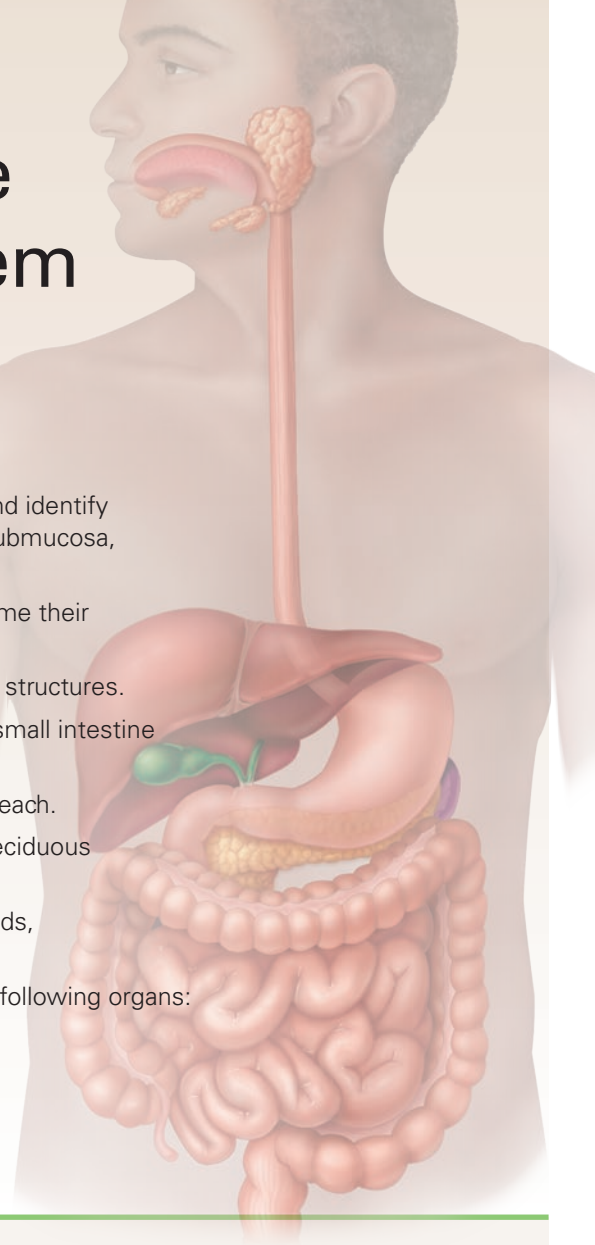
EXERCISE

38 Anatomy of the Digestive System



Objectives

- ☐ State the overall function of the digestive system.
- ☐ Describe the general histologic structure of the alimentary canal wall, and identify the following structures on an appropriate image of the wall: mucosa, submucosa, muscularis externa, and serosa or adventitia.
- ☐ Identify on a model or image the organs of the alimentary canal, and name their subdivisions, if any.
- ☐ Describe the general function of each of the digestive system organs or structures.
- ☐ List and explain the specializations of the structure of the stomach and small intestine that contribute to their functional roles.
- ☐ Name and identify the accessory digestive organs, listing a function for each.
- ☐ Describe the anatomy of the generalized tooth, and name the human deciduous and permanent teeth.
- ☐ List the major enzymes or enzyme groups produced by the salivary glands, stomach, small intestine, and pancreas.
- ☐ Recognize microscopically or in an image the histologic structure of the following organs:

small intestine, tooth, liver, salivary glands, stomach

Materials

- Dissectible torso model
- Anatomical chart of the human digestive system
- Prepared slides of the liver and mixed salivary glands; of longitudinal sections of the gastroesophageal junction and a tooth; and of cross sections of the stomach, duodenum, ileum, and large intestine
- Compound microscope
- Three-dimensional model of a villus (if available)

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Pre-Lab Quiz

1. The digestive system:
   a. eliminates undigested food
   b. provides the body with nutrients
   c. provides the body with water
   d. all of the above
2. Circle the correct underlined term. Digestion / Absorption occurs when small molecules pass through epithelial cells into the blood for distribution to the body cells.
3. The _____ abuts the lumen of the alimentary canal and consists of epithelium, lamina propria, and muscularis mucosae.
   a. mucosa **b.** serosa **c.** submucosa
4. Circle the correct underlined term. Approximately 25 cm long, the esophagus / alimentary canal conducts food from the pharynx to the stomach.
5. Wavelike contractions of the digestive tract that propel food along are called:
   a. digestion **c.** ingestion
   b. elimination **d.** peristalsis
6. The _____ is located on the left side of the abdominal cavity and is hidden by the liver and diaphragm.
   a. gallbladder **c.** small intestine
   b. large intestine **d.** stomach

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- Jaw model or human skull
- Three-dimensional model of liver lobules (if available)

For instructions on animal dissections, see the dissection exercises (starting on p. 705) in the cat and fetal pig editions of this manual.

7. Circle True or False. Nearly all nutrient absorption occurs in the small intestine.
8. Circle the correct underlined term. The ascending colon / descending colon traverses down the left side of the abdominal cavity and becomes the sigmoid colon.
9. A tooth consists of two major regions, the crown and the:
   a. dentin **c.** gingiva
   b. enamel **d.** root
10. Located inferior to the diaphragm, the _____ is the largest gland in the body.
    a. gallbladder **c.** pancreas
    b. liver **d.** thymus

The **digestive system** provides the body with the nutrients, water, and electrolytes essential for health. The organs of this system ingest, digest, and absorb food and eliminate the undigested remains as feces.

The digestive system consists of a hollow tube extending from the mouth to the anus, into which various accessory organs or glands empty their secretions (**Figure 38.1**). For ingested food to become available to the body cells, it must first be broken down into its smaller diffusible molecules—a process called **digestion.** The digested end products can then pass through the epithelial cells lining the tract into the blood for distribution to the body cells—a process termed **absorption.**

The organs of the digestive system are traditionally separated into two major groups: the **alimentary canal,** or **gastrointestinal (GI) tract,** and the **accessory digestive organs.** The alimentary canal consists of the mouth, pharynx, esophagus, stomach, and small and large intestines. The accessory structures include the teeth, which physically break down foods, and the salivary glands, gallbladder, liver, and pancreas, which secrete their products into the alimentary canal.

General Histological Plan of the Alimentary Canal

From the esophagus to the anal canal, the basic structure of the alimentary canal is similar. As we study individual parts of the alimentary canal, we will note how this basic plan is modified to provide the unique digestive functions of each subsequent organ.

Essentially the alimentary canal wall has four basic layers or tunics. From the lumen outward, these are the *mucosa,* the *submucosa,* the *muscularis externa,* and either a *serosa* or *adventitia* (**Figure 38.2**, p. 580). Each of these layers has a predominant tissue type and a specific function in the digestive process.

Table 38.1 on p. 581 summarizes the characteristics of the layers of the wall of the alimentary canal.

Organs of the Alimentary Canal

Activity 1

Identifying Alimentary Canal Organs

The sequential pathway and fate of food as it passes through the alimentary canal are described in the next sections. Identify each structure in Figure 38.1 and on the torso model or anatomical chart of the digestive system as you work.

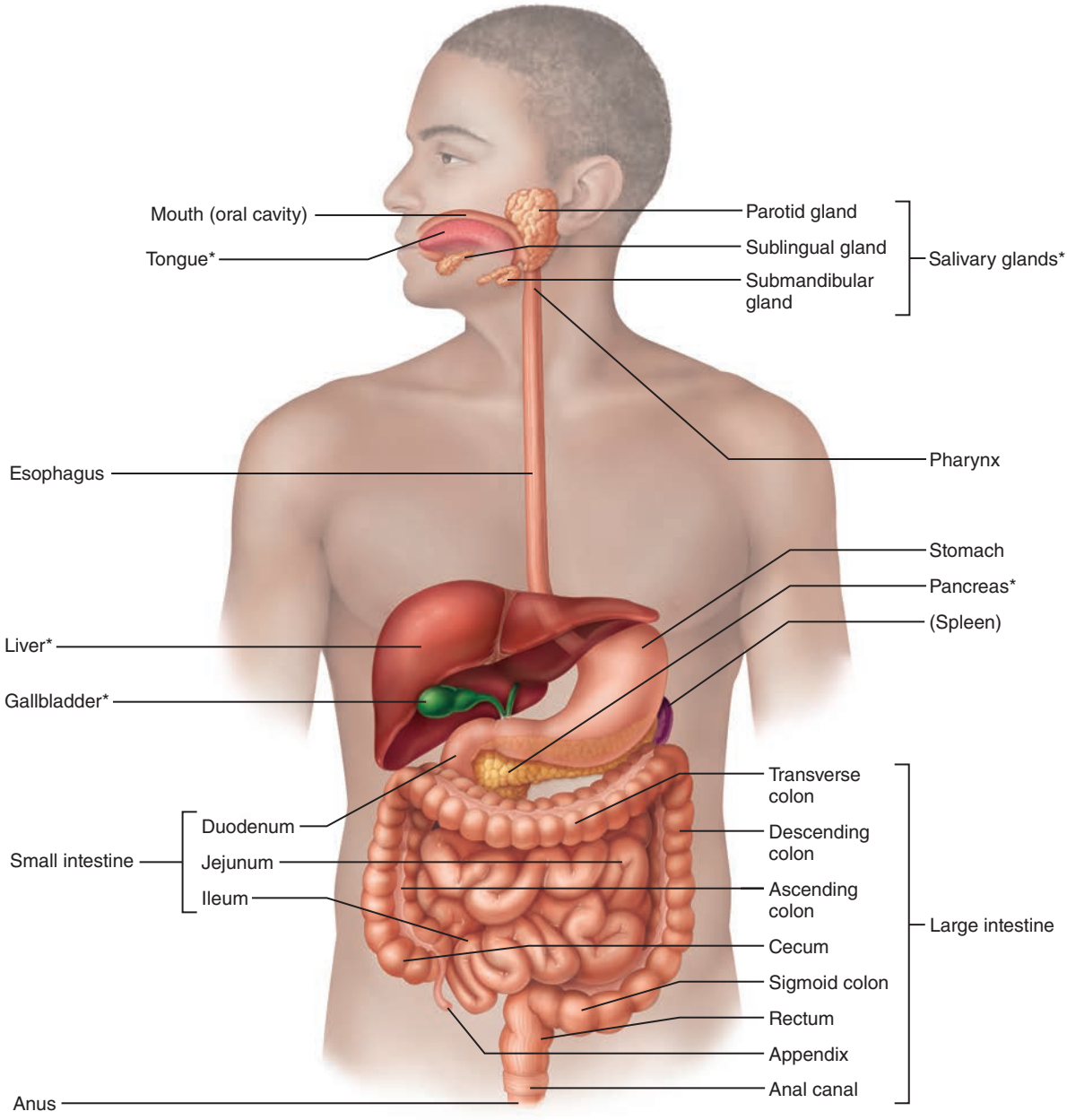


Figure 38.1 The human digestive system: alimentary tube and accessory organs. Organs marked with asterisks are accessory organs. Those without asterisks are alimentary canal organs (except the spleen, an organ of the lymphatic system).

Oral Cavity or Mouth

Food enters the digestive tract through the **oral cavity,** or **mouth** (**Figure 38.3**, p. 580). Within this mucous membrane–lined cavity are the gums, teeth, tongue, and openings of the ducts of the salivary glands. The **lips (labia)** protect the opening of the chamber anteriorly, the **cheeks** form its lateral walls, and the **palate,** its roof. The anterior portion of the palate is referred to as the **hard palate** because the palatine processes of the maxillae and horizontal plates of the palatine bones underlie it. The posterior **soft palate** is a fibromuscular structure that is unsupported by bone. The **uvula,** a fingerlike projection of the soft palate, extends inferiorly from its posterior margin. The floor of the oral cavity is occupied by the muscular **tongue,** which is largely supported by the *mylohyoid muscle* (**Figure 38.4**, p. 581) and attaches to the hyoid bone, mandible, styloid processes, and pharynx. A membrane called the **lingual frenulum** secures the inferior midline of the tongue to the floor of the mouth. The space between the teeth and cheeks (or lips) is the **oral vestibule;** the area that lies within the teeth and gums is the **oral cavity proper.** (The teeth and gums are discussed in more detail on pp. 588–590.)

