Activities Occurring in the Mouth, Pharynx, and Esophagus

Food Ingestion and Breakdown

Once food has been placed in the mouth, both mechanical and chemical digestion begin. First the food is *physically* broken down into smaller particles by chewing. Then, as the food is mixed with saliva, salivary amylase begins the *chemical* digestion of starch, breaking it down into maltose (Figure 14.13). The next time you eat a piece of bread, chew it for a few minutes before swallowing it. You will notice that it begins to taste sweet as the sugars are released.

Saliva is normally secreted continuously to keep the mouth moist; but, when food enters the mouth, much larger amounts of saliva pour out. However, the simple pressure of anything put in the mouth and chewed, such as rubber bands or sugarless gum, will also stimulate the release of saliva. Some emotional stimuli can also cause salivation. For example, the mere thought of a hot fudge sundae will make many a mouth water. All these reflexes, though initiated by different stimuli, are brought about by parasympathetic fibers in cranial nerves V and IX.

Essentially no food absorption occurs in the mouth. (However, some drugs such as nitroglycerine are absorbed easily through the oral mucosa.) The pharynx and esophagus have no digestive function; they simply provide passageways to carry food to the next processing site, the stomach.

Food Propulsion—Swallowing and Peristalsis

In order for food to be sent on its way from the mouth, it must first be swallowed. **Deglutition** (deg″loo-tish′un), or **swallowing,** is a complicated process that involves the coordinated activity of several structures (tongue, soft palate, pharynx, and esophagus). It has two major phases. The first phase, the voluntary **buccal phase,** occurs in the mouth. Once the food has been chewed and well mixed with saliva, the bolus (food mass) is forced into the pharynx by the tongue. As food enters the pharynx, it passes out of our control and into the realm of reflex activity.

The second phase, the involuntary **pharyngeal-esophageal phase,** transports food through the pharynx and esophagus. The parasympathetic division of the autonomic nervous system (primarily the vagus nerves) controls this phase and promotes the mobility of the digestive organs from this point on. All routes that the food might take except the desired route distal into the digestive tract are blocked off. The tongue blocks off the mouth, and the soft palate closes off the nasal passages. The larynx rises so that its opening (into the respiratory passageways) is covered by the flaplike epiglottis. Food is moved through the pharynx and then into the esophagus below by wavelike peristaltic contractions of their muscular walls—first the longitudinal muscles contract, and then the circular muscles contract. The events of the swallowing process are illustrated in Figure 14.14.

If we try to talk while swallowing, our routing mechanisms may be "short-circuited," and food may manage to enter the respiratory passages. This triggers still another protective reflex—coughing—during which air rushes upward from the lungs in an attempt to expel the food.

Once food reaches the distal end of the esophagus, it presses against the cardioesophageal sphincter, causing it to open, and the food enters the stomach. The movement of food through the pharynx and esophagus is so automatic that a person can swallow and food will reach the stomach even if he is standing on his head. Gravity plays no part in the transport of food once it has left the mouth, which explains why astronauts (in the zero gravity of outer space) can still swallow and get nourishment.

Activities of the Stomach

Food Breakdown

Secretion of **gastric juice** is regulated by both neural and hormonal factors. The sight, smell, and taste of food stimulate parasympathetic nervous system reflexes, which increase the secretion of gastric juice by the stomach glands. In addition, the presence of food and a falling pH in the stomach stimulate the stomach cells to release the hormone **gastrin.** Gastrin prods the stomach glands to produce still more of the protein-digesting enzymes (pepsinogens), mucus, and hydrochloric acid. Under normal conditions, 2 to 3 liters of gastric juice are produced every day.

Hydrochloric acid makes the stomach contents very acid. This is (somewhat) dangerous since both hydrochloric acid and the protein-digesting enzymes have the ability to digest the stomach itself, causing *ulcers* (see the "A Closer Look" box on pp. 472–473). However, as long as enough mucus is made, the stomach is "safe" and will remain unharmed.

