Digestion, Absorption and Transport

Chapter 3
Digestion

- Breaking down foods into nutrients
  - Prepare for absorption
- Challenges of digestion
  - Tasks of the mouth
  - Diaphragm
  - Steady movement
  - Lubrication of food
  - Digestive enzyme functions
  - Excretion of waste
Anatomy of the Digestive Tract

- Gastrointestinal (GI) tract
  - Flexible and muscular
  - Path
    - Mouth → esophagus → stomach → small intestine → large intestine → rectum → anus
  - Lumen
    - Continuous
The Gastrointestinal Tract
The mouth:
- Digestion begins
- Involves mastication (chewing)
- The stimulation of taste buds (sweet, salty, bitter, sour, savory)
- Aroma, texture, temp

Swallowing
- The epiglottis closes to prevent food from entering the pharynx. After swallowing the food is called a bolus.
The Teeth

- Incisors have chiseled edges that cut
- Canines (cusps) have pointed crowns that tear
- Premolars (bicuspids) and molars have ridged surfaces that crush and grind
- Tongue
The esophagus has 2 sphincters-
- Upper esophageal sphincter
- Lower esophageal sphincter

The stomach:
- adds juices
- grinds the bolus to a semiliquid mass called chyme.

The pyloric sphincter controls the flow of food
Anatomy of the Digestive Tract

- The small intestine: gallbladder and pancreas.
- The three segments:
  - duodenum
  - jejunum
  - ileum.
- Large intestine (colon)
  - Ileocecal valve
  - Withdrawal of water
  - Rectum and anus
The Colon

Opening from small intestine to large intestine

Transverse colon

Ascending colon

End of small intestine

Appendix

Descending colon

Rectum

Sigmoid colon

Anus
The Gastrointestinal Tract

**Ingestion**

- **Mouth**: Chews and mixes food with saliva
- **Pharynx**: Directs food from mouth to esophagus
- **Salivary glands**: Secretes saliva
- **Epiglottis**: Protects airways during swallowing
- **Trachea**: Allows air to pass to and from lungs
- **Esophagus**: Passes food from the mouth to the stomach
- **Esophageal sphincters**: Allow passage from mouth to esophagus and from esophagus to stomach; prevent backflow from stomach to esophagus and from esophagus to mouth
- **Diaphragm**: Separates the abdomen from the thoracic cavity
- **Stomach**: Churns, mixes, and grinds food to a liquid mass; adds acid, enzymes, and fluid
- **Pyloric sphincter**: Allows passage from stomach to small intestine; prevents backflow from small intestine
- **Liver**: Manufactures bile salts; detergent-like substances, to help digest fats
- **Gallbladder**: Stores bile until needed
- **Bile duct**: Conducts bile from the gallbladder to the small intestine

**Appendix**: Houses bacteria and lymph cells

**Small intestine**: Secretes enzymes that digest all energy-yielding nutrients to smaller nutrient particles; cells of wall absorb nutrients into blood and lymph

**Ileocecal valve (sphincter)**: Allows passage from small to large intestine; prevents backflow from large intestine

**Pancreas**: Manufactures enzymes to digest all energy-yielding nutrients and releases bicarbonate to neutralize acid chyme that enters the small intestine

**Pancreatic duct**: Conducts pancreatic juice from the pancreas to the small intestine

**Diaphragm**

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**Large intestine (colon)**: Absorbs water and minerals; passes waste (fiber, bacteria, and unabsorbed nutrients) along with water to the rectum

**Rectum**: Stores waste prior to elimination

**Anus**: Holds rectum closed; opens to allow elimination

**Elimination**
Peristalsis - wavelike muscular contractions of the GI tract that push its contents along.

Segmentation is contractions by circular muscles that contract and squeeze contents to promote mixing with digestive juices.

Sphincter contractions open and close passageways. This prevents reflux and controls the passage of contents.

