An Introduction to the Digestive System

• Learning Outcomes
  
  • 24-1 Identify the organs of the digestive system, list their major functions, describe the functional histology of the digestive tract, and outline the mechanisms that regulate digestion.
  
  • 24-2 Discuss the anatomy of the oral cavity, and list the functions of its major structures and regions.
  
  • 24-3 Describe the structure and functions of the pharynx.
  
  • 24-4 Describe the structure and functions of the esophagus.
An Introduction to the Digestive System

• Learning Outcomes

• 24-5 Describe the anatomy of the stomach, including its histological features, and discuss its roles in digestion and absorption.

• 24-6 Describe the anatomical and histological characteristics of the small intestine, explain the functions and regulation of intestinal secretions, and describe the structure, functions, and regulation of the accessory digestive organs.
An Introduction to the Digestive System

• Learning Outcomes

  • 24-7 Describe the gross and histological structure of the large intestine, including its regional specializations and role in nutrient absorption.

  • 24-8 List the nutrients required by the body, describe the chemical events responsible for the digestion of organic nutrients, and describe the mechanisms involved in the absorption of organic and inorganic nutrients.
An Introduction to the Digestive System

• Learning Outcomes
  
  • 24-9 Summarize the effects of aging on the digestive system.
  
  • 24-10 Give examples of interactions between the digestive system and other organ systems studied so far.
An Introduction to the Digestive System

• The Digestive System
  • Acquires nutrients from environment
  • Anabolism
    • Uses raw materials to synthesize essential compounds
  • Catabolism
    • Decomposes substances to provide energy cells need to function
An Introduction to the Digestive System

• Catabolic Reactions

  • Require two essential ingredients

  1. Oxygen

  2. Organic molecules broken down by intracellular enzymes

    • For example, carbohydrates, fats, and proteins
The Digestive Tract

- Also called gastrointestinal (GI) tract or alimentary canal
- Is a muscular tube
- Extends from oral cavity to anus
  - Passes through pharynx, esophagus, stomach, and small and large intestines
Figure 24-1  The Components of the Digestive System

<table>
<thead>
<tr>
<th>Major Subdivisions of the Digestive Tract</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral Cavity, Teeth, Tongue</td>
<td>Mechanical processing, moistening, mixing with salivary secretions</td>
</tr>
<tr>
<td>Pharynx</td>
<td>Muscular propulsion of materials into the esophagus</td>
</tr>
<tr>
<td>Esophagus</td>
<td>Transport of materials to the stomach</td>
</tr>
<tr>
<td>Stomach</td>
<td>Chemical breakdown of materials by acid and enzymes; mechanical processing through muscular contractions</td>
</tr>
<tr>
<td>Small Intestine</td>
<td>Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions</td>
</tr>
<tr>
<td>Large Intestine</td>
<td>Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions</td>
</tr>
</tbody>
</table>

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Figure 24-1  The Components of the Digestive System

Accessory Organs of the Digestive System

Salivary glands
- Secretion of lubricating fluid containing enzymes that break down carbohydrates

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
24-1 The Digestive Tract

• Six Functions of the **Digestive System**

1. Ingestion
2. Mechanical processing
3. Digestion
4. Secretion
5. Absorption
6. Excretion
The Digestive Tract

- **Ingestion**
  - Occurs when materials enter digestive tract via the mouth

- **Mechanical Processing**
  - Crushing and shearing
  - Makes materials easier to propel along digestive tract

- **Digestion**
  - The chemical breakdown of food into small organic fragments for absorption by digestive epithelium
24-1 The Digestive Tract

- **Secretion**
  - Is the release of water, acids, enzymes, buffers, and salts
  - By epithelium of digestive tract
  - By glandular organs
24-1 The Digestive Tract

• **Absorption**
  • Movement of organic substrates, electrolytes, vitamins, and water
  • Across digestive epithelium
  • Into interstitial fluid of digestive tract

• **Excretion**
  • Removal of waste products from body fluids
  • Process called *defecation* removes *feces*
24-1 The Digestive Tract

• The Lining of the Digestive Tract

• Safeguards surrounding tissues against:
  1. Corrosive effects of digestive acids and enzymes
  2. Mechanical stresses, such as abrasion
  3. Bacteria either ingested with food or that reside in digestive tract
The Digestive Tract

• The Digestive Organs and the Peritoneum
  • Lined with serous membrane consisting of:
    • Superficial mesothelium covering a layer of areolar tissue
    • Serosa, or *visceral peritoneum*
      • Covers organs within *peritoneal cavity*
    • *Parietal peritoneum*
      • Lines inner surfaces of body wall
• Peritoneal Fluid
  • Is produced by serous membrane lining
  • Provides essential lubrication
  • Separates parietal and visceral surfaces
  • Allows sliding without friction or irritation
  • About 7 liters produced and absorbed daily, but very little in peritoneal cavity at one time
    • Ascites – excess peritoneal fluid causing abdominal swelling
• **Mesenteries**
  
  • Are double sheets of peritoneal membrane
  
  • Suspend portions of digestive tract within peritoneal cavity by sheets of serous membrane
    
    • That connect parietal peritoneum
    
    • With visceral peritoneum
24-1 The Digestive Tract

- Mesenteries
  - Areolar tissue between mesothelial surfaces
    - Provides an access route to and from the digestive tract
    - For passage of blood vessels, nerves, and lymphatic vessels
  - Stabilize positions of attached organs
  - Prevent intestines from becoming entangled
• Mesentery Development
  • During embryonic development
    • Digestive tract and accessory organs are suspended in peritoneal cavity by:
      • *Dorsal mesentery*
      • *Ventral mesentery*
    • Later disappears along most of digestive tract except at the lesser omentum and at the falciform ligament
During embryonic development, the digestive tube is initially suspended by dorsal and ventral mesenteries.
24-1 The Digestive Tract

- The **Lesser Omentum**
  - Stabilizes position of stomach
  - Provides access route for blood vessels and other structures entering or leaving liver

- The **Falciform Ligament**
  - Helps stabilize position of liver
    - Relative to diaphragm and abdominal wall
24-1 The Digestive Tract

• The Dorsal Mesentery
  • Enlarges to form an enormous pouch, called the greater omentum
    • Extends inferiorly between:
      • The body wall and the anterior surface of small intestine
    • Hangs like an apron
      • From lateral and inferior borders of stomach
24-1 The Digestive Tract

- Adipose Tissue in Greater Omentum
  - Conforms to shapes of surrounding organs
  - Pads and protects surfaces of abdomen
  - Provides insulation to reduce heat loss
  - Stores lipid energy reserves
24-1 The Digestive Tract

• The **Mesentery Proper**
  • Is a thick mesenterial sheet
  • Provides stability
  • Permits some independent movement
  • Suspends all but first 25 cm (10 in.) of small intestine
  • Is associated with initial portion of small intestine (duodenum) and pancreas
  • Fuses with posterior abdominal wall, locking structures in position
24-1 The Digestive Tract

The **Mesocolon**

- A mesentery associated with a portion of the large intestine
  - *Transverse mesocolon* supports transverse colon
  - *Sigmoid mesocolon* supports sigmoid colon
- During development, mesocolon of *ascending colon*, *descending colon*, and the *rectum*:
  - Fuse to dorsal body wall
  - Lock regions in place
A diagrammatic view of the organization of mesenteries in an adult.
An anterior view of the empty peritoneal cavity, showing the attachment of mesenteries to the posterior body wall.
Figure 24-2d Mesenteries

A sagittal section showing the mesenteries of an adult. Notice that the pancreas, duodenum, and rectum are retroperitoneal.

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24-1 The Digestive Tract

• Histological Organization of the Digestive Tract
  • Four major layers of the digestive tract
    1. Mucosa
    2. Submucosa
    3. Muscularis externa
    4. Serosa
Figure 24-3  The Structure of the Digestive Tract

Mesenteric artery and vein

Plica circulares

Mesentery

Mucosa

Submucosa

Muscularis externa

Serosa (visceral peritoneum)
Figure 24-3  The Structure of the Digestive Tract

- Plica circulares
- Mucosal epithelium
- Lamina propria
- Villi
- Mucosal glands
- Submucosal gland
- Muscularis mucosae
- Lymphatic vessel
- Artery and vein
- Submucosal plexus
- Circular muscle layer
- Myenteric plexus
- Longitudinal muscle layer

- Mucosa
- Submucosa
- Muscularis externa
- Serosa (visceral peritoneum)
• The **Mucosa**

  • Is the inner lining of digestive tract
  • Is a *mucous membrane* consisting of:
    • Epithelium, moistened by glandular secretions
    • *Lamina propria* of areolar tissue
24-1 The Digestive Tract

• The Digestive Epithelium
  • Mucosal epithelium is simple or stratified
    • Depending on location, function, and stresses
The Digestive Epithelium

- Oral cavity, pharynx, and esophagus
  - Mechanical stresses
  - Lined by stratified squamous epithelium
- Stomach, small intestine, and most of large intestine
  - Absorption
  - Simple columnar epithelium with mucous cells
24-1 The Digestive Tract

• The Digestive Epithelium

  • **Enteroendocrine cells**
    
    • Are scattered among columnar cells of digestive epithelium
    
    • Secrete hormones that:
      
      • Coordinate activities of the digestive tract and accessory glands
24-1 The Digestive Tract

• Lining of Digestive Tract
  • Folding increases surface area for absorption
    • Longitudinal folds, disappear as digestive tract fills
    • Permanent transverse folds (*plicae circulares*)
24-1 The Digestive Tract

