26. Digestive System

Your body needs food for two primary purposes: growth and maintenance. Molecules and atoms in the food you eat are generally used to either build new molecules in your body or to provide the energy you need for metabolism. The overall functions of the digestive system are to digest food and absorb it into your body.

I. Introduction to the Digestive System

General functions of the digestive system
Your text breaks down the functions of the digestive system into a series of integrated steps:
A. **Ingestion** is the active process of getting food, water, etc. into the system.
B. **Motility** is the movement of food through the alimentary canal. This includes swallowing and peristalsis.
C. **Secretion** of various fluids that contain digestive enzymes, acids, bile, mucus, etc.
D. **Digestion** is the process of breaking foodstuffs down into smaller and smaller particles until they can be absorbed into the tissues. **Mechanical digestion** is chewing or other physical manipulation of ingested materials. Mechanical processing aids the passage of materials into the digestive tract and increases the surface area for chemical attack of the food. **Chemical digestion** is the breakdown of food into small molecules that can be absorbed by the digestive epithelium. Chemical digestion is accomplished by enzymes and acids.
E. **Absorption** is the movement of organic molecules, electrolytes, vitamins, etc. into the body.
F. **Elimination** is the removal of waste products (generally either undigested food or wastes from the body itself) in the form of feces.

Organization of the digestive system
The adult digestive system can be divided into two major components (Fig. 26.1):
A. The **gastrointestinal tract** (i.e., alimentary canal) is a hollow tube that runs from the mouth to the anus. What specific organs make up the digestive tract?

B. Working with the digestive tract are a variety of **accessory digestive organs**. What specific organs are included?

Gastrointestinal tract wall
Walls of the digestive tract consist of four tissue layers (Fig. 26.2). Some details may vary from one part of the tract to another, but the basics of the four layers apply to the entire tract.

A. The **mucosa** is the layer exposed to the lumen. Like all mucous membranes, it is composed of an epithelial layer and an underlying layer of areolar tissue, the **lamina propria**. The epithelium is stratified in areas that receive the most mechanical stress (e.g., the oral cavity, pharynx, and esophagus), and it is simple epithelium in the stomach, small intestine, and large intestine. The lamina propria contains blood vessels, mucous glands, and sensory nerve endings. In most areas of the digestive tract, the lamina propria also contains smooth muscle cells, which make up a layer of tissue called the
**muscularis mucosae.** This muscle produces local movements of the mucosa and does not really move food through the tract. In the small intestine this muscle makes folds in the mucosa to increase surface area.

B. The **submucosa** is a layer of moderately dense, irregular connective tissue. It contains blood vessels and some exocrine glands that secrete buffers and enzymes into the lumen of the digestive tract.

C. The **muscularis externa** is a region dominated by smooth muscle cells. The muscle cells are arranged in an inner, *circular*, layer and an outer, *longitudinal*, layer. It is these layers of muscle that are responsible for peristalsis. In several places along the tract, there are particularly thick areas of circular muscle that form **sphincters**.

D. The **serosa** is a serous membrane that lines most of the digestive tract inside the peritoneal cavity. The serosa is not present at the oral cavity, pharynx, esophagus, or rectum. In the pharynx, esophagus, and rectum the muscularis externa is lined by a network of collagen fibers called the **adventitia**.

Serous membranes of the abdominal cavity

Portions of the digestive tract are suspended within the **peritoneal cavity** by **mesenteries**. Mesenteries are sheets of serous membrane that connect the **parietal peritoneum** to the **visceral peritoneum**. Serous fluid can be found in the space between the parietal and visceral peritoneum. Mesenteries provide passage for blood vessels, nerves, and lymphatic vessels, and they support the positions of digestive organs within the peritoneal cavity.

Portions of some digestive organs, including the pancreas and large intestine, lose their mesentery and lie posterior to the peritoneum. These structures are said to be **retroperitoneal**.

**II. Upper Gastrointestinal Tract**

**Oral cavity and salivary glands**

The **oral** (or **buccal**) **cavity** is the mouth, which contains the teeth and the tongue (Fig. 26.4). Functions of the oral cavity include (1) ingestion, (2) analysis of food before swallowing, (3) mechanical digestion, (4) lubrication with mucus and saliva, and (5) limited chemical digestion.

