Digestive System

- **Functions of the Digestive System**

  - **Ingestion** – taking food into the mouth
  
  - **Secretion** – release of water, acid, buffers, and enzymes into the lumen of the GI tract
  
  - **Mixing and Propulsion** – churning and moving of food through the tract
  
  - **Digestion** – mechanical and chemical breakdown of food
  
  - **Defecation** – elimination of feces from the GI tract
Digestive System

- Layers of the GI Tract

Intrinsic nerve plexuses:
- Myenteric nerve plexus
- Submucosal nerve plexus

Gland in submucosa

Mucosa:
- Epithelium
- Lamina propria
- Muscularis mucosae

Submucosa

Muscularis externa:
- Longitudinal muscle
- Circular muscle

Serosa:
- Epithelium
- Connective tissue

Duct of gland outside alimentary canal

Gland in mucosa

Mucosa-associated lymphoid tissue

Mesentery

Nerve

Artery

Vein
Digestive System

- Mouth, Oropharynx and Esophagus
Digestive System

- Muscles of Mastication
  - Masseter
  - Temporals
  - Medial and Lateral Pterygoids

- Roof of Mouth – composed of the hard and soft palates

- Salivary Glands - Produce serous (ptyalin or amylase) and mucous secretions
Digestive System

- Oral Cavity
  - Lips and Cheeks
    - Facial expressions
    - Suckling
    - Mastication
    - Speech
  - Tongue
    - Speech
    - Taste
    - Mastication
    - Swallowing

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Digestive System

- Teeth

- 20 deciduous teeth replaced by 32 permanent teeth
- Each tooth type has a specific function
- Held in place by the periodontal ligament
- Enamel
- Dentin
- Dentinal tubules
- Pulp cavity (contains blood vessels and nerves)
- Gingiva (gum)
- Cementum
- Root canal
- Periodontal ligament
- Apical foramen
- Bone
Digestive System

- Functions of the Oral Cavity
  
  - Mechanical digestion of food, cut, tear and crushing action of the teeth
  
  - Saliva dissolves foods for taste
  
  - Mucin lubricates and binds food
  
  - Chemical digestion begins – amylase begins starch digestion
Digestive System

- Esophagus

(a) Esophageal cross-section showing:
- Mucosa (contains a stratified squamous epithelium)
- Submucosa (areolar connective tissue)
- Lumen
- Muscularis externa
  - Circular layer
  - Longitudinal layer
- Adventitia (fibrous connective tissue)

(b) Esophageal histology showing detailed structure.
Digestive System

- Deglutition (swallowing) – the movement of a bolus of food from the mouth to the stomach

Involves the:

- Raising of the soft palate to close off the nasopharynx
- Raising of the larynx to close off the laryngopharynx

Consists of:

- Voluntary Stage
- Pharyngeal Stage
- Esophageal Stage
Digestive System

(a) Upper esophageal sphincter contracted
(b) Upper esophageal sphincter relaxed
(c) Upper esophageal sphincter contracted
(d) Gastroesophageal sphincter closed
(e) Gastroesophageal sphincter open

- Tongue
- Pharynx
- Epiglottis
- Glottis
- Trachea
- Esophagus
- Uvula
- Bolus

Relaxed muscles
Circular muscles contract, constricting passageway and pushing bolus down
Longitudinal muscles contract, shortening passageway ahead of bolus
Gastroesophageal sphincter closed
Gastroesophageal sphincter open
Digestive System

- Stomach
Digestive System

Mucosa
- Surface epithelium
- Lamina propria
- Muscularis mucosae

Submucosa
- Contains submucosal plexus

Muscularis externa
- Contains myenteric plexus

Serosa

Stomach wall
- Oblique layer
- Circular layer
- Longitudinal layer

Gastric pits
- Surface epithelium
- Mucous neck cells
- Parietal cell
- Gastric glands
- Chief cell

Enteroendocrine cell
- Pepsinogen
- HCl
- Pepsin
- Mitochondria in parietal cell
- Parietal cell
- Chief cell
- Enteroendocrine cell
Digestive System

- Stomach Functions
  - Mechanical Digestion – mixing waves
  - Chemical Digestion – produces liquidy chyme
    - Proteins into peptides, via pepsin (low pH)
    - Lingual Lipase – secreted in the mouth, works in the stomach
    - Rennin

- Regulation of Gastric Secretion and Motility
  - Regulated by nervous and hormonal mechanisms
  - Three Phases
    - Cephalic
    - Gastric
    - Intestinal
Digestive System

