Chapter 24: The Digestive System
The Digestive System

- Gastrointestinal (GI) – mouth, pharynx, esophagus, stomach, small intestine, and large intestine
- Accessory digestive organs – teeth, tongue, salivary glands, liver, gallbladder, and pancreas
Functions

1. Ingestion
2. Secretion of water and enzymes into lumen
3. Digestion
   • Mechanical digestion
   • Chemical digestion
4. Absorption – passing into blood
5. Defecation
Functions

- The wall of GI tract from the lower esophagus to the anus has the same basic 4 layers.

1. **Mucosa** – inner lining
   - Epithelium for protection, secretion, and absorption.
   - mucosa-associated lymphatic tissue (MALT)

2. **Submucosa**
   - Connective tissue binding mucosa to muscularis (the next layer)
   - Contains blood and lymphatic vessels
Functions

3. **Muscularis**
   - Voluntary skeletal muscle found in mouth, pharynx, upper esophagus, and anal sphincter
   - Involuntary smooth muscle elsewhere

4. **Serosa**
   - Outermost covering of organs
   - Also called visceral peritoneum
   - Esophagus lacks serosa
Functions

- Enteric nervous system (ENS)
  - “brain of gut”
  - Neurons extend from esophagus to anus
- Autonomic nervous system
  - Parasympathetic stimulation increases secretion and stimulates the ENS
  - Sympathetic stimulation decreases secretions and inhibits the ENS
Peritoneum

• Largest serous membrane of the body

• Divided into
  • Parietal peritoneum – lines wall of cavity
  • Visceral peritoneum (aka serosa) – covers some organs
  • Space between is peritoneal cavity
Mouth - Oral or buccal cavity

- Formed by cheeks, hard and soft palates, and tongue
- Salivary glands - release saliva
  - Ordinarily, just enough is secreted to keep mouth and pharynx moist and clean
  - When food enters mouth, secretion increases to begin chemical digestion
Mouth - Oral or buccal cavity

• **Saliva**
  - Mostly water 99.5%
  - 0.5% – ions, mucus, lysozyme, and salivary amylase

• **Salivation**
  - Controlled by autonomic nervous system
  - Parasympathetic stimulation increases salivation
  - Sympathetic stimulation decreases salivation
Mouth - Oral or buccal cavity

- **Tongue**
  - Skeletal muscle covered by mucous membrane
  - Maneuvers food for chewing and swallowing
  - Secretes salivary lipase
- **Teeth**
  - 3 major regions – crown, root, and neck
  - Dentin of crown covered by enamel
Mouth - Oral or buccal cavity

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Digestion in the mouth

- Mechanical digestion in the mouth
  - **Mastication** = chewing

- Chemical digestion in the mouth
  - **Salivary amylase** starts the breakdown of carbohydrates.
  - **Lingual lipase** starts the breakdown of lipids.

- Passes from mouth into pharynx then to esophagus.
Esophagus

• Transports food
• 2 sphincters –
  • Upper esophageal sphincter (by the trachea) regulates movement into esophagus
  • Lower esophageal sphincter (top of stomach) regulates movement into stomach
• Pyloric sphincter – regulates movement out of the stomach.
Lumen of esophagus

Mucosa:
- Nonkeratinized stratified squamous epithelium
- Lamina propria
- Muscularis mucosae
- Submucosa

Muscularis (circular layer)

Muscularis (longitudinal layer)

Adventitia

Wall of the esophagus
Deglutition = swallowing

- Involves mouth, pharynx, and esophagus
- 3 stages
  - Voluntary – bolus passed to oropharynx
  - Pharyngeal – involuntary passage from pharynx into esophagus
  - Esophageal – involuntary passage from esophagus to stomach
- Peristalsis – muscle movements that push bolus forward
Stomach

- Serves as mixing chamber and holding reservoir
- 4 main regions - Cardia, fundus, body, pylorus
- Mucosa – contains gastric glands
Stomach

- **Parietal cells** – secrete hydrochloric acid
- **Chief cells** – makes lipase (to breakdown lipids) and pepsin (to breakdown proteins).
- **G cell** – secretes gastrin hormone
Stomach

