HUMAN PHYSIOLOGY AND CLINICAL BIOCHEMISTRY

Topic: Digestion

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Student Objectives

• Describe the general functions of the digestive system, and name its major divisions. • Explain the difference between mechanical and chemical digestion, and name the end products of digestion. • Explain the functions of saliva. • Describe the location and function of the pharynx and esophagus. • Describe the location, structure, and function of the stomach, small intestine, liver, gallbladder, and pancreas. • Describe absorption in the small intestine. • Describe the location and functions of the large intestine. • Explain the functions of the normal flora of the colon. • Describe the functions of the liver

REFERENCE: Human Physiology: Guyton
Open access

DIGESTIVE SYSTEM

The two divisions of the digestive system are the alimentary tube and the accessory organs. The alimentary tube extends from the mouth to the anus. It consists of the oral cavity, pharynx, esophagus, stomach, small intestine, and large intestine.

Digestion takes place within the oral cavity, stomach, and small intestine; most absorption of nutrients takes place in the small intestine.

Undigestible material, primarily cellulose, is eliminated by the large intestine (also called the colon). The accessory organs of digestion are the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

Digestion does not take place within these organs, but each contributes something to the digestive process.

REFERENCE: OPEN ACCESS

Mechanical digestion

is the physical breaking up of food into smaller pieces. Chewing is an example of this. As food is broken up, more of its surface area is exposed for the action of digestive enzymes.

Chemical digestion

The work of the digestive enzymes is the chemical digestion of broken-up food particles, in which complex chemical molecules are changed into much simpler chemicals that the body can utilize. Such enzymes are specific with respect to the fat, protein, or carbohydrate food molecules each can digest. For example, protein-digesting enzymes work only on proteins, not on carbohydrates or fats. Each enzyme is produced by a particular digestive organ and functions at a specific site.

ORAL CAVITY

Food enters the oral cavity (or buccal cavity) by way of the mouth. The boundaries of the oral cavity are the hard and soft palates superiorly; the cheeks laterally; and the floor of the mouth inferiorly. Within the oral cavity are the teeth and tongue and the openings of the ducts of the salivary glands

TEETH

The function of the teeth is, of course, chewing. This is the process that mechanically breaks food into smaller pieces and mixes it with saliva.

REFERENCE: OPEN ACCESS

SALIVARY GLANDS

The digestive secretion in the oral cavity is saliva, produced by three pairs of salivary glands.

The parotid glands are just below and in front of the ears.

The submandibular (also called sub maxillary) glands are at the posterior corners of the mandible, and the sublingual glands are below the floor of the mouth.

Each gland has at least one duct that takes saliva to the oral cavity

Saliva is mostly water, which is important to dissolve food for tasting and to moisten food for swallowing. The digestive enzyme in saliva is salivary amylase, which breaks down starch molecules to shorter chains of glucose molecules, or to maltose, a disaccharide.

PHARYNX

The oropharynx and laryngopharynx are food passageways connecting the oral cavity to the esophagus.

No digestion takes place in the pharynx.

function is swallowing, the mechanical movement of food. When the bolus of food is pushed backward by the tongue, the constrictor muscles of the pharynx contract as part of the swallowing reflex.

The reflex center for swallowing is in the medulla, which coordinates the many actions that take place: constriction of the pharynx, cessation of breathing, elevation of the soft palate to block the nasopharynx, elevation of the larynx and closure of the epiglottis, and peristalsis of the esophagus.

