Chapter 15

Gastrointestinal System

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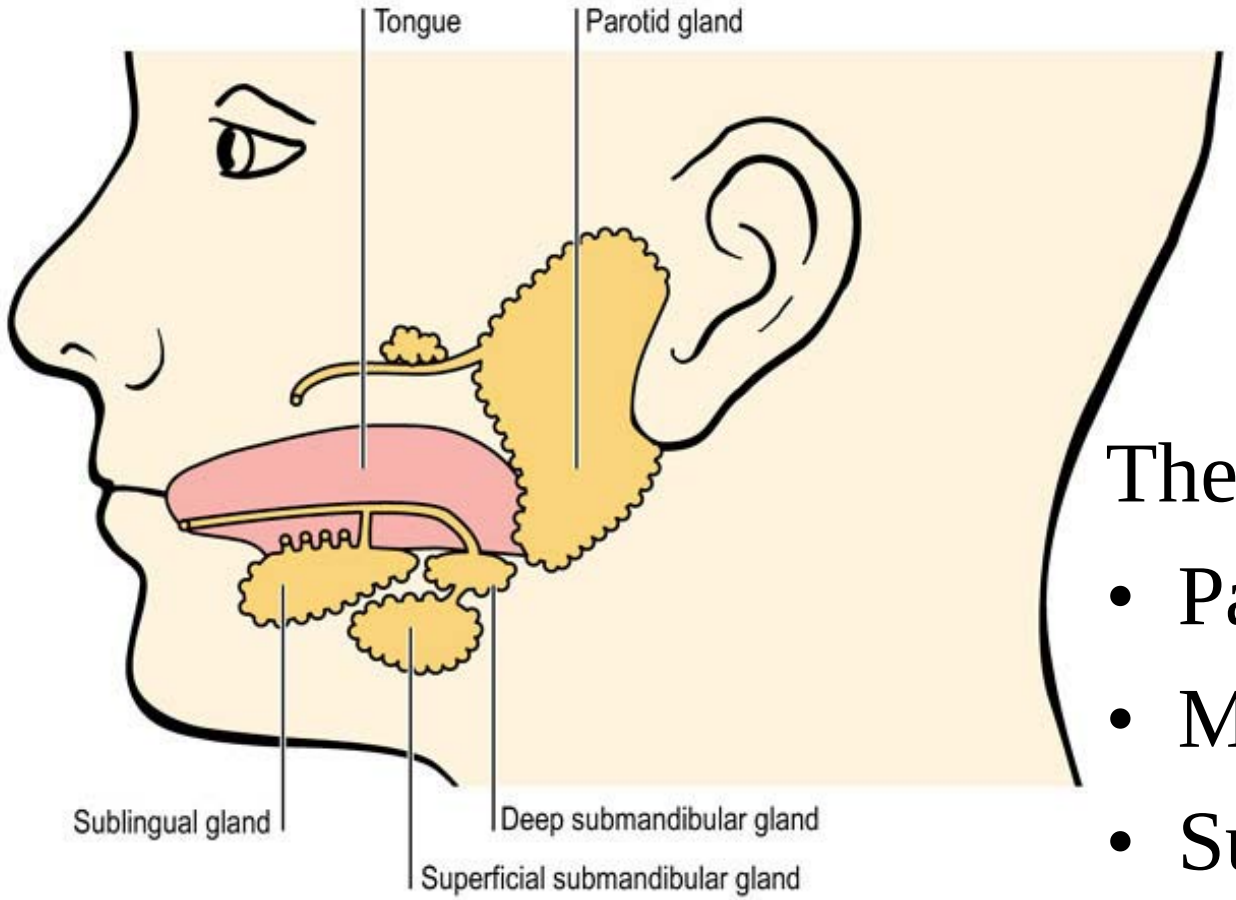
Mouth, Pharynx, and Esophagus

Mastication, or chewing, is the first step in the breakdown of complex foodstuffs and serves several functions as follows:

- breaking large pieces into small pieces, resulting in a massive increase in surface area, which is where digestive enzymes work
- softening of food and transformation into a size conducive to swallowing
- lubrication of food by impregnating it with saliva

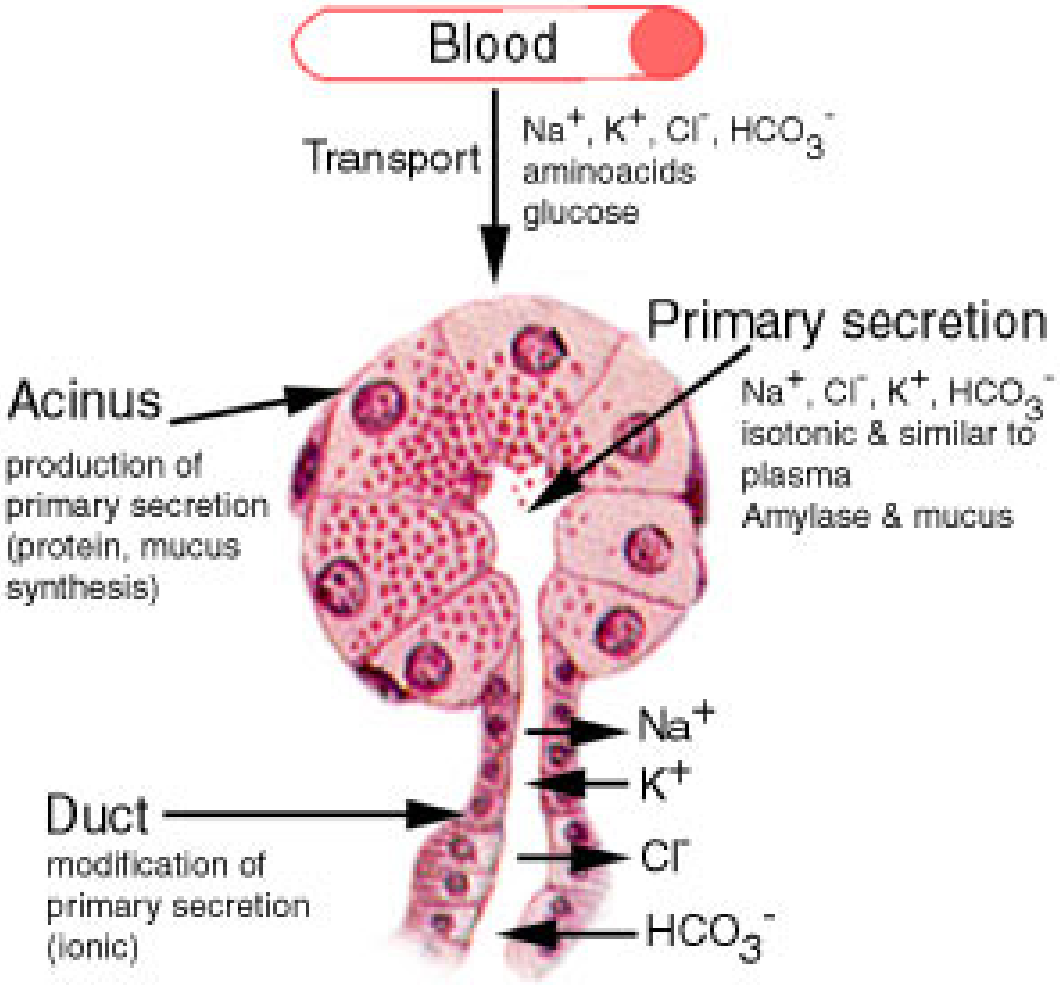
Secretion of saliva



The Salivary Glands

- Parotid gland
- Mandibular gland
- Sublingual gland

Saliva



1000 ml/d

pH 6.0~7.0

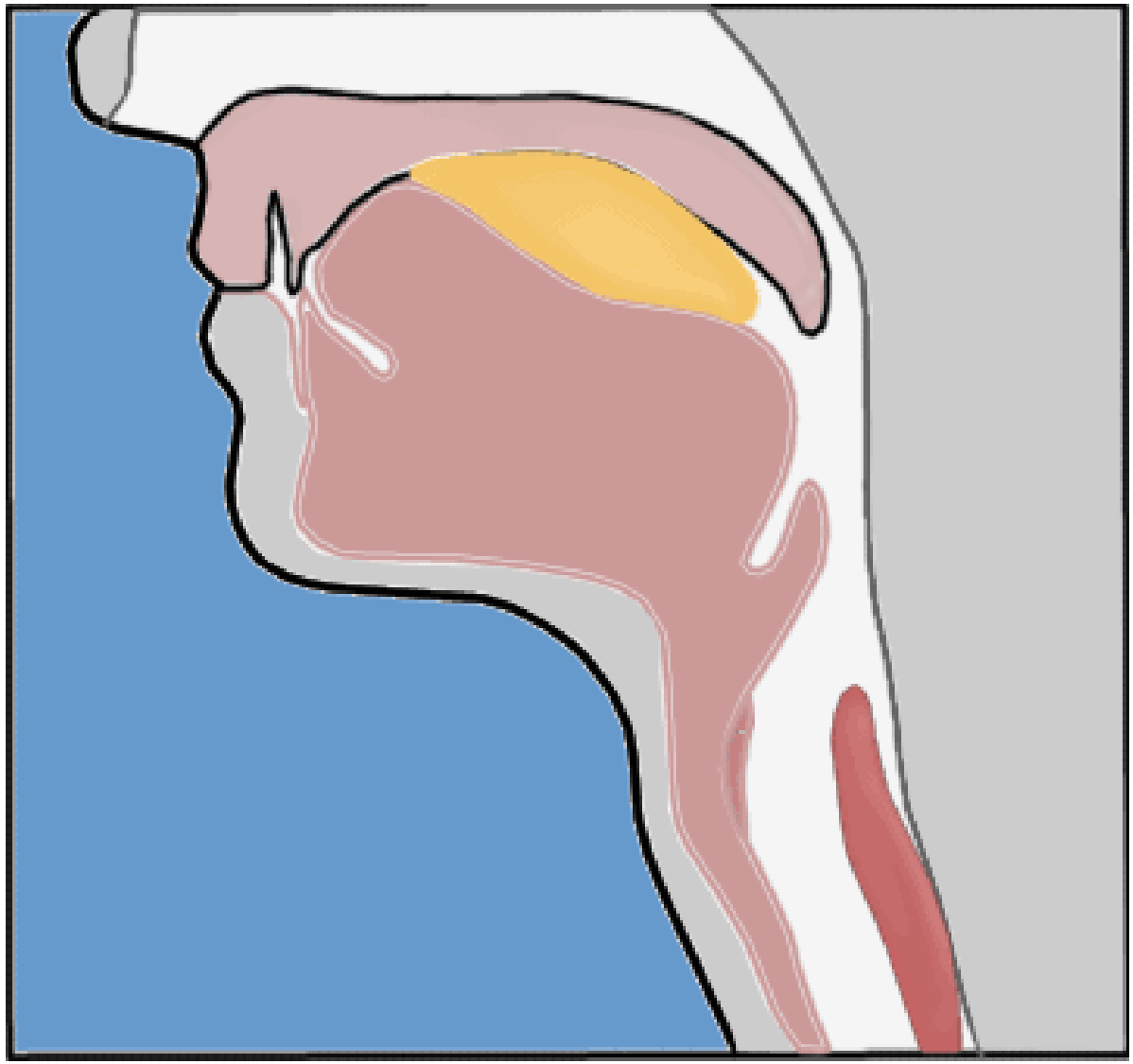
Composition of saliva

- H_2O
- Na^+, Cl^-, K^+, HCO_3^-
- Mucus (containing mucin)
- Amylase, lysozyme, …

Physiological functions of saliva

- Lubrication: mucus
- Solubilizes dry food
- Oral hygiene: lysozyme
- Initiates starch digestion: amylase

