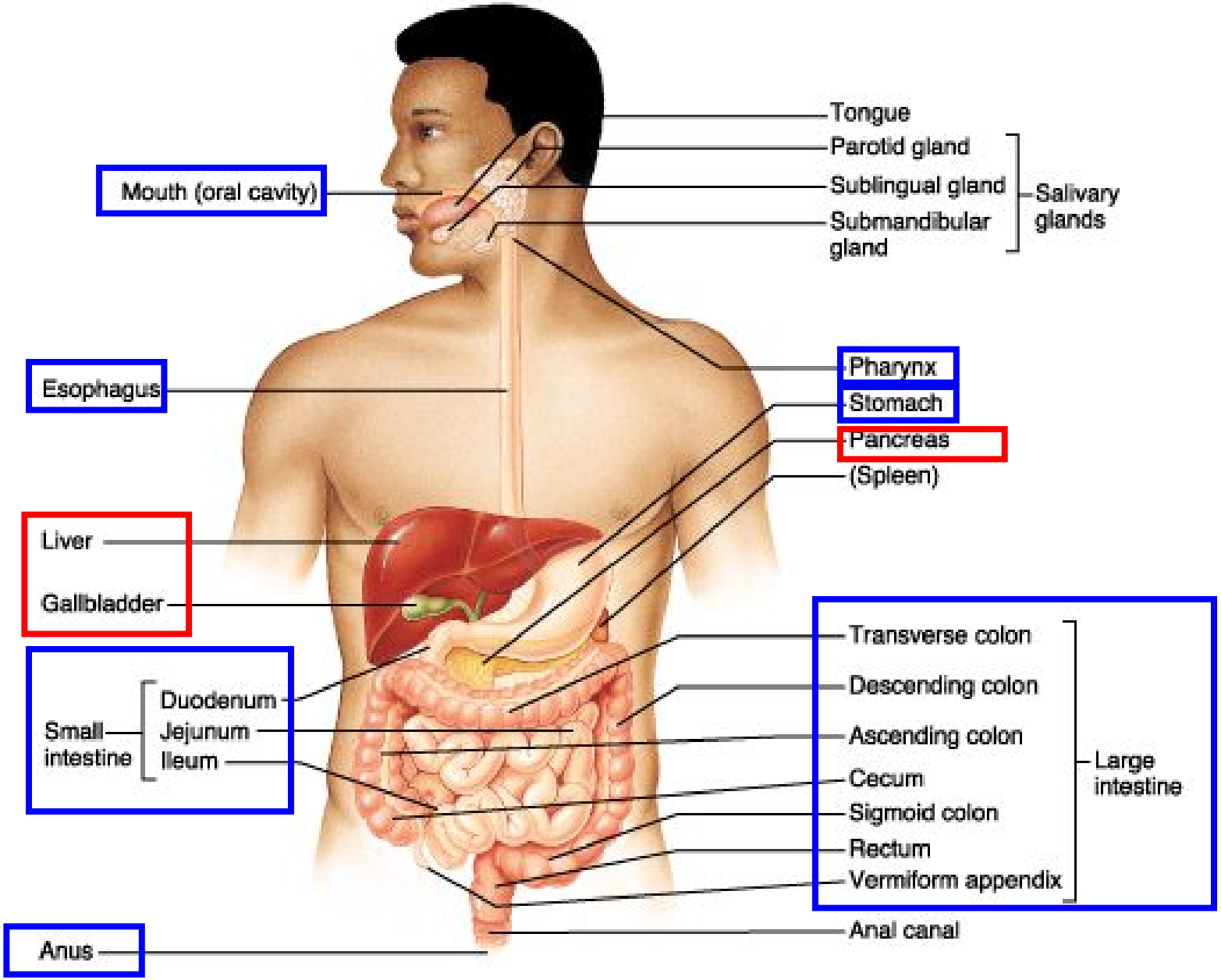
Functions of GI Organs

Dr. Denny C.W. Ma

Gastroinestinal Tract

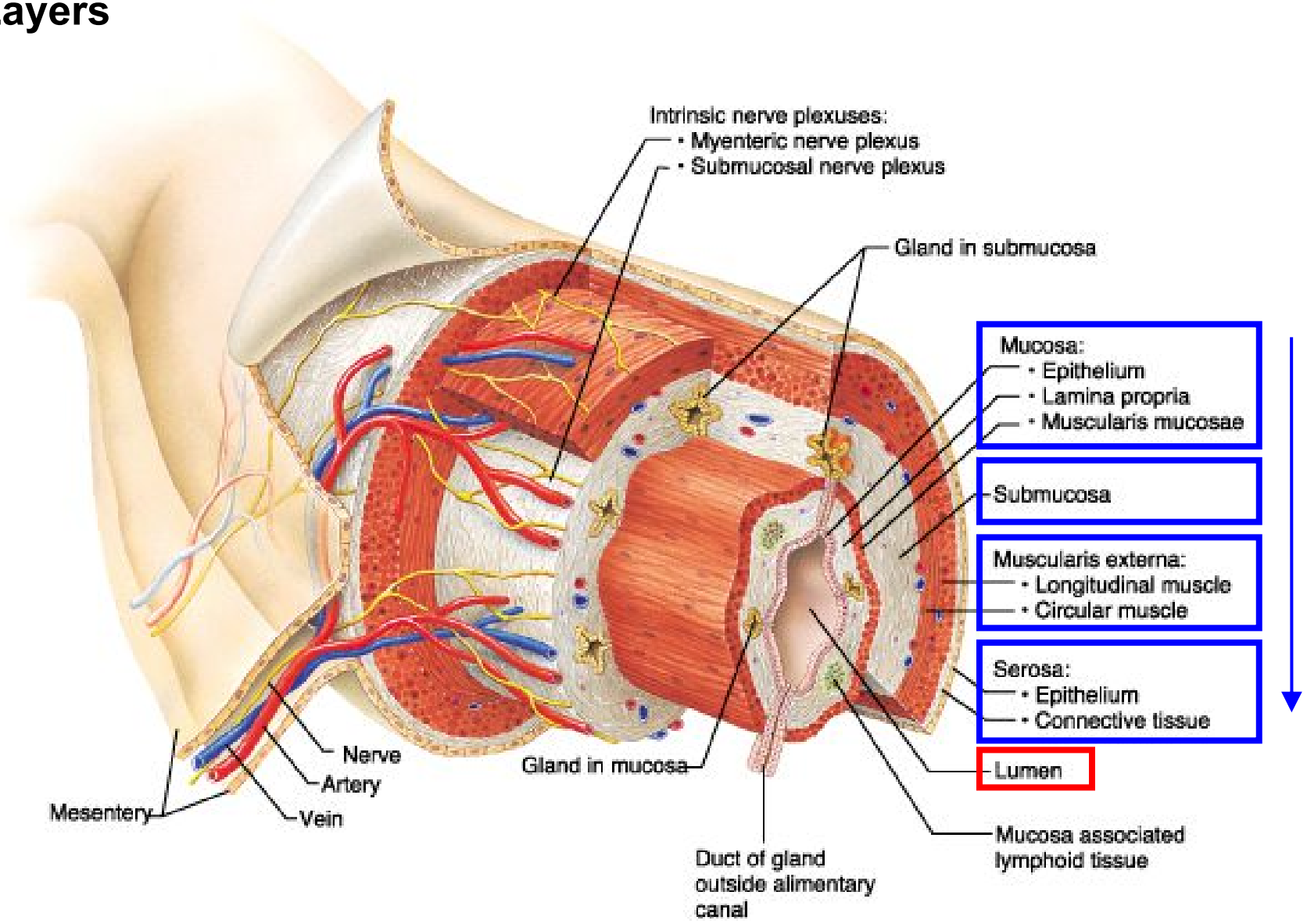
"All disease begins in the gut." – Hippocrates

Gastroinestinal Tract (alimentary canal)



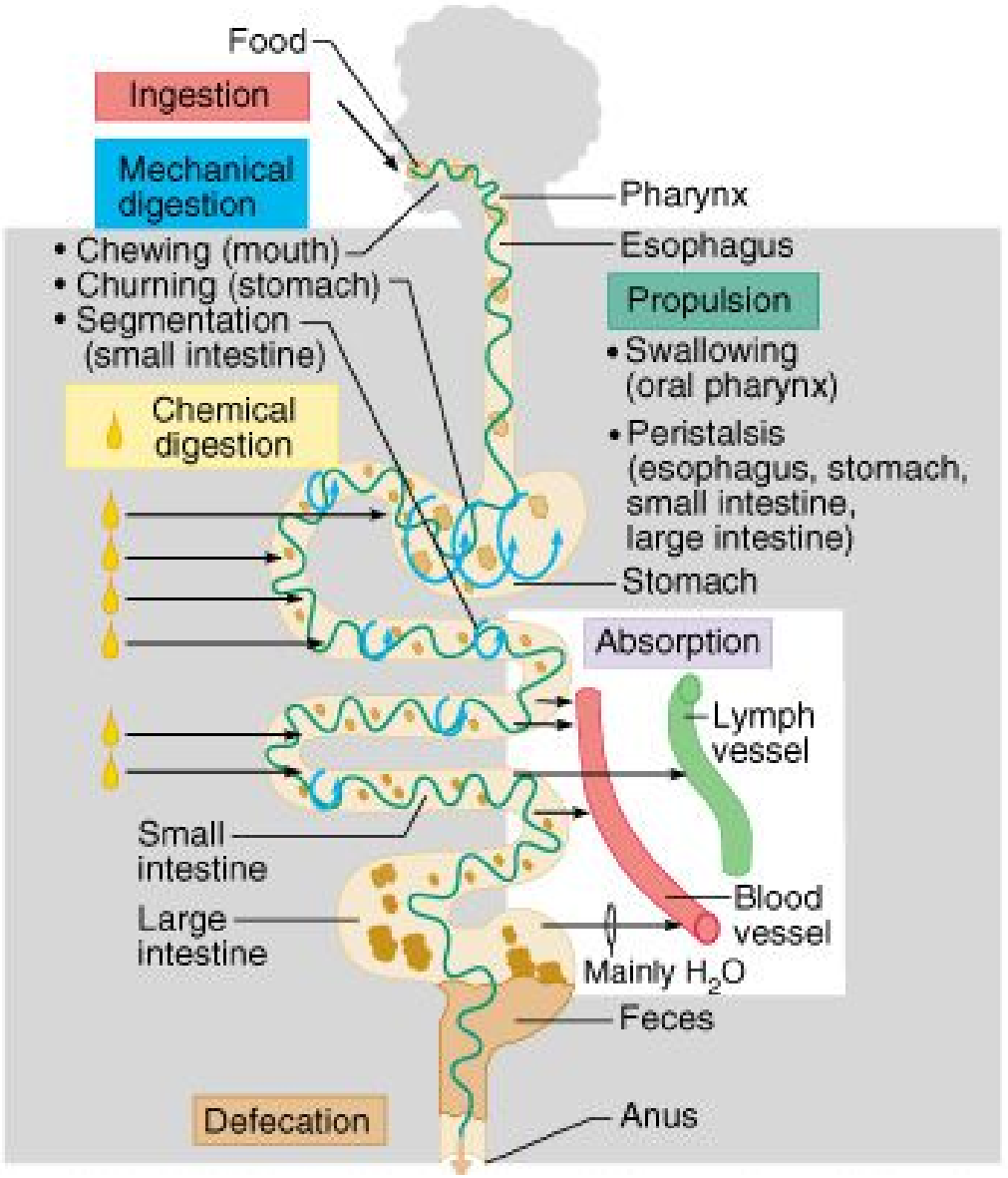
Gastroinestinal Tract (alimentary canal)