REFERENCE: OPEN ACCESS

ESOPHAGUS

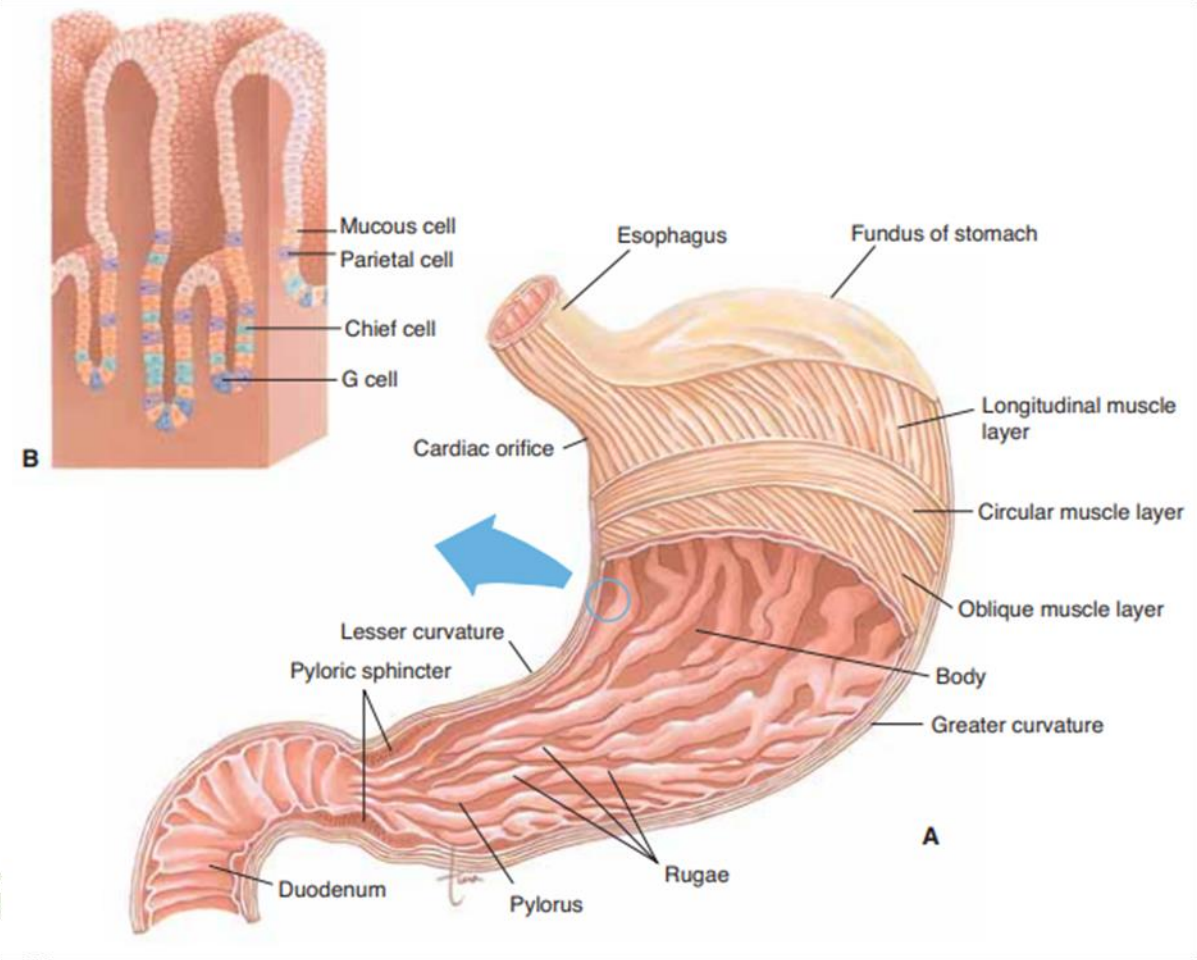
The esophagus is a muscular tube that takes food from the pharynx to the stomach; no digestion takes place here.

Peristalsis of the esophagus propels food in one direction and ensures that food gets to the stomach even if the body is horizontal or upside down.

At the junction with the stomach, the lumen (cavity) of the esophagus is surrounded by the lower esophageal sphincter (LES or **cardiac sphincter**), a circular smooth muscle.

The LES relaxes to permit food to enter the stomach, then contracts to prevent the backup of stomach contents. If the LES does not close completely, gastric juice may splash up into the esophagus; this is a painful condition we call heartburn, or gastroesophageal reflux disease (GERD).

REFERENCE: OPEN ACCESS


Mucous cell
Parietal cell
Chief cell
G cell
B
Esophagus
Fundus of stomach
Cardiac orifice
Longitudinal muscle layer
Circular muscle layer
Oblique muscle layer
Lesser curvature
Pyloric sphincter
Body
Greater curvature
Rugae
Duodenum
Pylorus
A

STOMACH

The stomach is located in the upper left quadrant of the abdominal cavity, to the left of the liver and in front of the spleen.

The stomach is not a tube, but rather a sac that extends from the esophagus to the small intestine.

Because it is a sac, the stomach is a reservoir for food, so that digestion proceeds gradually and we do not have to eat constantly. Both mechanical and chemical digestion take place in the stomach.

The **cardiac orifice** is the opening of the esophagus, and the **fundus** is the portion above the level of this opening. The **body** of the stomach is the large central portion, bounded laterally by the greater curvature and medially by the lesser curvature. The **pylorus** is adjacent to the duodenum of the small intestine, and the **pyloric sphincter** surrounds the junction of the two organs.