• The Lamina Propria
  • Consists of a layer of areolar tissue that contains:
    • Blood vessels
    • Sensory nerve endings
    • Lymphatic vessels
    • Smooth muscle cells
    • Scattered areas of lymphoid tissue
24-1 The Digestive Tract

• The Lamina Propria

• **Muscularis mucosae**
  
  • Narrow band of smooth muscle and elastic fibers in lamina propria
  
  • Smooth muscle cells arranged in two concentric layers
    
    • Inner layer encircles lumen (*circular muscle*)
    
    • Outer layer contains muscle cells parallel to tract (*longitudinal layer*)
The **Submucosa**

- Is a layer of dense, irregular connective tissue
- Surrounds muscularis mucosae
- Has large blood vessels and lymphatic vessels
- May contain exocrine glands
  - Secrete buffers and enzymes into digestive tract
24-1 The Digestive Tract

- **Submucosal Plexus**
  - Also called *plexus of Meissner*
  - Innervates the mucosa and submucosa
  - Contains:
    - Sensory neurons
    - Parasympathetic ganglionic neurons
    - Sympathetic postganglionic fibers
24-1 The Digestive Tract

• The **Muscularis Externa**
  
  • Is dominated by smooth muscle cells
  
  • Are arranged in:
    
    • Inner circular layer
    
    • Outer longitudinal layer
24-1 The Digestive Tract

- The Muscularis Externa
  - Involved in:
    - Mechanical processing
    - Movement of materials along digestive tract
  - Movements coordinated by enteric nervous system (ENS)
    - Sensory neurons
    - Interneurons
    - Motor neurons
24-1 The Digestive Tract

- The Muscularis Externa
  - ENS
    - Innervated primarily by parasympathetic division of ANS
      - Sympathetic postganglionic fibers
        - The mucosa
          - The myenteric plexus (plexus of Auerbach)
• The Serosa
  • Serous membrane covering muscularis externa
    • Except in oral cavity, pharynx, esophagus, and rectum
      • Where *adventitia*, a dense sheath of collagen fibers, firmly attaches the digestive tract to adjacent structures
The Movement of Digestive Materials

By muscular layers of digestive tract

Consist of visceral smooth muscle tissue

Along digestive tract

Has rhythmic cycles of activity

Controlled by *pacesetter cells*

Cells undergo spontaneous depolarization

Triggering wave of contraction through entire muscular sheet
24-1 The Digestive Tract

• Pacesetter Cells
  • Located in muscularis mucosae and muscularis externa
    • Surrounding lumen of digestive tract

• Peristalsis
  • Consists of waves of muscular contractions
  • Moves a bolus along the length of the digestive tract
24-1 The Digestive Tract

• Peristaltic Motion

1. Circular muscles contract behind bolus
   • While circular muscles ahead of bolus relax

2. Longitudinal muscles ahead of bolus contract
   • Shortening adjacent segments

3. Wave of contraction in circular muscles
   • Forces bolus forward
Figure 24-4 Peristalsis

1. Contraction of circular muscles behind bolus
   - From mouth
   - To anus

2. Contraction of longitudinal muscles ahead of bolus
   - Contraction

3. Contraction in circular muscle layer forces bolus forward
   - From mouth
   - To anus
24-1 The Digestive Tract

- **Segmentation**
  - Cycles of contraction
    - Churn and fragment the bolus
    - Mix contents with intestinal secretions
  - Does not follow a set pattern
    - Does not push materials in any one direction
24-1 The Digestive Tract

• Control of Digestive Functions
  • Local Factors
    • Prostaglandins, histamine, and other chemicals released into interstitial fluid
      • May affect adjacent cells within small segment of digestive tract
    • Coordinate response to changing conditions
      • For example, variations in local pH, chemical, or physical stimuli
    • Affect only a portion of tract
24-1 The Digestive Tract

• Control of Digestive Functions
  • Neural Mechanisms
    • Control
      • Movement of materials along digestive tract
      • Secretory functions
  • Motor neurons
    • Control smooth muscle contraction and glandular secretion
    • Located in myenteric plexus

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24-1 The Digestive Tract

• Neural Mechanisms

  • Short reflexes
    • Are responsible for local reflexes
    • Control small segments of digestive tract
    • Operate entirely outside of CNS control
      • Sensory neurons
      • Motor neurons
      • Interneurons
Neural Mechanisms

Long reflexes

- Higher level control of digestive and glandular activities
- Control large-scale peristaltic waves
- Involve interneurons and motor neurons in CNS
- May involve parasympathetic motor fibers that synapse in the myenteric plexus
  - Glossopharyngeal, vagus, or pelvic nerves
24-1 The Digestive Tract

- Hormonal Mechanisms
  - At least 18 peptide hormones that affect:
    - Most aspects of digestive function
    - Activities of other systems
  - Are produced by enteroendocrine cells in digestive tract
  - Reach target organs after distribution in bloodstream
Figure 24-5 The Regulation of Digestive Activities

2 Neural Control Mechanisms

- CNS
- Long reflex
- Myenteric plexus
- Short reflex
- Stretch receptors, chemoreceptors

3 Hormonal Control Mechanisms

- Secretory cells
- Enteroendocrine cells
- Via the bloodstream
- Hormones released

Local Factors

Buffers, acids, enzymes released

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24-2 The Oral Cavity

- Functions of the Oral Cavity

  1. *Sensory analysis*
     - Of material before swallowing
  2. *Mechanical processing*
     - Through actions of teeth, tongue, and palatal surfaces
  3. *Lubrication*
     - Mixing with mucus and salivary gland secretions
  4. Limited *digestion*
     - Of carbohydrates and lipids
24-2 The Oral Cavity

• Oral Mucosa
  • Lining of oral cavity
  • Has stratified squamous epithelium
  • Of cheeks, lips, and inferior surface of tongue
    • Is relatively thin, nonkeratinized, and delicate
  • Inferior to tongue is thin and vascular enough to rapidly absorb lipid-soluble drugs
  • Cheeks are supported by pads of fat and the buccinator muscles
Labia
- Also called lips
- Anteriorly, the mucosa of each cheek is continuous with that of the lips

Vestibule
- Space between the cheeks (or lips) and the teeth
• **Gingivae** (Gums)
  
  • Ridges of oral mucosa
  
  • Surround base of each tooth on alveolar processes of maxillary bones and mandible
Figure 24-6a The Oral Cavity

A sagittal section of the oral cavity

- Nasal cavity
- Hard palate
- Soft palate
- Palatoglossal arch
- Opening of parotid duct
- Upper lip
- Cheek
- Dorsum of tongue
- Lower lip
- Gingiva
- Vestibule
- Body of tongue
- Root of tongue
- Pharyngeal tonsil
- Entrance to auditory tube
- Nasopharynx
- Uvula
- Palatine tonsil
- Fauces
- Palatopharyngeal arch
- Oropharynx
- Lingual tonsil
- Epiglottis
- Hyoid bone
- Laryngopharynx
Figure 24-6b The Oral Cavity

An anterior view of the oral cavity as seen through the open mouth

- Hard palate
- Soft palate
- Fauces
- Palatoglossal arch
- Palatopharyngeal arch
- Palatine tonsil
- Lingual frenulum
- Gingiva
- Tongue
- Vestibule
- Openings of submandibular ducts

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The Oral Cavity

- The **Tongue**
  - Manipulates materials inside mouth
  - Functions of the tongue
    1. Mechanical processing by compression, abrasion, and distortion
    2. Manipulation to assist in chewing and to prepare material for swallowing
    3. Sensory analysis by touch, temperature, and taste receptors
    4. Secretion of mucins and the enzyme *lingual lipase*
Salivary Glands

Three pairs secrete into oral cavity

1. Parotid salivary glands
2. Sublingual salivary glands
3. Submandibular salivary glands

Each pair has distinctive cellular organization

And produces saliva with different properties
24-2 The Oral Cavity

- Parotid Salivary Glands
  - Inferior to zygomatic arch
  - Produce serous secretion
    - Enzyme *salivary amylase* (breaks down starches)
  - Drained by *parotid duct*
    - Which empties into vestibule at second molar
Sublingual Salivary Glands
- Covered by mucous membrane of floor of mouth
- Produce mucous secretion
  - Acts as a buffer and lubricant
- Sublingual ducts
  - Either side of lingual frenulum
24-2 The Oral Cavity

- **Submandibular Salivary Glands**
  - In floor of mouth
  - Within *mandibular groove*
  - Secrete buffers, glycoproteins (mucins), and salivary amylase

- **Submandibular ducts**
  - Open immediately posterior to teeth
  - Either side of lingual frenulum
A lateral view, showing the relative positions of the salivary glands and ducts on the left side of the head.
The submandibular gland secretes a mixture of mucins, produced by mucous cells, and enzymes, produced by serous cells.
24-2 The Oral Cavity

• Saliva
  • Glands produce 1.0–1.5 liters of saliva each day
    • 70% by submandibular glands
    • 25% by parotids
    • 5% by sublingual glands
24-2 The Oral Cavity

• Saliva
  • 99.4% water
  • 0.6% includes:
    • Electrolytes (Na\(^+\), Cl\(^-\), and HCO\(_3\)^-)
    • Buffers
    • Glycoproteins (mucins)
    • Antibodies
    • Enzymes
    • Waste products
Functions of Saliva

- Lubricating the mouth
- Moistening and lubricating materials in the mouth
- Dissolving chemicals that stimulate taste buds and provide sensory information
- Initiating digestion of complex carbohydrates by the enzyme *salivary amylase* (*ptyalin* or *alpha-amylase*)
24-2 The Oral Cavity

• Control of Salivary Secretions
  • By autonomic nervous system
    • Parasympathetic and sympathetic innervation
      • Parasympathetic accelerates secretion by all salivary glands
  • Salivatory nuclei of medulla oblongata influenced by:
    • Other brain stem nuclei
    • Activities of higher centers
The Oral Cavity

• The Teeth
  • Tongue movements pass food across occlusal surfaces of teeth
  • Chew (*masticate*) food
• Dentin
  • A mineralized matrix similar to that of bone
  • Does not contain cells

• Pulp Cavity
  • Receives blood vessels and nerves through the root canal
The Oral Cavity

- **Root**
  - Of each tooth sits in a bony socket (*alveolus*)
  - A layer of *cementum* covers dentin of the root
    - Providing protection and anchoring *periodontal ligament*

- **Crown**
  - Exposed portion of tooth
  - Projects beyond soft tissue of gingiva
  - Dentin covered by layer of *enamel*
24-2 The Oral Cavity

- Alveolar Processes
  - Of the maxillae
    - Form maxillary arcade (upper dental arch)
  - Of the mandible
    - Form mandibular arcade (lower dental arch)
Figure 24-8a Teeth

A diagrammatic section through a typical adult tooth.