On each side of the mouth at its posterior end are masses of lymphoid tissue, the **palatine tonsils** (see Figure 38.3). Each

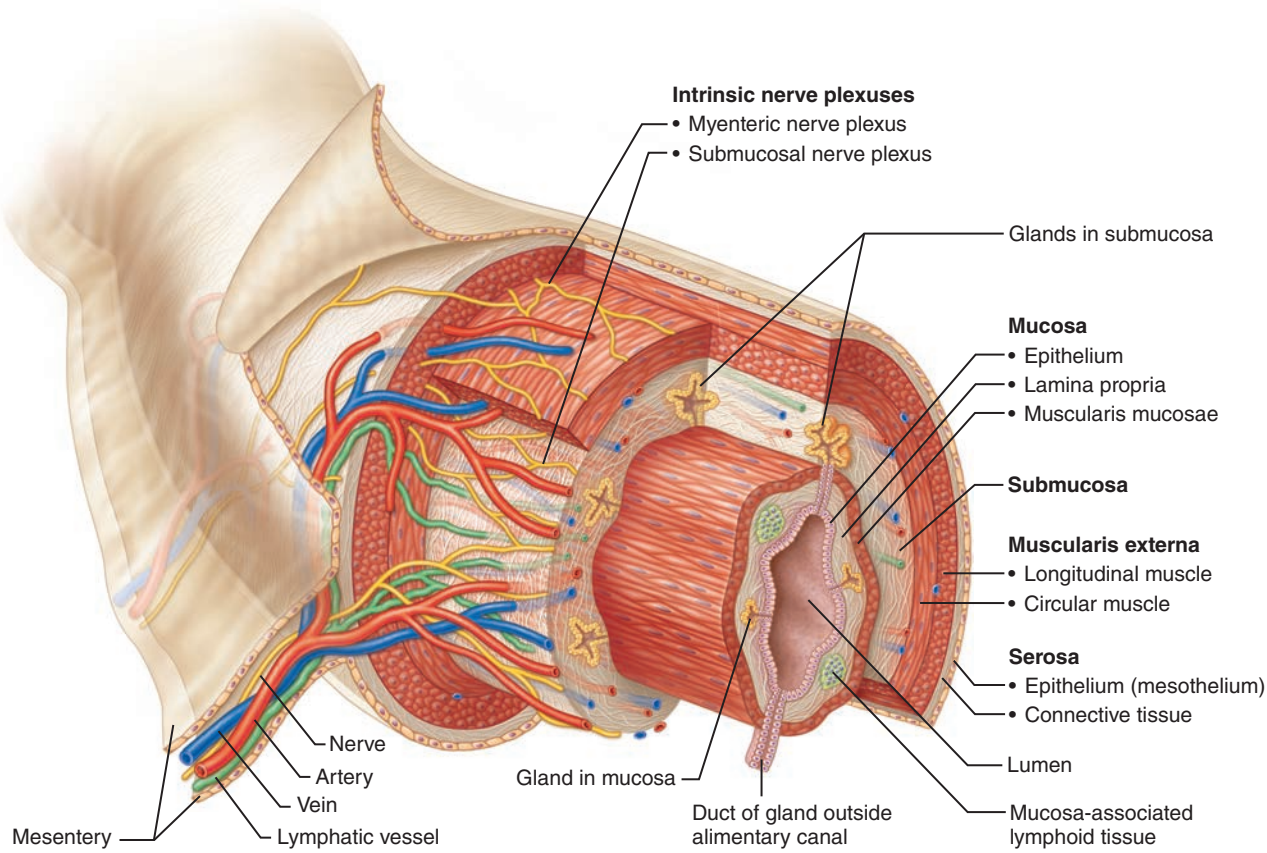


Figure 38.2 **Basic structural pattern of the alimentary canal wall.**

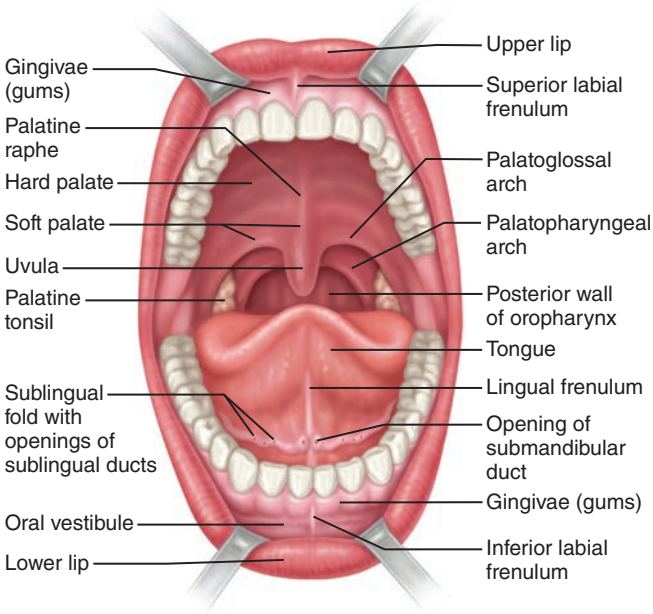


Figure 38.3 **Anterior view of the oral cavity.**

lies in a concave area bounded anteriorly and posteriorly by membranes, the **palatoglossal arch** and the **palatopharyngeal arch,** respectively. Another mass of lymphoid tissue, the **lingual tonsil** (see Figure 38.4), covers the base of the tongue, posterior to the oral cavity proper. The tonsils, in common with other lymphoid tissues, are part of the body's defense system.

Very often in young children, the palatine tonsils become inflamed and enlarge, partially blocking the entrance to the pharynx posteriorly and making swallowing difficult and painful. This condition is called **tonsillitis.** ✚

Three pairs of salivary glands duct their secretion, saliva, into the oral cavity. One component of saliva, salivary amylase, begins the digestion of starchy foods within the oral cavity. (The salivary glands are discussed in more detail on p. 590.)

As food enters the mouth, it is mixed with saliva and masticated (chewed). The cheeks and lips help hold the food between the teeth during mastication, and the highly mobile tongue manipulates the food during chewing and initiates swallowing. Thus the mechanical and chemical breakdown of food begins before the food has left the oral cavity.

Pharynx

When the tongue initiates swallowing, the food passes posteriorly into the pharynx, a common passageway for food, fluid, and air (see Figure 38.4). The pharynx is subdivided anatomically into three parts—the **nasopharynx** (behind the nasal cavity), the **oropharynx** (behind the oral cavity extending from the soft palate to the epiglottis), and the **laryngopharynx** (extending from the epiglottis to the base of the larynx).

The walls of the pharynx consist largely of two layers of skeletal muscle: an inner layer of longitudinal muscle and an outer layer of circular constrictor muscles. Together these initiate wavelike contractions that propel the food inferiorly

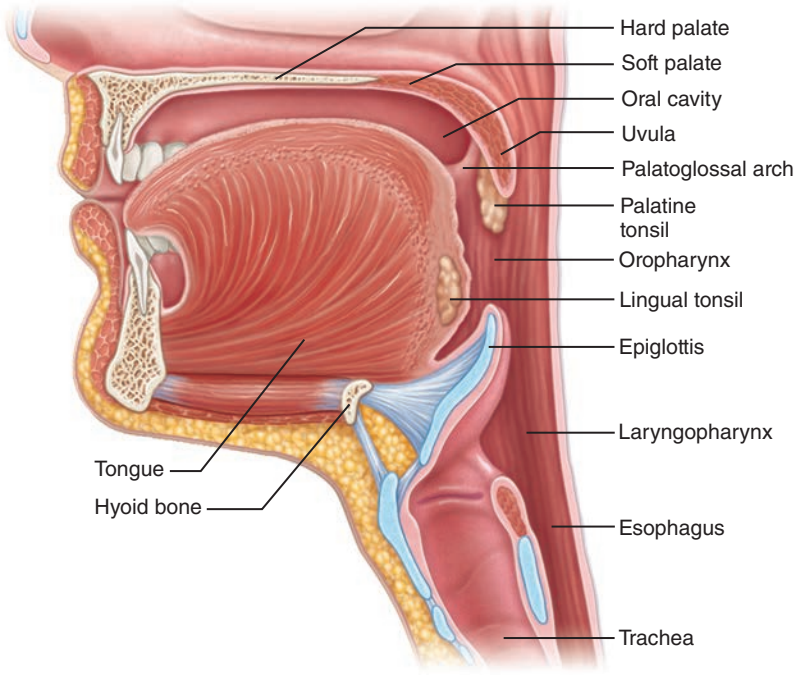


Figure 38.4 **Sagittal view of the head showing oral cavity and pharynx.**

into the esophagus. The mucosa of the oropharynx and laryngopharynx, like that of the oral cavity, contains a protective stratified squamous epithelium.

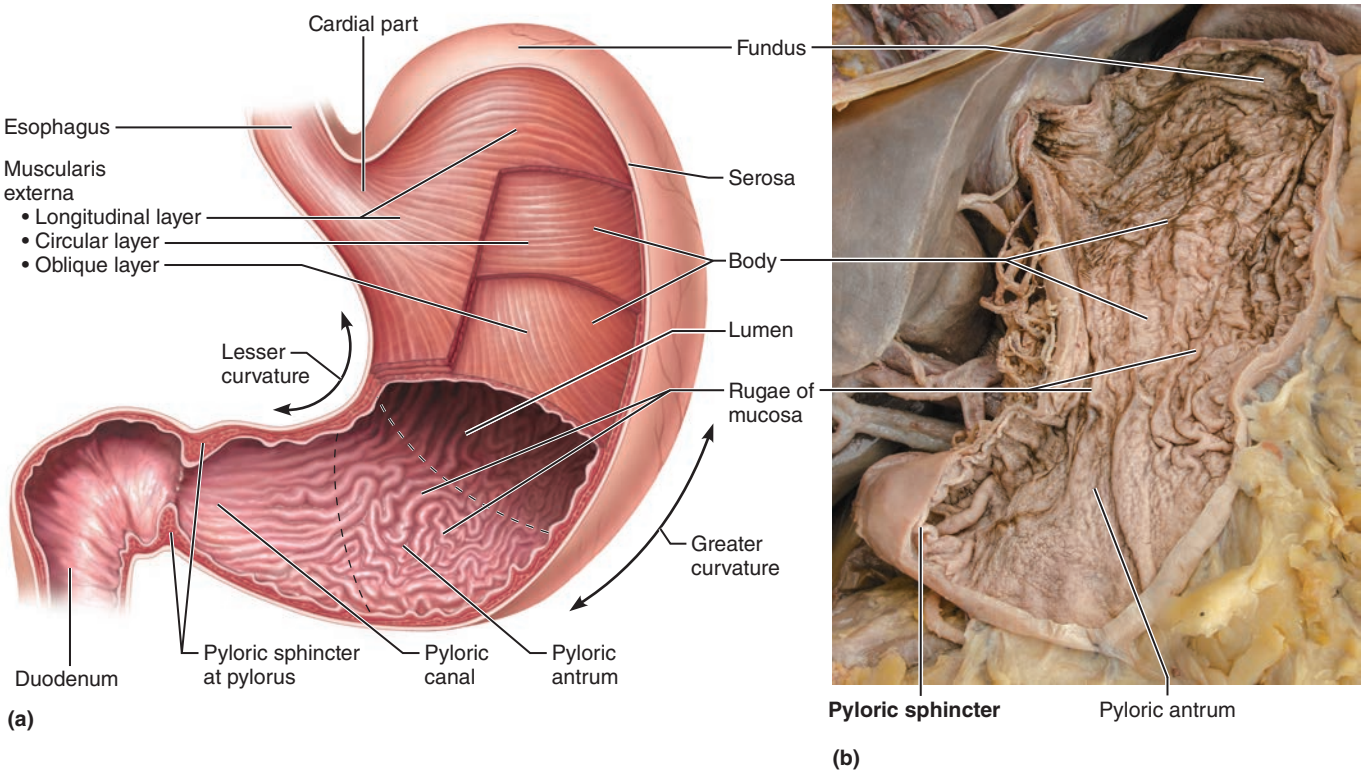
Esophagus

The **esophagus,** or gullet, extends from the pharynx through the diaphragm to the gastroesophageal sphincter in the superior aspect of the stomach. Approximately 25 cm long in humans, it is essentially a food passageway that conducts food to the stomach in a wavelike peristaltic motion. The esophagus has no digestive or absorptive function. The walls at its superior end contain skeletal muscle, which is replaced by smooth muscle in the area nearing the stomach. The **gastroesophageal sphincter,** a slight thickening of the smooth muscle layer at the esophagus-stomach junction, controls food passage into the stomach (Figure 38.6c).

