The Digestive System and Body Metabolism
The Digestive System Functions

- Ingestion—taking in food
- Digestion—breaking food down both physically and chemically
- Absorption—movement of nutrients into the bloodstream
- Defecation—rids the body of indigestible waste
Organs of the Digestive System

- Two main groups
  - Alimentary canal (gastrointestinal or GI tract)—continuous coiled hollow tube
  - Accessory digestive organs
Organs of the Digestive System

Figure 14.1

- Mouth (oral cavity)
- Tongue
- Parotid gland
- Sublingual gland
- Submandibular gland
- Salivary glands
- Pharynx
- Stomach
- Pancreas
- (Spleen)
- Esophagus
- Liver
- Gallbladder
- Small intestine
  - Duodenum
  - Jejunum
  - Ileum
- Large intestine
  - Transverse colon
  - Descending colon
  - Ascending colon
  - Cecum
  - Sigmoid colon
  - Rectum
  - Appendix
  - Anal canal
- Anus
Organs of the Alimentary Canal

- Mouth
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Anus
Mouth (Oral Cavity) Anatomy

- Lips (labia)—protect the anterior opening
- Cheeks—form the lateral walls
- Hard palate—forms the anterior roof
- Soft palate—forms the posterior roof
- Uvula—fleshy projection of the soft palate
Mouth (Oral Cavity) Anatomy

- Vestibule—space between lips externally and teeth and gums internally
- Oral cavity proper—area contained by the teeth
- Tongue—attached at hyoid bone and styloid processes of the skull, and by the lingual frenulum to the floor of the mouth
- Tonsils
  - Palatine
  - Lingual
Mouth (Oral Cavity) Anatomy

- Hard palate
- Oral cavity
- Lips (labia)
- Vestibule
- Lingual frenulum
- Tongue
- Hyoid bone
- Trachea
- Nasopharynx
- Soft palate
- Uvula
- Palatine tonsil
- Lingual tonsil
- Oropharynx
- Epiglottis
- Laryngopharynx
- Esophagus

Figure 14.2a
Mouth (Oral Cavity) Anatomy

- Upper lip
- Gingivae (gums)
- Hard palate
- Soft palate
- Uvula
- Palatine tonsil
- Oropharynx
- Tongue

Figure 14.2b
Mouth Physiology

- Mastication (chewing) of food
- Mixing masticated food with saliva
- Initiation of swallowing by the tongue
- Allows for the sense of taste
Pharynx Anatomy

- Nasopharynx—not part of the digestive system
- Oropharynx—posterior to oral cavity
- Laryngopharynx—below the oropharynx and connected to the esophagus
Pharynx Anatomy

Figure 14.2a

- Nasopharynx
- Soft palate
- Uvula
- Palatine tonsil
- Lingual tonsil
- Oropharynx
- Epiglottis
- Laryngopharynx
- Esophagus

- Hard palate
- Oral cavity
- Lips (labia)
- Vestibule
- Lingual frenulum
- Tongue
- Hyoid bone
- Trachea
Pharynx Physiology

- Serves as a passageway for air and food
- Food is propelled to the esophagus by two muscle layers
  - Longitudinal inner layer
  - Circular outer layer
- Food movement is by alternating contractions of the muscle layers (peristalsis)
Esophagus Anatomy and Physiology

- **Anatomy**
  - About 10 inches long
  - Runs from pharynx to stomach through the diaphragm

- **Physiology**
  - Conducts food by peristalsis (slow rhythmic squeezing)
  - Passageway for food only (respiratory system branches off after the pharynx)
Layers of Alimentary Canal Organs

- Four layers
  - Mucosa
  - Submucosa
  - Muscularis externa
  - Serosa
Layers of Alimentary Canal Organs

- **Mucosa**
  - Innermost, moist membrane consisting of
    - Surface epithelium
    - Small amount of connective tissue (lamina propria)
    - Small smooth muscle layer
Layers of Alimentary Canal Organs

Figure 14.3
Layers of Alimentary Canal Organs

- Submucosa
  - Just beneath the mucosa
  - Soft connective tissue with blood vessels, nerve endings, and lymphatics
Layers of Alimentary Canal Organs

