Chapter 16 The Digestive System

Organs of the Digestive System

- Mouth
- Tongue
- Pharynx
- Esophagus
- Liver
- Stomach
- Gallbladder
- Pancreas
- Large intestine
- Small intestine
- Rectum
- Anus

Images:
- A rabbit eating a watermelon slice.
- A boy eating a watermelon slice.
- A girl eating a watermelon slice.
I. Functions

- Ingest, mech/chem digest, absorb, defecation
- **Digestive Tract** (GI-Gastrointestinal tract): mouth to anus

### Digestive Function

<table>
<thead>
<tr>
<th>Area of the digestive tract</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>mouth</td>
<td>mechanical (chewing) and chemical (amylase) breakdown of food</td>
</tr>
<tr>
<td>esophagus</td>
<td>transfers food from mouth to stomach</td>
</tr>
<tr>
<td>stomach</td>
<td>stores food, mechanical breakdown of food, secretes enzymes</td>
</tr>
<tr>
<td>small intestine</td>
<td>digests food into small molecules, absorbs food molecules</td>
</tr>
<tr>
<td>liver</td>
<td>produces bile to emulsify fats in small intestine</td>
</tr>
<tr>
<td>pancreas</td>
<td>produces pancreatic juice to digest carbohydrates, fats, and protein, and to neutralize chyme</td>
</tr>
<tr>
<td>large intestine</td>
<td>absorbs water and salts from chyme, absorbs vitamins made by bacteria</td>
</tr>
</tbody>
</table>
II. Anatomy/Histology

A. **Tissues layers**: serosa (visceral peritoneum); muscularis (long & circular SM); submucosa (parasymp nerv/BV/glands); mucosa (inner)
B. **Mesentary**: serous membranes w/CT filler hold abdominal organs in place; fat accumults

- **Lesser omentum**: above stomach
- **Greater omentum**: below stomach
- **Retroperitoneal organs**: w/out mesentary
C. Oral Cavity: mouth

- **Mastication**: mech digest/chewing => **bolus**
  1. Lip, cheek, hard/soft palate (uvula), tongue, tonsils
    - Manipulate food
    - **Frenulum**: attaches tongue (tongue-tied)
2. Teeth

- 20 deciduous/milk teeth: lose 6-13 yrs
- 32 adult
  - 2 incisors; canine: cutting/tearing
  - 2 premolar (bicuspids), 3 molar: grinding
3. Salivary Glands: chem. digest/lysosome protection

- **Serous**: watery w/salivary amylase: starch (poly) splitting enzyme to maltose/isomaltose (di)
  - Carb digest begins here (5%); cellulose indigestible-cooking helps

- **Parotids**: largest, by ear, (mumps)

- **Submandibular**: side of tongue, ↑ water (squirts)

- **Mucous**: moisten w/mucus: ↑ w/fear: dry mouth

- **Sublingual**: smallest, under tongue
D. Pharynx/Eosophagus

- **Deglutination Phases**: (swallowing)
  1. Voluntary (bolus: mass of food)
  2. Pharyngeal (soft palate/epiglottis seal pharynx)
  3. Esophageal (peristaltic waves)
**Hiatal Hernia**: ↑ diaphragm opening = acid reflux
E. **Stomach**: storage/mixing chamber

1. Food not absorbed/water, salt, drugs, alcohol are stored
2. Cardiac, fundus, body, G/L curvature, pyloric
3. 3 muscle layers & **rugae**: large folds
a. **Surface & neck cells**: mucus to coat
b. **Parietal cells**: HCL (pH 3) & Intrinsic Factor (binds Vit B12 for SI absorption: DNA syn/RBC prod)
c. **Chief cells**: pepsinogen + HCL $\Rightarrow$ **pepsin**: enzyme digests protein to peptide chains w/pH 3
d. **Endocrine cells**: gastrin- reg hormone (bld): ↑ secretns
4. **Chyme**: semi-fluid gastric mix
   - 2 L gastric secretions/day