Table 38.1 **Alimentary Canal Wall Layers (Figure 38.1)**

Layer	Subdivision of the layer	Tissue type	Major functions (generalized for the layer)
Mucosa	Epithelium	Stratified squamous epithelium in the mouth, esophagus, and anus; simple columnar epithelium in the remainder of the canal	Secretion of mucus, digestive enzymes, and hormones; absorption of end products into the blood; protection against infectious disease.
	Lamina propria	Areolar connective tissue with blood vessels; many lymphoid follicles, especially as tonsils and mucosa-associated lymphoid tissue (MALT)	
	Muscularis mucosae	A thin layer of smooth muscle	
Submucosa	N/A	Areolar and dense irregular connective tissue containing blood vessels, lymphatic vessels, and nerve fibers (submucosal nerve plexus)	Blood vessels absorb and transport nutrients. Elastic fibers help maintain the shape of each organ.
Muscularis externa	Circular layer	Inner layer of smooth muscle	Segmentation and peristalsis of digested food along the tract are regulated by the myenteric nerve plexus.
	Longitudinal layer	Outer layer of smooth muscle	
Serosa* (visceral peritoneum)	Connective tissue	Areolar connective tissue	Reduces friction as the digestive system organs slide across one another.
	Epithelium (mesothelium)	Simple squamous epithelium	

*Since the esophagus is outside the peritoneal cavity, the serosa is replaced by an adventitia made of aerolar connective tissue that binds the esophagus to surrounding tissues.



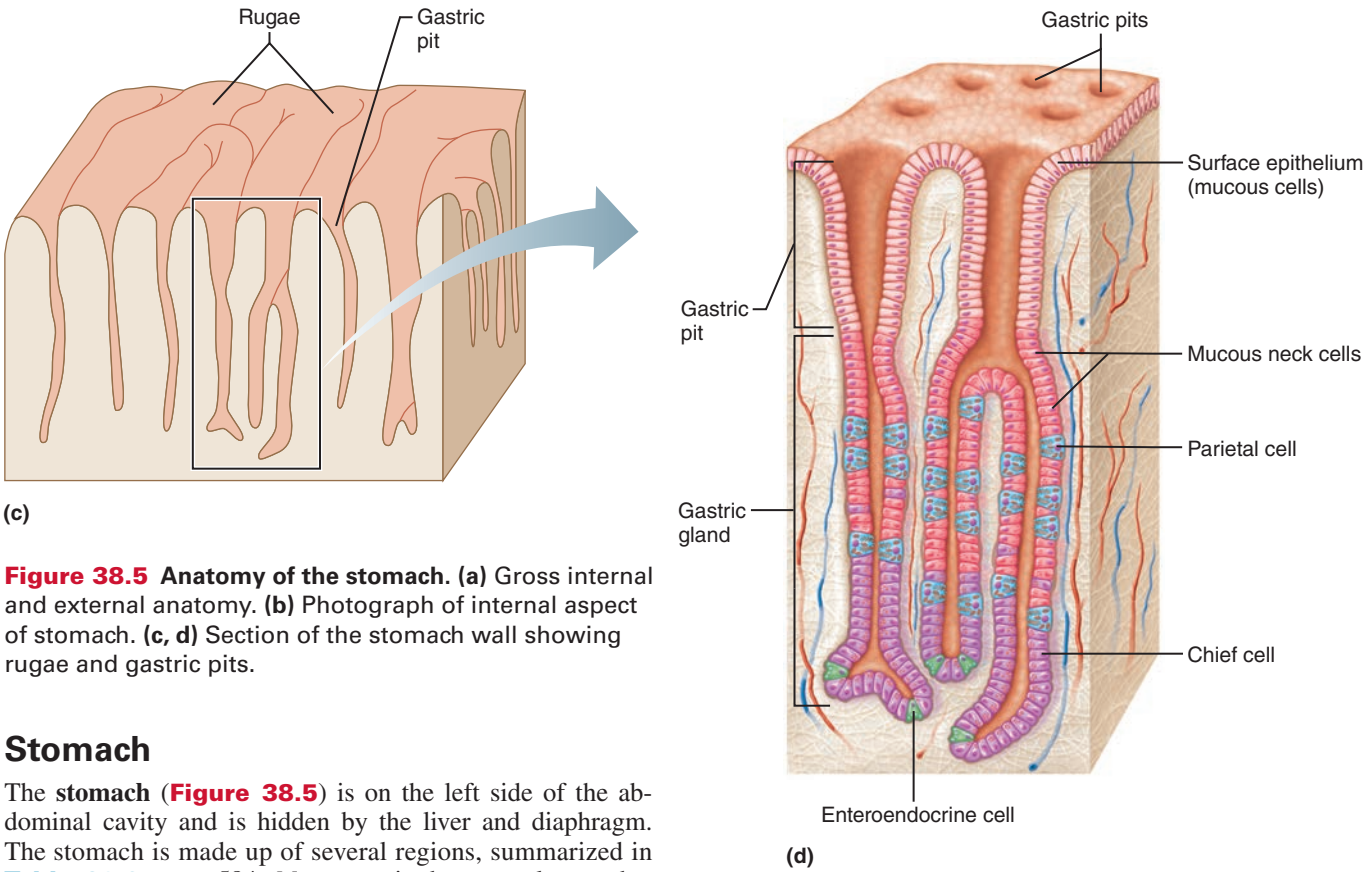


Figure 38.5 Anatomy of the stomach. (a) Gross internal and external anatomy. **(b)** Photograph of internal aspect of stomach. **(c, d)** Section of the stomach wall showing rugae and gastric pits.

Stomach

The **stomach** (**Figure 38.5**) is on the left side of the abdominal cavity and is hidden by the liver and diaphragm. The stomach is made up of several regions, summarized in **Table 38.2** on p. 584. *Mesentery* is the general term that refers to the double layer of the peritoneum that extends from the digestive organs to the body wall. There are two mesenteries, the **greater omentum** and **lesser omentum,** that connect to the stomach. The lesser omentum extends from the liver

to the **lesser curvature** of the stomach. The greater omentum extends from the **greater curvature** of the stomach, reflects downward, and covers most of the abdominal organs in an apronlike fashion. (Figure 38.7 on p. 585 illustrates the omenta as well as the other peritoneal attachments of the abdominal organs.)

The stomach is a temporary storage region for food as well as a site for mechanical and chemical breakdown of food. It contains a third (innermost) *obliquely* oriented layer of smooth muscle in its muscularis externa that allows it to churn, mix, and pummel the food, physically reducing it to smaller fragments. **Gastric glands** of the mucosa secrete hydrochloric acid (HCl) and hydrolytic enzymes. The *mucosal glands* also secrete a viscous mucus that helps prevent the stomach itself from being digested by the proteolytic enzymes. Most digestive activity occurs in the pyloric part of the stomach. After the food is processed in the stomach, it resembles a creamy mass called **chyme,** which enters the small intestine through the pyloric sphincter.

Activity 2

Studying the Histologic Structure of the Stomach and the Gastroesophageal Junction

1. **Stomach:** View the stomach slide first. Refer to **Figure 38.6a** as you scan the tissue under low power to locate the muscularis externa; then move to high power to more closely examine this layer. Try to pick out the three smooth muscle layers. How does the extra oblique layer of smooth muscle found in the stomach correlate with the stomach's churning movements?

Identify the gastric glands and the gastric pits (see Figures 38.5 and 38.6b). If the section is taken from the stomach fundus and is differentially stained, you can identify, in the gastric glands, the blue-staining **chief cells,** which produce pepsinogen, and the red-staining **parietal cells,** which secrete HCl. The enteroendocrine cells that release hormones are indistinguishable. Draw a small section of the stomach wall, and label it appropriately.

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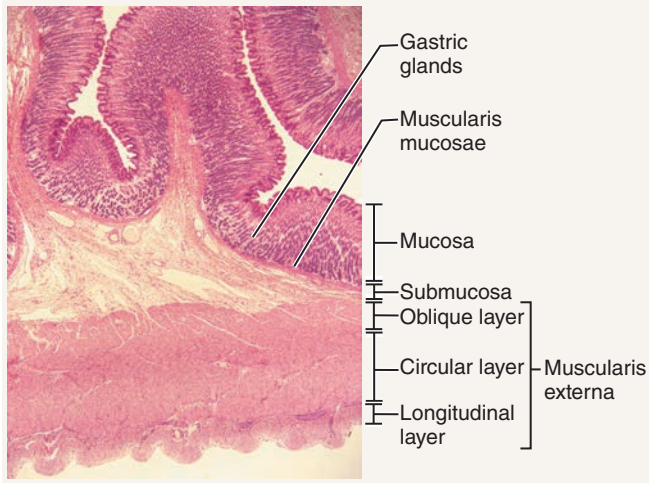

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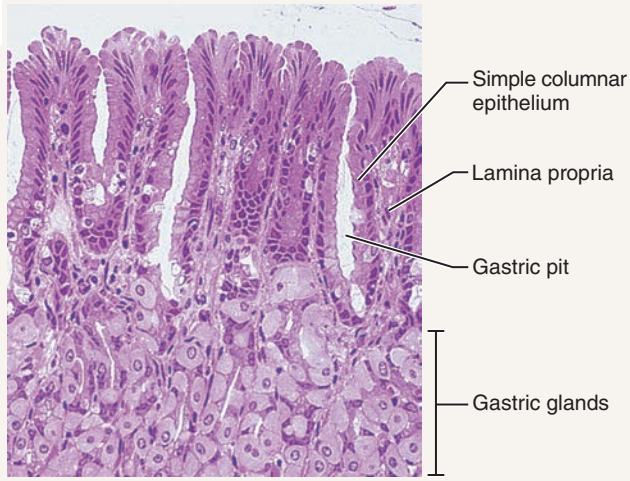

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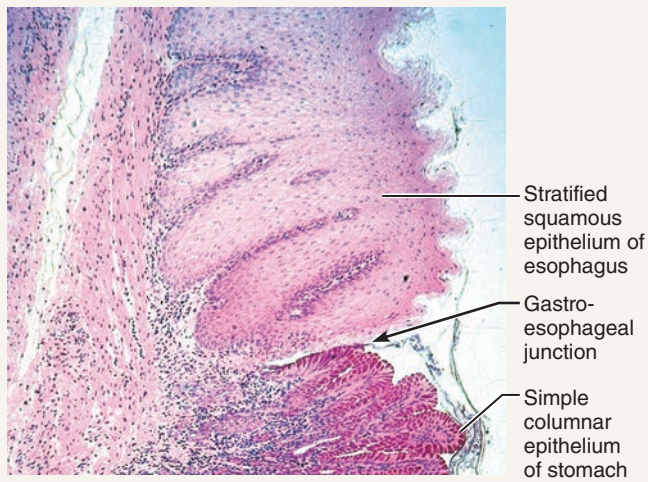

(c)

Figure 38.6 Histology of selected regions of the stomach and gastroesophageal junction. (a) Stomach wall (12×). **(b)** Gastric pits and glands (130×). **(c)** Gastroesophageal junction, longitudinal section (60×).

