The Digestive System

- The digestive system consists of a long tube, called the gastrointestinal (GI) tract that extends from the mouth to the anus, along with accessory glands.
- The digestive system is divided into specialized compartments for food processing.
- Nerves and hormones control digestive activities.

Function of the Digestive System

- The function of the digestive system is to:
  1. bring food into the body
  2. digest it into nutrients that are absorbed by the body
  3. eliminate wastes out of the body.

Terminology

- Digestion: The process of breaking complex molecules into simpler molecules which can be absorbed in the GI tract.
- Absorption: The process of transporting molecules across the wall of the GI tract into vessels to be transported to the liver.

Digestion

- Mechanical digestion - chewing of food, churning action of the stomach, and segmentation of the small intestine.
- Chemical digestion - action of enzymes and chemicals on foods.
The Digestive System

**ORGANS**

- **Mouth**
  - Entrance to digestive system
  - Teeth chew food
  - Tongue positions and tastes food

- **Stomach**
  - J-shaped muscular sac
  - Stores food
  - Secretes gastric juice (pepsin and HCl)
  - Mixes food with gastric juice
  - Protein digestion begins

- **Small intestine**
  - Long, muscular tube
  - Mixes food with bile and with intestinal and pancreatic enzymes
  - Digests most nutrients
  - Absorbs most nutrients and water

- **Colon**
  - Muscular tube
  - Absorbs water and some nutrients
  - Stores waste materials (feces)

- **Rectum**
  - Region of large intestine
  - Passageway for feces
  - Stretching of wall stimulates the defecation reflex

- **Anus**
  - Opening at end of system
  - Expels feces

**ACCESSORY STRUCTURES**

- **Salivary glands**
  - Three pairs of glands that secrete saliva

- **Liver**
  - Large organ in abdominal cavity
  - Secretes bile, which emulsifies fats

- **Gallbladder**
  - Small sac
  - Stores bile

- **Pancreas**
  - Gland located behind stomach
  - Secretes enzymes that digest all major nutrients

- **Gastrointestinal tract**
  - Region of small intestine

**Wall of the Digestive Tract**

- Along most of its length, the wall of the digestive system has four basic layers
  1. Mucosa
  2. Submucosa
  3. Muscularis
  4. Serosa

**Wall of the Digestive Tract - Mucosa**

- **Mucosa** - Mucus membrane layer lines the GI tract
  - The open area inside the GI tract is the **lumen**
  - Glandular epithelial cells secrete digestive enzymes.
  - Goblet cells secrete mucus, which lubricates.
  - Simple columnar epithelial cells line the lumen

**Wall of the Digestive Tract - Submucosa**

- **Submucosa** – layer of connective tissue with nerves, blood supply, lymph vessels.
  - Protect us from disease, nerves stimulate muscles, transport of nutrients.
Wall of the Digestive Tract - Muscularis

- **Muscularis** – Layer of smooth muscles.
- Has two layers of muscle, one circular and one longitudinal
- Functions to mix and moves food.

Wall of the Digestive Tract - Serosa

- **Serosa** – a layer covering the GI tract that secretes serous fluid.
- The fluid functions to reduce friction between moving layers of tissue.

Components of the GI Tract

- The major GI Tract components
  - Mouth
  - Esophagus
  - Stomach
  - Small intestine
  - Large intestine

Accessory Organs

- The digestive organs are aided by several accessory organs
  - Salivary glands
  - Pancreas
  - Gallbladder
  - Liver

The Digestive System Has Specialized Compartments

<table>
<thead>
<tr>
<th>Structure</th>
<th>Description/Functions</th>
<th>Mechanical Digestion</th>
<th>Chemical Digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>Receives food, conducts salt and tongue, tongue flavors food and moisture quality</td>
<td>Teeth tear and crush food into smaller pieces</td>
<td>Digestion of carbohydrates begins</td>
</tr>
<tr>
<td>Pharynx</td>
<td>Also the birth canal and air passage</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Esophagus</td>
<td>Tube that transports food from mouth to stomach</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Stomach</td>
<td>Lakes the muscular sac for food storage</td>
<td>Churning of stomach mixes food with gastric juices creating liquid form</td>
<td>Protein digestion begins</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Long tube where digestion is completed and nutrients are absorbed</td>
<td>Segmental contractions mix food with intestinal enzymes, pancreatic enzymes, and bile</td>
<td>Carbohydrates, protein, and fat digestion completed</td>
</tr>
<tr>
<td>Large intestine</td>
<td>Hindgut region of Cloaca, absorbs water and ions, houses bacteria, forms and releases feces</td>
<td>None</td>
<td>Some digestion is carried out by bacteria</td>
</tr>
<tr>
<td>Anal Receptors</td>
<td>Terminal canal of digestive tract</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Parts of the Digestive Tract - Mouth