The fundus and body are mainly storage areas, **whereas most digestion takes place in the pylorus**.

When the stomach is empty, the mucosa appears wrinkled or folded.

These folds are called **rugae**;

The **gastric pits** are the glands of the stomach and consist of several types of cells; their collective secretions are called gastric juice. **Mucous cells** secrete mucus, which coats the stomach lining and helps prevent erosion by the gastric juice. **Chief cells** secrete pepsinogen, an inactive form of the enzyme pepsin.

Parietal cells produce hydrochloric acid (HCl); these cells have enzymes called proton pumps, which secrete H+ ions into the stomach cavity.

The H+ ions unite with Cl– ions that have diffused from the parietal cells to form HCl in the lumen of the stomach. HCl converts pepsinogen to pepsin, which then begins the digestion of proteins to polypeptides, and also gives gastric juice its pH of 1 to 2.

This very acidic pH is necessary for pepsin to function and also kills most microorganisms that enter the stomach.

The parietal cells also secrete intrinsic factor, which is necessary for the absorption of vitamin B12.

Enteroendocrine cells called G cells secrete the hormone gastrin.

The presence of food in the stomach causes the G cells to secrete gastrin, a hormone that stimulates the secretion of greater amounts of gastric juice.

SMALL INTESTINE

The small intestine is about 1 inch (2.5 cm) in diameter and approximately 20 feet (6 m) long and extends from the stomach to the cecum of the large intestine.

The **duodenum** is the first 10 inches (25 cm) of the small intestine. The common bile duct enters the duodenum at the **ampulla of Vater** (or hepatopancreatic ampulla).

The **jejunum** is about 8 feet long, and the ileum is about 11 feet in length. In a living person, however, the small intestine is always contracted and is therefore somewhat shorter.

Digestion is completed in the small intestine, and the end products of digestion are absorbed into the blood and lymph.

REFERENCE: OPEN ACCESS

The mucosa has simple columnar epithelium that includes cells with microvilli and goblet cells that secrete mucus.

Enteroendocrine cells secrete the hormones of the small intestine.

Lymph nodules called **Peyer's patches** are especially abundant in the ileum to destroy absorbed pathogens.

The external muscle layer has the typical circular and longitudinal smooth muscle layers that mix the chyme with digestive secretions and propel the chyme toward the colon.

LIVER

The liver consists of two large lobes, right and left, and fills the upper right and center of the abdominal cavity, just below the diaphragm.

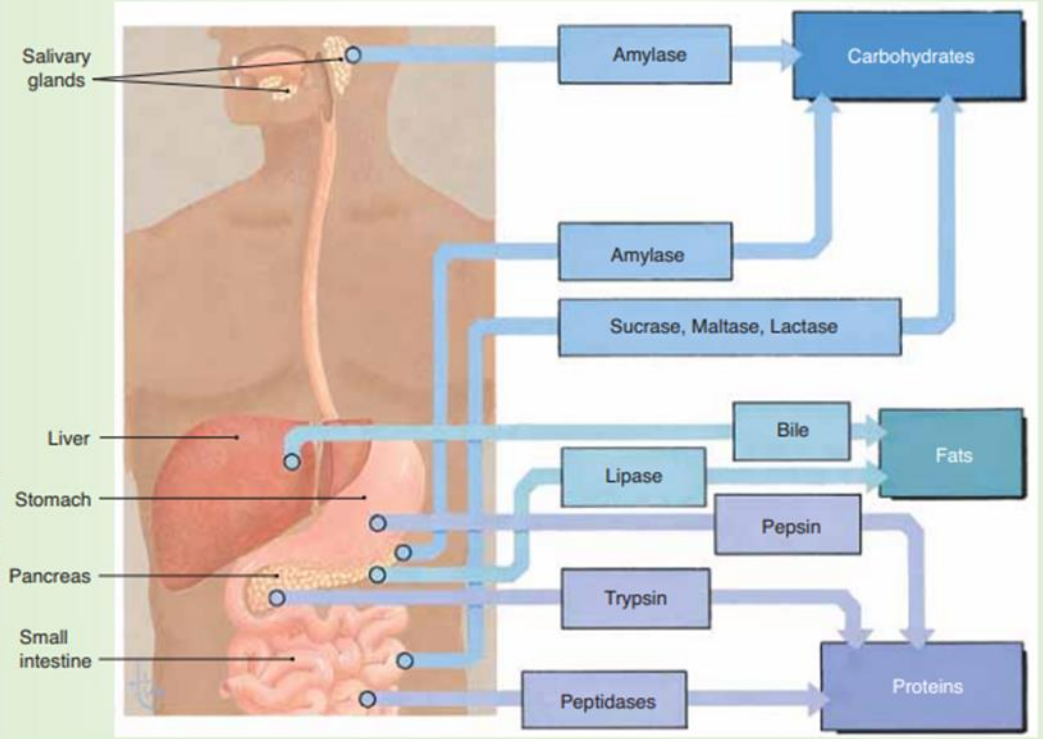
The structural unit of the liver is the liver lobule, a roughly hexagonal column of liver cells (hepatocytes).