Swallowing



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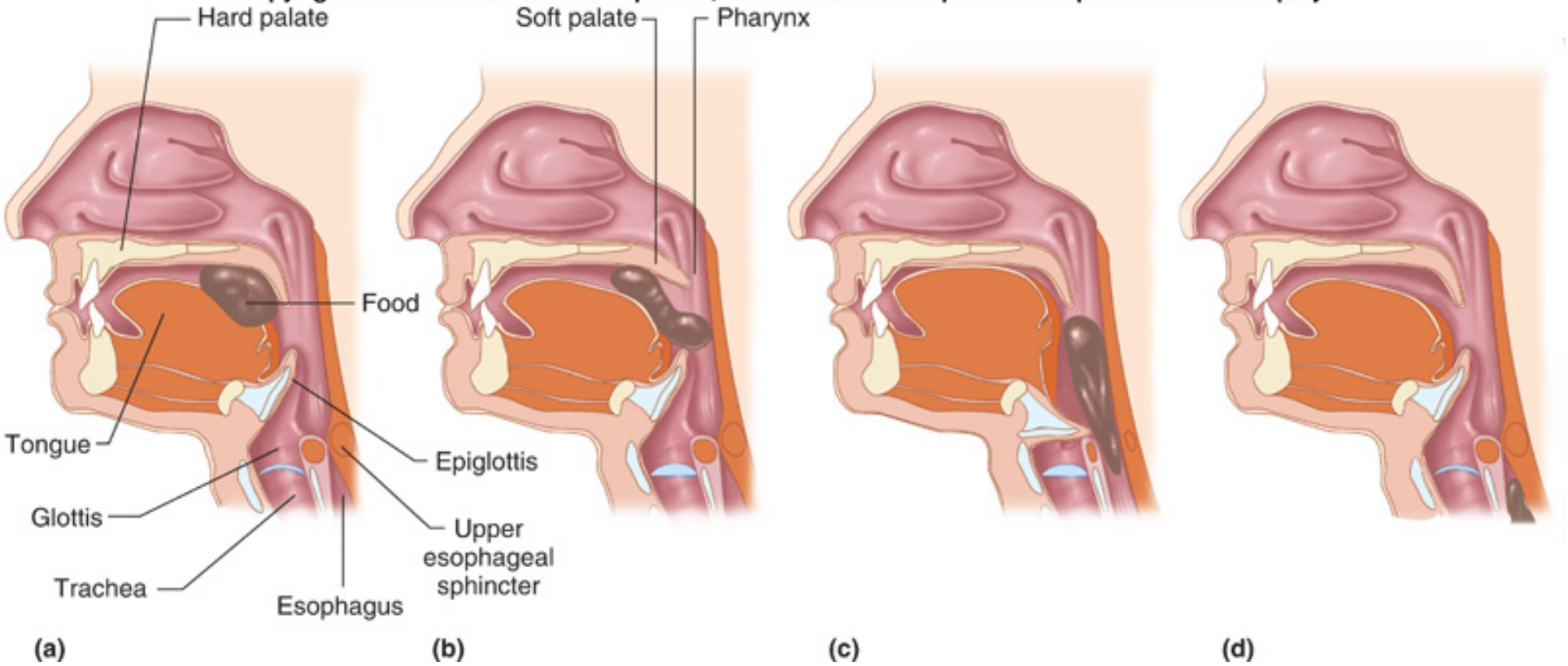

The swallowing reflex is coordinated by the medulla oblongata, which stimulates the appropriate sequence of contraction and relaxation in the participating skeletal muscle, sphincters, and smooth muscle groups.

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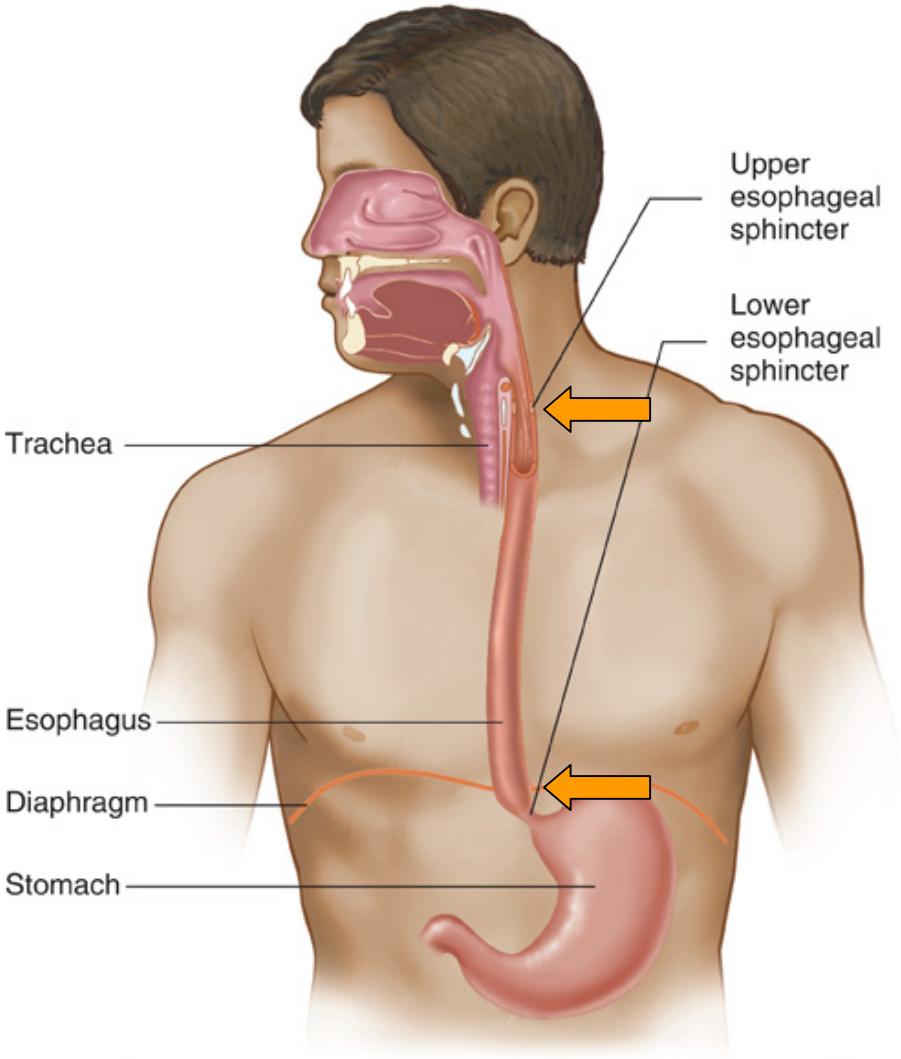
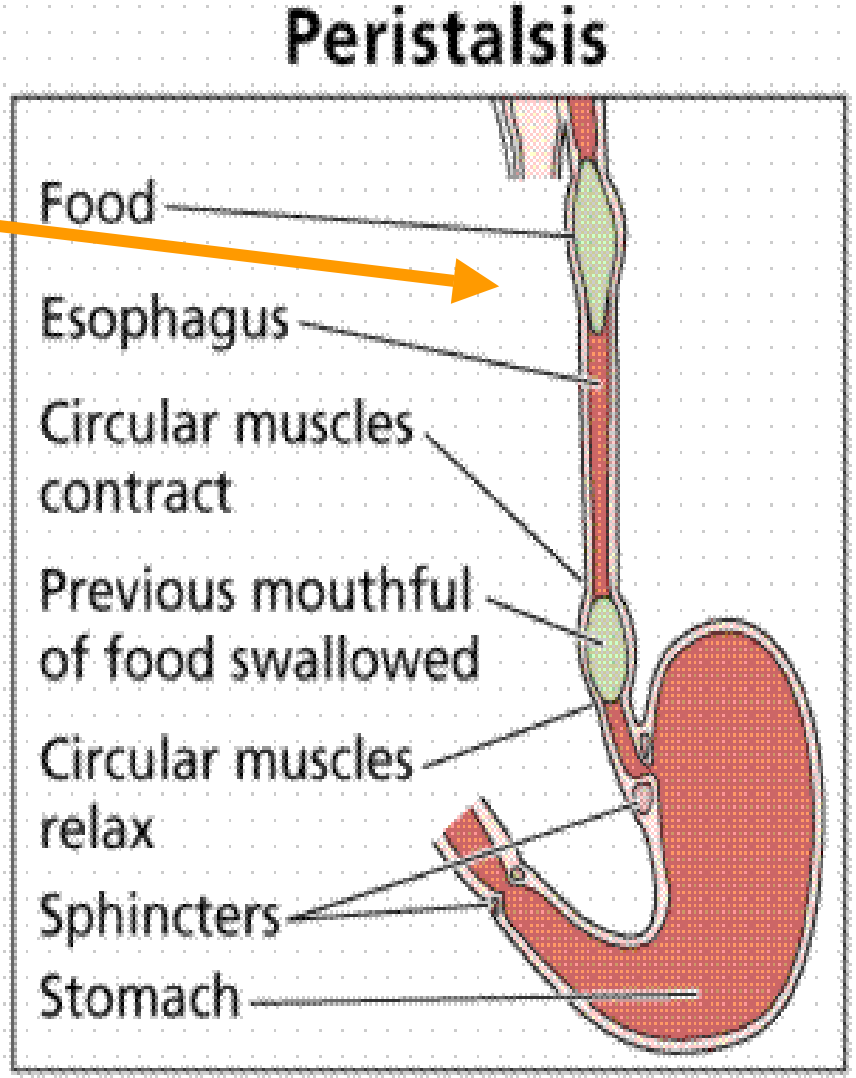


The coordinated sequence of contraction and relaxation in the upper esophageal sphincter, the esophagus, and the lower esophageal sphincter is necessary to deliver swallowed food to the stomach.

