

Digestion in the Mouth and Stomach

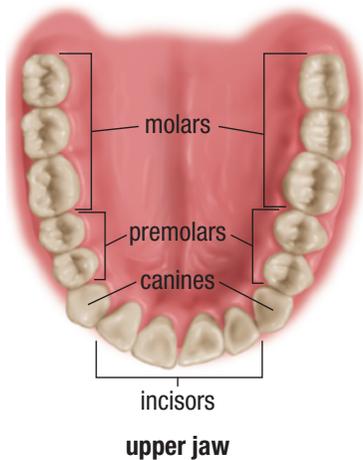


Figure 1 Human teeth are specialized for certain functions.

enzyme any chemical produced by cells that facilitates biochemical reactions in the body, such as those involved in digestion and metabolism; all enzymes are proteins

amylase an enzyme that breaks down complex carbohydrates

mucus a protective secretion produced by the epithelial cells that form the mucous membrane

LEARNING TIP

Secrete and Secretion

The word “secrete” means to produce and release a chemical substance from a cell or a gland.

The word “secretion” refers to the process of secreting, but can also refer to the substance that is produced. Secretions usually have a specific function.

Imagine working on a reverse assembly line. Instead of putting parts together to create something, the task is to break an object down into its component parts. The digestive system is similar to this “disassembly line.” Various specialized locations along the gastrointestinal tract work to break food down physically and chemically. In this section, we will look at the digestive processes that take place in the mouth and stomach. You will learn about the rest of the gastrointestinal tract, specifically the intestines, in the next section.

Physical and Chemical Digestion in the Mouth

In humans, digestion begins in the mouth. Food is broken down into smaller pieces by the teeth (physical digestion). Teeth in the front of your mouth, called incisors and canines, are specialized for grabbing and cutting your food. Behind these teeth are premolars and molars—broad flattened teeth specialized for grinding and crushing food (Figure 1). The type of teeth an animal has is directly related to its diet. For example, mammalian herbivores have many molars for chewing plant matter, whereas mammalian carnivores have canine teeth that allow them to grab and kill prey.

The presence of food in the mouth and, often, simply the sight or smell of food, triggers the salivary glands to secrete a watery fluid called saliva. Saliva contains **enzymes**—chemicals that increase the rate of chemical reactions in living things. One enzyme found in saliva is **amylase**, which breaks down starch into smaller disaccharides (chemical digestion). Saliva also dissolves food particles, making it possible for you to taste food. Saliva contains **mucus**, a protective secretion that acts as a lubricant and aids in swallowing. On average, you produce 0.75 L to 1.5 L of saliva per day. Most of this saliva is water, which moistens the food into a ball, or *bolus*, so that it can be swallowed.

Once food has been chewed and mixed with saliva in the mouth, the tongue pushes it to the back of the mouth where it is swallowed (Figure 2(a)). As the food is pushed into the pharynx, the soft palate is raised to prevent food from entering the nasal passages. At the same time, the larynx is raised against a flap of soft tissue called the epiglottis. This covers the entrance to the trachea to prevent food from entering the lungs (Figure 2(b)). (If you place your finger on the outside of your neck over your larynx as you swallow, you will feel the larynx rise.) This process of taking food into the body through the mouth (by swallowing) is called ingestion.

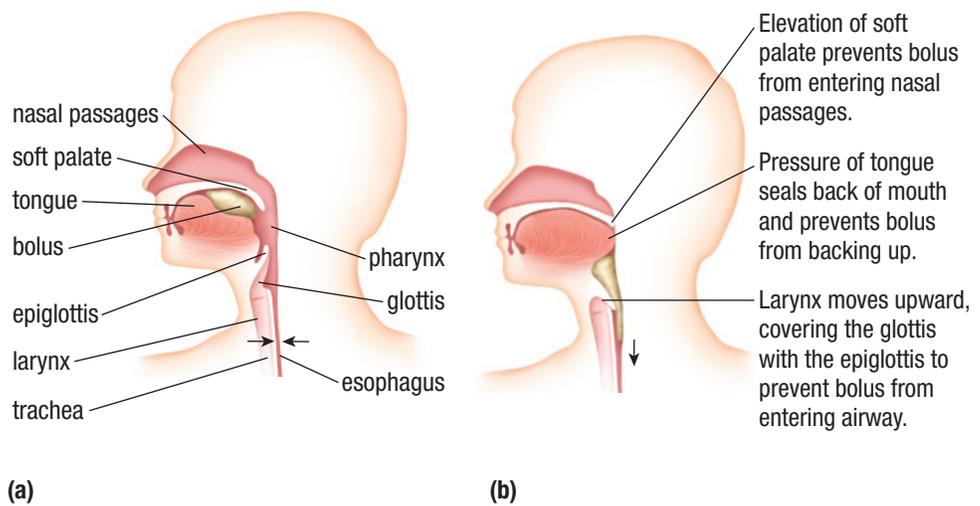


Figure 2 (a) Structures of the mouth, pharynx, and esophagus involved in the swallowing reflex (b) Motions that seal the nasal passages, mouth, and trachea during the swallowing reflex