The cells of the liver have many functions, but their only digestive function is the production of bile.

Bile enters the small bile ducts, called **bile canaliculi,** on the liver cells, which unite to form larger ducts and finally merge to form the hepatic duct, which takes bile out of the liver

REFERENCE: OPEN ACCESS

Organ	Enzyme or Other Secretion	Function	Site of Action
Salivary glands	Amylase	• Converts starch to maltose	Oral cavity
Stomach	Pepsin	• Converts proteins to polypeptides	Stomach
	HCl	• Changes pepsinogen to pepsin; maintains pH 1–2; destroys pathogens	Stomach
Liver	Bile salts	• Emulsify fats	Small intestine
Pancreas	Amylase	• Converts starch to maltose	Small intestine
	Trypsin	• Converts polypeptides to peptides	Small intestine
	Lipase	• Converts emulsified fats to fatty acids and glycerol	Small intestine
Small intestine	Peptidases	• Convert peptides to amino acids	Small intestine
	Sucrase	• Converts sucrose to glucose and fructose	Small intestine
	Maltase	• Converts maltose to glucose (2)	Small intestine
	Lactase	• Converts lactose to glucose and galactose	Small intestine



REFERENCE: OPEN ACCESS

REGULATION OF DIGESTIVE SECRETIONS

Secretion	Nervous Regulation	Chemical Regulation
Saliva	Presence of food in mouth or sight of food; parasympathetic impulses along 7th and 9th cranial nerves	None
Gastric juice	Sight or smell of food; parasympathetic impulses along 10th cranial nerves	Gastrin—produced by the G cells of the gastric mucosa when food is present in the stomach
Bile		
Secretion by the liver	None	Secretin—produced by the enteroendocrine cells of the duodenum when chyme enters
Contraction of the gallbladder	None	Cholecystokinin—produced by the enteroendocrine cells of the duodenum when chyme enters
Enzyme pancreatic juice	None	Cholecystokinin—from the duodenum
Bicarbonate pancreatic juice	None	Secretin—from the duodenum
Intestinal juice	Presence of chyme in the duodenum; parasympathetic impulses along 10th cranial nerves	None

REFERENCE: OPEN ACCESS

The **hepatic duct** unites with the cystic duct of the gallbladder to form the common bile duct, which takes bile to the duodenum.

Bile is mostly water and has an excretory function in that it carries bilirubin and excess cholesterol to the intestines for elimination in feces.

The digestive function of bile is accomplished by bile salts, which emulsify fats in the small intestine.

Emulsification means that large fat globules are broken into smaller globules. **This is mechanical, not chemical, digestion;** the fat is still fat but now has more surface area to facilitate chemical digestion.

Production of bile is stimulated by the **hormone secretin**, which is produced by the duodenum when food enters the small intestine.

GALLBLADDER

The gallbladder is a sac about 3 to 4 inches long located on the undersurface of the right lobe of the liver. Bile in the hepatic duct of the liver flows through the cystic duct into the gallbladder , which stores bile until it is needed in the small intestine.

The gallbladder also concentrates bile by absorbing water. When fatty foods enter the duodenum, the enteroendocrine cells of the duodenal mucosa secrete the hormone cholecystokinin. This hormone stimulates contraction of the smooth muscle in the wall of the gallbladder, which forces bile into the cystic duct, then into the common bile duct, and on into the duodenum.

REFERENCE: OPEN ACCESS

PANCREAS

The pancreas is located in the upper left abdominal quadrant between the curve of the duodenum and the spleen and is about 6 inches (15 cm) in length.

The exocrine glands of the pancreas are called acini (singular: acinus).

