Overview of the Digestive Tract

The Digestive System

• Consists of the muscular digestive tract assisted by various accessory organs

• Digestive functions include:
  • Ingestion
  • Mechanical processing
  • Digestion
  • Secretion
  • Absorption
  • Excretion
Overview of the Digestive Tract

Digestive Tract Components

- Oral cavity
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Rectum
- Anus
Overview of the Digestive Tract

The Components of the Digestive System and Their Functions

- **ORAL CAVITY, TEETH, TONGUE**
  - Mechanical processing, moistening, mixing with salivary secretions

- **LIVER**
  - Secretion of bile (important for lipid digestion), storage of nutrients, many other vital functions

- **GALLBLADDER**
  - Storage and concentration of bile

- **PANCREAS**
  - Exocrine cells secrete buffers and digestive enzymes; endocrine cells secrete hormones

- **LARGE INTESTINE**
  - Dehydration and compaction of undigestible materials in preparation for elimination

- **SALIVARY GLANDS**
  - Secretion of lubricating fluid containing enzymes that break down carbohydrates

- **PHARYNX**
  - Muscular propulsion of materials into the esophagus

- **ESOPHAGUS**
  - Transport of materials to the stomach

- **STOMACH**
  - Chemical breakdown of materials by acid and enzymes; mechanical processing through muscular contractions

- **SMALL INTESTINE**
  - Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions

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Figure 16-1
Overview of the Digestive Tract

Histological Organization—Four Layers

- **Mucosa**
  - Epithelium
  - *Lamina propria* (connective tissue)
- **Submucosa**
  - Connective tissue, nerves, blood vessels
- **Muscularis externa**
  - Loose connective tissue cover (*adventitia*)
- **Serosa** (in peritoneal cavity)
  - Continuous with *mesentery*
Overview of the Digestive Tract

The Structure of the Digestive Tract

- Mesenteric artery and vein
- Plicae
- Mesentery
- Serosa (visceral peritoneum)
- Muscularis externa
- Submucosa
- Mucosa

Figure 16-2(a)

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Overview of the Digestive Tract

The Structure of the Digestive Tract

- Mucous epithelium
- Lamina propria
- Villi
- Mucosal glands
- Submucosal gland
- Muscularis mucosae
- Artery and vein
- Lymphatic vessel
- Submucosal plexus
- Myenteric plexus

Figure 16-2(b)
Movement of Digestive Materials

- Involuntary control of smooth muscle of muscularis externa

- Two kinds of movement
  1. *Peristalsis* propels material along the tract
  2. *Segmentation* churns material in the small intestine
**STEP 1**

Contraction of circular muscles behind food mass

Longitudinal muscle

Circular muscle

From mouth → To anus

**STEP 2**

Contraction of longitudinal muscles ahead of food mass

Contraction

**STEP 3**

Contraction of circular muscle layer forces food mass forward
Contraction of circular muscles behind food mass

Step 1

- Longitudinal muscle
- Circular muscle

From mouth to anus

Contraction
Contraction of circular muscles behind food mass

Contraction of longitudinal muscles ahead of food mass

From mouth to anus

Contraction

Contraction
**Figure 16-3**

**STEP 1**
Contraction of circular muscles behind food mass

- Longitudinal muscle
- Circular muscle

From mouth to anus

**STEP 2**
Contraction of longitudinal muscles ahead of food mass

- Contraction

**STEP 3**
Contraction of circular muscle layer forces food mass forward

- Contraction

---

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Functions of the Oral Cavity

1. Sensory analysis of potential foods
2. Mechanical processing using teeth, tongue, and palate
3. Lubrication of food by mucus in saliva
4. Enzymatic digestion by enzymes in saliva
Anatomy of the Oral Cavity

• Also called, buccal cavity
• Tongue forms floor
• Hard and soft palate form roof
• Buccal mucosa forms walls
  • Composed of stratified squamous epithelium
The Oral Cavity

Functions of the Tongue

1. Mechanical processing of food
2. Manipulation to assist chewing and swallowing
3. Sensory analysis (taste, texture)
4. Participation in speech
The Oral Cavity