Layers



Essential Activities of Digestive Process

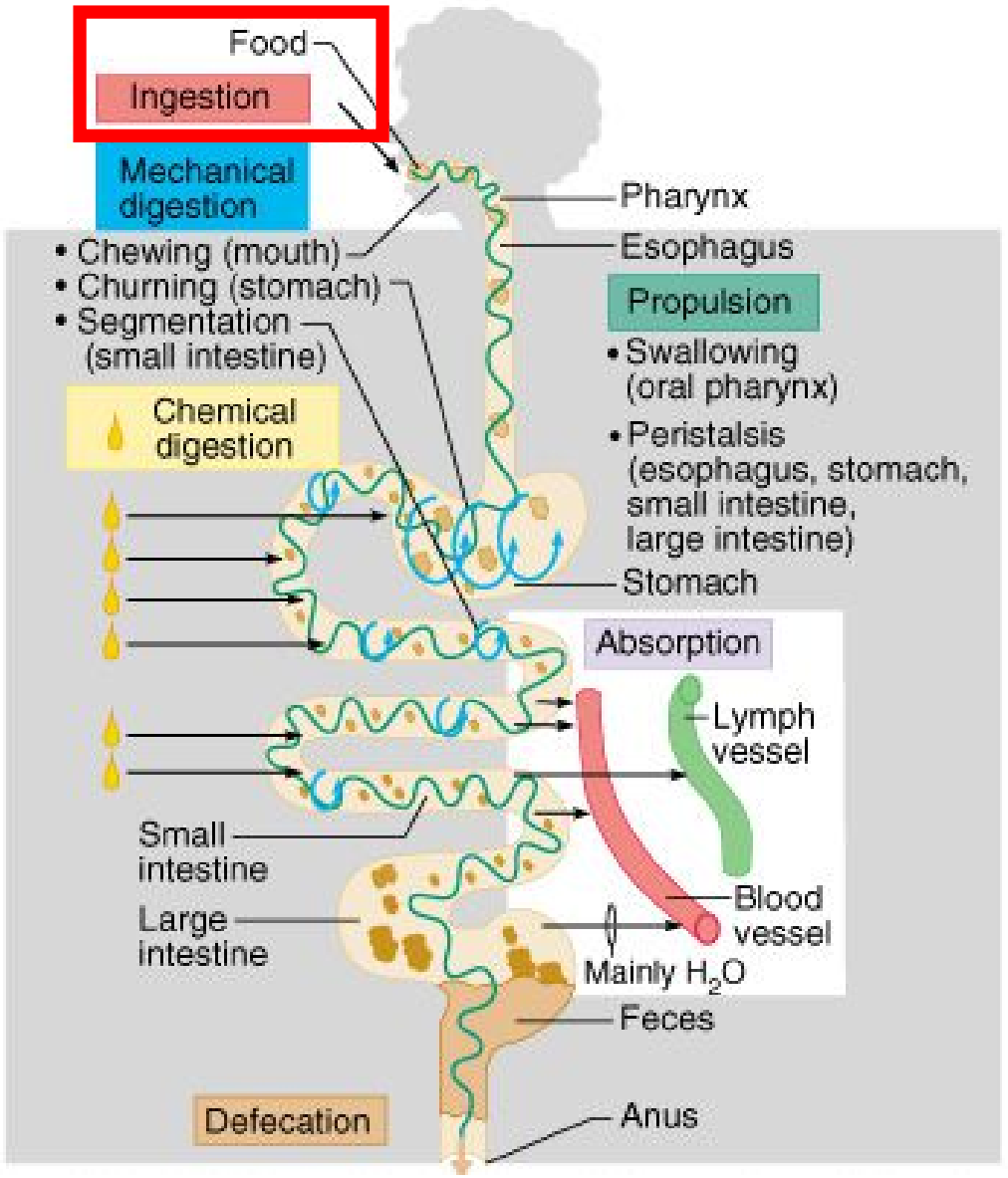
1. Ingestion
2. Propulsion
3. Mechanical digestion
4. Chemical digestion
5. Absorption
6. Defecation



Essential Activities of Digestive Process

1. **Ingestion**
2. **Propulsion**
3. **Mechanical digestion**
4. **Chemical digestion**
5. **Absorption**
6. **Defecation**

Taking in food through mouth into GI tract



Essential Activities of Digestive Process

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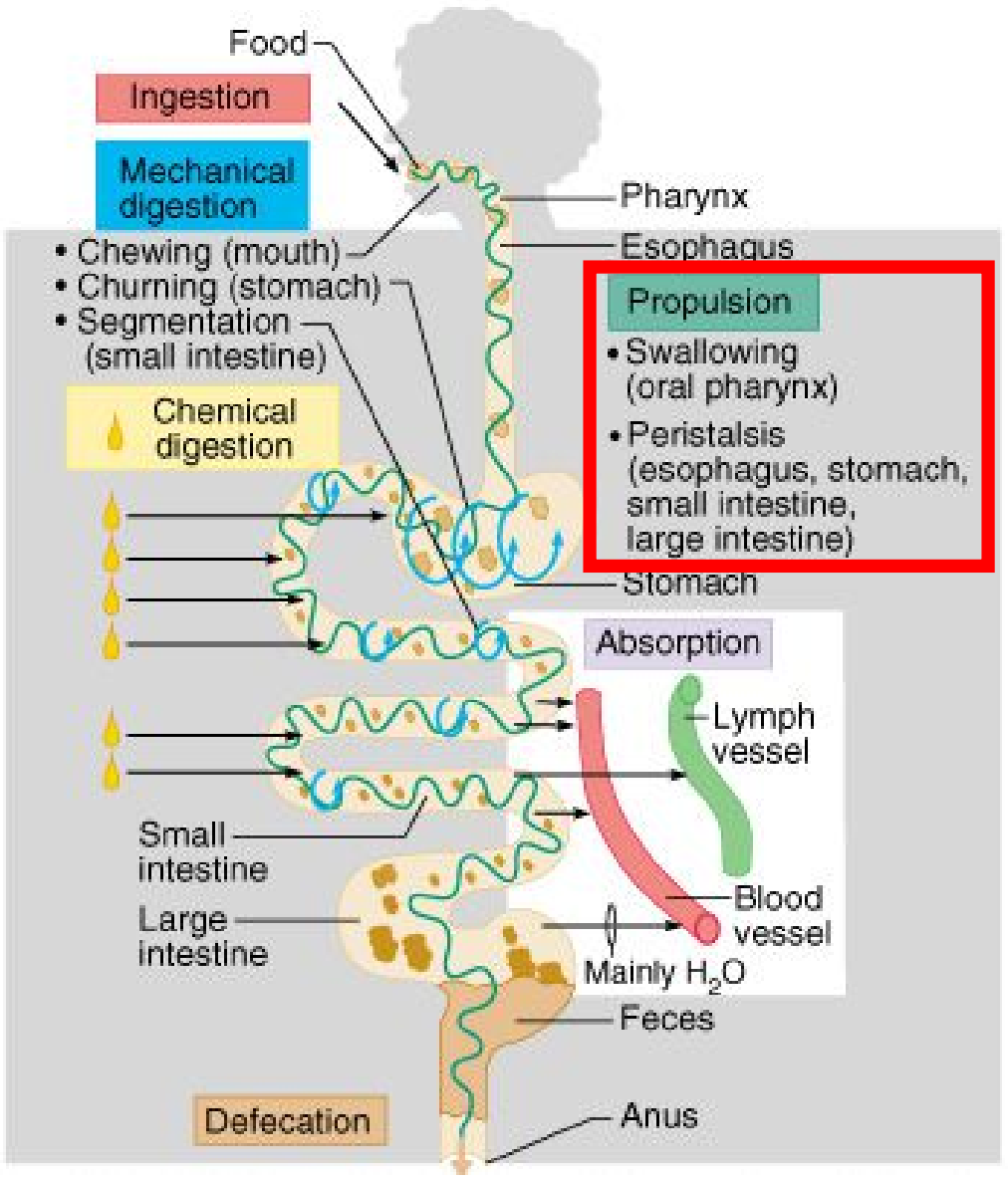
Movement of food along GI tract