Peristaltic waves

Progressive wave of
muscle contraction

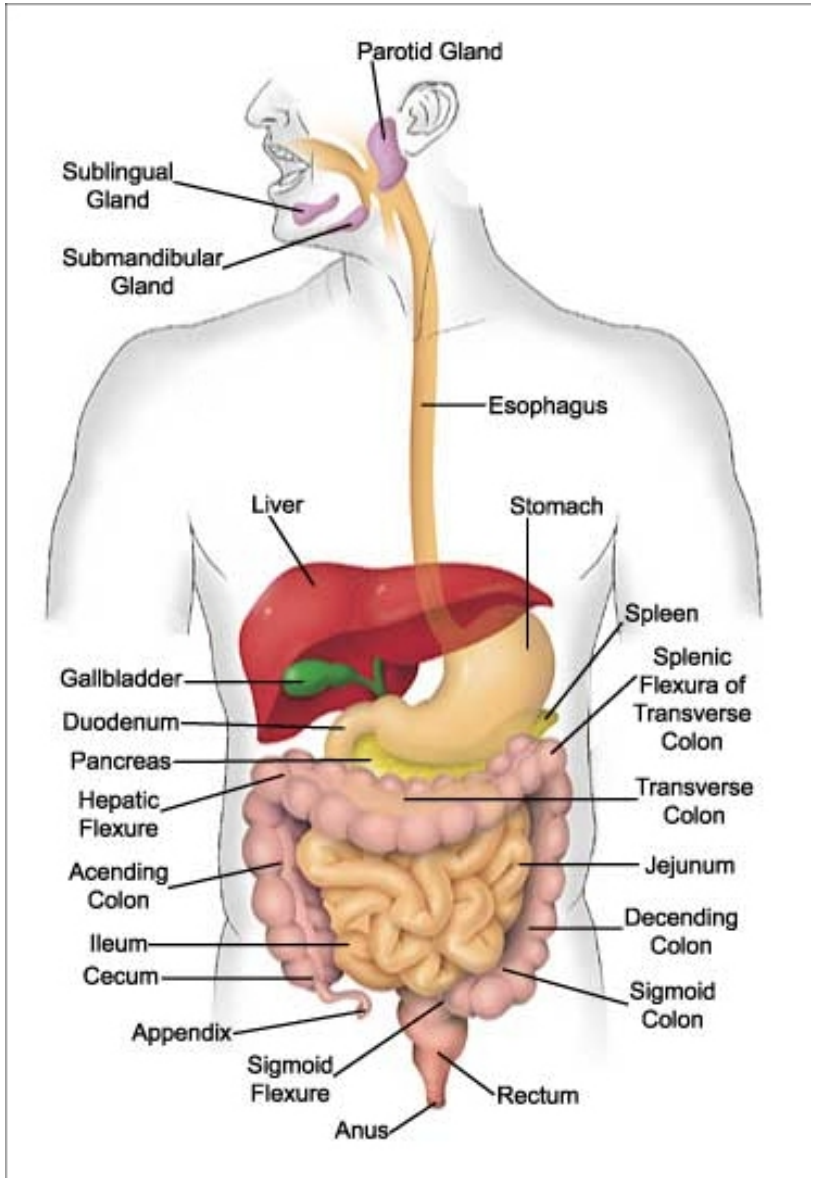


Heartburn

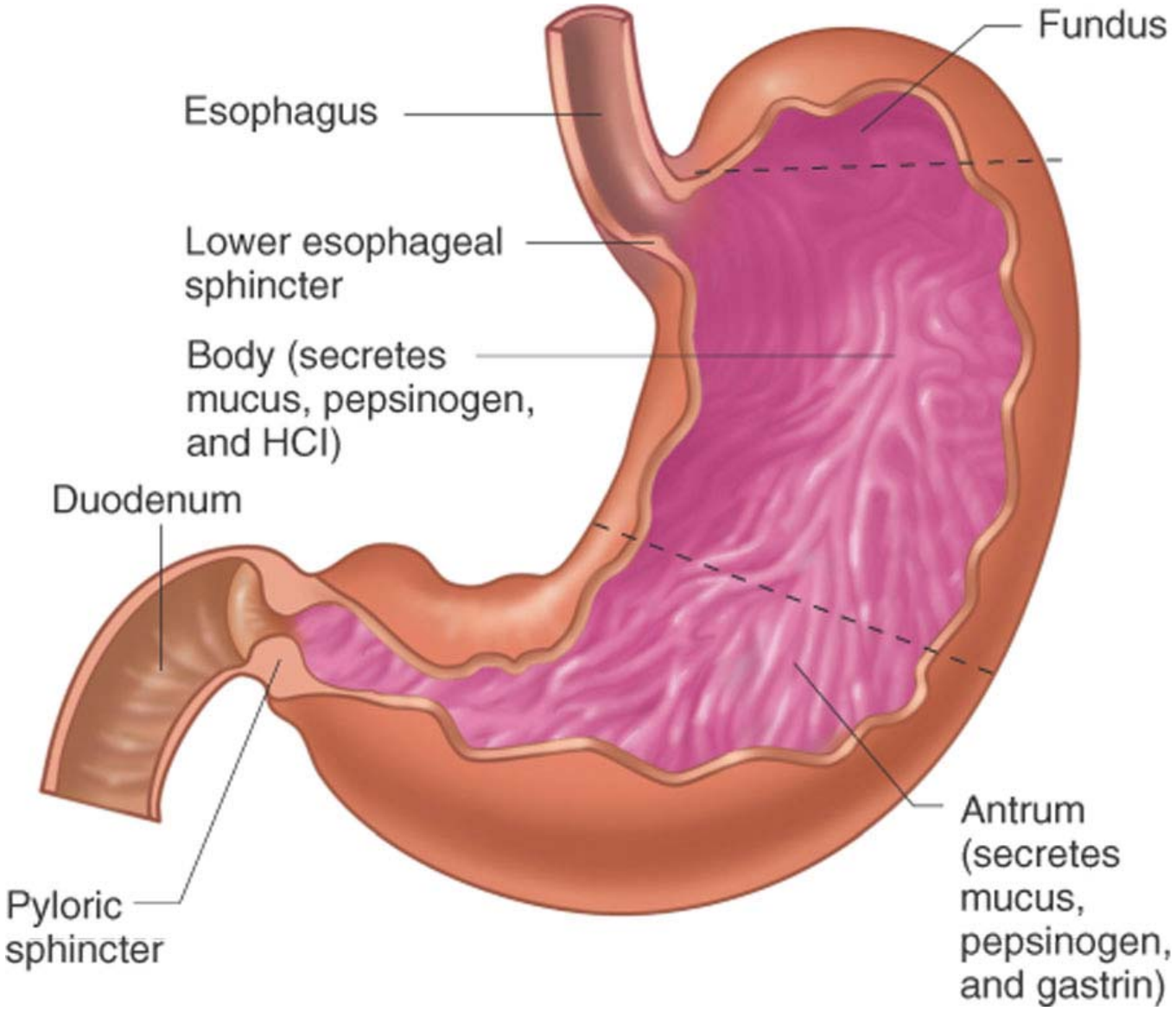
(because the pain appears to be
located in the area of the heart)

Gastroesophageal reflux

Digestion in the Stomach



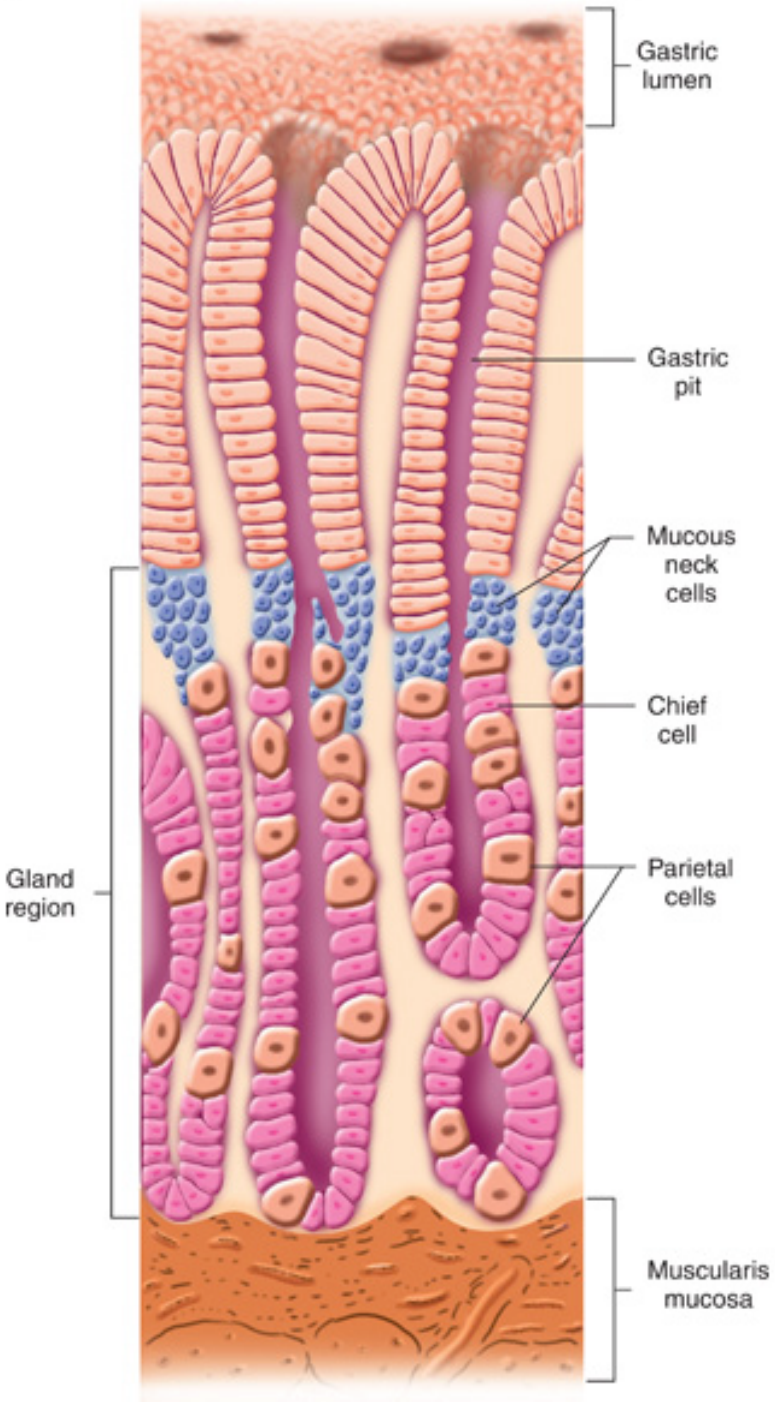
Specialized cells in the stomach synthesize and secrete mucous fluid, enzyme precursors, hydrochloric acid, and hormones.

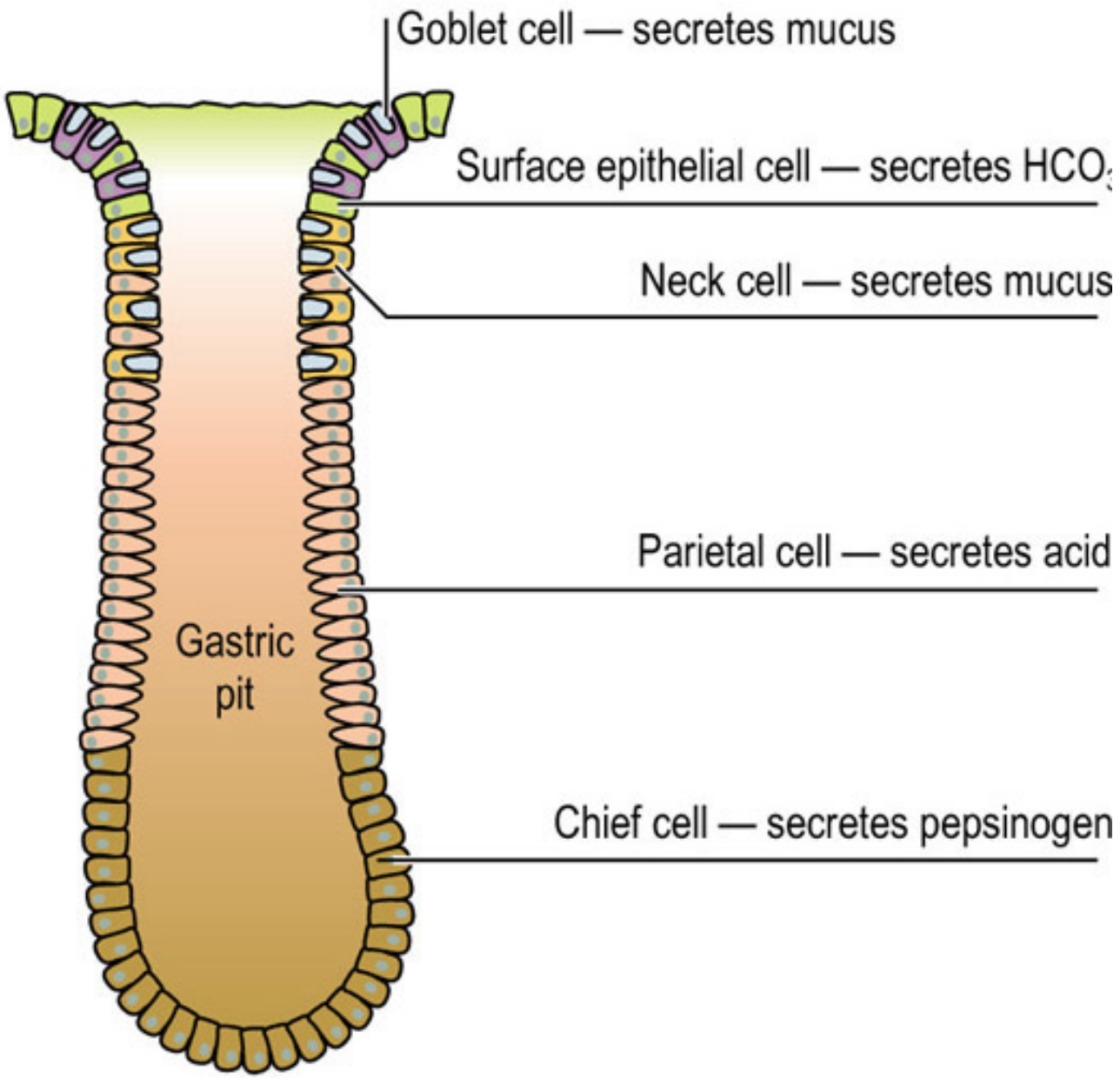


The abundant smooth muscle in the stomach is responsible for gastric motility.

Chief cells synthesize and secrete the protease precursor known as pepsinogen.

Parietal cells synthesize and secrete the hydrochloric acid responsible for the acidic pH in the gastric lumen.