Stomach action involves circular, longitudinal, and diagonal muscles.
Stomach Muscles

- **Stomach action:** Thickest walls and strongest muscles
- **Chyme is churned and liquefied**
- **Pyloric sphincter controls release of chyme into the duodenum**
Peristalsis & Segmentation

The small intestine has two muscle layers that work together in peristalsis and segmentation.

Circular muscles are inside.

Longitudinal muscles are outside.

PERISTALSIS

The inner circular muscles contract, tightening the tube and pushing the food forward in the intestine.

Chyme

When the circular muscles relax, the outer longitudinal muscles contract, and the intestinal tube is loose.

As the circular and longitudinal muscles tighten and relax, the chyme moves ahead of the constriction.

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Muscular Action of Digestion

- Segmentation

**SEGMENTATION**

Circular muscles contract, creating segments within the intestine.

As each set of circular muscles relaxes and contracts, the chyme is broken up and mixed with digestive juices.

These alternating contractions, occurring 12 to 16 times per minute, continue to mix the chyme and bring the nutrients into contact with the intestinal lining for absorption.

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Sphincter contractions

- Periodically open and close to control the pace of the GI contents
  - Upper esophageal sphincter
  - Lower esophageal sphincter
    - Prevents reflux of stomach contents
  - Pyloric sphincter
  - Ileocecal valve
  - Anus
An Example of a Sphincter Muscle

- **Circular muscle**
- **Longitudinal muscle**
- **Esophagus muscles relax, opening the passageway.**
- **Diaphragm muscles relax, opening the passageway.**
- **Esophagus muscles contract, squeezing on the inside.**
- **Diaphragm muscles contract, squeezing on the outside.**
Secretions of Digestion

- Five organs
  - Salivary glands, stomach, pancreas, liver, small intestine
- Secretions
  - Water
  - Enzymes
    - Protein facilitator of chemical reactions
    - Hydrolysis – the addition of water to break a molecule into smaller pieces
The Salivary Glands

- **Saliva**
  - Salivary glands
  - Secrete saliva which moistens food
  - Contains:
    - water, salts, mucus, enzymes
  - Carbohydrate digestion
  - Protective role
Secretions of Digestion

- Stomach
  - Protein digestion
  - Gastric glands
    - Water, enzymes, hydrochloric acid (HCl)

- Goblet cells of the stomach wall secrete mucus to protect the walls of the stomach from the high acidity
Secretions of Digestion

- Pancreatic juice and intestinal enzymes
  - Released via ducts into duodenum
  - Enzymes act on all three energy nutrients (carbohydrase, lipase, protease)
- Sodium bicarbonate
- Bile
  - Liver produces it
  - Gallbladder stores it
The Gastrointestinal Tract

**INGESTION**

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**ELIMINATION**
### TABLE 3-1 Summary of Digestive Secretions and Their Major Actions

<table>
<thead>
<tr>
<th>Organ or Gland</th>
<th>Target Organ</th>
<th>Secretion</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salivary glands</td>
<td>Mouth</td>
<td>Saliva</td>
<td>Fluid eases swallowing; salivary enzyme breaks down some carbohydrate.*</td>
</tr>
<tr>
<td>Gastric glands</td>
<td>Stomach</td>
<td>Gastric juice</td>
<td>Fluid mixes with bolus; hydrochloric acid uncoils proteins; enzymes break down proteins; mucus protects stomach cells.*</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Small intestine</td>
<td>Pancreatic juice</td>
<td>Bicarbonate neutralizes acidic gastric juices; pancreatic enzymes break down carbohydrates, fats, and proteins.</td>
</tr>
<tr>
<td>Liver</td>
<td>Gallbladder</td>
<td>Bile</td>
<td>Bile is stored until needed.</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>Small intestine</td>
<td>Bile</td>
<td>Bile emulsifies fat so that enzymes can have access to break it down.</td>
</tr>
<tr>
<td>Intestinal glands</td>
<td>Small intestine</td>
<td>Intestinal juice</td>
<td>Intestinal enzymes break down carbohydrate, fat, and protein fragments; mucus protects the intestinal wall.</td>
</tr>
</tbody>
</table>