Figure 14.3
Layers of Alimentary Canal Organs

- Muscularis externa—smooth muscle
  - Inner circular layer
  - Outer longitudinal layer
- Serosa—outermost layer of the wall contains fluid-producing cells
  - Visceral peritoneum—outermost layer that is continuous with the innermost layer
  - Parietal peritoneum—innermost layer that lines the abdominopelvic cavity
Layers of Alimentary Canal Organs

- Visceral peritoneum
- Intrinsic nerve plexuses
- Myenteric nerve plexus
- Submucosal nerve plexus
- Submucosal glands
- Mucosa
- Surface epithelium
- Lamina propria
- Muscle layer
- Submucosa
- Muscularis externa
- Longitudinal muscle layer
- Circular muscle layer
- Serosa (visceral peritoneum)
- Gland in mucosa
- Duct of gland outside alimentary canal
- Lumen
- Lymph nodule

Figure 14.3
Alimentary Canal Nerve Plexuses

- Two important nerve plexuses serve the alimentary canal
- Both are part of the autonomic nervous system
  - Submucosal nerve plexus
  - Myenteric nerve plexus
- Function is to regulate mobility and secretory activity of the GI tract organs
The Digestive System and Body Metabolism
Stomach Anatomy

- Located on the left side of the abdominal cavity
- Food enters at the cardioesophageal sphincter
- Food empties into the small intestine at the pyloric sphincter (valve)
Stomach Anatomy

- Regions of the stomach
  - Cardiac region—near the heart
  - Fundus—expanded portion lateral to the cardiac region
  - Body—midportion
  - Pylorus—funnel-shaped terminal end
Stomach Anatomy

- Rugae—internal folds of the mucosa
- External regions
  - Lesser curvature—concave medial surface
  - Greater curvature—convex lateral surface
Stomach Anatomy

Figure 14.4a

- Cardioesophageal sphincter
- Fundus
- Serosa
- Body
- Rugae of mucosa
- Greater curvature
- Lesser curvature
- Muscularis externa
  - Longitudinal layer
  - Circular layer
  - Oblique layer
- Pylorus
- Duodenum (a)
- Pyloric sphincter (valve)
- Pyloric antrum

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Stomach Anatomy

Figure 14.4b

- Fundus
- Body
- Rugae of mucosa
- Pyloric sphincter
- Pyloric antrum

(b)
Stomach Anatomy

- Layers of peritoneum attached to the stomach
  - Lesser omentum—attaches the liver to the lesser curvature
  - Greater omentum—attaches the greater curvature to the posterior body wall
    - Contains fat to insulate, cushion, and protect abdominal organs
    - Has lymph nodules containing macrophages
Stomach Anatomy

Figure 14.5a

- Diaphragm
- Falciform ligament
- Liver
- Spleen
- Gallbladder
- Stomach
- Greater omentum
- Small intestine
- Large intestine
- Cecum
Stomach Anatomy

- Diaphragm
- Liver
- Stomach
- Visceral peritoneum
- Greater omentum
- Parietal peritoneum
- Small intestine
- Uterus
- Urinary bladder
- Lesser omentum
- Pancreas
- Duodenum
- Transverse colon
- Mesenteries
- Peritoneal cavity
- Rectum
- Anus

Figure 14.5b
Stomach Physiology

- Temporary storage tank for food
- Site of food breakdown
- Chemical breakdown of protein begins
- Delivers chyme (processed food) to the small intestine
Structure of the Stomach Mucosa

- Mucosa is simple columnar epithelium
- Mucous neck cells—produce a sticky alkaline mucus
- Gastric glands—situated in gastric pits and secrete gastric juice
- Chief cells—produce protein-digesting enzymes (pepsinogens)
- Parietal cells—produce hydrochloric acid
- Enteroendocrine cells—produce gastrin
Structure of the Stomach Mucosa

Figure 14.4c
Structure of the Stomach Mucosa

Pepsinogen \rightarrow Pepsin

HCl

Parietal cells

Chief cells

Enteroendocrine cell

Figure 14.4d
Small Intestine

- The body’s major digestive organ
- Site of nutrient absorption into the blood
- Muscular tube extending from the pyloric sphincter to the ileocecal valve
- Suspended from the posterior abdominal wall by the mesentery
Subdivisions of the Small Intestine

- Duodenum
  - Attached to the stomach
  - Curves around the head of the pancreas
- Jejunum
  - Attaches anteriorly to the duodenum
- Ileum
  - Extends from jejunum to large intestine
Chemical Digestion in the Small Intestine

