes down to the level of single cells.

- The 6-meter-long organ is coiled to fit into the abdominal cavity.
- The inner wall of the organ is thrown into circular folds called plicae circulares, which not only increase surface area, but aid in mixing.
- The mucosal villi project into the lumen, providing more surface area than a flat membrane would.
- The individual cells that line the small intestine have microvilli, tiny finger-like folds of the plasma membrane that increase surface area tremendously.

Together, these structural features of the small intestine result in an absorptive surface area estimated to be about 250 square meters! Folding is present in other parts of the digestive system and in other areas of the body as well. Can you name other systems that show this folding pattern?

anal sphincter provides voluntary control over defecation (see Fig. 19-8).

While the food residue is stored in the large intestine, bacteria that normally live in the colon act on it to produce vitamin K and some of the B-complex vitamins. As mentioned, systemic antibiotic therapy may destroy these symbiotic (helpful) bacteria living in the large intestine, causing undesirable side effects.

Checkpoint 19-8 What are the divisions of the large intestine?

Checkpoint 19-9 What are the functions of the large intestine?

- The **parotid** (pah-ROT-id) **glands**, the largest of the group, are located inferior and anterior to the ear.
- The **submandibular** (sub-man-DIB-u-lar), or **submaxillary** (sub-MAK-sih-ler-e), **glands** are located near the body of the lower jaw.
- The **sublingual** (sub-LING-gwal) **glands** are under the tongue.

All these glands empty through ducts into the oral cavity.

Checkpoint 19-10 What are the names of the salivary glands?

The Accessory Organs

The accessory organs (Fig. 19-10) release secretions through ducts into the digestive tract. The salivary glands deliver their secretions into the mouth. All of the others accessory organs release secretions into the duodenum.

The Salivary Glands

While food is in the mouth, it is mixed with **saliva** (sah-LI-vah), which moistens the food and facilitates mastication (chewing) and deglutition (swallowing). Saliva helps to keep the teeth and mouth clean. It also contains some antibodies and an enzyme (lysozyme) that help reduce bacterial growth.

This watery mixture contains mucus and an enzyme called **salivary amylase** (AM-ih-laze), which begins the digestive process by converting starch to sugar. Saliva is manufactured by three pairs of glands (see Fig. 19-4):

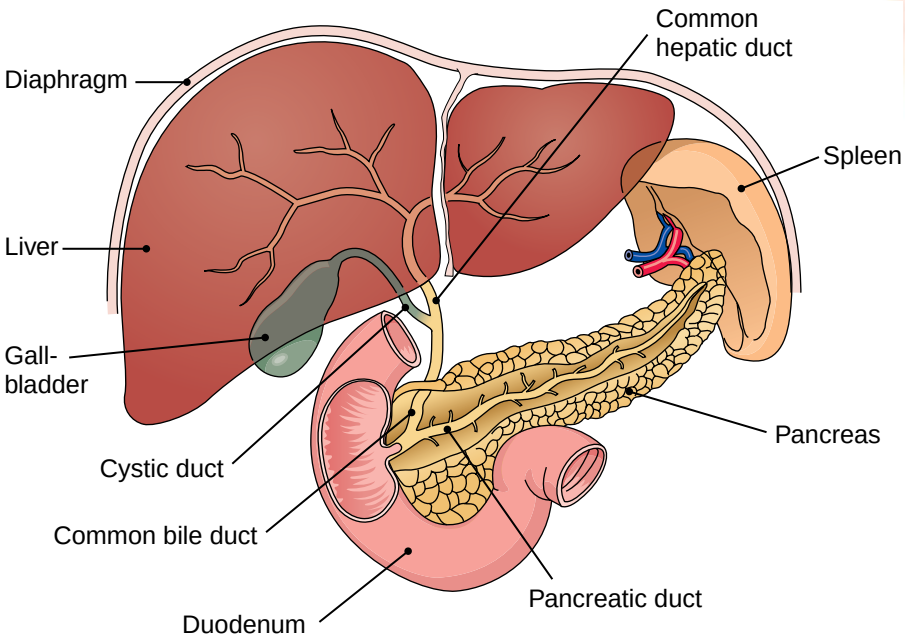


Figure 19-10 Accessory organs of digestion. *ZOOMING IN ✦ Into what part of the intestine do these accessory organs secrete?*

19

The Liver

The liver, often referred to by the word root *hepat,* is the body's largest glandular organ (see Fig. 19-10). It is located in the upper right portion of the abdominal cavity under the dome of the diaphragm. The lower edge of a normal-sized liver is level with the lower margin of the ribs. The human liver is the same reddish brown color as animal liver seen in the supermarket. It has a large right lobe and a smaller left lobe; the right lobe includes two inferior smaller lobes. The liver is supplied with blood through two vessels: the portal vein and the hepatic artery (the portal system and blood supply to the liver were described in Chapter 15). These vessels deliver about 1.5 quarts (1.6 L) of blood to the liver every minute. The hepatic artery carries oxygenated blood, whereas the venous portal system carries blood that is rich in digestive end products. This most remarkable organ has many functions that affect digestion, metabolism, blood composition, and elimination of waste. Some of its major activities are:

- The manufacture of **bile**, a substance needed for the digestion of fats.
- The storage of glucose (simple sugar) in the form of **glycogen,** the animal equivalent of the starch found in plants. When the blood sugar level falls below normal, liver cells convert glycogen to glucose, which is released into the blood restoring the normal blood sugar concentration.
- The modification of fats so that they can be used more efficiently by cells all over the body.
- The storage of some vitamins and iron.
- The formation of blood plasma proteins, such as albumin, globulins, and clotting factors.
- The destruction of old red blood cells and the recycling or elimination of their breakdown products. One byproduct, a pigment called **bilirubin** (BIL-ih-ru-bin), is eliminated in bile and gives the stool its characteristic dark color.
- The synthesis of **urea** (u-RE-ah), a waste product of protein metabolism. Urea is released into the blood and transported to the kidneys for elimination.
- The **detoxification** (de-tok-sih-fih-KA-shun) (removal of the poisonous properties) of harmful substances, such as alcohol and certain drugs.

Bile The main digestive function of the liver is the production of bile, a substance needed for the processing of fats. The salts contained in bile act like a detergent to **emulsify** fat, that is, to break up fat into small droplets that can be acted on more effectively by digestive enzymes. Bile also aids in fat absorption from the small intestine.

