Chapter 22: Digestive System

Converts food into raw materials necessary for cell maintenance and growth.

**Digestive System:**

Main Divisions of Digestive System:

1) **Alimentary Canal** (gastrointestinal tract)
   - Continuous, muscular tube (lumen "outside" body)
   - Digests / absorbs food

2) **Accessory Organs**
   - Glands; line / located outside GI tract
   - Produce digestive secretions

Main Divisions of Digestive System:

1) **Ingestion**
   - Taking food in (mouth)

2) **Propulsion**
   - Food movement through GI tract
   - Swallowing (Voluntary)
   - Peristalsis (Involuntary)

3) **Mechanical Digestion**
   - Physical breakdown / mixing of food
   - Chewing (oral cavity) / Mixing (stomach)
   - Segmentation

4) **Chemical Digestion**
   - Enzymatic breakdown of food → monomers

5) **Absorption**
   - Movement of monomers into blood / lymph
   - Organics / vitamins / minerals / water

6) **Defecation**
   - Elimination of indigestible material (via anus)

Movement of Materials Through System:

**Sphincters** (smooth muscle rings) regulate passage of materials through system:

1) **Lips** (guard entrance - voluntary)
2) **Cardiac Sphincter** (entrance to stomach)
3) **Pyloric Sphincter** (exit to stomach)
4) **Iliocecal Valve** (small intestine → large intestine)
5) **Internal Anal Sphincter** (involuntary)
6) **External Anal Sphincter** (voluntary)

**Histology of GI Tract:**

Four Layers: 3 – 6 days

1) **Mucosa** (mucous membrane)
   - 3 layers:
     - **Epithelium** (simple / stratified)
     - **Lamina propria** (areolar tissue)
     - **Muscularis mucosae** (smooth muscle)
   - Functions:
     - Secretes mucus
     - Absorbs monomers
     - Protects from infection

2) **Submucosa**
   - Dense irregular connective tissue
   - Nerves / vessels / lymphoid tissue / glands
   - **Plexus of Meissner** (submucosal plexus)
   - Regulates glands / muscle in mucosa

3) **Muscularis externa**
   - Smooth muscle
     - 2 layers – circular / longitudinal
     - Mixes / propels food (e.g., peristalsis)
     - **Plexus of Auerbach** (myenteric plexus)
     - Controls GI tract mobility

4) **Serosa / Adventitia**
   - Serosa = serous membrane
   - Adventitia = no serosa; fibrous sheath
Digestive System – Oral (Buccal) Cavity:

Function:
1) Sensory Analysis
2) Mechanical Processing
3) Lubrication
4) Chemical Digestion (limited...)

1) Tongue:
- Contains extrinsic (gross control) and intrinsic (fine control) muscles
- Contains papillae
  - Filiform (rough friction)
  - Fungiform (taste buds)
  - Circumvallate (taste buds)

Taste Buds:
- ~3000
- Lifespan: 10 days

Chapters 22: Digestive System

Salivary Control:
- Activation of parasympathetic motor neurons
- Stimulation of chemoreceptors and mechanoreceptors
- Increased salivation (watery saliva)
- Release of mucus-rich saliva (“dry mouth”)
- Constriction of blood vessels to salivary glands

Chapters 22: Digestive System

Salivary Glands:
- Produce and secrete saliva (1 – 1.5 L / day)
- Lubricate mouth
- Protect body
- Chemical digestion
  - Water (~99.5%)
  - Ions
  - Mucin (glycoproteins)
  - Salivary amylase (carbohydrates)
  - Lysozymes
  - Antibodies

A) Intrinsic Glands (Buccal glands)
- Inside oral cavity

B) Extrinsic Glands
- Outside oral cavity; connected via ducts
  - Parotid / Submandibular / Sublingual
    - Serous cells (parotid / ½ submandibular)
    - Water / ions / enzymes
    - Mucous cells (sublingual / ½ submandibular)
    - Mucus (mucin / glycoproteins)