The Oral Cavity

- Uvula
- Upper labium (lip)
- Palatine tonsil
- Lingual frenulum
- Lower labium (lip)
- Tongue
The Oral Cavity

- Nasal cavity
- Soft palate
- Pharyngeal tonsil
- Entrance to auditory tube
- Nasopharynx
- Uvula
- Palatine tonsil
- Oropharynx
- Lingual tonsil
- Epiglottis
- Laryngopharynx

Figure 16-4(b)

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The Oral Cavity

Salivary Glands

• Three pairs of glands
  1. Parotid (mumps = infection of parotid glands)
  2. Sublingual
  3. Submandibular

• Functions of saliva
  1. Lubricates, cleanses oral cavity
  2. Dissolves chemicals
  3. Suppresses bacterial growth
The Oral Cavity

The Salivary Glands

Figure 16-5
The Oral Cavity

Teeth

• Participate in *mastication* of food
• Anchored to bone by *periodontal ligament*
• *Dentin* forms basic shape
  • *Enamel* covers *crown*
  • *Cementum* covers *root*
• 20 *deciduous* teeth ("baby teeth")
• 32 *secondary* teeth ("adult teeth")
The Oral Cavity

Teeth: Structural Components and Dental Succession

Central incisors (7.5 mo)

Lateral incisor (9 mo)

Cuspid (18 mo)

Primary 1st molar (14 mo)

Primary 2nd molar (24 mo)

Primary 2nd molar (20 mo)

Primary 1st molar (12 mo)

Cuspid (16 mo)

Lateral incisor (7 mo)

Central incisors (6 mo)

(b) Primary teeth

UPPER JAW

HARD PALATE

LOWER JAW

Figure 16-6(b)
The Oral Cavity

Teeth: Structural Components and Dental Succession

Central incisors (7–8 yr)
Lateral incisor (8–9 yr)
Cuspids (11–12 yr)
1st Premolar (10–11 yr)
2nd Premolar (10–12 yr)
1st Molar (6–7 yr)
2nd Molar (12–13 yr)
3rd Molar (17–21 yr)
3rd Molar (17–21 yr)
2nd Molar (11–13 yr)
1st Molar (6–7 yr)
2nd Premolar (11–12 yr)
1st Premolar (10–12 yr)
Cuspids (9–10 yr)
Lateral incisor (7–8 yr)
(c) Secondary teeth

Figure 16-6(c)
The Pharynx

Functions of the Pharynx

1. Common passageway for food, drink, and air

2. Pharyngeal muscles propel food along esophagus toward the stomach during swallowing
Anatomy of the Esophagus

- Muscular tube about 25 cm (10 in) long
- Lined by stratified squamous epithelium
- Posterior to trachea
- Penetrates diaphragm at esophageal hiatus
- Possess upper and lower esophageal sphincters
  - Sphincter—A circular band of muscle that can pinch close a muscular tube
Swallowing (Deglutition)—Three Steps

- Named for where they take place
  1. Oral phase
     - Compaction of *bolus* = *what we call food at this stage*
     - Entry into pharynx
  2. Pharyngeal phase
     - Elevation of larynx
     - Bending of *epiglottis*, closing of *glottis*
  3. Esophageal phase
     - Peristalsis pushes bolus toward stomach
STEP 1 Oral phase

Nasopharynx
- Soft palate
- Bolus
- Epiglottis
- Trachea
Figure 16-7

STEP 1 Oral phase
- Nasopharynx
- Soft palate
- Bolus
- Epiglottis
- Trachea

STEP 2 Pharyngeal phase
- Tongue
Oral phase

Pharyngeal phase

Esophageal phase

STEP 1
- Nasopharynx
- Soft palate
- Bolus
- Epiglottis
- Trachea

STEP 2
- Tongue

STEP 3
- Peristalsis
- Esophagus

Figure 16-7
Figure 16-7

STEP 1 Oral phase
- Nasopharynx
  - Soft palate
  - Bolus
  - Epiglottis
  - Trachea

STEP 2 Pharyngeal phase
- Tongue

STEP 3 Esophageal phase
- Peristalsis
- Esophagus

STEP 4 Bolus enters stomach
- Thoracic cavity
- Lower esophageal sphincter
- Stomach
- Diaphragm
Hiatal Hernia

