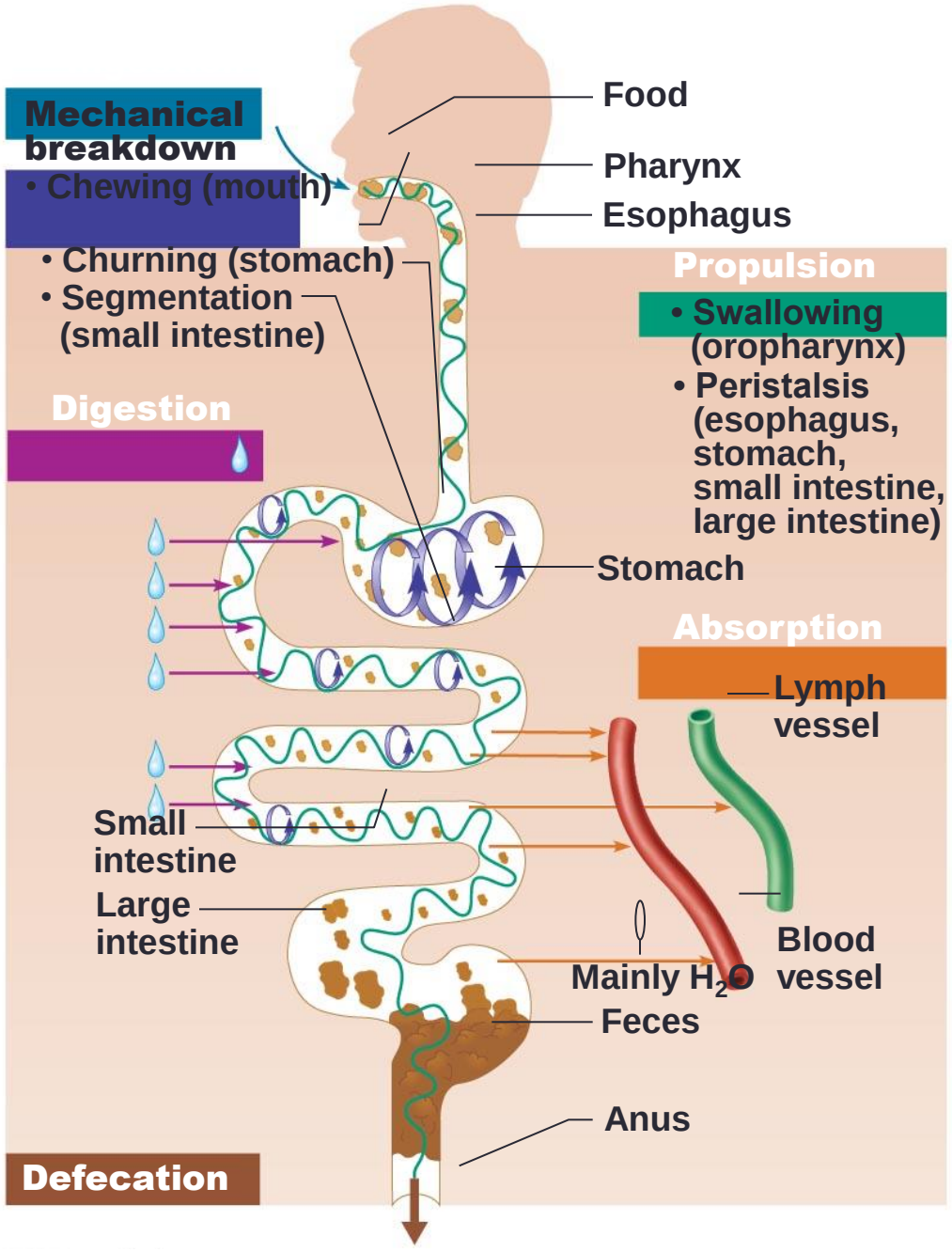
THE DIGESTIVE PROCESS: PART I

Digestive Processes

- Six essential activities
  1. Ingestion
  2. Propulsion
  3. Mechanical breakdown
  4. Digestion
  5. Absorption
  6. Defecation


Mechanical breakdown
• Chewing (mouth)
• Churning (stomach)
• Segmentation (small intestine)
Digestion
Food
Pharynx
Esophagus
Propulsion
• Swallowing (oropharynx)
• Peristalsis (esophagus, stomach, small intestine, large intestine)
Stomach
Absorption
Lymph vessel
Small intestine
Large intestine
Blood vessel
Mainly H_2O
Feces
Anus
Defecation