*Saliva and gastric juice also contain lipases, but most fat breakdown occurs in the small intestine.*
The Final Stage

- Vitamin and mineral absorption
- Undigested residues
  - Fiber
  - Exercise intestinal muscles
  - Retention of water
- Colon
  - Intestinal bacteria
  - Recyclable materials
    - Water and dissolved salts
Colon
- Undigested residues, such as fibers, are not absorbed
- Intestinal flora - bacteria -
  - ferment some fibers, producing gas, water, small fat fragments
  - Prevent infectious bacteria from reproducing
Digestion of a Sandwich

MOUTH: CHEWING AND SWALLOWING, WITH LITTLE DIGESTION

- **Carbohydrate** digestion begins as the salivary enzyme starts to break down the starch from bread and peanut butter.
- **Fiber** covering on the sesame seeds is crushed by the teeth, which exposes the nutrients inside the seeds to the upcoming digestive enzymes.
- **Fat** digestion is minimal. Some hard fats begin to melt as they reach body temperature.
- **Protein** foods are moistened by saliva.

STOMACH: COLLECTING AND CHURNING, WITH SOME DIGESTION

- **Carbohydrate** digestion continues until the mashed sandwich has been mixed with the gastric juices; the stomach acid of the gastric juices inactivates the salivary enzyme, and carbohydrate digestion ceases.
- **Proteins** from the bread, seeds, and peanut butter begin to uncoil when they mix with the gastric acid, making them available to the gastric protease enzymes that begin to digest proteins.
- **Fat** from the peanut butter and seeds forms a separate layer on top of the watery mixture.

SMALL INTESTINE: DIGESTING AND ABSORBING

- **Carbohydrate** digestion picks up when the pancreas sends pancreatic enzymes to the small intestine via the pancreatic duct to break down starch. Enzymes on the surfaces of the small intestinal cells complete the process of breaking down starch into small fragments that can be absorbed through the intestinal cell walls and into the hepatic portal vein. Sugars from the banana require so little digestion that they begin to traverse the intestinal cells immediately on contact.
- **Fat** from the peanut butter and seeds is emulsified with the watery digestive fluids by bile. Now the pancreatic and intestinal lipases can begin to break down the fat to smaller fragments that can be absorbed through the cells of the small intestinal wall and into the lymph.
- **Protein** digestion depends on the pancreatic and intestinal proteases. Small fragments of protein are liberated and absorbed through the cells of the small intestinal wall and into the hepatic portal vein.
- **Vitamins and minerals** are absorbed.

Note: Sugars and starches are members of the carbohydrate family.

LARGE INTESTINE: ABSORBING AND ELIMINATING

- **Fluids and some minerals** are absorbed.
- **Some fibers** from the seeds, whole-wheat bread, peanut butter, and banana are partly digested by the bacteria living in the large intestine, and some of these products are absorbed.
- **Most fibers** pass through the large intestine and are excreted as feces; some fat, cholesterol, and minerals bind to fiber and are also excreted.
Digestion of a Sandwich
Absorption

- Small intestine
  - Majority of absorption
  - Ten feet long
    - Surface area
  - Absorption techniques
    - Simple diffusion
    - Facilitated diffusion
    - Active transport
Anatomy of the Absorptive System

Wall of the small intestine is wrinkled into hundreds of folds

- **Villi** - fingerlike projections on the folds
  - **Microvilli** - traps nutrients and transports them into the cells

- **Crypts** - lie between the villi
  - Secrete intestinal juices

- **Goblet cells**
  - Secrete mucus

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The wall of the small intestine is wrinkled into thousands of folds and is carpeted with villi.

Microvilli

This is a photograph of part of an actual human intestinal cell with microvilli.

