The Digestive System

Overview of the Digestive Tract

The Digestive System

- Consists of the muscular digestive tract assisted by various accessory organs
- Digestive functions include:
  - Ingestion
  - Mechanical processing
  - Digestion
  - Secretion
  - Absorption
  - Excretion

Overview of the Digestive Tract

Digestive Tract Components

- Oral cavity
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Rectum
- Anus

Overview of the Digestive Tract

The Components of the Digestive System and Their Functions

Overview of the Digestive Tract

Histological Organization—Four Layers

- **Mucosa**
  - Epithelium
  - Lamina propria (connective tissue)
- **Submucosa**
  - Connective tissue, nerves, blood vessels
- **Muscularis externa**
  - Loose connective tissue cover (adventitia)
• Serosa (in peritoneal cavity)
  • Continuous with mesentery

**Overview of the Digestive Tract**
The Structure of the Digestive Tract

**Overview of the Digestive Tract**
The Structure of the Digestive Tract

**Overview of the Digestive Tract**
Movement of Digestive Materials
  • Involuntary control of smooth muscle of muscularis externa
  • Two kinds of movement
    • Peristalsis propels material along the tract
    • Segmentation churns material in the small intestine

**The Oral Cavity**
Functions of the Oral Cavity
  • Sensory analysis of potential foods
  • Mechanical processing using teeth, tongue, and palate
  • Lubrication of food by mucus in saliva
  • Enzymatic digestion by enzymes in saliva

**The Oral Cavity**
Anatomy of the Oral Cavity
  • Also called, buccal cavity
  • Tongue forms floor
  • Hard and soft palate form roof
  • Buccal mucosa forms walls
    • Composed of stratified squamous epithelium

**The Oral Cavity**
Functions of the Tongue
  • Mechanical processing of food
  • Manipulation to assist chewing and swallowing
  • Sensory analysis (taste, texture)
  • Participation in speech

**The Oral Cavity**
The Oral Cavity

**The Oral Cavity**
The Oral Cavity

**The Oral Cavity**
Salivary Glands
  • Three pairs of glands
    • Parotid
• Sublingual
• Submandibular

Functions of saliva
• Lubricates, cleanses oral cavity
• Dissolves chemicals
• Suppresses bacterial growth

The Oral Cavity
The Salivary Glands

The Oral Cavity
Teeth
• Participate in mastication of food
• Anchored to bone by periodontal ligament
• Dentin forms basic shape
  • Enamel covers crown
  • Cementum covers root
• 20 deciduous teeth (“baby teeth”)
• 32 secondary teeth (“adult teeth”)

The Oral Cavity
Teeth: Structural Components and Dental Succession

The Oral Cavity
Teeth: Structural Components and Dental Succession

The Oral Cavity
Teeth: Structural Components and Dental Succession

The Pharynx
Functions of the Pharynx
• Common passageway for food, drink, and air
• Pharyngeal muscles propel food along esophagus toward the stomach during swallowing

The Esophagus
Anatomy of the Esophagus
• Muscular tube about 25 cm long
• Lined by stratified squamous epithelium
• Posterior to trachea
• Penetrates diaphragm at esophageal hiatus
• Possess upper and lower esophageal sphincters
  • Sphincter—A circular band of muscle that can pinch close a muscular tube

The Esophagus
Swallowing (Deglutition)—Three Steps
• Named for where they take place
  1. Oral phase
     • Compaction of *bolus*
     • Entry into pharynx
  2. Pharyngeal phase
     • Elevation of larynx
     • Bending of *epiglottis*, closing of *glottis*
  3. Esophageal phase
     • Peristalsis pushes bolus toward stomach

**The Stomach**
Functions of the Stomach
• Temporary storage of ingested food
• Mechanical breakdown of food
  • Forms *chyme*, a liquid suspension
• Breakage of chemical bonds in food by action of acid and enzymes
  • Production of *intrinsic factor*
    • Required for vitamin B$_{12}$ absorption

**The Stomach**
Regions of the Stomach
• Cardia
  • Closest to heart
• Fundus
  • “Hump” on top
• Body
  • Shaped like the letter “C”
• Pylorus
  • Pyloric sphincter guards the exit