The Chewing Process

- The pace of the chewing will set the rhythm for the rest of the digestive process
- Chewing at the proper rate gives the stomach time to tell the brain that food has arrived.
- More importantly saliva contains leptin (decreases appetite) and grehlin (increases appetite) which signals the brain to help make the decisions to stop eating.
- Saliva is also a source of enzymes for carbohydrates (salivary amylase) and has an alkaline ph
- Saliva also contains strains of good bacteria, antibodies and anti-microbial compounds

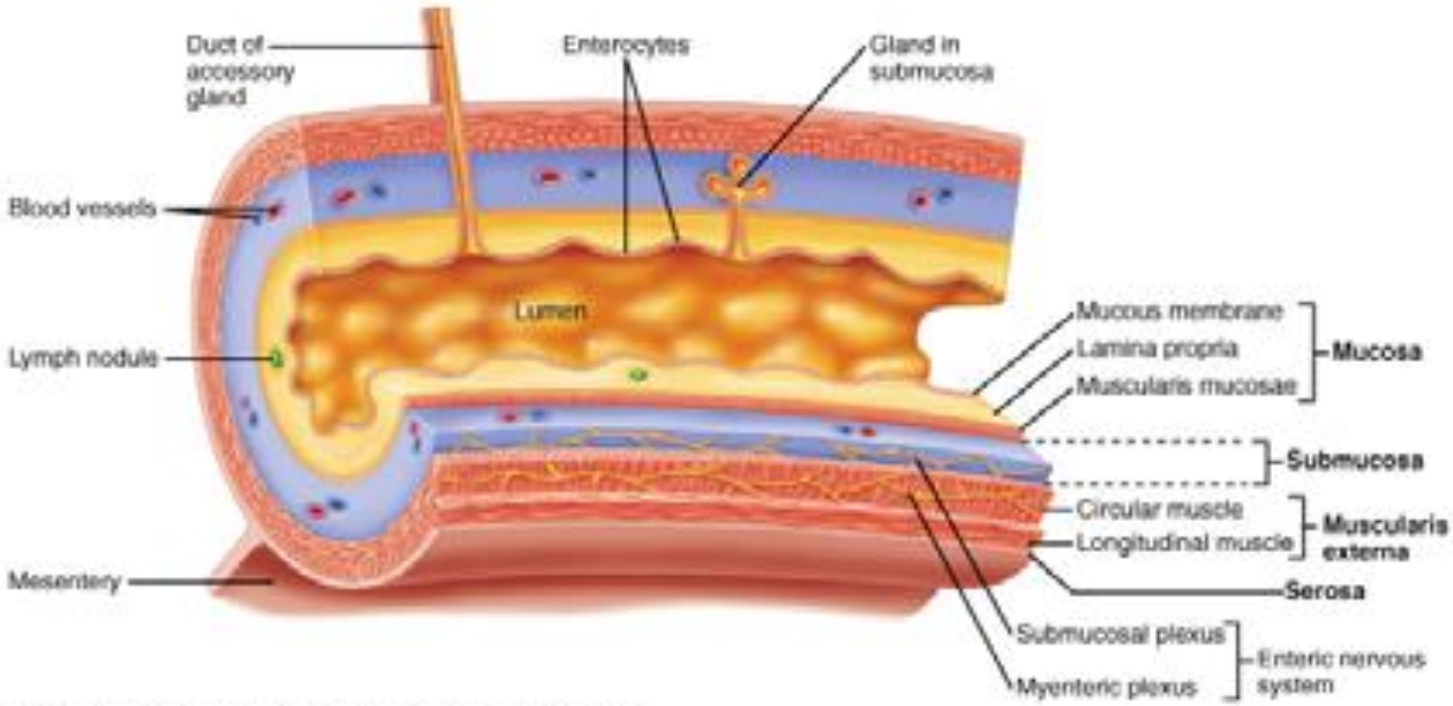
Chewing

- According to a study at Harbin Medical University in China, people who chewed each bite 40 times (as compared to 15 times) ate 12 % less food and blood tests showed lowered ghrelin levels
- A study of 1000 Subway consumers showed they chewed on average each bite 6 times
- Chewing 20- 30 times on average is good – it depends on the food and how dense it is
- Chew until it is liquid