Goblet cell — secretes mucus
Surface epithelial cell — secretes HCO_3^-
Neck cell — secretes mucus
Parietal cell — secretes acid
Gastric pit
Chief cell — secretes pepsinogen

(I) Gastric juice

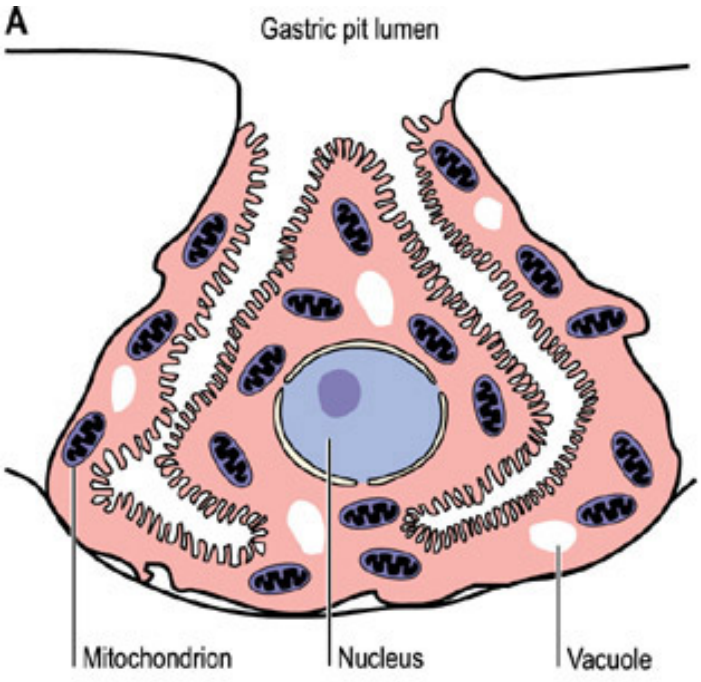
- Properties
  - pH 0.9~1.5
  - 1~2.5 L/day
- Major components
  - Hydrochloric acid
  - Pepsinogen
  - Mucus
  - Intrinsic factor

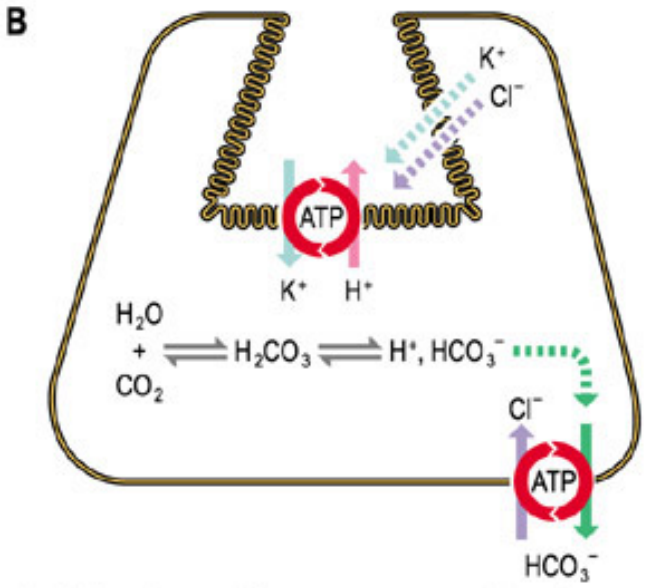
(1) Hydrochloric acid

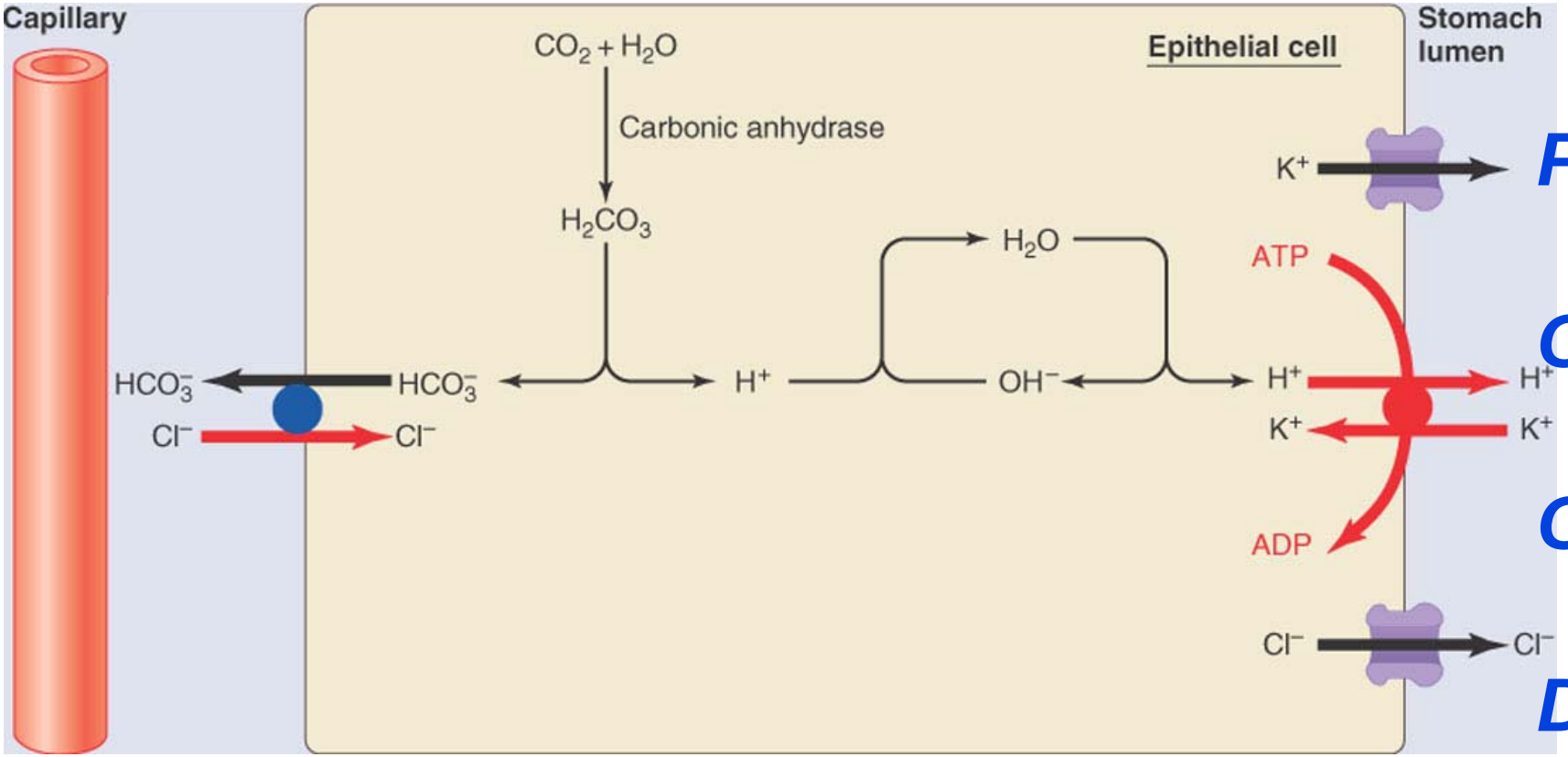
- Secreted by the parietal cells
- Output
  - Basal: 0~5 mmol/h
  - Maximal: 20~25 mmol/h

- Mechanism of HCl secretion

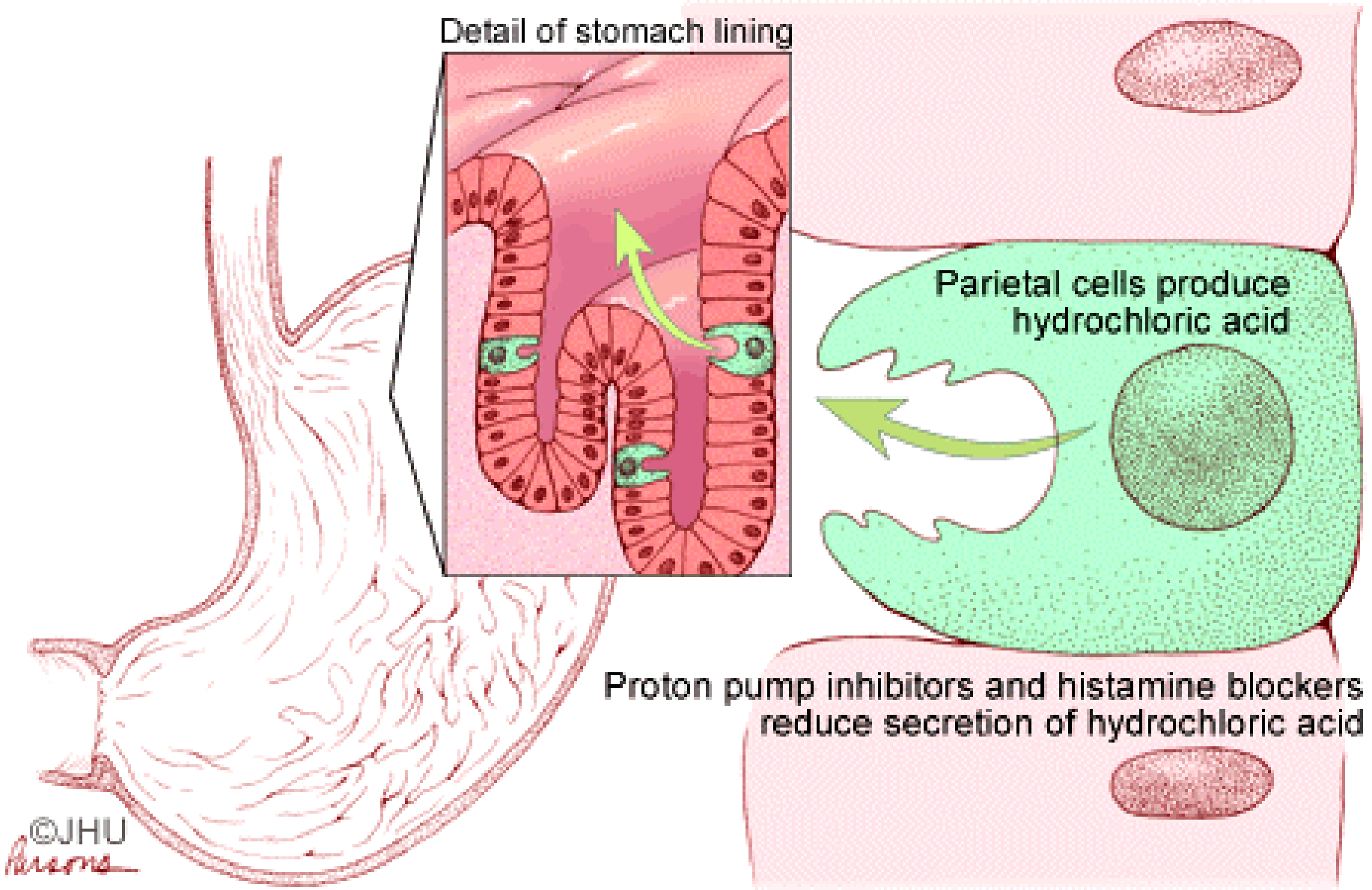
- HCl is actively secreted against a huge concentration gradient
- H^+/K^+ ATPase or "proton pump"







Acid production by the parietal cells in the stomach depends on the generation of carbonic acid; subsequent movement of hydrogen ions into the gastric lumen results from primary active transport.hydrochloric_acid.swf


Detail of stomach lining
Parietal cells produce hydrochloric acid
Proton pump inhibitors and histamine blockers reduce secretion of hydrochloric acid
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Four chemical messengers regulate HCl secretion

One inhibitory and three stimulatory signals that alter acid secretion by parietal cells in the stomach.