Bile leaves the lobes of the liver by two ducts that merge to form the **common hepatic** duct. After collecting bile from the gallbladder, this duct, now called the **common bile duct,** delivers bile into the duodenum. These and the other accessory ducts are shown in Figure 19-10.

The Gallbladder

The gallbladder is a muscular sac on the inferior surface of the liver that stores bile. Although the liver may manufacture bile continuously, the body needs it only a few times a day. Consequently, bile from the liver flows into the hepatic ducts and then up through the **cystic** (SIS-tik) **duct,** connected with the gallbladder (see Fig. 19-10). When chyme enters the duodenum, the gallbladder contracts, squeezing bile through the cystic duct and into the common bile duct, leading to the duodenum.

The Pancreas

The pancreas is a long gland that extends from the duodenum to the spleen (see Fig. 19-10). The pancreas produces enzymes that digest fats, proteins, carbohydrates, and nucleic acids. The protein-digesting enzymes are produced in inactive forms which must be converted to active forms in the small intestine by other enzymes.

The pancreas also produces large amounts of alkaline (basic) fluid, that neutralizes the acidic chyme in the small intestine, thus protecting the lining of the digestive tract. These juices collect in a main duct that joins the common bile duct or empties into the duodenum near the common bile duct. Most people have an additional smaller duct that opens into the duodenum.

As described in Chapter 12, the pancreas also functions as an endocrine gland, producing the hormones insulin and glucagon that regulate sugar metabolism. These islet cell secretions are released directly into the blood.

Checkpoint 19-11 What is the role of the gallbladder?

Checkpoint 19-12 What is the role of bile in digestion?

Enzymes and the Digestive Process

Although the different organs of the digestive tract are specialized for digesting different types of food, the basic chemical process of digestion is the same for fats, proteins, and carbohydrates. In every case, this process requires enzymes. Enzymes are catalysts, substances that speed the rate of chemical reactions, but are not themselves changed or used up in the reaction.

All enzymes are proteins, and they are highly specific in their actions. In digestion, an enzyme acts only in a certain type of reaction involving a certain type of nutrient molecule. For example, the carbohydrate-digesting enzyme amylase only splits starch into the disaccharide (double sugar) maltose. Another enzyme is required to split maltose into two molecules of the monosaccharide

(simple sugar) glucose. Other enzymes split fats into their building blocks, glycerol and fatty acids, and still others split proteins into smaller units called *peptides* and into their building blocks, amino acids.

The Role of Water

Because water is added to nutrient molecules as they are split by enzymes, the process of digestion is referred to chemically as **hydrolysis** (hi-DROL-ih-sis), which means "splitting by means of water." About 7 liters of water are secreted into the digestive tract each day, in addition to the nearly 2 liters taken in with food and drink. You can now understand why so large an amount of water is needed. Water not only is used to produce digestive juices and to dilute food so that it can move more easily through the digestive tract, but also is used in the chemical process of digestion itself.

Digestion, Step by Step

Let us see what happens to a mass of food from the time it is taken into the mouth to the moment that it is ready to be absorbed (see Table 19-1).

In the mouth, the food is chewed and mixed with saliva, softening it so that it can be swallowed easily. Salivary amylase initiates the process of digestion by changing some of the starches into sugar.

Digestion in the Stomach When the food reaches the stomach, it is acted on by gastric juice, with its hydrochloric acid (HCl) and enzymes. The hydrochloric acid has the important function of breaking down proteins and preparing them for digestion. In addition, HCl activates the enzyme pepsin, which is secreted by gastric cells in an inactive form. Once activated by hydrochloric acid, pepsin works to digest protein; this enzyme is the first to digest nearly every type of protein in the diet. The stomach also secretes a fat-digesting enzyme (lipase), but it is of little importance in adults.

The food, gastric juice, and mucus (which is also secreted by cells of the gastric lining) are mixed to form chyme. This semiliquid substance is moved from the stomach to the small intestine for further digestion.

Digestion in the Small Intestine In the duodenum, the first part of the small intestine, chyme is mixed with the greenish yellow bile delivered from the liver and the gallbladder through the common bile duct. Bile does not contain enzymes; instead, it contains salts that emulsify fats to allow the powerful secretions from the pancreas to act on them most efficiently.

Pancreatic juice contains a number of enzymes, including:

- **Lipase.** After bile divides fats into tiny particles, the highly active pancreatic enzyme lipase digests almost all of them. In this process, fats are usually broken down into two simpler compounds, glycerol (glycerin) and fatty acids, which are more readily absorbable. If pancreatic lipase is absent, fats are expelled with the feces in undigested form.
- **Amylase.** This enzyme changes starch to sugar.
- **Trypsin** (TRIP-sin). This enzyme splits proteins into amino acids, which are small enough to be absorbed through the intestine.
- **Nucleases** (NU-kle-ases). These enzymes digest the nucleic acids DNA and RNA.

It is important to note that most digestion occurs in the small intestine under the action of pancreatic juice, which has the ability to break down all types of foods. When pancreatic juice is absent, serious digestive disturbances always occur.

The small intestine also produces a number of enzymes, including three that act on complex sugars to transform them into simpler, absorbable forms. These enzymes are **maltase**, **sucrase**, and **lactase**, which act on the disaccharides maltose, sucrose, and lactose, respectively.

Table 19•1 Summary of Digestion

ORGAN	ACTIVITY	NUTRIENTS DIGESTED	ACTIVE SECRETIONS
Mouth	Chews food and mixes it with saliva; forms into bolus for swallowing	Starch	Salivary amylase
Esophagus	Moves food by peristalsis into stomach	—	—
Stomach	Stores food, churns food, and mixes it with digestive juices	Proteins	Hydrochloric acid, pepsin
Small intestine	Secretes enzymes, neutralizes acidity, receives secretions from pancreas and liver, absorbs nutrients and water into the blood or lymph	Fats, proteins, carbohydrates, nucleic acids	Intestinal enzymes, pancreatic enzymes, bile from liver
Large intestine	Reabsorbs some water; forms, stores, and eliminates stool	—	—

Table 19-2 summarizes the main substances used in digestion. Note that, except for HCl, sodium bicarbonate, and bile salts, all the substances listed are enzymes.