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Histology of the stomach

(a) Three-dimensional view of layers of the stomach

(b) Sectional view of the stomach mucosa showing gastric glands and cell types

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Pancreas

- Lies posterior to greater curvature of stomach
- Pancreatic juice secreted into pancreatic duct and accessory duct and to small intestine
  - Pancreatic duct joins common bile duct and enters duodenum at hepatopancreatic ampulla
- Histology
  - 99% of cells are acini
    - Exocrine
      - Secrete pancreatic juice – mixture of fluid and digestive enzymes
  - 1% of cells are pancreatic islets (islets of Langerhans)
    - Endocrine
      - Secrete hormones glucagon, insulin, somatostatin, and pancreatic polypeptide
Relation of the pancreas to the liver, gallbladder, and duodenum
Pancreatic juice

- 1200-1500ml daily
- Mostly water
  - Sodium bicarbonate – buffers acidic stomach chyme
  - Enzymes
    - Pancreatic amylase
    - Proteolytic enzymes – trypsin (secreted as trypsinogen), chymotrypsin (chymotrypsinogen), carboxypeptidase (procarboxypeptidase), elastase (proelastase)
    - Pancreatic lipase
    - Ribonuclease and deoxyribonuclease
Liver and gallbladder

• Liver is the heaviest gland of the body
• Liver is composed of
  • Hepatocytes – major functional cells of liver
    • Wide variety of metabolic, secretory, and endocrine functions – secrete bile (excretory product and digestive secretion)
  • Bile canaliculi – ducts between hepatocytes that collect bile
    • Exits livers as common hepatic duct, joins cystic duct from gallbladder to form common bile duct
  • Hepatic sinusoids – highly permeable blood capillaries receiving oxygenated blood from hepatic artery and deoxygenated nutrient-rich blood from hepatic portal vein
• 3 different ways to organize units
  • Hepatic acinus – preferred method
    • Hepatocytes arranged in 3 zones around short axis with no sharp boundaries
Histology of the Liver

(a) Overview of histological components of liver

(b) Details of histological components of liver

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Histology of the Liver
Gallbladder

• Contraction of smooth muscle fibers eject contents of gall bladder into cystic duct
• Functions to store and concentrate bile produced by the liver until it is needed in the small intestine
• Absorbs water and ions to concentrate bile up to ten-fold
Hepatic blood flow

- Liver receives blood from
- Hepatic artery carrying oxygenated blood
- Hepatic portal vein carrying deoxygenated blood with newly absorbed nutrients and possibly drugs, microbes or toxins from GI tract
Role and composition of bile

- Hepatocytes secrete 800-1000mL of bile daily
- Mostly water, bile salts, cholesterol, lecithin, bile pigments and several ions
- Partially excretory product/ partially digestive secretion
- Bilirubin – principal bile pigment
  - Derived from heme of recycled RBCs
  - Breakdown product stercobilin gives feces brown color
- Bile salts play role in emulsification
  - Also aid in absorption of lipids following digestion
Small intestine

- 3 regions – duodenum, jejunum, and ileum
- Same 4 layers
  1. Mucosa
     - Absorptive cells (digest and absorb), goblet cells (mucus), intestinal glands (intestinal juice), Paneth cells (lysozyme), and enteroendocrine cells
     - Abundance of MALT
  2. Submucosa
     - Duodenal glands secrete alkaline mucus
  3. Muscularis
  4. Serosa
     - Completely surrounds except for major portion of duodenum
Anatomy of the small intestine

(a) Anterior view of external anatomy

(b) Internal anatomy of jejunum

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Special structural features increase surface area for digestion and absorption

- **Circular folds**
  - Permanent ridges of mucosa and submucosa
  - Cause chyme to spiral
- **Villi**
  - Fingerlike projections of mucosa
  - Contains arteriole, venule, blood capillary, and lacteal
- **Microvilli**
  - Projects of apical membrane of absorptive cells
  - Brush border with brush border enzymes
Histology of the small intestine
Histology of the duodenum and ileum
Intestinal juice and brush-border enzymes

• Intestinal juice
  • 1-2L daily
  • Contains water and mucus, slightly alkaline
  • Provide liquid medium aiding absorption

• Brush border enzymes
  • Inserted into plasma membrane of absorptive cells
  • Some enzymatic digestion occurs at surface rather than just in lumen
  • α-dextrinase, maltase, sucrase, lactase, aminopeptidase, dipeptidase, nucleosidases and phosphatases
Mechanical Digestion