Circular muscles Longitudinal muscles

Lymphatic vessel (lacteal)

Capillaries A villus Goblet cells

Crypts Artery Vein Lymphatic vessel

Each villus in turn is covered with even smaller projections, the microvilli. Microvilli on the cells of villi provide the absorptive surfaces that allow the nutrients to pass through to the body.
Absorption

Some nutrients (such as water and small lipids) are absorbed by simple diffusion. They cross into intestinal cells freely.

Some nutrients (such as the water-soluble vitamins) are absorbed by facilitated diffusion. They need a specific carrier to transport them from one side of the cell membrane to the other. (Alternatively, facilitated diffusion may occur when the carrier changes the cell membrane in such a way that the nutrients can pass through.)

Some nutrients (such as glucose and amino acids) must be absorbed actively. These nutrients move against a concentration gradient, which requires energy.

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Villi cells
- Regulate nutrient absorption based on needs

Microvilli
- Enzymes and ‘pumps’

Specialized cells

Food combining
- Enhanced use in the body
Preparing Nutrients for Transport

- Transport pathways
  - Bloodstream
    - Water-soluble nutrients (carbohydrate, protein, vitamins and minerals) and smaller products of fat digestion
    - Liver
  - Lymphatic system
    - Larger fats and fat-soluble vitamins
    - Chylomicrons
    - Bypass liver at first
Vascular System

1. Blood leaves the right side of the heart by way of the pulmonary artery.
2. Blood loses carbon dioxide and picks up oxygen in the lungs and returns to the left side of the heart by way of the pulmonary vein.
3. Blood leaves the left side of the heart by way of the aorta, the main artery that launches blood on its course through the body.
4. Blood may leave the aorta to go to the upper body and head; or
   Blood may leave the aorta to go to the lower body.
5. Blood may go to the digestive tract and then the liver; or
   Blood may go to the pelvis, kidneys, and legs.
6. Blood returns to the right side of the heart.
7. Lymph from most of the body's organs, including the digestive system, enters the bloodstream near the heart.

Legend:
- = Arteries
- = Capillaries
- = Veins
- = Lymph vessels

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Circulatory Systems
The Liver

1. Vessels gather up nutrients and reabsorbed water and salts from all over the digestive tract.

   Not shown here: Parallel to these vessels (veins) are other vessels (arteries) that carry oxygen-rich blood from the heart to the intestines.

2. The vessels merge into the portal vein, which conducts all absorbed materials to the liver.

3. The hepatic artery brings a supply of freshly oxygenated blood (not loaded with nutrients) from the lungs to supply oxygen to the liver's own cells.

4. Capillaries branch all over the liver, making nutrients and oxygen available to all its cells and giving the cells access to blood from the digestive system.

5. The hepatic vein gathers up blood in the liver and returns it to the heart.

In contrast, nutrients absorbed into lymph do not go to the liver first. They go to the heart, which pumps them to all the body's cells. The cells remove the nutrients they need, and the liver then has to deal only with the remnants.
Gastrointestinal Bacteria-flora

- Most are *non-disease-causing bacteria*

- **Probiotics** are bacteria found in the GI tract that can be beneficial to health. An example is the bacteria found in yogurt.
  - Help alleviate diarrhea, constipation, ulcers, IBD

- **Prebiotics** are foods that are used as food energy by intestinal bacteria (some fibers)
Gastrointestinal Hormones and Nerve Pathways

- Endocrine and nervous systems
  - Homeostatic regulation
    - Endocrine System (Hormones) and Nervous System regulate digestion and absorption
    - Stimulate or inhibit of digestive secretions
  - Feedback mechanisms
    - Examples
- GI hormones
  - Gastrin
  - Secretin
  - Cholecystokinin (CCK)
Gastrointestinal Hormones and Nerve Pathways

**ON** Food in the stomach causes the cells of the stomach wall to start releasing gastrin.

Gastrin stimulates stomach glands to release the components of hydrochloric acid.

Stomach pH reaches 1.5 acidity.