Essential Activities of Digestive Process

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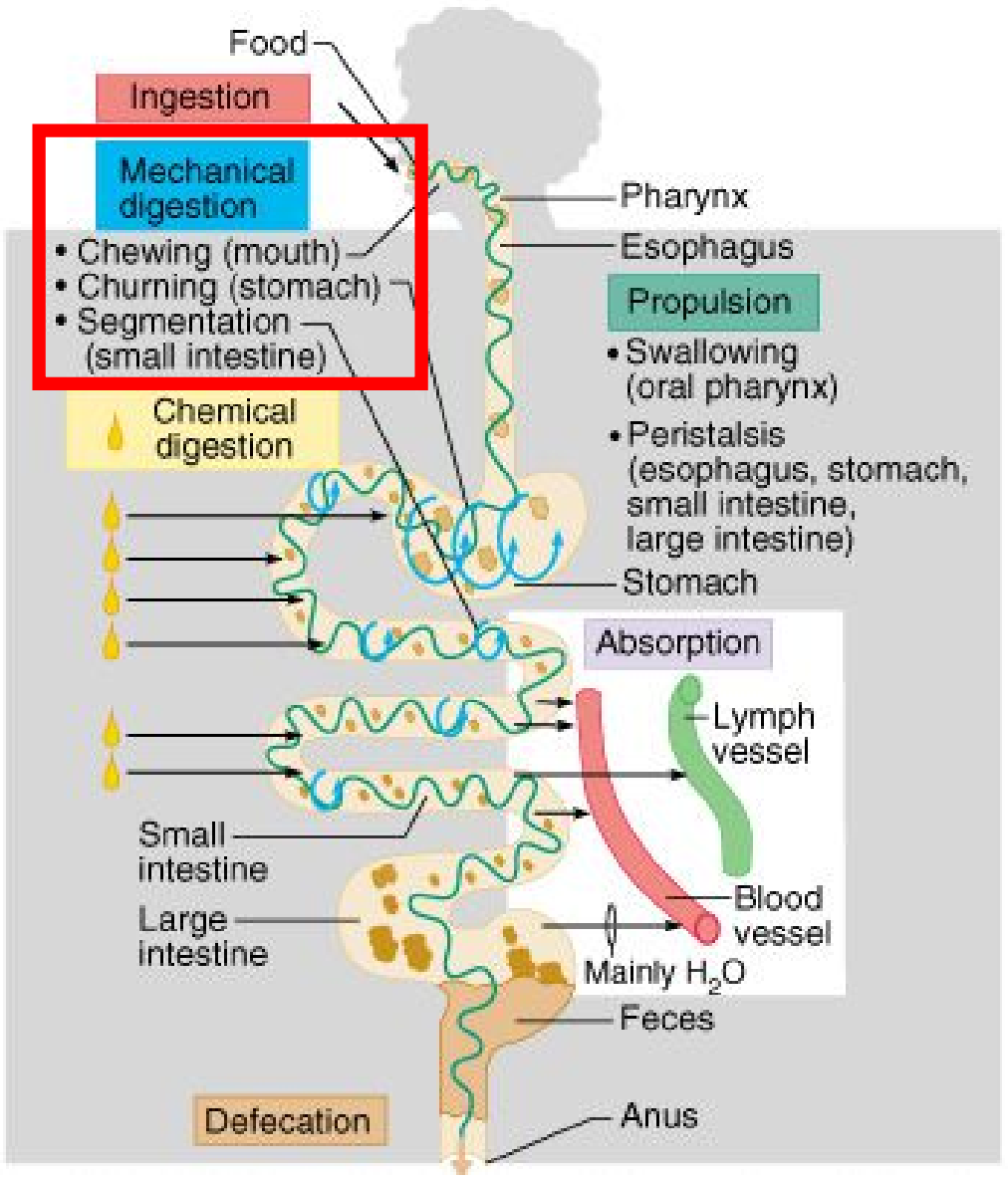
Physical breakdown of food by force



Essential Activities of Digestive Process

1. Ingestion
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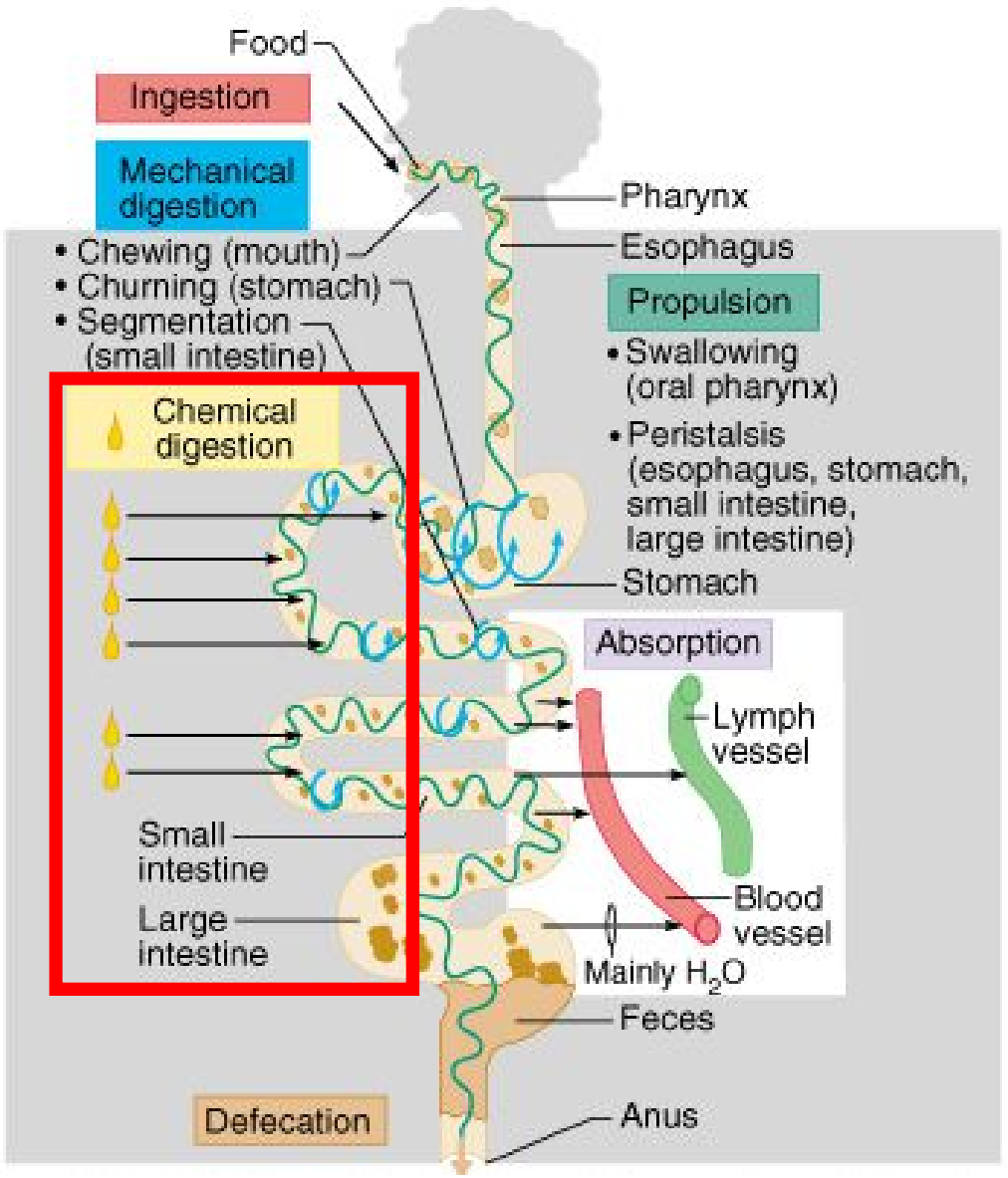
Catabolic breakdown of food molecules by digestive enzymes



Essential Activities of Digestive Process

1. Ingestion
2. Propulsion
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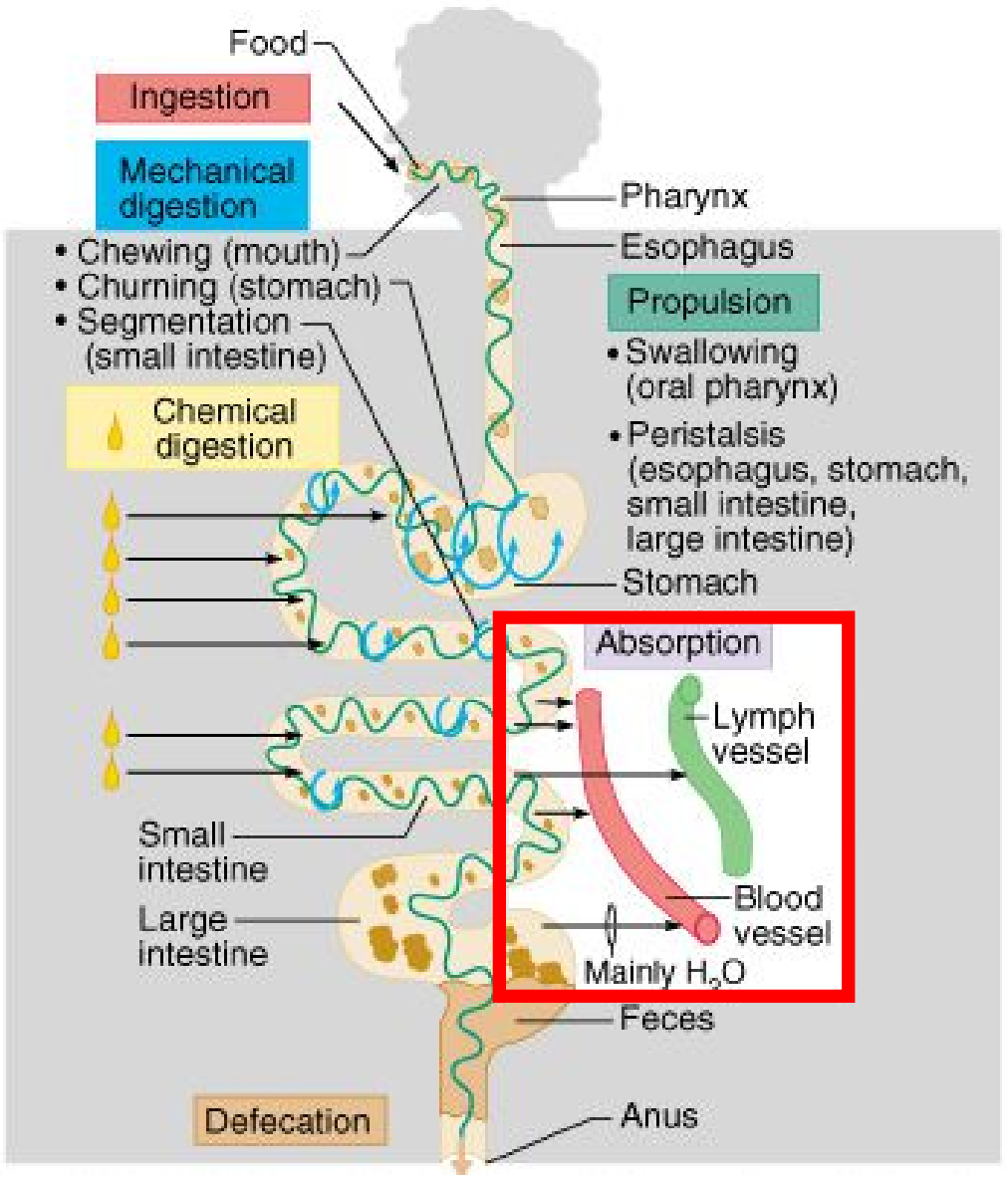
Movement of nutrients from GI tract to blood or lymph