Checkpoint 19-13 What organ produces the most complete digestive secretions?

Table 19•2 Digestive Juices Produced by Digestive Tract Organs and Accessory Organs

ORGAN	MAIN DIGESTIVE JUICES SECRETED	ACTION
Salivary glands	Salivary amylase	Begins starch digestion
Stomach	Hydrochloric acid (HCl)*	Breaks down proteins
	Pepsin	Begins protein digestion
Small intestine	Peptidases	Digests proteins to amino acids
	Lactase, maltase, sucrase	Digests disaccharides to monosaccharides
Pancreas	Sodium bicarbonate*	Neutralizes HCl
	Amylase	Digests starch
	Trypsin	Digests protein to amino acids
	Lipases	Digests fats to fatty acids and glycerol
	Nucleases	Digests nucleic acids
Liver	Bile salts*	Emulsifies fats

**Not enzymes*

Absorption

The means by which digested nutrients reach the blood is known as **absorption**. Most absorption takes place through the villi in the mucosa of the small intestine (see Fig. 19-9). Within each villus is an arteriole and a venule bridged with capillaries. Simple sugars, small proteins (peptides), amino acids, some simple fatty acids, and most of the water in the digestive tract are absorbed into the blood through these capillaries. From here, they pass by way of the portal system to the liver, to be processed, stored, or released as needed.

Absorption of Fats

Most fats have an alternative method of reaching the blood. Instead of entering the blood capillaries, they are absorbed by the villi's more permeable lymphatic capillaries called **lacteals**. The absorbed fat droplets give the lymph a milky appearance. The mixture of lymph and fat globules that drains from the small intestine after fat has been digested is called **chyle** (kile). Chyle merges with the lymphatic circulation and eventually enters the blood when the lymph drains into veins near the heart. The absorbed fats then circulate to the liver for further processing.

Absorption of Vitamins and Minerals

Minerals and vitamins ingested with food are also absorbed from the small intestine. The minerals and some of the vitamins dissolve in water and are absorbed directly into the blood. Other vitamins are incorporated in fats and are absorbed along with the fats. Vitamin K and some B vitamins are produced by bacterial action in the colon and are absorbed from the large intestine.

Checkpoint 19-14 What is absorption?

Control of Digestion

As food moves through the digestive tract, its rate of movement and the activity of each organ it passes through must be carefully regulated. If food moves too slowly or digestive secretions are inadequate, the body will not get enough nourishment. If food moves too rapidly or excess secretions are produced, digestion may be incomplete or the lining of the digestive tract may be damaged. There are two types of control over digestion: nervous and hormonal. Both illustrate the principles of feedback control.

The nerves that control digestive activity are located in the submucosa and between the muscle layers of the organ walls. Instructions for action come from the autonomic (visceral) nervous system. In general, parasympathetic stimulation increases activity, and sympathetic stimulation decreases activity. Excess sympathetic stimulation, as in stress, can block the movement of food through the digestive tract and inhibit the secretion of mucus, which is crucial in protecting the lining of the digestive tract.

The digestive organs themselves produce the hormones involved in the regulation of digestion. The following is a discussion of some of these controls (Table 19-3).

The sight, smell, thought, taste, or feel of food in the mouth stimulates, through the nervous system, the secretion of saliva and the release of gastric juice. Once in the stomach, food stimulates the release into the blood of the hormone **gastrin**, which promotes stomach secretions and motility (movement).

When chyme enters the duodenum, nerve impulses inhibit movement of the stomach, so that food will not move too rapidly into the small intestine. This action is a good example of negative feedback. At the same time, hormones released from the duodenum not only function in digestion, but also feed back to the stomach to reduce its activity. **Gastric-inhibitory peptide (GIP)** is one such hormone. It acts on the stomach to inhibit the release of

Table 19•3 Hormones Active in Digestion

HORMONE	SOURCE	ACTION
Gastrin	Stomach	Stimulates release of gastric juice
Gastric-inhibitory peptide (GIP)	Duodenum	Stimulates insulin release from pancreas when glucose enters duodenum; inhibits release of gastric juice
Secretin	Duodenum	Stimulates release of water and bicarbonate from pancreas, stimulates release of bile from liver; inhibits the stomach
Cholecystokinin (CCK)	Duodenum	Stimulates release of digestive enzymes from pancreas, stimulates release of bile from gallbladder; inhibits the stomach

gastric juice. Its more important action is to stimulate insulin release from the pancreas when glucose enters the duodenum. Another of these hormones, **secretin** (se-KRE-tin) stimulates the pancreas to release water and bicarbonate to dilute and neutralize chyme. **Cholecystokinin** (ko-le-sis-to-KI-nin) **(CCK)**, stimulates the release of enzymes from the pancreas and causes the gallbladder to release bile.

Checkpoint 19-15 What are the two types of control over the digestive process?

Hunger and Appetite

Hunger is the desire for food, which can be satisfied by the ingestion of a filling meal. Hunger is regulated by hypothalamic centers that respond to the levels of nutrients in the blood. When these levels are low, the hypothalamus stimulates a sensation of hunger. Strong, mildly painful contractions of the empty stomach may stimulate a feeling of hunger. Messages received by the hypothalamus reduce hunger as food is chewed and swallowed and begins to fill the stomach. The short-term regulation of food intake works to keep the amount of food eaten within the limits of what the intestine can process. The long-term regulation of food intake maintains appropriate blood levels of certain nutrients.

Appetite differs from hunger in that, although it is basically a desire for food, it often has no relationship to the need for food. Even after an adequate meal that has relieved hunger, a person may still have an appetite for additional food. A variety of factors, such as emotional state, cultural influences, habit, and memories of past food intake, can affect appetite. The regulation of appetite is not well understood (see Box 19-2).

Eating Disorders

A chronic loss of appetite, called **anorexia** (an-o-REK-se-ah), may be caused by a great variety of physical and mental disorders. Because the hypothalamus and the higher brain centers are involved in the regulation of hunger, it is possible that emotional and social factors contribute to the development of anorexia.

Anorexia nervosa is a psychological disorder that predominantly afflicts young women. In a desire to be excessively thin, affected people literally starve themselves, sometimes to the point of death. A related disorder, **bulimia** (bu-LIM-e-ah), is also called the *binge-purge syndrome*. Affected individuals eat huge quantities of food at one time, and then induce vomiting or take large doses of laxatives to prevent absorption of the food.