**Mixing Chyme**

- A thick mixture of food and gastric fluid
- High acidity kills many pathogens
- Mixed and moved by waves of stomach contractions (peristalsis)
5. Cephalic Phase

- Oral/nasal stimulation => medulla oblongata
- ↑ mucus, HCL, pepsinogen, IF, gastrin

Gastric secretion

control is in 3 phases

1. Cephalic phase - entirely dependent on the vagal nerve
accounts for 10%-15% total volume of secretion

acid secretion stimulated by sight, smell, chewing and swallowing

Oral/nasal chemoreceptors → vagal nucleus → Ach + GRP release → acetylcholine + gastrin + histamine = acid secretion
6. Gastric Phase

- Food mixed w/↑ secretions
- Positive feedback:
  - w/Distention => stimulate stretch receptors ↑ secretions
  - w/Peptides = ↑ gastrin = ↑ HCL => ↑ peptides

2. Gastric phase - accounts for at least 50% of gastric secretion

controlled by local reflexes, vagovagal reflexes and hormones

Distension of stomach → local mechanoreceptors → acetylcholine and gastrin release → acid and pepsinogen secretion

Amino acids/peptides → local chemoreceptors → gastrin release → acid and pepsinogen secretion
3. Intestinal phase - about 5% of secretion

Primarily hormonal - denervated stomach will be stimulated to secrete acid by protein in duodenum

Hormone still unknown

Very small number of G-cells in duodenum also release gastrin in response to amino acids

7. Intestinal Phase: chyme in duodenum => hormones & ↓ CNS stimulation

- ↓ pH = ↑ affect:
  - A. Secretin: ↓ gastric secretions

- FA/Lipids:
  - A. Cholecystokinin: ↓ gastric secretions; gallbladder=>bile; pancreas=>enzymes
  - B. Gastric inhibitory polypeptide: ↓ secretions
F. Small Intestine:
- 12 ft; duodenum (12 in), jejunum 2.5m, ileum 3.5m
- 90% of absorption (most in duo & jej. in 3-5 hours)

Approximate daily volumes of fluid (ml) handled by the human gastrointestinal tract.

<table>
<thead>
<tr>
<th>Fluid volume (ml)</th>
<th>Input</th>
<th>Absorption</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet</td>
<td>1500</td>
<td>Small intestine 7500</td>
<td>Stool 200</td>
</tr>
<tr>
<td>Digestive juices</td>
<td>7500</td>
<td>Colon 1300</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in figure 2.2, most of this fluid is absorbed in the small intestine.
- Circular folds w/villi & microvilli ↑ SA
- Villus has BVs & Lacteal (lymph takes in fat)
1. Absorptive cells: digestive enzymes/absorb food
   a) Peptidase: peptides$\rightarrow$AA
   b) Amylase: starch$\rightarrow$disaccharides
   c) Disaccharidases$\rightarrow$glucose
      - Sucrase, maltase, lactase (for lactose=milk sugar)
   d) Lipase: lipids$\rightarrow$FA (lacteals absorb-lymph)

2. Goblet cells: mucus

3. Endocrine cells: regulatory hormones
   a) W/ acidic chyme = ↑ secretin release = ↓ gastric secretions
   b) Also: sodium bicarbonate from pancreas/bile from liver

4. Paneth’s cells: immune (upper SI)

5. Peyer’s Patches: immune (lower SI)
G. Liver

1. Two major lobes
2. Blood sources:
   a) Hepatic arteries nourish
   b) Hepatic portal vein: $O_2$ poor/nutrient rich

- Liver processes nutrients/detoxifies bld (ie: ammonia from AA metabolism to urea to bld to kidneys for elimination)
3. Hepatocytes (liver cells) produce bile
   a) stored in gallbladder
   b) duodenum secretin => release/cholecystokinin contracts gallbladder
   - Fat gobules to smaller droplets
   - W/bilirubin – from RBC breakdown
4. Stores glucose (as glycogen), fat, vitamins, Cu, Fe