Once swallowed, food moves from the mouth to the stomach by way of the esophagus. The **esophagus** is a long, muscular tube that carries food from the pharynx to the stomach. The food stretches the walls of the esophagus, activating the smooth muscles to undergo rhythmic, wave-like contractions called **peristalsis** (Figure 3). Peristalsis ensures the movement of food down the esophagus and into the stomach. It takes about 8 s for food to travel down the esophagus into the stomach. Although gravity helps, it is peristalsis that ensures the movement of food down through the esophagus to the stomach and through the entire digestive system. If you were to stand on your head, you would still be able to swallow liquids!

The Structure of the Stomach

The stomach is a J-shaped, muscular organ that continues the mechanical and chemical digestion that started in the mouth. The stomach can expand in size to store up to 2 L of food. Proteins are partly digested in the stomach and continue digesting in the small intestine. Lipids and carbohydrates are not digested in the stomach.

The movement of food into and out of the stomach is controlled by circular muscles called **sphincters**. There are more than 50 sphincters in the human body, and several of these are in the digestive tract. The gastroesophageal sphincter is located where the esophagus joins the stomach (Figure 4). When relaxed, the gastroesophageal sphincter allows food to enter the stomach. When contracted, it prevents food from moving back into the esophagus.

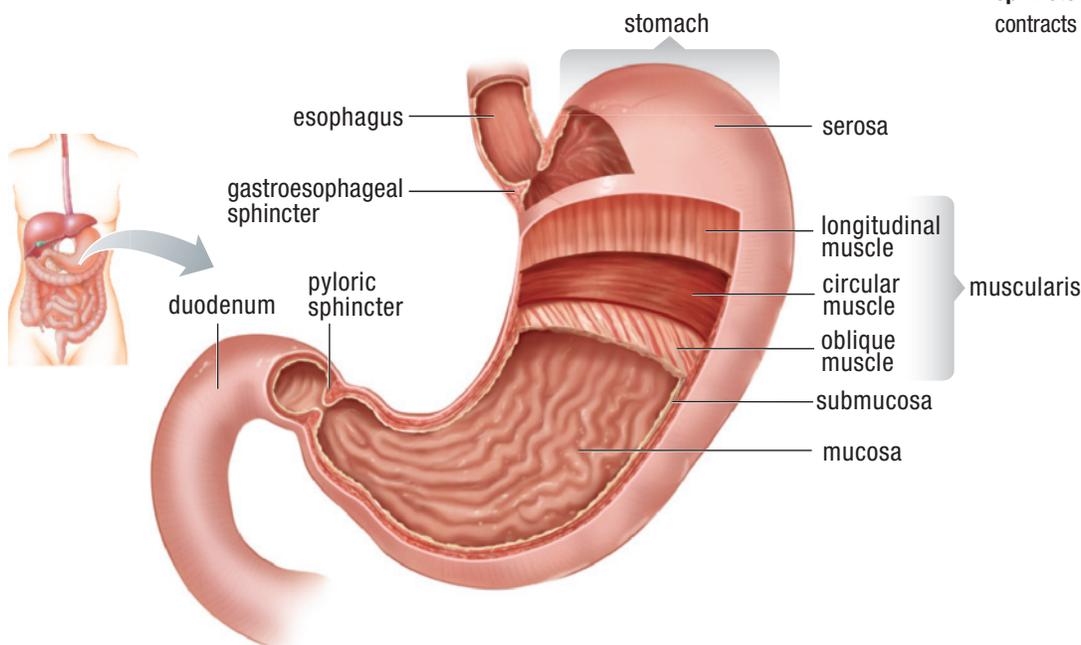


Figure 4 The stomach is a muscular, J-shaped organ. A sphincter muscle at either end controls the movement of food in and out of the stomach.