The oral cavity is bordered by the **palate, lips, tongue, and cheeks**. The palate enables you to chew food and breathe at the same time. Chewing food before swallowing allows quicker digestion and faster processing of energy. The **vestibule** is the space between the cheeks or lips and the teeth. The area within the teeth and gums is the **oral cavity proper**. The **gingivae** are the gums. The **uvula** is a dangling extension of the soft palate, which helps prevent food from entering the nasopharynx.

**The tongue**

The **tongue** occupies the lower portion of the oral cavity. It is made of skeletal muscle (voluntary control) covered in a layer of mucous membrane. The anterior portion of the tongue is referred to as the **body**, and the posterior portion is the **root**. The tongue moves food around the mouth during chewing, helps mix food with saliva, and forms food into a **bolus** for swallowing.
The superior surface of the tongue is covered with projections called the lingual papillae. The papillae contain taste buds and make the surface of the tongue rough. The front of the tongue is attached to the floor of the mouth by the lingual frenulum.

**Salivary glands**

Salivary glands secrete saliva into the oral cavity (Fig. 26.5). The major functions of salivary glands are as follows:

1. Lubricate food. Saliva is 97 to 99.5% water, and it contains a protein called mucin (the main ingredient of mucus) that thickens saliva and lubricates ingested food.
2. Begin digestion. Saliva contains the enzyme amylase, which helps to break down carbohydrates.

Humans have three pairs of extrinsic salivary glands:

A. **Parotid glands** contain many serous cells, which produce thin, watery saliva that contains salivary amylase. Secretions of the parotid glands travel to the oral cavity via the parotid duct, which empties into the vestibule by the second upper molar.

B. **Sublingual glands** contain serous cells and mucous cells, which produce thicker saliva with higher amounts of mucin. The glands are located below the tongue and empty on either side of the lingual frenulum.

C. **Submandibular glands** lie in the posterior floor of the mouth, just inside the mandible. These glands also contain a mix of serous cells and mucous cells, and they also empty into the mouth on either side of the lingual frenulum.

Briefly describe the intrinsic salivary glands:

Briefly describe the effects of the parasympathetic and sympathetic systems on salivary glands:

**Pharynx and esophagus**

We already covered the pharynx when we discussed the respiratory system.

The esophagus connects the pharynx to the stomach. The ANS moves food down the esophagus via peristaltic waves of smooth muscle contraction. The esophagus passes through an opening in the diaphragm called the esophageal hiatus. Compression of the abdomen may force parts of the lower digestive tract through this opening and into the thoracic cavity, a condition known as a hiatal hernia.

Muscles at the inferior end of the esophagus form the gastroesophageal sphincter, which is normally in a state of contraction to prevent backflow of materials from the stomach. The opening of the esophagus into the stomach is referred to as the cardiac orifice. Heartburn is the condition that results when gastric juice is regurgitated through the cardiac orifice and into the esophagus.
Stomach
The esophagus connects to the stomach. The stomach performs four major functions:
1. Storage of ingested food.
2. Mechanical digestion.
3. Chemical digestion.
4. Production of intrinsic factor, which is required for absorption of vitamin B\textsubscript{12}.

Anatomy of the stomach is shown in Fig. 26.9. The lesser curvature of the stomach forms the medial edge of the stomach, and the greater curvature forms the lateral edge. There are four major anatomical regions of the stomach in humans:
A. The cardia (or cardiac region) is the superior end of the stomach within about 3 cm of the esophagus. It contains many mucous glands whose secretions help protect the esophagus from acidic secretions of the stomach.
B. The fundus is the superior region of the stomach. Gastric glands in the fundus and body secrete most of the acids and enzymes involved in gastric digestion.
C. The body is the largest portion of the stomach. Much mechanical mixing of food occurs here.
D. The pylorus is the inferior part of the stomach. Much mechanical mixing of food occurs here. The pyloric sphincter regulates passage of food into the small intestine.