- Chemical digestion begins in the small intestine
  - Enzymes are produced by
    - Intestinal cells
    - Pancreas
  - Pancreatic ducts carry enzymes to the small intestine
  - Bile, formed by the liver, enters via the bile duct
Chemical Digestion in the Small Intestine

Figure 14.6
Small Intestine Anatomy

- Three structural modifications that increase surface area
  - Microvilli—tiny projections of the plasma membrane (create a brush border appearance)
  - Villi—fingerlike structures formed by the mucosa
  - Circular folds (plicae circulares)—deep folds of mucosa and submucosa
Small Intestine Anatomy

(a) Small intestine

Blood vessels serving small intestine

Muscle layers

Large circular folds (plicae circulares)

Villi

Figure 14.7a
Small Intestine Anatomy

Figure 14.7b

- Absorptive cells
- Lacteal
- Blood capillaries
- Vein
- Artery
- Submucosa

(b) Villi
Small Intestine Anatomy

Microvilli

(c) Absorptive cells

Figure 14.7c
Large Intestine

- Larger in diameter, but shorter in length, than the small intestine
- Frames the internal abdomen
Large Intestine Anatomy

- Cecum—saclike first part of the large intestine
- Appendix
  - Accumulation of lymphatic tissue that sometimes becomes inflamed (appendicitis)
  - Hangs from the cecum
Large Intestine

Figure 14.8
Large Intestine Anatomy

- Colon
  - Ascending—travels up right side of abdomen
  - Transverse—travels across the abdominal cavity
  - Descending—travels down the left side
  - Sigmoid—enters the pelvis
- Rectum and anal canal—also in pelvis
Large Intestine

Figure 14.8
Large Intestine Anatomy

- Anus—opening of the large intestine
  - External anal sphincter—formed by skeletal muscle and under voluntary control
  - Internal involuntary sphincter—formed by smooth muscle
  - These sphincters are normally closed except during defecation
Large Intestine

- Left colic (splenic) flexure
- Transverse mesocolon
- Descending colon
- Cut edge of mesentery
- Teniae coli
- Sigmoid colon
- Cecum
- Ileocecal valve
- Ileum (cut)
- Ascending colon
- Haustra
- Transverse colon
- Right colic (hepatic) flexure
- Rectum
- Anal canal
- External anal sphincter

Figure 14.8
Large Intestine Anatomy

- No villi present
- Goblet cells produce alkaline mucus which lubricates the passage of feces
- Muscularis externa layer is reduced to three bands of muscle called teniae coli
- These bands cause the wall to pucker into haustra (pocketlike sacs)
The Digestive System and Body Metabolism
Accessory Digestive Organs

- Teeth
- Salivary glands
- Pancreas
- Liver
- Gallbladder
Teeth

- Function is to masticate (chew) food
- Humans have two sets of teeth
  - Deciduous (baby or “milk”) teeth
  - 20 teeth are fully formed by age two
Teeth

- Permanent teeth
  - Replace deciduous teeth between the ages of 6 and 12
  - A full set is 32 teeth, but some people do not have wisdom teeth (third molars)
  - If they do emerge, the wisdom teeth appear between ages of 17 and 25
Classification of Teeth

- Incisors—cutting
- Canines—tearing or piercing
- Premolars—grinding
- Molars—grinding
Human Deciduous and Permanent Teeth

**Incisors**
- Central (6–8 mo)
- Lateral (8–10 mo)
- Canine (eyetooth) (16–20 mo)

**Molars**
- First molar (10–15 mo)
- Second molar (about 2 yr)

**Permanent teeth**
- Incisors
  - Central (7 yr)
  - Lateral (8 yr)
- Canine (eyetooth) (11 yr)
- Premolars (bicuspids)
  - First premolar (11 yr)
  - Second premolar (12–13 yr)
- Molars
  - First molar (6–7 yr)
  - Second molar (12–13 yr)
- Third molar (wisdom tooth) (17–25 yr)

**Figure 14.9**
Regions of a Tooth

- **Crown**—exposed part
  - **Enamel**—hardest substance in the body
  - **Dentin**—found deep to the enamel and forms the bulk of the tooth
  - **Pulp cavity**—contains connective tissue, blood vessels, and nerve fibers
  - **Root canal**—where the pulp cavity extends into the root
Regions of a Tooth