**Stimulatory Events**

**Cephalic phase**
1. Sight and thought of food → Cerebral cortex
2. Stimulation of taste and smell receptors → Hypothalamus and medulla oblongata → Vagus nerve

**Gastric phase**
1. Stomach distension activates stretch receptors → Vagovagal reflexes → Medulla → Vagus nerve → Local reflexes
2. Food chemicals (especially peptides and caffeine) and rising pH activate chemoreceptors → G cells → Gastrin release to blood

**Intestinal phase**
1. Presence of low pH and partially digested foods in duodenum when stomach begins to empty → Intestinal (enteric) gastrin release to blood

**Inhibitory Events**

**Cerebral cortex**
1. Loss of stimulatory impulses to parasympathetic center

**Gastrin secretion declines**

**Sympathetic nervous system (SNS) activation**
1. Excessive acidity (< pH 2) in stomach
2. Emotional upset

**Enterogastric reflex**
1. Distension of duodenum; presence of fatty, acidic, hypertonic chyme, and/or irritants in the duodenum

**Local reflexes**
1. Distension; presence of fatty, acidic, partially digested food in the duodenum

**Vagal nuclei in medulla**

**Pyloric sphincter**

**Release of intestinal hormones (secretin, gastric inhibitory peptide, cholecystokinin, vasoactive intestinal peptide)**

**Key:**
- Stimulate
- Inhibit
Digestive System

- Gastric Motility and Emptying
Digestive System

Presence of fatty, hypertonic, acidic chyme in duodenum

Duodenal entero-endocrine cells

Chemoreceptors and stretch receptors

Enterogastrones (secretin, CCK, GIP)

Secrete

Target

Via short reflexes

Via long reflexes

Enteric neurons

CNS centers

↑ SNS activity;
↓ parasympathetic activity

Duodenal stimuli decline

Contractile force and rate of stomach emptying decline

Key:
- Initial stimulus
- Physiological response
- Result
- Stimulate
- Inhibit
Digestive System

- **Small Intestine**
  - Ranges from the pyloric sphincter to the ileocecal sphincter
  - Divided into the:
    - Duodenum
    - Jejunum
    - Ileum
Digestive System

- **Muscle layers**
- **Large circular folds**
- **Villi**
- **Vein carrying blood to hepatic portal vessel**
- **Lumen**
- **Absorptive cells**
- **Lacteal**
- **Goblet cell**
- **Blood capillaries**
- **Intestinal crypt**
- **Muscularis mucosae**
- **Duodenal glands**
- **Submucosa**
- **Microvilli**
- **Crypt**
- **Goblet cells**
- **Absorptive cells**

Part (a) shows the overall structure, part (b) focuses on the internal layers, part (c) highlights absorptive cells and microvilli, and part (d) illustrates the structure of a villus with crypts and goblet cells.
Digestive System

- Liver – right and left lobes separated by falciform ligament
Digestive System
Digestive System

1. Oxygenated blood from hepatic artery
2. Liver sinusoids
3. Central vein
4. Hepatic vein
5. Inferior vena cava
6. Right atrium of heart

Nutrient-rich, deoxygenated blood from hepatic portal vein
Digestive System

- Bile
  - Excretory – removes components of worn-out RBC’s
  - A digestive secretion involved in the emulsification of fats
  - Regulation – hormonal and nervous
Digestive System

- Other Liver Functions
  - Carbohydrate, fat, and protein metabolism
  - Removal of drugs and hormones from the blood
  - Excretion of bile
  - Synthesis of bile salts
  - Storage of vitamins and minerals
  - Phagocytosis
  - Activation of vitamin D

- Jaundice
  - Prehepatic (hemolytic) jaundice
  - Hepatic (medical) jaundice
  - Extrahepatic (obstructive) jaundice
Digestive System

- Pancreas
- **Pancreatic Secretions**
  - Pancreatic Enzymes
    - Pancreatic Amylase – starch
    - Pancreatic Proteases
      » Trypsin
      » Chymotrypsin
      » Elastase
      » Carboxypeptidases
    - Pancreatic Lipase
    - Ribonuclease
    - Deoxyribonuclease
  - Sodium Bicarbonate
- **Regulation of Pancreatic Secretion**
  - Nervous
  - Hormonal
Digestive System

- Regulation of Pancreatic Secretions

1. Acidic chyme entering duodenum causes the enteroendocrine cells of the duodenal wall to release secretin, whereas fatty, protein-rich chyme induces release of cholecystokinin