- Enamel
- Dentin
- Pulp cavity
- Gingiva
- Gingival sulcus
- Cementum
- Periodontal ligament
- Root canal
- Bone of alveolus
- Apical foramen
- Branches of alveolar vessels and nerve

a A diagrammatic section through a typical adult tooth.
Figure 24-8b Teeth

<table>
<thead>
<tr>
<th>Incisors</th>
<th>Cuspids (canines)</th>
<th>Bicuspid (premolars)</th>
<th>Molars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Upper jaw**
- Incisors
- Cuspids (canines)
- Bicuspid (premolars)
- Molars

**Lower jaw**
- Incisors
- Cuspids (canines)
- Bicuspid (premolars)
- Molars

The adult teeth from the right side of the upper and lower jaws. Figure 24-9a,b provides a view of the occlusal surfaces.
24-2 The Oral Cavity

• Types of Teeth

1. Incisors
2. Cuspids (canines)
3. Bicuspid (premolars)
4. Molars
• **Incisors**
  - Blade-shaped teeth
  - Located at front of mouth
  - Used for clipping or cutting
  - Have a single root
24-2 The Oral Cavity

- **Cuspid**s (*Canines*)
  - Conical
  - Sharp ridgeline
  - Pointed tip
  - Used for tearing or slashing
  - Have a single root
24-2 The Oral Cavity

- **Bicuspid (Premolars)**
  - Flattened crowns
  - Prominent ridges
  - Used to crush, mash, and grind
  - Have one or two roots
24-2 The Oral Cavity

• **Molars**
  
  • Very large, flat crowns
  
  • With prominent ridges
  
  • Used for crushing and grinding
  
  • Have three or more roots
Dental Succession

- During embryonic development, two sets of teeth form
  - Primary dentition, or deciduous teeth
  - Secondary dentition, or permanent dentition
Deciduous Teeth

- Also called *primary teeth, milk teeth, or baby teeth*
- 20 temporary teeth of primary dentition
- Five on each side of upper and lower jaws
  - 2 incisors
  - 1 cuspid
  - 2 deciduous molars
The primary teeth, with the age at eruption given in months.
Secondary Dentition

- Also called *permanent dentition*
- Replaces deciduous teeth
- 32 permanent teeth
- Eight on each side, upper and lower
  - 2 incisors
  - 1 cuspid
  - 5 molars
The adult teeth, with the age at eruption given in years.
The adult teeth, with the age at eruption given in years.

- Central incisors (6–7 yr)
- Lateral incisor (7–8 yr)
- Cuspid (9–10 yr)
- 1st Premolar (10–12 yr)
- 2nd Premolar (11–12 yr)
- 1st Molar (6–7 yr)
- 2nd Molar (11–13 yr)
- 3rd Molar (17–21 yr)
Maxilla exposed to show developing permanent teeth

Erupted deciduous teeth

First and second molars

Mandible exposed to show developing permanent teeth

**c** Maxilla and mandible with unerupted teeth exposed.
Mastication

• Also called chewing

• Food is forced from oral cavity to vestibule and back
  • Crossing and recrossing occlusal surfaces
24-2 The Oral Cavity

- **Muscles of Mastication**
  - Close the jaws
  - Slide or rock lower jaw from side to side
  - Chewing involves mandibular:
    - Elevation and depression
    - Protraction and retraction
    - Medial and lateral movement
24-3 The Pharynx

• The **Pharynx** (Throat)

  • A common passageway for solid food, liquids, and air

  • Regions of the pharynx:
    
    • Nasopharynx
    • Oropharynx
    • Laryngopharynx

  • Food passes through the oropharynx and laryngopharynx to the esophagus
The Esophagus

- A hollow muscular tube
- About 25 cm (10 in.) long and 2 cm (0.80 in.) wide
- Conveys solid food and liquids to the stomach
- Begins posterior to cricoid cartilage
- Enters abdominopelvic cavity through the esophageal hiatus
- Is innervated by fibers from the esophageal plexus
24-4 The Esophagus

• Resting Muscle Tone
  • In the circular muscle layer in the superior 3 cm (1.2 in.) of esophagus prevents air from entering

• Histology of the Esophagus
  • Wall of esophagus has three layers
    1. Mucosal
    2. Submucosal
    3. Muscularis
24-4 The Esophagus

• Histology of the Esophagus
  • Mucosa contains:
    • Nonkeratinized and stratified squamous epithelium
  • Mucosa and submucosa form:
    • Large folds that extend the length of the esophagus
  • Muscularis mucosae consists of:
    • Irregular layer of smooth muscle
• Histology of the Esophagus
  • Submucosa contains *esophageal glands*
    • Which produce mucous secretion
    • Reduces friction between bolus and esophageal lining
  • Muscularis externa has:
    • Usual inner circular and outer longitudinal layers
A transverse section through an empty esophagus.
This light micrograph illustrates the extreme thickness of the epithelial portion of the esophageal mucosal layer.
Swallowing

- Also called *deglutition*
- Can be initiated voluntarily
- Proceeds automatically
- Is divided into three phases
  1. Buccal phase
  2. Pharyngeal phase
  3. Esophageal phase
Figure 24-11 The Swallowing Process

1 **Buccal Phase**
- Soft palate
- Bolus
- Epiglottis
- Esophagus
- Trachea

2 **Pharyngeal Phase**
- Tongue
- Bolus

3 **Esophageal Phase**
- Peristalsis
- Trachea

4 **Bolus Enters Stomach**
- Lower esophageal sphincter
- Thoracic cavity
- Stomach
The buccal phase begins with the compression of the bolus against the hard palate. Subsequent retraction of the tongue then forces the bolus into the oropharynx and assists in the elevation of the soft palate, thereby sealing off the nasopharynx. Once the bolus enters the oropharynx, reflex responses begin and the bolus is moved toward the stomach.
The pharyngeal phase begins as the bolus comes into contact with the palatoglossal and palatopharyngeal arches and the posterior pharyngeal wall. Elevation of the larynx and folding of the epiglottis direct the bolus past the closed glottis. At the same time, the uvula and soft palate block passage back to the nasopharynx.
The esophageal phase begins as the contraction of pharyngeal muscles forces the bolus through the entrance to the esophagus. Once in the esophagus, the bolus is pushed toward the stomach by a peristaltic wave.
Figure 24-11 The Swallowing Process

Bolus Enters Stomach

The approach of the bolus triggers the opening of the lower esophageal sphincter. The bolus then continues into the stomach.

Thoracic cavity

Lower esophageal sphincter

Stomach
24-5 The Stomach

• Major Functions of the **Stomach**

1. Storage of ingested food
2. Mechanical breakdown of ingested food
3. Disruption of chemical bonds in food material by acid and enzymes
4. Production of *intrinsic factor*, a glycoprotein required for absorption of vitamin $\text{B}_{12}$ in small intestine
Anatomy of the Stomach

- The stomach is shaped like an expanded J
  - Short lesser curvature forms medial surface
  - Long greater curvature forms lateral surface
- Anterior and posterior surfaces are smoothly rounded
- Shape and size vary from individual to individual and from one meal to the next
- Stomach typically extends between levels of vertebrae T7 and L3
24-5 The Stomach

- Regions of the Stomach
  1. Cardia
  2. Fundus
  3. Body
  4. Pylorus
Figure 24-12a  The Stomach

The position and external appearance of the stomach, showing superficial landmarks:

- Esophagus
- Right lobe of liver
- Vagus nerve (N X)
- Lesser omentum
- Lesser curvature
- Duyodenum
- Pyloric sphincter
- Pylorus
- Left gastroepiploic vessels
- Fundus
- Cardia
- Spleen
- Greater curvature with greater omentum attached
- Greater omentum

The position and external appearance of the stomach, showing superficial landmarks.
Figure 24-12b The Stomach

- **Esophagus**
- **Cardia**
- **Longitudinal muscle layer**
- **Circular muscle layer**
- **Lesser curvature (medial surface)**
- **Pyloric sphincter**
- **Duodenum**
- **Fundus**
- **Anterior surface**
- **Oblique muscle layer overlying mucosa**
- **Left gastroepiploic vessels**
- **Body**
- **Rugae**
- **Greater curvature (lateral surface)**

**b** The structure of the stomach wall
24-5 The Stomach

• Smooth Muscle

  • Muscularis mucosae and muscularis externa
    • Contain extra layers of smooth muscle cells
    • **Oblique layer** in addition to circular and longitudinal layers
24-5 The Stomach

