Outline – Digestive System

I. Functions
II. Layers of the GI tract
III. Major parts: mouth, pharynx, esophagus, stomach, small intestine, large intestine, salivary glands, pancreas, liver, gallbladder
IV. Digestive enzymes
V. Control of digestive secretions

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.
Functions of the Digestive System

- The functions of the digestive system are to:
  1. Bring food into the body.
  2. Digest food into nutrients that are absorbed by the body.
  3. Eliminate wastes from the body.

Terminology

- Digestion: the process of breaking complex molecules into simpler molecules that can be absorbed in the GI tract.

- Absorption: the process of transporting molecules across the wall of the GI tract into blood 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
Digestive System

ORGANS

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

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

Pharynx
- Passage for food (and air)
- Plays a role in swallowing

Esophagus
- Muscular tube
- Moves food from pharynx to stomach

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
- Passage 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
- Saliva moistens food
- Enzyme (amylase) in saliva begins starch digestion

Pancreas
- Gland located behind stomach
- Secretes enzymes that digest all major nutrients
- Secretes buffers that neutralize HCl from stomach
- Releases secretions into small intestine

Liver
- Large organ in abdominal cavity
- Secretes bile, which emulsifies fats
- Plays role in processing and storing certain nutrients

Gallbladder
- Small sac
- Stores bile
- Releases bile into 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**
- Mucus membrane layer that 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.

**Submucosa**
- Layer of connective tissue containing nerves, blood supply, and lymph vessels.
  - Protects from disease.
  - Nerves stimulate muscles.
  - Transport of nutrients.
Wall of the Digestive Tract – Muscularis

- Layers of smooth muscles:
  - One muscle layer is circular.
  - One muscle layer is longitudinal.

- Functions to mix and move food.

Wall of the Digestive Tract – Serosa

- 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
  - Pharynx
  - Esophagus
  - Stomach
  - Small intestine
  - Large intestine
Accessory Organs

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

Parts of the Digestive Tract – Mouth

- **Mouth**: specialized for tasting and moistening food, mechanical and enzymatic digestion, and speech.

- The mouth contains:
  1. **Salivary glands** – moisten food; secrete enzymes that help digest starch.
  2. **Tongue** – mixes chewed food with saliva; forms food bolus for swallowing; important for speech.
  3. **Teeth** – break food into smaller pieces.
  4. **Tonsils** – protect against infections.
  5. **Uvula** – closes off the nasopharynx.

Mouth – Pharynx

- **Pharynx**: common passageway for air, liquids, and food where the nasal and oral cavities join.

- Swallowing reflex begins here.
Esophagus

- **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**.

![Esophagus diagram](image)

**Stomach**

- **Stomach**: breaks up food through muscular contractions.
  - There are three layers of smooth muscle.
- The food that leaves the stomach is only partially digested.
- The functions of the stomach include:
  1. 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 – 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.
Gastric Pits

Figure 15.8c: The holes seen in this electron micrograph are the gastric pits, openings in the stomach wall through which gastric glands release their secretions.

Q: The thick soupy acidic liquid that leaves the stomach is called:
1. chylomicrons
2. bolus
3. chyme
4. feces

Q: How many layers of smooth muscle are in the wall of the stomach?
1. One
2. Two
3. Three
4. Four

Q: What is the muscular tube that passes foodstuffs from the pharynx to the stomach?
1. Trachea
2. Larynx
3. Esophagus
4. Small intestine

Q: The primary function of the stomach is:
1. to break down fats
2. to store food, liquefy, begin digestion
3. to absorb major nutrients
4. package feces
Small Intestine

- **Small intestine**: thin long tube (2.5 cm in diameter and about 6 meters long.)
- Smooth muscles surround the intestine to push the food through the digestive tract.
- The small intestine has three regions:
  1. Duodenum
  2. Jejunum
  3. Ileum

Functions 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 gallbladder.

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 for absorption.

Small Intestine Structure – Villi

- Villi (villus, singular) greatly increase the absorption area of the small intestine.
  - They contain:
    - Blood capillaries: absorb nutrients, including glucose and amino acids.
    - Lacteals: absorb fatty acids.
  - Each villus is covered with microvilli:
    - Increases the surface area.
    - Called the brush border.
Small Intestine – Villi

Microvilli

Large Intestine

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

- Functions:
  1. Absorb water, salts, and vitamins.
  2. Store feces.
  3. Excrete feces.
Main Components of the Large Intestine

- **Colon** – largest portion of the large intestine.
  - Absorbs 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 blood clotting.
  - Undigested food residue that leaves the colon is called **feces**.

- **Rectum** – holds feces temporarily and opens into the anus.

- **Anus** – has sphincter muscles that control 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.

The pancreas produces several digestive enzymes that act in the small intestine.

Small intestine

Pancreatic duct

Gallbladder

Liver

Pancreas (behind stomach)

Common bile duct

Stomach

Pancreas

- Releases hormones into the bloodstream that regulate glucose levels.
- Secretes digestive enzymes into the small intestine.
- Secretes bicarbonate ions into the small intestine to neutralize the acid in the chyme.