Essential Activities of Digestive Process

1. Ingestion
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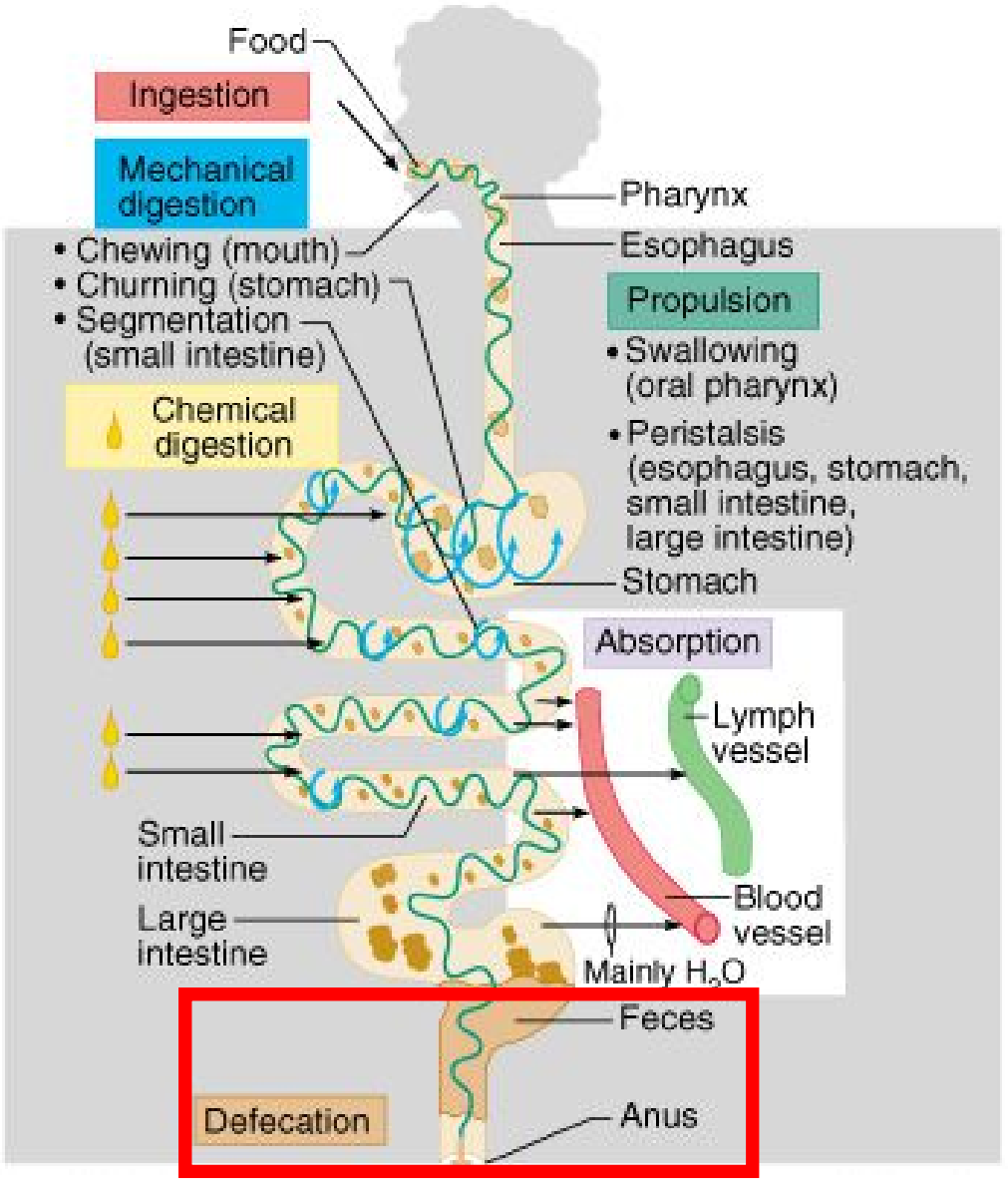
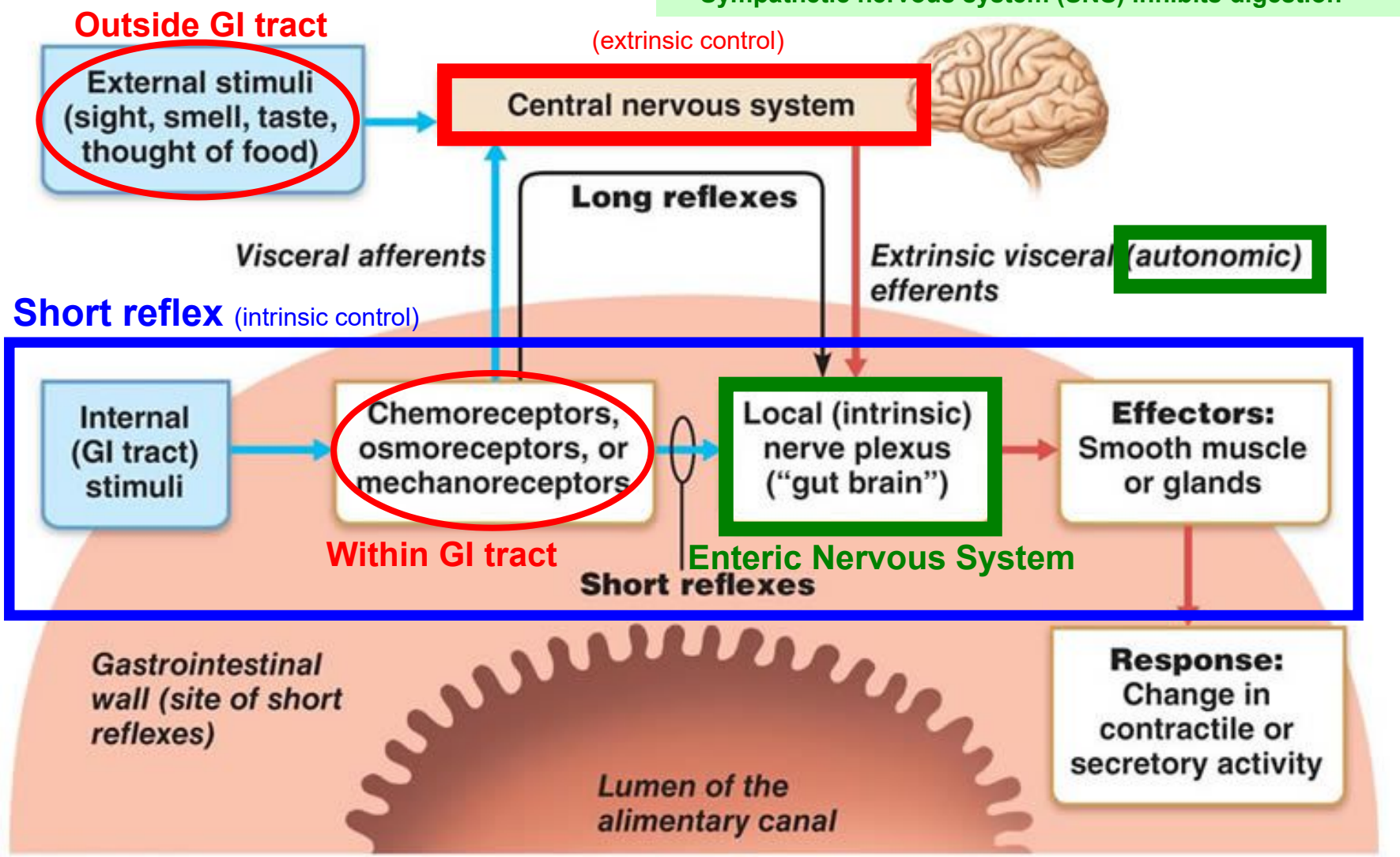
Elimination of indigestible wastes from GI tract