Benefits of Chewing

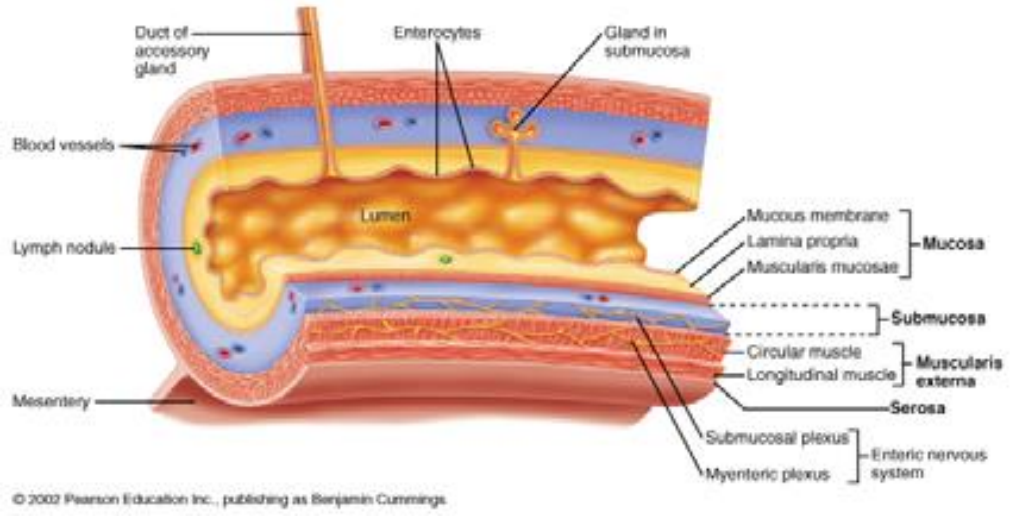
- Aids digestion
- Increases the availability and absorption of nutrients
- Decreases risk of diarrhea, constipation, stomach discomfort and nausea
- Reduces bloating and gas
- May aid weight loss

Structure of the GIT



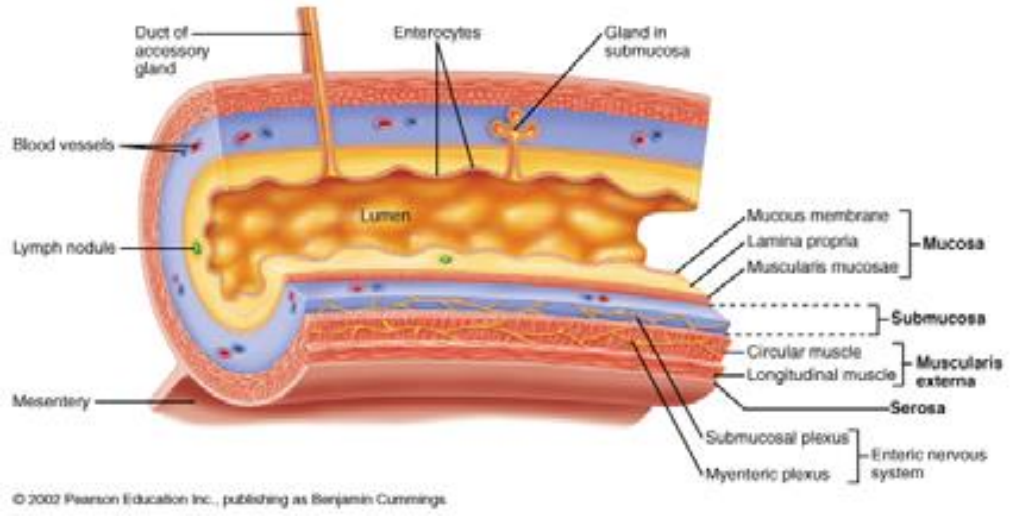
- Mucosa
  - Consists of an epithelium, the lamina propia (mucous membrane), and muscularis mucosae (thin layer of muscle outside the lamina)
  - Epithelial cells are specialized for secretion or absorption
  - Contraction of the muscularis mucosae causes a change in surface area for secretion or absorption

Structure of the GIT



- Submucosa
  - Consists largely of loose connective tissue with collagen and elastin fibers
  - Glands may be present in some regions

Structure of the GIT



- Muscularis externa
  - Inner circular , outer longitudinal
  - Contraction of the circular muscle causes a decrease in diameter of the lumen of the GIT
  - Contraction of the longitudinal muscle causes shortening of a segment of the GIT

Definition of Innervation:

- 1. To supply (an organ or a body part) with nerves.