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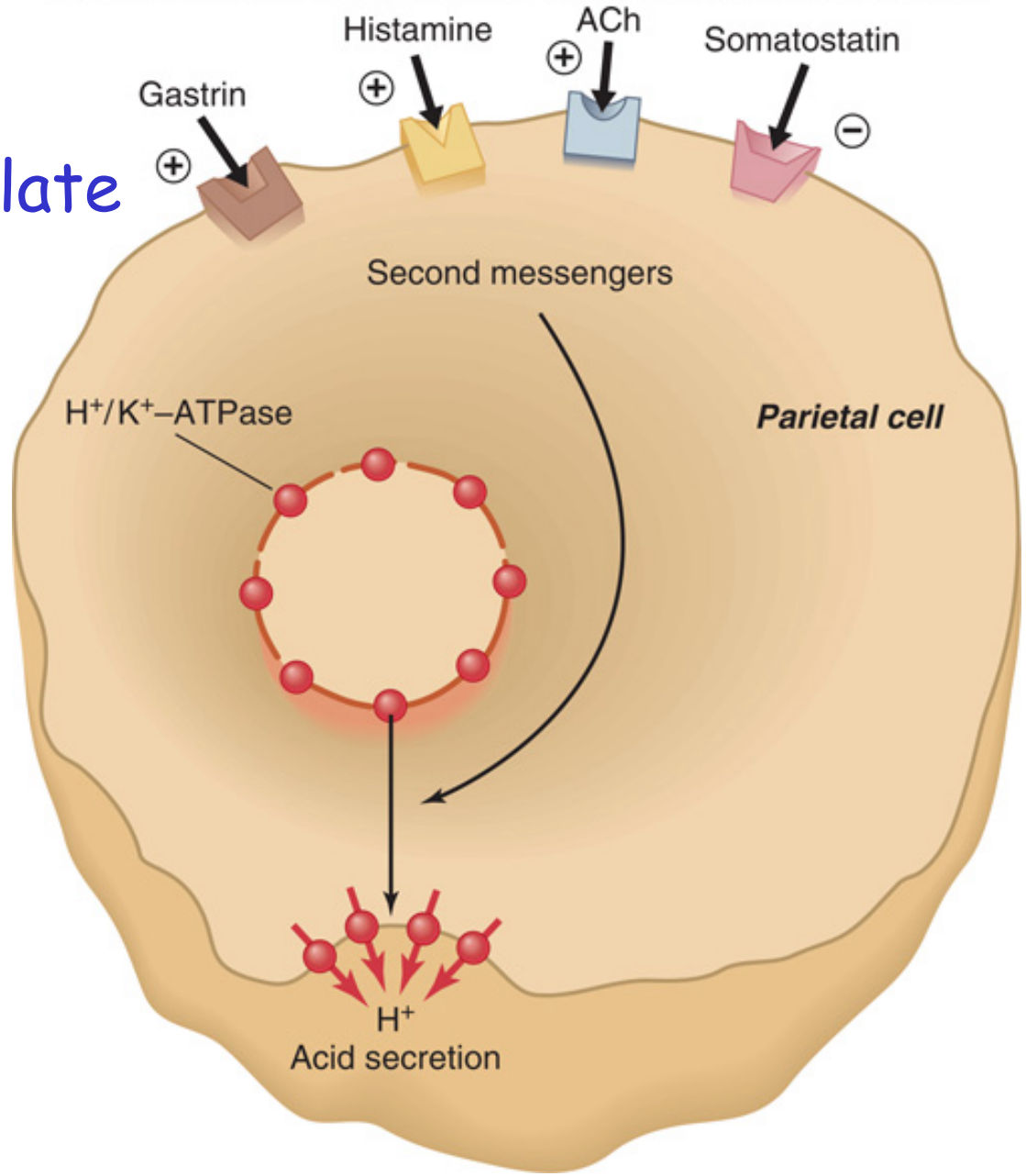
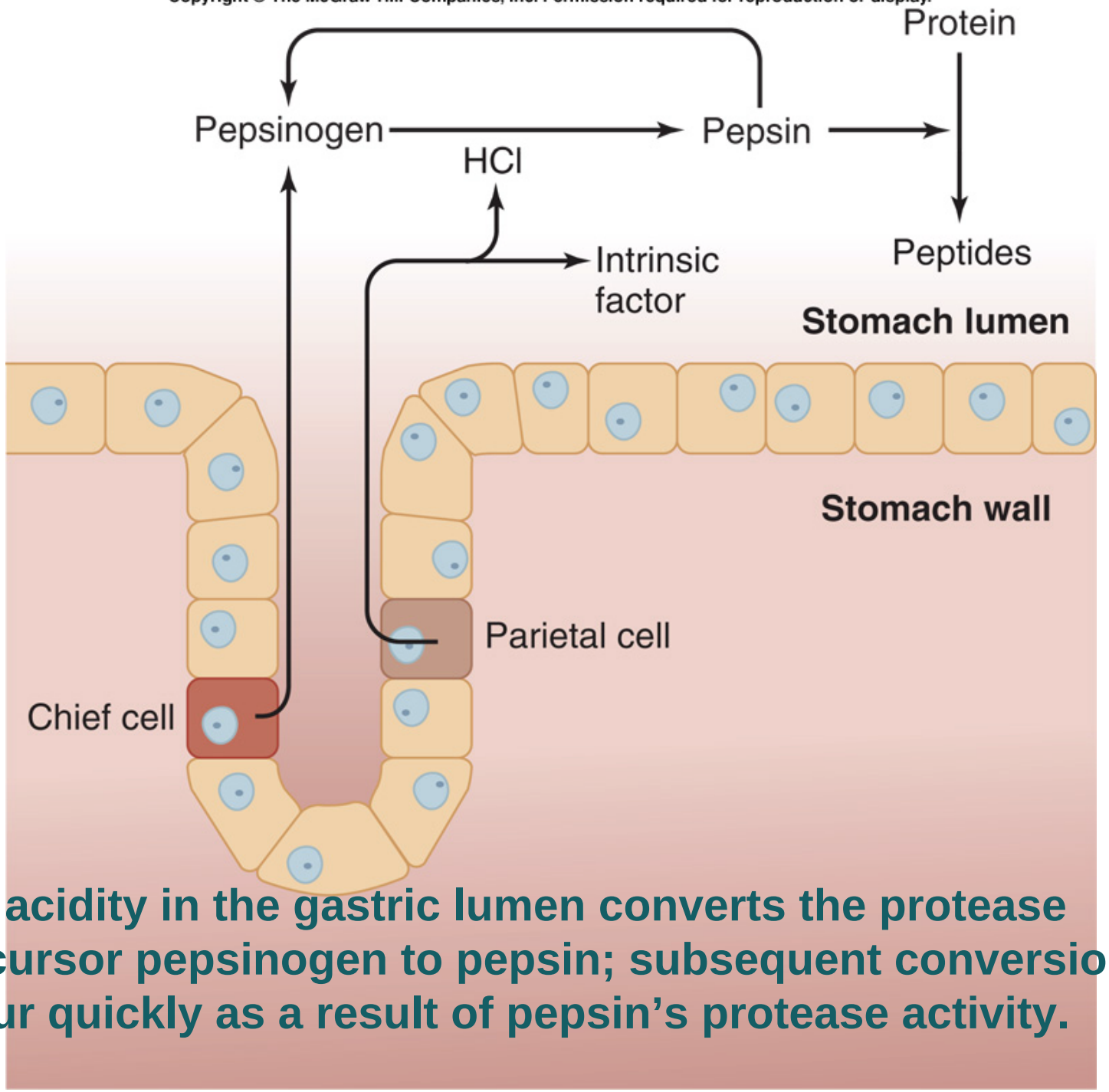


- Role of HCl
  - Acid sterilization
  - Activation of pepsinogen
  - Promotion of secretin secretion
  - Assisted effect of iron and calcium absorption

(2) Pepsinogen

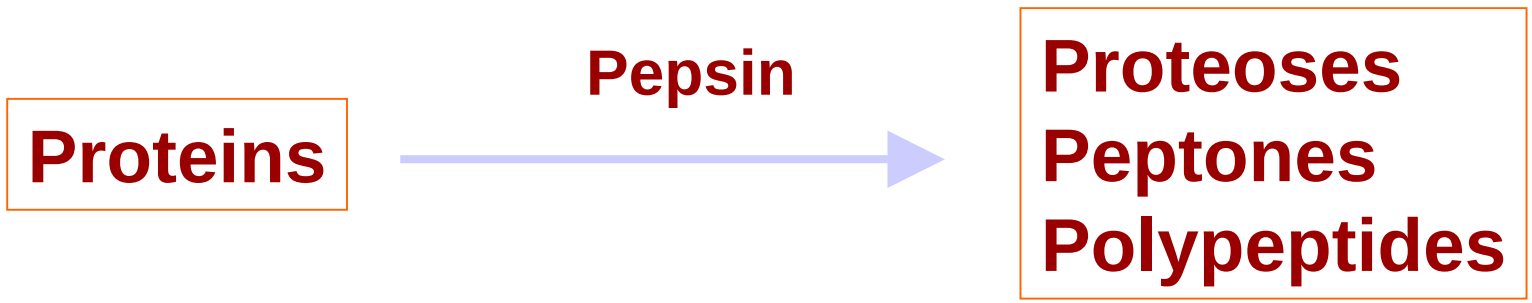
- Secreted by the chief cells as an inactive precursor of pepsin
- Activated in the stomach, initially by H^+ ions and then by active pepsin, autocatalytic activation
- Active *pepsin* (MW: 35,000)



The acidity in the gastric lumen converts the protease precursor pepsinogen to pepsin; subsequent conversions occur quickly as a result of pepsin's protease activity.

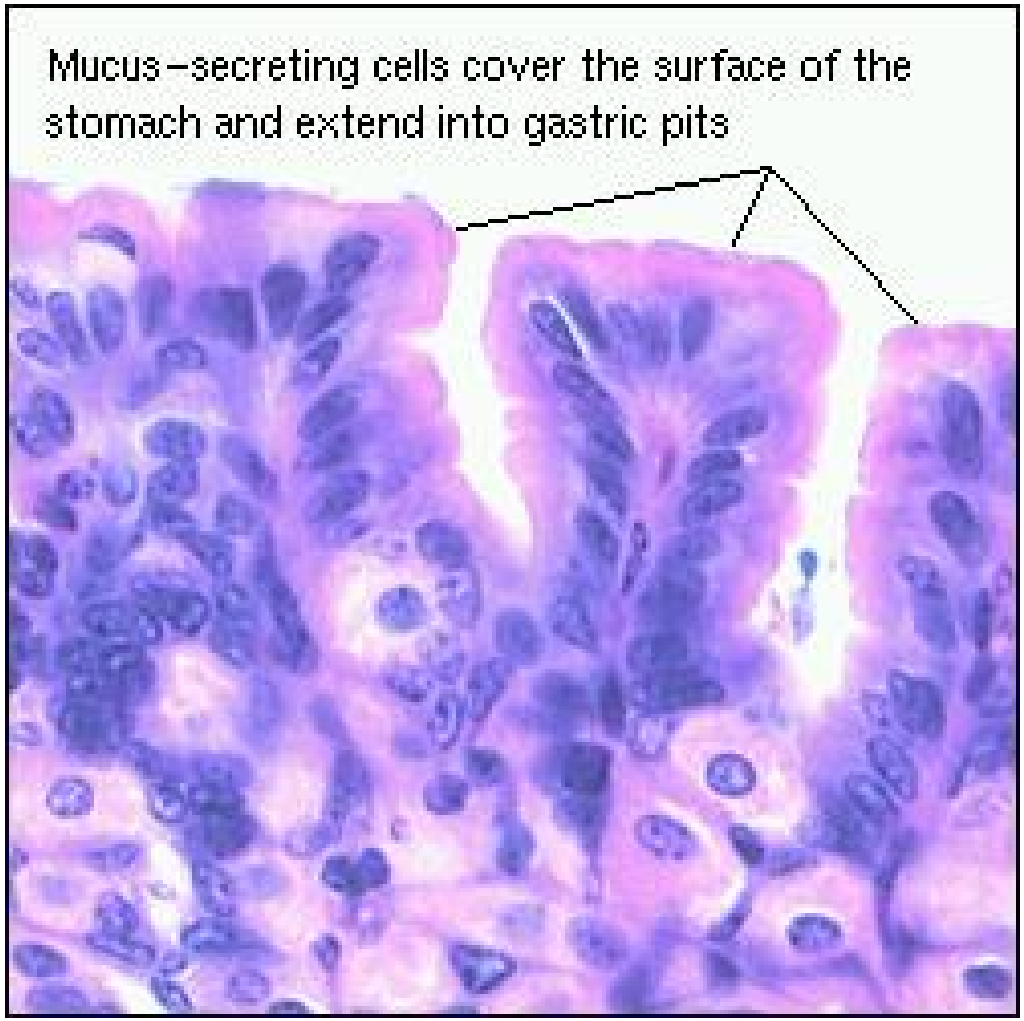
- Effect of pepsin

  Pepsin is an endopeptidase, which attacks peptide bonds in the interior of large protein molecules