They produce enzymes that are involved in the digestion of all three types of complex food molecules.

The pancreatic enzyme amylase digests starch to maltose. Pancreatic amylase is responsible for most digestion of starch.

Lipase converts emulsified fats to fatty acids and glycerol. The emulsifying or fat-separating action of bile salts increases the surface area of fats so that lipase works effectively.

Trypsinogen is an inactive enzyme that is changed to active trypsin in the duodenum.

Trypsin digests polypeptides to shorter chains of amino acids. The pancreatic enzyme juice is carried by small ducts that unite to form larger ducts, then finally the main pancreatic duct, that joins the common bile duct to the duodenum.

The pancreas also produces a bicarbonate juice (containing sodium bicarbonate), which is alkaline.

Secretion of pancreatic juice is stimulated by the hormones secretin and cholecystokinin, which are produced by the duodenal mucosa when chyme enters the small intestine.

Secretin stimulates the production of bicarbonate juice by the pancreas, and **cholecystokinin** stimulates the secretion of the pancreatic enzymes.

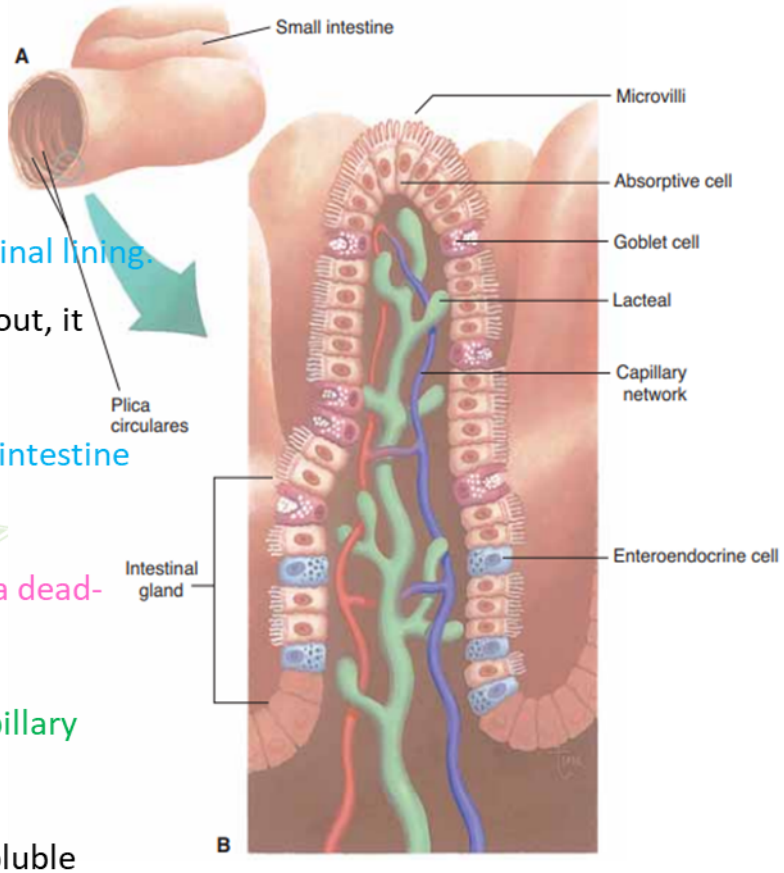
COMPLETION OF DIGESTION AND ABSORPTION SMALL INTESTINE

- The secretion of the epithelium of the intestinal glands (or crypts of Lieberkühn) is stimulated by the presence of food in the duodenum.
- The intestinal enzymes are the peptidases and sucrase, maltase, and lactase.
- Peptidases complete the digestion of protein by breaking down short polypeptide chains to amino acids.
- Sucrase, maltase, and lactase, respectively, digest the disaccharides sucrose, maltose, and lactose to monosaccharides.
- The enteroendocrine cells of the intestinal glands secrete the hormones of the small intestine. Secretion is stimulated by food entering the duodenum.

ABSORPTION

- **Most absorption of the end products of digestion takes place in the small intestine (although the stomach does absorb water and alcohol).**
- **The process of absorption requires a large surface area, which is provided by several structural modifications of the small intestine.**
- The mucosa is folded into projections called villi, which give the inner surface of the intestine a velvet like appearance.