- Stomach slides up through the opening in the diaphragm
- Can cause acid reflux
The Stomach

Functions of the Stomach

1. Temporary storage of ingested food
2. Mechanical breakdown of food
   • Forms *chyme*, a liquid suspension of partially digested food
3. Breakage of chemical bonds in food by action of acid and enzymes
4. Production of *intrinsic factor*
   • Required for vitamin $B_{12}$ absorption
Regions of the Stomach

1. Cardia
   - Closest to heart
   - Cardiac sphincter between esophagus and stomach

2. Fundus
   - “Hump” on top

3. Body
   - Shaped like the letter “C”

4. Pylorus
   - Pyloric sphincter found between stomach and small intestine
The Stomach

Size:

- Empty = size and shape of a sausage
- Full = can contain 1-1.5 liters of material

Rugae = ridges and folds inside the stomach

Greater Omentum = pouch of fat that hangs over and protects abdominal organs
The Stomach

The Anatomy of the Stomach

- Esophagus
- Body
- Cardia
- Diaphragm
- Fundus
- Lesser curvature (medial surface)
- Lesser omentum
- Pylorus
- Greater curvature (lateral surface)
- Greater omentum
- Rugae

Figure 16-8(a)
The Stomach

The Anatomy of the Stomach

Figure 16-8(b)
The Stomach

Secretions of the Gastric Glands

- **Parietal** cells
  - Secrete HCl (strong acid), *intrinsic factor*

- **Chief** cells
  - Produce *pepsinogen*, an inactive enzyme
  - HCl activates pepsinogen to *pepsin* *(digests proteins)*

- **Goblet** cells
  - Produce *mucus*

- **Endocrine** cells
  - Produce *gastrin*, a hormone
The Stomach

The Anatomy of the Stomach

- Gastric pit (opening to gastric gland)
- Mucous epithelium
- Lymphatic vessel
- Lamina propria
- Muscularis mucosae
- Submucosa
- Oblique muscle
- Circular muscle
- Longitudinal muscle
- Serosa

(c) Myenteric plexus  Artery and vein

Figure 16-8(c)
The Anatomy of the Stomach

Gastric pit

Mucous cells

Neck

Parietal cells

Smooth muscle cell

Chief cells

Endocrine cell

(d)

Figure 16-8(d)
The Regulation of Gastric Activity

- **Cephalic phase**
  - CNS prepares the stomach to receive food

- **Gastric phase**
  - Begins when food enters stomach

- **Intestinal phase**
  - Controls the pace of gastric emptying
The Stomach

The Phases of Gastric Secretion

**Step 1** Cephalic phase
- Sight, smell, taste, or thoughts of food
- Central Nervous System
- Vagus nerve (X)
- Submucosal plexus
- Gastrin
- Endocrine cells

**Step 2** Gastric phase
- Submucosal and myenteric plexuses
- Circulatory transport
- Mucous cells
- Chief cells
- Parietal cells
- Peptinogen
- HCl
- Gastrin
- Distension
- Elevated pH
- Chemoreceptors

**Step 3** Intestinal phase
- Enterogastric reflex
- Myenteric plexus
- Circulatory transport
- Chief cells
- Parietal cells
- Peristalsis

KEY
- Stimulation
- Inhibition

Figure 16-9
The Stomach

The Phases of Gastric Secretion

STEP 1

Cephalic phase

Sight, smell, taste, or thoughts of food

Central Nervous System

Vagus nerve (X)

Submucosal plexus

Mucous cells

Chief cells

Parietal cells

Endocrine cells

Gastrin

Mucus

Pepsinogen

HCl

KEY

Stimulation

Inhibition

Figure 16-9 (1 of 3)
The Stomach

The Phases of Gastric Secretion

**STEP 2**

- **Gastric phase**

  - **Submucosal and myenteric plexuses**
  - **Distension** → **Stretch receptors**
  - **Elevated pH** → **Chemoreceptors**
  - **Circulatory transport**
    - **Gastrin**
  - **Mucous cells** → **Mucus**
  - **Chief cells** → **Pepsinogen**
  - **Parietal cells** → **HCl**
  - **Endocrine cells** → **Partly digested peptides**
  - **Mixing waves**

