Digestive System

**ORAL CAVITY, TEETH, TONGUE**
- Mechanical processing, moistening, mixing with salivary secretions

**LIVER**
- Secretion of bile (important for lipid digestion), storage of nutrients, many other vital functions

**GALLBLADDER**
- Storage and concentration of bile

**ESOPHAGUS**
- Pharyngeal muscles propel materials into the esophagus

**STOMACH**
- Transport of materials to the stomach
- Chemical breakdown of materials via acid and enzymes; mechanical processing through muscular contractions

**SMALL INTESTINE**
- Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions

**LARGE INTESTINE**
- Dehydration and compaction of indigestible materials in preparation for elimination

**SALIVARY GLANDS**
- Secretion of lubricating fluid containing enzymes that break down carbohydrates

**PHARYNX**
- Pharyngeal muscles propel materials into the esophagus

**PANCREAS**
- Exocrine cells secrete buffers and digestive enzymes; endocrine cells secrete hormones

**ACCESSORY DIGESTIVE ORGANS**
- Teeth
- Tongue
- Salivary glands
- Liver
- Gallbladder
- Pancreas

**ALIMENTARY CANAL / GASTROINTESTINAL TRACT (G.I.):**
- Oral cavity
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Rectum
- Anus

Amy Warden Czura, Ph.D.
1. Mucosa (Mucous membrane)
   Functions to secrete mucus, digestive enzymes, and hormones, to absorb end products of digestion, and provide protection from pathogens
   A. Epithelium (continuously renewed, surface cells last only 2-6 days)
      Stratified squamous: oral cavity, pharynx, esophagus, anus
      Simple columnar: stomach, intestine: has goblet cells (mucus) and enteroendocrine cells (hormones)
   B. Lamina propria
      Loose areolar connective tissue with blood vessels, lymphatic vessels, nerves, mucous glands and lymphoid tissue (extending from submucosa): MALT (mucosa associated lymphatic tissue e.g. Peyer’s patches) or tonsils
   C. Muscularis mucosae
      Bands of smooth muscle and elastic fibers: one layer circumferential one longitudinal
      Functions to change shape of plicae and villi
   Villi: finger-like projections of the mucosa layer; increase surface area
   Plicae (small intestine): folds of mucosa and submucosa; increase surface area
   Rugae (stomach): pleats of mucosa and submucosa; expand to accommodate volume
2. Submucosa
   Dense irregular connective tissue, contains large vessels, glands to secrete digestive enzymes and mucus, houses the Submucosal Nerve Plexus (autonomic nervous system control of glands and smooth muscle of mucosa)
3. Muscularis Externa
   Consists of inner circular layer and outer longitudinal layer of smooth muscle for mixing and moving lumenal contents, circular layer thickened to create sphincters at junctions to prevent backflow
   Contains the Myenteric Nerve Plexus to control G.I. mobility via local reflex arcs and ANS stimulation
4. Serosa or Adventitia
   Serosa = visceral peritoneum: areolar connective tissue plus mesothelium, covers all abdominal / peritoneal G.I. tract organs
   Adventitia = dense irregular connective tissue, anchors organs to surrounding tissues, covers oral cavity, pharynx, esophagus, and rectum
Regulation of gastric activity

(a) The Cephalic Phase
Prepares stomach for food
Triggered by seeing, smelling, or thinking of food
Lasts a few minutes
Neural response: parasympathetic ANS triggers increase in all gastric secretions (mucus, enzymes, acid) and triggers G cells to release Gastrin (causes secretion and motility)

(b) The Gastric Phase
Initiates stomach digestive activities
Triggered by food entering stomach (stimuli = distension, peptides, low acidity)
Lasts 3-4 hours (Three responses:)
Neural response: stretch receptors activate ENS reflexes and parasympathetic ANS innervation, both stimulate secretions from parietal cells (acid), Chief cells (pepsin) and G cells (Gastrin)
Hormonal response: triggered by neural response, peptides and increased pH, G cells release Gastrin which trigger secretion by parietal and chief cells and also gastric mobility
Local response: triggered by distortion, Mast cells release histamine which stimulates parietal cells