5. Kupffer cells breakdown old RBC/WBC

6. Blood protein synthesis (ie: clotting factor, globulins)
H. Pancreas

1. Endocrine (insulin/glucagon: reg bld sugar levels)

2. Exocrine: acini cells produce digestive enzymes to pancreatic duct to duodenum
   a) Sodium bicarbonate: ↑ pH - helps enzyme function but stops pepsin digestion
      - Stimulated by duodenum’s secretin (w/acidic chyme)
   b) Pancreatic amylase/lipase/nucleases (dig enzymes)
      - Stimulated by duodenum’s cholecystokinin (w/presence of FA/AA)
   c) Trypsin/chymotrypsin continue protein breakdown
I. Large Intestine

- Materials pass in 18-24 hours
- Chyme to feces (bacteria help/also vit K); water/salt reabsorbed
- Defecation reflex: stimulated by rectal wall distention
- Anal sphincter (skeletal M): w/inspired air and abdominal muscle contraction => ↑ pressure move contents out anus

1. Cecum (Ileocecal valve): betwn Sm/Lg intestine (appendix)
2. Colon: ascending/transverse/descending to sigmoid colon (S-shaped tube to rectum)
   - Crypts: mucosal glands w/mucus producing goblet cells
3. Rectum
4. Anal canal
   - Internal sphincter (SM) relax w/ parasym NS/external sphincter
J. Peritoneum

1. Serous membranes: parietal lines body wall; visceral (serosa) cover organs

2. Mesenteries: serous membranes with CT between that keep organs in place
   - Lesser omentum: above stomach
   - Greater omentum: below stomach (fat accumulation)

3. Retroperitoneal (organs near body wall w/parietal)
III. Digestion/absorption/transport

- **Mechanical:** smaller particles
- **Chemical:** enzymes break bonds
- **Absorption:** begins in stomach; most in SI

A. Carbohydrates:

1. Starches, cellulose (fiber), sucrose (table sugar), lactose (milk sugar), fructose (fruit sugar)
2. Salivary (mouth) & pancreatic (duodenum) amylase $\Rightarrow$ polysaccharides to disaccharides
3. Disaccharidase to monosaccharides
4. Converted to glucose by liver (some stored as glycogen) rest to bld to cells w/insulin (energy)

- Diabetes affects glucose uptake/most lost in urine
B. Lipids:

1. Include triacylglycerol (triglycerides), phospholipids, steroids, vitamins

2. Triglycerides (most common) have 3 fatty acids w/glycerol
   - Saturated (single bonds) solid at room temp (meat, egg)
   - Unsaturated (double bonds) liquid at room temp (fish)

3. Pancreatic/SI lipase digest after bile salts emulsify to FA and glycerol

4. Lacteal (immune) absorb => chyle (milky lymph)

5. Stored in liver/adipose tissue (reserve energy)
C. Proteins: amino acid chains
   1. Pepsin (stomach) => polypeptide chains
   2. Trypsin (SI) => short peptide chains
   3. Peptidases (SI) => peptide to AA
   4. AA to various cells (↑ w/GH) to build protein