Neural Control of GI Tract

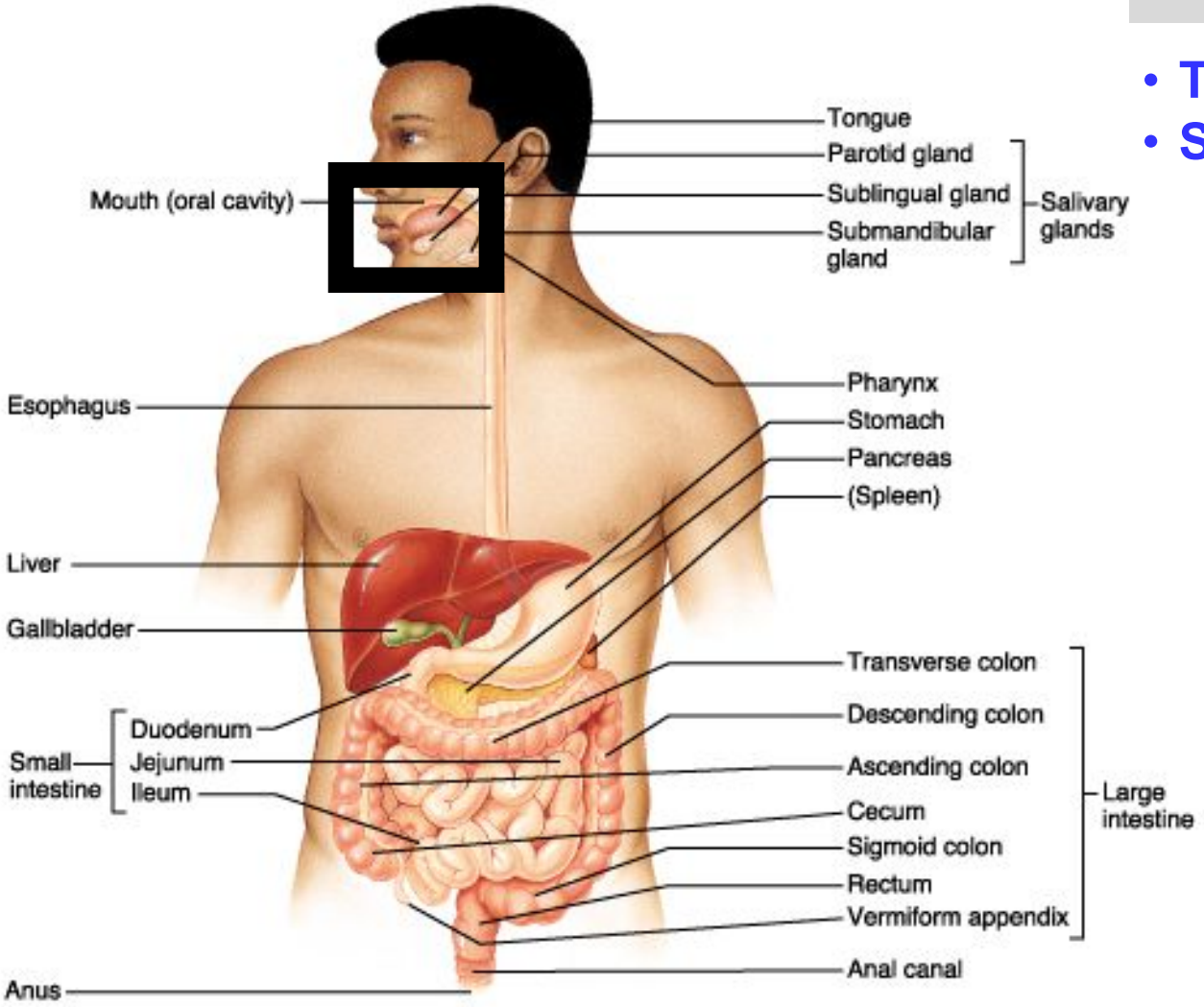
- Parasympathetic nervous system (PNS) stimulates digestion
- Sympathetic nervous system (SNS) inhibits digestion



- Food substrates / Digestion products / pH
- Osmolality
- Stretch

Mouth

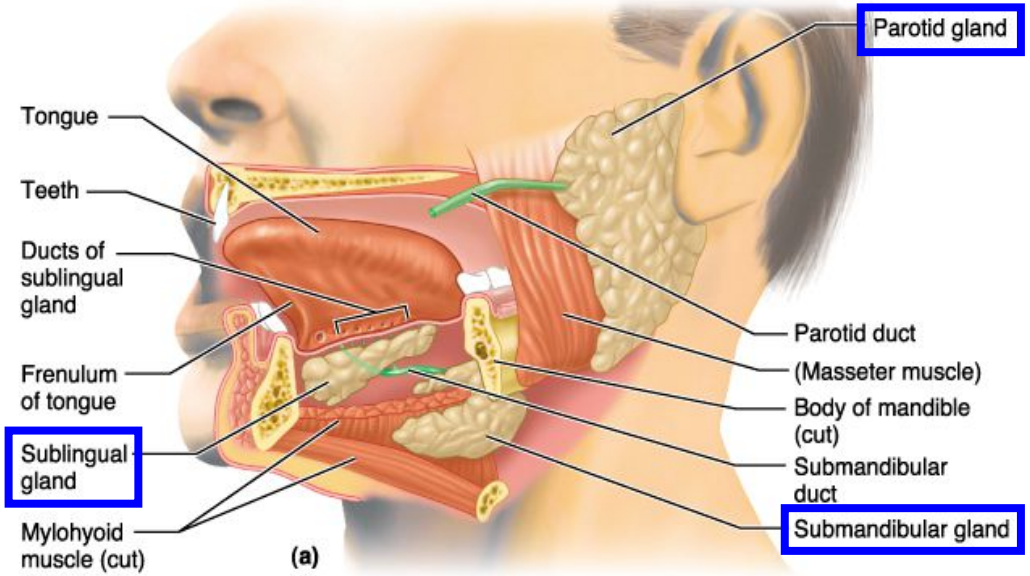
- **Teeth** (mechanical digestion)
- **Saliva** (chemical digestion)



Response: Change in contractile or secretory activity

Saliva

3 pairs of extrinsic glands



~99.5% water

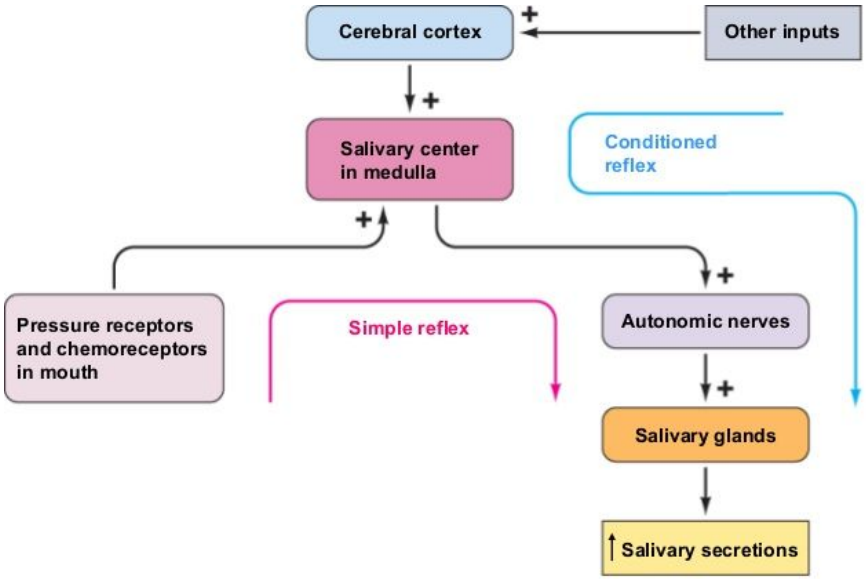
Major functions

- Cleanses the mouth
- Moistens & dissolves food
- Aids formation of bolus (food in a ready-to-be-swallowed state)
- Contains lysozyme to provides anti-bacterial protection
- Contains amylase for chemical digestion of starch
- Contains lingual lipase (from **von Ebner's gland** of the tongue) for chemical digestion of lipid

Regulation of Salivation

Salivation is mediated by neural reflexes upon:

- Presence of food (in mouth)
- Thought of food

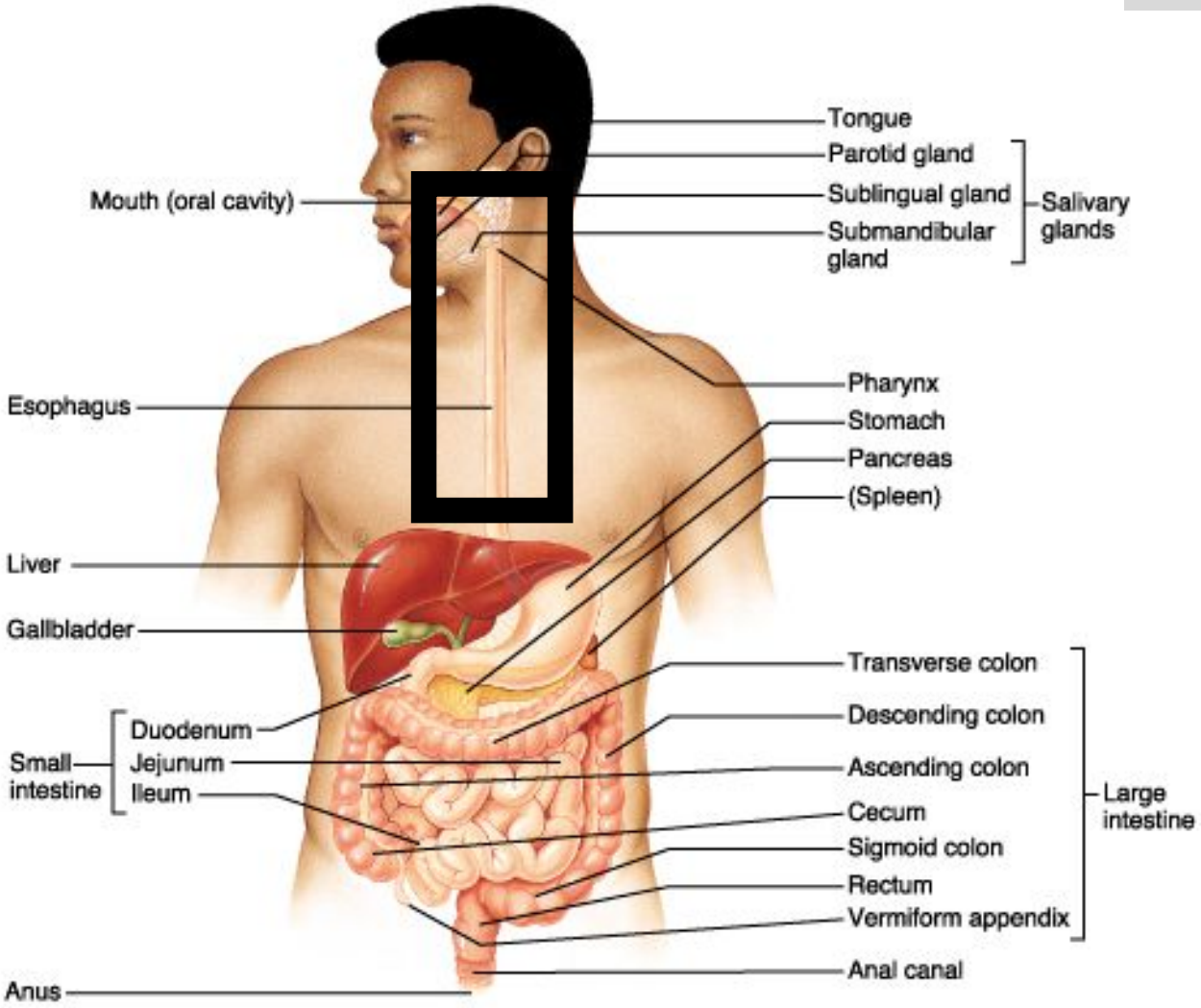


- **PNS** stimulates a large volume of watery saliva rich in enzymes
- **SNS** stimulates a small volume of thick saliva rich in mucus

(Mouth becomes dry when we are under stress)

Pharynx & Esophagus

- **Swallowing**
- **Peristalsis**

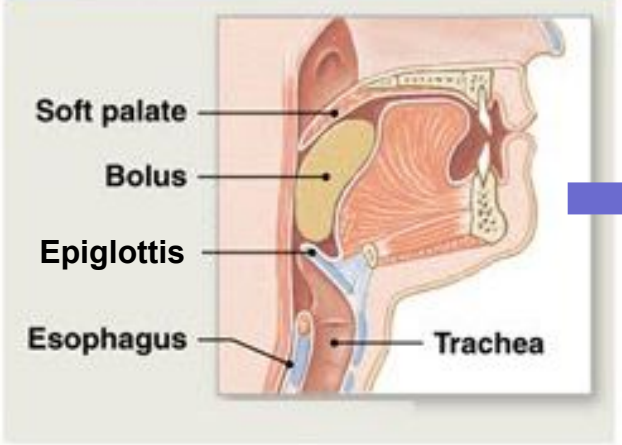


Response:
Change in contractile or secretory activity

Swallowing (Deglutition)

Complex neuromuscular activities

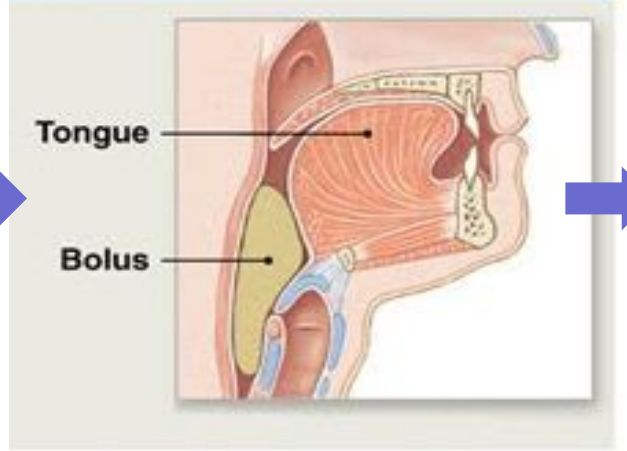
Buccal Phase



Voluntary

Bolus is forced posteriorly from buccal cavity into oropharynx

Pharyngeal Phase



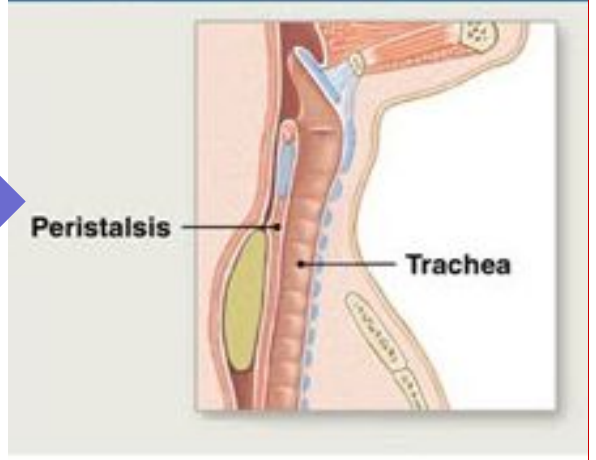
Involuntary

Soft palate is elevated to close nasopharynx

Epiglottis moves down to close larynx (preventing food from moving into trachea)

Pharyngeal constrictor muscles **contract** to move food towards esophagus

Esophageal Phase



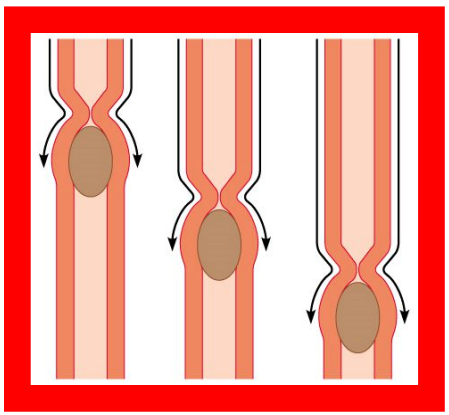
Involuntary

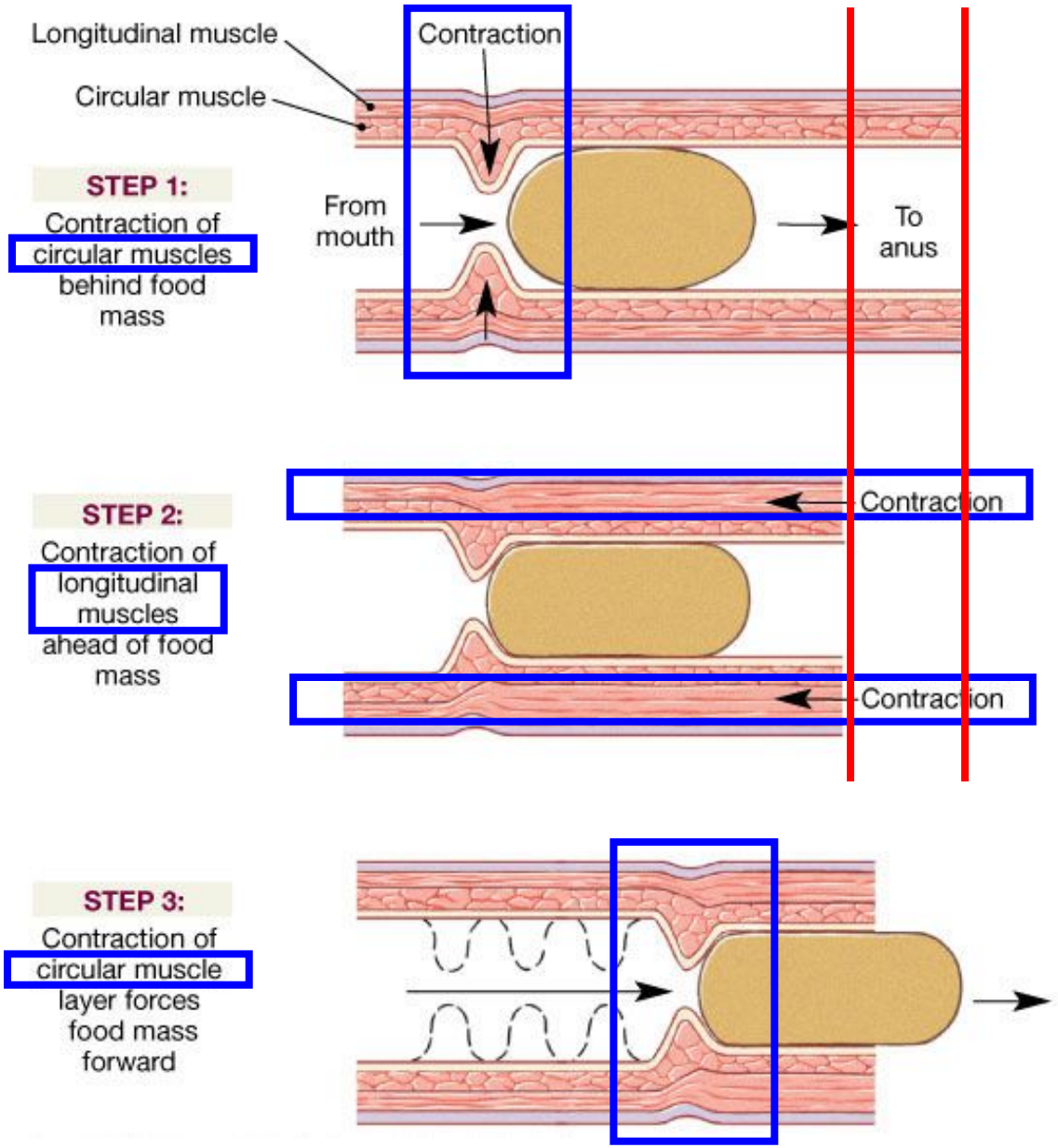
Upper esophageal sphincter **relaxes** to let food pass into esophagus