**The Stomach**
The Anatomy of the Stomach

**The Stomach**
The Anatomy of the Stomach

**The Stomach**
Secretions of the Gastric Glands
• *Parietal cells*
  • Secrete HCl (strong acid), *intrinsic factor*
• *Chief cells*
  • Produce *pepsinogen*, an inactive enzyme
  • HCl activates pepsinogen to *pepsin*
• Goblet cells
  • Produce mucus
• Endocrine cells
  • Produce gastrin, a hormone

The Stomach
The Anatomy of the Stomach

The Stomach
The Regulation of Gastric Activity
  • Cephalic phase
    • CNS prepares the stomach to receive food
  • Gastric phase
    • Begins when food enters stomach
  • Intestinal phase
    • Controls the pace of gastric emptying

The Stomach
The Phases of Gastric Secretion

The Stomach
The Phases of Gastric Secretion

Key Note
The stomach provides for the physical breakdown of food that must precede chemical digestion. Pepsin and acid begin the digestion of proteins. For a variable period of time after food arrives in the stomach, starch continues the digestion that began with salivary amylase.

The Small Intestine
Regions of the Small Intestine
  • Duodenum
  • Jejunum
  • Ileum
    • Ileocaecal valve (a sphincter) marks junction with large intestine

The Small Intestine
The Segments of the Small Intestine

The Small Intestine

The Intestinal Wall

- Mucosa has transverse folds, *plicae circulares*
- Plicae have small projections, *villi*
- Both increase surface area of mucosa for absorption
- Each villus has a lymphatic capillary, a *lacteal*

The Small Intestine

Two Forms of Peristalsis

- Small-scale periodic contractions of the muscularis externa
- Large-scale contractions coordinated by reflex
  - *Gastroenteric reflex*
  - *Gastrocolic reflex*

The Small Intestine

Intestinal Secretions

- Intestinal glands secrete
  - Intestinal juice
    - Moistens chyme
    - Buffers stomach acid
    - Dissolves digestive enzymes
    - Dissolves products of digestion
  - Mucus
  - Hormones

The Small Intestine

Intestinal Hormones

- Gastrin
- Secretin
- Cholecystokinin (CCK)
- Gastric Inhibitory Peptide (GIP)

The Small Intestine

The Activities of Major Digestive Tract Hormones
The Small Intestine

Digestion in the Small Intestine

- Most enzymatic digestion and absorption occurs in the small intestine
- Digestive enzymes and buffers are released by:
  - Pancreas
  - Liver
  - Gall bladder

The Small Intestine

Key Note

The small intestine receives chyme from the stomach and raises its pH. It then absorbs water, ions, vitamins, and the products released from food molecules by the action of digestive enzymes produced by intestinal glands and the pancreas.

The Pancreas

Anatomy of the Pancreas

- Pancreatic duct enters duodenum
- Duct delivers *pancreatic juice*
- Duct branches repeatedly
- Fine branches end in *pancreatic acini*
- Endocrine cells are found among the acini

The Pancreas

Secretions of the Pancreas

- Endocrine secretion (hormones)
  - Insulin
  - Glucagon
- Exocrine secretion (digestive)
  - Water
  - Ions
  - Enzymes
    - Carbohydrases
    - Lipases
    - Proteases
    - Nucleases
Control of Pancreatic Secretion
- Chyme entering duodenum triggers hormone release
- Hormones trigger release of pancreatic juice
  - Secretin triggers water and bicarbonate
  - CCK triggers enzymes
    - Amylase, lipase
    - Proteases
      Trypsin, chymotrypsin, carboxypeptidase

The Pancreas

Key Note
The exocrine pancreas produces a mixture of buffers and enzymes essential for normal digestion. Pancreatic secretion is stimulated by hormones (secretin and CCK) released from the duodenum.