- Neck
  - Region in contact with the gum
  - Connects crown to root
- Root
  - Cementum—covers outer surface and attaches the tooth to the periodontal membrane
Regions of a Tooth

Figure 14.10

- Enamel
- Dentin
- Pulp cavity
- Gum (gingiva)
- Periodontal membrane
- Bone
- Cementum
- Root canal
- Blood vessels and nerves in pulp
Salivary Glands

- Three pairs of salivary glands empty secretions into the mouth
  - Parotid glands
  - Submandibular glands
  - Sublingual glands
Salivary Glands

Figure 14.1
Saliva

- Mixture of mucus and serous fluids
- Helps to form a food bolus
- Contains salivary amylase to begin starch digestion
- Dissolves chemicals so they can be tasted
Pancreas

- Found posterior to the parietal peritoneum
- Extends across the abdomen from spleen to duodenum
Pancreas

- Produces a wide spectrum of digestive enzymes that break down all categories of food
- Enzymes are secreted into the duodenum
- Alkaline fluid introduced with enzymes neutralizes acidic chyme coming from stomach
- Hormones produced by the pancreas
  - Insulin
  - Glucagon
Pancreas

Figure 14.1
Pancreas

Figure 14.6
Liver

- Largest gland in the body
- Located on the right side of the body under the diaphragm
- Consists of four lobes suspended from the diaphragm and abdominal wall by the falciform ligament
- Connected to the gallbladder via the common hepatic duct
Liver

Figure 14.1
Liver

Figure 14.5
Bile

- Produced by cells in the liver
- Composition is
  - Bile salts
  - Bile pigments (mostly bilirubin from the breakdown of hemoglobin)
  - Cholesterol
  - Phospholipids
  - Electrolytes
Bile

- Function—emulsify fats by physically breaking large fat globules into smaller ones
Gallbladder

- Sac found in hollow fossa of liver
- When no digestion is occurring, bile backs up the cystic duct for storage in the gallbladder
- When digestion of fatty food is occurring, bile is introduced into the duodenum from the gallbladder
- Gallstones are crystallized cholesterol which can cause blockages
Gallbladder
Gallbladder

Figure 14.6
Functions of the Digestive System

- Ingestion—getting food into the mouth
- Propulsion—moving foods from one region of the digestive system to another
  - Peristalsis—alternating waves of contraction and relaxation that squeezes food along the GI tract
  - Segmentation—moving materials back and forth to aid with mixing in the small intestine
Functions of the Digestive System
Functions of the Digestive System

- Food breakdown as *mechanical* digestion
  - **Examples:**
    - Mixing food in the mouth by the tongue
    - Churning food in the stomach
    - Segmentation in the small intestine
  - Mechanical digestion prepares food for further degradation by enzymes
Functions of the Digestive System

- Food breakdown as *chemical* digestion
  - Enzymes break down food molecules into their building blocks
  - Each major food group uses different enzymes
    - Carbohydrates are broken to simple sugars
    - Proteins are broken to amino acids
    - Fats are broken to fatty acids and alcohols
Functions of the Digestive System

**Carbohydrate digestion**

- **Foodstuff**: Starch and disaccharides
  - Oligosaccharides* and disaccharides
    - Lactose
    - Maltose
    - Sucrose
  - Galactose
  - Glucose
  - Fructose

- **Enzyme(s) and source**: Salivary amylase, Pancreatic amylase
  - Mouth
  - Small intestine

- **Site of action**: Small intestine

- **Carbohydrate absorption**
  - The monosaccharides glucose, galactose, and fructose enter the capillary blood in the villi and are transported to the liver via the hepatic portal vein.