The human stomach has within it folds called rugae. These folds allow the stomach to expand to accommodate a large meal. In addition to circular and longitudinal muscles, the muscularis externa of the stomach has oblique muscles, which help the stomach grind food.

Chemical breakdown is done primarily by secretions of gastric glands. These glands produce secretions that are collectively called gastric juice, and the gastric juice is released into the stomach via gastric pits. You should be familiar with the structures of gastric glands and gastric pits from your activities in lab.

The gastric glands contain two types of secretory cells: (1) Parietal cells secrete the aforementioned intrinsic factor, and they secrete hydrochloric acid (HCl). This acid kills most microorganisms that enter the stomach, breaks down proteins and plant cell walls, and activates the enzyme pepsin. (2) Chief cells secrete the protein pepsinogen, which is converted to pepsin in the presence of stomach acid. Pepsin digests proteins.

Digestive processes of the stomach are regulated by various hormones and the nervous system. These processes can be divided into three phases:

The cephalic phase of stomach activity is initiated by the thought, smell, sight, and/or taste of food. Conscious thoughts of food trigger the hypothalamus to send signals to the medulla oblongata. The medulla stimulates the stomach via the vagus nerve, causing an increase in motility of the stomach muscle and increased activity of gastric glands.

The gastric phase of stomach activity is when the stomach is actively digesting food. This is triggered by stretch of the stomach by food, which further stimulates motility of the stomach muscle and activity of gastric glands. The presence of food in the stomach also stimulates the release of the hormone gastrin, which also contributes to activity of stomach muscle and particularly the release of HCl into the stomach. Gastrin also stimulates contraction of the pyloric sphincter, to keep food in the stomach.
The intestinal phase of digestion involves movement of chyme into the duodenum. Cells of the duodenum release secretin and cholecystokinin (CCK). These chemicals inhibit secretion and motility of the stomach, stimulate the production of pancreatic juice and bile, stimulate contractions of the gall bladder, and cause relaxation of the hepatopancreatic sphincter.

III. Lower Gastrointestinal Tract

Small intestine
The small intestine is where most digestion and absorption of food occurs. The human intestine is approximately 20 feet long, and it can be divided into three major regions:
A. The duodenum begins at the pyloric sphincter, and it accounts for about the first 10” of the small intestine. The duodenum contains duodenal glands (or Brunner's glands), which secrete alkaline mucus into the duodenum to neutralize stomach acid.
B. The jejunum is the middle segment, and it is about 8’ long.
C. The ileum is the final segment, and it is about 11’ long. The ileocecal valve regulates the passage of material from the ileum into the large intestine.

The intestinal lining forms folds within the intestine called circular folds (or plicae circulares), which greatly increase the surface area for digestion (Fig. 26.15). Unlike rugae of the stomach, the plicae do not stretch. Another characteristic feature of the small intestine is the presence of villi. These are finger-like evaginations of the intestine that project into the lumen and further increase the surface area for absorption. The villi are, in turn, covered with cells that have smaller projections (microvilli) that further increase the surface area of the intestine. The region of microvilli is often referred to as the brush border of the intestine.

Accessory organs and ducts

Liver
The liver is the second largest organ in the human body (the skin is the largest). Tissue of the liver is divided among four lobes (Fig. 26.18): the right lobe, the left lobe, the caudate lobe, and the quadrate lobe.

The primary functional cells of the liver are called hepatocytes. Hepatocytes are arranged into functional units called hepatic lobules (Fig. 26.19). (Try to avoid confusing the words “lobe” and “lobule.”) Cells in a lobule are arranged around a central vein. Around the edges of the lobules are arterioles from the hepatic artery and venules from the hepatic portal vein. Blood from the hepatic artery and blood from the hepatic portal vein enter the lobules, nutrients are absorbed into the hepatocytes or released from the hepatocytes as necessary, and then blood passes into the central vein. The central vein eventually leads to the hepatic veins.

From what organs does most of the blood entering the liver come from? Recall the flow of blood into and out of the liver, and understand the functions of the hepatic artery, hepatic portal vein, and hepatic veins.

