Digestion

A. Overview of the Digestive System

GI Tract | Accessory Organs
---------|-------------------
mouth | salivary glands
pharynx | liver
esophagus | gallbladder
stomach | pancreas
small intestine | large intestine

Functions of the Digestive System:
- **digestion** - chemical breakdown of food molecules by *hydrolysis*
- **absorption** of nutrients, electrolytes and H₂O
- **secretion** - mucus, digestive enzymes, acid, bicarbonate, electrolytes
- **motility** - muscular movements of GI tract to mix and propel food
  - *peristalsis* - moves material forward
  - segmental contractions - mix contents

Regional specialization ("assembly line"):
-ingestion → mechanical breakdown → chemical digestion → absorption → waste processing

B. Structure and Function of the Digestive System

GI tract structure: 4-layered tube
- **mucosa** - epithelium + lamina propria (areolar CT) + muscularis mucosae
- **submucosa** - connective tissue, vascular
- **muscularis** (externa) - smooth muscle, usually inner circular and outer longitudinal layers
- **serosa** - thin covering membrane (visceral peritoneum)

1. Mouth, Pharynx and Esophagus
- functions: ingestion, mastication (chewing), deglutition (swallowing)
- salivary glands secrete saliva: H₂O, ions, mucus, enzymes: amylase, lipase
  - amylase begins chemical digestion of starch → disaccharides
- esophagus: swallowing (upper portion), peristalsis (lower portion)
  - *lower esophageal sphincter* controls entry into the stomach

2. Stomach
- functions: storage
  - mechanical breakdown of food → chyme
  - sterilization
- chemical digestion: acid (HCl) and enzymes (pepsin)
  - mucus cells secrete alkaline mucus to protect stomach epithelium
- structure: mucosa: simple columnar epithelium, *gastric glands*
  - secrete acidic gastric juice (pH 1-2), 1-3 L/day
  - mucus cells secrete alkaline mucus to protect stomach epithelium
- muscularis: 3 layers thick
  - *pyloric sphincter* controls passage of chyme from stomach to duodenum

a. acid secretion
  - *parietal cells* secrete hydrochloric acid (HCl)
    \[ \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \]
    - H⁺ is actively transported into the lumen, Cl⁻ follows via diffusion through channels
    - HCO₃⁻ is transported back into ECF (countertransport with Cl⁻)

b. enzyme secretion
  - *chief cells* secrete pepsinogen (inactive), activated at low pH to form pepsin
  - pepsin digests proteins into smaller peptides
4. Small Intestine, Liver and Pancreas

functions: chemical digestion and absorption

SI regions: duodenum, jejunum, ileum

a. Digestion
- duodenum receives chyme from stomach, secretions from liver and pancreas
- Liver - processes absorbed nutrients (delivered via hepatic portal vein)
  - secretes bile, stored in gallbladder
  - bile salts - derived from cholesterol, function to emulsify fats → micelles
    - bile pigments (bilirubin, biliverdin) - waste products from hemoglobin breakdown

Pancreas - acinar cells secrete digestive enzymes:
  - trypsin, chymotrypsin, carboxypeptidase, amylase, lipase
  - many enzymes are secreted in inactive form (zymogens), activated by trypsin in lumen
- duct cells secrete bicarbonate (NaHCO₃) to neutralize acid (pH → 8)

SI (brush border) enzymes complete digestion

b. Absorption
- small intestine has huge surface area, specialized for absorption
  (1) length > 3 meters
  (2) circular folds
  (3) villi - epithelium (enterocytes and goblet cells) + lamina propria (capillaries and lacteals)
  (4) microvilli - “brush border” membrane
  - Na⁺, Cl⁻, K⁺ absorbed via active transport and diffusion through channels
  - glucose & amino acids - cotransport with Na⁺ (secondary active transport)
  - H₂O - via osmosis, follows solute transport
water-soluble nutrients are absorbed into intestinal capillaries → liver (via HPV)
lipids are formed into chylomicrons and absorbed into lymphatic vessels (lacteals)

5. Large Intestine

functions: fluid absorption, waste packaging and elimination
- LI absorbs most remaining water and ions from chyme
- intestinal microflora - bacteria in colon, produce some vitamins (K, B₁₂)
- defecation reflex

C. Neural and Hormonal Control

1. Enteric Nervous System - submucosal and myenteric plexuses
   - local control within the GI tract (short reflex)

2. Autonomic Nervous System
  - parasympathetic: vagus nerve - stimulates GI tract motility and secretion (long reflex)
  - sympathetic division mostly inhibits GI tract

3. GI Peptides

4. Hormones
  - gastrin - secreted by G cells in the gastric glands
    - stimulates gastric acid secretion; stimulates gastric motility and mucosal growth
    - acid secretion is also stimulated by histamine secreted by ECL cells in gastric glands
  - CCK (cholecystokinin) - secreted by endocrine cells in intestinal crypts
    - stimulates bile release from gallbladder and pancreatic enzyme secretion
  - secretin - stimulates bicarbonate secretion by pancreas
  - GIP (gastric inhibitory peptide) - stimulates insulin secretion by pancreas;
    - GIP, CCK and secretin all inhibit gastric acid secretion

D. Phases of Digestion and GI Regulation

1. Cephalic Phase - sensory stimuli and thoughts of food activate autonomic NS (vagus n.)
2. Gastric Phase - vagus n., mechanical & chemical stimuli in stomach stimulate gastric secretion
3. Intestinal Phase - arrival of chyme in duodenum triggers SI endocrine and exocrine secretion;
   hormonal feedback inhibits gastric acid secretion and slows stomach emptying