Table 38.2 Parts of the Stomach (Figure 38.5)

Structure	Description
Cardial part (cardia)	The area surrounding the cardial orifice through which food enters the stomach
Fundus	The dome-shaped area that is located superior and lateral to the cardial part
Body	Midportion of the stomach and largest region
Pyloric part:	Funnel-shaped pouch that forms the distal stomach
Pyloric antrum	Wide superior portion of the pyloric part
Pyloric canal	Narrow tubelike portion of the pyloric part
Pylorus	Distal end of the pyloric part that is continuous with the small intestine
Pyloric sphincter	Valve that controls the emptying of the stomach into the small intestine

2. Gastroesophageal junction: Scan the slide under low power to locate the mucosal junction between the end of the esophagus and the beginning of the stomach, the gastroesophageal junction. Draw a small section of the junction and label it appropriately.

Compare your observations to Figure 38.6c. What is the functional importance of the epithelial differences seen in the two organs?

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Small Intestine

The **small intestine** is a convoluted tube, 6 to 7 meters (about 20 feet) long in a cadaver but only about 2 m (6 feet) long during life because of its muscle tone. It extends from the pyloric sphincter to the ileocecal valve. The small intestine is suspended by a double layer of peritoneum, the fan-shaped **mesentery,** from the posterior abdominal wall (**Figure 38.7**), and it lies, framed laterally and superiorly by the large intestine, in the abdominal cavity. The small intestine has three subdivisions (see Figure 38.1):

1. The **duodenum** extends from the pyloric sphincter for about 25 cm (10 inches) and curves around the head of the pancreas; most of the duodenum lies in a retroperitoneal position.

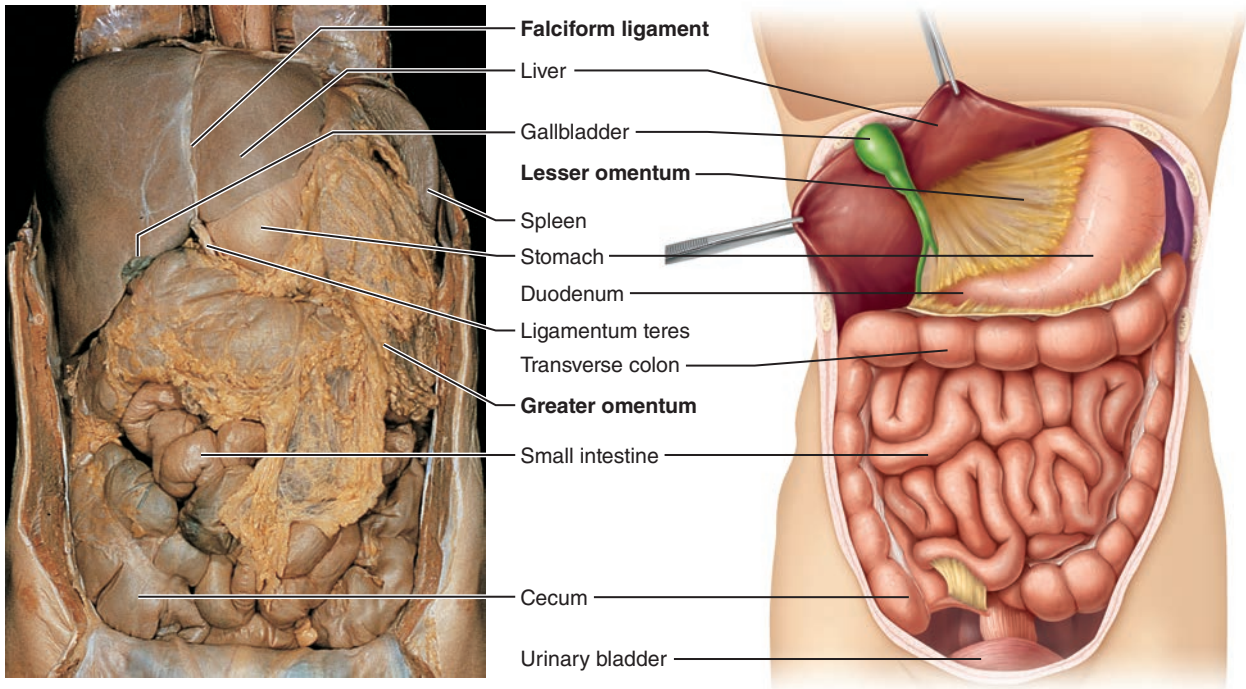
2. The **jejunum,** continuous with the duodenum, extends for 2.5 m (about 8 feet). Most of the jejunum occupies the umbilical region of the abdominal cavity.

3. The **ileum,** the terminal portion of the small intestine, is about 3.6 m (12 feet) long and joins the large intestine at the **ileocecal valve.** It is located inferiorly and somewhat to the right in the abdominal cavity, but its major portion lies in the hypogastric region.

In the small intestine, enzymes from two sources complete the digestion process: **brush border enzymes,** which are hydrolytic enzymes bound to the microvilli of the columnar epithelial cells; and, more important, enzymes produced by the pancreas and ducted into the duodenum largely via the **main pancreatic duct.** Bile (formed in the liver) also enters the duodenum via the **bile duct** in the same area. At the duodenum, the ducts join to form the bulblike **hepatopancreatic ampulla** and empty their products into the duodenal lumen through the **major duodenal papilla,** an orifice controlled by a muscular valve called the **hepatopancreatic sphincter** (see Figure 38.15 on p. 591).

Nearly all nutrient absorption occurs in the small intestine, where three structural modifications increase the absorptive surface of the mucosa: the microvilli, villi, and circular folds (**Figure 38.8**, p. 586).

- **Microvilli:** Microscopic projections of the surface plasma membrane of the columnar epithelial lining cells of the mucosa.
- **Villi:** Fingerlike projections of the mucosa tunic that give it a velvety appearance and texture.
- **Circular folds:** Deep, permanent folds of the mucosa and submucosa layers that force chyme to spiral through the intestine, mixing it and slowing its progress. These structural modifications decrease in frequency and size toward the end of the small intestine. Any residue remaining undigested and unabsorbed at the terminus of the small intestine enters the large intestine through the ileocecal valve. The amount of lymphoid tissue in the submucosa of the small intestine (especially the aggregated lymphoid nodules called **Peyer's patches,** **Figure 38.9b**, p. 587) increases along the length of the small intestine and is very apparent in the ileum.



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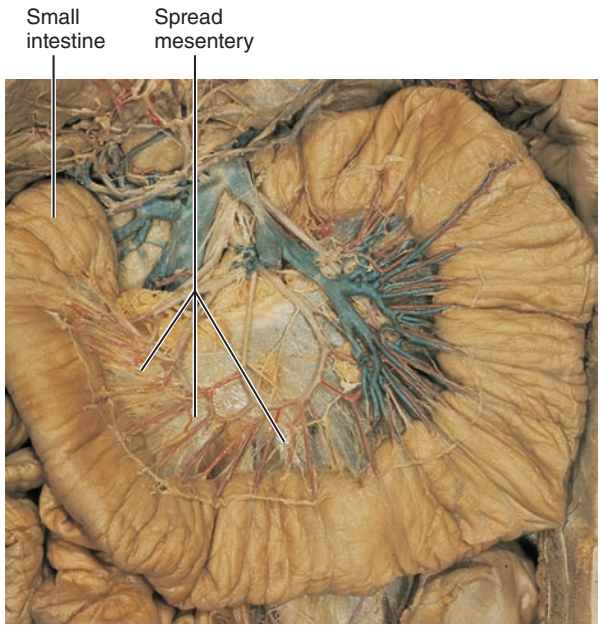

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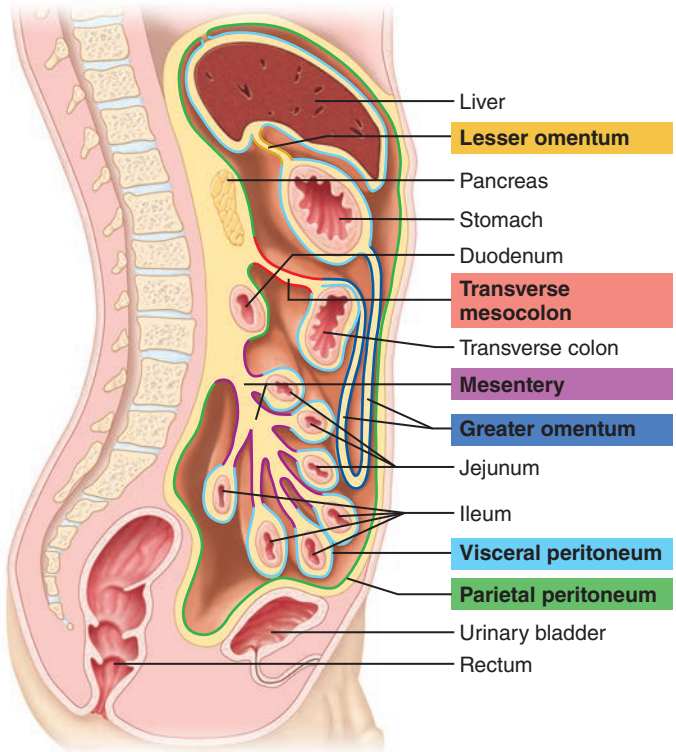

(d)

Figure 38.7 Peritoneal attachments of the abdominal organs. Superficial anterior views of abdominal cavity: **(a)** photograph with the greater omentum in place and **(b)** diagram showing greater omentum removed and liver and gallbladder reflected superiorly. **(c)** Mesentery of the small intestine. **(d)** Sagittal view of a male torso. Mesentery labels appear in colored boxes.