The primary glandular function of the liver is secretion of bile. Bile secreted by the hepatocytes flows through tiny canals called the bile canaliculi (Fig. 26.19). Bile from the canaliculi enters one of many bile ducts in the liver, and the bile ducts eventually lead to either the right or left hepatic duct. Bile is
released from the liver via the common hepatic duct, which leads to (1) the cystic duct, which carries bile to the gallbladder, and (2) the common bile duct, which carries bile to the duodenum (Fig. 26.17).

Under what conditions does bile flow from the liver to the gallbladder?

Under what conditions does bile flow from the gallbladder to the duodenum?

**Reticuloendothelial cells** (or Kupffer cells) are macrophages in the liver, and they are responsible for engulfing pathogens, cellular debris, and damaged blood cells.

The liver performs many functions for the body:
A. The primary digestive function of the liver is the production of bile. Bile is a mixture of water, ions, cholesterol, and a collection of lipids known as bile salts. Because lipids are insoluble in water, they tend to clump together in the digestive tract. Bile salts emulsify (break apart) these clumps of lipids so that digestive enzymes can digest the individual lipid molecules.
B. The liver works with the pancreas to regulate the blood glucose. The liver stores glucose, and in response to glucagon the liver releases glucose into the blood.
C. The liver absorbs lactic acid from the blood and converts it to glucose.
D. The liver regulates the levels of triglycerides, fatty acids, and cholesterol in the blood.
E. The liver removes excess amino acids, hormones, and antibodies from the blood; the liver also removes various toxins from the blood.
F. The liver stores a variety of vitamins and minerals.
G. The liver produces the major plasma proteins.

**Gallbladder**
The gallbladder is located in a recess on the lower portion of the posterior side of the liver’s right lobe (Fig. 26.18). Bile enters the duodenum only when chyme is present, yet the liver is always producing bile. When bile is not released into the duodenum, it is stored in the gallbladder via the cystic duct (Fig. 26.17).

**Pancreas**
The pancreas lies posterior to the stomach and extends toward the duodenum (Fig. 26.20). The head of the pancreas lies within a loop formed as the duodenum leaves the pylorus, the body extends along the stomach, and there is a short, rounded tail. Cells of the pancreas are divided into lobules by partitions of connective tissue. Each lobule contains clusters of cells, which form pockets called the pancreatic acini (Fig. 26.21). Small ducts lead from the acini to larger ducts, which eventually lead to the pancreatic duct. The pancreatic duct carries exocrine secretions of the pancreas to the duodenum.

The acinar cells and epithelial cells that line the ducts have exocrine functions and secrete pancreatic juice into the ducts. Spread among the lobules are clusters of cells called pancreatic islets (or Islets of Langerhans). These cells have endocrine functions and account for only about 1% of the pancreatic cells.

Exocrine functions of the pancreas involve the secretion of pancreatic juice into intestine. This fluid is alkaline (why is this important?), and it contains water, enzymes, and various ions. Enzymes secreted by the pancreas include amylase to digest carbohydrates, pancreatic lipase to digest lipids,
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Endocrine functions involve the production of insulin and glucagon, which regulate blood glucose
levels. Beta cells produce insulin and alpha cells produce glucagon. Both of these cell types are located
in the pancreatic islets.

Understand the functions of both insulin and glucagon, and understand the conditions under which each
is secreted.

Large intestine
The large intestine is larger in diameter than the small intestine, but the small intestine is the longer of
the two. In humans, the large intestine is about five feet long. The major functions of the large intestine
are (1) water absorption and compaction of the remaining contents into feces, (2) absorption of vitamins,
and (3) storage of feces prior to elimination.

The human large intestine is divided into three regions (Fig. 26.22):
A. The cecum is a short, blind sac located where the small intestine joins the large intestine. The ileum
opens to the cecum through the ileocecal valve. The vermiform appendix (or appendix) extends from
the cecum.
B. The colon can be subdivided into four regions: the ascending colon, the transverse colon, the
descending colon, and the sigmoid colon. The wall of the colon forms a series of folds, called haustra,
which expand and contract as food moves through the colon.
C. The rectum is a straight tube extending to the anus.

Colon cancers are one of the more common forms of cancer, almost 100,000 cases diagnosed in the US
each year. Mortality is high if it is not detected and treated early.