1. **Mouth**: specialized for tasting, speech, moistening food, and mechanical and enzymatic digestion.
### Parts of the Digestive Tract - Mouth

- The mouth contains:
  1. **Salivary glands** - secretes salivary amylase that begins the process of digesting starch.
  2. **Tongue** - mixes chewed food with saliva.
  3. **Teeth** – break food into smaller pieces
  4. **Tonsils** – protect against infections
  5. **Uvula** – working with the soft palate, closes off the nasopharynx

### Mouth - Salivary glands

- **Saliva**:
  - Moistens food
  - Dissolves the chemicals in the food
  - Contains the enzyme, salivary amylase
    - Begins digestion of carbohydrates

### Mouth - Tongue

- **The tongue**
  - A large skeletal muscle with taste buds
  - Important in speech
  - Helps form food into a **bolus**
    - A soft mass of food, suitable for swallowing

### Teeth

- **Enamel**
- **Dentin**
- **Pulp cavity** (contains blood vessels and nerves)
- **Gum (gingiva)**
- **Root canal**
- **Cementum**
- **Bone**

(b) The structure of the human tooth is suited for its function of breaking food into smaller pieces.

### Mouth - Pharynx

2. **Pharynx**: behind the uvula where the nasal and oral cavities join. Common passageway for air, liquids, and food.

- Swallowing reflex begins here.

  - **Epiglottis** covers opening in the larynx that leads to the trachea when swallowing.
3. **Esophagus** — passage that connects the pharynx to the stomach.

- No digestive processes occur here

---

- Food is pushed through our digestive system by a series of muscular contractions called **peristalsis**

---

- **Sphincters** - circular muscles that control the entrance and exit of materials to and from the stomach.

- **Acid reflux** - heartburn occurs when partially digested food comes back up into the esophagus and produces a burning sensation.

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4. **Stomach**

- The stomach breaks up food through muscular contractions. There are **three layers of smooth muscle**

- The food that leaves the stomach is only partially digested.
4. Stomach functions

- The functions of the stomach include:
  1. Responsible for the storage of food
  2. Turns food into a soupy mixture called **chyme**
  3. Adds digestive enzymes and acids that begin chemical digestion of proteins

---

Stomach - Storage of Food

- The stomach expands to accommodate amounts of food
  - When empty the stomach can hold about 50 ml (1/4 cup)
  - When full, can hold several liters of food

---

Stomach – Secretions

- Gastric glands secrete:
  1. The digestive enzyme, **pepsin**, that begins the digestion of proteins.
  2. Hydrochloric acid (HCl) - strong acid that kills bacteria, aids in the digestion of proteins, begins to break down connective tissues, and activates **pepsin**.

- The wall of the stomach is protected by a thick layer of mucus secreted by goblet cells

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Stomach - Storage of Food

- Very little nutrition is actually absorbed into the blood stream from the stomach.
  - Exceptions include alcohol and some drugs including aspirin

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Layers of the Stomach

- Surface epithelium
- Mucosa
- Submucosa
- Muscularis
- Serosa

(b) Gastric glands in the wall of the stomach produce gastric juice, a mixture of hydrochloric acid and pepsin.

---

Gastric Pits

(c) The holes seen in this electron micrograph are the gastric pits, openings in the stomach wall through which gastric glands release their secretions.
5. The Small Intestine

- Small intestine – thin long tube (2.5 cm in diameter and about 6 meters long.
- Secretions from the pancreas, liver and gall bladder enter the small intestine.
- Smooth muscles surround the intestine to push the food through the digestive tract.

Parts of the Small Intestine

- The small intestine has three regions:
  1. Duodenum
  2. Jejunum
  3. Ileum

Function of the Small Intestine

1. This is the primary site of digestion (mainly chemical, but also mechanical)
2. Where most (80%) of the nutrients are absorbed into the body.

