Chapter 24: DIGESTIVE SYSTEM

I. OVERVIEW

A. Gross anatomy (Fig. 24.1) and functions (Table 24.1)

B. "You are what you eat."

1. The problem: Ingestion (eating) is not the same as absorption.

2. The solution: Change large nonabsorbable molecules to small absorbable molecules.

   a. Mechanically break down food

      Move Ex.:

      Dissolve Spread __________________ throughout fluid

      Emulsify Stabilize ___________ in ____________

   b. Chemically digest large nonabsorbable molecules to small absorbable molecules (enzymes are required)

      Proteins (chains of amino acids) to:

      Polysaccharides (starches) to:

      Fats (triglycerides) to:

   c. Absorb small molecules: Move molecules from digestive tract into blood

   d. Eliminate nondigestibles
C. Histology of the gastrointestinal (GI) tract (Fig. 24.4)

1. Mucosa

2. Submucosa

3. Muscularis

4. Serosa or adventitia

D. Glands

1. Exocrine (glands with ducts) Secrete onto ____________.
   a. Salivary glands
   b. Pancreas
   a. Liver
   b. Gastric glands
   c. Intestinal glands
   d. Mucus glands

2. Endocrine (hormone glands) Secrete into ____________.
   a. Pancreas
   b. Stomach
   c. Small intestine
E. Visceral smooth muscle

1. Structure:
   a. Small cells (Fig. 9.22, p. 305)
   b. Cell-to-cell spread of action potentials

   Function of action potentials:
   c. ___________ contraction and relaxation

2. Location:

3. Movements
   a. Peristalsis (Fig. 24.2)
      Def.: Wave of ________________ followed by wave of ________________

      Function:

      Location:

   b. Segmental contractions (Fig. 24.3)
      Def.: Alternating segments of ________________ and ________________.

      Function:

      Location:
F. Innervation of the gastrointestinal tract

1. Extrinsic: Autonomic nervous system
   a. Parasympathetic
      Nerves:
      Function:

   b. Sympathetic
      Function:

2. Intrinsic: Enteric Nervous System (ENS; Enteric plexus) (Fig. 24.4)
   a. Myenteric plexus
      Location:
      Function:
      \textit{Hirschprung disease (megacolon)}

   b. Submucosal plexus
      Location:
      Function:
II. ORAL CAVITY, PHARYNX, ESOPHAGUS

A. Teeth and mastication (chewing)

1. Function:

2. Mastication reflex: Food in mouth —> Medulla oblongata—> chewing muscles

B. Salivary glands (1 liter/day secreted; pH 6-7)

1. Components | Functions
---|---
Water (99%) | Dissolving food molecules, taste
Mucus | Lubrication
Amylase | Digests starch to maltose
Lysozyme | Kills bacteria
IgA antibodies | Immune defense

2. Control: Autonomic nervous system (ANS)

   Chemical or mechanical stimulation —>
   Brainstem —> Cranial nerves VII and IX—> Secretion
   Cortical inputs

C. Swallowing (deglutition ) (Fig. 24.10)

1. Voluntary stage: Bolus formed, pushed by ______________

2. Pharyngeal stage:

   a. Soft palate: Closes off ____________________________

   b. Epiglottis: Closes off ____________________________

   c. Larynx: ________________________________

   d. True vocal cords: Close off ____________________________

   e. Pharyngeal muscles
3. Esophageal stage
   a. Relaxation of upper and lower esophageal sphincters
   b. Peristalsic waves

   *Swallowing disorders*

III. THE STOMACH

A. Secretory functions (Fig. 24.11)

1. Gastric juice from gastric pits (2-3 liters/day; pH 1-3)

<table>
<thead>
<tr>
<th>Secretion</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric acid (HCl)</td>
<td>Kills bacteria, activates pepsin</td>
</tr>
<tr>
<td>Pepsinogen</td>
<td>Activated to pepsin, which begins protein digestion</td>
</tr>
<tr>
<td>Intrinsic factor</td>
<td>Binds with vitamin $\text{B}_{12}$ for later absorption</td>
</tr>
<tr>
<td>Mucus</td>
<td>Protects stomach wall from acid</td>
</tr>
</tbody>
</table>

2. Gastrin (hormone) (Table 24.3, p. 885 [892])
   a. From endocrine cells
   b. Secreted into blood
   c. Stimulated by ____________________________.
   d. Function:
B. Control of stomach secretion: (Fig.24.13)

1. Cephalic phase: Taste, smell, thought of food $\rightarrow$ medulla oblongata $\rightarrow$ Vagus nerves $\rightarrow$__________ stomach secretion and ________ gastrin (hormone)