**OFF** Acidity in the stomach causes the cells of the stomach wall to stop releasing gastrin.

**NEGATIVE FEEDBACK**
# The Primary actions of Selected GI Hormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Responds to</th>
<th>Secreted from</th>
<th>Stimulates</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrin</td>
<td>Food in the stomach</td>
<td>Stomach wall</td>
<td>Stomach glands</td>
<td>Hydrochloric acid secreted into the stomach</td>
</tr>
<tr>
<td>Secretin</td>
<td>Acidic chyme in the small intestine</td>
<td>Duodenal wall</td>
<td>Pancreas</td>
<td>Bicarbonate-rich juices secreted into the small intestine</td>
</tr>
<tr>
<td>Cholecystokinin</td>
<td>Fat or protein in the small intestine</td>
<td>Intestinal wall</td>
<td>Gallbladder</td>
<td>Bile secreted into the duodenum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pancreas</td>
<td>Bicarbonate- and enzyme-rich juices secreted into the small intestine</td>
</tr>
</tbody>
</table>
How does the pH of the Stomach stay 1.5-1.7?

Food in Stomach \( \rightarrow \) Causes release of Gastrin

\( \text{pH}=1.5 \) \( \leftarrow \) Hydrochloric Acid (HCl)
Feedback Mechanisms of the G.I. Tract

**Pyloric Sphincter Controls Passage of Chyme**

- Sphincter relaxes ➔ Acidic Chyme Slips thru
- Chyme Neutralized ➔ Cells on Intestinal Side
  - Bicarbonate ➔ Sense Acid - Sphincter Closes
Feedback Mechanisms of the G.I. Tract

Release of Bicarbonate from Pancreas Maintains Alkaline pH of Small Intestine

Chyme in Duodenum → Hormone Secretin Released → Goes to the Pancreas

Secretin stops → ph is alkaline → releases bicarbonate
Pancreatic Enzymes

- Tailored to what was eaten
- Enzymes change in proportion to amounts of CHO, Fat, and Protein
How the Gallbladder Controls the Amount of Bile Secreted

Fat in Intestine → Release of Cholecystokinin (CCK) → Via Blood to Gallbladder → Release of Bile

Fat is Emulsified → Stimulates Contraction of gall bladder
CCK and Gastric Inhibitory Peptide (GIP)
- released in response to protein or fat in the small intestine
- slows gastrointestinal motility
- allows for fat and protein digestion
Common Digestive Problems
Digestive Problems

- What part of the GI tract is affected?
- What is the cause?
- What are the symptoms?
- What is the treatment?
Choking

- Food slips into trachea
  - Cuts off breathing
- International sign for choking
  - Heimlich maneuver
- Foods commonly associated with choking
- Prevention of choking
**Swallowing.** The epiglottis closes over the larynx, blocking entrance to the lungs via the trachea. The red arrow shows that food is heading down the esophagus normally.

**Choking.** A choking person cannot speak or gasp because food lodged in the trachea blocks the passage of air. The red arrow points to where the food should have gone to prevent choking.
The universal signal for choking is when a person grabs his throat. It alerts others to the need for assistance. If this happens, stand behind the person, and wrap your arms around him. Place the thumb side of one fist snugly against his body, slightly above the navel and below the rib cage. Grasp your fist with your other hand and give him a sudden strong hug inward and upward. Repeat thrusts as necessary.

If you are choking and need to self-administer first aid, place the thumb side of one fist slightly above your navel and below your rib cage, grasp the fist with your other hand, and then press inward and upward with a quick motion. If this is unsuccessful, quickly press your upper abdomen over any firm surface such as the back of a chair, a countertop, or a railing.
Vomiting and Diarrhea

- Vomiting
  - Adaptive mechanism of the body
  - Medical treatment
    - Dehydration and projectile vomiting
- Diarrhea
  - Symptom of medical conditions & treatments
    - Irritable bowel syndrome (IBS)
    - Colitis
  - Treatment
Constipation

- Not a disease
- Symptoms of constipation
- Causes
  - Lifestyle
  - Side effect of medications
- Prevention
  - Fiber and water
  - Physical activity
Belching and Gas