Esophageal peristalsis moves food from pharynx to esophagus

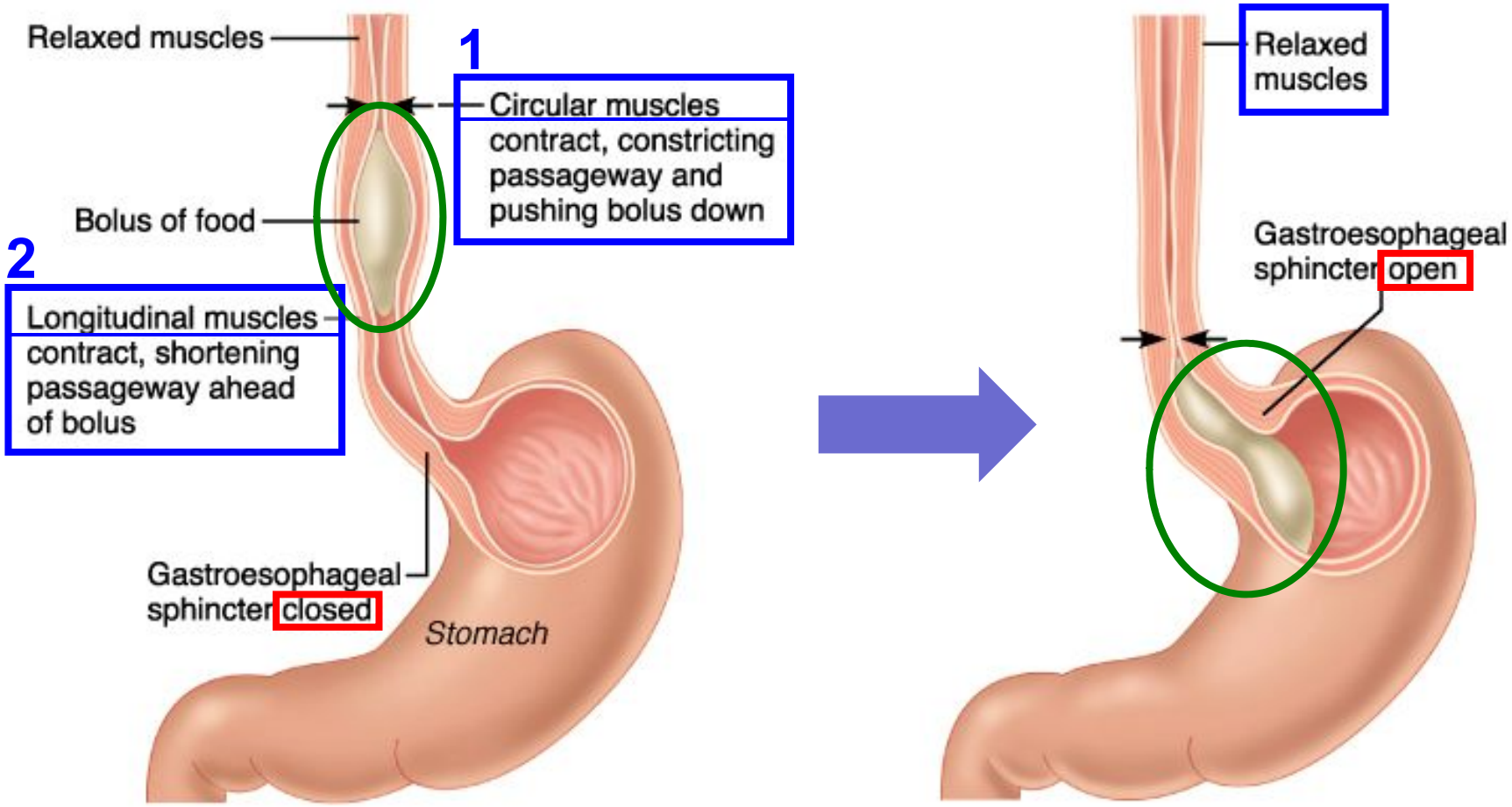
Peristalsis

Series of wave-like muscle contraction & relaxation
(to push food mass forward)