Liver

- Blood from capillaries of the intestine, carrying nutrients, goes to the liver through the hepatic portal veins.
- Functions:
  1. Produces bile (helps break down fats).
  2. Processes (metabolizes) nutrients from the GI tract.
- The liver has many enzymes that help the body metabolize.
More Liver Functions

4. Produces plasma proteins.
5. Breaks down old blood cells, producing bilirubin.
7. Stores iron and fat soluble vitamins A, D, E, K, and B\textsubscript{12}.
8. Stores glucose as glycogen.
9. Regulates the quantity of cholesterol in the blood.

Accessory Organs – Gallbladder

- **Gallbladder**: stores excess bile.
Digestive Enzymes

- **Digestive enzymes** – break down macromolecules into smaller molecules.

### Table 15.1 Major Digestive Enzymes

<table>
<thead>
<tr>
<th>Site of Action</th>
<th>Enzyme</th>
<th>Substrate and Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salivary glands</td>
<td>Salivary amylase</td>
<td>Starch into disaccharides</td>
</tr>
<tr>
<td>Stomach</td>
<td>Pepsin</td>
<td>Proteins into polypeptides</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Trypsin</td>
<td>Proteins into polypeptides</td>
</tr>
<tr>
<td></td>
<td>Chymotrypsin</td>
<td>Proteins and polypeptides into smaller fragments</td>
</tr>
<tr>
<td></td>
<td>Amylase</td>
<td>Polysaccharides into disaccharides</td>
</tr>
<tr>
<td></td>
<td>Carbohydrase</td>
<td>Disaccharides into monosaccharides</td>
</tr>
<tr>
<td></td>
<td>Lipase</td>
<td>Triglycerides into fatty acids and glycerol</td>
</tr>
<tr>
<td></td>
<td>Nucleases (deoxyribonuclease and deoxyribonuclease)</td>
<td>DNA into RNA into nucleotides</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Maltase</td>
<td>Disaccharides into glucose units</td>
</tr>
<tr>
<td></td>
<td>Sucrase</td>
<td>Disaccharides into glucose and fructose</td>
</tr>
<tr>
<td></td>
<td>Lactase</td>
<td>Disaccharides into glucose and galactose</td>
</tr>
<tr>
<td></td>
<td>Disaccharase</td>
<td>Disaccharides into monosaccharides</td>
</tr>
<tr>
<td></td>
<td>Amylase</td>
<td>Polysaccharides into disaccharides</td>
</tr>
</tbody>
</table>

Carbohydrate Digestion

(a) Carbohydrate digestion

![Carbohydrate digestion diagram](image)

(b) Protein digestion

![Protein digestion diagram](image)
Control of Digestive Secretions

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

- The stretching of the stomach causes the stomach to release the hormone gastrin.
- Gastrin circulates in the bloodstream and stimulates the stomach to release more gastric secretions.
Control of Digestive 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. Gallbladder to release bile.
  4. Small intestine to release hormones that aid digestion.

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>

Q: The pancreas is responsible for releasing hormones that control blood levels of what?

1. Sodium
2. Glucose
3. Calcium
4. Fat

Q: The largest portion of the large intestine is the:

1. Anus
2. Colon
3. Rectum
Q: Nutrients are primarily absorbed in the:
1. Stomach
2. Small Intestine
3. Large Intestine

Q: Release of digestive secretions is controlled by which of the following:
1. Chewing food
2. Stretching of the stomach
3. Chyme entering the small intestine
4. All of the above!

Important Concepts
- Read Chapter 15
- What is the purpose of the digestive system?
- What is the difference between mechanical and chemical digestion?
- What are the four layers of the GI tract? How would you describe each of the layers and what are the functions of the different layers?
- What is the function of the goblet cells?
- 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, salivary glands, pancreas, liver, and gallbladder).
- What is the function of the acid secreted in the stomach?
- What are the three regions of the small intestine?
Important Concepts

- How is food absorbed in the small intestine?

- What is the structure of villi, and what are the roles of blood capillaries and lacteals?

- What type of muscle is found in the wall of the GI tract?
  - How many layers of muscle are in the stomach and in the rest of the GI tract?
  - What is the function of these muscles?

- What are the main components of the large intestine and their functions?

- What three kinds of substances does the pancreas release, and what are the functions of these substances?

- What are the three primary functions of the liver, and what does bile do?

- For digestive enzymes, you should know:
  - Their overall function.
  - The four primary sites of release.
  - The three primary sites of action.

- How are digestive secretions controlled?
  - Be able to describe the three examples of neural control that we discussed.
Definitions

- Gastrointestinal (GI) tract, digestion, absorption, mechanical digestion, chemical digestion, lumen, peristalsis, chyme, bolus, sphincters, villi, microvilli, brush border, lacteals, goblet cells, emulsification, feces