The Liver

Overview of Liver
- Largest visceral organ
- Over 200 known functions
- Four Lobes
  - Right (largest by far)
  - Left
  - Caudate
  - Quadrate

The Liver

The Surface Anatomy of the Liver

The Liver

Histology of the Liver
- Liver lobule is basic functional unit
- Blood supply from hepatic artery and hepatic portal vein
- Blood flows past sheets of hepatocytes
- Blood channels are sinusoids
- Blood collects in central vein
- Bile canaliculi carry bile toward bile ducts
Liver Histology

The Liver
Bile Ducts
- Each lobe has a bile duct
- Bile ducts unite to form **common hepatic duct**
- **Cystic duct** carries bile to gall bladder
- Common bile duct carries bile to the duodenum

The Liver
Functions of the Liver
- Metabolic regulation
  - Store absorbed nutrients, vitamins
  - Release nutrients as needed
- Hematological regulation
  - Plasma protein production
  - Remove old RBCs
- Production of bile
  - Required for fat breakdown

The Gallbladder
- Gall bladder stores and concentrates bile for release into duodenum
- Relaxation of the hepatopancreatic sphincter permits bile to enter small intestine
  - CCK relaxes this sphincter

**Key Note**
The liver is the body's center for metabolic regulation. It produces bile that will be ejected by the gallbladder into the duodenum under stimulation of CCK. Bile is essential for the efficient digestion of lipids; it *emulsifies* fats so that individual lipid molecules can be readily attacked by digestive enzymes.

The Gallbladder
The Gall Bladder

The Large Intestine
Overview of the Large Intestine
- Reabsorbs water and compacts feces
- Absorbs vitamins made by bacteria
- Stores feces before defecation
• Consists of three parts
  • Cecum
  • Colon
  • Rectum

**The Large Intestine**

**Cecum**
  • Collects and stores material from ileum
  • Begins process of compaction
  • Attaches to *vermiform appendix*

**The Large Intestine**

**The Anatomy of the Colon**
  • Larger diameter, thinner wall than small intestine
  • Bears *haustra* (pouches)
  • Possesses *taenia coli* (longitudinal bands of smooth muscle)

**The Large Intestine**

**The Rectum**
  • Expandable for temporary storage of feces
  • Terminates in *anal canal*
  • Leads to *anus*
  • Circular muscle forms *internal anal sphincter*
  • Encircled by skeletal muscle
    • Forms *external anal sphincter*

**The Large Intestine**

**The Large Intestine**

**The Rectum**
  • Expandable for temporary storage of feces
  • Terminates in *anal canal*
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**The Large Intestine**

**The Large Intestine**

**Functions of the Large Intestine**
  • Absorption
    • Water
    • Ions
    • Vitamins
    • Organic wastes
    • Bile salts
    • Toxins
    • Bacterial growth

**The Large Intestine**

**Control of the Large Intestine**
  • Stretching of stomach and duodenum triggers peristalsis of feces
from colon into rectum
• Sphincters control movement of feces toward the anus
• Stretching of rectum triggers defecation reflex
  • Release of feces requires relaxation of external anal sphincter

The Large Intestine
Key Note
The large intestine stores digestive wastes and reduces their volume by reabsorbing water. Bacteria that live in the large intestine are an important source of vitamins, especially vitamin K, biotin, and vitamin B_5_.

Digestion and Absorption
Processing and Absorption of Nutrients
• Two Steps in Processing
  • Mechanical processing to break down physical structure of foods
  • Chemical processing to break the covalent bonds between food subunits
    • Enzymes catalyze this
    • Activate the hydrolysis of large food molecules

Digestion and Absorption
Processing and Absorption of Carbohydrates
• Carbohydrates
  • Starches are broken down by amylases
    • Results in di- and trisaccharides
  • Enzymes on cell surface split them to monosaccharides
  • Absorbed by the intestinal epithelium by facilitated diffusion or co-transport

Digestion and Absorption
The Digestion and Absorption of Carbohydrates

Digesftion and Absorption
The Digestion and Absorption of Carbohydrates

Digestion and Absorption
Processing and Absorption of Fats
• Bile emulsifies fats to small droplets
• Lipase hydrolyzes triglycerides into fatty acids and monoglycerides
• Lipid products form micelles
• Lipids diffuse into epithelial cells
• Triglycerides are reformed
• Secreted as \textit{chylomicrons} into \textit{lacteals} 
• Transported in lymph to thoracic duct