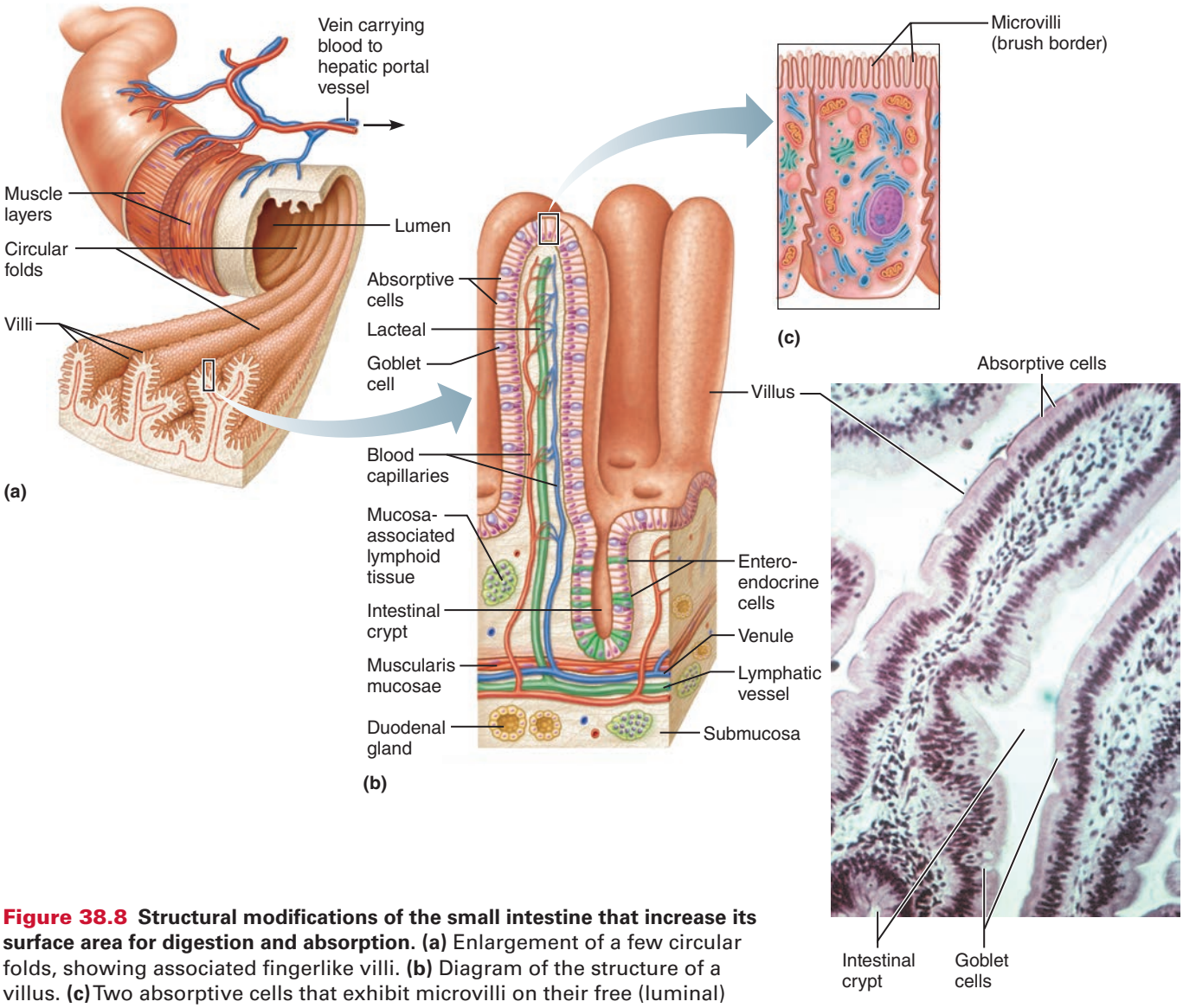

Figure 38.8 Structural modifications of the small intestine that increase its surface area for digestion and absorption. (a) Enlargement of a few circular folds, showing associated fingerlike villi. **(b)** Diagram of the structure of a villus. **(c)** Two absorptive cells that exhibit microvilli on their free (luminal) surface. **(d)** Photomicrograph of the mucosa showing villi (105×).

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Activity 3

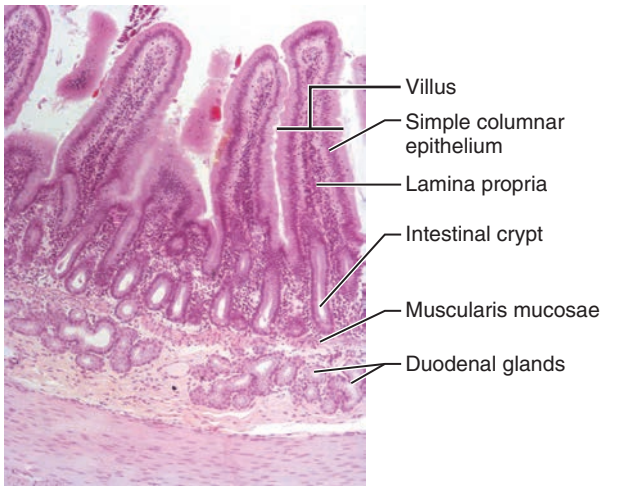
Observing the Histologic Structure of the Small Intestine

1. **Duodenum:** Secure the slide of the duodenum to the microscope stage. Observe the tissue under low power to identify the four basic tunics of the intestinal wall—that is, the **mucosa** and its three sublayers, the **submucosa,** the **muscularis externa,** and the **serosa,** or *visceral peritoneum*. Consult Figure 38.9a to help you identify the scattered mucus-producing **duodenal glands** in the submucosa.

What type of epithelium do you see here? _____

_____

Examine the large leaflike *villi,* which increase the surface area for absorption. Notice the scattered mucus-producing goblet cells in the epithelium of the villi. Note also the **intestinal crypts** (see also Figure 38.8), invaginated areas of the mucosa between the villi containing the cells that produce intestinal juice, a watery mucus-containing mixture that serves as a carrier fluid for absorption of nutrients from the chyme. Sketch and label a small section of the duodenal wall, showing all layers and villi.



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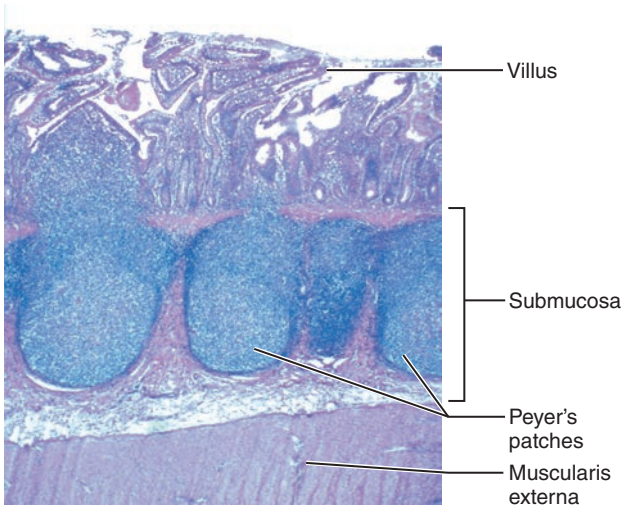

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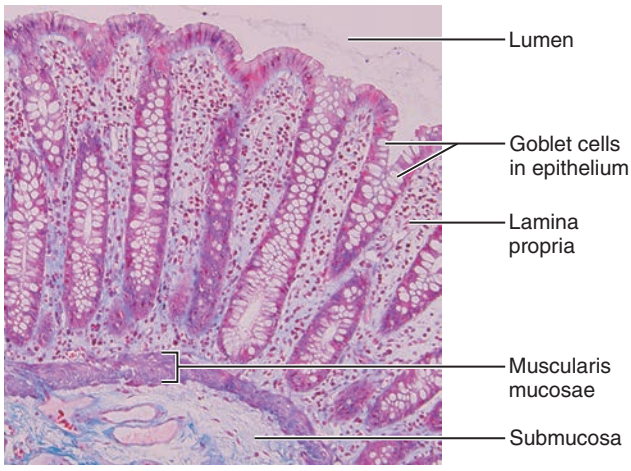

(c)

Figure 38.9 Histology of selected regions of the small and large intestines. Cross-sectional views. **(a)** Duodenum of the small intestine (95×). **(b)** Ileum of the small intestine (20×). **(c)** Large intestine (80×).

2. **Ileum:** The structure of the ileum resembles that of the duodenum, except that the villi are less elaborate (because most of the absorption has occurred by the time that chyme reaches the ileum). Secure a slide of the ileum to the microscope stage for viewing. Observe the villi, and identify the four layers of the wall and the large, generally spherical Peyer's patches (Figure 38.9b). What tissue type are Peyer's patches?

3. If a villus model is available, identify the following cells or regions before continuing: absorptive epithelium, goblet cells, lamina propria, the muscularis mucosae, capillary bed, and lacteal. If possible, also identify the intestinal crypts.

Large Intestine

The **large intestine** (**Figure 38.10**, p. 588) is about 1.5 m (5 feet) long and extends from the ileocecal valve to the anus. It encircles the small intestine on three sides and consists of the following subdivisions: **cecum, appendix, colon, rectum,** and **anal canal.**

The blind wormlike appendix, which hangs from the cecum, is a trouble spot in the large intestine. Since it is generally twisted, it provides an ideal location for bacteria to accumulate and multiply. Inflammation of the appendix, or appendicitis, is the result. ✚

The colon is divided into several distinct regions. The **ascending colon** travels up the right side of the abdominal cavity and makes a right-angle turn at the **right colic (hepatic) flexure** to cross the abdominal cavity as the **transverse colon.** It then turns at the **left colic (splenic) flexure** and continues down the left side of the abdominal cavity as the **descending colon,** where it takes an S-shaped course as the **sigmoid colon.** The sigmoid colon, rectum, and the anal canal lie in the pelvis anterior to the sacrum and thus are not considered abdominal cavity structures. Except for the transverse and sigmoid colons, the colon is retroperitoneal.

The anal canal terminates in the **anus,** the opening to the exterior of the body. The anal canal has two sphincters, a voluntary *external anal sphincter* composed of skeletal muscle, and an involuntary *internal anal sphincter* composed of smooth muscle. The sphincters are normally closed except during defecation, when undigested food and bacteria are eliminated from the body as feces.

In the large intestine, the longitudinal muscle layer of the muscularis externa is reduced to three longitudinal muscle bands called the **teniae coli.** Since these bands are shorter than the rest of the wall of the large intestine, they cause the wall to pucker into small pocketlike sacs called **haustra.** Fat-filled pouches of visceral peritoneum, called *epiploic appendages,* hang from the colon's surface.

The major function of the large intestine is to consolidate and propel the unusable fecal matter toward the anus and eliminate it from the body. While it does this task, it (1) provides a site where intestinal bacteria manufacture vitamins B and K; and (2) reclaims most of the remaining water from undigested food, thus conserving body water.

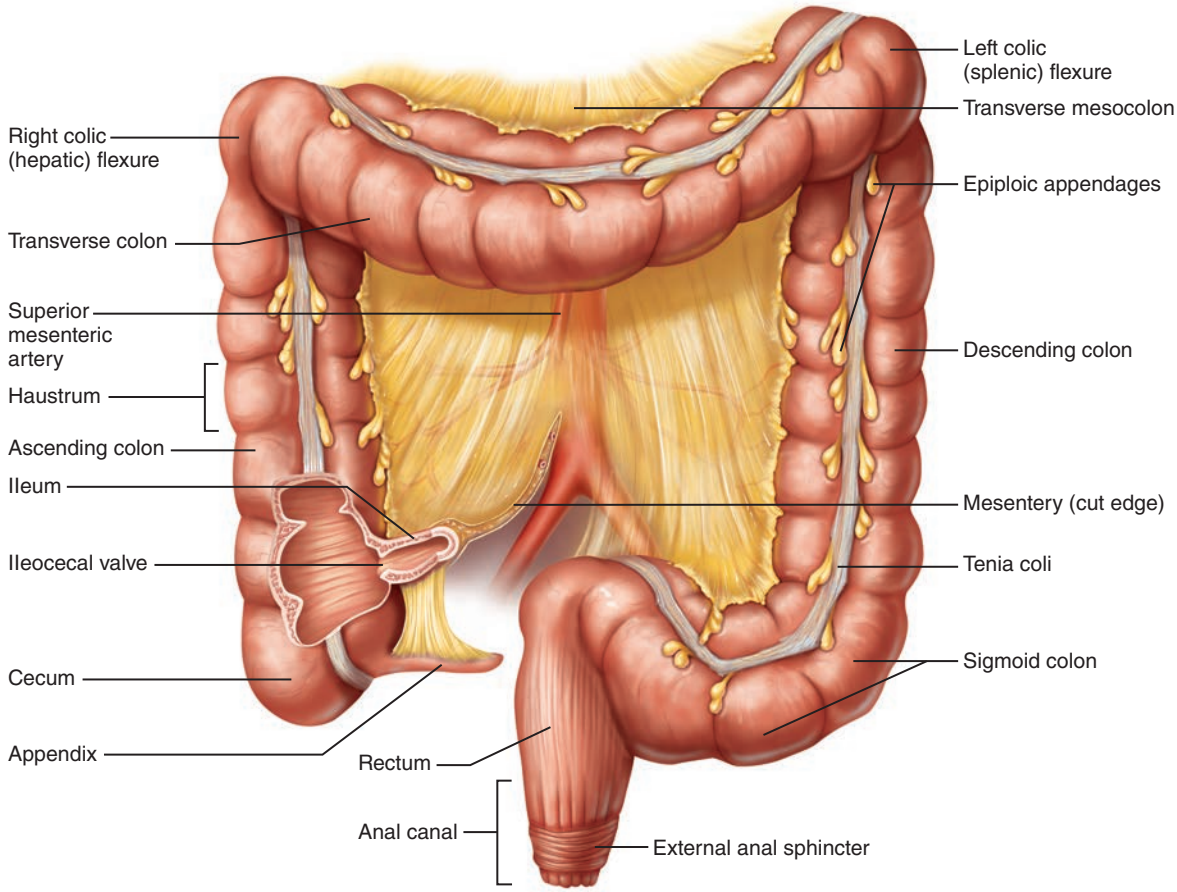

Figure 38.10 The large intestine. (Section of the cecum removed to show the ileocecal valve.)

