



(Objective Checklist, continued)

- List the major enzymes or enzyme groups produced by the digestive organs or accessory glands, and name the foodstuffs on which they act.
- Name the end products of protein, fat, and carbohydrate digestion.
- State the function of bile in the digestive process.

## **PART II: NUTRITION AND METABOLISM**

### **NUTRITION (pp. 478–480)**

- Define *nutrient* and *calorie*.
- List the six major nutrient categories. Note important dietary sources and the principal cellular uses of each.

### **METABOLISM (pp. 480–490)**

- Define *enzyme*, *metabolism*, *anabolism*, and *catabolism*.
- Describe the metabolic roles of the liver.
- Recognize the sources of carbohydrates, fats, and proteins and their uses in cell metabolism.
- Explain the importance of energy balance in the body, and indicate consequences of energy imbalance.
- List several factors that influence metabolic rate, and indicate the effect of each.
- Describe how body temperature is regulated.

## **PART III: DEVELOPMENTAL ASPECTS OF THE DIGESTIVE SYSTEM AND METABOLISM (pp. 490–491)**

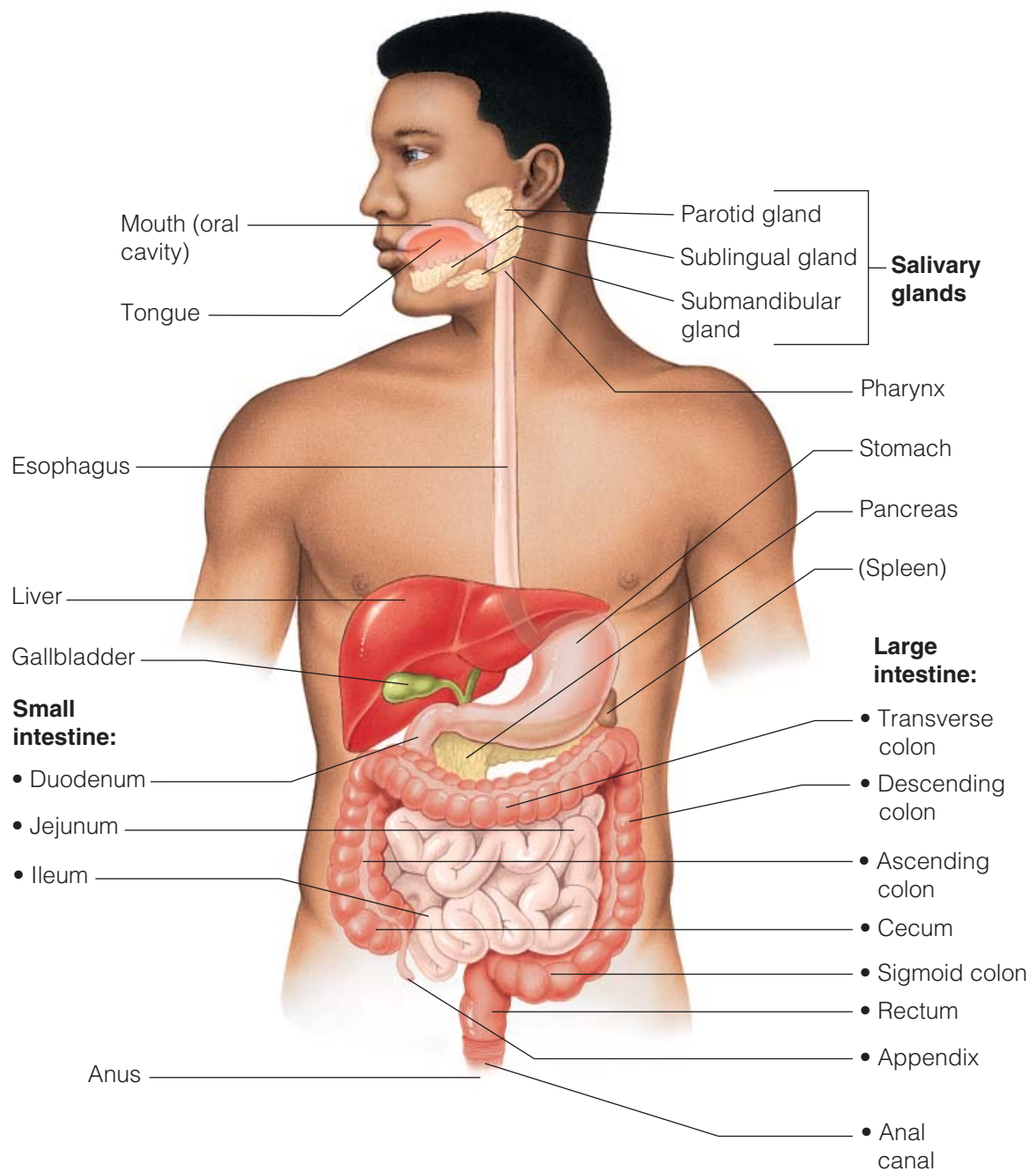
- Name important congenital disorders of the digestive system and significant inborn errors of metabolism.
- Describe the effect of aging on the digestive system.