- 2. To stimulate (a nerve, muscle, or body part) to action

Chemoreceptors: a sensory receptors in a biological cell membrane to which an external molecule binds to generate a smell or taste sensation

Mechanoreceptors: Pressure-sensitive sensory receptors, responding to touch or sound or shifts in the body's balance

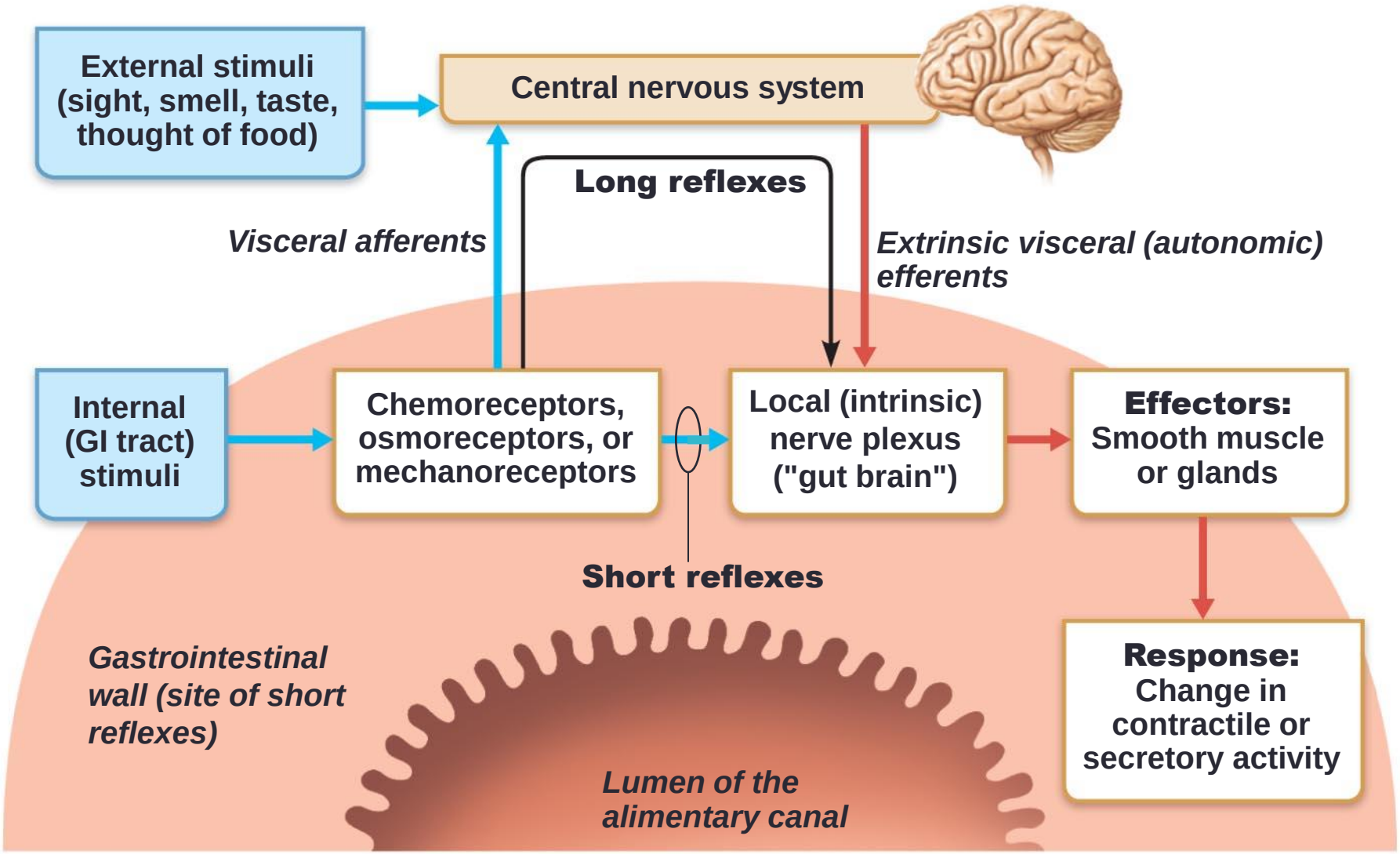
GI Tract Regulatory Mechanisms

The structure of the GIT varies greatly from region to region, but common features exists in the overall organization of the tissues