Digestion in the Small Intestine

- The digestion of complex molecules (carbohydrates, proteins, fats, and nucleic acids) in the small intestine is aided by:
  1. enzymes released from the pancreas and the small intestine
  2. and by bile from the gall bladder

Small Intestine Structure

- The lining of the small intestine is
  - Pleated (has folds)
  - The pleats have numerous finger-like projections called villi to increase surface area
Small Intestine Structure - Villi

- **Villi** (villus, singular) - greatly increase the absorption area of the small intestine.
  - Villi contain blood capillaries and lymphatic vessels called lacteals
    - **Lacteals** — absorb fatty acids.
    - **Blood capillaries** — absorb nutrients including glucose and amino acids.

Absorption

- Absorption — once complex molecules are broken down into smaller molecules, they are transported across the intestine wall.
  - Each villus contains a network of capillaries and a lacteal

Microvilli

- Each villus is covered with **microvilli**
  - Gives the small intestine a velvety appearance, increases the surface area
  - Called the **brush border**
6. Large Intestine

- By the time the food enters the large intestine most of the nutrients have been removed.

Large Intestine - Functions

1. Water, salts, & vitamins are absorbed from the large intestine, adjusting the consistency of the waste material, feces.
2. The feces are stored
3. The feces is excreted from the body

Components of the Large Intestine

- Cecum - lies below the junction with the small intestine.
- Appendix – slender pouch extending from cecum, may play a role in fighting infections but may become inflamed.

Components of the Large Intestine

- Colon – largest portion of the large intestine
  - absorbs much of the remaining water, and sodium and potassium ions
  - Contains beneficial bacteria which act on indigestible material (causing gas), produce B complex vitamins, and most of the vitamin K needed for clotting of blood.
  - The undigested food residue that leaves the colon is called feces.
- Rectum - holds feces temporarily and opens into the anus.
- Anus – has sphincter muscles controls defecation (reflex action).
Accessory Organs of the Digestive System

The liver produces bile, which is stored in the gallbladder before being released into the small intestine.

Liver

Gallbladder

Common bile duct

Stomach

Pancreas

Pancreatic duct

Small intestine

The liver produces bile, which is stored in the gallbladder before being released into the small intestine.

Pancreas

- The pancreas releases secretions into the small intestine to aid in digestion
- The pancreas is also a gland that releases hormones

Pancreas - Functions

1. Produces the hormones into the bloodstream which regulate glucose levels.
2. Secretes digestive enzymes into the small intestine.
3. Secretes bicarbonate ions into the small intestine to neutralize the acid in the chyme

Pancreas - Hormones

- The pancreas secretes two hormones into the blood to regulate glucose levels:
  1. Insulin - decreases blood glucose levels.
  2. Glucagon - increases blood glucose levels.

Pancreas – Digestive Enzymes

- The pancreas produce and release three enzymes into the small intestine:
  1. Pancreatic amylase - digests starch.
  2. Trypsin - digests proteins.
  3. Lipase - digests fats.

Liver

- Blood from capillaries of the intestine, carrying nutrients, goes to the liver through the hepatic portal veins.
**Liver functions - digestion**

1. Produces Bile
2. Processes (metabolizes) nutrients from the GI tract.
3. Metabolizes drugs and toxins
   - The liver has many enzymes that help the body metabolize.

**More Liver Functions**

4. Produces plasma proteins.
5. Breaks old blood cells down, producing bilirubin
6. Breaks down amino acids, forming urea
7. Stores iron and fat soluble vitamins A, D, E, K, and B₁₂.
8. Stores glucose as glycogen.
9. Regulates the quantity of cholesterol in the blood

**Liver - Bile**

- The liver produces bile which helps to break down fats.

**Accessory Organs - Gallbladder**

- Gall bladder - stores excess bile. Bile emulsifies fat

**Digestive Enzymes**

- Digestive enzymes - break down macromolecules into smaller molecules.

- See page 301, Table 15.2
### Carbohydrate Digestion - Amylase
- **Secreted by:**
  - the salivary glands in the mouth
  - and by the pancreas.
- **Site of action:** Mouth, small intestine
- **Function:** breaks down starch into maltose (a disaccharide)

### Carbohydrate Digestion - Maltase
- **Secreted by:** the small intestine
- **Site of action:** Small intestine
- **Function:** breaks down maltose into glucose
- **Glucose is then absorbed by capillaries**

### Protein Digestion - Pepsin
- **Secreted by the stomach**
- **Site of action:** Stomach
- **Function:** Breaks proteins and polypeptides into smaller pieces
### Protein Digestion - Trypsin
- Secreted by the pancreas
- Site of action: Small intestine
- Function: breaks proteins and polypeptides into smaller pieces