The stomach has four layers, each of which has a special structure and function (Figure 4). The innermost layer is an extensively folded layer called the mucosa. The mucosa secretes gastric juice, which is a mixture of digestive enzymes, acid, and mucus. The epithelial cells in the mucosa divide rapidly to heal any damage. In fact, the entire stomach lining is replaced about every three days! The next layer is the submucosa—a layer of connective tissue that contains networks of nerves and blood vessels. The third layer, called the muscularis, or muscle layer, consists of smooth muscles. These muscles contract frequently, churning and mixing the food with gastric juices to produce a semi-liquid material called **chyme**. The smooth, outermost layer of the stomach, called the serosa, holds the stomach in place and secretes a lubricating fluid that eliminates friction between organs.

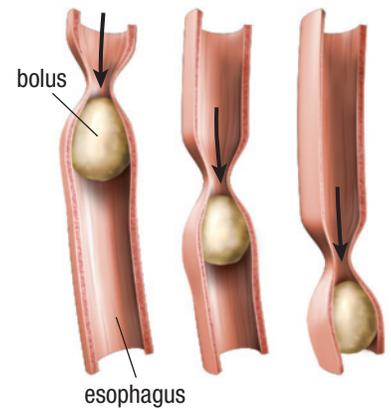


Figure 3 Peristalsis ensures that food is kept moving through the digestive system.

esophagus an organ consisting of a muscular tube that passes food from the pharynx to the stomach

peristalsis the rhythmic, involuntary wave-like contractions of the smooth muscles of the gastrointestinal tract

sphincter the circular muscle that contracts to close an opening in the body

chyme a semi-liquid mixture of food and gastric juice

Chemical Digestion in the Stomach

gastrin a hormone that stimulates the release of hydrochloric acid and pepsinogen in the stomach

pepsin a protein-digesting enzyme produced in the stomach

The process of digestion is a carefully controlled and coordinated process that involves enzymes, hormones, and nerves. The nerves in the submucosa detect when food is present and initiate the release of a hormone called gastrin. **Gastrin** is released into the bloodstream and transported to gastric cells in the stomach, where it stimulates the release of gastric juice. Each gastric gland secretes only a tiny amount of gastric juice, but since there are millions of glands, the total amount of gastric juice produced is up to 2 L per day. Gastric juice is mostly made up of mucus, but also contains acid and digestive enzymes. The mucus, a slippery secretion, coats and protects the lining of the stomach from acid and digestive enzymes.

The acid present in gastric juice is very strong; it normally ranges from pH 2.0 to pH 3.0. In comparison, lemon juice is pH 2.4 and battery acid is pH 1.0. The acidic gastric juice kills many harmful micro-organisms that are ingested with food. It stops the action of amylase but provides the necessary pH for the activation of other digestive enzymes, such as pepsinogen. The hydrochloric acid present in gastric juice converts pepsinogen to its active form, **pepsin**, which begins the breakdown of proteins into separate amino acids. Secreting the inactive enzyme pepsinogen is a safety mechanism that prevents damage to the stomach tissue. If gastric glands were to make pepsin instead of pepsinogen, the stomach would digest itself.

Nerve endings in the lining of the stomach are stimulated when food enters the stomach and stretches the lining walls. When this happens, the nerves release signals that cause an increase in muscular contractions, which mixes the food with gastric juice.

Acid Reflux

If the gastroesophageal sphincter does not close completely, acid from the stomach can enter the esophagus. This causes a burning sensation in the lower throat that we know as heartburn, or acid reflux. An overfilled stomach can force some of the acidic stomach contents back up into the esophagus. Smoking can also be a significant contributing factor because it relaxes the gastroesophageal sphincter and stimulates acid production in the stomach.

Stomach Ulcers

Stomach acid is strong enough to kill most bacteria that enter the stomach. However, one species of bacteria, *Helicobacter pylori* (commonly known as *H. pylori*), is able to survive by secreting acid-neutralizing enzymes and by burrowing through the mucosa. These bacteria prevent mucus-producing cells from producing enough mucus to protect the stomach lining. When the lining is exposed to the strong stomach acid, an open sore, called an **ulcer**, can develop (**Figure 5**). Ulcers can bleed and can be quite painful. Bleeding ulcers can also be quite dangerous because the bacteria can enter the bloodstream and produce an infection throughout the body.

H. pylori may be transmitted through food or water, but the bacteria have also been found in the saliva of people with ulcers. *H. pylori* is usually successfully eliminated with antibiotics.