- **Belching**
  - Swallowed air
  - Prevention
- **Intestinal gas**
  - Consumption of certain foods
    - Individually determined
- **Hiccups**
Heartburn and “Acid Indigestion”

- Gastroesophageal reflux (heartburn)
  - Causes
  - Prevention
- Indigestion
  - Causes
  - Antacids and acid controllers
- Damage to esophagus
  - Barrett’s esophagus
Gastroesophageal Reflux
Ulcers

- Peptic ulcers
  - Gastric ulcers
  - Duodenal ulcers
- Causes
  - Bacterial infection (*Helicobacter pylori*) infection
  - Anti-inflammatory drugs
  - Excessive gastric acid secretion
- Ulcer treatment regimen
Diverticula in the Colon

- Diverticulum (singular)
- Diverticula (plural)
Ulcers
- Peptic ulcer
- *Helicobacter pylori* infection
- Use of certain anti-inflammatory drugs
- Disorders that cause excessive acid secretion
## Strategies to Prevent or Alleviate Common GI Problems

<table>
<thead>
<tr>
<th>GI Problem</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choking</td>
<td>• Take small bites of food.</td>
</tr>
<tr>
<td></td>
<td>• Chew thoroughly before swallowing.</td>
</tr>
<tr>
<td></td>
<td>• Don’t talk or laugh with food in your mouth.</td>
</tr>
<tr>
<td></td>
<td>• Don’t eat when breathing hard.</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>• Avoid strenuous activity.</td>
</tr>
<tr>
<td></td>
<td>• Rest.</td>
</tr>
<tr>
<td></td>
<td>• Drink fluids to replace losses.</td>
</tr>
<tr>
<td></td>
<td>• Call for medical help if diarrhea persists.</td>
</tr>
<tr>
<td>Constipation</td>
<td>• Eat a high-fiber diet.</td>
</tr>
<tr>
<td></td>
<td>• Drink plenty of fluids.</td>
</tr>
<tr>
<td></td>
<td>• Exercise regularly.</td>
</tr>
<tr>
<td></td>
<td>• Respond promptly to the urge to defecate.</td>
</tr>
<tr>
<td>Intestinal gas</td>
<td>• Eat bothersome foods in moderation.</td>
</tr>
<tr>
<td>Belching</td>
<td>• Eat slowly.</td>
</tr>
<tr>
<td></td>
<td>• Chew thoroughly.</td>
</tr>
<tr>
<td></td>
<td>• Relax while eating.</td>
</tr>
<tr>
<td>Heartburn</td>
<td>• Eat small meals.</td>
</tr>
<tr>
<td></td>
<td>• Drink liquids between meals.</td>
</tr>
<tr>
<td></td>
<td>• Sit up while eating; elevate your head when lying down.</td>
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<tr>
<td></td>
<td>• Wait 3 hours after eating before lying down.</td>
</tr>
<tr>
<td></td>
<td>• Wait 2 hours after eating before exercising.</td>
</tr>
<tr>
<td></td>
<td>• Refrain from wearing tight-fitting clothing.</td>
</tr>
<tr>
<td></td>
<td>• Avoid foods, beverages, and medications that aggravate your heartburn.</td>
</tr>
<tr>
<td></td>
<td>• Refrain from smoking cigarettes or using tobacco products.</td>
</tr>
<tr>
<td></td>
<td>• Lose weight if overweight.</td>
</tr>
<tr>
<td>Ulcer</td>
<td>• Take medicine as prescribed by your physician.</td>
</tr>
<tr>
<td></td>
<td>• Avoid coffee and caffeine- and alcohol-containing beverages.</td>
</tr>
<tr>
<td></td>
<td>• Avoid foods that aggravate your ulcer.</td>
</tr>
<tr>
<td></td>
<td>• Minimize aspirin, ibuprofen, and naproxen use.</td>
</tr>
<tr>
<td></td>
<td>• Refrain from smoking cigarettes.</td>
</tr>
</tbody>
</table>