21B—The Digestive System

Knowledge of human digestive processes was very limited until 1833. In that year William Beaumont published the results of the experiments that he had conducted on Alexis St. Martin, whose stomach and body wall had been accidentally perforated by a musket shot. Even after surgical repair and healing, the opening through the body wall and stomach persisted. Beaumont attempted to close it but failed.

Beaumont was able to conduct numerous experiments by inserting food (tied to a string) into the valvelike opening of St. Martin's stomach. Beaumont would then remove the food to determine the extent and speed of digestion. The permanent opening also allowed observation of the churning action of the stomach. Since 1833, scientists have learned much more about the functions of the digestive organs.

Beaumont and St. Martin by Dean Cornwell; Reproduced with permission of Wyeth Pharmaceuticals

21B.1
U.S. Army surgeon William Beaumont (1785–1853) was one of the first researchers to study the physiology of digestion.

21B-1 Organs of the Digestive System

21B-1 Objectives

- Describe the functions of the digestive system
- Summarize the functions of each digestive system organ

The organs of the digestive system provide a means for **ingestion** (food intake) and provide structures and enzymes for **digestion** (breakdown of food to soluble substances). They also allow **absorption** of soluble food molecules into the bloodstream. While the foods are utilized for growth and repair, the large intestine is involved in **egestion** (elimination of undigested, unabsorbed material). Muscle tissue in the walls of the digestive system moves the food material along while these functions are being performed.

The organs for digestion are usually divided into the following two groups:

- **Alimentary*** (AL uh MEN tuh ree) **canal** includes the mouth, pharynx, esophagus, stomach, small intestine, and large intestine.
- **Accessory organs** include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

The alimentary canal, or *gastrointestinal** (GAS troh in TES tuh nul) tract, is a continuous tube extending from mouth to anus, measuring about 9 m (29 ft). The walls that form the organs of the alimentary canal are typically composed of four layers. Certain areas of the canal are specialized for particular functions and the layers are somewhat modified in those places, but all four layers are present. Starting from the inside of the canal, the layers are as follows:

✦ *Mucosa, or mucous membrane.* This layer is formed by epithelium and comes into direct contact with food as it passes through the canal. This membrane secretes mucus that protects and lubricates the lining and has many modifications to perform various functions in different areas of the alimentary canal.

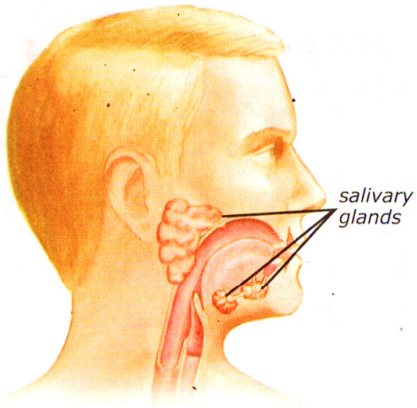
✦ *Submucosa.* The submucosa is composed of loose connective tissue, blood vessels, and many nerve endings. The blood vessels carry away the nutrients that are absorbed, and the nerve endings stimulate the muscle fibers so that the food is continually moving.

✦ *Muscular layer.* This layer, consisting of a circular band and a longitudinal band of visceral muscle, is the thickest of the four layers. The main function of the muscular layer is to produce **peristalsis** (PEHR ih STAHL sis), wavelike contractions that move the food along the canal from esophagus to rectum.

✦ *Serous layer.* The outermost portion of the canal wall is the serous layer. It is continuous with the **mesentery**, the connective tissues that attach to the posterior body wall and hold the digestive organs in their proper position.

alimentary: aliment- (L. ALERE to nourish)

gastrointestinal: gastro- (belly) + -intestinal (L. INTESTINUS, internal)

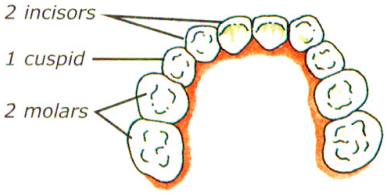


21B.2
Location of the salivary glands (top) and an SEM of the papillae of the tongue (bottom)

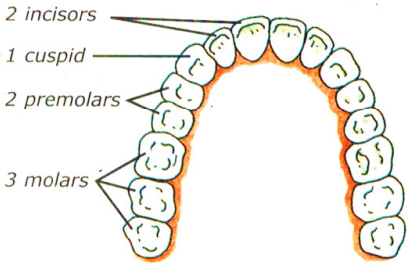
amylase: amyl- (Gk. AMULON, starch) + -ase (E. -ASE, enzyme)

mastication: (Gk. MASTIKHAN, to grind the teeth)

succedaneous: (L. SUCCEDANEUS, substituted)



deciduous teeth (20)



succedaneous teeth (32)