(3) Mucus

- Secreted by the epithelial cells all over the mucosa and by the neck mucus cells in the upper portion of the gastric glands and pyloric glands



- a layer ~500 μm thick
- composed chiefly of mucins

•Role

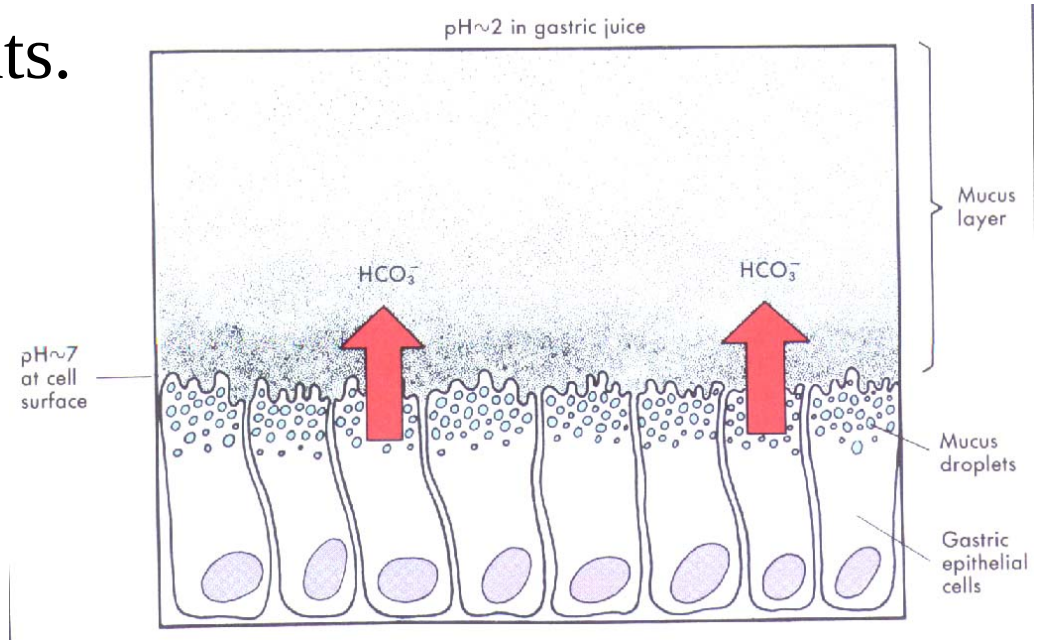
–Lubrication of the mucosal surface

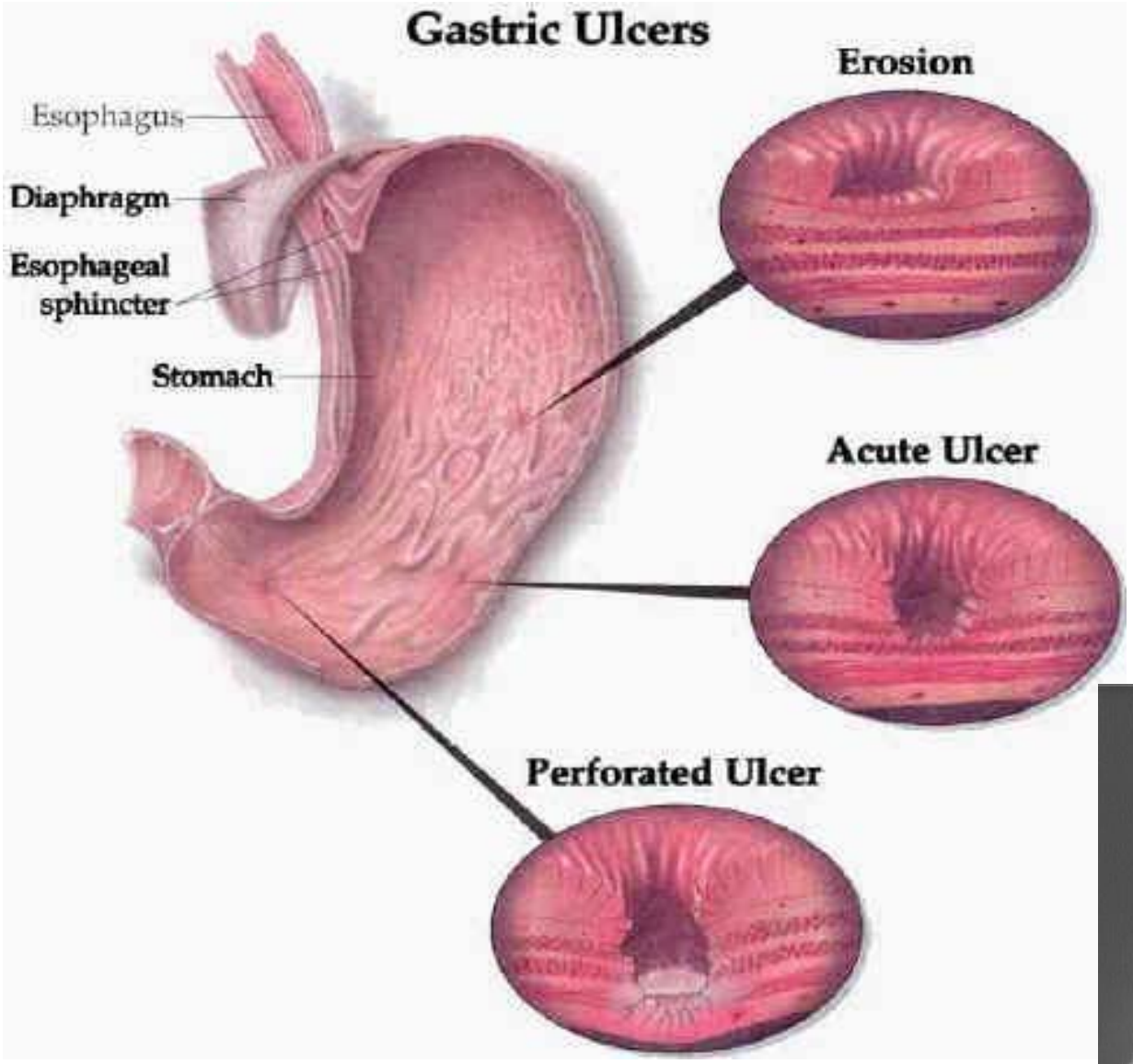
–Protection of the tissue from mechanical damage by food particles

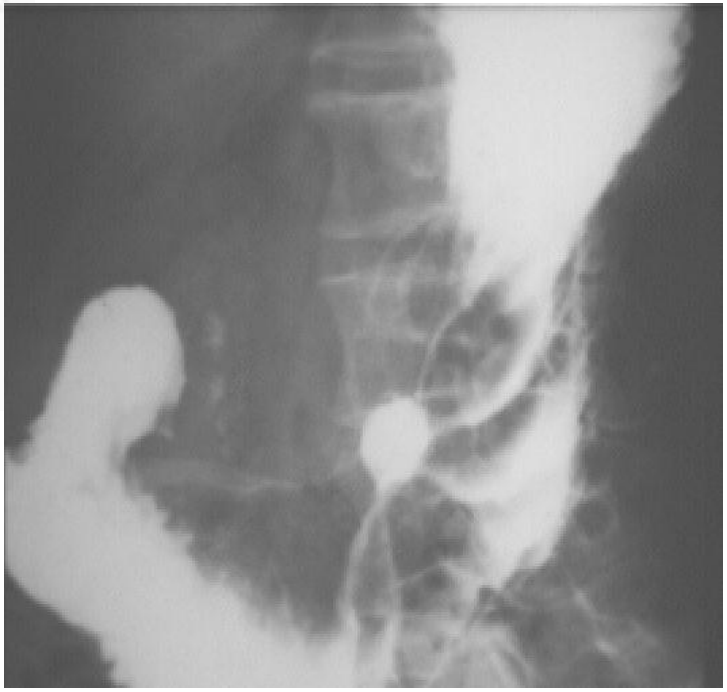
Mucus-HCO_3^- barrier

•Epithelial cells and neck mucus cells secrete a bicarbonate-rich mucus that coats and lubricates the gastric surface

•*Serves an important role* in protecting the epithelium from acid and other chemical insults. The mucus layer also traps HCO_3^- secreted by the mucosal cells and this buffers, or chemically insulates, the mucosa from the acidic stomach contents.



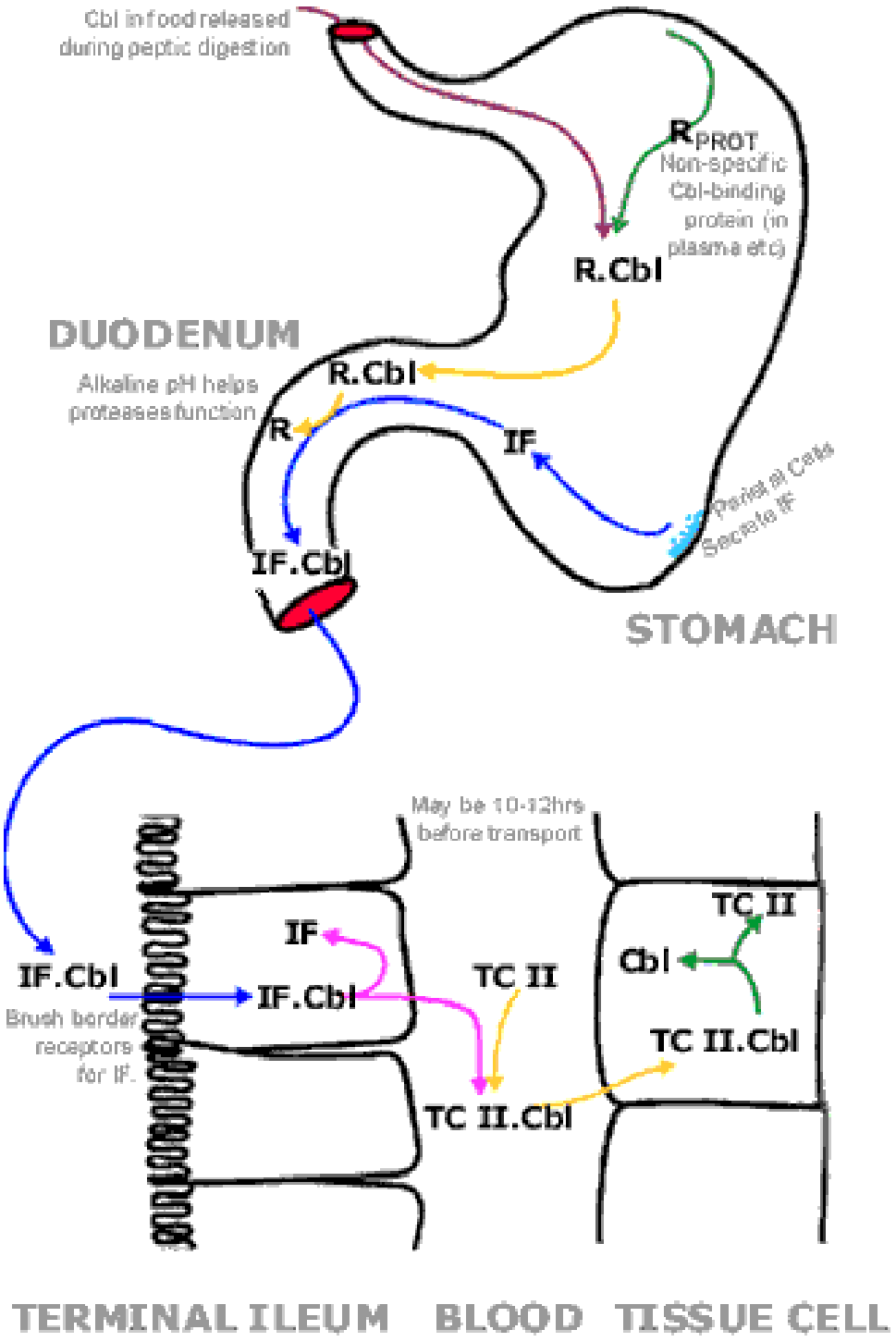




If the mucus-HCO_3^- barrier is weak?