Children have a special fascination with the workings of the digestive system: They relish crunching a potato chip, delight in making “mustaches” with milk, and giggle when their stomach “growls.” As adults, we know that a healthy digestive system is essential for good health because it converts food into the raw materials that build and fuel our body’s cells. Specifically, the digestive system takes in food (*ingests* it), breaks it down physically and chemically into nutrient molecules (*digests* it), and *absorbs* the nutrients into the bloodstream. Then it rids the body of the indigestible remains (*defecates*).

## **PART I: ANATOMY AND PHYSIOLOGY OF THE DIGESTIVE SYSTEM**

### **Anatomy of the Digestive System**

The organs of the digestive system can be separated into two main groups: those forming the *alimentary* (al’ē-men’tar-e; *aliment* = nourish) *canal*,



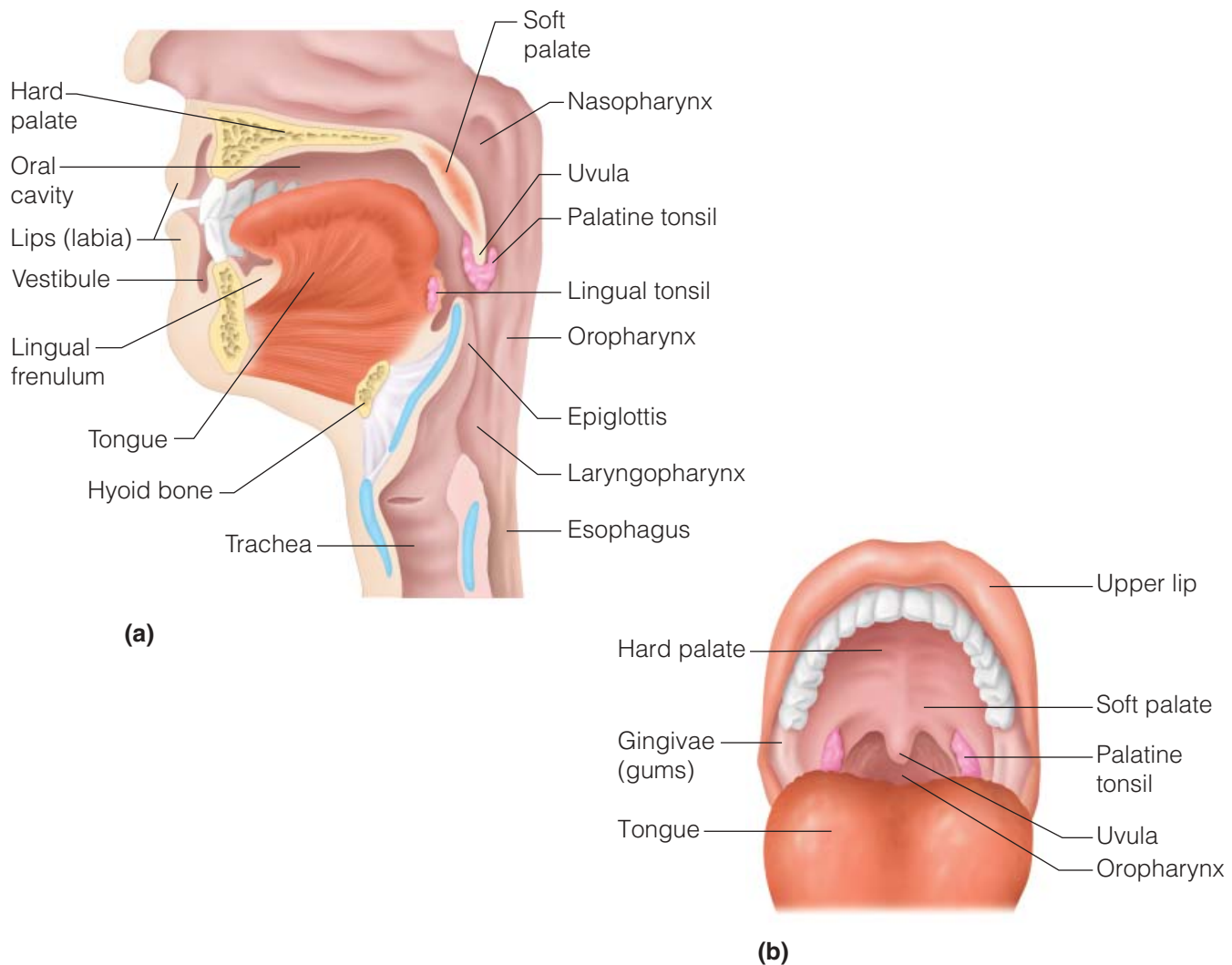
**FIGURE 14.1** The human digestive system: Alimentary canal and accessory organs. (Liver and gallbladder are reflected superiorly and to the right side of the body.)