• Histology of the Stomach
  • Simple columnar epithelium lines all portions of stomach
  • Epithelium is a secretory sheet
    • Produces mucus that covers interior surface of stomach
    • **Gastric pits**, shallow depressions that open onto the gastric surface
    • Mucous cells, at the base, or neck, of each gastric pit, actively divide, replacing superficial cells
• **Gastric Glands**
  
  - In fundus and body of stomach
  - Extend deep into underlying lamina propria
  - Each gastric pit communicates with several gastric glands
    - *Parietal cells*
    - *Chief cells*
### Layers of the Stomach Wall

<table>
<thead>
<tr>
<th>Layer</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mucosa</td>
<td>Gastric pit (opening to gastric gland)</td>
</tr>
<tr>
<td></td>
<td>Mucous epithelium</td>
</tr>
<tr>
<td></td>
<td>Lamina propria</td>
</tr>
<tr>
<td></td>
<td>Muscularis mucosae</td>
</tr>
<tr>
<td>Submucosa</td>
<td></td>
</tr>
<tr>
<td>Muscularis externa</td>
<td>Oblique muscle</td>
</tr>
<tr>
<td></td>
<td>Circular muscle</td>
</tr>
<tr>
<td></td>
<td>Longitudinal muscle</td>
</tr>
<tr>
<td>Serosa</td>
<td></td>
</tr>
</tbody>
</table>

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Figure 24-13b The Stomach Lining

- Lamina propria
- Mucous cells
- Neck

Cells of Gastric Glands
- Parietal cells
- G cell
- Chief cells
- Smooth muscle cell

Gastric pit

Gastric gland
24-5 The Stomach

- **Parietal Cells**
  - Secrete intrinsic factor and hydrochloric acid (HCl)

- **Chief Cells**
  - Are most abundant near base of gastric gland
    - Secrete *pepsinogen* (inactive proenzyme)
Figure 24-14 The Secretion of Hydrochloric Acid

1. Hydrogen ions (H\(^+\)) are generated inside a parietal cell as the enzyme carbonic anhydrase converts CO\(_2\) and H\(_2\)O to carbonic acid (H\(_2\)CO\(_3\)), which then dissociates.

2. A countertransport mechanism ejects the bicarbonate ions into the interstitial fluid and imports chloride ions into the cell.

3. The chloride ions then diffuse across the cell and exit through open chloride channels into the lumen of the gastric gland.

4. The hydrogen ions are actively transported into the lumen of the gastric gland.

CO\(_2\) + H\(_2\)O → H\(_2\)CO\(_3\)

H\(_2\)CO\(_3\) → H\(^+\) + HCO\(_3\)^{-}

HCO\(_3\)^{-} \rightarrow \text{Alkaline tide} \rightarrow \text{Interstitial fluid} \rightarrow \text{Bloodstream}

KEY
- Diffusion
- Carrier-mediated transport
- Active transport
- Countertransport
24-5 The Stomach

- Pepsinogen
  - Is converted by HCl in the gastric lumen
    - To pepsin (active proteolytic enzyme)
24-5 The Stomach

- **Pyloric Glands**
  - Located in the pylorus
  - Produce mucous secretion
    - Scattered with enteroendocrine cells
      - G cells produce *gastrin*
      - D cells release *somatostatin*, a hormone that inhibits release of gastrin
Regulation of Gastric Activity

Production of acid and enzymes by the gastric mucosa can be:

- Controlled by the CNS
- Regulated by short reflexes of ENS
- Regulated by hormones of digestive tract

Three phases of gastric control

1. Cephalic phase
2. Gastric phase
3. Intestinal phase
Figure 24-15 Regulation of Gastric Activity

1  CEPHALIC PHASE

Food

Sight, smell, taste, or thoughts of food

Central nervous system

Vagus nerve (N X)

Submucosal plexus

Gastrin

Mucus

Pepsinogen

HCl

KEY

Stimulation

Mucous cells

Chief cells

Parietal cells

G cells
GASTRIC PHASE

Submucosal and myenteric plexuses

Distension

Elevated pH

Mixing waves

Partly digested peptides

Mucous cells

Chief cells

Parietal cells

G cells

Gastrin

via bloodstream

Mucus

Pepsinogen

HCl

Chemoreceptors

Stretch receptors

Neural Response

ATLAS: Plate 50c
INTESTINAL PHASE

Neural Responses

Enterogastric reflex

via bloodstream

Duodenal stretch and chemoreceptors

CCK

GIP

Secretin

Presence of lipids and carbohydrates

Decreased pH

Myenteric plexus

Chief cells

Parietal cells

Peristalsis

KEY

Inhibition

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24-5 The Stomach

• Digestion and Absorption in the Stomach
  • Stomach performs preliminary digestion of proteins by pepsin
    • Some digestion of carbohydrates (by salivary amylase)
  • Lipids (by lingual lipase)
24-5 The Stomach

• Digestion and Absorption in the Stomach
  • Stomach contents
    • Become more fluid
    • pH approaches 2.0
    • Pepsin activity increases
    • Protein disassembly begins
  • Although digestion occurs in the stomach, nutrients are not absorbed there
24-6 The Small Intestine

• The **Small Intestine**
  
  • Plays key role in digestion and absorption of nutrients
  
  • 90% of nutrient absorption occurs in the small intestine
• The **Duodenum**
  
  • The segment of small intestine closest to stomach
  
  • 25 cm (10 in.) long
  
  • “Mixing bowl” that receives chyme from stomach and digestive secretions from pancreas and liver
  
  • Functions of the duodenum:
    
    • To receive chyme from stomach
    
    • To neutralize acids before they can damage the absorptive surfaces of the small intestine
• The **Jejunum**
  • Is the middle segment of small intestine
  • 2.5 meters (8.2 ft) long
  • Is the location of most:
    • Chemical digestion
    • Nutrient absorption
  • Has few plicae circulares
  • Small villi
24-6 The Small Intestine

• The **ileum**
  • The final segment of small intestine
  • 3.5 meters (11.48 ft) long
  • Ends at the **ileocecal valve**
    • A sphincter that controls flow of material from the ileum into the *cecum* of the large intestine
Regions of the Small Intestine

- Duodenum
- Jejunum
- Ileum

Large intestine

Rectum

The positions of the duodenum, jejunum, and ileum in the abdominopelvic cavity
24-6 The Small Intestine

• Histology of the Small Intestine
  • Plicae circulares
    • Transverse folds in intestinal lining
    • Are permanent features
      • Do not disappear when small intestine fills
  • Intestinal villi
    • A series of fingerlike projections in mucosa of small intestine
    • Covered by simple columnar epithelium
      • Covered with microvilli
Figure 24-16b Segments of the Intestine

A representative view of the jejunum

Plicae circulares

b A representative view of the jejunum
24-6 The Small Intestine

• Histology of the Small Intestine
  • **Intestinal glands** *(Crypts of Lieberkühn)*
    • Mucous cells between columnar epithelial cells
    • Eject mucins onto intestinal surfaces
    • Openings from intestinal glands
      • To intestinal lumen at bases of villi
    • Entrances for brush border enzymes
A single plica circulares and multiple villi
The organization of the intestinal wall

**Layers of the Small Intestine**

- Mucosa
- Muscularis mucosae
- Submucosa
- Muscularis externa
- Serosa

**Key Structures**

- Villi
- Intestinal crypt
- Lymphoid nodule
- Lacteal
- Submucosal artery and vein
- Lymphatic vessel
- Submucosal plexus
- Circular layer of smooth muscle
- Myenteric plexus
- Longitudinal layer of smooth muscle

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Figure 24-17c  The Intestinal Wall

Internal structures in a single villus, showing the capillary and lymphatic supplies
Figure 24-17d  The Intestinal Wall

- Capillaries
- Mucous cells
- Lacteal
- Brush border

Tip of villus  LM $\times$ 250

d A villus in sectional view

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24-6 The Small Intestine

- Intestinal Glands
  - *Brush border enzymes*
    - Integral membrane proteins
    - On surfaces of intestinal microvilli
    - Break down materials in contact with brush border
24-6 The Small Intestine

- Intestinal Glands
  - *Enteropeptidase*
    - A brush border enzyme
    - Activates pancreatic proenzyme trypsinogen
  - Enteroendocrine cells
    - Produce intestinal hormones such as gastrin, cholecystokinin, and secretin
• Intestinal Glands

  • Duodenal glands
    • Also called *submucosal glands* or *Brunner’s glands*
    • Produce copious quantities of mucus
      • When chyme arrives from stomach
24-6 The Small Intestine

- Intestinal Secretions
  - Watery *intestinal juice*
  - 1.8 liters per day enter intestinal lumen
  - Moisten chyme
  - Assist in buffering acids
  - Keep digestive enzymes and products of digestion in solution
Intestinal Movements

- Chyme arrives in duodenum
- Weak peristaltic contractions move it slowly toward jejunum
  - Myenteric reflexes
  - Not under CNS control
  - Parasympathetic stimulation accelerates local peristalsis and segmentation
The Gastroenteric Reflex
- Stimulates motility and secretion
  - Along entire small intestine

The Gastroileal Reflex
- Triggers relaxation of ileocecal valve
- Allows materials to pass from small intestine into large intestine
CENTRAL REFLEXES

- **Central Gastric Reflexes**
  - The gastroenteric reflex stimulates motility and secretion along the entire small intestine.
  - The gastroileal (gas-trō-IL-ē-al) reflex triggers the opening of the ileocecal valve, allowing materials to pass from the small intestine into the large intestine.