Watery stools, or **diarrhea,** result from any condition that rushes undigested food residue through the large intestine before it has had sufficient time to absorb the water. Conversely, when food residue remains in the large intestine for extended periods, excessive water is absorbed and the stool becomes hard and difficult to pass, causing **constipation.** +

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Activity 4

Examining the Histologic Structure of the Large Intestine

Large intestine: Secure a slide of the large intestine to the microscope stage for viewing. Observe the numerous goblet cells in the epithelium (Figure 38.9c). Why do you think the large intestine produces so much mucus?

_____

_____

Accessory Digestive Organs

Teeth

By the age of 21, two sets of teeth have developed (**Figure 38.11**). The initial set, called the **deciduous** (or **milk**) **teeth,** normally appears between the ages of 6 months and 2½ years. The first of these to erupt are the lower central incisors. The child begins to shed the deciduous teeth around the age of 6, and a second set of teeth, the **permanent teeth,** gradually replaces them. As the deeper permanent teeth progressively enlarge and develop, the roots of the deciduous teeth are resorbed, leading to their final shedding.

Teeth are classified as **incisors, canines** *(eye teeth, cuspids),* **premolars** *(bicuspids),* and **molars.** The incisors are chisel shaped and exert a shearing action used in biting. Canines are cone-shaped teeth used for tearing food. The premolars have two *cusps* (grinding surfaces); the molars have broad crowns with rounded cusps specialized for the fine grinding of food.

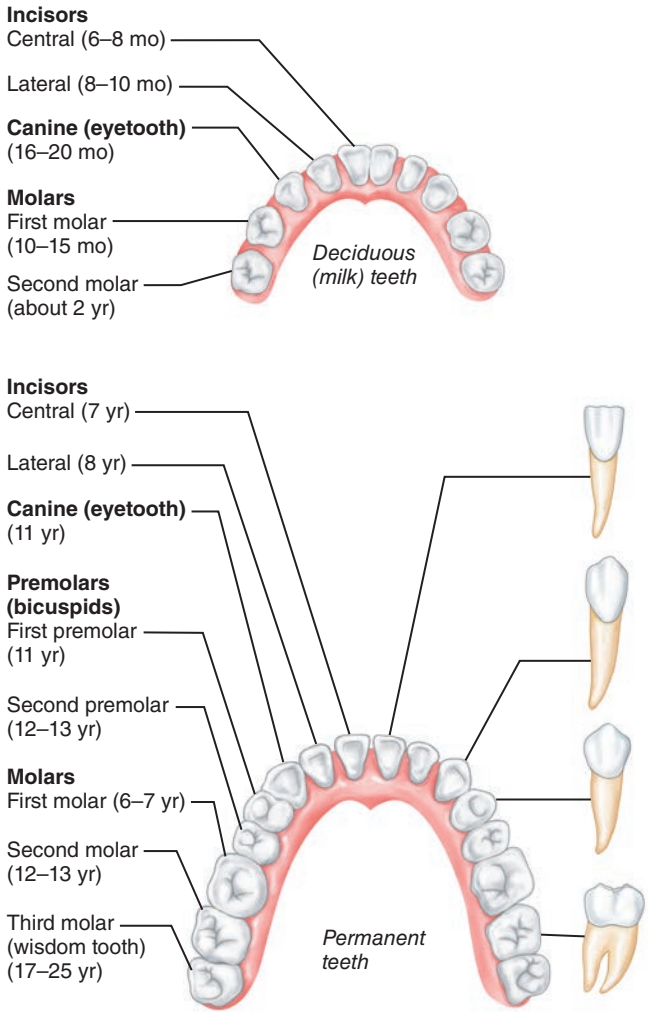


Figure 38.11 Human deciduous teeth and permanent teeth. (Approximate time of teeth eruption shown in parentheses.)

Dentition is described by means of a **dental formula,** which designates the numbers, types, and position of the teeth in one side of the jaw. Because tooth arrangement is bilaterally symmetrical, it is necessary to designate one only side of the jaw. The complete dental formula for the deciduous teeth from the medial aspect of each jaw and proceeding posteriorly is as follows:

$$\frac{\text{Upper teeth: 2 incisors, 1 canine, 0 premolars, 2 molars}}{\text{Lower teeth: 2 incisors, 1 canine, 0 premolars, 2 molars}} \times 2$$

This formula is generally abbreviated to read as follows:

$$\frac{2,1,0,2}{2,1,0,2} \times 2 \text{ (20 deciduous teeth)}$$

The permanent teeth are then described by the following dental formula:

$$\frac{2,1,2,3}{2,1,2,3} \times 2 \text{ (32 permanent teeth)}$$

Although 32 is designated as the normal number of permanent teeth, not everyone develops a full set. In many people, the third molars, commonly called *wisdom teeth,* never erupt.

Activity 5

Identifying Types of Teeth

Identify the four types of teeth (incisors, canines, premolars, and molars) on the jaw model or human skull.

A tooth consists of two major regions, the **crown** and the **root.** These two regions meet at the **neck** near the gum line. A longitudinal section made through a tooth shows the following basic anatomical plan (**Figure 38.12**). The crown is the superior portion of the tooth visible above the **gingiva,** or **gum,** which surrounds the tooth. The surface of the crown is covered by **enamel.** Enamel consists of 95% to 97% inorganic calcium salts and thus is heavily mineralized. The crevice between the end of the crown and the upper margin of the gingiva is referred to as the *gingival sulcus.*

That portion of the tooth embedded in the bone is the root. The outermost surface of the root is covered by **cement,** which is similar to bone in composition and less brittle than enamel. The cement attaches the tooth to the **periodontal ligament,** which holds the tooth in the tooth socket and exerts a cushioning effect. **Dentin,** which composes the bulk of the tooth, is the bonelike material interior to the enamel and cement.

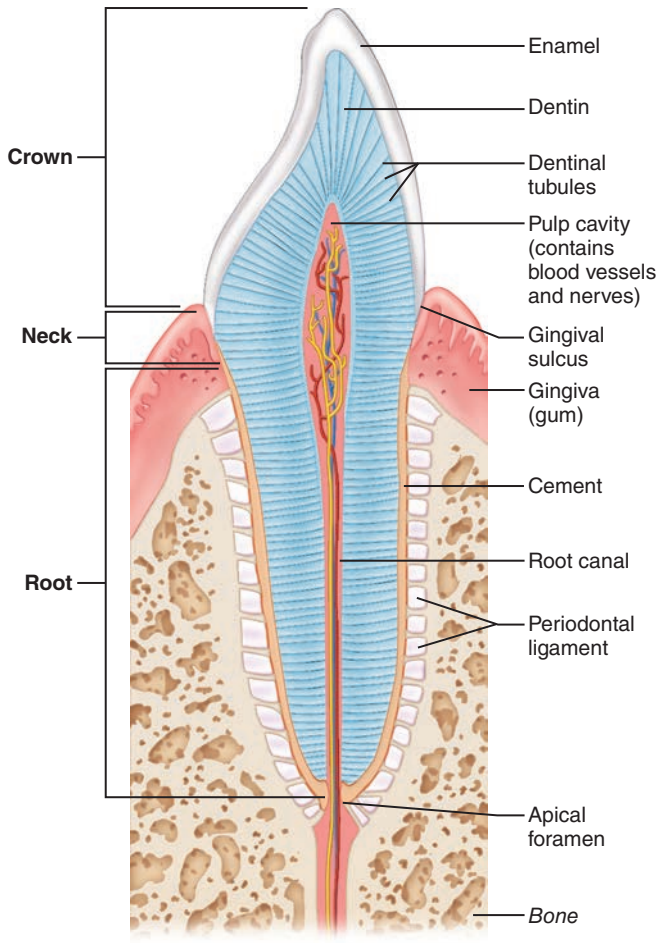


Figure 38.12 Longitudinal section of human canine tooth within its bony socket (alveolus).

The **pulp cavity** occupies the central portion of the tooth. **Pulp,** connective tissue liberally supplied with blood vessels, nerves, and lymphatics, occupies this cavity and provides for tooth sensation and supplies nutrients to the tooth tissues. **Odontoblasts,** specialized cells in the outer margins of the pulp cavity, produce the dentin. Odontoblasts have slender processes that extend into the *dentinal tubules* of the dentin. The pulp cavity extends into distal portions of the root and becomes the **root canal.** An opening at the root apex, the **apical foramen,** provides a route of entry into the tooth for blood vessels, nerves, and other structures from the tissues beneath.

Activity 6

Studying Microscopic Tooth Anatomy

Observe a slide of a longitudinal section of a tooth, and compare your observations with the structures detailed in Figure 38.12. Identify as many of these structures as possible.

Salivary Glands

Three pairs of major **salivary glands** (see Figure 38.1) empty their secretions into the oral cavity.

Parotid glands: Large glands located anterior to the ear and ducting into the mouth over the second upper molar through the parotid duct.

Submandibular glands: Located along the medial aspect of the mandibular body in the floor of the mouth, and ducting under the tongue to the base of the lingual frenulum.

Sublingual glands: Small glands located most anteriorly in the floor of the mouth and emptying under the tongue via several small ducts.

Food in the mouth and mechanical pressure stimulate the salivary glands to secrete saliva. Saliva consists primarily of a glycoprotein called *mucin,* which moistens the food and helps to bind it together into a mass called a **bolus,** and a clear serous fluid containing the enzyme *salivary amylase.* Salivary amylase begins the digestion of starch. Parotid gland secretion is mainly serous; the submandibular is a mixed gland that produces both mucin and serous components; and the sublingual gland is a mixed gland that produces mostly mucin.

Activity 7

Examining Salivary Gland Tissue

Examine salivary gland tissue under low power and then high power to become familiar with the appearance of a glandular tissue. Notice the clustered arrangement of the cells around their ducts. The cells are basically triangular, with their pointed ends facing the duct opening. Differentiate between mucus-producing cells, which have a clear cytoplasm, and serous cells, which have granules in their cytoplasm. The serous cells often form *demilunes* (caps) around the more central mucous cells. (**Figure 38.13** may be helpful in this task.)

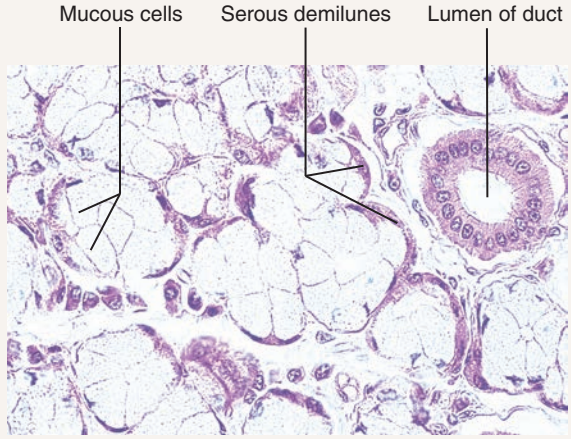


Figure 38.13 Histology of a mixed salivary gland. Sublingual gland (170×).

Liver and Gallbladder

The **liver** (see Figure 38.1), the largest gland in the body, is located inferior to the diaphragm, more to the right than the left side of the body. The human liver has four lobes and is suspended from the diaphragm and anterior abdominal wall by the **falciform ligament** (**Figure 38.14**).

The liver performs many metabolic roles. However, its digestive function is to produce bile, which leaves the liver through the **common hepatic duct** and then enters the duodenum through the **bile duct** (**Figure 38.15**). Bile has no enzymatic action but emulsifies fats, breaking up fat globules into small droplets. Without bile, very little fat digestion or absorption occurs.

When digestive activity is not occurring in the digestive tract, bile backs up into the **cystic duct** and enters the **gallbladder,** a small, green sac on the inferior surface of the liver. Bile is stored there until needed for the digestive process.