2. Gastric phase: Distention of stomach and chemicals in chyme $\rightarrow$ _______ Vagal stimulation and _______ Gastrin

_________ stomach secretion

3. Intestinal phase: Chyme in small intestine, especially acid or fatty chyme, reflexly ________ stomach secretions and movements

a. Small intestine hormones (Tab. 24.3)

Cholecystokinin (CCK), stimulated by ____________ chyme

Secretin, stimulated by ___________ chyme

Function: Both _________ stomach secretions

b. Enterogastric reflex _________ stomach secretions

Mostly local
C. Motor functions of the stomach

1. Filling and storage

2. Mixing waves (Fig. 24.14)

3. Peristaltic waves (Fig. 24.14)

4. Stomach emptying (p. 890; [or “Pregame Meal, p. 896, 8th ed.]
   a. Neural mechanisms caused by stomach distention
      ___________ secretion, movements and emptying
   b. Carbohydrate meals empty ___________
   c. Fatty meals stimulate ___________ (hormone), which
      strongly ___________ stomach emptying

5. Vomiting (see “Vomiting,” p. 888 [896])

D. Absorption by the stomach


E. Stomach disorders

1. Peptic ulcers (p.887 [894])  2. Pyloric stenosis (p. 882 [888])

3. Gastrointestinal reflux (p. 888)  4. Hunger pangs (p. 889 [895])
IV. SMALL INTESTINE

A. Functions:
   1. Mixes and propels chyme
   2. Chemical digestion
   3. Absorption

B. Structural features which promote absorption (Fig. 24.16)
   1. Length and circular folds
   2. Mucosa
      a. Villi
      b. Microvilli (brush border)
      c. Blood capillaries within villi for nutrient absorption
      d. Lacteals: Lymph capillaries within villi; absorb __________

Celiac disease

C. Glands
   1. Exocrine
      a. Duodenal glands
      b. Intestinal glands
   2. Endocrine (Table 24.3)
      a. Secretin, stimulated by ________________
      b. Cholecystokinin (CCK), stimulated by ________________
D. Intestinal enzymes and secretions (2 liters/day)

1. Water and mucus

2. **Major enzymes**

   - **Maltase**: Digests maltose to 2 glucose
   - **Sucrase**: Digests sucrose to 1 glucose + 1 fructose
   - **Lactase**: Digests lactose to 1 glucose + 1 galactose

   *Lactose intolerance* (p. 908 [913])

   - **Peptidases**: Digests peptides to free amino acids
   - **Enterokinase**: Activates trypsinogen from the pancreas to trypsin in small intestine

E. Movements (Fig. 24.2, 24.3)

1. Segmental contractions and peristaltic contractions:

   - Local control: Distention $\rightarrow$ myenteric plexus $\rightarrow$ movements

3. Ileocecal sphincter

   a. Regulates movement from ____________ to ____________

   b. Control: Tone (contraction) is normally high: _________________

      - Peristalsis of ileum _____ tone (______________) and _______ emptying
      - Distention of cecum _____ tone (______________) and _______ emptying
V. THE LIVER

A. Microscopic structure: Lobule (Fig. 24.19)

1. Radiating sheets of liver cells
2. Blood flows between and along cells in hepatic sinusoids
3. Blood enters a central vein and leaves liver

B. Blood supply (Fig. 24.20)

1. Hepatic artery supplies liver with $O_2$ and nutrients
2. Hepatic portal vein

   Structure and function: Transports nutrient-laden blood from the digestive organs directly to the liver, where the nutrients are taken up by the liver cells and processed

C. Functions of hepatocytes (liver cells): Examples:

1. Produce bile
2. Store nutrients
3. Interconvert nutrients
4. Detoxify wastes and drugs
5. Synthesize blood proteins

D. Function of phagocytic cells (Kupffer cells)

   Phagocytosis of old blood cells and bacteria
E. Bile (0.5-1 liter/day; pH 7.5-8.5)

1. Major components Functions
   a. Water
   b. Bile salts Emulsify fats
   c. Cholesterol
   d. Bilirubin Excretory product of ________________
   e. Bicarbonate _____ pH

2. Control: Hormonal and neural (Fig. 24.21 #2 and #4)
   a. Bile is continuously produced
   b. Secretin increases bile production
   c. Bile salts in blood increases bile production

3. Recycling of bile salts: Bile salts enter ___________ _______________; emulsify fats, but are reabsorbed out of ileum, travel via _____________ _____________ to ____________, and are secreted in bile again.