19

Box 19-2 Hot Topics

Leptin: The Weight-Loss Hormone

Despite day-to-day variations in food intake and physical activity, a healthy individual maintains a constant body weight and energy reserves of fat over long periods. Clearly, long-term negative feedback mechanisms are at work, but until recently scientists did not understand them. With the discovery of the hormone **leptin** (from the Greek word *leptos*, meaning thin), researchers have been able to piece together one long-term mechanism for regulating weight. Leptin is produced by adipocytes, the cells in adipose tissue. Fat storage that occurs when food intake exceeds the body's demands stimulates adipocytes to release more leptin into the bloodstream. Centers in the hypothalamus respond to the increased leptin by decreasing food intake and increasing energy expenditure, which result in weight loss. If this feedback mechanism is disrupted, obesity will result. For example, mice with a genetic mutation that prevents them from making leptin are obese. Injecting the mice with leptin causes them to lose weight.

After discovering leptin and demonstrating that it could reverse obesity in genetically obese mice, researchers hoped that leptin could be used to treat obesity in humans. It is now known that unlike genetically obese mice, the vast majority of obese humans are able to make leptin. Human obesity appears to be caused by an inability of the hypothalamus to respond to leptin, rather our inability to make the hormone.

These disorders stress all body systems. In women, a lack of estrogen may cause menstrual periods to cease. Loss of bone mass may lead to osteoporosis. Degeneration of the myocardium can result in heart failure. Mental function is impaired. The reflux of acidic substances in bulimia causes erosion of the esophagus and destruction of tooth enamel.

Checkpoint 19-16 What is the difference between hunger and appetite?

Disorders of the Digestive System

Infections, ulcers, cancer, and structural abnormalities all affect the digestive system at almost any level. Stones may form in the accessory organs or their ducts. Mechanical, nervous, chemical, and hormonal factors may be at the source of digestive problems.

Peritonitis

Inflammation of the peritoneum, termed **peritonitis** (per-ih-to-NI-tis), is a serious complication that may follow infection of an organ covered by the peritoneum—often, the appendix. The frequency and severity of peritonitis have been greatly reduced by the use of antibiotics. The disorder still occurs, however, and can be dangerous. If the infection is kept in one area, it is said to be *localized peritonitis*. A *generalized peritonitis,* as may be caused by a ruptured appendix, a perforated ulcer, or a penetrating wound, may lead to the growth of so many disease organisms and the release of so much bacterial toxin as to be fatal. Immediate surgery to repair the rupture and medical care are needed.

Diseases of the Mouth and Teeth

Tooth decay is also termed dental **caries** (KA-reze) (from Latin meaning "rottenness"). It has a number of causes, including diet, heredity, mechanical problems, and endocrine disorders. People who ingest a lot of sugar are particularly prone to this disease. Because a baby's teeth begin to develop before birth, a mother's diet during pregnancy is important in ensuring the formation of healthy teeth in her baby.

Any infection of the gum is called **gingivitis** (jin-jih-VI-tis). If such an infection continues untreated, it may lead to a more serious condition, **periodontitis** (per-e-o-don-TI-tis), which involves not only the gum tissue but also the supporting bone of the teeth. Tooth loosening and bone destruction follow unless periodontitis is halted by proper treatment and improved dental hygiene. Periodontitis is responsible for nearly 80% of tooth loss in people older than 45 years of age.

Vincent disease, a kind of gingivitis caused by a spirochete or a bacillus, is most prevalent in teenagers and young adults. Characterized by inflammation, ulceration, and infection of the oral mucous membranes, this disorder is highly contagious, particularly by oral contact. Patients on antibiotic therapy are more likely than normal to develop fungal infections of the mouth and tongue because these drugs may destroy the normal bacterial flora and allow other organisms to grow.

Leukoplakia (lu-ko-PLA-ke-ah) is characterized by thickened white patches on the mucous membranes of the mouth. It is common in smokers and is considered precancerous.

Checkpoint 19-17 What are some common diseases of the mouth and teeth?

Disorders of the Esophagus and Stomach

The distal portion of the esophagus is a common site for ulcer development due to acid reflux (backflow) from the stomach. In cases of liver disease, the esophagus is prone to develop varicose veins, which are subject to severe bleeding.

As noted, a weakness in the diaphragm at the point where the esophagus joins the stomach may allow the stomach to protrude upward as a **hiatal** (hi-A-tal) **hernia**. Minor irregularities in this area are common and may cause no problem, but the incidence and severity of hiatal hernia increase with age. A hiatal hernia may cause discomfort after meals, gastritis, or ulceration, and serious cases may need surgical repair.

Weakness in the lower esophageal sphincter (LES) may allow the acidic contents of the stomach to flow back into the distal esophagus. The result is a burning sensation below or behind the sternum that is described as *heartburn*. The symptom does not involve the heart in any way, but is felt in the vicinity of the heart. Often it is mistaken for a heart attack. More dangerously, a heart attack can be mistaken for heartburn, and people may fail to seek medical attention thinking they have a minor disturbance. Chronic reflux is referred to as **gastroesophageal reflux disease (GERD)**. Overfilling of the stomach and meals high in fat contribute to reflux and GERD by initiating nervous responses that relax the LES. Acid reflux irritates the mucous membrane of the esophagus, leading to esophagitis. Eventually there may be edema and formation of scar tissue that narrows the esophagus and interferes with digestion. GERD also increases the risk of esophageal cancer.

Acid reflux and GERD are treated with antacids and drugs that inhibit the production of HCl. People with this problem should avoid certain foods and beverages, including fats, caffeine, chocolate, and alcohol, and should not smoke. Other measures that may help are eating in an upright position, not bending down for long periods, not lying down for several hours after eating, and sleeping with the head elevated. Weight loss may also help in cases of obesity.

Nausea is an unpleasant sensation that may follow distention or irritation of the distal esophagus or the stomach as a result of various nervous and mechanical factors. It may be a symptom of interference with normal peristalsis in the stomach and intestine, and thus may be followed by vomiting.