If the common hepatic or bile duct is blocked (for example, by wedged gallstones), bile is prevented from entering the small intestine, accumulates, and eventually backs up into the liver. This exerts pressure on the liver cells, and bile begins to enter the bloodstream. As the bile circulates through the body, the tissues become yellow, or jaundiced.

Blockage of the ducts is just one cause of jaundice. More often it results from actual liver problems such as **hepatitis,** (which is any inflammation of the liver,) or **cirrhosis,** a condition in which the liver is severely damaged and becomes hard and fibrous. ✚

As demonstrated by its highly organized anatomy, the liver (**Figure 38.16**, p. 592) is very important in the initial processing of the nutrient-rich blood draining the digestive organs. Its structural and functional units are called **lobules.** Each lobule is a basically hexagonal structure consisting of cordlike arrays of **hepatocytes** or *liver cells,* which radiate outward from a central vein running upward in the longitudinal axis of the lobule. At each of the six corners of the lobule is a **portal triad,** so named because three basic structures are always present there: a *portal arteriole* (a branch of the *hepatic artery,* the functional blood supply of the liver), a *portal venule* (a branch of the *hepatic portal vein* carrying nutrient-rich blood from the digestive viscera), and a *bile duct.* Between the liver cells are blood-filled spaces, or **sinusoids,** through which

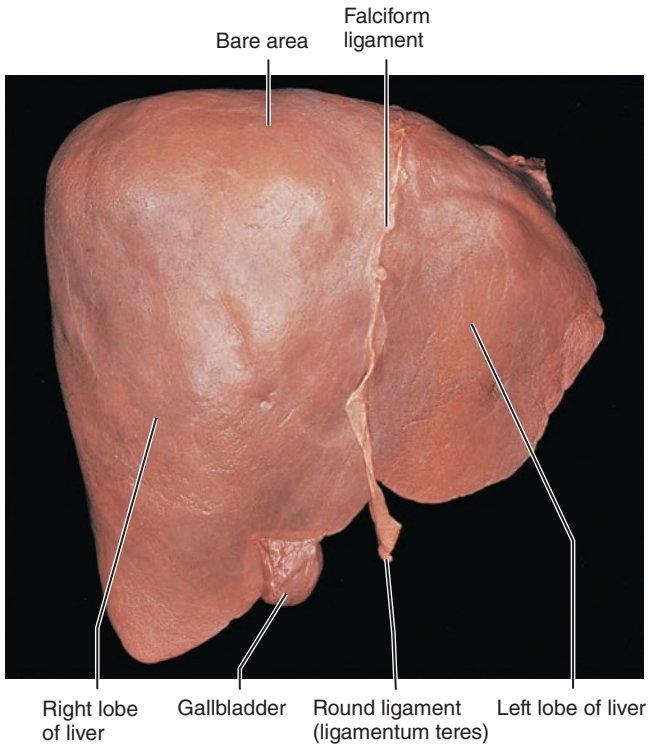


Figure 38.14 Gross anatomy of the human liver. **(a)** Anterior view. **(b)** Posteroinferior aspect. The four liver lobes are separated by a group of fissures in this view.

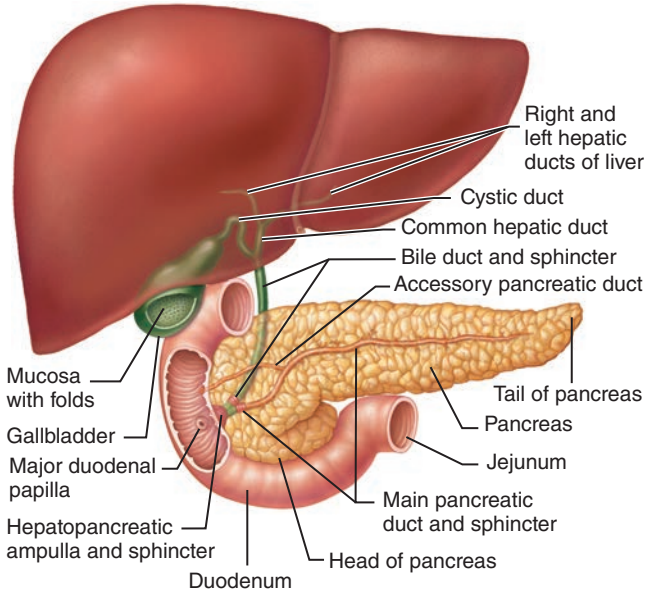


Figure 38.15 Ducts of accessory digestive organs.

blood from the hepatic portal vein and hepatic artery percolates. **Stellate macrophages,** special phagocytic cells, also called **hepatic macrophages,** line the sinusoids and remove debris such as bacteria from the blood as it flows past, while the hepatocytes pick up oxygen and nutrients. The sinusoids empty into the central vein, and the blood ultimately drains from the liver via the *hepatic veins.*

Bile is continuously being made by the hepatocytes. It flows through tiny canals, the **bile canaliculi,** which run between adjacent cells toward the bile duct branches in the triad regions, where the bile eventually leaves the liver.

Activity 8

Examining the Histology of the Liver

Examine a slide of liver tissue and identify as many as possible of the structural features (see Figure 38.16). Also examine a three-dimensional model of liver lobules if this is available. Reproduce a small pie-shaped section of a liver lobule in the space below. Label the hepatocytes, the stellate macrophages, sinusoids, a portal triad, and a central vein.

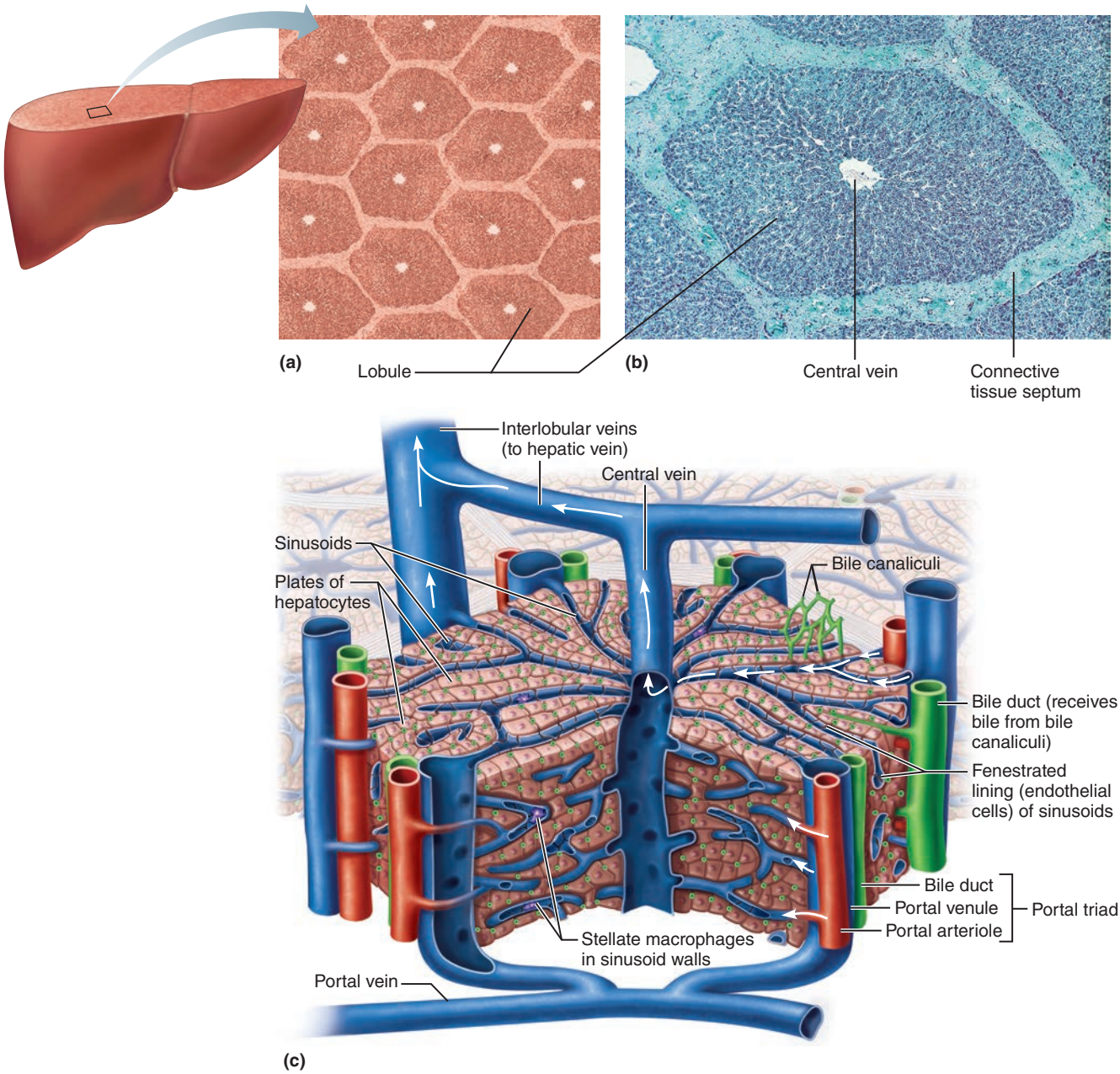


Figure 38.16 Microscopic anatomy of the liver. (a) Schematic view of the cut surface of the liver showing the hexagonal nature of its lobules. **(b)** Photomicrograph of one liver lobule (55×). **(c)** Enlarged three-dimensional diagram of one liver lobule. Arrows show direction of blood flow. Bile flows in the opposite direction toward the bile ducts.

Pancreas

The **pancreas** is a soft, triangular gland that extends horizontally across the posterior abdominal wall from the spleen to the duodenum (see Figure 38.1). Like the duodenum, it is a retroperitoneal organ (see Figure 38.7). The pancreas has both an endocrine function, producing the hormones insulin and glucagon, and an exocrine function. Its exocrine secretion includes many hydrolytic enzymes produced by the acinar cells and is secreted into the duodenum through the pancreatic duct. Pancreatic juice is very alkaline. Its high concentration of bicarbonate ion (HCO_3^-) neutralizes the acidic chyme entering the duodenum from the stomach, enabling the pancreatic and intestinal enzymes to operate at their optimal pH, which is slightly alkaline. (See Figure 27.3c.)

For instructions on animal dissections, see the dissection exercises (starting on p. 705) in the cat and fetal pig editions of this manual.

EXERCISE 38

REVIEW SHEET

Anatomy of the Digestive System

Name _____ Lab Time/Date _____

General Histological Plan of the Alimentary Canal

1. The general anatomical features of the alimentary canal are listed below. Fill in the table to complete the information.

Wall layer	Subdivisions of the layer (if applicable)	Major functions
Mucosa		
Submucosa		
Muscularis externa		
Serosa or adventitia		

Organs of the Alimentary Canal

2. The tubelike digestive system canal that extends from the mouth to the anus is known as the _____ canal or the _____ tract.

3. How is the muscularis externa of the stomach modified? _____

How does this modification relate to the function of the stomach? _____

4. What transition in epithelial type exists at the gastroesophageal junction? _____

How do the epithelia of these two organs relate to their specific functions?