VI. GALL BLADDER (Fig. 24.18])

A. Histology:

B. Gross structure:

C. Significance: Bile backs up into gall bladder
   for storage, but is ejected into __________________
D. **Functions:**

1. **Bile storage**

2. **Concentrates bile by removing Na\(^+\) and water from walls**

3. **Ejection:** Contraction of smooth muscle; relaxation of ______________

E. **Control of ejection** (Fig. 24.21 (#1 and #3):

1. **Mainly Cholecystokinin (CCK), also vagus**

   **Stimulus for CCK:**

   *Gallstones*

VII. **THE PANCREAS**

A. **Exocrine function** (1-1.5 liter/day; pH = 7-8)

1. **Duct(s) empties into ________________**

2. **Pancreatic juice**

   a. **Components**

   **Functions** (Table 24.2)

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicarbonate</td>
<td>_____ pH</td>
</tr>
<tr>
<td>Enzymes</td>
<td><strong>Trypsin(ogen)</strong> Begins protein digestion</td>
</tr>
<tr>
<td></td>
<td><strong>Chymotrypsin(ogen)</strong> Begins protein digestion</td>
</tr>
<tr>
<td></td>
<td><strong>(pro)Carboxypeptidase</strong> Completes protein digestion</td>
</tr>
<tr>
<td></td>
<td><strong>Amylase</strong> Digests starch to glucose</td>
</tr>
<tr>
<td></td>
<td><strong>Lipase</strong> Triglycerides to 3 fatty acids + glycerol (or monoglycerides)</td>
</tr>
</tbody>
</table>
b. Control of pancreatic juice: Neural and hormonal (Fig. 24.24)

Acid chyme --> Secretin from small intestine --> bicarbonate-rich juice

Fatty chyme --> CCK from small intestine --> enzyme-rich juice

Food in stomach --> Vagal stimulation --> enzyme-rich juice

VIII. ABSORPTION BY THE SMALL INTESTINE

A. Carbohydrate absorption (Fig. 24.29)

1. Glucose: Active transport into blood
2. Galactose: Active transport into blood
3. Fructose: Facilitated diffusion into blood

B. Protein absorption (Fig. 24.32 [24.32])

1. Amino acids: Active transport into ________________
2. Dipeptides and tripeptides are also absorbed

C. Ion absorption

1. Na+, K+, magnesium, phosphate: Active transport into ________________
2. Ca++: Requires vitamin D; active transport into ________________
3. Iron (Fe^{2+/-}) Active transport; proportional to need into ______________

D. Lipid absorption (Fig. 24.30) Absorption is into ________________
Absorption out of the Small Intestine

**Carbohydrates**
- glucose
  - active transport
- galactose
- fructose
  - facilitated diffusion

**Proteins**
- amino acids
  - active transport

**Triglycerides**
- lipase
- 3 fatty acids
  + glycerol
  + bile salts
- micelles
- bile salts

\[ \text{fatty acids} + \text{glycerol} \rightarrow \text{triglycerides} \]
\[ \rightarrow \text{protein coat} \]
\[ \rightarrow \text{chylomicrons} \]
E. Vitamins

1. B’s, C: Diffusion into _______________.

2. B₁₂: Requires intrinsic factor; absorbed out of the ileum

3. D,E,A,K: Within micelles into _______________. If fat absorption is abnormal?

F. Water: Absorbed by osmosis: 9 liters enter, 1% excreted with feces (Fig. 24.34 [24.33])

IX. THE LARGE INTESTINE

A. Histology (Fig. 24.26)

1. Mucosa

2. Muscularis

B. Secretions

1. Mucus

2. Bicarbonate

C. Bacteria

1. Synthesize
   a. Vitamin K
   b. B vitamins
2. Decompose:
   a. Bilirubin to urobilinogen
   b. Carbohydrates —> flatus

D. Absorption

1. Water: 1 liter/day enters; 0.1 l/day eliminated
2. $\text{Na}^+$
3. B vitamins
4. Vitamin K

E. Feces

1. Components
   a. Water
   b. Bacteria
   c. Fiber
   d. Mucus
   e. Other molecules

2. Storage: Transverse colon to rectum

F. Movements

1. Segmental mixing movements
2. Weak peristalsis
3. Mass movements: Strong peristalsis

a. Control: (Fig. 24.26, #1 and 2)
   Stomach, duodenum distention —> local reflexes —> mass movements

b. Effect: Movement of feces from transverse colon to rectum

c. Frequency

4. Defecation reflex (Fig. 24.26, #5-9)

   Mass movement
   Rectal distention
   Sacral sensory neurons

   Spinal cord  Brain
   Sacral parasympathetic nerves

   Smooth muscle contraction of sigmoid and rectum
   Voluntary components

   Straining:
   
   and
   Relaxation of internal anal sphincter (smooth muscle)
   Relaxation of external anal sphincter (skeletal muscle)

Defecation

Constipation  Diarrhea