21B.3
Human teeth

The Mouth

Food taken into the mouth is mixed with saliva from the **salivary glands**. The saliva moistens and lubricates the food for easy swallowing. Three pairs of salivary glands, as well as numerous small glands distributed in the lining of the mouth, secrete saliva. All the salivary glands secrete *salivary amylase** (AM uh LASE), an enzyme that begins the chemical breakdown of starch to sugar. Taking food into the mouth or even the sight, smell, or thought of food triggers the production of saliva.

During **mastication*** (MAS tih KAY shun), the chewing of food, the lips keep food in the mouth cavity, and the tongue pushes food toward the teeth. The taste sensations—sweet, salty, sour, and bitter—that are experienced as food is chewed originate with the **taste buds**, located in small bumplike structures called *papillae* on the surface of the tongue. However, because the sense of taste is closely associated with the sense of smell, much of what is defined as taste is actually the detection of odors from the food. That is why food does not taste the same to a person with a cold.

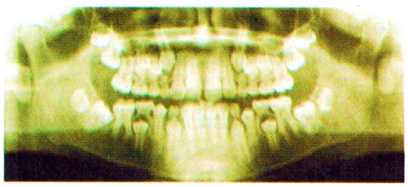
The Teeth

Four different types of teeth are involved in mastication. The eight chisel-shaped **incisors** bite, the four cone-shaped **cuspids** tear, and the **premolars** and **molars** have surfaces for crushing and grinding food.

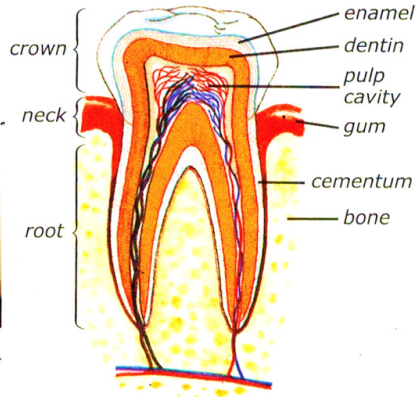
A child's first set of teeth, called *deciduous teeth*, lacks premolars and has only eight molars. The *succedaneous** (SUK suh DAY nee us)—sometimes called adult or permanent—set of teeth in adults has the same number of incisors and cuspids as the deciduous set but has eight premolars and twelve molars. The last molars, or wisdom teeth, frequently fail to emerge into the mouth or, if they do, are often crooked.

Teeth are set in sockets in the bony ridges of the jaws. The *gingivae*, or gums, cover these ridges and merge with the connective tissue that attaches each tooth in its socket. The part of the tooth above the gingivae is called the **crown**, and the part that is anchored in the socket is called the **root**. Between the crown and the root is the **neck**, the part of the tooth surrounded by the gingiva.

Each tooth is composed of two layers of hard tissues. **Dentin**, which is similar to bone, forms most of the tooth structure. In the crown portion, the dentin is covered by the **enamel**, the hardest material in the body. The enamel protects the tooth from physical damage and chemical corrosion. A thin layer of bone-like **cementum** covers the dentin in the root region and is attached to the con-



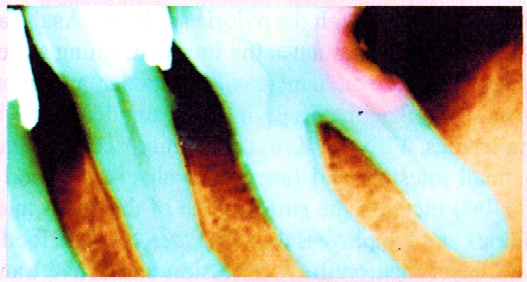
Radiograph showing permanent teeth forming in the bone



Dental Caries

Dental caries—sometimes called dental decay or cavities—is the single most common childhood disease. Over 50% of children aged five to nine and over 70% of seventeen-year-olds have at least one filling. This disease is caused by organic acids produced by bacteria that ferment the sugary film (plaque) on the surface of the tooth.

After these acids break down the enamel, the bacteria and acids may enter the dentin. Spreading rapidly through the dentin, dental caries may invade the pulp and cause pus formation in the pulp and in the socket between the root of the tooth and the gum. Such a tooth is abscessed. A tooth with caries or an abscess should receive professional dental care to prevent the loss of the tooth and/or the spread of infection to the other organs of the body.