Vomiting, also called **emesis** (EM-eh-sis), is the expulsion of gastric (and sometimes intestinal) contents through the mouth by reverse peristalsis. The contraction of muscles in the abdominal wall forcibly empties the stomach. Vomiting is frequently caused by overeating or by inflammation of the stomach lining, a condition called **gastritis** (gas-TRI-tis). Gastritis results from irritation of the mucosa by certain drugs, food, or drinks. For example, the long-term use of aspirin, highly spiced foods, or alcohol can lead to gastritis. The nicotine in cigarettes can also cause gastritis.

Flatus (FLA-tus) usually refers to excessive amounts of air (gas) in the stomach or intestine. The resulting condition is referred to as **flatulence** (FLAT-u-lens). In some cases, a physician may need to insert a tube into the stomach or rectum to aid the patient in expelling flatus.

Stomach Cancer Although stomach cancer has become rare in the United States, it is common in many parts of the world, and it is an important disorder because of the high death rate associated with it. Men are more susceptible than women to stomach cancer. The tumor nearly always develops from the epithelial or mucosal lining of the stomach, and is often of the type called **adenocarcinoma** (ad-en-o-kar-sih-NO-mah). Sometimes, the victim has suffered from long-standing indigestion (discomfort after meals) but has failed to consult a physician until the cancer has metastasized (spread) to other organs, such as the liver or lymph nodes. Persistent indigestion is one of the important warning signs of cancer of the stomach.

Peptic Ulcer An ulcer is an area of the skin or mucous membrane in which the tissues are gradually destroyed. **Peptic ulcers** (named for the enzyme pepsin) occur in the mucous membrane of the esophagus, stomach, or duodenum (the first part of the small intestine) and are most common in people between the ages of 30 and 45 years. Peptic ulcers in the stomach are termed *gastric ulcers;* those in the duodenum are *duodenal* (du-o-DE-nal) *ulcers*.

Smoking cigarettes and taking aspirin or other antiinflammatory drugs are major causative factors. It also has been found that infection with a bacterium, *Helicobacter pylori*, is a factor in causing peptic ulcers. The organism is associated with inflammation of the stomach and duodenum, and most people with ulcers who have an *H. pylori* infection are cured when the organism is eliminated with antibiotics. Drugs that inhibit the secretion of stomach acids are often effective in treating peptic ulcers.

Pyloric Stenosis Normally, the stomach contents are moved through the pyloric sphincter within approximately 2 to 6 hours after eating. Some infants, however, most often boys, are born with an obstruction of the pyloric sphincter, a condition called **pyloric stenosis** (steh-NO-sis). Usually, surgery is required in these cases to modify the muscle, so that food can pass from the stomach into the duodenum.

Intestinal Disorders

Many intestinal disorders involve inflammation. **Appendicitis** (ah-pen-dih-SI-tis) is inflammation of the appendix, which may result from infection or obstruction. The cause of obstruction is usually a **fecalith** (FE-cah-lith), a hardened piece of fecal material. The first sign of acute appendicitis is usually abdominal pain, with loss of appetite and sometimes nausea or vomiting. Pain eventually localizes in the right lower quadrant of the abdomen. Laboratory blood tests show elevated leukocytes. Surgery (appendectomy) is required to remove an inflamed appendix. Untreated, it can rupture to spread infection into the peritoneal cavity.

Two similar diseases are included under the heading of **inflammatory bowel disease** (IBD): **Crohn** (krone) **disease** and **ulcerative colitis**. Both occur mainly in adolescents and young adults and cause similar symptoms of pain, diarrhea, weight loss, and rectal bleeding. Crohn disease usually involves inflammation of the distal part of the small intestine. It may be an autoimmune disease, which may in part be hereditary. Ulcerative colitis involves inflammation and ulceration of the colon, and usually the rectum.

Irritable bowel syndrome (IBS) is a common gastrointestinal disorder seen typically in young to middle-aged women. Symptoms include pain and constipation or diarrhea, or sometimes both conditions in alternation. In IBS, the intestine is overly sensitive to stimulation, often brought on by stress. Although the condition is chronic and causes much pain, frustration, and anxiety, it is not life-threatening and does not develop into more serious diseases of the bowel.

Difficulties with digestion or absorption may be due to **enteritis** (en-ter-I-tis), an intestinal inflammation. When both the stomach and the small intestine are involved, the disorder is called **gastroenteritis** (gas-tro-en-ter-I-tis). The symptoms of gastroenteritis include nausea, vomiting, and diarrhea as well as acute abdominal pain (colic). The disorder may be caused by a variety of pathogenic organisms, including viruses, bacteria, and protozoa. Chemical irritants, such as alcohol, certain drugs (*e.g.,* aspirin), and other toxins, have been known to cause this disorder as well.

Diverticula (di-ver-TIK-u-lah) are small pouches in the wall of the intestine, most commonly in the colon. A diet low in fiber contributes to the formation of large numbers of diverticula. Collection of waste and bacteria

in these sacs leads to **diverticulitis** (di-ver-tik-u-LI-tis), which is accompanied by pain and sometimes bleeding. There is no cure for diverticulitis; it is treated with diet, stool softeners, and drugs to reduce intestinal motility.

Checkpoint 19-18 What two diseases fall into the category of inflammatory bowel disease?

Diarrhea

Diarrhea is a symptom characterized by abnormally frequent watery bowel movements. The danger of diarrhea is dehydration and loss of salts, especially in infants. Diarrhea may result from excess activity of the colon, faulty absorption, or infection. Infections resulting in diarrhea include cholera, dysentery, and food poisoning. Tables 1 and 5 in Appendix 5 list some of the organisms causing these diseases. Such infections are often spread by poor sanitation and contaminated food, milk, or water. A stool examination may be required to establish the cause of diarrhea; examination may reveal the presence of pathogenic organisms, worm eggs, or blood.

Constipation

Millions of dollars are spent each year in an effort to remedy a condition called **constipation.** What is constipation? Many people erroneously think they are constipated if they go a day or more without having a bowel movement. Actually, what is normal varies greatly; one person may normally have a bowel movement only once every 2 or 3 days, whereas another may normally have more than one movement daily. The term *constipation* is also used to refer to hard stools or difficulty with defecation.