Figure 16-9 (2 of 3)
The Phases of Gastric Secretion

**STEP 3**

**Intestinal phase**

- Enterogastric reflex
- Myenteric plexus
- Circulatory transport
  - Intestinal stretch and chemoreceptors
  - Chief cells
  - Parietal cells
- Peristalsis

**Regulatory Factors**
- **CCK**
- **GIP**
- **Secretin**
- Presence of lipids and carbohydrates
- Decreased pH

*Figure 16-9 (3 of 3)*
Digestion in the stomach

Salivary amylase remains active until the pH of the stomach contents falls below 4.5, usually within 1-2 hours after a meal.
The Stomach

Key Note

The stomach provides for the physical breakdown of food that must precede chemical digestion. Pepsin and acid begin the digestion of proteins. For a variable period of time after food arrives in the stomach, starch continues the digestion that began with salivary amylase.
Regions of the **Small Intestine**

1. *Duodenum*
2. *Jejunum*
3. *Ileum*
   - *Ileocaecal valve* (a sphincter) marks junction with large intestine

**Length**: 20 ft.
The Small Intestine

The Segments of the Small Intestine

Figure 16-10(b)
The Small Intestine

The Intestinal Wall

- Mucosa has transverse folds, *plicae*
  Plicae have small projections, *villi*
- Both increase surface area of mucosa for absorption
- Each villus has a lymphatic capillary, a *lacteal*
- *Each vilus also have small projections called microvilli*
The Small Intestine

The Intestinal Wall

Figure 16-11(a)
The Small Intestine

The Intestinal Wall

Mucosa
Muscularis mucosae
Submucosa
Muscularis externa
Serosa
Villi
Lacteal
Intestinal gland
Lymphoid nodule
Lymphatic vessel
Submucosal plexus
Circular layer of smooth muscle
Myenteric plexus
Longitudinal layer of smooth muscle
Submucosal artery and vein

Figure 16-11(b)
The Small Intestine

The Intestinal Wall

- Epithelium
- Goblet cell
- Lacteal
- Capillary network
- Nerve
- Lamina propria
- Arteriole
- Venule
- Lymphatic vessel

Figure 16-11(c)
The Small Intestine

Two Forms of Peristalsis

• Small-scale periodic contractions of the muscularis externa

• Large-scale contractions coordinated by reflex
  • Gastroenteric reflex
  • Gastrocolic reflex
The Small Intestine

Intestinal Secretions

• Intestinal glands secrete
  • Intestinal juice
    • Moistens chyme
    • Buffers stomach acid
    • Dissolves digestive enzymes
    • Dissolves products of digestion
  • Mucus
  • Hormones
The Small Intestine

Intestinal Hormones

- Gastrin
- Secretin
- Cholecystokinin (CCK)
- Gastric Inhibitory Peptide (GIP)
The Small Intestine

The Activities of Major Digestive Tract Hormones

Figure 16-12
The Small Intestine

Digestion in the Small Intestine

• Most enzymatic digestion and absorption occurs in the small intestine

• Digestive enzymes and buffers are released by:
  • Pancreas
  • Liver
  • Gall bladder
The small intestine receives chyme from the stomach and raises its pH. It then absorbs water, ions, vitamins, and the products released from food molecules by the action of digestive enzymes produced by intestinal glands and the pancreas.
The Pancreas

Anatomy of the Pancreas

• Pancreatic duct enters duodenum
• Duct delivers pancreatic juice
• Duct branches repeatedly
• Fine branches end in pancreatic acini
• Endocrine cells are found among the acini
The Pancreas

Location: behind the stomach
Length: 6 in.
Weight: 3 oz.
The Pancreas

Abdominal aorta
Celiac trunk
Common bile duct
Head of pancreas
Pancreatic duct
Duodenum

Stomach
Splenic artery
Tail of pancreas
Body of pancreas
Superior mesenteric artery

Figure 16-13(a)
Secretions of the Pancreas

- **Endocrine secretion (hormones)**
  1. Insulin
  2. Glucagon

- **Exocrine secretion (digestive)**
  - 3. Pancreatic juices
    - Water
    - Ions
    - Enzymes
      - Carbohydrases
      - Lipases
      - Proteases
      - Nucleases
The Pancreas

The **pancreatic duct** carries the previous secretions to the duodenum.