(c) The Intestinal Phase
Controls chyme entry into duodenum
Triggered by chyme entering duodenum
Lasts many hours
Involves excitatory and inhibitory control of gastric activity depending on chyme composition
Neural response: stretch receptors trigger Enterogastric Reflex which turns off ENS and parasympathetic stimulation of G cells and stimulates sympathetic stimulation of pyloric sphincter (contracts)
Hormonal responses: (different hormones depending on chyme composition):
Lipids, carbohydrates, peptides → Cholecystokinin and Gastric Inhibitory Peptide: inhibit gastric secretion and motility (also stimulates pancreas + gallbladder secretion)
Low pH → Secretin: inhibits gastric secretion (also stimulates pancreas and liver secretion)
Proteins → Intestinal Gastrin: stimulates parietal and chief cells, stimulates gastric mobility

*Sympathetic stimulation shuts down gastric secretion via somatostatin from D cells

*(Sympathetic stimulation shuts down gastric secretion via somatostatin from D cells)
Coordination of Secretion and Absorption in the Small Intestine:

1. Neural Mechanisms
   A. ANS:
      parasympathetic = increase digestive activity
      sympathetic = decrease digestive activity
   B. ENS reflexes:
      coordinate movement of materials from one region to next

2. Hormonal Mechanisms
   Hormones from intestinal glands of duodenum control small intestine, stomach, and accessory organs to coordinate digestive activities
   A. Enterocrinin:
      released when chyme enters duodenum, stimulates mucus production in duodenum
   B. Intestinal Gastrin:
      released when chyme contains protein, stimulates gastric activity
      (“activity” = secretion and motility)
   C. Gastric Inhibitory Peptide:
      released when chyme contains lipids and carbohydrates, inhibits gastric activity
   D. Secretin:
      released when chyme is acidic, stimulates release of bile from liver and buffers from pancreas, and reduces gastric activity
   E. Cholecystokinin:
      released when chyme contains lipids and peptides, stimulates:
      -secretion of enzymes from pancreas,
      -contraction of gallbladder for bile release
      -relaxes hepatopancreatic sphincter to allow entry of bile and enzymes into duodenum
      -inhibits gastric activity
      -reduces hunger sensation (20min post food consumption)
   F. Vasoactive Intestinal Peptide:
      released when chyme enters duodenum, inhibits gastric secretion, stimulates intestinal secretion, dilates local capillaries for absorption
   G. Somatostatin:
      released in response to sympathetic stimulation,
      -inhibits gastric activity
      -inhibits secretion from pancreas and gallbladder
      -inhibits blood flow to intestine thus inhibiting absorption
# Digestion And Absorption

<table>
<thead>
<tr>
<th>Substance</th>
<th>Digestion Method</th>
<th>Absorption Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>Amylases (saliva, pancreas): polysaccharides → di- and trisaccharides Brusher Border Enzymes (small intestine): di- and trisaccharides → monosaccharides</td>
<td>Facilitated diffusion or Cotransport of monosaccharides</td>
</tr>
<tr>
<td>Lipids</td>
<td>Bile salts (liver): emulsification Lipases (tongue, pancreas) triglycerides → monoglycerides and fatty acids</td>
<td>Micelles form: monoglycerides, fatty acids and bile salts Micelles absorbed by intestinal epithelium, proteins added = chylomicron (water soluble) Chylomicrons exocytosed into lumen Chylomicrons absorbed by lacteal</td>
</tr>
<tr>
<td>Proteins</td>
<td>Mastication (mouth) Churning (stomach) Pepsin + Acid (stomach) protein → polypeptide Proteases + Peptidases (pancreas, brush border) polypeptide → amino acids</td>
<td>Facilitated diffusion or Cotransport of amino acids</td>
</tr>
<tr>
<td>Nucleic Acids</td>
<td>Nucleases (pancreas) nucleic acid → nucleotides Brusher Border Enzymes (small intestine) nucleotides → nitrogenous bases + sugar + phosphate ions</td>
<td>Active transport of nitrogenous bases + sugar + phosphate ions</td>
</tr>
<tr>
<td>Water</td>
<td>No digestion required 2L from food, 7L from secretions</td>
<td>Osmosis (95% in small intestine) (~150ml lost in feces)</td>
</tr>
<tr>
<td>Ions</td>
<td>No digestion required Na⁺, Ca²⁺, K⁺, Mg²⁺, Fe³⁺, Cl⁻, I⁻, HCO₃⁻</td>
<td>Diffusion, Cotransport, Active Transport</td>
</tr>
<tr>
<td>Vitamins</td>
<td>No digestion required Fat soluble: A, D, E, K Water soluble: most B vitamins, C Vitamin B12</td>
<td>Mixed with fats in micelle → chylomicrons (fat soluble) Diffusion (water soluble) Bound to intrinsic factor, binds receptors, endocytosed (B12)</td>
</tr>
</tbody>
</table>
Summary of all the hormones involved in digestion:

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Site of Production</th>
<th>Stimulus for Production</th>
<th>Target Organ</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrin</td>
<td>Stomach mucosa</td>
<td>Food (particularly partially digested proteins in stomach (chemical stimulation), acetylcholine released by nerve fibers)</td>
<td>Stomach</td>
<td>Causes gastric glands to increase secretory activity; most pronounced effects on HCl secretion; stimulates gastric emptying</td>
</tr>
<tr>
<td>Serotonin</td>
<td>Stomach mucosa</td>
<td>Food in stomach</td>
<td>Stomach</td>
<td>Causes contraction of stomach muscle</td>
</tr>
<tr>
<td>Histamine</td>
<td>Stomach mucosa</td>
<td>Food in stomach</td>
<td>Stomach</td>
<td>Activates parietal cells to release HCl</td>
</tr>
<tr>
<td>Somatostatin</td>
<td>Stomach mucosa; duodenal mucosa</td>
<td>Food in stomach; stimulation by sympathetic nerves fibers</td>
<td>Stomach</td>
<td>Inhibits gastric secretion of all products, inhibits gastric motility and emptying; inhibits secretion</td>
</tr>
<tr>
<td>Intestinal gastrin</td>
<td>Duodenal mucosa</td>
<td>Acidic and partially digested foods in duodenum</td>
<td>Stomach</td>
<td>Inhibits gastric gland secretion and gastric motility during gastric phase of secretion; increases output of pancreatic juice rich in bicarbonate ions; potentiates CCK's action; increases bile output</td>
</tr>
<tr>
<td>Secretin</td>
<td>Duodenal mucosa</td>
<td>Acidic chyme (also partially digested proteins, fats, hypertonic or hypotonic fluids, or irritants in chyme)</td>
<td>Stomach</td>
<td>Increases output of pancreatic juice rich in bicarbonate ions; potentiates CCK's action</td>
</tr>
<tr>
<td>Cholecystokinin (CCK)</td>
<td>Duodenal mucosa</td>
<td>Fatty chyme, in particular, but also partially digested proteins</td>
<td>Liver</td>
<td>Increases bile output</td>
</tr>
<tr>
<td>Gastric inhibitory peptide (GIP)</td>
<td>Duodenal mucosa</td>
<td>Fatty and/or glucose-containing chyme</td>
<td>Liver/pancreas</td>
<td>Potentiates pancreatin's actions on these organs</td>
</tr>
<tr>
<td>Vasoactive intestinal peptide (VIP)</td>
<td>Duodenal mucosa</td>
<td>Chyme containing partially digested foods</td>
<td>Duodenum</td>
<td>Stimulates buffer secretion; dilates intestinal capillaries</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stomach</td>
<td>Inhibits gastric gland secretion and gastric motility during gastric phase; relaxes to allow entry of bile into duodenum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Small intestine</td>
<td>Inhibits HCl production</td>
</tr>
</tbody>
</table>

*Except for somatostatin, all of these polypeptides also stimulate the growth (particularly of the mucosa) of the organs they affect.

*Also called gastric insulinotropic peptide because it stimulates the release of insulin from the pancreatic islets.

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