*Oligosaccharides consist of a few linked monosaccharides.
Functions of the Digestive System

**Protein digestion**

- **Foodstuff**: Protein
- **Enzyme(s) and source**: Pepsin (stomach glands) in the presence of HCl
- **Site of action**: Stomach

- **Large polypeptides**
- **Enzyme(s) and source**: Pancreatic enzymes (trypsin, chymotrypsin, carboxypeptidase)
- **Site of action**: Small intestine

- **Small polypeptides, small peptides**
- **Enzyme(s) and source**: Brush border enzymes (aminopeptidase, carboxypeptidase, and dipeptidase)
- **Site of action**: Small intestine

- **Amino acids (some dipeptides and tripeptides)**

**Protein absorption**

Amino acids enter the capillary blood in the villi and are transported to the liver via the hepatic portal

---

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Figure 14.13 (2 of 3)
## Functions of the Digestive System

<table>
<thead>
<tr>
<th>Foodstuff</th>
<th>Enzyme(s) and source</th>
<th>Site of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemulsified fats</td>
<td>Emulsified by the detergent action of bile salts from the liver</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Monoglycerides and fatty acids</td>
<td>Pancreatic lipase</td>
<td>Small intestine</td>
</tr>
</tbody>
</table>

**Fat digestion**

**Fat absorption**

Fatty acids and monoglycerides enter the lacteals of the villi and are transported to the systemic circulation via the lymph in the thoracic duct. (Glycerol and short-chain fatty acids are absorbed into the capillary blood in the villi and transported to the liver via the hepatic portal vein.)

---

**Figure 14.13 (3 of 3)**
Functions of the Digestive System

- **Absorption**
  - End products of digestion are absorbed in the blood or lymph
  - Food must enter mucosal cells and then into blood or lymph capillaries

- **Defecation**
  - Elimination of indigestible substances from the GI tract in the form of feces
Functions of the Digestive System

- **Ingestion**
  - Food intake

- **Mechanical digestion**
  - Chewing (mouth)
  - Churning (stomach)
  - Segmentation (small intestine)

- **Chemical digestion**
  - Enzyme action

- **Pharynx**

- **Esophagus**

- **Propulsion**
  - Swallowing (oropharynx)
  - Peristalsis (esophagus, stomach, small intestine, large intestine)

- **Stomach**

- **Small intestine**

- **Large intestine**

- **Absorption**
  - Lymph vessel
  - Blood vessel
  - Mainly H₂O

- **Defecation**
  - Feces
  - Anus

*Figure 14.11*
Control of Digestive Activity

- Mostly controlled by reflexes via the parasympathetic division
- Chemical and mechanical receptors are located in organ walls that trigger reflexes
Control of Digestive Activity

- Stimuli include
  - Stretch of the organ
  - pH of the contents
  - Presence of breakdown products

- Reflexes include
  - Activation or inhibition of glandular secretions
  - Smooth muscle activity
Digestive Activities of the Mouth

- Mechanical breakdown
  - Food is physically broken down by chewing
- Chemical digestion
  - Food is mixed with saliva
  - Starch is broken down into maltose by salivary amylase
Activities of the Pharynx and Esophagus

- These organs have no digestive function
- Serve as passageways to the stomach
Deglutition (Swallowing)

- Buccal phase
  - Voluntary
  - Occurs in the mouth
  - Food is formed into a bolus
  - The bolus is forced into the pharynx by the tongue
Deglutition (Swallowing)

- Pharyngeal-esophageal phase
  - Involuntary transport of the bolus
  - All passageways except to the stomach are blocked
    - Tongue blocks off the mouth
    - Soft palate (uvula) blocks the nasopharynx
    - Epiglottis blocks the larynx
Deglutition (Swallowing)

- Pharyngeal-esophageal phase (continued)
  - Peristalsis moves the bolus toward the stomach
  - The cardioesophagaeal sphincter is opened when food presses against it
Deglutition (Swallowing)

Figure 14.14a–b

(a) Upper esophageal sphincter contracted

(b) Upper esophageal sphincter relaxed
Deglutition (Swallowing)

Figure 14.14c–d
Food Breakdown in the Stomach

- Gastric juice is regulated by neural and hormonal factors.
- Presence of food or rising pH causes the release of the hormone gastrin.
- Gastrin causes stomach glands to produce:
  - Protein-digesting enzymes
  - Mucus
  - Hydrochloric acid
Food Breakdown in the Stomach

- Hydrochloric acid makes the stomach contents very acidic

- Acidic pH
  - Activates pepsinogen to pepsin for protein digestion
  - Provides a hostile environment for microorganisms
Digestion and Absorption in the Stomach

- Protein digestion enzymes
  - Pepsin—an active protein-digesting enzyme
  - Rennin—works on digesting milk protein in infants, not adults
- Alcohol and aspirin are the only items absorbed in the stomach
Propulsion in the Stomach