Pancreas secretes about **1 quart of pancreatic juice per day**.
Control of Pancreatic Secretion

- Chyme entering duodenum triggers hormone release
- Hormones trigger release of pancreatic juice
  - *Secretin* triggers water and *bicarbonate* to neutralize acidic chyme
  - *CCK* triggers enzymes
    - Amylase, lipase
    - Proteases
      - Trypsin, chymotrypsin, carboxypeptidase
The exocrine pancreas produces a mixture of buffers and enzymes essential for normal digestion. Pancreatic secretion is stimulated by hormones (secretin and CCK) released from the duodenum.
Overview of Liver

- Largest visceral organ (weighs about 3.3 pounds); 2.5 % of body’s weight
- Over 200 known functions
- Four Lobes
  - Right (largest by far)
  - Left
  - Caudate
  - Quadrate
The Liver

The Surface Anatomy of the Liver

Coronary ligament

Gallbladder

Falciform ligament

Right lobe

Left lobe

Round ligament

(a) Anterior surface
The Liver

The Surface Anatomy of the Liver

- Left hepatic vein
- Inferior vena cava
- Left lobe
- Caudate lobe
- Hepatic portal vein
- Hepatic artery
- Right lobe
- Quadrant lobe
- Gallbladder

(b) Posterior surface

Figure 16-14(b)
The Liver

Histology of the Liver

- *Liver lobule* is basic functional unit
- Blood supply from hepatic artery and *hepatic portal vein*
- Blood flows past sheets of *hepatocytes*
- Blood channels are sinusoids
- Blood collects in *central vein*
- *Bile canaliculi* carry bile toward bile ducts
The Liver

Liver Histology

Figure 16-15(a)
Liver Histology

- Central vein
- Kupffer cells
- Hepatocytes
- Sinusoid
- Bile canaliculi
- Branch of hepatic artery
- Bile duct
- Branch of hepatic portal vein

Figure 16-15(b)
The Liver

Liver Histology

- Branch of hepatic artery
- Branch of hepatic portal vein
- Central vein
- Sinusoid
- Lobules
- Portal area

Figure 16-15(c)
The Liver

Bile Ducts

- Each lobe has a bile duct
- Bile ducts unite to form common hepatic duct
- Cystic duct carries bile to gall bladder
- Common bile duct carries bile to the duodenum
Functions of the Liver

1. **Metabolic regulation**
   - Store absorbed nutrients, vitamins
   - Release nutrients as needed

2. **Hematological regulation**
   - Plasma protein production
   - Remove old RBCs

3. **Production of bile**
   - Required for fat breakdown
The Liver

Bile contains:

1. Water
2. Ions
3. Bilirubin (pigment)
4. Cholesterol
5. Bile salts
The Gallbladder

- Gall bladder stores and concentrates bile for release into duodenum
- Relaxation of the hepatopancreatic sphincter permits bile to enter small intestine
  - CCK relaxes this sphincter
The Gallbladder

Key Note

The liver is the body’s center for metabolic regulation. It produces bile that will be ejected by the gallbladder into the duodenum under stimulation of CCK. Bile is essential for the efficient digestion of lipids; it *emulsifies* fats so that individual lipid molecules can be readily attacked by digestive enzymes.
The Gallbladder

The Gall Bladder

Cystic duct

Gallbladder

Common bile duct

Common hepatic duct

Cut edge of lesser omentum

Hepatic portal vein

Hepatic artery

Liver

Duodenum

Stomach

Pancreas

Figure 16-16(a)
The Gallbladder

The Gall Bladder

- Hepatopancreatic sphincter
- Common bile duct
- Duodenal papilla
- Pancreatic duct
- Intestinal lumen

Figure 16-16(b)
The Large Intestine

Overview of the Large Intestine

1. Reabsorbs water and compacts feces
2. Absorbs vitamins made by bacteria (vitamin K for blood clotting)
3. Stores feces before defecation