5. Differentiate the colon from the large intestine. _____

6. Match the items in column B with the descriptive statements in column A.

Column A

_____ 1. structure that suspends the small intestine from the posterior body wall

_____ 2. fingerlike extensions of the intestinal mucosa that increase the surface area for absorption

_____ 3. large collections of lymphoid tissue found in the submucosa of the small intestine

_____ 4. deep folds of the mucosa and submucosa that extend completely or partially around the circumference of the small intestine

_____ 5. mobile organ that manipulates food in the mouth and initiates swallowing

_____ 6. conduit for both air and food

_____ 7. the "gullet"; no digestive/absorptive function

_____ 8. folds of the gastric mucosa

_____ 9. pocketlike sacs of the large intestine

_____ 10. projections of the plasma membrane of a mucosal epithelial cell

_____ 11. valve at the junction of the small and large intestines

_____ 12. primary region of food and water absorption

_____ 13. membrane securing the tongue to the floor of the mouth

_____ 14. absorbs water and forms feces

_____ 15. area between the teeth and lips/cheeks

_____ 16. wormlike sac that outpockets from the cecum

_____ 17. initiates protein digestion

_____ 18. structure attached to the lesser curvature of the stomach

_____ 19. covers most of the abdominal organs like an apron

_____ 20. valve controlling food movement from the stomach into the duodenum

_____ 21. posterosuperior boundary of the oral cavity

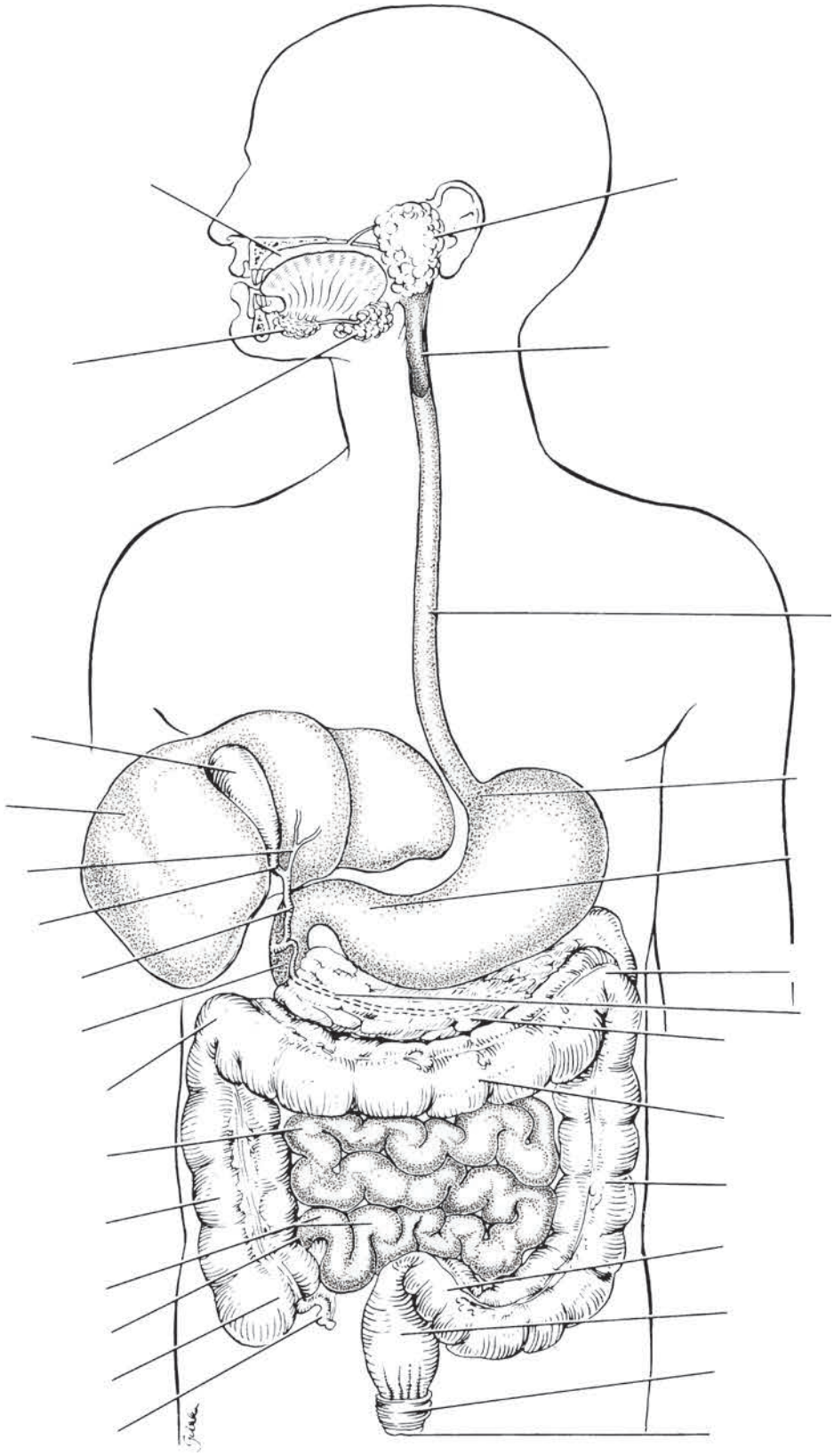
_____ 22. region containing two sphincters through which feces are expelled from the body

_____ 23. bone-supported anterosuperior boundary of the oral cavity

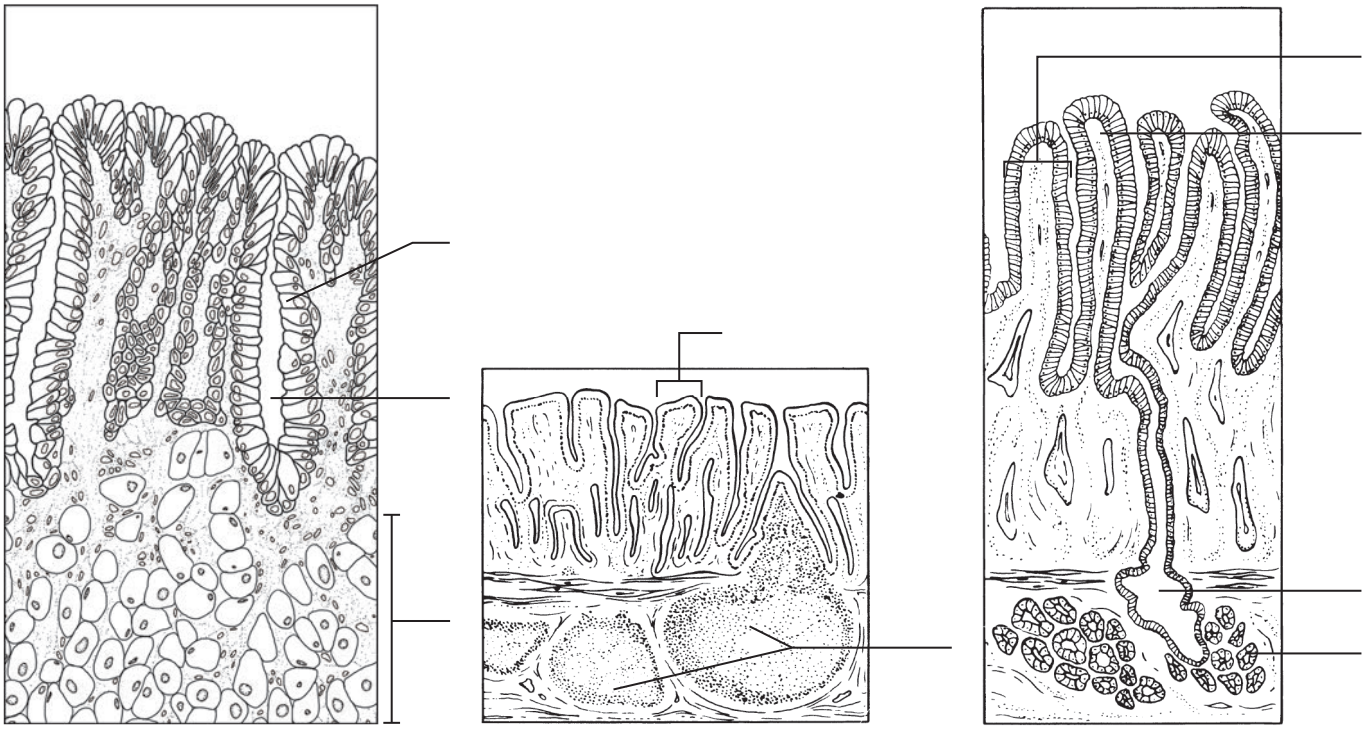
Column B

a. anus
b. appendix
c. circular folds
d. esophagus
e. frenulum
f. greater omentum
g. hard palate
h. haustra
i. ileocecal valve
j. large intestine
k. lesser omentum
l. mesentery
m. microvilli
n. oral vestibule
o. Peyer's patches
p. pharynx
q. pyloric valve
r. rugae
s. small intestine
t. soft palate
u. stomach
v. tongue
w. villi

7. Correctly identify all organs depicted in the diagram below.



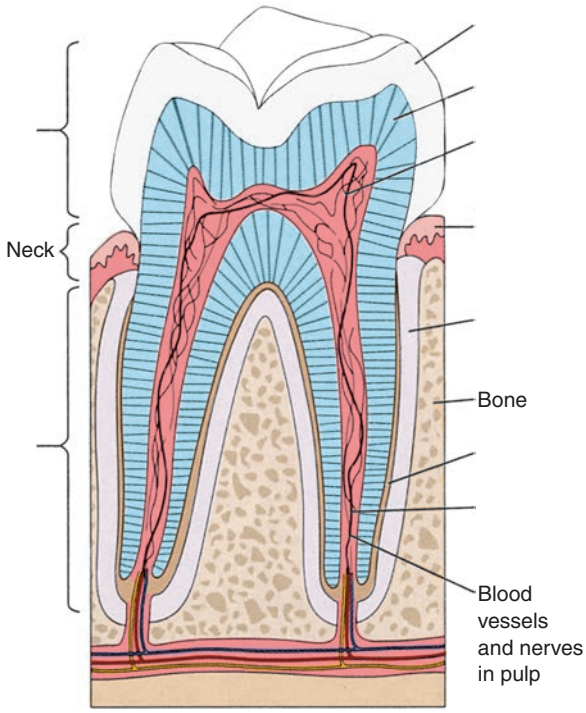
8. You have studied the histologic structure of a number of organs in this laboratory. Three of these are diagrammed below. Identify and correctly label each.



(a) _____ (b) _____ (c) _____

Accessory Digestive Organs

9. Correctly label all structures provided with leader lines in the diagram of a molar below. (Note: Some of the terms in the key for question 10 may be helpful in this task.)



10. Use the key to identify each tooth area described below.

Key: a. cement
b. crown
c. dentin
d. enamel
e. gingival sulcus
f. odontoblast
g. periodontal ligament
h. pulp
i. root

_____ 1. visible portion of the tooth in situ

_____ 2. material covering the tooth root

_____ 3. hardest substance in the body

_____ 4. attaches the tooth to the tooth socket

_____ 5. portion of the tooth embedded in bone

_____ 6. forms the major portion of tooth structure; similar to bone

_____ 7. produces the dentin

_____ 8. site of blood vessels, nerves, and lymphatics

_____ 9. narrow gap between the crown and the gum

11. In the human, the number of deciduous teeth is _____; the number of permanent teeth is _____.

12. The dental formula for permanent teeth is $\frac{2,1,2,3}{2,1,2,3} \times 2$

Explain what this means. _____

_____

What is the dental formula for the deciduous teeth? _____ × _____ (_____ deciduous teeth)

13. Which teeth are the "wisdom teeth"? _____

14. Various types of glands form a part of the alimentary canal wall or duct their secretions into it. Match the glands listed in column B with the function/locations described in column A.

Column A

_____ 1. produce(s) mucus; found in the submucosa of the small intestine

_____ 2. produce(s) a product containing amylase that begins starch breakdown in the mouth

_____ 3. produce(s) many enzymes and an alkaline fluid that is secreted into the duodenum

_____ 4. produce(s) bile that it secretes into the duodenum via the bile duct

_____ 5. produce(s) HCl and pepsinogen

_____ 6. found in the mucosa of the small intestine; produce(s) intestinal juice

Column B

a. duodenal glands
b. gastric glands
c. intestinal crypts
d. liver
e. pancreas
f. salivary glands

15. Which of the salivary glands produces a secretion that is mainly serous? _____

16. What is the role of the gallbladder? _____

17. Name three structures always found in the portal triad regions of the liver. _____,

_____, and _____

18. Where would you expect to find the stellate macrophages of the liver? _____

What is their function? _____

19. Why is the liver so dark red in the living animal? _____

_____

20. The pancreas has two major populations of secretory cells—those in the islets and the acinar cells. Which population serves the digestive process? _____