- **Ileocecal Valve**
  - The ileocecal valve controls the passage of materials into the large intestine.
• **The Pancreas**
  
  • Lies posterior to stomach
    
    • From duodenum toward spleen
  
  • Is bound to posterior wall of abdominal cavity
  
  • Is wrapped in thin, connective tissue capsule
24-6 The Pancreas

• Regions of the Pancreas
  • **Head**
    • Broad
    • In loop of duodenum
  • **Body**
    • Slender
    • Extends toward spleen
  • **Tail**
    • Short and rounded
24-6 The Pancreas

- Histological Organization
  - Lobules of the pancreas
    - Are separated by connective tissue partitions (septa)
    - Contain blood vessels and tributaries of pancreatic ducts
  - In each lobule:
    - Ducts branch repeatedly
    - End in blind pockets *(pancreatic acini)*
24-6 The Pancreas

• Histological Organization
  
  • **Pancreatic acini**
    
    • Blind pockets
    
    • Are lined with simple cuboidal epithelium
    
    • Contain scattered pancreatic islets
  
  • **Pancreatic islets**
    
    • Endocrine tissues of pancreas
    
    • Scattered (1% of pancreatic cells)
The gross anatomy of the pancreas. The head of the pancreas is tucked into a C-shaped curve of the duodenum that begins at the pylorus of the stomach.
Diagram of the cellular organization of the pancreas:

- Pancreatic duct
- Connective tissue septum
- Exocrine cells in pancreatic acini
- Endocrine cells in pancreatic islet
Figure 24-18c  The Pancreas

Light micrograph of the cellular organization of the pancreas

- Duct
- Pancreatic acini (exocrine)
- Pancreatic islet (endocrine)

Pancreas  
LM × 75
24-6 The Pancreas

- Functions of the Pancreas
  - Endocrine cells of the pancreatic islets
    - Secrete insulin and glucagon into bloodstream
  - Exocrine cells
    - Acinar cells and epithelial cells of duct system secrete pancreatic juice
24-6 The Pancreas

• Physiology of the Pancreas
  • 1000 mL (1 qt) pancreatic juice per day
  • Controlled by hormones from duodenum
  • Contain pancreatic enzymes
24-6 The Pancreas

- Pancreatic Enzymes
  - Include:
    - Pancreatic alpha-amylase
    - Pancreatic lipase
    - Nucleases
    - Proteolytic enzymes
• **Pancreatic Alpha-Amylase**
  - A carbohydrate
  - Breaks down starches
  - Similar to salivary amylase

• **Pancreatic Lipase**
  - Breaks down complex lipids
  - Releases products (e.g., fatty acids) that are easily absorbed
24-6 The Pancreas

- **Nucleases**
  - Break down nucleic acids

- **Proteolytic Enzymes**
  - Break certain proteins apart
  - **Proteases** break large protein complexes
  - **Peptidases** break small peptides into amino acids
  - 70% of all pancreatic enzyme production
  - Secreted as inactive proenzymes
  - Activated after reaching small intestine
24-6 The Liver

• The Liver
  • Is the largest visceral organ (1.5 kg; 3.3 lb)
  • Lies in right hypochondriac and epigastric regions
  • Extends to left hypochondriac and umbilical regions
  • Performs essential metabolic and synthetic functions
24-6 The Liver

• Anatomy of the Liver
  • Wrapped in tough fibrous capsule
  • Covered by visceral peritoneum
  • Divided into lobes
Figure 24-19a  The Anatomy of the Liver

- Falciform ligament
- Porta hepatis
- Right lobe of liver
- Caudate lobe of liver
- Inferior vena cava
- Pleural cavity
- Cut edge of diaphragm
- Left lobe of liver
- Stomach
- Lesser omentum
- Aorta
- Spleen

A horizontal section through the superior abdomen (diagrammatic view)
The anterior surface of the liver

Coronary ligament

Right lobe

Left lobe

Falciform ligament

Round ligament

Gallbladder

Figure 24-19b  The Anatomy of the Liver
The posterior surface of the liver

- **Left hepatic vein**
- **Inferior vena cava**
- **Caudate lobe**
- **Common bile duct**
- **Hepatic portal vein**
- **Hepatic artery proper**
- **Porta hepatis**
- **Quadrate lobe**
- **Gallbladder**
- **Coronary ligament**
- **Right lobe**

**c** The posterior surface of the liver
• **Hepatic Blood Supply**
  
  • 1/3 of blood supply
  
  • Arterial blood from hepatic artery proper
  
  • 2/3 venous blood from hepatic portal vein, originating at:
    
    • Esophagus
    
    • Stomach
    
    • Small intestine
    
    • Most of large intestine
• Histological Organization of the Liver
  • Liver lobules
    • The basic functional units of the liver
    • Each lobe is divided by connective tissue
      • About 100,000 liver lobules
      • 1 mm diameter each
    • Hexagonal in cross section
    • With six portal areas (*portal triads*)
      • One at each corner of lobule
24-6 The Liver

• A Portal Area

• Contains three structures
  1. Branch of hepatic portal vein
  2. Branch of hepatic artery proper
  3. Small branch of bile duct
A diagrammatic view of liver structure, showing relationships among lobules.

- Interlobular septum
- Bile duct
- Branch of hepatic portal vein
- Portal area
- Bile ductules
A single liver lobule and its cellular components

- Sinusoid
- Hepatocytes
- Branch of hepatic artery proper
- Bile duct
- Branch of hepatic portal vein
- Central vein
- Kupffer cells
- Bile canaliculi
A sectional view showing the vessels and ducts within a portal area
24-6 The Liver

- Hepatocytes
  - Adjust circulating levels of nutrients
    - Through selective absorption and secretion
  - In a liver lobule form a series of irregular plates arranged like wheel spokes
Hepatocytes

- Many Kupffer cells (stellate reticuloendothelial cells) are located in sinusoidal lining
- As blood flows through sinusoids:
  - Hepatocytes absorb solutes from plasma and secrete materials such as plasma proteins
The Liver

- The Bile Duct System
  - Liver secretes **bile fluid**
    - Into a network of narrow channels (**bile canaliculi**)
    - Between opposing membranes of adjacent liver cells
24-6 The Liver

• **Right and Left Hepatic Ducts**
  - Collect bile from all bile ducts of liver lobes
  - Unite to form **common hepatic duct** that leaves the liver

• **Bile Flow**
  - From common hepatic duct to either:
    - The **common bile duct**, which empties into duodenal ampulla
    - The **cystic duct**, which leads to gallbladder
The Common Bile Duct

- Is formed by union of:
  - Cystic duct
  - Common hepatic duct
- Passes within the lesser omentum toward stomach
- Penetrates wall of duodenum
- Meets pancreatic duct at duodenal ampulla
Figure 24-21a The Anatomy and Physiology of the Gallbladder and Bile Ducts

A view of the inferior surface of the liver, showing the position of the gallbladder and ducts that transport bile from the liver to the gallbladder and duodenum. A portion of the lesser omentum has been cut away.
Figure 24-21b The Anatomy and Physiology of the Gallbladder and Bile Ducts

A sectional view through a portion of the duodenal wall, showing the duodenal ampulla and related structures.

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

b A sectional view through a portion of the duodenal wall, showing the duodenal ampulla and related structures.
Figure 24-21c The Anatomy and Physiology of the Gallbladder and Bile Ducts

Physiology of the gallbladder

In the lumen of the digestive tract, bile salts break the lipid droplets apart by emulsification.

As it remains in the gallbladder, bile becomes more concentrated.

The release of CCK by the duodenum triggers dilation of the hepatopancreatic sphincter and contraction of the gallbladder. This ejects bile into the duodenum through the duodenal ampulla.

The liver secretes bile continuously—roughly 1 liter per day.
The Physiology of the Liver

1. Metabolic regulation

2. Hematological regulation

3. Bile production
24-6 The Liver

• Metabolic Regulation

• The liver regulates:
  1. Composition of circulating blood
  2. Nutrient metabolism
  3. Waste product removal
  4. Nutrient storage
  5. Drug inactivation
Composition of Circulating Blood

- All blood leaving absorptive surfaces of digestive tract
  - Enters hepatic portal system
  - Flows into the liver
- Liver cells extract nutrients or toxins from blood
  - Before they reach systemic circulation through hepatic veins
- Liver removes and stores excess nutrients
  - Corrects nutrient deficiencies by mobilizing stored reserves or performing synthetic activities
24-6 The Liver

• Metabolic Activities of the Liver
  • *Carbohydrate metabolism*
  • *Lipid metabolism*
  • *Amino acid metabolism*
  • *Waste product removal*
  • *Vitamin storage*
  • *Mineral storage*
  • *Drug inactivation*
24-6 The Liver

• Hematological Regulation
  • Largest blood reservoir in the body
  • Receives 25% of cardiac output
24-6 The Liver

• Functions of Hematological Regulation
  • Phagocytosis and antigen presentation
  • Synthesis of plasma proteins
  • Removal of circulating hormones
  • Removal of antibodies
  • Removal or storage of toxins
  • Synthesis and secretion of bile
The Functions of Bile

- Dietary lipids are not water soluble
- Mechanical processing in stomach creates large drops containing lipids
- Pancreatic lipase is not lipid soluble
  - Interacts only at surface of lipid droplet
- Bile salts break droplets apart (emulsification)
  - Increases surface area exposed to enzymatic attack
  - Creates tiny emulsion droplets coated with bile salts
24-6 The Gallbladder

- The **Gallbladder**
  - Is a hollow, pear-shaped, muscular sac
  - Stores and concentrates bile prior to excretion into small intestine
  - Is located in the fossa on the posterior surface of the liver’s right lobe
24-6 The Gallbladder