- Food must first be well mixed
- Rippling peristalsis occurs in the lower stomach
- The pylorus meters out chyme into the small intestine (30 mL at a time)
- The stomach empties in 4–6 hours
Propulsion in the Stomach

Figure 14.15a–c

(a) Pyloric sphincter closed

(b) Pyloric sphincter closed

(c) Pyloric sphincter slightly open
Digestion in the Small Intestine

- Enzymes from the brush border function to
  - Break double sugars into simple sugars
  - Complete some protein digestion
Digestion in the Small Intestine

- Pancreatic enzymes play the major digestive function
  - Help complete digestion of starch (pancreatic amylase)
  - Carry out about half of all protein digestion
  - Digest fats using lipases from the pancreas
  - Digest nucleic acids using nucleases
- Alkaline content neutralizes acidic chyme
Regulation of Pancreatic Juice Secretion

- Release of pancreatic juice into the duodenum is stimulated by
  - Vagus nerve
  - Local hormones
    - Secretin
    - Cholecystokinin (CCK)
- Hormones travel the blood to stimulate the pancreas to release enzyme- and bicarbonate-rich product
Regulation of Pancreatic Juice Secretion

- Secretin causes the liver to increase bile output
- CCK causes the gallbladder to release stored bile
  - Bile is necessary for fat absorption and absorption of fat-soluble vitamins (K, D, A)
Regulation of Pancreatic Juice Secretion

1. Chyme entering duodenum causes the enteroendocrine cells of the duodenum to release secretin and cholecystokinin

2. Cholecystokinin and secretin enter bloodstream

3. Upon reaching the pancreas, cholecystokinin induces secretion of enzyme-rich pancreatic juice; secretin causes secretion of bicarbonate-rich pancreatic juice

4. Secretin causes the liver to secrete more bile; cholecystokinin stimulates the gallbladder to release stored bile

Stimulation by vagal nerve fibers causes release of pancreatic juice and weak contractions of the gallbladder

Figure 14.16
## Hormones and Hormonelike Products that Act in Digestion

**Table 14.1**

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Source</th>
<th>Stimulus for secretion</th>
<th>Action</th>
</tr>
</thead>
</table>
| Gastrin          | Stomach               | Food in stomach (chemical stimulus); ACH released by nerve fibers                      | • Stimulates release of gastric juice  
|                  |                       |                                                                                        | • Stimulates stomach emptying                                          |
| Intestinal gastrin| Duodenum              | Acidic food in stomach                                                                 | • Stimulates gastric secretion and emptying                           |
| Histamine        | Stomach               | Food in stomach                                                                        | • Activates parietal cells to secrete hydrochloric acid.               |
| Somatostatin     | Stomach and duodenum  | Food in stomach; stimulated by sympathetic nerve fibers                                  | • Inhibits secretion of gastric juice and pancreatic juice  
|                  |                       |                                                                                        | • Inhibits emptying of stomach and gallbladder.                       |

Table 14.1 (1 of 2)
### Hormones and Hormonelike Products that Act in Digestion (continued)

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Source</th>
<th>Stimulus for secretion</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secretin</td>
<td>Duodenum</td>
<td>Acidic chyme and partially digested foods in duodenum</td>
<td>• Increases output of pancreatic juice rich in bicarbonate ions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Increases bile output by liver</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Inhibits gastric mobility and gastric gland secretion.</td>
</tr>
<tr>
<td>Cholecystokinin (CCK)</td>
<td>Duodenum</td>
<td>Fatty chyme and partially digested proteins in duodenum</td>
<td>• Increases output of enzyme-rich pancreatic juice</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Stimulates gallbladder to expel stored bile</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Relaxes sphincter of duodenal papilla to allow bile and pancreatic juice to enter the duodenum.</td>
</tr>
<tr>
<td>Gastric inhibitory peptide (GIP)</td>
<td>Duodenum</td>
<td>Fatty chyme in duodenum</td>
<td>• Inhibits secretion of gastric juice.</td>
</tr>
</tbody>
</table>

Table 14.1 (2 of 2)
Absorption in the Small Intestine

- Water is absorbed along the length of the small intestine
- End products of digestion
  - Most substances are absorbed by active transport through cell membranes
  - Lipids are absorbed by diffusion
- Substances are transported to the liver by the hepatic portal vein or lymph
Propulsion in the Small Intestine