and the *accessory digestive organs* (see Figure 14.1). The alimentary canal performs the whole menu of digestive functions (ingests, digests, absorbs, and defecates). The accessory organs (teeth, tongue, and several large digestive glands) assist the process of digestive breakdown in various ways.

## Organs of the Alimentary Canal

The **alimentary canal**, also called the **gastrointestinal (GI) tract**, is a continuous, coiled, hollow, muscular tube that winds through the ventral body cavity and is open at both ends. Its organs are the

**Q** What is the protective value of having several sets of tonsils at the oral entrance to the pharynx?



**FIGURE 14.2 Anatomy of the mouth (oral cavity).** (a) Sagittal view of the oral cavity and pharynx. (b) Anterior view of the oral cavity.

*mouth, pharynx, esophagus, stomach, small intestine, and large intestine.* The large intestine leads to the terminal opening, or *anus*. In a cadaver, the alimentary canal is approximately 9 m (about 30 feet) long, but in a living person, it is considerably shorter because of its relatively constant muscle tone. Food material within this tube is technically

outside the body, because it has contact only with cells lining the tract and the tube is open to the external environment at both ends. As each organ of the alimentary canal is described next, find it in Figure 14.1.

### Mouth

Food enters the digestive tract through the **mouth**, or **oral cavity**, a mucous membrane-lined cavity (Figure 14.2). The **lips (labia)** protect its anterior opening, the **cheeks** form its lateral walls, the **hard palate** forms its anterior roof, and the **soft**

**A**

The mouth is a favored site of body entry by bacteria, and the presence of the tonsils (lymphocyte- and macrophage-filled organs) is very effective in preventing many pathogens from getting further into the digestive tract.

**palate** forms its posterior roof. The **uvula** (u'vu-lah) is a fleshy fingerlike projection of the soft palate, which extends downward from its posterior edge. The space between the lips and cheeks externally and the teeth and gums internally is the **vestibule**. The area contained by the teeth is the **oral cavity proper**. The muscular **tongue** occupies the floor of the mouth. The tongue has several bony attachments—two of these are to the hyoid bone and the styloid processes of the skull. The **lingual frenulum** (ling'gwah fren'u-lum), a fold of mucous membrane, secures the tongue to the floor of the mouth and limits its posterior movements (see Figure 14.2a).

### Homeostatic Imbalance

Children born with an extremely short frenulum are often referred to as “tongue-tied” because distorted speech results when tongue movement is restricted. This congenital condition can be corrected surgically by cutting the frenulum. ▲

At the posterior end of the oral cavity are paired masses of lymphatic tissue, the **palatine tonsils**. The **lingual tonsil** covers the base of the tongue just beyond. The tonsils, along with other lymphatic tissues, are part of the body's defense system. When the tonsils become inflamed and enlarge, they partially block the entrance into the throat (pharynx), making swallowing difficult and painful.