Mumps:
Viral infection of Parotid gland

Chapters 22: Digestive System

Thinking... Smelling... Tasting...
Digestive System – Oral (Buccal) Cavity:

3) Teeth:

- **Mastication** = Chewing (complicated process)
  - Break down connective tissue (meat) and fibers (plants)
  - Saturate food with salivary secretions / enzymes

2 Sets of Teeth

1) **Deciduous (milk)**
  - 20 total (10 top / 10 bottom)
  - In by 2 yrs. of age

2) **Permanent**
  - 32 total (16 top / 16 bottom)
  - Incisors (cutting)
  - Canines (tearing)
  - Premolars (crushing)
  - Molars (grinding)

Digestive System – Esophagus:

- Conveys food / liquids to stomach (dorsal to trachea / heart)
- Contains all four histological layers

1) **Mucosa**: Stratified squamous epithelium (non-keratinized)
   - Irregular muscularis mucosae layer

2) **Submucosa**: Esophageal glands (mucus-secreting)

3) **Muscularis externa**: (2 layers – circular / longitudinal)
   - Superior = skeletal muscle
   - Middle = ½ skeletal / ½ smooth muscle
   - Inferior = smooth muscle

4) Primarily adventitia (anchors esophagus)

Take Home Message…

Digestive Processes of Mouth → Esophagus:

1) Ingestion
2) Mechanical Digestion (e.g., mastication)
3) Chemical Digestion
   - Salivary amylase (Carbs → polysacc.)
   - Lingual Lipase (Lipids → fatty acids)
4) Propulsion
   - Deglutination (swallowing)
     - Buccal phase (voluntary)
     - Pharyngeal-esophageal phase (swallowing reflex – involuntary)

Time from Mouth → Stomach = 1 – 8 seconds

Food = bolus

Respiratory centers inhibited
Diaphragm

Esophagus

Cardiac Sphincter

Lesser Curvature

Pyloric Sphincter

Fundus

Body

Greater Curvature

Storage tank (distensible)
• Max = 1 - 1.5 L

Location of chemical digestion
• Bolus → chyme

• Goblet cells = mucus (protection from acids / enzymes)
• Rugae: Prominent folds – allow for distention
• Gastric Pits (produce gastric juices – 1.5 L / day)

A) Mucous Neck Cells
• Secrete mucus

B) Parietal Cells
• Secrete hydrochloric acid (pH 1.5 - 3.5)

HCl not produced directly in cytoplasm (too corrosive)
Stomach – Acid Production:

• HCl not produced directly in cytoplasm (too corrosive)

FUNCTIONS:
• Kill microorganisms
• Denature proteins
• Active digestive enzymes

Alkaline Tide:
• pH increase in gastric blood return due to $\text{HCO}_3^-$ entry

Gastric Ulcer
• Breach in mucosal barrier

1) Mucosa: Simple columnar epithelium

2) Submucosa

3) Muscularis externa (3 layers – oblique / circular / longitudinal)

4) Serosa – Connective tissues / mesothelium (visceral peritoneum)
Stomach - Regulation of Gastric Secretion (3 phases):

1) **Cephalic Phase**
   - Occurs before food ingested (Sensing of food...)
   - CNS triggers gastric juice secretion (stomach preparation)

2) **Gastric Phase**
   - Gastric secretion triggered by distension, peptides, pH (food in stomach)
     A) Neural Response = ACh release (short reflex arc – stretch receptors)
     B) Hormonal Response = *Gastrin* release (chemoreceptors)

3) **Intestinal Phase**
   - Gastric secretion regulated by chyme entering small intestine
     A) **Enterogastric Reflex**: Inhibits gastric secretions / motility
     B) Hormone Release
        - Cholecystokinin (CCK) / Gastric Inhibitory Peptide (GIP)
        - Triggered by lipids / carbs
        - Secretin
        - Triggered by ↓ pH in SI