1. Mechanoreceptors and chemoreceptors
   - Respond to stretch, changes in osmolarity (concentration of a solution) and pH, and presence of the product to be digested and end products of digestion
   - Initiate reflexes that
     - Activate or inhibit digestive glands
     - Stimulate smooth muscle to mix and move lumen contents

GI Tract Regulatory Mechanisms

2. Intrinsic (stimulated within the organ) and extrinsic (external to the organ) controls
   - **Short reflexes -** enteric nerve plexuses (gut brain) respond to stimuli in GI tract
   - **Long reflexes** respond to stimuli inside or outside GI tract; involve CNS centers and autonomic nerves
   - Hormones from cells in stomach and small intestine stimulate target cells in same or different organs to secrete or contract


External stimuli (sight, smell, taste, thought of food)
Central nervous system
Long reflexes
Visceral afferents
Extrinsic visceral (autonomic) efferents
Internal (GI tract) stimuli
Chemoreceptors, osmoreceptors, or mechanoreceptors
Local (intrinsic) nerve plexus ("gut brain")
Effectors: Smooth muscle or glands
Short reflexes
Gastrointestinal wall (site of short reflexes)
Response: Change in contractile or secretory activity
Lumen of the alimentary canal

Gastric Gland Secretions

- Glands in fundus (the upper part of the stomach) and the body produce most gastric juice
- Parietal cell secretions
  - *Hydrochloric acid* (HCl)
    - $\rightarrow$ pH 1.5–3.5 denatures protein, activates pepsin, breaks down plant cell walls, kills many bacteria
  - *Intrinsic factor*
    - Glycoprotein required for absorption of vitamin B_{12} in small intestine

Gastric Gland Secretions

- Chief cell secretions
  - *Pepsinogen* - inactive enzyme
    - Activated to pepsin by HCl and by pepsin itself (a positive feedback mechanism)
  - *Lactobascillus present in the stomach to control gastric acid production*
  - *Acid Lipases (unlike lipase from the pancreas) does not need bile and works in the stomach*
    - Digest ~15% of fat

Gastric Gland Secretions

- Enteroendocrine cells (specialized endocrine cells of the pancreas and the GI tract)
  - Secrete chemical messengers into lamina propria (muccus membranes)
    - Act as paracrines (hormones that has effect only in the vicinity of the gland secreting it)
      - Serotonin - increases mucous and inhibits gastric acid
      - Histamine – stimulates gastric acid, increase mucous and regulates muscle contractions

Gastric Gland Secretions

- Hormones
  - Somatostatin (also acts as paracrine) is produced in the pancreas and inhibits the production of insulin and glucagon
  - Gastrin stimulates the secretion of HCl and is released by G cells (a cell that release gastrin) in the pyloric antrum of the stomach, duodenum, and the pancreas.

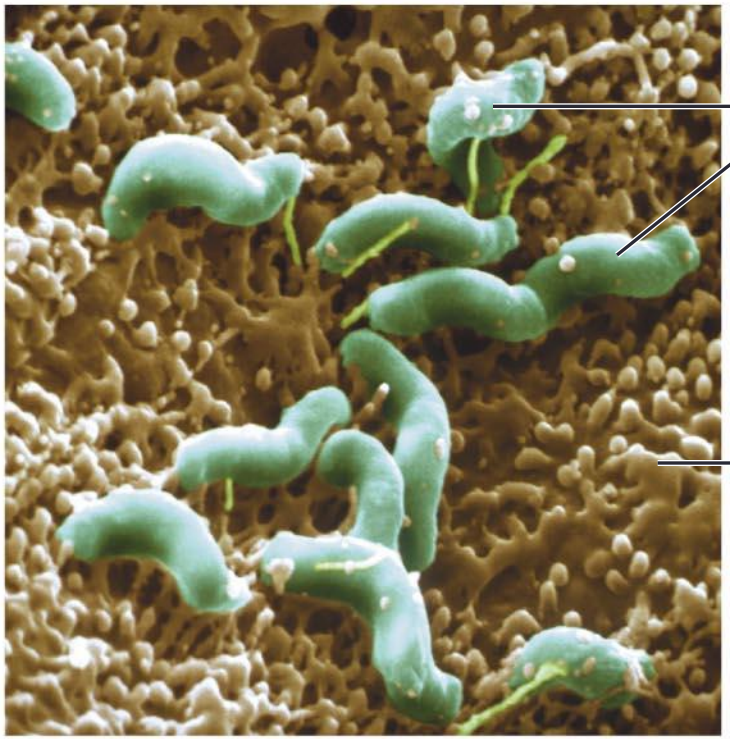
Mucosal Barrier

- Strong acid digestive conditions in stomach
- The **mucosal barrier** protects lining
  - Thick layer of bicarbonate-rich mucous
  - Tight junctions between epithelial cells
    - Prevent juice seeping underneath tissue
  - Damaged epithelial cells quickly replaced by division of stem cells
    - Surface cells replaced every 3–6 days