Radiograph showing caries (pink highlighted area)

People can prevent, or at least slow down, caries by using fluoride-containing toothpaste and by brushing and flossing properly after every meal. Eating less candy and drinking fewer sugary beverages can also decrease dental caries by reducing plaque formation.

Regular dental examinations can identify dental caries before the tooth becomes abscessed. Repairing dental caries often requires an injection of anesthetic, which allows the dentist to remove the caries painlessly using a dental handpiece, or "drill." Newer techniques for removing dental caries utilize special types of lasers or micro-air abrasion instruments, although they are not applicable in all situations. Sometimes these new techniques do not require an injection to anesthetize the teeth. However, the old saying "An ounce of prevention is worth a pound of cure" is still true.

nective tissue that anchors the tooth. Inside each tooth is a **pulp cavity** filled with blood vessels, lymph vessels, nerves, and connective tissues collectively called the *pulp*.

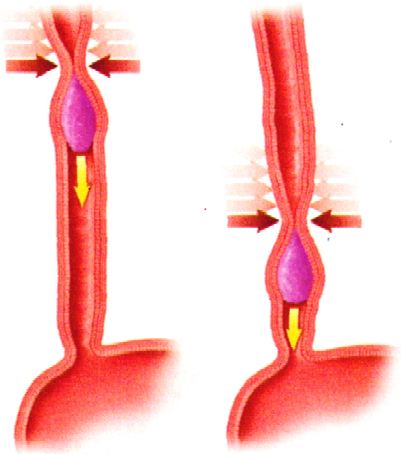
The Pharynx, Esophagus, and Stomach

As the food is chewed, softened, and lubricated, it is formed into a ball-like mass called a *bolus* and is swallowed. During swallowing, the tongue pushes superiorly and posteriorly to direct the bolus into the *pharynx*. At the same time the *uvula* moves superiorly, closing the back of the nose to prevent the food from moving into the nasal cavities. The pharynx constricts after receiving the food in order to direct it into the esophagus. The *epiglottis* covers the *glottis* of the *larynx* as the food moves into the esophagus, which is stretched open to receive the food.

The **esophagus** is a muscular tube that is lubricated by many mucous glands so that the food can be easily moved downward by peristalsis. Swallowed food takes about three seconds to get to the stomach from the mouth.

The esophagus joins the **stomach** at the *cardiac sphincter*, a muscular valve that remains closed except when food passes into the stomach, a J-shaped muscular pouch. The folds of the stomach lining and the elasticity of the muscular walls enable the stomach to hold about 2 L (2.1 qt) of food.

The thick, muscular walls of the stomach churn and mix the food with the acidic gastric juices that are secreted by the epithelial lining of the stomach. The gastric juices contain enzymes for protein digestion and would digest the walls of the stomach if they were not protected by the slimy mucus also secreted by the mucous-membrane lining of the stomach. The duration of churning may be four hours for coarse foods like celery and spinach, while foods like oatmeal or pudding move rapidly through the stomach. Although the stomach lining does not absorb many food molecules, it does absorb alcohol, water, and certain drugs.



21B.4
As the muscles contract and relax, the bolus is moved to the stomach.

21B.5
SEM of small intestine villi

After the food is thoroughly broken down into a semiliquid state called *chyme* (KYME), the peristaltic contractions propel the food through the pyloric sphincter into the small intestine in small spurts. This pyloric valve usually remains closed until the food is converted to chyme.

The Small Intestine

Most of the digestion and absorption of food occurs in the **small intestine**. The entire small intestine is about 7 m (23 ft) long and 2.5 cm in diameter. The **duodenum**, the first section of the small intestine, is about 25 cm (10 in.) long and receives the chyme as it passes through the pyloric sphincter. As the acidic chyme passes into the duodenum, it stimulates the intestinal lining to secrete hormones. These hormones stimulate the pancreas, gallbladder, and intestinal lining to secrete enzymes and other materials into the duodenum to break down food into small molecules. **Villi*** (VIL EYE) are microscopic fingerlike structures that line the small intestine and function to absorb the food molecules. The villi (*sing.* villus) increase the surface area of the small intestine and contain small capillaries and lymph vessels called *lacteals*. The food molecules cross the epithelial layer of the villi by diffusion and active transport and are absorbed through the vessels within the villi. These vessels then distribute the food molecules throughout the body.