Carbs / liquids = fast digestive rate
fats / proteins = slow digestive rate

Digestive Processes of Stomach:

1) **Mechanical Digestion** (Churning of stomach)
2) **Chemical Digestion**
   - *Pepsin* (Proteins → small peptides)
   - *Rennin* (milk proteins) / *Gastric Lipase* (fats)
3) **Propulsion** (Peristalsis)
4) **Absorption**
   - Lipid-soluble substances (e.g., alcohol / drugs)

**Small Intestine**:

1) **Duodenum (~10”)**:
   - Receives chyme from stomach and exocrine secretions from liver / pancreas
2) **Jejunum (~8’)**:
   - Chemical digestion / nutrient absorption
3) **Ileum (~12’)**:
   - Joins large intestine at ileocecal valve

**Modifications for Absorption**:

1) **Plicae circulares** (circular folds)
   - Permanent folds (mucosa) / submucosa; mix chyme
2) **Villi**
   - Finger-like projections of mucosa; surface area
   - **Lacteal**: Modified lymphatic capillaries; absorb lipids
3) **Microvilli**
   - Finger-like projections of plasma membrane; surface area
   - Contain digestive enzymes (brush border enzymes)

Surface Area:

Without Modifications = ~ 3.5 sq. ft.
With Modifications = ~ 2200 sq. ft.
Digestive System – Small Intestine:
Contains all four histological layers:
1) **Mucosa**: Simple columnar epithelium (microvilliated)
   - Many goblet cells; scattered enteroendocrine cells
   - **Intestinal crypts** (Crypts of Lieberkuhn)
   - Secrete intestinal juices / generation of epithelial cells
2) **Submucosa**
   - Brunner’s Glands: Secrete alkaline mucus (neutralize chyme)
   - Peyer’s Patches: lymphoid nodules

Digestive System – Small Intestine:
Structural Arrangement:

Digestive System – Liver / Gallbladder:
1) **Liver**:
   - Largest gland in body (~ 3 lbs)
   - 4 lobes (right (largest); left; caudate; quadrate)
   - Produces bile and filters / processes blood

Digestive System – Liver / Gallbladder:
Function unit = Liver lobule
(~ 100,000 / liver)
Central Vein
Hepatic Triad
Liver sinusoids

Sinusoids lack basal lamina

Digestive System – Liver / Gallbladder:
1) Liver:
• Sinusoids lack basal lamina

Hepatocytes (Hepatic cord)
• Produce bile (emulsification)
• Processes nutrients
  • glucose → glycogen
  • amino acids → proteins
• Store fat-soluble vitamins
• Store iron (ferritin)
• Ammonia → urea
• Drug inactivation
• Toxin / antibody removal

Kupffer Cells:
• Phagocytes (pathogens / debris)
• Store iron, lipids, heavy metals

Digestive System – Liver / Gallbladder:
1) Liver:
Kupffer Cells:
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Hepatocytes (Hepatic cord)

Liver sinusoids

Bile canaliculus

Composition of Bile:
1) Bile Salts
• Acids derived from cholesterol (e.g., cholic acid)
• Emulsify fats
• Recycled (Enterohepatic circulation of bile)
2) Bilirubin
• Waste product of hemoglobin (HbCO)
• Metabolized in gut to form urobiligen
• Makes feces brown
3) Cholesterol / neutral fats / phospholipids

Bile DOES NOT contain enzymes that digest fats…
Digestive System – Liver / Gallbladder:

1) Liver:
   - Largest gland in body (~ 3 lbs)
   - 4 lobes (right; largest; left; caudate; quadrate)
   - Produces bile and filters / processes blood

2) Gallbladder:
   - Sack-like structure; stores / concentrates bile
   - Too concentrated – Gallstones

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Digestive System – Pancreas:

- Mixed endocrine / exocrine gland (exocrine = digestion)