• Regions of the Gallbladder

  1. Fundus
  2. Body
  3. Neck
The Cystic Duct

- Extends from gallbladder
- Union with common hepatic duct forms common bile duct
24-6 The Gallbladder

• Physiology of the Gallbladder
  • Stores bile
  • Releases bile into duodenum, but only under stimulation of intestinal hormone cholecystokinin (CCK)
  • CCK
    • Hepatopancreatic sphincter remains closed
    • Bile exiting liver in common hepatic duct cannot flow through common bile duct into duodenum
    • Bile enters cystic duct and is stored in gallbladder
• Physiology of the Gallbladder
  • Full gallbladder contains 40–70 mL bile
  • Bile composition gradually changes in gallbladder
    • Water is absorbed
    • Bile salts and solutes become concentrated
24-6 Coordination of Secretion and Absorption

- **Neural and Hormonal Mechanisms**
  - Coordinate activities of digestive glands
  - Regulatory mechanisms center around duodenum
    - Where acids are neutralized and enzymes added
24-6 Coordination of Secretion and Absorption

- Neural Mechanisms of the CNS
  - Prepare digestive tract for activity (parasympathetic innervation)
  - Inhibit gastrointestinal activity (sympathetic innervation)
  - Coordinate movement of materials along digestive tract (the enterogastric, gastroenteric, and gastroileal reflexes)
  - Motor neuron synapses in digestive tract release neurotransmitters
24-6 Coordination of Secretion and Absorption

- **Intestinal Hormones**
  - Intestinal tract secretes peptide hormones with multiple effects
    - In several regions of digestive tract
    - In accessory glandular organs
• Hormones of Duodenal Enteroendocrine Cells
  • Coordinate digestive functions
    • Gastrin
    • Secretin
    • Gastric inhibitory peptide (GIP)
    • Cholecystokinin (CCK)
    • Vasoactive intestinal peptide (VIP)
    • Enterocrinin
24-6 Coordination of Secretion and Absorption

• **Gastrin**
  - Is secreted by G cells in duodenum
    - When exposed to incompletely digested proteins
    - Promotes increased stomach motility
    - Stimulates acids and enzyme production

• **Secretin**
  - Is released when chyme arrives in duodenum
  - Increases secretion of bile and buffers by liver and pancreas
• **Gastric Inhibitory Peptide (GIP)**
  - Is secreted when fats and carbohydrates enter small intestine

• **Cholecystokinin (CCK)**
  - Is secreted in duodenum
    - When chyme contains lipids and partially digested proteins
    - Accelerates pancreatic production and secretion of digestive enzymes
    - Relaxes hepatopancreatic sphincter and gallbladder
      - Ejecting bile and pancreatic juice into duodenum
Vasoactive Intestinal Peptide (VIP)
- Stimulates secretion of intestinal glands
- Dilates regional capillaries
- Inhibits acid production in stomach

Enterocrinin
- Is released when chyme enters small intestine
- Stimulates mucin production by submucosal glands of duodenum
### The Activities of Major Digestive Tract Hormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid production by parietal cells</td>
<td>Gastrin</td>
</tr>
<tr>
<td>Stimulation of gastric motility; mixing waves increase in intensity</td>
<td>Secretin and CCK</td>
</tr>
<tr>
<td>Release of insulin from pancreas</td>
<td>GIP</td>
</tr>
<tr>
<td>Release of pancreatic enzymes and buffers</td>
<td>Secretin and CCK</td>
</tr>
<tr>
<td>Bile secretion and ejection of bile from gallbladder</td>
<td>Secretin and CCK</td>
</tr>
<tr>
<td>Dilation of intestinal capillaries</td>
<td>Secretin and CCK</td>
</tr>
<tr>
<td>Nutrient absorption</td>
<td>Secretin and CCK</td>
</tr>
</tbody>
</table>

**KEY**
- **stimulates**
- **inhibits**

__NUTRIENT UTILIZATION BY ALL TISSUES__
24-6 Coordination of Secretion and Absorption

• Intestinal Absorption
  • It takes about 5 hours for materials to pass from duodenum to end of ileum
  • Movements of the mucosa increase absorptive effectiveness
    • Stir and mix intestinal contents
    • Constantly change environment around epithelial cells
The Large Intestine

- Is horseshoe shaped
- Extends from end of ileum to anus
- Lies inferior to stomach and liver
- Frames the small intestine
- Also called *large bowel*
- Is about 1.5 meters (4.9 ft) long and 7.5 cm (3 in.) wide
24-7 The Large Intestine

• Functions of the Large Intestine
  • Reabsorption of water
  • Compaction of intestinal contents into feces
  • Absorption of important vitamins produced by bacteria
  • Storage of fecal material prior to **defecation**
24-7 The Large Intestine

- Parts of the Large Intestine

1. Cecum
   - The pouchlike first portion

2. Colon
   - The largest portion

3. Rectum
   - The last 15 cm (6 in.) of digestive tract
The Cecum

- Is an expanded pouch
- Receives material arriving from the ileum
- Stores materials and begins compaction
Appendix

- Also called *vermiform appendix*
- Is a slender, hollow appendage about 9 cm (3.6 in.) long
- Is dominated by lymphoid nodules (a lymphoid organ)
- Is attached to posteromedial surface of cecum
  - *Mesoappendix* connects appendix to ileum and cecum
24-7 The Large Intestine

• The Colon
  • Has a larger diameter and thinner wall than small intestine
  • The wall of the colon
    • Forms a series of pouches (haustra)
  • Haustra permit expansion and elongation of colon
• Colon Muscles

• Three longitudinal bands of smooth muscle (taeniae coli)
  • Run along outer surfaces of colon
  • Deep to the serosa
  • Similar to outer layer of muscularis externa

• Muscle tone in taeniae coli creates the haustra
24-7 The Large Intestine

• Serosa of the Colon
  • Contains numerous teardrop-shaped sacs of fat
    • **Fatty appendices** or **epiploic appendages**
24-7 The Large Intestine

- Four Regions of the Colon
  1. Ascending colon
  2. Transverse colon
  3. Descending colon
  4. Sigmoid colon
• **Ascending Colon**
  
  • Begins at superior border of cecum
  
  • Ascends along right lateral and posterior wall of peritoneal cavity
    
    • To inferior surface of the liver and bends at *right colic flexure* (*hepatic flexure*)
24-7 The Large Intestine

• **Transverse Colon**
  
  • Crosses abdomen from right to left; turns at **left colic flexure** (*splenic flexure*)
  
  • Is supported by transverse mesocolon
  
  • Is separated from anterior abdominal wall by greater omentum
24-7 The Large Intestine

- **Descending Colon**
  - Proceeds inferiorly along left side to the iliac fossa (inner surface of left ilium)
  - Is retroperitoneal, firmly attached to abdominal wall
Sigmoid Colon

- Is an S-shaped segment, about 15 cm (6 in.) long
- Starts at *sigmoid flexure*
- Lies posterior to urinary bladder
- Is suspended from sigmoid mesocolon
- Empties into *rectum*
24-7 The Large Intestine

• Blood Supply of the Large Intestine
  • Receives blood from tributaries of:
    • Superior mesenteric and inferior mesenteric arteries
  • Venous blood is collected from:
    • Superior mesenteric and inferior mesenteric veins
The gross anatomy and regions of the large intestine

- Ileocecal valve
- Cecum
- Appendix
- Ileum
- Rectum
- Rectal artery
- Fatty appendices
- ASCENDING COLON
- Right colic artery and vein
- Middle colic artery and vein
- Right colic (hepatic) flexure
- Hepatic portal vein
- Superior mesenteric artery
- Superior mesenteric vein
- Inferior mesenteric vein
- Left colic (splenic) flexure
- Greater omentum (cut)
- DESCENDING COLON
- Left colic artery
- Left colic vein
- Inferior mesenteric artery
- Inferior mesenteric vein
- Left colic venous return
- Sigmoid arteries and veins
- Haustra
- Taenia coli
- Sigmoid flexure
- SIGMOID COLON
- Sigmoid arteries and veins
- Greater omentum (cut)

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24-7 The Large Intestine

- **The Rectum**
  - Forms last 15 cm (6 in.) of digestive tract
  - Is an expandable organ for temporary storage of feces
  - Movement of fecal material into rectum triggers urge to defecate

- **The Anal Canal**
  - Is the last portion of the rectum
  - Contains small longitudinal folds called **anal columns**
24-7 The Large Intestine

• **Anus**
  
  • Also called *anal orifice*
  
  • Is exit of the anal canal
  
  • Has keratinized epidermis like skin
24-7 The Large Intestine

• Anal Sphincters

  • **Internal anal sphincter**
    • Circular muscle layer of muscularis externa
    • Has smooth muscle cells, not under voluntary control

  • **External anal sphincter**
    • Encircles distal portion of anal canal
    • A ring of skeletal muscle fibers, under voluntary control
The cecum and appendix

- Ileocecal valve
- Cecum (cut open)
- Appendix
Figure 24-24c  The Large Intestine

The rectum and anus

- Rectum
- Anal canal
- Anal columns
- Internal anal sphincter
- External anal sphincter
- Anus

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24-7 The Large Intestine

• Histology of the Large Intestine
  • Lacks villi
  • Abundance of mucous cells
  • Presence of distinctive intestinal glands
    • Are deeper than glands of small intestine
    • Are dominated by mucous cells
The Large Intestine

- Histology of the Large Intestine
  - Does not produce enzymes
  - Provides lubrication for fecal material
  - Large lymphoid nodules are scattered throughout the lamina propria and submucosa
  - The longitudinal layer of the muscularis externa is reduced to the muscular bands of taeniae coli
Figure 24-25a The Mucosa and Glands of the Colon