Homeostatic Acid Imbalance

- *Gastritis*
  - Inflammation caused by anything that breaches mucosal barrier
- Peptic or gastric ulcers
  - Erosions of stomach wall
    - Can perforate → peritonitis; hemorrhage
  - Caused by *Helicobacter pylori* bacteria
  - Some by NSAIDs, aspirin, ibuprofen
  - Stress

(a) A gastric ulcer lesion



(b) *H. pylori* bacteria

Regulation of Gastric Secretion

- Neural and hormonal mechanisms
- Gastric mucosa → up to 3 L gastric juice/day
- Vagus nerve stimulation → secretion ↑
- Sympathetic stimulation → secretion ↓
- Hormonal control largely gastrin
  - → ↑Enzyme and HCl secretion
  - Most small intestine secretions - gastrin antagonists

Regulation of Gastric Secretion

- Three phases of gastric secretion
  - **Cephalic** (**reflex**) **phase** – conditioned reflex triggered by aroma, taste, sight, thought
  - **Gastric phase** – lasts 3–4 hours; ⅔ gastric juice released
    - Stimulated by distension, protein foods, low acidity, gastrin (major stimulus)
    - Enteroendocrine G cells stimulated by caffeine, protein food increases gastrin to produce more acid

Stimuli of Gastric Phase

- Gastrin → enzyme and HCl release
  - Low pH inhibits gastrin secretion (as between meals)
- Buffering action of ingested proteins → rising pH → gastrin secretion
- Three chemicals – Ach (acetylcholine secrete by both long and short reflexes of the parasympathetic nerve fibers), histamine, and gastrin - stimulate parietal cells
  - All three are necessary for maximum HCl secretion

Enterogastric Reflex

- Three reflexes act to
  - Inhibit signals from the vagas nerve
  - Inhibit local reflexes
  - Activate sympathetic fibers → tightening of pyloric sphincter → no more food entry to small intestine
- → Decreased gastric activity → protects small intestine from excessive acidity

Intestinal Phase

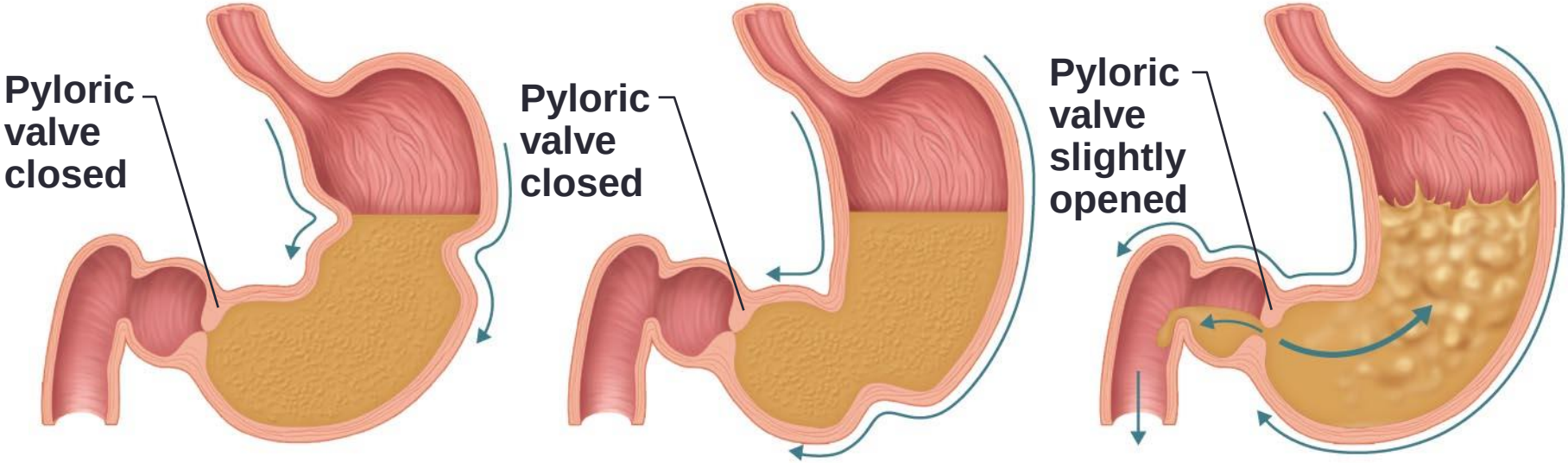
- **Enterogastrones** (hormones secreted by the mucosa of the duodenum) are released
  - **Secretin, cholecystokinin (CCK), vasoactive intestinal peptide (VIP)**
    - All inhibit gastric secretion
- If small intestine pushed to accept more chyme → *dumping syndrome*
  - Nausea and vomiting
  - Common in people who have gastric by-pass

