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
Functions 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:

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

Cellular Lifespan:

- 3 – 6 days

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:**
   - Mechanical processing (compression / abrasion / distortion)
   - Assist chewing / prepare for swallowing
   - Sensory analysis
   - Chemical digestion – **Lingual lipase** (fats)
   - Contains extrinsic (gross control) and intrinsic (fine control) muscles
   - Contains papillae
     - Filiform (rough - friction)
     - Fungiform (taste buds)
     - Circumvallate (taste buds)

~ 3000
Lifespan: 10 days
Digestive System – Oral (Buccal) Cavity:

2) Salivary Glands:
   - Produce and secrete saliva (1 – 1.5 L / day)

Lubricate mouth: Protect body: Chemical digestion:
Water (~ 99.5%) Antibodies Salivary amylase (carbs)
Ions Lysozymes
Mucin (glycoproteins) Buffers

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
Salivary Control:

Stimulation of chemoreceptors and mechanoreceptors

Increased salivation (watery saliva)

Activation of parasympathetic motor neurons

Chapters 22: Digestive System

Thinking...
Smelling...
Tasting...

Salivary Control:

Release of mucus-rich saliva ("dry mouth")

Constriction of blood vessels to salivary glands

Stimulation of the sympathetic motor neurons

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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

   ![Tooth Diagram]

   **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)
      - Premolars (crushing)
      - Canines (tearing)
      - Molars (grinding)

Digestive System – Oral (Buccal) Cavity:

3) **Teeth:**

   ![Dental Plaque Diagram]

   **Layers:**

   1a) **Enamel** (crown)
      
      - Acellular; highly mineralized

   1b) **Cementum** (root)
      
      - Periodontal ligament

   2) **Dentin**
      
      - Bone-like material (acellular)

   3) **Pulp Cavity**
      
      - Blood vessels, / nerves
      - Root canal
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)
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

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Digestive System – Stomach:

1) **Mucosa**: Simple columnar epithelium
   - **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)
Stomach – Acid Production:

- HCl not produced directly in cytoplasm (too corrosive)

Functions:
- Kill microorganisms
- Denature proteins
- Break down cell walls / CTs
- Active digestive enzymes

Alkaline Tide:
- pH increase in gastric blood return due to HCO₃⁻ entry

Digestive System – Stomach:
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   - 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)
        - Secrete intrinsic factor (vitamin B₁₂)
     C) Chief Cells
        - Secrete Pepsin (protein breakdown)
        - Secrete Rennin / Gastric Lipase (infants)
     D) Enteroendocrine Cells
        - Secrete hormones (e.g., G cells = gastrin)

Gastric Juices (1.5 L / day)
Digestive System – Stomach:
1) Mucosa: Simple columnar epithelium
2) Submucosa
3) Muscularis externa (3 layers – oblique / circular / longitudinal)
4) Serosa – Connective tissues / mesothelium (visceral peritoneum)

Gastric Ulcer
Breach in mucosal barrier
Digestive System – Stomach:
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)
Digestive System – Stomach:
Stomach - Regulation of Gastric Secretion (3 phases):

3) Intestinal Phase
   • Gastric secretion regulated by chyme entering small intestine
     A) Enterogastric Reflex: Inhibits gastric secretions / motility
     B) Hormone Release
        \[ \text{Inhibit gastric secretions} \]
        \[ \begin{align*}
            \text{• Cholecystokinin (CCK) / Gastric Inhibitory Peptide (GIP)} & \quad \text{• Triggered by lipids / carbs} \\
            \text{• Secretin} & \quad \text{• Triggered by } \downarrow \text{pH in SI}
        \end{align*} \]

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 \(\rightarrow\) small peptides)
   • Rennin (milk proteins) / Gastric Lipase (fats)
3) Propulsion (Peristalsis)
4) Absorption
   • Lipid-soluble substances (\textit{e.g.}, alcohol / drugs)
Digestive System – 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

![Histological image of small intestine](image-url)
Digestive System – Small Intestine:
Contains all four histological layers:
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   • 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
3) Muscularis externa (2 layers – circular / longitudinal)
   Myogenic Reflexes:
   Weak peristaltic contractions (limited distance)
   Gastroenteric Reflex:
   Stimulates motility along SI
   Gastroilial Reflex:
   Triggers relaxation of iliocecal valve
4) Serosa (jejunum / ileum); Adventitia (duodenum)

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:
1) Liver:

Function unit = Liver lobule
(~ 100,000 / liver)
Digestive System – Liver / Gallbladder:

1) Liver:

- Hepatic Triad
  - Liver sinusoids
  - Central Vein
  - Sinusoids lack basal lamina

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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
Hepatocytes (Hepatic cord)