The Liver, Gallbladder, and Pancreas

The **liver**, the largest internal organ, is located in the upper right part of the abdomen immediately inferior to the diaphragm. It is composed of soft tissue that contains many microscopic spaces called *sinusoids* (SYE nuh SOYDZ). The sinusoids can serve as blood reservoirs. The blood from all digestive organs (stomach, small and large intestine) flows through the liver sinusoids before going elsewhere in the body. As the blood passes through the sinusoids, it comes in contact with the liver cells. Each liver cell may perform more than five hundred separate functions. Several functions of the liver cells include the following:

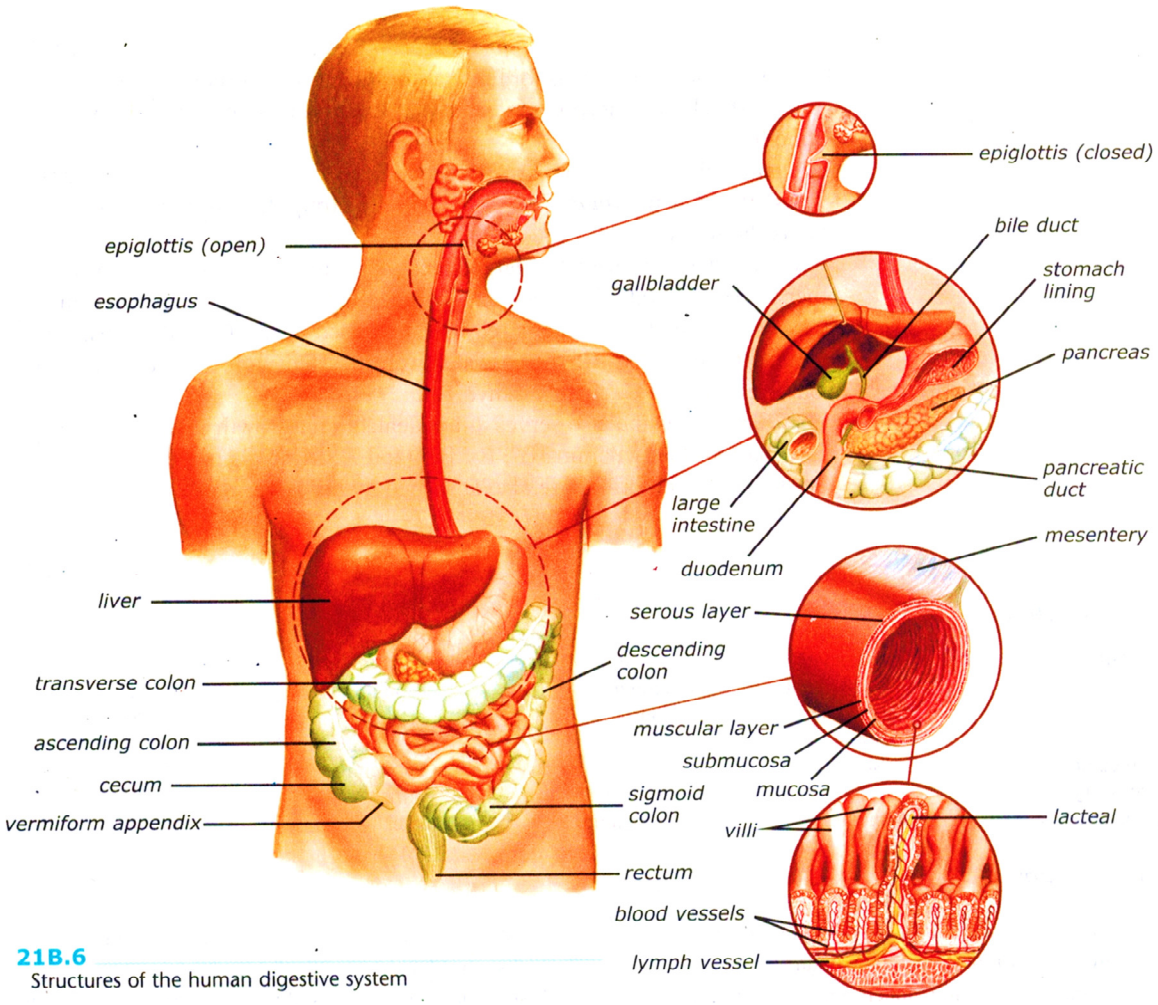
- Engulfing bacteria and worn-out red blood cells
- Removing many drugs and poisons from the blood and detoxifying them
- Converting excess glucose into glycogen and storing it
- Changing excess glucose into fats
- Absorbing amino acids from the blood and using them to manufacture most of the proteins found in the blood
- Storing the fat-soluble vitamins, iron, and copper

Perhaps the most familiar function of the liver is the formation of **bile**, a greenish fluid that is necessary for the breakdown and absorption of fatty substances in the small intestine. The liver secretes about 0.5 L (1 pt) of bile a day.