- Peristalsis is the major means of moving food
- Segmental movements
  - Mix chyme with digestive juices
  - Aid in propelling food
Segmentation

Figure 14.12b
Food Breakdown and Absorption in the Large Intestine

- No digestive enzymes are produced
- Resident bacteria digest remaining nutrients
  - Produce some vitamin K and B
  - Release gases
- Water and vitamins K and B are absorbed
- Remaining materials are eliminated via feces
Food Breakdown and Absorption in the Large Intestine

- Feces contains
  - Undigested food residues
  - Mucus
  - Bacteria
  - Water
Propulsion in the Large Intestine

- Sluggish peristalsis
- Mass movements
  - Slow, powerful movements
  - Occur three to four times per day
- Presence of feces in the rectum causes a defecation reflex
  - Internal anal sphincter is relaxed
  - Defecation occurs with relaxation of the voluntary (external) anal sphincter
Nutrition

- **Nutrient**—substance used by the body for growth, maintenance, and repair

- **Major nutrients**
  - Carbohydrates
  - Lipids
  - Proteins
  - Water

- **Minor nutrients**
  - Vitamins
  - Minerals
## Five Basic Food Groups and Some of Their Major Nutrients

<table>
<thead>
<tr>
<th>Group</th>
<th>Example foods</th>
<th>Major nutrients supplied in significant amounts:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>Apples, bananas, dates, oranges, tomatoes</td>
<td>Carbohydrate&lt;br&gt;Water&lt;br&gt;Vitamins: A, C, folic acid&lt;br&gt;Minerals: iron, potassium&lt;br&gt;Fiber</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Broccoli, cabbage, green beans, lettuce, potatoes</td>
<td>Carbohydrate&lt;br&gt;Water&lt;br&gt;Vitamins: A, C, E, K, and&lt;br&gt;B vitamins except B₁₂&lt;br&gt;Minerals: calcium, magnesium, iodine, manganese, phosphorus&lt;br&gt;Fiber</td>
</tr>
<tr>
<td>Grain products</td>
<td>Breads, rolls, bagels; cereals, dry and cooked; pasta; rice, other grains; tortillas, pancakes, waffles; crackers; popcorn</td>
<td>Carbohydrate&lt;br&gt;Protein&lt;br&gt;Vitamins: thiamin (B₁), niacin&lt;br&gt;Water&lt;br&gt;Fiber&lt;br&gt;Minerals: iron, magnesium, selenium</td>
</tr>
</tbody>
</table>

### Five Basic Food Groups and Some of Their Major Nutrients (continued)

<table>
<thead>
<tr>
<th>Group</th>
<th>Example foods</th>
<th>Major nutrients supplied in significant amounts:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>By all in group</td>
</tr>
<tr>
<td>Milk products</td>
<td>Milk, yogurt; cheese; ice cream, ice milk, frozen yogurt</td>
<td>Protein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vitamins: riboflavin, B₁₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minerals: calcium, phosphorus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water</td>
</tr>
<tr>
<td>Meats and meat alternatives</td>
<td>Meat, fish, poultry; eggs; seeds; nuts, nut butters; soybeans, tofu; other legumes (peas and beans)</td>
<td>Protein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vitamins: niacin, B₆</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minerals: iron, zinc</td>
</tr>
</tbody>
</table>


Table 14.2 (2 of 2)
USDA Food Guide Pyramid

Key:
- Grains
- Vegetables
- Fruits
- Oils
- Milk
- Meat and beans

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Figure 14.17
Dietary Sources of Major Nutrients

- **Carbohydrates**
  - Most are derived from plants
  - Exceptions: lactose from milk and small amounts of glycogens from meats

- **Lipids**
  - Saturated fats from animal products
  - Unsaturated fats from nuts, seeds, and vegetable oils
  - Cholesterol from egg yolk, meats, and milk products
Dietary Sources of Major Nutrients

- **Proteins**
  - Complete proteins—contain all essential amino acids
    - Most are from animal products
  - Legumes and beans also have proteins, but are incomplete

- **Vitamins**
  - Most vitamins are used as coenzymes
  - Found in all major food groups
Dietary Sources of Major Nutrients

- Minerals
  - Play many roles in the body
  - Most mineral-rich foods are vegetables, legumes, milk, and some meats