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Kupffer Cells:
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Digestive System – Liver / Gallbladder:
1) Liver:
   - Hepatitis
   - Cirrhosis

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

1) Liver:

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 (RBCs)
   • 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

Bile Flow:

- Liver
- Common Hepatic duct
- Gallbladder
- Cystic duct
- Common bile duct
- Pyloric sphincter
- Pancreatic duct
- Hepatopancreatic ampulla
- Duodenal papilla (Sphincter of Oddi)
- Stomach
- Pancreas
- Duodenum
Digestive System – Pancreas:
• Mixed endocrine / exocrine gland (exocrine = digestion)
Digestive System – Pancreas:
- Mixed endocrine / exocrine gland (exocrine = digestion)
- Exocrine cell types: (produce pancreatic juice; ~ 1 L / day)
  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)

Regulation of Pancreatic Juice and Bile Secretion:
Digestive Processes of Small Intestine:
1) Mechanical Digestion (segmentation)
2) Chemical Digestion
   - Trypsin / Chymotrypsin / Carboxypeptidase (Proteins → small peptides)
   - Pancreatic amylase (Carbs → disaccharides)
   - Pancreatic lipase / Bile salts (Lipids → fatty acids / glycerol)
   - Nuclease (Nucleic acids → nucleotides)
3) Propulsion (Peristalsis – migrating mobility complex ~ 5-hour trip)
4) Absorption
   - Primary site of nutrient absorption

Digestive System – Large Intestine:
- Extends from ileocecal valve to anus (~ 5')
- Functions: 1) absorb water from indigestible food
  2) absorb essential vitamins
  3) store fecal material
- Contains bacterial flora
- Ferment indigestible carbohydrates (500 ml gas / day)
- Synthesize B complex vitamins and vitamin K

Antibiotics
(affect gut flora)

Diet

Promotes "good" gut flora growth

~ 1000 species
(10^{14} cells)
Digestive System – Large Intestine:

All four histological layers present:

1) **Mucosa**: Simple columnar / Stratified squamous (rectum)
   - No plicae circulares / villi; many goblet cells

2) **Submucosa**:
   - Superficial venous plexi \(\text{(hemorrhoids)}\)

3) **Muscularis externa** (2 layers – circular / longitudinal)
   - Longitudinal layer reduced to taeniae coli \(\text{(muscular band)}\)

4) **Serosa** (transverse / sigmoid); **Adventitia** (ascending / descending)
Digestive Processes of Large Intestine:

1) Absorption
   - Water: 75% water / 20% indigestible waste / 5% bacteria
   - Ions
   - Vitamins

Feces:

Water flows down concentration gradients

2) Propulsion
   - Cecum → Transverse Colon (very slow…)
     - Haustral Churning = segmentation (mixes adjacent haustra)
     - Peristalsis
   - Transverse Colon → 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

Diarrhea
Constipation
### Digestive Processes of Large Intestine:

1) **Absorption**

2) **Propulsion**
   - Cecum → Transverse Colon (very slow...)
     - Haustral Churning = segmentation (mixes adjacent haustra)
   - Peristalsis
   - Transverse Colon → Rectum (more rapid...)
     - Mass Movements = powerful peristaltic waves (several times / day)
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   - Defecation Reflex: Distension of rectal wall triggers multiple positive feedback loops

**Voluntary Control of Defecation**

- **Valsalva’s Maneuver**: Forced exhalation with glottis closed
  - If pressure > 55 mm Hg in rectum, external sphincter involuntarily relaxes
Physiology of Chemical Digestion:

- **Catabolic process** (breakdown)

  Hydrolysis = addition of water at chemical bonds

  ![Hydrolysis example](image)

  Macromolecules → Monomers
  - **Carbohydrates** → Monosaccharides
  - **Proteins** → Amino acids
  - **Lipids** → Monoglycerides & Fatty acids
  - **Nucleic acids** → Bases, phosphates & ribose

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Physiology of Chemical Digestion:

1) **Carbohydrates**

- **Oligosaccharides** → **Disaccharides**
  - Salivary amylase
  - Pancreatic amylase

- **Monosaccharides**
  - Brush border enzymes
  - Galactose
  - Glucose
  - Fructose
Physiology of Chemical Digestion:

2) Proteins

Mouth → Esophagus → Stomach → Small Intestine → Large Intestine

- Peptides
  - Pepsin / HCl
  - Trypsin, Chymotrypsin, Carboxypeptidase, Brush border enzymes
  - Amino acids

3) Lipids

Mouth → Esophagus → Stomach → Small Intestine → Large Intestine

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

3) **Lipids**

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

**Chapters 22: Digestive System**

- **Mouth**
- **Esophagus**
- **Stomach**
- **Small Intestine**
- **Large Intestine**

4) **Nucleic Acids**

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