- Taenia coli
- Fatty appendices
- Haustrum

Layers of the Colon:
- Simple columnar epithelium
- Goblet cells
- Intestinal crypt
- Muscularis mucosae
- Submucosa
- Serosa

Sublayers:
- Aggregated lymphoid nodule
- Longitudinal layer (taenia coli)
- Circular layer
- Muscularis externa
Figure 24-25b The Mucosa and Glands of the Colon

- Simple columnar epithelium
- Goblet cells
- Intestinal crypt
- Muscularis mucosae
- Submucosa
- Serosa

The colon

LM × 114
24-7 The Large Intestine

• Physiology of the Large Intestine
  • Less than 10% of nutrient absorption occurs in large intestine
  • Prepares fecal material for ejection from the body
Absorption in the Large Intestine

- Reabsorption of water
- Reabsorption of bile salts
  - In the cecum
  - Transported in blood to liver
- Absorption of vitamins produced by bacteria
- Absorption of organic wastes
Vitamins

- Are organic molecules
- Important as cofactors or coenzymes in metabolism
- Normal bacteria in colon make three vitamins that supplement diet
Three Vitamins Produced in the Large Intestine

1. *Vitamin K* (fat soluble)
   - Required by liver for synthesizing four clotting factors, including prothrombin

2. *Biotin* (water soluble)
   - Important in glucose metabolism

3. *Vitamin B₅* (pantothenic acid) (water soluble)
   - Required in manufacture of steroid hormones and some neurotransmitters
Organic Wastes

Bacteria convert bilirubin to *urobilinogens* and *stercobilinogens*

- Urobilinogens absorbed into bloodstream are excreted in urine
- Urobilinogens and stercobilinogens in colon convert to *urobilins* and *stercobilins* by exposure to oxygen
• Organic Wastes

• Bacteria break down peptides in feces and generate:

1. Ammonia
   • As soluble ammonium ions

2. Indole and skatole
   • Nitrogen compounds responsible for odor of feces

3. Hydrogen sulfide
   • Gas that produces “rotten egg” odor
24-7 The Large Intestine

• Organic Wastes
  • Bacteria feed on indigestible carbohydrates (complex polysaccharides)
    • Produce *flatus*, or intestinal gas, in large intestine
• Movements of the Large Intestine
  • Gastroileal and gastroenteric reflexes
    • Move materials into cecum while you eat
  • Movement from cecum to transverse colon is very slow, allowing hours for water absorption
  • Peristaltic waves move material along length of colon
  • Segmentation movements (*haustral churning*) mix contents of adjacent haustra
24-7 The Large Intestine

• Movements of the Large Intestine
  • Movement from transverse colon through rest of large intestine results from powerful peristaltic contractions (mass movements)
  • Stimulus is distension of stomach and duodenum; relayed over intestinal nerve plexuses
  • Distension of the rectal wall triggers defecation reflex
    • Two positive feedback loops
    • Both loops triggered by stretch receptors in rectum
Two Positive Feedback Loops

1. Short reflex
   - Triggers peristaltic contractions in rectum

2. Long reflex
   - Coordinated by sacral parasympathetic system
   - Stimulates mass movements
Rectal Stretch Receptors
- Also trigger two reflexes important to voluntary control of defecation
  - A long reflex
    - Mediated by parasympathetic innervation in pelvic nerves
    - Causes relaxation of internal anal sphincter
  - A somatic reflex
    - Motor commands carried by pudendal nerves
    - Stimulates contraction of external anal sphincter (skeletal muscle)
The first loop is a short reflex that triggers a series of peristaltic contractions in the rectum that move feces toward the anus.

Stimulation of stretch receptors

Stimulation of myenteric plexus in sigmoid colon and rectum

Stimulation of parasympathetic motor neurons in sacral spinal cord

Increased local peristalsis

Stimulation of somatic motor neurons

Increased peristalsis throughout large intestine

Relaxation of internal anal sphincter; feces move into anal canal

Involuntary contraction of external anal sphincter

If external sphincter is voluntarily relaxed, DEFECATION OCCURS

The long reflex is coordinated by the sacral parasympathetic system. This reflex stimulates mass movements that push feces toward the rectum from the descending colon and sigmoid colon.
24-7 The Large Intestine

• Elimination of Feces
  • Requires relaxation of internal and external anal sphincters
  • Reflexes open internal sphincter, close external sphincter
  • Opening external sphincter requires conscious effort
24-8 Digestion

- Nutrients
  - A balanced diet contains:
    - Carbohydrates
    - Lipids
    - Proteins
    - Vitamins
    - Minerals
    - Water
24-8 Digestion

- The Processing and Absorption of Nutrients
  - Breaks down physical structure of food
  - Disassembles component molecules
  - Molecules released into bloodstream are:
    - Absorbed by cells
    - Broken down to provide energy for ATP synthesis
    - Or used to synthesize carbohydrates, proteins, and lipids
24-8 Digestion

• Digestive Enzymes
  • Are secreted by:
    • Salivary glands
    • Tongue
    • Stomach
    • Pancreas
24-8 Digestion

• Digestive Enzymes

  • Break molecular bonds in large organic molecules
    • Carbohydrates, proteins, lipids, and nucleic acids
    • In a process called **hydrolysis**
  • Are divided into classes by targets
    • *Carbohydrases* break bonds between simple sugars
    • *Proteases* break bonds between amino acids
    • *Lipases* separate fatty acids from glycerides
24-8 Digestion

• Digestive Enzymes

  • Brush border enzymes break nucleotides into:
    • Sugars
    • Phosphates
    • Nitrogenous bases
Table 24-1  Digestive Enzymes and Their Functions

<table>
<thead>
<tr>
<th>Enzyme (proenzyme)</th>
<th>Source</th>
<th>Optimal pH</th>
<th>Target</th>
<th>Products</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CARBOHYDRASES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maltase, sucrase, lactase</td>
<td>Brush border of small intestine</td>
<td>7–8</td>
<td>Maltose, sucrose, lactose</td>
<td>Monosaccharides</td>
<td>Found in membrane surface of microvilli</td>
</tr>
<tr>
<td>Pancreatic alpha-amylase</td>
<td>Pancreas</td>
<td>6.7–7.5</td>
<td>Complex carbohydrates</td>
<td>Disaccharides and trisaccharides</td>
<td>Breaks bonds between simple sugars</td>
</tr>
<tr>
<td>Salivary amylase</td>
<td>Salivary glands</td>
<td>6.7–7.5</td>
<td>Complex carbohydrates</td>
<td>Disaccharides and trisaccharides</td>
<td>Breaks bonds between simple sugars</td>
</tr>
</tbody>
</table>
Figure 24-27 Chemical Events in Digestion

REGION and Hormonal Controls

ORAL CAVITY

ESOPHAGUS

STOMACH
Stimulus: Anticipation or arrival of food
Hormone: Gastrin
Source: G cells of stomach
Proenzyme released: Pepsinogen by chief cells, activated to pepsin by HCl

SMALL INTESTINE
Stimulus: Arrival of chyme in duodenum
Hormone: CCK
Proenzymes released: Chymotrypsinogen, procarboxypeptidase, proelastase, trypsinogen, Enteropeptidase activates trypsin, which activates other enzymes
Enzymes released: Pancreatic amylase, pancreatic lipase, nuclease, enteropeptidase

INTESTINAL MUCOSA

ROUTE TO BLOODSTREAM
Carbohydrates and amino acids are absorbed and transported by intestinal capillaries. Lipids form chylomicrons that diffuse into lacteals and are delivered to the left subclavian vein by the thoracic duct.

CARBOHYDRATES

Salivary amylase

Disaccharides

Pancreatic alpha-amylase

Disaccharides

Trisaccharides

Pancreatic amylase, pancreatic lipase, nuclease, enteropeptidase

Monosaccharides

Maltase, Sucrase

Lactase

FACILITATED DIFFUSION AND COTRANSPORT

FACILITATED DIFFUSION
Table 24-1  Digestive Enzymes and Their Functions

<table>
<thead>
<tr>
<th>Enzyme (proenzyme)</th>
<th>Source</th>
<th>Optimal pH</th>
<th>Target</th>
<th>Products</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTEASES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carboxypeptidase</td>
<td>Pancreas</td>
<td>7–8</td>
<td>Proteins, polypeptides, amino acids</td>
<td>Short-chain peptides</td>
<td>Activated by trypsin</td>
</tr>
<tr>
<td>(procarboxypeptidase)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chymotrypsin</td>
<td>Pancreas</td>
<td>7–8</td>
<td>Proteins, polypeptides</td>
<td>Short-chain peptides</td>
<td>Activated by trypsin</td>
</tr>
<tr>
<td>(chymotrypsinogen)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dipeptidases, peptidases</td>
<td>Brush border of small intestine</td>
<td>7–8</td>
<td>Dipeptides, tripeptides</td>
<td>Amino acids</td>
<td>Found in membrane surface of brush border</td>
</tr>
<tr>
<td>Elastase (proelastase)</td>
<td>Pancreas</td>
<td>7–8</td>
<td>Elastin</td>
<td>Short-chain peptides</td>
<td>Activated by trypsin</td>
</tr>
<tr>
<td>Enteropeptidase</td>
<td>Brush border and lumen of small intestine</td>
<td>7–8</td>
<td>Trypsinogen</td>
<td>Trypsin</td>
<td>Reaches lumen through disintegration of shed epithelial cells</td>
</tr>
<tr>
<td>Pepsin (pepsinogen)</td>
<td>Chief cells of stomach</td>
<td>1.5–2.0</td>
<td>Proteins, polypeptides</td>
<td>Short-chain polypeptides</td>
<td>Secreted as proenzyme pepsinogen; activated by ( \text{H}^+ ) in stomach acid</td>
</tr>
<tr>
<td>Rennin</td>
<td>Stomach</td>
<td>3.5–4.0</td>
<td>Milk proteins</td>
<td></td>
<td>Secreted only in infants; causes protein coagulation</td>
</tr>
<tr>
<td>Trypsin (trypsinogen)</td>
<td>Pancreas</td>
<td>7–8</td>
<td>Proteins, polypeptides</td>
<td>Short-chain peptides</td>
<td>Proenzyme activated by enteropeptidase; activates other pancreatic proteases</td>
</tr>
</tbody>
</table>
# Chemical Events in Digestion