• Consists of three parts
  • Cecum
  • Colon
  • Rectum
Cecum (1st part of large intestine)

- Collects and stores material from ileum
- Begins process of compaction
- Appendix attaches here
The Anatomy of the Colon

• Larger diameter, thinner wall than small intestine
• Bears *haustra* (pouches)
• Possesses *taenia coli* (longitudinal bands of smooth muscle)

• 4 segments:
  • Ascending
  • Transverse
  • Descending
  • Sigmoid
The Large Intestine

The Rectum

- Expandable for temporary storage of feces
- Terminates in anal canal
- Leads to anus
- Circular muscle forms internal anal sphincter
- Encircled by skeletal muscle
  - Forms external anal sphincter
Functions of the Large Intestine

- Absorption
  - Water
  - Ions
  - Vitamins
  - Organic wastes
  - Bile salts
  - Toxins (ammonia, N containing compounds, hydrogen sulfide -- “rotten egg smell”)
- Bacterial growth
Control of the Large Intestine

- Stretching of stomach and duodenum triggers peristalsis of feces from colon into rectum
- Sphincters control movement of feces toward the anus
- Stretching of rectum triggers defecation reflex
  - Release of feces requires relaxation of external anal sphincter
The Large Intestine

Key Note

The large intestine stores digestive wastes and reduces their volume by reabsorbing water. Bacteria that live in the large intestine are an important source of vitamins, especially vitamin K, biotin, and vitamin B₅.
Processing and Absorption of Nutrients

• Two Steps in Processing
  • Mechanical processing to break down physical structure of foods
  • Chemical processing to break the covalent bonds between food subunits
  • Enzymes catalyze this
  • Activate the hydrolysis of large food molecules
Digestion and Absorption

Processing and Absorption of Nutrients

- **Carbohydrates**
  - Starches are broken down by *amylases*
    - Results in di- and trisaccharides
  - Enzymes on cell surface split them to *monosaccharides*
  - Absorbed by the intestinal epithelium by *facilitated diffusion* or *co-transport*
The Digestion and Absorption of Carbohydrates

<table>
<thead>
<tr>
<th>REGION</th>
<th>CARBOHYDRATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORAL CAVITY</td>
<td>← Salivary amylase</td>
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<tr>
<td>ESOPHAGUS</td>
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</tr>
<tr>
<td>STOMACH</td>
<td></td>
</tr>
<tr>
<td>SMALL INTESTINE</td>
<td>Pancreatic amylase</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disaccharides</td>
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<tr>
<td></td>
<td>Trisaccharides</td>
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</tbody>
</table>

Figure 16-18(a) (1 of 2)
The Digestion and Absorption of Carbohydrates
Processing and Absorption of Fats

- Bile *emulsifies* fats to small droplets
- *Lipase* hydrolyzes triglycerides into fatty acids and *monoglycerides*
- Lipid products form *micelles*
- Lipids diffuse into epithelial cells
- Triglycerides are reformed
- Secreted as *chylomicrons* into lacteals
- Transported in lymph to thoracic duct
Digestion and Absorption

The Digestion and Absorption of Lipids

<table>
<thead>
<tr>
<th>REGION</th>
<th>LIPIDS</th>
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<tbody>
<tr>
<td>ORAL CAVITY</td>
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<td>ESOPHAGUS</td>
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<td>STOMACH</td>
<td></td>
</tr>
<tr>
<td>SMALL INTESTINE</td>
<td>Bile salts and pancreatic lipase</td>
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Monoglycerides
Fatty acids in micelles

Figure 16-18(b) (1 of 2)
The Digestion and Absorption of Lipids

<table>
<thead>
<tr>
<th>REGION</th>
<th>LIPIDS</th>
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<tbody>
<tr>
<td>INTESTINAL MUCOSA</td>
<td>MONOGLYCERIDES, FATTY ACIDS</td>
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<td>CHYLOMICRONS</td>
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<td>EXOCYTOSIS</td>
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<td>BLOODSTREAM</td>
<td>CHYLOMICRONS</td>
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</table>