As food enters the mouth, it is mixed with saliva and **masticated** (chewed). The cheeks and closed lips hold the food between the teeth during chewing. The nimble tongue continually mixes food with saliva during chewing and initiates swallowing. Thus, the breakdown of food begins before the food has even left the mouth. As noted in Chapter 8, *papillae* containing taste buds, or taste receptors, are found on the tongue surface. And so, besides its food-manipulating function, the tongue allows us to enjoy and appreciate the food as it is eaten.

## Pharynx

From the mouth, food passes posteriorly into the *oropharynx* and *laryngopharynx*, both of which are common passageways for food, fluids, and air. As explained in Chapter 13, the pharynx is subdivided into the *nasopharynx*, part of the respiratory passageway; the **oropharynx**, posterior to the

oral cavity; and the **laryngopharynx**, which is continuous with the esophagus below.

The walls of the pharynx contain two skeletal muscle layers. The cells of the inner layer run longitudinally; those of the outer layer (the constrictor muscles) run around the wall in a circular fashion. Alternating contractions of these two muscle layers propel food through the pharynx into the esophagus below. This propelling mechanism, called *peristalsis* (per'i-stal'sis), is described later.

## Esophagus

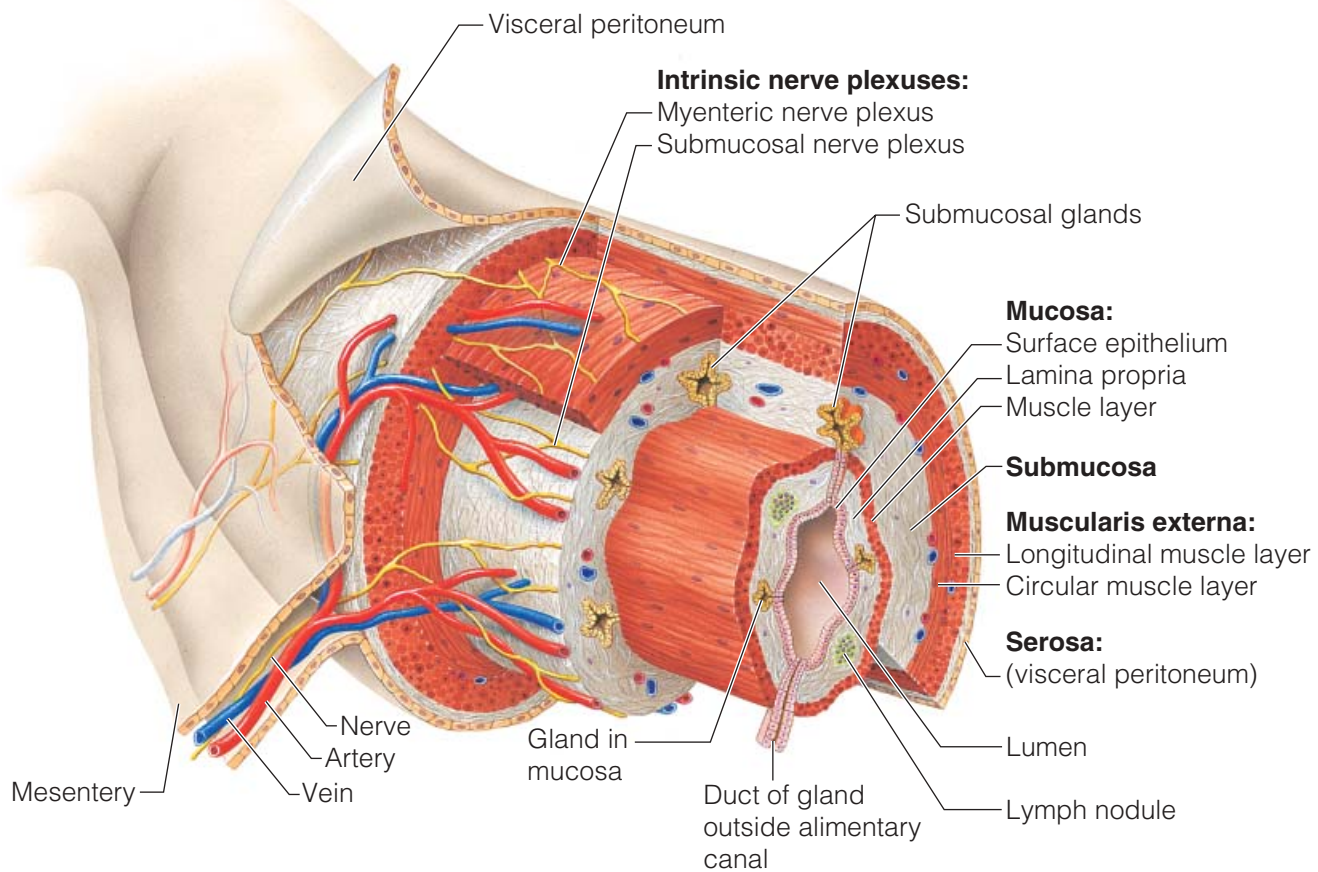
The **esophagus** (ě-sof'ah-gus), or *gullet*, runs from the pharynx through the diaphragm to the stomach. About 25 cm (10 inches) long, it is essentially a passageway that conducts food (by peristalsis) to the stomach.