D. Water/minerals
   1. 9 L/day (2 from food/7 from digestive secretions)
   2. 92% absorbed SI/7% absorbed LI
   3. Vitamin D helps absorb Ca
<table>
<thead>
<tr>
<th>AREA</th>
<th>PROCESSES</th>
<th>SECRETIONS</th>
<th>CONTROLS</th>
<th>HISTOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>mechanical digestion</td>
<td>saliva: salivary amylase (ptyalin), serous fluid, mucus, salts, lysozyme,</td>
<td>cephalic</td>
<td>non-keratinized stratified squamous; salivary glands</td>
</tr>
<tr>
<td></td>
<td>chemical digestion: starches-&gt;shorter chains</td>
<td></td>
<td>physical contact (pressoreceptors)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deglutition</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Esophagus</td>
<td>peristalsis begins</td>
<td>mucus</td>
<td>involuntary reflex</td>
<td>non-keratinized stratified squamous esophageal glands</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>skeletal &amp; smooth muscle</td>
</tr>
<tr>
<td>Stomach</td>
<td>storage (up to 4 hrs) mechanical digestion</td>
<td>mucus</td>
<td>cephalic; physical contact (pressoreceptors)</td>
<td>simple columnar epithelium with goblet cells</td>
</tr>
<tr>
<td></td>
<td>some absorption</td>
<td></td>
<td>gastric phase: gastrin</td>
<td>gastric pits</td>
</tr>
<tr>
<td></td>
<td>chemical digestion: polypeptides --&gt; shorter</td>
<td>pepsinogen + H+ =&gt; pepsin pH = 1.5 to 3.5</td>
<td>intestinal phase: gastrin, GIP, enterogastric reflex</td>
<td>mucus neck cells</td>
</tr>
<tr>
<td></td>
<td>chains</td>
<td></td>
<td></td>
<td>enteroendocrine cells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3-layered smooth muscle</td>
</tr>
<tr>
<td>From pancreas:</td>
<td>$CCK$ from the duodenal enteroendocrine cells, stimulates pancreatic secretion, release of bile from gallbladder, secretion of bile by liver, relaxation of the Sphincter of Oddi; inhibits stomach.</td>
<td></td>
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<tr>
<td>Polysaccharides -&gt; shorter chains and maltose</td>
<td>amylase</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Polypeptides -&gt; shorter chains &amp; dipeptides</td>
<td>trypsin, chymotrypsin, carboxypeptidase</td>
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<td></td>
</tr>
<tr>
<td>Dipeptides -&gt; amino acids</td>
<td>lipase</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fats -&gt; glycerol &amp; fatty acids</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From intestine brush border:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipeptides -&gt; amino acids</td>
<td>amino- &amp; carboxypeptidases</td>
</tr>
<tr>
<td>Disaccharides -&gt; monosaccharides</td>
<td>sucrase, maltase, lactase</td>
</tr>
<tr>
<td>From monosaccharides</td>
<td>secretin, cholecystokinin ($CCK$)</td>
</tr>
<tr>
<td>Neutralizes acid</td>
<td>bicarbonate from pancreas $pH = 8$</td>
</tr>
<tr>
<td>Emulsification of fats</td>
<td>bile from gallbladder: $CCK$</td>
</tr>
<tr>
<td>jejunum</td>
<td>absorption of all digestive end products and 95% of water, takes place over 4 to 6 hours</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ileum</td>
<td></td>
</tr>
<tr>
<td>colon</td>
<td>absorption over 12 hrs., mostly water hastral churning mass peristalsis</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>rectum</td>
<td>defecation</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>anus</td>
<td></td>
</tr>
</tbody>
</table>
**Table 24.4 Digestion of the Three Major Food Types**

<table>
<thead>
<tr>
<th>Carbohydrates</th>
<th>Proteins</th>
<th>Lipids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mouth (Salivary Glands)</strong></td>
<td>Salivary amylase → Polysaccharides → Disaccharides</td>
<td>Lingual lipase</td>
</tr>
<tr>
<td><strong>Stomach</strong></td>
<td>Gastric amylase and gelatinase →</td>
<td>Polypeptides</td>
</tr>
<tr>
<td><strong>Duodenum (Pancreas)</strong></td>
<td>Pancreatic amylase → Disaccharides</td>
<td>Trypsin → Chymotrypsin → Carboxypeptidase</td>
</tr>
<tr>
<td><strong>Lining of Small Intestine</strong></td>
<td>Lactase, Sucrase, Maltase, Isomaltase → Monosaccharides</td>
<td>Aminopeptidase, Peptidase → Tripeptides, Dipeptides, Amino acids</td>
</tr>
</tbody>
</table>