- Each columnar cell (except the mucus-secreting goblet cells) of the villi also has microvilli on its free surface.
- Microvilli are microscopic folds of the cell membrane, and are collectively called the brush border.
- All of these folds greatly increase the surface area of the intestinal lining.
- It is estimated that if the intestinal mucosa could be flattened out, it would cover more than 2000 square feet
- The absorption of nutrients takes place from the lumen of the intestine into the vessels within the villi.
- within each villus is a capillary network and a lacteal, which is a dead-end lymph capillary.
- Water-soluble nutrients are absorbed into the blood in the capillary networks.
- Monosaccharides, amino acids, positive ions, and the water-soluble vitamins (vitamin C and the B vitamins) are absorbed by active transport.
- Negative ions may be absorbed by either passive or active transport mechanisms.



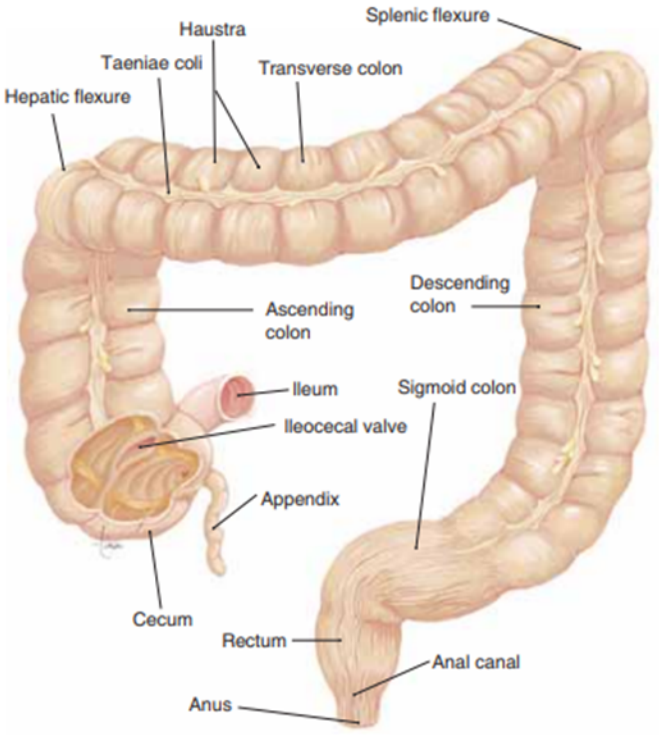
REFERENCE: OPEN ACCESS

- Water is absorbed by osmosis following the absorption of minerals, especially sodium.
- Certain nutrients have additional special requirements for their absorption: For example, vitamin B12 requires the intrinsic factor produced by the parietal cells of the gastric mucosa, and the efficient absorption of calcium ions requires parathyroid hormone and vitamin D.
- Fat-soluble nutrients are absorbed into the lymph in the lacteals of the villi.
- Bile salts are necessary for the efficient absorption of fatty acids and the fat-soluble vitamins (A, D, E, and K). Once absorbed, fatty acids are recombined with glycerol to form triglycerides.
- These triglycerides then form globules that include cholesterol and protein; these lipid–protein complexes are called chylomicrons. In the form of chylomicrons, most absorbed fat is transported by the lymph and eventually enters the blood in the left subclavian vein.
- Blood from the capillary networks in the villi does not return directly to the heart but first travels through the portal vein to the liver.
- This pathway enables the liver to regulate the blood levels of glucose and amino acids, store certain vitamins, and remove potential poisons from the blood.

LARGE INTESTINE

The large intestine, also called the colon, is approximately 2.5 inches (6.3 cm) in diameter and 5 feet (1.5 m) in length. It extends from the ileum of the small intestine to the anus, the terminal opening. The cecum is the first portion, and at its junction with the ileum is the ileocecal valve, which is not a sphincter but serves the same purpose. After undigested food (which is now mostly cellulose) and water pass from the ileum into the cecum, closure of the **ileocecal valve** prevents the backflow of fecal material.

- The functions of the colon are the absorption of water, minerals, and vitamins and the elimination of undigestible material.
- About 80% of the water that enters the colon is absorbed (400 to 800 mL per day).
- Positive and negative ions are also absorbed. The vitamins absorbed are those produced by the normal flora, the trillions of bacteria that live in the colon.
- Vitamin K is produced and absorbed. Other vitamins produced in smaller amounts include riboflavin, thiamin, biotin, and folic acid.
- Everything absorbed by the colon circulates first to the liver by way of portal circulation.
- Another function of the normal colon flora is to inhibit the growth of pathogens



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