2. Cholecystokinin and secretin enter bloodstream

3. Upon reaching the pancreas, cholecystokinin induces the secretion of enzyme-rich pancreatic juice; secretin causes copious secretion of bicarbonate-rich pancreatic juice
Digestive System

- Large Intestine (Colon)

- Left colic (splenic) flexure
- Transverse mesocolon
- Epiploic appendages
- Descending colon
- Cut edge of mesentery
- Teniae coli
- Sigmoid colon
- Right colic (hepatic) flexure
- Transverse colon
- Superior mesenteric artery
- Haustrum
- Ascending colon
- Ileum
- Ileocecal valve
- Cecum
- Vermiform appendix
- Rectum
- Anal canal
- External anal sphincter

(a)
Digestive System

- Columnar cells with striated border
- Lamina propria
- Goblet cells
- Crypt
- Muscularis mucosae
Digestive System

- Functions of the Large Intestine

  - Chemical Digestion – bacterial action with the synthesis of some vitamins

  - Absorption
    - Water
    - Electrolytes
    - Some vitamins
Digestive System

- Chemical Digestion

**Carbohydrate digestion**

- **Foodstuff**: Starch and disaccharides
  - **Enzyme(s) and source**: Salivary amylase, Pancreatic amylase
  - **Site of action**: Mouth, Small intestine
  - **Path of absorption**: The monosaccharides glucose and galactose are absorbed via cotransport with sodium ions; fructose passes via facilitated diffusion. All monosaccharides enter the capillary blood in the villi and are transported to the liver via the hepatic portal vein.

- **Foodstuff**: Oligosaccharides and disaccharides
  - **Enzyme(s) and source**: Brush border enzymes in small intestine (dextrinase, glucoamylase, lactase, maltase, and sucrase)
  - **Site of action**: Small intestine

**Protein digestion**

- **Foodstuff**: Protein
  - **Enzyme(s) and source**: Pepsin (stomach glands) in the presence of HCl
  - **Site of action**: Stomach
  - **Path of absorption**: Amino acids are absorbed via cotransport with sodium ions; they enter the capillary blood in the villi and are transported to the liver via the hepatic portal vein.

- **Foodstuff**: Large polypeptides
  - **Enzyme(s) and source**: Pancreatic enzymes (trypsin, chymotrypsin, carboxypeptidase)
  - **Site of action**: Small intestine

- **Foodstuff**: Small polypeptides, small peptides
  - **Enzyme(s) and source**: Brush border enzymes (aminopeptidase, carboxypeptidase, and dipeptidase)
  - **Site of action**: Small intestine
Digestive System

**Fat digestion**

- **Foodstuff**: Unemulsified fats
- **Enzyme(s) and source**: Emulsified by the detergent action of bile salts ducted in from the liver
- **Site of action**: Small intestine
- **Path of absorption**: Fatty acids and monoglycerides enter the intestinal cells via diffusion. They are combined with proteins within the cells, and the resulting chylomicrons are extruded. They enter the lacteals of the villi and are transported to the systemic circulation via the lymph in the thoracic duct. (Glycerol and short-chain fatty acids are absorbed into the capillary blood in the villi and transported to the liver via the hepatic portal vein.)

**Nucleic acid digestion**

- **Foodstuff**: Nucleic acids
- **Enzyme(s) and source**: Pancreatic ribonuclease and deoxyribonuclease
- **Site of action**: Small intestine
- **Path of absorption**: Active transport via membrane carriers; absorbed into capillary blood in the villi and transported to the liver via the hepatic portal vein.
Digestive System

- Proteins
• Lipids

Digestive System

Fat globule

Emulsification

Nonpolar region

Bile salt

Polar (charged) regions

Fat droplets coated with bile salts are suspended in water
Digestive System

1. Fatty acids and monoglycerides associated with micelles in lumen of intestine

2. Fatty acids and monoglycerides resulting from fat digestion leave micelles and enter epithelial cell by diffusion

3. Fatty acids are used to synthesize triglycerides in agranular endoplasmic reticulum

4. Fatty globules are combined with proteins to form chylomicrons (within Golgi apparatus)

5. Vesicles containing chylomicrons migrate to the basal membrane where they are extruded from the epithelial cell and enter a lacteal (lymph capillary)

6. Lymph in the lacteal transports chylomicrons away from intestine

Lumen of intestine
Golgi
Absorptive epithelial cell
Lacteal

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**Note:** The diagram illustrates the process of lipid absorption in the small intestine, detailing the steps of digestion and transport of fatty acids and triglycerides into the lymphatic system.