The **gallbladder** is a 7.5–10 cm (3–4 in.) green pear-shaped sac attached to the liver by the bile duct. The gallbladder serves as a reservoir for bile. During a meal, when fatty materials enter the duodenum, the gallbladder contracts and sends bile into the small intestine.

The gallbladder stores bile between meals and concentrates the bile by removing water. If the concentration becomes excessive, cholesterol crystals may form and develop into solids known as *gallstones*. Some gallstones pass unnoticed through the bile duct and into the intestine. Some, however, get into the bile duct and block the flow of bile, causing considerable pain. Occasionally

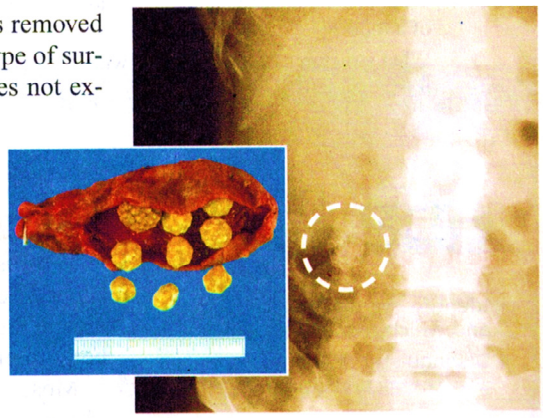
villi: (L. VILLUS, shaggy hair)



21B.6
Structures of the human digestive system

such gallstones must be removed surgically. Often the gallbladder is removed so that the body cannot produce gallstones in the future. After this type of surgery the liver continues to produce bile, and the person usually does not experience any difficulty in digesting fats.

The **pancreas** is a soft, pinkish white gland 15–25 cm (6–10 in.) long and 2.5 cm (1 in.) wide. About 97% of the pancreas cells produce digestive juices that contain enzymes for digesting carbohydrates, fats, and proteins. These digestive juices flow into the small intestine through the *pancreatic duct.* Often the pancreatic duct merges with the common bile duct before entering the duodenum. Most of the remaining pancreas cells produce hormones involved in regulating the amount of sugar in the blood.



21B.7
Radiograph showing gall stones (circled) and surgical specimen

The Large Intestine

The **large intestine**, or colon, is 1.5–2 m (5–6 ft) long and about 6.5 cm (2.5 in.) in diameter. It has four major sections—ascending, transverse, descending, and sigmoid—that correspond to their shape and direction in which they move food and waste.

Material from the small intestine moves into the *cecum* (SEE kum), which is a pouch about 6 cm (2 in.) long at the start of the ascending colon. The narrow

end of the cecum is the *vermiform** *appendix** (VUR muh FORM • uh PEN diks), which secretes mucus for lubrication and harbors certain microorganisms that digest cellulose. Reports indicate that it also forms certain leukocytes and antibodies.

A major function of the large intestine is the removal of **feces** (waste materials) through the *anus*. The *rectum* is the straight, muscular portion that expels the feces.

A second function of the large intestine is the reabsorption of water. In other words, the water in saliva, bile, pancreatic juices, and secretions from the stomach and small intestine is recycled and used again. On a daily basis this amounts to about 7.5 L. If this water were egested with the feces, a person would soon become severely dehydrated.

The large intestine also serves as an ideal site for growth of the bacteria and yeast that produce vitamins B_1, B_2, B_{12}, and K. Minerals (especially sodium, potassium, and chlorine) are also absorbed by the large intestine.

Unit 6: The Digestive System

1. What are the four main functions of the digestive system?
2. Saliva contains the enzyme amylase which breaks down food. What kind of food does it break down?
3. What are the four types of teeth in a human's mouth?
4. How long does it take food to get from the mouth to the stomach?
5. What prevents the stomach from digesting itself?
6. List several functions of the liver.
7. List the structures of the digestive system, in order, that a piece of food would come in contact with as it travels from the mouth through the rest of the system.
8. Where are most of the nutrients from food absorbed in the body?