1) Acinar Cells
   - Produce digestive enzymes:
     - Trypsin, Carboxypeptidase, Chymotrypsin (proteins)
     - Pancreatic Amylase (carbohydrates)
     - Pancreatic Lipase (lipids)
     - Nucleases (nucleic acids)

2) Duct Cells
   - Produce bicarbonate-rich fluid (pH ~ 8)

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Regulation of Pancreatic Juice and Bile Secretion:

- CCK
- Secretin
- Gastric secretion
- Vagal input

- Gallbladder contractions
- Duodenal papilla relaxed
- Bile released to duodenum
- Bile salts absorbed (returned to liver)
- Bile production
Digestive Processes of Small Intestine:
1) Mechanical Digestion (segmentation)
2) Chemical Digestion
   • Trypsin / Chymotrypsin / Carboxypeptidase (Proteins \(\rightarrow\) small peptides)
   • Pancreatic amylase (Carbs \(\rightarrow\) disaccharides)
   • Pancreatic lipase / Bile salts (Lipids \(\rightarrow\) fatty acids / glycerol)
   • Nucleases (Nucleic acids \(\rightarrow\) nucleotides)
3) Propulsion (Peristalsis – migrating mobility complex ~ 5-hour trip)
4) Absorption
   • Primary site of nutrient absorption

Digestive Processing of Large Intestine:
1) Absorption
   • Water: 75% water / 20% indigestible waste / 5% bacteria
   • Ions
   • Vitamins

2) Propulsion
   • Cecum \(\rightarrow\) Transverse Colon (very slow...)
     • Haustral Churning = segmentation (mixes adjacent haustra)
     • Peristalsis
   • Transverse Colon \(\rightarrow\) Rectum (more rapid...)
     • Mass Movements = powerful peristaltic waves (several times / day)
     • Triggered by food in stomach (clear system...)
3) Defecation
   Defecation Reflex: Distension of rectal wall triggers multiple positive feedback loops
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Digestive Processes of Large Intestine:
1) Absorption
2) Propulsion
   - Cecum → Transverse Colon (very slow...)
   - Haustral Churning = segmentation (mises adjacent haustra)
   - Peristalsis
   - Transverse Colon → Rectum (more rapid...)
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3) Defecation
   - Defecation Reflex: Distension of rectal wall triggers multiple positive feedback loops
   - Valsalva's Maneuver: Forced exhalation with glottis closed
     - Voluntary Control of Defecation
       - If pressure > 55 mm Hg in rectum, external sphincter involuntarily relaxes

Physiology of Chemical Digestion:

1) Carbohydrates
   - Hydrolysis = addition of water at chemical bonds
   - Macromolecules → Monomers
     - Carbohydrates → Monosaccharides
     - Proteins → Amino acids
     - Lipids → Monoglycerides & Fatty acids
     - Nucleic acids → Bases, phosphates & ribose
   - Mouth
   - Esophagus
   - Stomach
   - Small Intestine
   - Large Intestine
   - Salivary amylase
   - Pancreatic amylase
   - Brush border enzymes
   - Maltose
   - Sucrose
   - Lactose
   - Oligosaccharides
   - Disaccharides

2) Proteins
   - Peptides
   - Amino acids
   - Pepsin / HCl
   - Trypsin
   - Chymotrypsin
   - Carboxypeptidase
   - Brush border enzymes

3) Lipids
   - Monoglycerides & Fatty acids
   - Bile salts
   - Pancreatic lipase
   - (Lingual lipase)
Physiology of Chemical Digestion:

3) Lipids

- Triglycerides, fatty acids & bile salts
- Simple diffusion to Micelles
- Micelles
- Lumen
- Triglycerides & Fatty acids
- Protein Coat
- Chylomicrons
- Exocytosis
- Interstitial Fluid
- Lacteal of lymphatic system
- Enters bloodstream @ ll. subclavian vein

4) Nucleic Acids

- Bases, phosphates & ribose
- Pancreatic nucleases
- Brush border enzymes