A CURE FOR ULCERS

Until the 1980s, the medical community believed that ulcers were caused by stress and diet. Dr. Robin Warren, an Australian doctor, was puzzled by the discovery of bacteria (later named *Helicobacter pylori*) in the stomachs of patients who were suffering from ulcers. A colleague of Dr. Warren's, Dr. Barry Marshall, was fascinated by this discovery and decided to conduct further research. He was convinced that there was a connection between the bacteria and ulcers. To test this connection, he drank a solution containing *H. pylori* bacteria and developed the same symptoms exhibited by ulcer patients. This earned him the nickname "the guinea pig doctor." He successfully treated himself with antibiotics. 🌐

ulcer a lesion or open sore on the epithelium of an organ

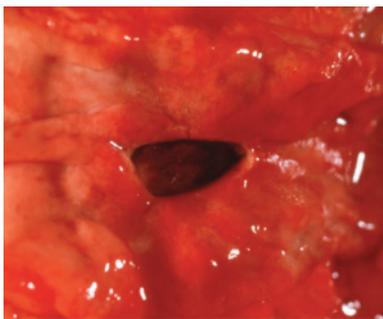


Figure 5 A break in the mucosal layer can result in an ulcer.

CAREER LINK

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Dr. Marshall presented his ideas at medical conferences and in publications. Unfortunately, the established ideas about the causes and treatments for ulcers and other stomach ailments were very resistant to change. Looking back on his fight to have his research accepted, Dr. Marshall said, “To gastroenterologists, the concept of a germ causing ulcers was like saying that the Earth is flat.” When he challenged the medical community to prove him wrong, experiments designed to refute his hypothesis actually confirmed it. By the mid-1990s, Dr. Marshall’s persistence paid off and his hypothesis was generally accepted. Dr. Marshall and Dr. Warren were awarded the Nobel Prize in Medicine in 2005 (**Figure 6**). Antibiotic treatment of most ulcers is now the standard practice worldwide.



Figure 6 Dr. Robin Warren, left, and Dr. Barry Marshall, nicknamed “the guinea pig doctor,” changed our understanding of the causes and treatments of ulcers.

9.4 Summary

- The act of swallowing moves the chewed food from the mouth, through the esophagus, where wave-like contractions, called peristalsis, move the food to the stomach.
- The process of digestion starts in the mouth, with the physical breakdown of food by the teeth. Chemical digestion also starts in the mouth, with the action of amylase, an enzyme found in saliva.
- The stomach is an organ where food is temporarily stored and chemical digestion continues.
- Gastric juice provides the necessary acidic environment for enzymes to function. It also kills most of the bacteria or other micro-organisms that enter the stomach.
- Mucus present in gastric juice helps protect the stomach from acid damage.
- Gastrin is the major hormone that regulates acid secretion in the stomach.
- Pepsinogen is secreted in the stomach and is converted to pepsin, a protein-digesting enzyme, when exposed to the acid present in gastric juice.
- An ulcer is an open sore in the lining of the stomach caused by the presence of *H. pylori* bacteria in the stomach.

9.4 Questions

1. The trachea and the esophagus are located side by side. What mechanisms prevent food from entering the trachea and the lungs when swallowing? **K/U**
2. Explain the mechanism that moves food through the gastrointestinal tract. **K/U**
3. What is the role of the stomach in digestion? Describe how the structure of the stomach relates to its function. **K/U A**
4. Strong acids can dissolve or chemically burn living matter. Why is the stomach tissue not damaged by stomach acid? Describe the mechanism by which the stomach lining is protected from the very acidic gastric juice. **K/U A**
5. Pepsinogen is sometimes referred to as a pre-enzyme because it is the inactive form of the enzyme pepsin. Why is it necessary to have a pre-enzyme? **K/U A**
6. A cheaper but tougher cut of steak can be made more enjoyable by the process of “tenderizing.” Use the Internet and other sources to find methods of tenderizing meat. **T/I A**
 - (a) Explain the process of meat tenderizing.
 - (b) What are the natural sources of chemical tenderizers?
 - (c) How is the process of meat tenderizing similar to digestion?
7. (a) What does the Marshall/Warren story tell us about the nature of science?
(b) Why might the medical or scientific community be reluctant to accept new ideas? **K/U A**
8. Use the Internet and other sources to research stomach stapling and gastric banding. Write a brief report explaining why these procedures are used, how they work, and what the associated risks and benefits are. **T/I C**
9. Ruminants are mammals that have a specialized stomach adapted for digesting plant material. Use the Internet and other sources to find information to help you answer the following questions: **T/I C**
 - (a) Give three examples of ruminant animals.
 - (b) Name the four compartments of the stomach of ruminants. Briefly explain the function of each.
 - (c) How is the specialized stomach of the ruminant adapted to digesting plant material?
 - (d) What does the word *ruminant* mean in everyday language?



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