On the basis of its onset, constipation may be classified as acute or chronic. Acute constipation occurs suddenly and may be due to an intestinal obstruction, such as a tumor or diverticulitis. Extreme constipation is termed **obstipation** (ob-stih-PA-shun). Chronic constipation, in contrast, has a more gradual onset and may be divided into two groups:

- **Spastic constipation,** in which the intestinal musculature is overstimulated so that the canal becomes narrowed and the lumen (space) inside the intestine is not large enough to permit the passage of fecal material.
- **Flaccid** (FLAK-sid) **constipation,** which is characterized by a lazy, or **atonic** (ah-TON-ik), intestinal muscle. Elderly people and those on bed rest are particularly susceptible to this condition. Often, it results from repeated denial of the urge to defecate. Regular bowel habits, moderate exercise, an increase in the ingestion of vegetables and other bulky foods, and an increase in fluid may help people who have sluggish intestinal muscles.

People should avoid the chronic use of laxatives and enemas, which interfere with the natural defecation reflex. They may also alter electrolyte balance and result in fluid loss. The streams of fluid used in enemas may injure the intestinal lining by removing the normal protective mucus. In addition, enemas aggravate hemorrhoids. Enemas should be done only on the order of a physician, and sparingly.

Intestinal Obstruction

Intussusception (in-tuh-suh-SEP-shun) is the slipping of a part of the intestine into an adjacent part (Fig. 19-11). It occurs mainly in male infants in the ileocecal region. **Volvulus** (VOL-vu-lus) is a twisting of the intestine, usually the sigmoid colon. It may be a congenital malformation or the result of a foreign body. Both intussusception and volvulus can be fatal if not treated quickly. **Ileus** (IL-e-us) is an intestinal obstruction caused by lack of peristalsis or by muscle contraction. A physician can insert a tube to release intestinal material. **Hemorrhoids** (HEM-o-roydz) are varicose veins in the rectum. These enlarged veins may cause pain and bleeding and may eventually extend out through the rectum.

Cancer of the Colon and Rectum

Tumors of the colon and rectum are among the six most common types of cancer in the United States. These tumors are usually adenocarcinomas that arise from the mucosal lining. The occurrence of colon cancer is evenly divided between the

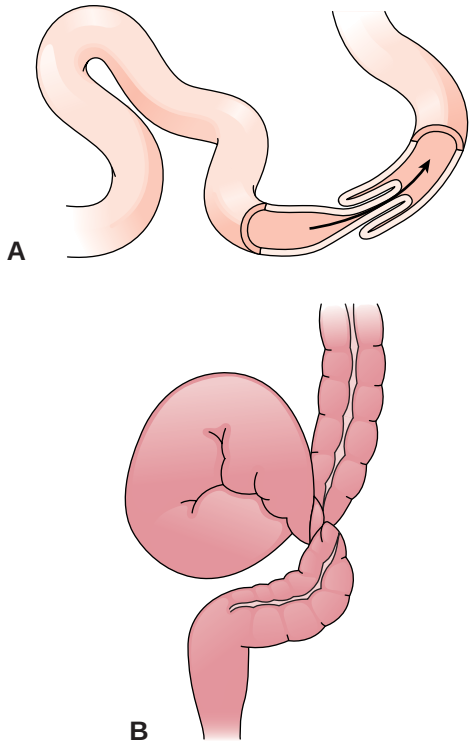


Figure 19-11 Intestinal obstructions. (**A**) Intussusception. A part of the intestine slips into an adjacent part. (**B**) Volvulus. A twisting of the intestine. (Modified with permission from Cohen BJ. Medical Terminology. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2004.)

sexes, but malignant tumors of the rectum are more common in men than in women.

Tumors may be detected by direct examination of the rectum and lower colon with an instrument called a **sigmoidoscope** (sig-MOY-do-skope) (named for the sigmoid colon). A **colonoscope** (ko-LON-o-skope) is used to examine deeper regions of the colon (see Box 19-3). The presence of blood in the stool may indicate cancer of the bowel or some other gastrointestinal disturbance. A simple chemical test can detect extremely small quantities of blood in the stool, referred to as *occult* ("hidden") *blood.* Early detection and treatment are the keys to increasing survival rates.

Infection of the Salivary Glands

The contagious disease commonly called *mumps* is a viral infection of the parotid salivary glands. This type of **parotitis** (par-o-TI-tis), or inflammation of the parotid glands, may lead to inflammation of the testicles by the same virus. Males affected after puberty are at risk for permanent damage to these sex organs, resulting in sterility. Another complication of mumps that occurs in about 10% of cases is meningitis. Mumps now can be prevented by childhood immunization with a vaccine (MMR).

Cirrhosis and Other Liver Diseases

Cirrhosis (sih-RO-sis) of the liver is a chronic disease in which active liver cells are replaced by inactive connective (scar) tissue. The most common type of cirrhosis is alcoholic (portal) cirrhosis. Alcohol has a direct damaging effect on liver cells that is compounded by malnutrition. Hepatic cell destruction hampers the portal circulation, causing blood to accumulate in the spleen and gastrointestinal tract and causing fluid (ascites) to accumulate in the peritoneal cavity.

Jaundice Damage to the liver or blockage in any of the bile ducts may cause bile pigment to accumulate in the blood. As a result, the stool may become pale in color and the skin and sclera of the eyes may become yellowish; this symptom is called **jaundice** (JAWN-dis) (from French *jaune* for "yellow"). Jaundice may also be caused by excess destruction of red blood cells. In addition, it is often seen in newborns, in whom the liver is immature and not yet functioning efficiently.

Hepatitis Inflammation of the liver, called **hepatitis** (hep-ah-TI-tis), may be caused by drugs, alcohol, or infection (see Table 2 in Appendix 5). The known viruses that cause hepatitis are named A through E. These vary in route (pathway) of infection, severity, and complications. All types of hepatitis are marked by hepatic cell destruction and such symptoms as loss of appetite, jaundice, and liver enlargement. In most patients, the liver cells regenerate with little residual damage. The types of hepatitis virus and their primary routes of transmission are as follows:

Hepatitis A (HAV)*:* commonly transmitted in fecal matter and contaminated food and water. There is a vaccine for hepatitis A, which is recommended for people traveling to areas where this disease is a threat.

Hepatitis B (HBV)*:* transmitted by exposure to the virus in blood or body fluids, although it also can be spread by fecal contamination. This is the most prevalent form of hepatitis. HBV and other blood-borne types of hepatitis virus (C and D) have been linked to long-term development of liver cancer. Also, people with these forms of hepatitis may develop into carriers, able to transmit the disease but not showing any symptoms. HBV is usually transmitted by use of improperly sterilized needles. A vaccine is available that is now recommended for childhood immunization and for people working in healthcare and childcare.