The walls of the alimentary canal organs from the esophagus to the large intestine are made up of the same four basic tissue layers, or tunics (Figure 14.3):

1. The **mucosa** is the innermost layer, a moist membrane that lines the cavity, or **lumen**, of the organ. It consists primarily of a *surface epithelium*, plus a small amount of connective tissue (*lamina propria*) and a scanty *smooth muscle layer*. Beyond the esophagus, which has a friction-resisting stratified squamous epithelium, the epithelium is mostly simple columnar.
2. The **submucosa** is found just beneath the mucosa. It is a soft connective tissue layer containing blood vessels, nerve endings, lymph nodules, and lymphatic vessels.
3. The **muscularis externa** is a muscle layer typically made up of an inner *circular layer* and an outer *longitudinal layer* of smooth muscle cells.
4. The **serosa** is the outermost layer of the wall. It consists of a single layer of flat serous fluid-producing cells, the **visceral peritoneum** (per'i-to-ne'um). The visceral peritoneum is continuous with the slick, slippery **parietal peritoneum**, which lines the abdominopelvic cavity by way of a membrane extension, the **mesentery** (mes'en-ter'e). These relationships are illustrated in Figure 14.5.

The alimentary canal wall contains two important *intrinsic nerve plexuses*—the **submucosal nerve**





**FIGURE 14.3** Basic structure of the alimentary canal wall.

**plexus** and the **myenteric** (mi-en'ter-ik; "intestinal muscle") **nerve plexus**. An additional small *subserous plexus* is associated with the serosa. These networks of nerve fibers are actually part of the autonomic nervous system. They help regulate the mobility and secretory activity of GI tract organs.

### Stomach

The **C-shaped stomach** (Figure 14.4) is on the left side of the abdominal cavity, nearly hidden by the liver and diaphragm. Different regions of the stomach have been named. The *cardiac region* (named for its position near the heart) surrounds the **cardioesophageal** (kar'de-o-ě-sof'ah-je'al) **sphincter**, through which food enters the stomach from the esophagus. The *fundus* is the expanded part of the stomach lateral to the cardiac region. The *body* is the midportion, and as it narrows inferiorly, it becomes the *pyloric antrum*, and then the funnel-

shaped *pylorus* (pi-lo'rus), the terminal part of the stomach. The pylorus is continuous with the small intestine through the **pyloric sphincter**, or **valve**. The stomach is approximately 25 cm (10 inches) long, but its diameter depends on how much food it contains. When it is full, it can hold about 4 liters (1 gallon) of food. When it is empty, it collapses inward on itself, and its mucosa is thrown into large folds called **rugae** (roo'ge; *ruga* = wrinkle, fold). The convex lateral surface of the stomach is the **greater curvature**; its concave medial surface is the **lesser curvature**.

The **lesser omentum** (o-men'tum), a double layer of peritoneum, extends from the liver to the lesser curvature. The **greater omentum**, another extension of the peritoneum, drapes downward and covers the abdominal organs like a lacy apron before attaching to the posterior body wall (Figure 14.5). The greater omentum is riddled with