### Protein Digestion - Chymotrypsin
- Secreted by the pancreas
- Site of action: Small intestine
- Function: breaks proteins and polypeptides into smaller pieces

### Protein Digestion - Pepsidases
- Secreted by:
  - the small intestine - carboxypeptidase
  - and the pancreas - aminopeptidase
- Site of action: Small intestine
- Function: breaks proteins and polypeptides into amino acids
- Amino acids are absorbed by capillaries

### Nucleic Acid Digestion - Nucleases
- Secreted by: Pancreas
- Site of action: Small intestine
- Function: breaks nucleic acids (DNA and RNA) into nucleotides
- Nucleotides are absorbed by capillaries

### Digestion of Fats
- Bile
- Lipase
Digestion of Fats - Bile

- Bile is produced by the liver, stored in the gallbladder
- Site of action: Small intestine
- Function: Emulsifies fat droplets into smaller droplets = emulsification

Digestion of Fats - Lipase

- Secreted by the pancreas
- Site of action: Small intestine
- Function: Breaks triglycerides into monoglycerides

Digestion of Fats - Absorption

- Monoglycerides combine with bile salts to form micelles.
- Micelles are absorbed into the epithelial lining of the small intestine.

- Inside the epithelial cells, the monoglycerides combine into triglycerides and join with cholesterol, proteins and phospholipids to form chylomicrons.
- The chylomicrons are absorbed by the lacteals.

Fat Digestion

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Produced by</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amylase</td>
<td>salivary glands, pancreas</td>
<td>breaks down starch to maltose</td>
</tr>
<tr>
<td>Maltase</td>
<td>small intestine</td>
<td>breaks down maltose to glucose</td>
</tr>
<tr>
<td>Pepsin</td>
<td>stomach</td>
<td>breaks proteins into smaller pieces</td>
</tr>
<tr>
<td>Trypsin</td>
<td>pancreas</td>
<td>breaks proteins into smaller pieces</td>
</tr>
<tr>
<td>Pepidases</td>
<td>small intestine and pancreas</td>
<td>breaks proteins and polypeptides into amino acids</td>
</tr>
<tr>
<td>Nucleases</td>
<td>Pancreas</td>
<td>Breaks nucleic acids into nucleotides</td>
</tr>
<tr>
<td>Lipase</td>
<td>pancreas</td>
<td>digests fat molecules into monoglyceride fatty acids</td>
</tr>
</tbody>
</table>
Control of Digestive Secretions

- Control of digestive secretions is controlled by hormones and nerves.

- Release of saliva is controlled by nerves.
- The chewing of food stimulates nerves that control the stomach, causing it to begin to release gastric secretions.

- The stretching of the stomach causes the stomach to release the hormone gastrin.
- Gastrin circulates in bloodstream and stimulates the stomach to release more gastric secretions.

- The presence of acidic chyme entering the small intestine triggers nerves that stimulate:
  1. pancreas to release digestive enzymes
  2. small intestine to release digestive enzymes
  3. gall bladder to release bile
  4. small intestine to release hormones

- The small intestine releases hormones:
  - Vasoactive intestinal peptide – stimulates the small intestine to release enzymes
  - Secrin – stimulates the pancreas to release a buffer
  - Cholecystokinin – causes the pancreas to release digestive enzymes and the gall bladder to release bile

Nerves and Hormones Control Digestive Activities

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight of food, thought of food, presence of food in mouth</td>
<td>Release of saliva from salivary glands</td>
</tr>
<tr>
<td>Chewing food</td>
<td>Release of gastric juice (enzymes from stomach and HCl) and mucus from cells of stomach lining</td>
</tr>
<tr>
<td>Presence of acidic chyme in small intestine</td>
<td>Release of enzymes from small intestine and pancreas into the small intestine; release of bile from gallbladder into small intestine; increased motility in small intestine</td>
</tr>
</tbody>
</table>
**Nerves and Hormones Control Digestive Activities**

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Metabolism</th>
<th>Origin</th>
<th>Target</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrin</td>
<td>Stimulation of acid by food presence of partially digested protein in stomach</td>
<td>Stomach</td>
<td>Stomach</td>
<td>Release of gastric juice (separate from stomach and HCl)</td>
</tr>
<tr>
<td>Insulin</td>
<td>Presence of acid by small intestine</td>
<td>Small intestine</td>
<td>Small intestine</td>
<td>Release of enzymes from small intestine</td>
</tr>
<tr>
<td>Somatostatin</td>
<td>Presence of acid by small intestine</td>
<td>Small intestine</td>
<td>Pancreas</td>
<td>Release of sodium bicarbonate from pancreas into small intestine to neutralize acid chyme</td>
</tr>
<tr>
<td>Cholecystokinin</td>
<td>Mobilization of chyme containing fats</td>
<td>Small intestine</td>
<td>Visceral</td>
<td>Gastric secretion</td>
</tr>
</tbody>
</table>

**Stomach Disorders - Ulcers**

- **Ulcer** - Open sore often found in the stomach.