Hepatitis C (HCV)*:* transmitted primarily by exposure to infected blood. There is some evidence of limited sexual transmission. Clinical symptoms of hepatitis C may develop many years after exposure to the virus.

Hepatitis D (HDV)*:* transmitted by direct exchange of blood. It occurs only in those with hepatitis B infection.

19

Box 19-3 Clinical Perspectives

Endoscopy: A View From Within

Modern medicine has made great strides toward looking into the body without resorting to invasive surgery. An instrument that has made this possible in many cases is the **endoscope**, which is inserted into the body through an orifice or small incision and used to examine passageways, hollow organs, and body cavities. The first endoscopes were rigid lighted telescopes that could only be inserted a short distance into the body. Today, physicians are able to navigate the twists and turns of the digestive tract using long **fiberoptic endoscopes** composed of flexible bundles of glass or plastic that transmit light.

In the gastrointestinal tract, endoscopy can detect structural abnormalities, bleeding ulcers, inflammation, and tumors. In addition, endoscopes can be used to remove fluid samples or tissue biopsy specimens. Some surgery can even be done with an endoscope, such as polyp removal from the colon or expansion of a sphincter. Endoscopy can also be used to examine and operate on joints (arthroscopy), the bladder (cystoscopy), respiratory passages (bronchoscopy), and the abdominal cavity (laparoscopy).

Capsular endoscopy, a recent technological advance, has made examination of the gastrointestinal tract even easier. It uses a pill-sized camera that can be swallowed! As the camera moves through the digestive tract, it transmits video images to a data recorder worn on the patient's belt.

Hepatitis E (HEV): transmitted by fecal contamination of water. Most cases have been linked to epidemics in Asia, Africa, and Central America.

An additional related virus has been designated hepatitis G. It is similar in structure to HCV and is found in blood, but does not appear to cause hepatitis.

There is no specific treatment for hepatitis.

Cancer The metastasis (spread) of cancer to the liver is common in cases that begin as cancer in one of the abdominal organs; the tumor cells are carried in the blood through the portal system to the liver.

Checkpoint 19-19 What is hepatitis?

Gallstones

The most common disease of the gallbladder is the formation of stones, or **cholelithiasis** (ko-le-lih-THI-ah-sis). Stones are formed from the substances contained in bile, mainly cholesterol. They may remain in the gallbladder or may lodge in the bile ducts, causing extreme pain. Cholelithiasis is usually associated with inflammation of the gallbladder, or **cholecystitis** (ko-le-sis-TI-tis).

Pancreatitis

Because they are usually confined to proper channels, pancreatic enzymes do not damage body tissues. If the bile ducts become blocked, however, pancreatic enzymes back up into the pancreas. Also, in some cases of gastric inflammation from excess alcohol consumption or in gallbladder disease, irritation may extend to the pancreas and cause abnormal activation of the pancreatic enzymes. In either circumstance, the pancreas suffers destruction by its own juice, and the outcome can be fatal; this condition is known as **acute pancreatitis**.

Aging and the Digestive System

With age, receptors for taste and smell deteriorate, leading to a loss of appetite and decreased enjoyment of food. A decrease in saliva and poor gag reflex make swallowing more difficult. Tooth loss or poorly fitting dentures may make chewing food more difficult.

Activity of the digestive organs decreases. These changes can be seen in poor absorption of certain vitamins and poor protein digestion. Slowing of peristalsis in the large intestine and increased consumption of easily chewed, refined foods contribute to the common occurrence of constipation.

The tissues of the digestive system require constant replacement. Slowing of this process contributes to a variety of digestive disorders, including gastritis, ulcers, and diverticulosis. As with many body systems, tumors and cancer occur more frequently with age.

Summary

Medical terms are built from standardized word parts (prefixes, roots, and suffixes). Learning the meanings of these parts can help you remember words and interpret unfamiliar terms.

WORD PART	MEANING	EXAMPLE
Function and Design of the Digestive System		
ab-	away from	In *absorption*, digested materials are taken from the digestive tract into the circulation.
enter/o	intestine	The *mesentery* is the portion of the peritoneum around the intestine.
mes/o-	middle	The *mesocolon*, like the mesentery, comes from the middle layer of cells in the embryo, the mesoderm.
Organs of the Digestive Tract		
gastr/o	stomach	The *gastrointestinal* tract consists mainly of the stomach and intestine.
The Accessory Organs		
amyl/o	starch	The starch-digesting enzyme in saliva is salivary *amylase*.
lingu/o	tongue	The *sublingual* salivary glands are under the tongue.
hepat/o	liver	The *hepatic* portal system carries blood to the liver.
bil/i	bile	*Bilirubin* is a pigment found in bile.
cyst/o	bladder, sac	The *cystic* duct carries bile into and out of the gallbladder.
Control of Digestion		
chole	bile, gall	*Cholecystokinin* is a hormone that activates the gallbladder (cholecyst/o).

WORD PART	MEANING	EXAMPLE
Disorders of the Digestive System		
odont/o	tooth	*Periodontitis* is a disease of the gums and the tissue around a tooth.
-lith	stone	A *fecalith* is a hardened piece of fecal material.
-rhea (the *r* is doubled when added to a word)	flow, discharge	*Diarrhea* is flow of watery bowel movments through (dia-) the digestive tract.