(4) Intrinsic factor

- A high molecular weight glycoprotein, synthesized and secreted by the parietal cells
- The intrinsic factor binds to Vit B_{12} and facilitates its absorption


Cbl in food released during peptic digestion
R PROT
Non-specific Cbl-binding protein (in plasma etc)
R.Cbl
DUODENUM
Alkaline pH helps proteases function
R.Cbl
R
IF
Parietal Cells Secrete IF
IF.Cbl
STOMACH
May be 10-12hrs before transport
IF
IF.Cbl
IF.Cbl
Brush border receptors for IF
TC II
TC II.Cbl
TC II
Cbl
TC II.Cbl
TERMINAL ILEUM
BLOOD
TISSUE CELL

(5) Secretion of other enzymes

- Gastric lipase
- Gastric amylase
- Gelatinase

(II) Regulation of gastric secretion

(1) Basic factors that stimulate gastric secretion

- Acetylcholine (+ all secretory cells)
- Gastrin (+ parietal cells)
- Histamine (+ parietal cells)

(2) Nervous regulation

- ‘Short’ reflex pathways
  - ‘Short’ excitatory reflexes: mediated by cholinergic neurons in the plexuses
  - ‘Short’ inhibitory reflexes: mediated by non-adrenergic non-cholinergic (NANC) neurons

(2) Nervous regulation

‘Long’ autonomic pathways

- ‘Long’ excitatory reflexes: parasympathetic
- ‘Long’ inhibitory pathways: sympathetic

(3) Humoral regulation

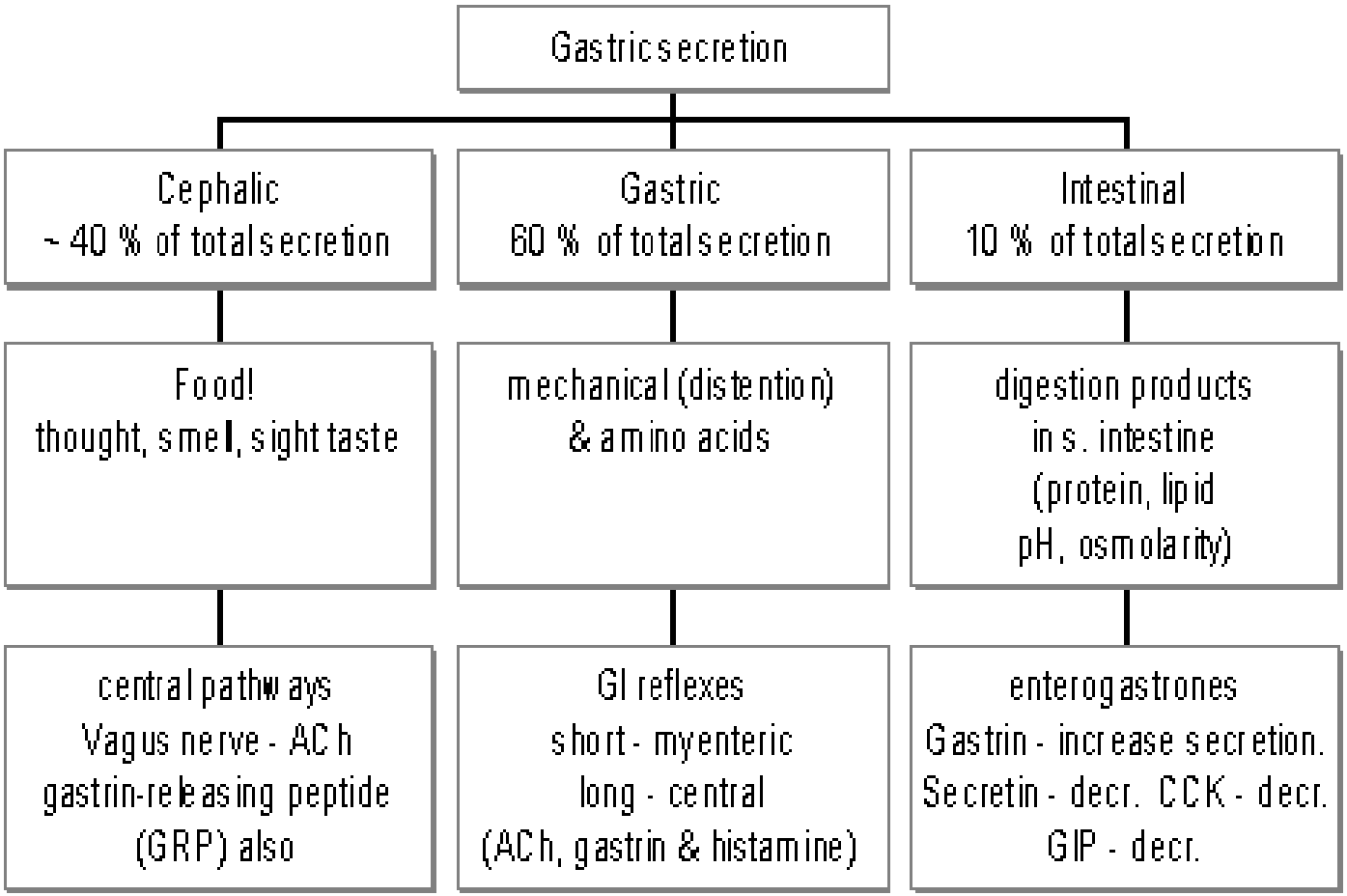
Excitatory	Inhibitory
ACh	Somatostatin
Histamine	Secretin
Gastrin	5-hydroxytryptamine (5-HT)
	Prostaglandin

(4) Phases of gastric secretion

- Cephalic phase
- Gastric phase
- Intestinal phase

Control of gastric secretion

Phases of gastric secretion

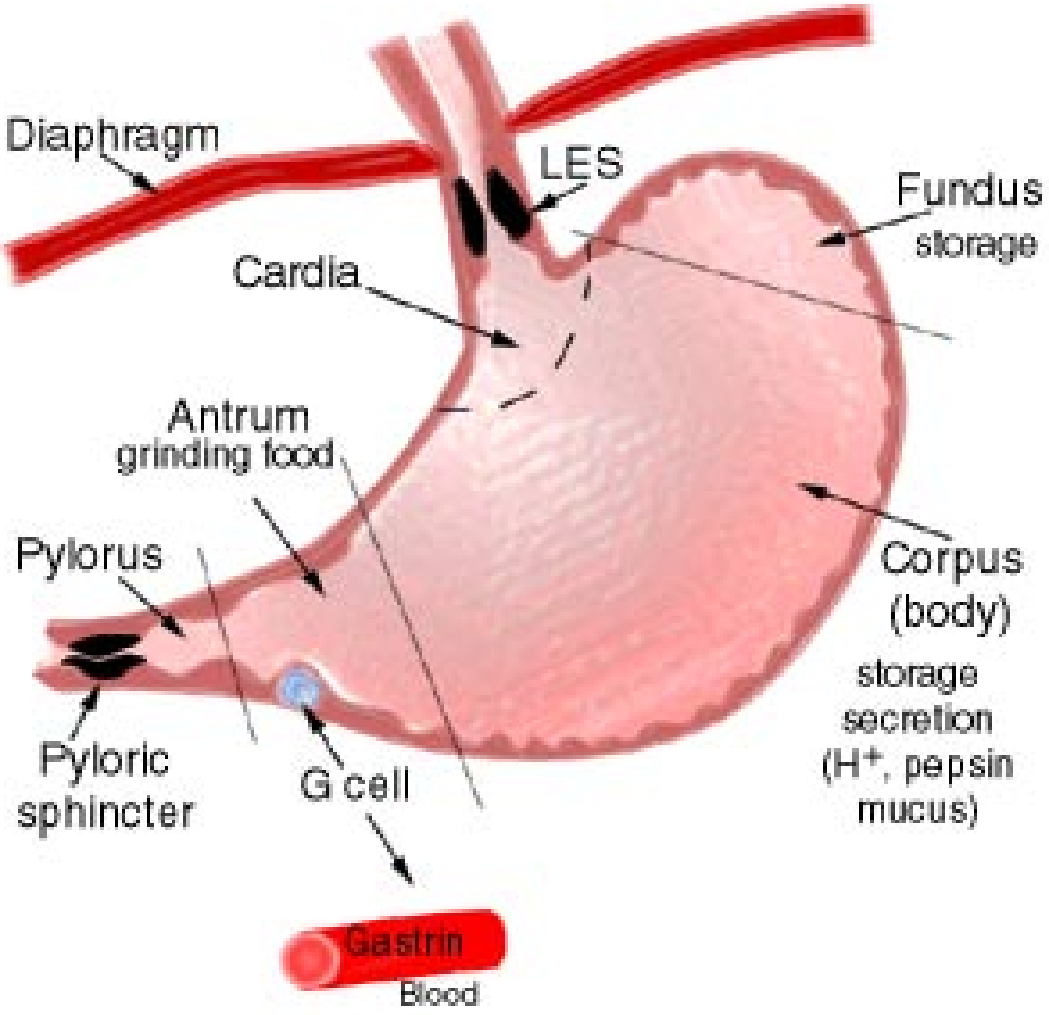


November 1999

(5) Inhibition of gastric secretion

The functional purpose of the inhibition of gastric secretion by intestinal factors is presumably to slow the release of chyme from the stomach when the small intestine is already filled or overactive