• Governed by myenteric plexus
• Segmentations
  • Localized, mixing contractions
  • Mix chyme and bring it in contact with mucosa for absorption
• Migrating motility complexes (MMC)
  • Type of peristalsis
  • Begins in lower portion of stomach and pushes food forward
Chemical digestion

• Carbohydrates
  • Pancreatic amylase
  • α-dextrinase, sucrase, lactase, maltase in brush border
  • Ends with monosaccharides which can be absorbed

• Proteins
  • Trypsin, chymotrypsin, carboxypeptidase, and elastase from pancreas
  • Aminopeptidase and dipeptidase in brush border
Lipids and Nucleic Acids

- **Lipids**
  - Pancreatic lipase most important in triglyceride digestion
  - Emulsification by bile salts increases surface area
    - Amphipathic – hydrophobic and hydrophilic regions

- **Nucleic acids**
  - Ribonuclease and deoxyribonuclease in pancreatic juice
  - Nucleosidases and phosphatases in brush border
Absorption of:

• Monosaccharides
  • All dietary carbohydrates digested are absorbed
  • Only indigestible cellulose and fibers left in feces
  • Absorbed by facilitated diffusion or active transport into blood

• Amino acids, dipetides and tripeptides
  • Most absorbed as amino acids via active transport into blood
  • ½ of absorbed amino acids come from proteins in digestive juice and dead mucosal cells
Lipids

- All dietary lipids absorbed by simple diffusion
- Short-chain fatty acids go into blood for transport
- Long-chain fatty acids and monoglycerides
  - Large and hydrophobic
  - Bile salts form micelles to ferry them to absorptive cell surface
  - Reform into triglycerides forming chylomicrons
  - Leave cell by exocytosis
  - Enter lacteals to eventually enter blood with protein coat of chylomicron keeping them suspended and separate
Absorption of digested nutrients in the small intestine

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Absorption of:

- **Electrolytes**
  - From GI secretions or food
  - Sodium ions ($Na^+$) reclaimed by active transport
  - Other ions also absorbed by active transport

- **Vitamins**
  - Fat-soluble vitamins A, D, E, and K absorbed by simple diffusion and transported with lipids in micelles
  - Most water-soluble vitamins also absorbed by simple diffusion

- **Water**
  - 9.3L comes from ingestion (2.3L) and GI secretions (7.0L)
  - Most absorbed in small intestine, some in large intestine
  - Only 100ml excreted in feces
  - All water absorption by osmosis
Daily volumes of fluid ingested, secreted, absorbed, and excreted from the GI tract
Large intestine

- Overall function to complete absorption, produce certain vitamins, and form and expel feces
- 4 major regions – cecum, colon, rectum, and anal canal
- Ileocecal sphincter between small and large intestine
- Colon divided into ascending, transverse, descending and sigmoid
- Opening of anal canal (anus) guarded by internal anal sphincter of smooth muscle and external anal sphincter of skeletal muscle
Anatomy of the large intestine

(a) Anterior view of large intestine showing major regions

(b) Frontal section of anal canal

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Large Intestine

• Same 4 layers
• Mucosa – mostly absorptive and goblet cells
  • No circular folds or villi
  • Does have microvilli
• Submucosa
• Muscularis
  • Longitudinal muscle modified to form teniae coli
  • Forms haustra – pouches
• Serosa
Digestion of the Large Intestine

• Mechanical digestion
  • Haustral churning
  • Peristalsis
  • Mass peristalsis – drives contents of colon toward rectum

• Chemical digestion
  • Final stage of digestion through bacterial action
    • Ferment carbohydrates, produce some B vitamins and vitamin K
    • Mucus but no enzymes secreted

• Remaining water absorbed along with ions and some vitamins
Histology of the large intestine
Histology of the large intestine

(c) Portion of the wall of the large intestine

(d) Details of mucosa of large intestine
Phases of digestion

• Cephalic phase
  • Smell, sight, thought or initial taste of food activates neural centers – prepares mouth and stomach for food to be eaten

• Gastric phase
  • Neural and hormonal mechanisms promote gastric secretion and motility

• Intestinal phase
  • Begins when food enter small intestine
  • Slows exit of chyme from stomach
  • Stimulates flow of bile and pancreatic juice
The gastric phase of digestion

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