Summary

I. Function and design of the digestive system

A. Functions—digestion, absorption elimination
B. Two groups of organs—digestive tract and accessory organs
   1. The wall of the digestive tract—mucous membrane (mucosa), submucosa, smooth muscle, serous membrane (serosa)
   2. The peritoneum
C. Serous membrane that lines the abdominal cavity and folds over organs
D. Divisions—mesentery, mesocolon, greater omentum, lesser omentum

II. Organs of the digestive tract

A. Mouth
   1. Functions
      a. Ingest food
      b. Begin digestion of starch with salivary amylase
      c. Mastication (chewing)
      d. Deglutition (swallowing)
   2. Tongue—aids mastication and deglutition; has taste buds
   3. Teeth
      a. Deciduous (baby) teeth—20 (incisors, canines, molars)
      b. Permanent teeth—32 (incisors, canines, premolars, molars)
B. Pharynx (throat)—moves bolus (portion) of food into esophagus by reflex swallowing
C. Esophagus—long muscular tube that carries food to stomach by peristalsis
D. Stomach
   1. Functions
      a. Storage of food
      b. Breakdown of food by churning to form chyme
      c. Breakdown of protein with hydrochloric acid (HCl)
      d. Digestion of protein with enzyme pepsin
E. Small intestine
   1. Functions
      a. Digestion of food
      b. Absorption of nutrients and water through villi (small projections of intestinal lining)
   2. Divisions—duodenum, jejunum, ileum
F. Large intestine
   1. Functions
      a. Storage and elimination of waste (defecation)
      b. Reabsorption of water
   2. Divisions—cecum; ascending, transverse, descending, and sigmoid colons; rectum; anus

III. Accessory organs

A. Salivary glands—secrete saliva
   1. Functions of saliva
      a. Moistening food—aids chewing and swallowing
      b. Cleaning of mouth and teeth
      c. Digestion of starch with amylase
   2. Three pairs—parotid, submandibular, sublingual
B. Liver
   1. Functions
      a. Manufacture of bile—emulsifies fats
      b. Storage of glucose
      c. Modification of fats
      d. Storage of vitamins and iron
      e. Formation of blood plasma proteins
      f. Destruction of old red blood cells
      g. Synthesis of urea—waste product of proteins
      h. Detoxification of harmful substances
C. Gallbladder
   1. Stores bile until needed for digestion
D. Pancreas
   1. Secretes powerful digestive juice
   2. Secretes alkali (base) to neutralize chyme

IV. Enzymes and the digestive process

A. Enzymes—catalysts that speed reactions
   1. Products of digestion
      a. Simple sugars (monosaccharides) from carbohydrates
      b. Peptides and amino acids from proteins
      c. Glycerol and fatty acids from fats
B. The role of water
   1. Used to split foods (hydrolysis)
   2. Lubricates and dilutes food
C. Digestion, step-by-step
   1. Mouth—starch
   2. Stomach—protein
   3. Small intestine—remainder of food

V. Absorption—movement of nutrients into the circulation

A. Nutrients and water from small intestine into blood
B. Most fats into lymph through lacteals

VI. Control of digestion

A. Nervous control
   1. Parasympathetic system—generally increases activity
   2. Sympathetic system—generally decreases activity
B. Hormonal control
   1. Stimulation of digestive activity
   2. Feedback to inhibit stomach activity

3. Examples—gastrin, GIP, secretin, CCK

C. Hunger and appetite

D. Eating disorders- e.g. anorexia, bulimia

VII. Disorders of the digestive system

A. Peritonitis

B. Diseases of the mouth and teeth—caries, gingivitis, periodontitis, Vincent disease, leukoplakia

C. Disorders involving the esophagus and stomach
1. Hiatal hernia—protrusion of organ through diaphragm
2. Gastroesophageal reflux disease (GERD)
3. Nausea, vomiting (emesis)
4. Cancer
5. Ulcer—peptic ulcer in esophagus, stomach or duodenum
6. Pyloric stenosis

D. Intestinal disorders
1. Inflammatory diseases—appendicitis, Crohn disease, ulcerative colitis, irritable bowel syndrome (IBS), diverticulitis
2. Diarrhea
3. Constipation
4. Obstruction—intussuception, volvulus, ileus, hemorrhoids
5. Cancer

E. Infection of the salivary glands
1. Mumps—viral infection of parotid salivary gland

F. Diseases of the liver
1. Cirrhosis
2. Jaundice—yellow color due to bile pigments in blood
3. Hepatitis—viruses A to E
4. Cancer

G. Gallstone- cholelithiasis

H. Pancreatitis

VIII. Aging and the digestive system

Questions for Study and Review

Building Understanding

Fill in the blanks

1. The wave-like movement of the digestive tract wall is called _____.
2. The small intestine is connected to the posterior abdominal wall by _____.
3. The liver can store glucose in the form of _____.
4. The parotid glands secrete _____.
5. Inflammation of the gallbladder is termed _____.

Matching

Match each numbered item with the most closely related lettered item.

___ 6. Digests starch
___ 7. Begins protein digestion
___ 8. Digests fats
___ 9. Digests protein to amino acids
___ 10. Emulsify fats

a. lipase
b. amylase
c. trypsin
d. pepsin
e. bile salts

Multiple choice

___ 11. The teeth break up food into small parts by a process called
a. absorption
b. deglutition
c. ingestion
d. mastication

___ 12. Hydrochloric acid and pepsin are secreted by the
a. salivary glands
b. stomach
c. pancreas
d. liver

___ 13. The double layer of peritoneum that extends from the lower border of the stomach and hangs over the intestine is the
a. greater omentum
b. lesser omentum
c. mesentery
d. mesocolon

___ 14. The soft, fleshy V-shaped mass of tissue that hangs from the soft palate is the
a. epiglottis
b. esophageal hiatus
c. uvula
d. gingiva

___ 15. Thickened white patches on the oral mucous membranes characterizes the disorder called
a. peridontitis
b. cholelithiasis
c. pancreatitis
d. leukoplakia

Understanding Concepts

16. Differentiate between the terms in each of the following pairs:
a. digestion and absorption
b. parietal and visceral peritoneum
c. gastrin and gastric-inhibitory peptide
d. secretin and cholecystokinin

17. Name the four layers of the digestive tract. What tissue makes up each layer? What is the function of each layer?
18. Trace the path of a bolus of food through the digestive system.
19. Describe the structure and function of the liver, pancreas, and gallbladder. How are the products of these organs delivered to the digestive tract?
20. Where does absorption occur in the digestive tract, and what structures are needed for absorption? What types of nutrients are absorbed into the blood? Into the lymph?
21. Name several hormones that regulate digestion.
22. Compare and contrast the following disorders:
    a. anorexia and bulimia
    b. inflammatory bowel disease and irritable bowel syndrome
    c. intussusception and volvulus
23. What are the causes and effects of hepatitis?

Conceptual Thinking

24. Why should a person who suffers from peptic ulcers avoid the use of aspirin (acetylsalicylic acid)?
25. Cholelithiasis can cause pancreatitis. Why?