Response of the Stomach to Filling

- Stretches to accommodate incoming food
  - Pressure constant until 1.5 L food ingested
    - Reflex-mediated **receptive relaxation**
      - Coordinated by swallowing center of brain stem
  - **Gastric accommodation**
    - Plasticity (stress-relaxation response) of smooth muscle of the stomach

Gastric Contractile Activity

- Peristaltic waves move toward pylorus at rate of 3 per minute
  - Basic electrical rhythm (BER) set by enteric pacemaker cells (formerly interstitial cells of Cajal)
  - Pacemaker cells linked by gap junctions help muscles contracts smoothly
- Distension and gastrin increase force of contraction



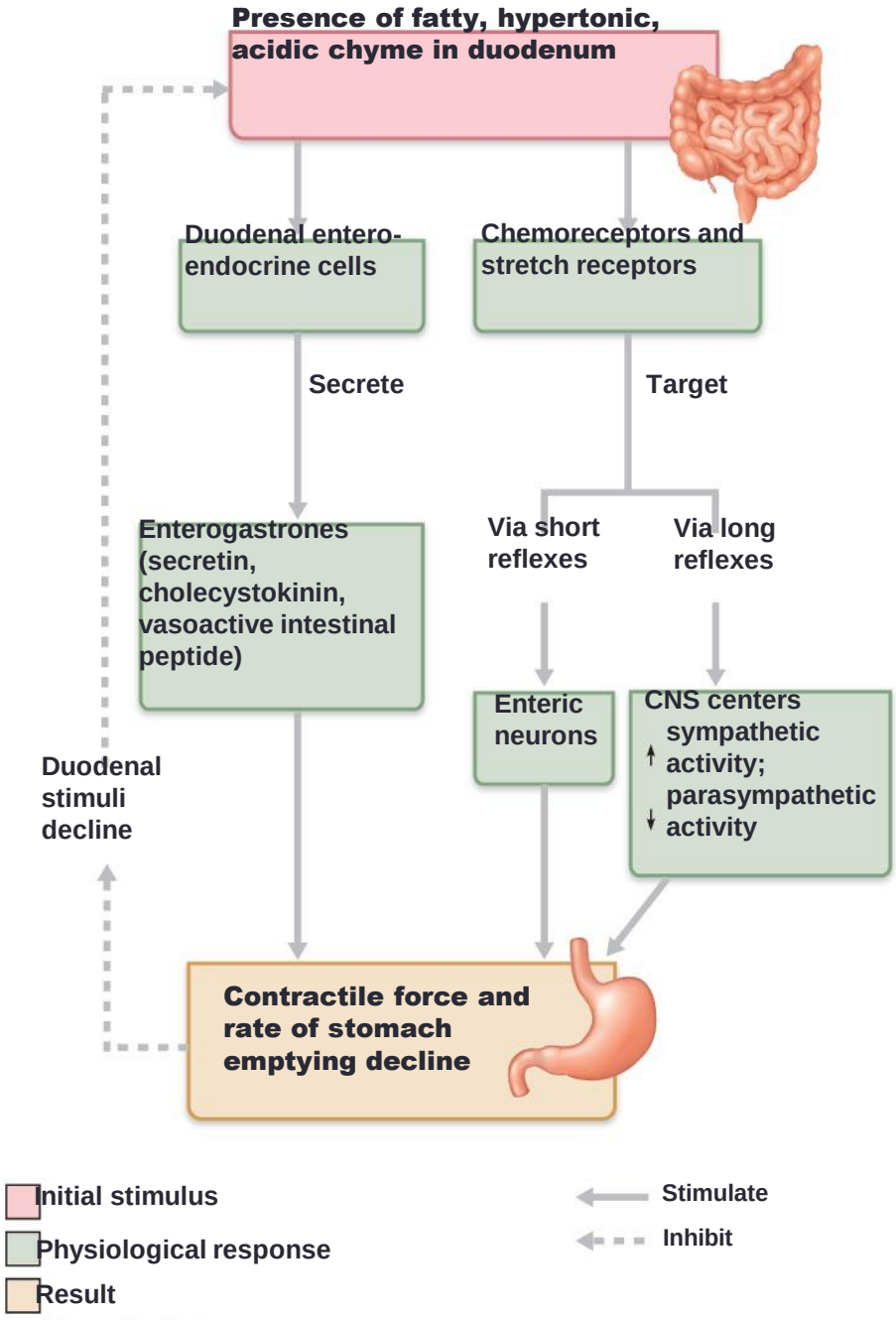
① **Propulsion:** Peristaltic waves move from the fundus toward the pylorus.