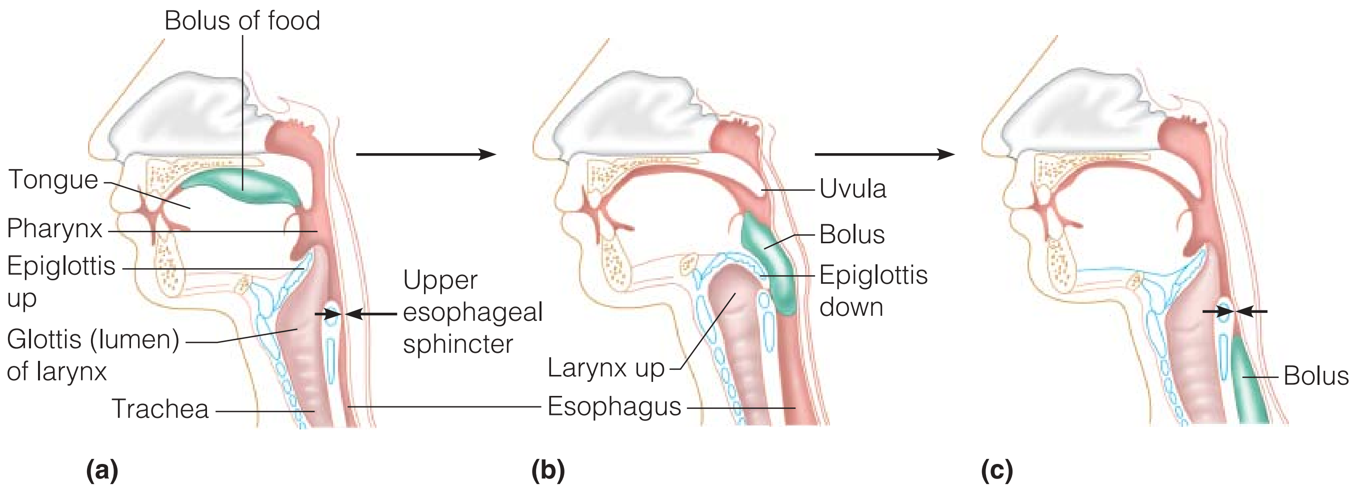

FIGURE 14.14 **Swallowing. (a)** The tongue pushes the food bolus posteriorly and against the soft palate. **(b)** The soft palate rises to close off the nasal passages as the bolus enters the pharynx. The larynx rises so that the epiglottis covers its opening as peristalsis carries the food through the pharynx and into the esophagus. The upper esophageal sphincter relaxes to allow food entry. **(c)** The upper esophageal sphincter contracts again as the larynx and epiglottis return to their former positions and the food bolus moves inferiorly to the stomach.

Homeostatic Imbalance

Occasionally, the cardioesophageal sphincter fails to close tightly and gastric juice backs up into the esophagus, which has little mucus protection. This results in a characteristic pain known as *heartburn,* which, if uncorrected, leads to inflammation of the esophagus (*esophagitis* [ĕ-sof′ah-ji′tis]) and perhaps even to ulceration of the esophagus. A common cause is a *hiatal hernia,* a structural abnormality in which the superior part of the stomach protrudes slightly above the diaphragm. Since the diaphragm no longer reinforces the cardioesophageal sphincter, which is a weak sphincter to begin with, gastric juice flows into the unprotected esophagus. Conservative treatment involves restricting food intake after the evening meal, taking antacids, and sleeping with the head elevated. ▲

The extremely acidic environment that hydrochloric acid provides *is* necessary, because it activates *pepsinogen* to *pepsin,* the active protein-digesting enzyme. *Rennin,* the second protein-digesting enzyme produced by the stomach, works primarily on milk protein and converts it to a substance that looks like sour milk. Many mothers mistakenly think that when their infants spit up a curdy substance after having their bottle that the milk has soured in their stomach. Rennin is produced in large amounts in infants, but it is not believed to be produced in adults.

Other than the beginning of protein digestion, little chemical digestion occurs in the stomach. With the exception of aspirin and alcohol (which seem somehow to have a “special pass”), virtually no absorption occurs through the stomach walls.

As food enters and fills the stomach, its wall begins to stretch (at the same time the gastric juices are being secreted, as just described). Then the three muscle layers of the stomach wall become active. They compress and pummel the food, breaking it apart physically, all the while continually mixing the food with the enzyme-containing gastric juice so that the semifluid chyme is formed. The process looks something like the preparation of a cake mix, in which the floury mixture is continually folded on itself and mixed with the liquid until it reaches uniform texture.