<table>
<thead>
<tr>
<th>REGION and Hormonal Controls</th>
<th>LIPIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORAL CAVITY</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ESOPHAGUS</strong></td>
<td></td>
</tr>
<tr>
<td><strong>STOMACH</strong></td>
<td></td>
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<tr>
<td>Stimulus: Anticipation or arrival of food</td>
<td></td>
</tr>
<tr>
<td>Hormone: Gastrin</td>
<td></td>
</tr>
<tr>
<td>Source: G cells of stomach</td>
<td></td>
</tr>
<tr>
<td>Proenzyme released: Pepsinogen by chief cells, activated to pepsin by HCl</td>
<td></td>
</tr>
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<td>Hormone: CCK</td>
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</tr>
<tr>
<td>Enzymes released: Pancreatic amylase, pancreatic lipase, nuclease, enteropeptidase</td>
<td></td>
</tr>
<tr>
<td><strong>INTESTINAL MUCOSA</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ROUTE TO BLOODSTREAM</strong></td>
<td></td>
</tr>
<tr>
<td>Carbohydrates and amino acids are absorbed and transported by intestinal capillaries. Lipids form chylomicrons that diffuse into lacteals and are delivered to the left subclavian vein by the thoracic duct.</td>
<td></td>
</tr>
</tbody>
</table>

- **Brush border**
- **Cell body**
- **ROUTE TO BLOODSTREAM**
- **Carbohydrates and amino acids are absorbed and transported by intestinal capillaries. Lipids form chylomicrons that diffuse into lacteals and are delivered to the left subclavian vein by the thoracic duct.**

**LIPIDS**

- **Lingual lipase**
- **Bile salts and pancreatic lipase**
- **Monoglycerides, Fatty acids in micelles**
- **Monoglycerides, Fatty acids**
- **Triglycerides**
- **Chylomicrons**
- **EXOCYTOSIS**
- **Lacteal**
- **Chylomicrons**
<table>
<thead>
<tr>
<th>Enzyme (proenzyme)</th>
<th>Source</th>
<th>Optimal pH</th>
<th>Target</th>
<th>Products</th>
<th>Remarks</th>
</tr>
</thead>
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<tr>
<td><strong>LIPASES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lingual lipase</td>
<td>Glands of tongue</td>
<td>3.0–6.0</td>
<td>Triglycerides</td>
<td>Fatty acids and monoglycerides</td>
<td>Begins lipid digestion</td>
</tr>
<tr>
<td>Pancreatic lipase</td>
<td>Pancreas</td>
<td>7–8</td>
<td>Triglycerides</td>
<td>Fatty acids and monoglycerides</td>
<td>Bile salts must be present for efficient action</td>
</tr>
<tr>
<td><strong>NUCLEASES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pancreas</td>
<td>7–8</td>
<td>Nucleic acids</td>
<td>Nitrogenous bases and simple sugars</td>
<td>Includes ribonuclease for RNA and deoxyribonuclease for DNA</td>
</tr>
</tbody>
</table>
**Figure 24-27 Chemical Events in Digestion**

### REGION and Hormonal Controls

**ORAL CAVITY**

**ESOPHAGUS**

**STOMACH**
- **Stimulus:** Anticipation or arrival of food
- **Hormone:** Gastrin
- **Source:** G cells of stomach
- **Proenzyme released:** Pepsinogen by chief cells, activated to pepsin by HCl

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- **Hormone:** CCK
- **Proenzymes released:** Chymotrypsinogen, procarboxypeptidase, proelastase, trypsinogen, Enteropeptidase activates trypsin, which activates other enzymes
- **Enzymes released:** Pancreatic amylase, pancreatic lipase, nuclease, enteropeptidase

**INTESTINAL MUCOSA**
- **Brush border**
- **Cell body**

**ROUTE TO BLOODSTREAM**
- Carbohydrates and amino acids are absorbed and transported by intestinal capillaries. Lipids form chylomicrons that diffuse into lacteals and are delivered to the left subclavian vein by the thoracic duct.

### PROTEINS

- **Polypeptides**
  - **Trypsin**
  - **Chymotrypsin**
  - **Elastase**
  - **Carboxypeptidase**

- **Short peptides, Amino acids**
  - **Dipeptidases**

- **Amino acids**
  - **Facilitated diffusion and cotransport**
  - **FACILITATED DIFFUSION AND COTRANSPORT**
  - **Amino acids**
  - **Capillary**
24-8 Digestion

• Water Absorption
  • Cells cannot actively absorb or secrete water
  • All movement of water across lining of digestive tract:
    • Involves passive water flow down osmotic gradients
Figure 24-28 Digestive Secretion and Absorption of Water

**Dietary Input**
- Food and drink: 2000 mL

**Digestive Secretions**
- Saliva: 1500 mL
- Gastric secretions: 1500 mL
- Liver (bile): 1000 mL
- Pancreas (pancreatic juice): 1000 mL
- Intestinal secretions: 2000 mL
- Colonic mucous secretions: 200 mL

**Water Reabsorption**
- Small intestine reabsorbs: 7800 mL
- Colon reabsorbs: 1250 mL

**Losses**
- 150 mL lost in feces
24-8 Digestion

• Ion Absorption
  • Osmosis does not distinguish among solutes
    • Determined only by total concentration of solutes
  • To maintain homeostasis:
    • Concentrations of specific ions must be regulated
  • Sodium ion absorption
    • Rate increased by aldosterone (steroid hormone from adrenal cortex)
24-8 Digestion

• Ion Absorption
  • Calcium ion absorption
    • Involves active transport at epithelial surface
    • Rate increased by parathyroid hormone (PTH) and calcitriol
  • Potassium ion concentration increases:
    • As other solutes move out of lumen
    • Other ions diffuse into epithelial cells along concentration gradient
24-8 Digestion

• Ion Absorption
  • Cation absorption (magnesium, iron)
    • Involves specific carrier proteins
    • Cell must use ATP to transport ions to interstitial fluid
  • Anions (chloride, iodide, bicarbonate, and nitrate)
    • Are absorbed by diffusion or carrier-mediated transport
  • Phosphate and sulfate ions
    • Enter epithelial cells by active transport
24-8 Digestion

• Vitamins
  • Are organic compounds required in very small quantities
  • Are divided into two major groups
    1. Fat-soluble vitamins
    2. Water-soluble vitamins
Table 24-2 The Absorption of Ions and Vitamins

<table>
<thead>
<tr>
<th>Ion or Vitamin</th>
<th>Transport Mechanism</th>
<th>Regulatory Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>Channel-mediated diffusion, cotransport, or active transport</td>
<td>Increased when sodium-linked cotransport is under way; stimulated by aldosterone</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>Active transport</td>
<td>Stimulated by calcitriol and PTH</td>
</tr>
<tr>
<td>K⁺</td>
<td>Channel-mediated diffusion</td>
<td>Follows concentration gradient</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>Active transport</td>
<td></td>
</tr>
<tr>
<td>Fe²⁺</td>
<td>Active transport</td>
<td></td>
</tr>
<tr>
<td>Cl⁻</td>
<td>Channel-mediated diffusion or carrier-mediated transport</td>
<td></td>
</tr>
<tr>
<td>I⁻</td>
<td>Channel-mediated diffusion or carrier-mediated transport</td>
<td></td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>Channel-mediated diffusion or carrier-mediated transport</td>
<td></td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>Channel-mediated diffusion or carrier-mediated transport</td>
<td></td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>Active transport</td>
<td></td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>Active transport</td>
<td></td>
</tr>
<tr>
<td>Water-soluble vitamins (except B₁₂)</td>
<td>Channel-mediated diffusion</td>
<td>Follows concentration gradient</td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>Active transport</td>
<td>Must be bound to intrinsic factor prior to absorption</td>
</tr>
<tr>
<td>Fat-soluble vitamins</td>
<td>Diffusion</td>
<td>Absorbed from micelles along with dietary lipids</td>
</tr>
</tbody>
</table>
24-9 Effects of Aging on the Digestive System

- **Age-Related Changes**
  - Division of epithelial stem cells declines
    - Digestive epithelium becomes more susceptible to damage by abrasion, acids, or enzymes
  - Smooth muscle tone and general motility decrease
    - Peristaltic contractions become weaker
  - Cumulative damage from toxins (alcohol, other chemicals)
    - Absorbed by digestive tract and transported to liver for processing
Age-Related Changes

- Rates of colon cancer and stomach cancer rise with age
  - Oral and pharyngeal cancers common among elderly smokers
- Decline in olfactory and gustatory sensitivities
  - Leads to dietary changes that affect entire body
Figure 24-29 System Integrator: The Digestive System

For all systems, the digestive system absorbs organic substrates, vitamins, ions, and water required by all cells.