② **Grinding:** The most vigorous peristalsis and mixing action occur close to the pylorus.

③ **Retropulsion:** The pyloric end of the stomach acts as a pump that delivers small amounts of chyme into the duodenum, simultaneously forcing most of its contained material backward into the stomach.

Regulation of Gastric Emptying

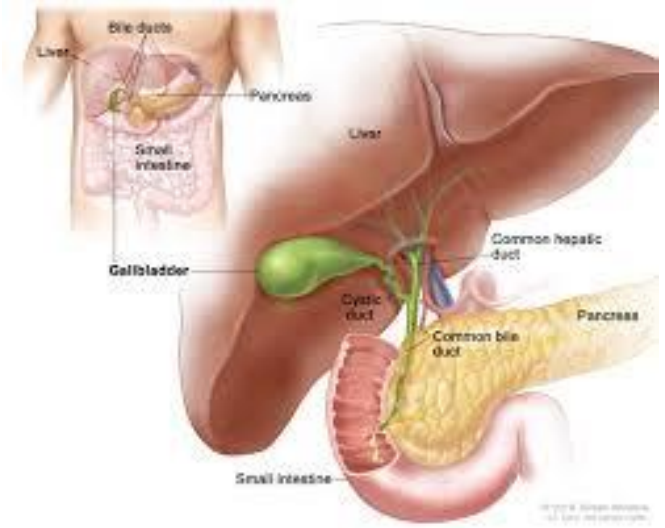
- As chyme enters the duodenum
  - Receptors respond to stretch and chemical signals
  - Enterogastric reflex and enterogastrones inhibit gastric secretion and the filling of the duodenum
- Carbohydrate-rich chyme moves quickly through duodenum
- Fatty chyme remains in the stomach and duodenum 6 hours or more


Presence of fatty, hypertonic, acidic chyme in duodenum
Duodenal entero-endocrine cells
Chemoreceptors and stretch receptors
Secrete
Target
Enterogastrones (secretin, cholecystokinin, vasoactive intestinal peptide)
Via short reflexes
Via long reflexes
Enteric neurons
CNS centers sympathetic activity; parasympathetic activity
Duodenal stimuli decline
Contractile force and rate of stomach emptying decline
Initial stimulus
Physiological response
Result
Stimulate
Inhibit

Regulation of Bile Secretion

- Bile secretion stimulated by
  - Bile salts in enterohepatic circulation (the path of circulation between the liver, gallbladder and intestines)
  - *Secretin* from intestinal cells that has been exposed to HCl and fatty chyme
- Hepatopancreatic sphincter closed unless digestion active → bile stored in gallbladder
  - Released to small intestine

  ~ only with contraction



Regulation of Bile Secretion

- Gallbladder contraction stimulated by
  - *Cholecystokinin* (CCK) from intestinal cells exposed to acidic, fatty chyme
  - Vagus nerve stimulation
- CCK also causes
  - Secretion of pancreatic juice
  - Hepatopancreatic sphincter to relax

Regulation of Pancreatic Secretion

- CCK also induces secretion of enzyme-rich pancreatic juice
- Secretin causes secretion of bicarbonate-rich pancreatic juice by duct cells
- Vagus nerve stimulation also causes release of pancreatic juice

- End of Part I