Food Propulsion

Once the food has been well mixed, a rippling peristalsis begins in the lower half of the stomach, and the contractions increase in force as the pyloric valve is approached. The pylorus of the stomach, which holds about 30 ml of chyme, acts

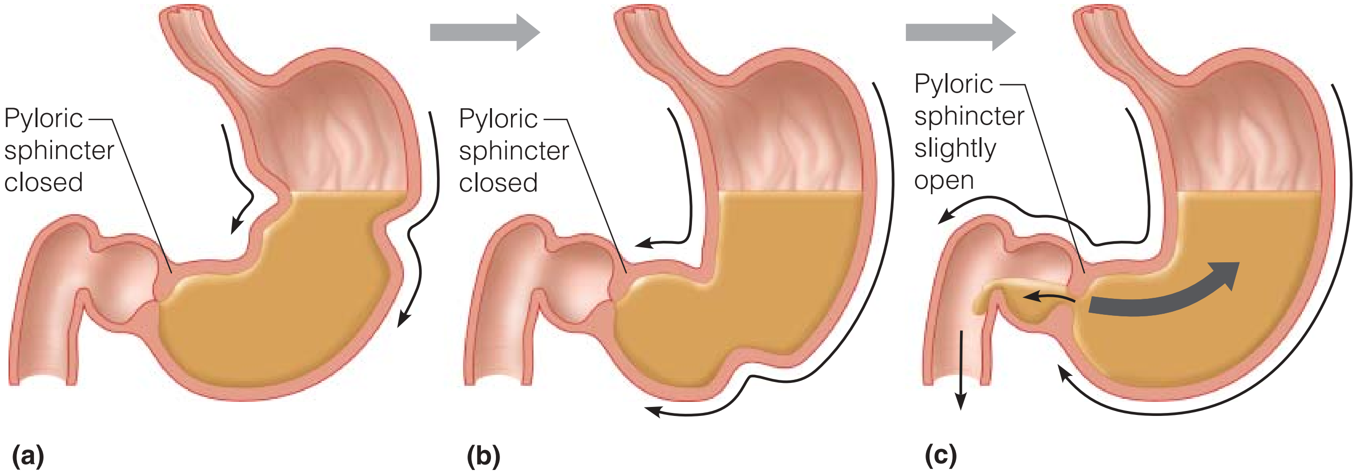

FIGURE 14.15 Peristaltic waves act primarily in the inferior portion of the stomach to mix and move chyme through the pyloric valve. **(a)** Peristaltic waves move toward the pylorus. **(b)** The most vigorous peristalsis and mixing action occurs close to the pylorus. **(c)** The pyloric end of the stomach acts as a pump that delivers small amounts of chyme into the duodenum while forcing most of the contained material backward into the stomach, where it undergoes further mixing.

like a meter that allows only liquids and very small particles to pass through the pyloric sphincter (Figure 14.15). Because the pyloric sphincter barely opens, each contraction of the stomach muscle squirts 3 ml or less of chyme into the small intestine. Since the contraction also *closes* the valve, the rest (about 27 ml) is propelled backward into the stomach for more mixing. When the duodenum is filled with chyme and its wall is stretched, a nervous reflex, the *enterogastric* (en″ter-o-gas′trik) *reflex,* occurs. This reflex “puts the brakes on” gastric activity and slows the emptying of the stomach by inhibiting the vagus nerves and tightening the pyloric sphincter, thus allowing time for intestinal processing to catch up. Generally, it takes about 4 hours for the stomach to empty completely after eating a well-balanced meal and 6 hours or more if the meal has a high fat content.

Homeostatic Imbalance

Local irritation of the stomach, such as occurs with bacterial food poisoning, may activate the *emetic* (ĕ-met′ik) *center* in the brain (medulla). The emetic center, in turn, causes **vomiting (emesis).** Vomiting is essentially a reverse peristalsis occurring in the stomach (and perhaps the small intestine), accompanied by contraction of the abdominal muscles and the diaphragm, which increases the pressure on the abdominal organs. The emetic center may also be activated through other pathways; disturbance of the equilibrium apparatus of the inner ear during a boat ride on rough water is one example.

Activities of the Small Intestine

Food Breakdown and Absorption

Food reaching the small intestine is only partially digested. Carbohydrate and protein digestion have been started, but virtually no fats have been digested up to this point. Here the process of chemical food digestion is accelerated as the food now takes a rather wild 3- to 6-hour journey through the looping coils and twists of the small intestine. By the time the food reaches the end of the small intestine, digestion is complete and nearly all food absorption has occurred.

The microvilli of small intestine cells bear a few important enzymes, the so-called **brush border enzymes** that break down double sugars into simple sugars and complete protein digestion (see Figure 14.13). *Intestinal juice* itself is relatively enzyme-poor, and protective mucus is probably the most important intestinal gland secretion. However, foods entering the small intestine are literally deluged with enzyme-rich **pancreatic**