\textbf{Digestion and Absorption}  
The Digestion and Absorption of Lipids

\textbf{Digestion and Absorption}  
The Digestion and Absorption of Lipids

\textbf{Digestion and Absorption}  
Processing and Absorption of Nutrients

• Proteins  
  • Breakdown starts in stomach  
    • Pepsin and HCl produce fragments  
  • Breakdown continues in small intestine  
    • Pancreatic proteases produce small \textit{peptides}  
    • Peptidases releases amino acids  
    • Intestinal epithelium absorbs amino acids into the body

\textbf{Digestion and Absorption}  
The Digestion and Absorption of Proteins

\textbf{Digestion and Absorption}  
The Digestion and Absorption of Proteins

\textbf{Digestion and Absorption}  
Water and Electrolyte Absorption

• About nine liters/day enter the digestive tract  
  • Two liters of ingested water  
  • Seven liters of watery secretions  
• Ions are absorbed by many mechanisms  
  • Sodium, calcium, chloride, bicarbonate  
• All but about 150 ml is absorbed by osmosis, as water “follows” the ions

\textbf{Digestion and Absorption}  
Absorption of Vitamins

• Fat-soluble vitamins combine with lipid micelles for absorption  
• Water-soluble vitamins diffuse across the digestive epithelium  
  • Exception: vitamin B_{12} requires \textit{intrinsic factor} (from the gastric mucosa) for absorption

\textbf{Aging and the Digestive System}  
Age-Related Changes in the Digestive System

• Thinner, more fragile epithelium  
• Reduced epithelial stem cell division  
• Weaker peristaltic contraction
• Reduced smooth muscle tone

**The Integumentary System**
- Provides vitamin D\(_3\) needed for the absorption of calcium and phosphorus
- Provides lipids for storage by adipocytes in subcutaneous layer

**The Skeletal System**
- Skull, ribs, vertebrae, and pelvic girdle support and protect parts of digestive tract; teeth important in mechanical processing of food
- Absorbs calcium and phosphate ions for incorporation into bone matrix; provides lipids for storage in yellow marrow

**The Muscular System**
- Protects and supports digestive organs in abdominal cavity; controls entrances and exits of digestive tract
- Liver regulates blood glucose and fatty acid levels, metabolizes lactic acid from active muscles

**The Nervous System**
- ANS regulates movement and secretion; reflexes coordinate passage of materials along tract; control over skeletal muscles regulates ingestion and defecation; hypothalamic centers control hunger, satiation, and feeding behaviors
- Provides substrates essential for neurotransmitter synthesis

**The Endocrine System**
- Epinephrine and norepinephrine stimulate constriction of sphincters and depress digestive activity; hormones coordinate activity along tract
- Provides nutrients and substrates to endocrine cells; endocrine cells of pancreas secrete insulin and glucagon; liver produces angiotensinogen

**The Cardiovascular System**
- Distributes hormones of the digestive tract; carries nutrients, water, and ions from sites of absorption; delivers nutrients and toxins to liver
- Absorbs fluid to maintain normal blood volume; absorbs vitamin K; liver excretes heme (as bilirubin), synthesizes coagulation proteins

**The Lymphatic System**
- Tonsils and other lymphoid nodules along digestive tract defend against infection and toxins absorbed from the tract; lymphatic vessels carry absorbed lipids to venous system
- Secretions of digestive tract (acids and enzymes) provide nonspecific defense against pathogens
The Respiratory System
• Increased thoracic and abdominal pressure through contraction of respiratory muscles can assist in defecation
• Pressure of digestive organs against the diaphragm can assist in exhalation and limit inhalation

The Urinary System
• Excretes toxins absorbed by the digestive epithelium; excretes some bilirubin produced by liver
• Absorbs water needed to excrete waste products at the kidneys; absorbs ions needed to maintain normal body fluid concentrations

The Reproductive System
• Provides additional nutrients required to support gamete production and (in pregnant women) embryonic and fetal development