Motor Function of the Stomach



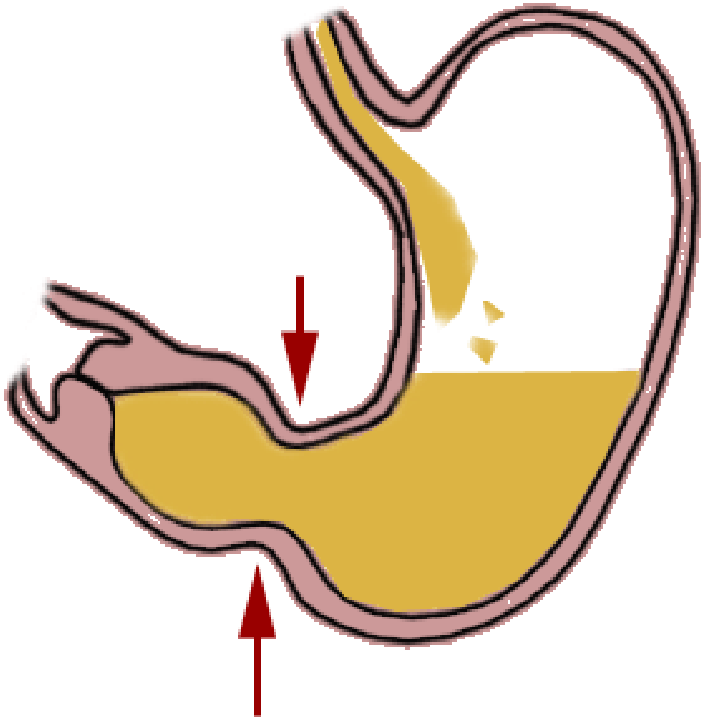
Proximal stomach

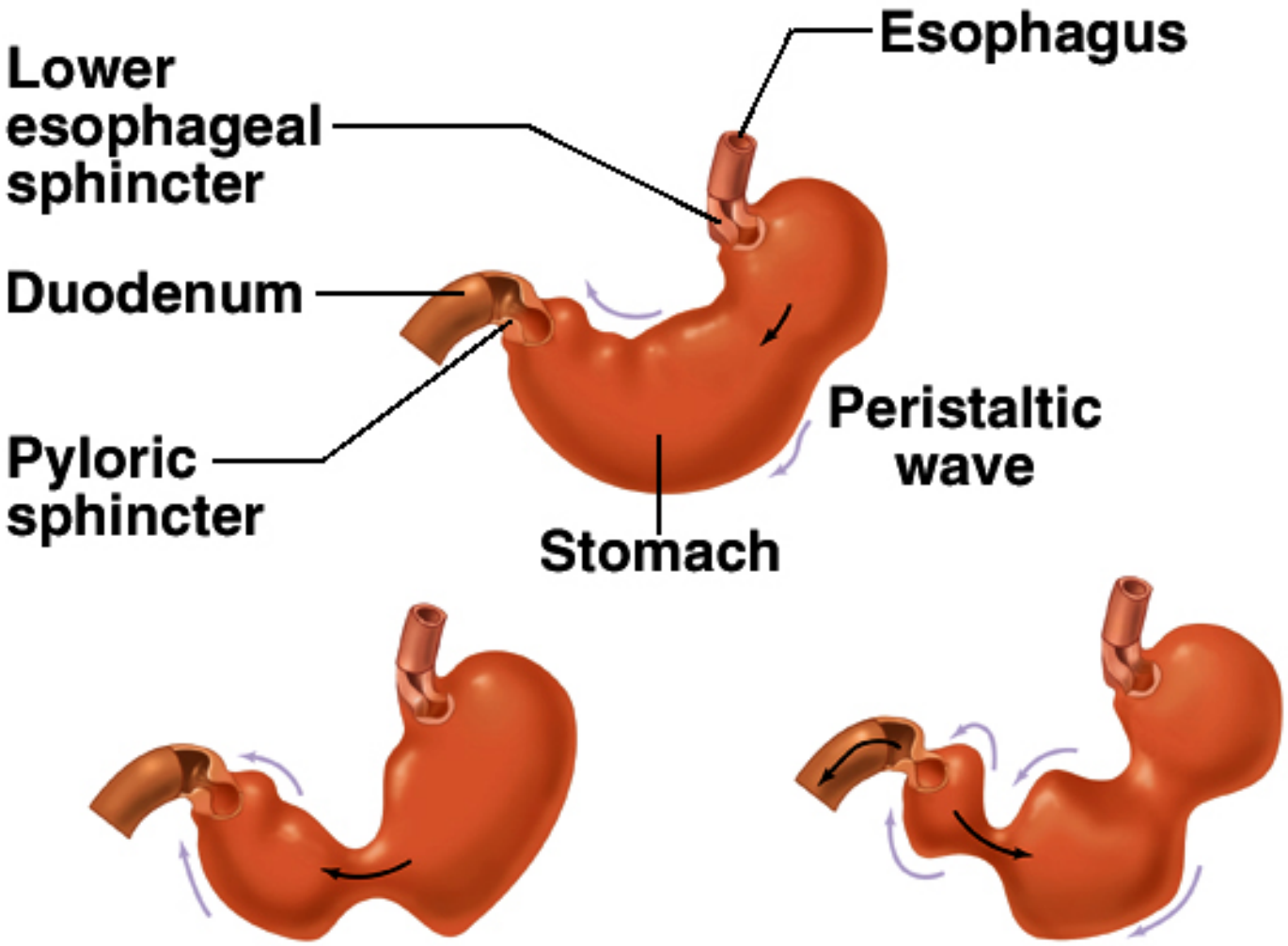
- cardia
- fundus
- corpus (body)

Distal stomach

- antrum
- pylorus
- pyloric sphincter

- Receptive relaxation
  - Storage function (1.0~1.5 L)
  - Vago-vagal reflex
- Peristalsis
  - BER in the stomach

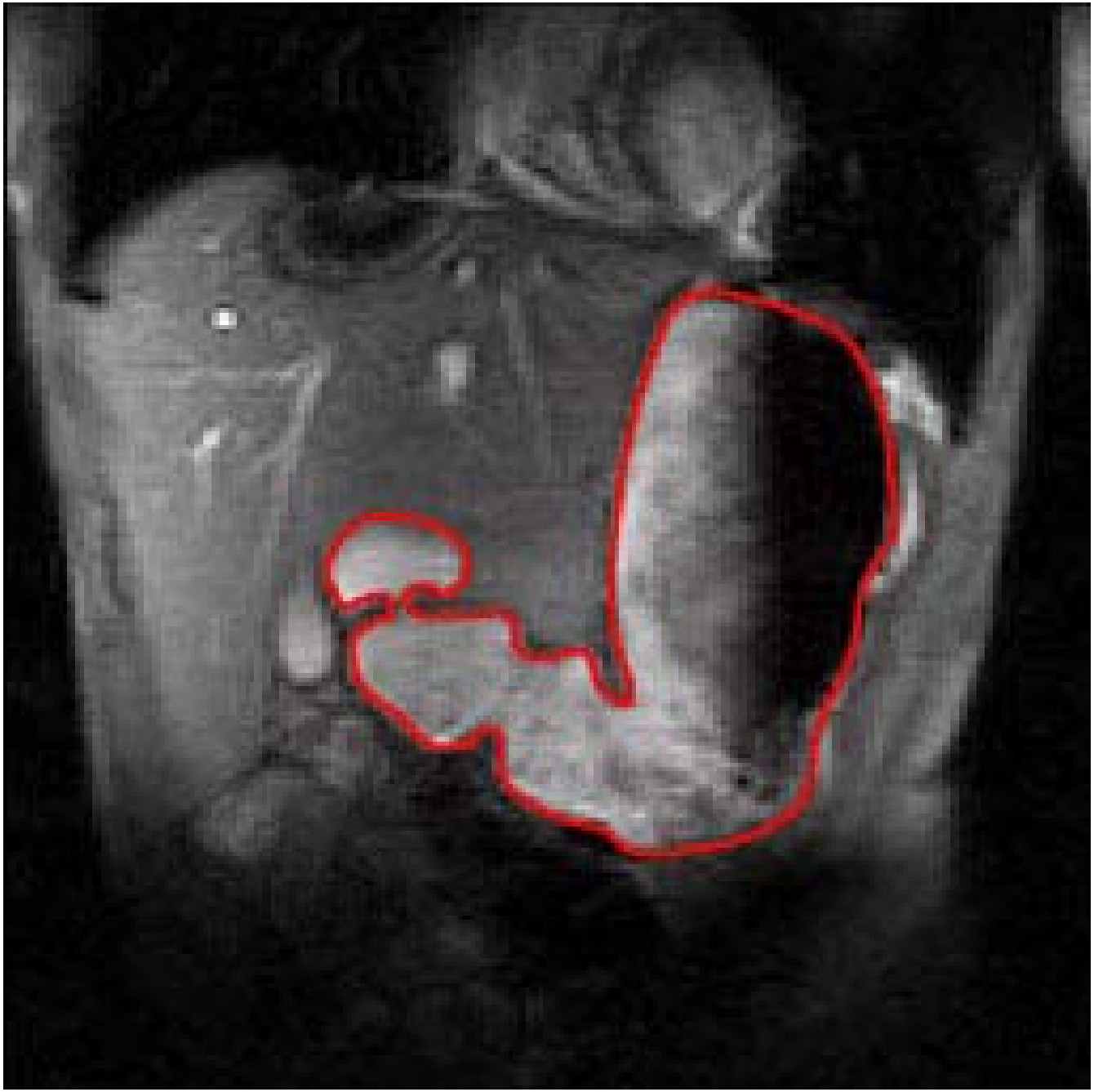




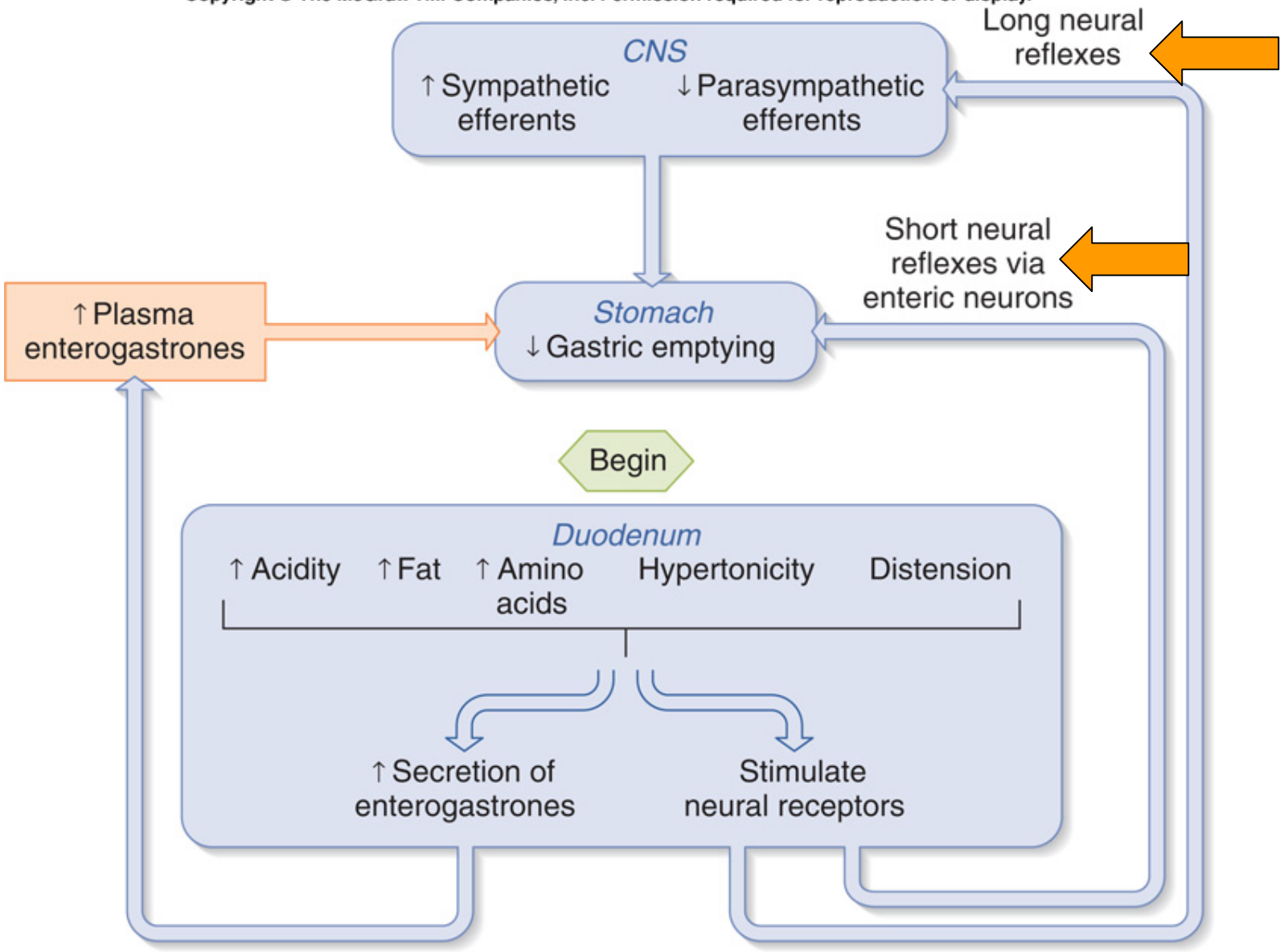
Waves of smooth muscle contraction mix and propel the ingested contents of the gastric lumen, but only a small amount of the material enters the small intestine (duodenum) as a result of each wave cycle.

Emptying of the stomach

- Emptying rate
  - Fluid > viscous
  - Small particle > large particle
  - Isosmotic > hyper- & hypo-osmotic
  - Carbohydrates > Protein > Fat
  - Regular meal 4～6 hrs



- Regulation of stomach emptying
  - Gastric factors that promote emptying
    - **Gastric food volume**
    - **Gastrin**
  - Duodenal factors that inhibit stomach emptying
    - **Enterogastric nervous reflexes**
    - **Fat**
    - **Cholecystokinin**



Delivery of acid and nutrients into the small intestine initiates signaling that slows gastric motility and secretion which allows adequate time for digestion and absorption in the duodenum.

Summary

- Terms:
  - Receptive relaxation (Storage function of the stomach)
  - Mucus-HCO_3^- barrier
  - Intrinsic factor
- Gastric secretion (including the composition and physiological function of the gastric juice, the regulation of gastric secretion)

Intensive reading

- **Textbook of Human Physiology**
  - **P590-600**


Thank you!