- **Causes:**
  - Most are caused by a bacterial infection (*Helicobacter pylori*) that impairs the ability of the epithelial cells to produce protective mucus.
  - Also maybe caused by pain relievers, alcohol, smoking and stress.

- **Symptoms:** burning sensation in stomach

- **Treatment:** antibiotics if caused by bacteria

**Esophagus Disorders – Acid Reflux**

- **Acid reflux** - heartburn occurs when partially digested food comes back up into the esophagus and produces a burning sensation.

- Can be caused by alcohol consumption, may lead to esophageal ulcers.

**Liver Disorders - Hepatitis**

- **Hepatitis** - inflammation of the liver

- **Caused by five types of hepatitis viruses (A-E):**
  - Hep. A - usually acquired from sewage-contaminated drinking water (vaccine available)
  - Hep. B - usually spread by sexual contact. (vaccine available)
  - Hep C - usually acquired by contact with infected blood. (no vaccine)

- **Effect:** liver can not process bilirubin, leads to Jaundice. HBV form can lead to cancer.

**Liver Disorders - Cirrhosis**

- **Cirrhosis** - the liver becomes fatty and is eventually replaced by scar tissue. Usually due to excessive drinking of alcohol.

**Disorders of the Gallbladder**

- **Gall stones** – When the cholesterol content of bile comes out of solution and form crystals

- **Obstructive jaundice** - gall stones may block the common bile duct and cause pain then the gall bladder must be removed.
Large Intestine - Disorders

- **Diarrhea** – Material passes through the large intestine too quickly and not enough water is removed. Can lead to dehydration

- **Constipation** – Material does not move quickly enough and too much water is removed

Large Intestine - Disorders

- **Diverticulosis** – When pouches form in the wall of the large intestine, called **diverticula**.

- When they get infected and inflamed it is called **diverticulitis**.

Large Intestine - Disorders

- **Polyps** – Small growths from the epithelial lining.

  - Fiber in the diet decreases the growth of polyps, fats increase the growth

  - Polyps can develop into **colon cancer**

Important Concepts

- Read Ch 16

- What is the purpose of the digestive system?

- What are the layers of the GI tract and be able to describe the layers and what are the functions of the layers?

- What are the parts of the mouth and their functions?

Important Concepts

- What are the major parts of the digestive system and their functions. Be able to describe the parts of the digestive system (mouth, pharynx, esophagus, stomach, small intestine, large intestine, pancreas, liver, gall bladder)

  - What are the three regions of the small intestine, what is their order (food passes through it in what order)

- How is food absorbed in the small intestine? How are fats absorbed versus other nutrients. What is the structure of villi, what is the role of blood capillaries and lacteals. What is the role of bile and lipase in fat digestion.

- What type of muscle is found in the wall of the GI tract, how many layers are in the stomach and the in the rest of the GI tract. What is the function of these muscles
Important Concepts

- What are the components of the large intestine and their functions? Know the function of the Ig intestine.
- What is the function of bile
- What do pancreatic secretions contain, and what are their functions.
- What are the digestive enzymes, and chemical secretions (bile and acid) what are their specific functions, and where they are secreted from and where is their site of action.
- Be able to describe in detail how the digestive secretions are controlled, which are controlled by nerves and which by hormone, what are the hormones that control the release of digestive secretions, where are these hormones produced and where is their site of action?
- What is the function of the acid secreted in the stomach
- What is the function of the globlet cells.
- Be able to describe all the disorders of the digestive system, including the causes, effects and treatments

Definitions

- Gastrointestinal (GI) tract, digestion, absorption, mechanical, chemical digestion, lumen, peristalsis, chyme, bolus, sphincters, villi, microvilli, brush border, lacteals, bilirubin, goblet cells, emulsifies/emulsification, micelles, chylomicrons, feces, polyps, diverticula