Figure 16-18(b) (2 of 2)
Processing and Absorption of Nutrients

- Proteins
  - Breakdown starts in stomach
    - Pepsin and HCl produce fragments
  - Breakdown continues in small intestine
    - Pancreatic proteases produce small peptides
    - Peptidases releases amino acids
  - Intestinal epithelium absorbs amino acids into the body
Digestion and Absorption

The Digestion and Absorption of Proteins

<table>
<thead>
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<th>REGION</th>
<th>PROTEINS</th>
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<td>ORAL CAVITY</td>
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<td>ESOPHAGUS</td>
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<td>Polypeptides</td>
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<td>SMALL INTESTINE</td>
<td>Trypsin, Chymotrypsin, Carboxypeptidase</td>
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<td>Short peptides</td>
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<td>Amino acids</td>
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</table>

Figure 16-18(c) (1 of 2)
The Digestion and Absorption of Proteins

Figure 16-18(c) (2 of 2)
Digestion and Absorption

Water and Electrolyte Absorption

- About nine liters/day enter the digestive tract
  - Two liters of ingested water
  - Seven liters of watery secretions
- Ions are absorbed by many mechanisms
  - Sodium, calcium, chloride, bicarbonate
- All but about 150 ml is absorbed by osmosis, as water “follows” the ions
Absorption of Vitamins

- Fat-soluble vitamins combine with lipid micelles for absorption
- Water-soluble vitamins diffuse across the digestive epithelium
  - Exception: vitamin $\text{B}_{12}$ requires *intrinsic factor* (from the gastric mucosa) for absorption
Age-Related Changes in the Digestive System

• Thinner, more fragile epithelium
• Reduced epithelial stem cell division
• Weaker peristaltic contraction
  • Reduced smooth muscle tone
The Digestive System in Perspective

FIGURE 16-19
Functional Relationships Between the Digestive System and Other Systems
The Integumentary System

- Provides vitamin D$_3$ needed for the absorption of calcium and phosphorus
- Provides lipids for storage by adipocytes in subcutaneous layer
The Skeletal System

- Skull, ribs, vertebrae, and pelvic girdle support and protect parts of digestive tract; teeth important in mechanical processing of food

- Absorbs calcium and phosphate ions for incorporation into bone matrix; provides lipids for storage in yellow marrow
The Muscular System

- Protects and supports digestive organs in abdominal cavity; controls entrances and exits of digestive tract
- Liver regulates blood glucose and fatty acid levels, metabolizes lactic acid from active muscles
The Nervous System

• ANS regulates movement and secretion; reflexes coordinate passage of materials along tract; control over skeletal muscles regulates ingestion and defecation; hypothalamic centers control hunger, satiation, and feeding behaviors

• Provides substrates essential for neurotransmitter synthesis
The Endocrine System

- Epinephrine and norepinephrine stimulate constriction of sphincters and depress digestive activity; hormones coordinate activity along tract

- Provides nutrients and substrates to endocrine cells; endocrine cells of pancreas secrete insulin and glucagon; liver produces angiotensinogen
The Cardiovascular System

- Distributes hormones of the digestive tract; carries nutrients, water, and ions from sites of absorption; delivers nutrients and toxins to liver.

- Absorbs fluid to maintain normal blood volume; absorbs vitamin K; liver excretes heme (as bilirubin), synthesizes coagulation proteins.
The Lymphatic System

- Tonsils and other lymphoid nodules along digestive tract defend against infection and toxins absorbed from the tract; lymphatic vessels carry absorbed lipids to venous system.
- Secretions of digestive tract (acids and enzymes) provide nonspecific defense against pathogens.
The Respiratory System

- Increased thoracic and abdominal pressure through contraction of respiratory muscles can assist in defecation.

- Pressure of digestive organs against the diaphragm can assist in exhalation and limit inhalation.
The Urinary System

- Excretes toxins absorbed by the digestive epithelium; excretes some bilirubin produced by liver
- Absorbs water needed to excrete waste products at the kidneys; absorbs ions needed to maintain normal body fluid concentrations
The Reproductive System

- Provides additional nutrients required to support gamete production and (in pregnant women) embryonic and fetal development