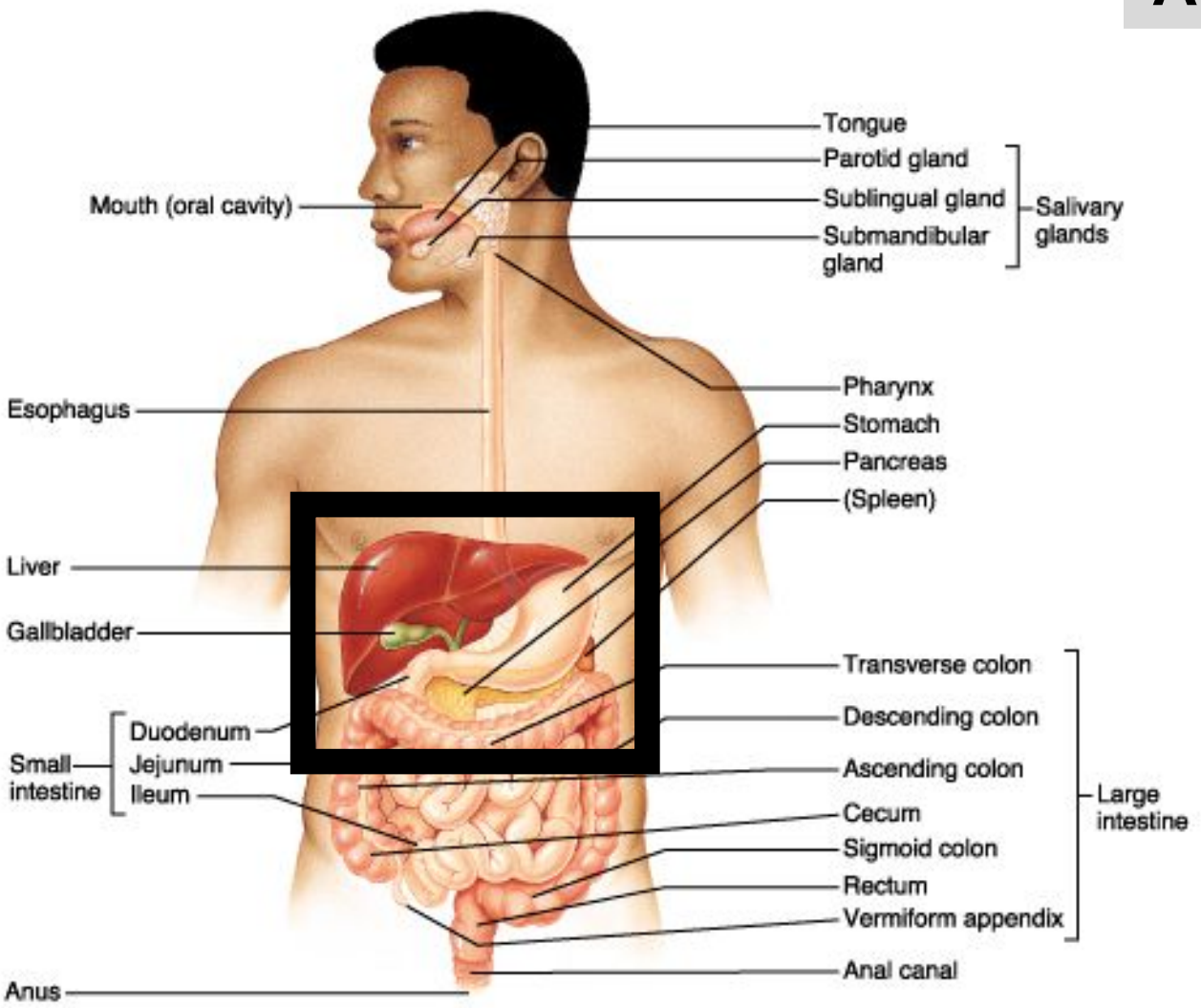




Peristalsis



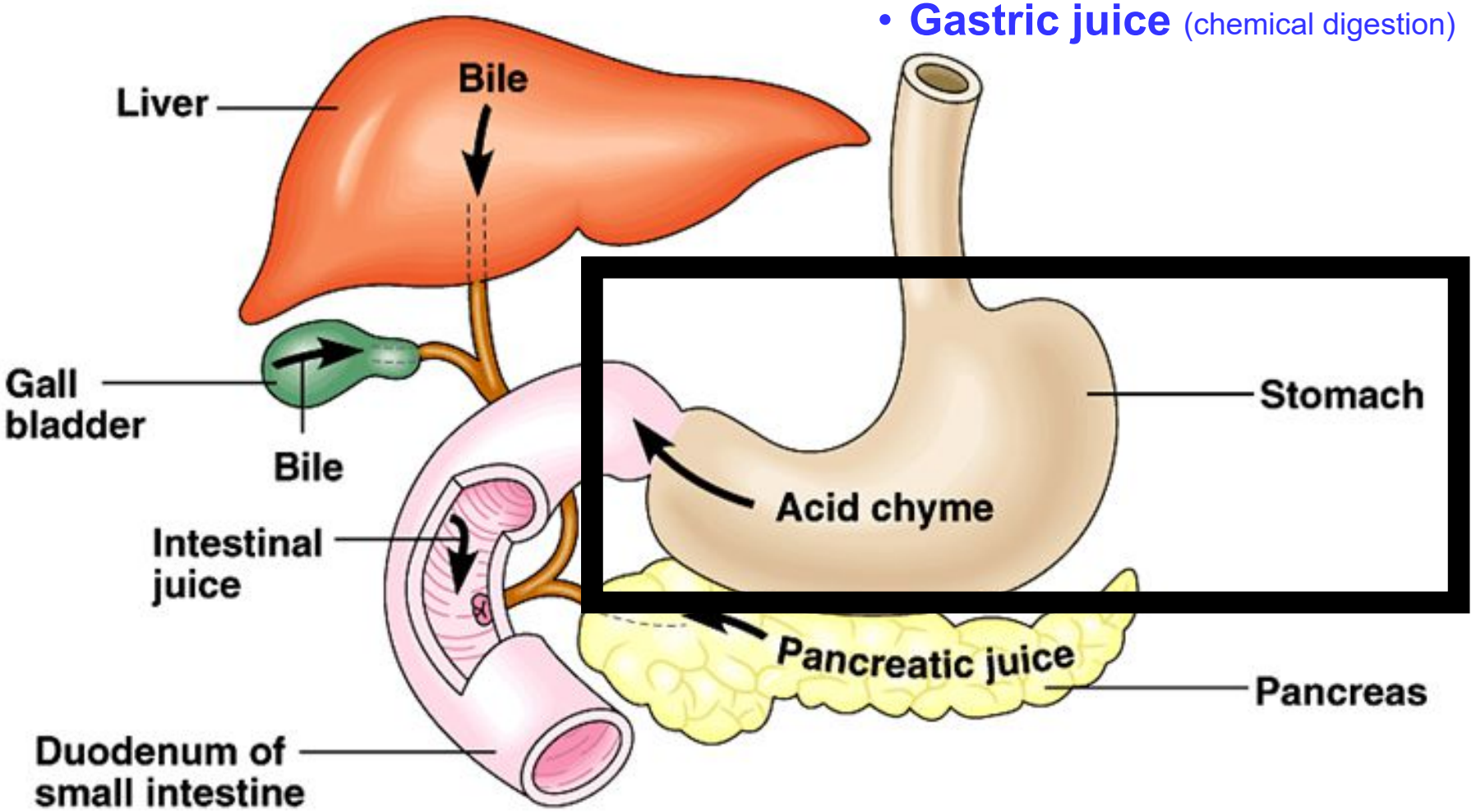
Abdominal Organs



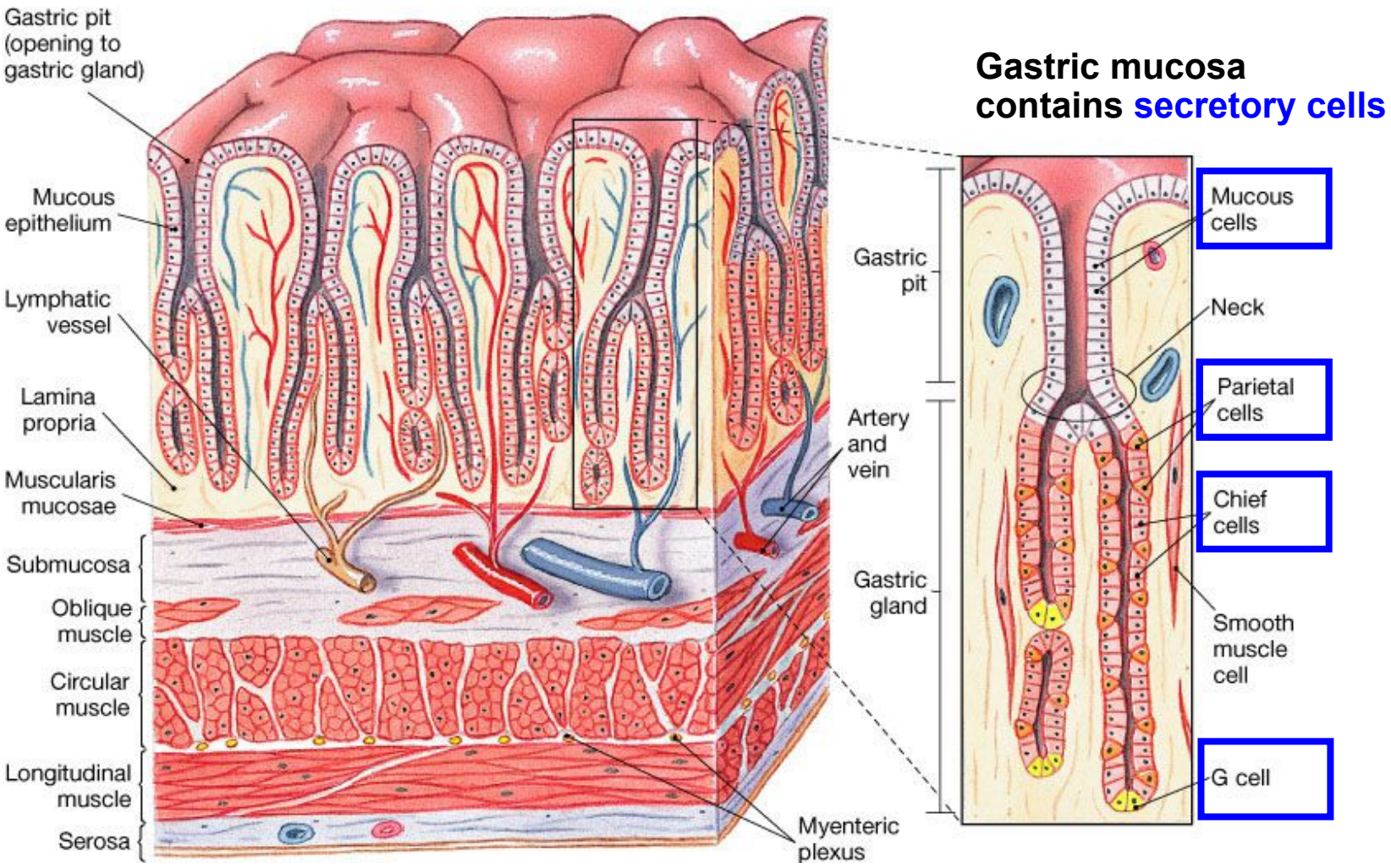
Response: Change in contractile or secretory activity

Stomach

- **Churning** (mechanical digestion)
- **Gastric juice** (chemical digestion)



Gastric Secretions



Gastric mucosa contains secretory cells

Gastric Secretions

Chief (peptic) cells

- **Pepsinogen** (inactive)
- **Gastric lipase**

Parietal (oxyntic) cells

- **Hydrochloric acid (HCl)** (activates pepsinogen to **pepsin**)
- **Intrinsic factor** (is required for vitamin B_{12} absorption)

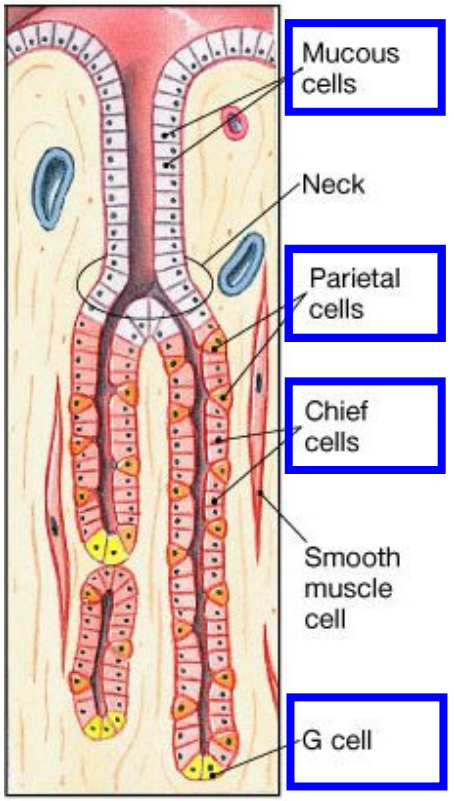
G cells

- **Gastrin** (hormone that stimulates parietal & chief cells)

Mucous cells

- **Mucus** (protects stomach wall by forming a barrier against pepsin & acid)

Gastric mucosa contains secretory cells

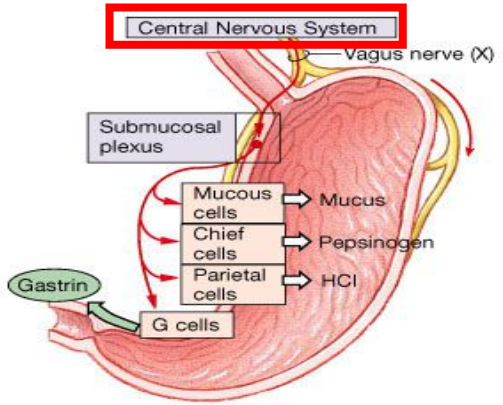


Protein digestion is initiated in the stomach

Regulation of Gastric Activities

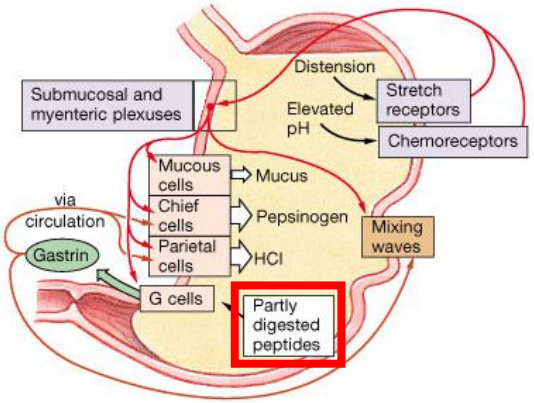
Cephalic Phase (minutes)

- **Function:** Prepare stomach for arrival of food



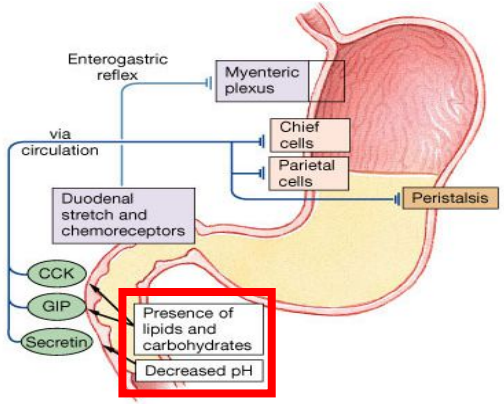
Gastric Phase (~3 hours)

- **Functions:** Homogenize & acidify chyme +
  Initiate protein digestion by pepsin



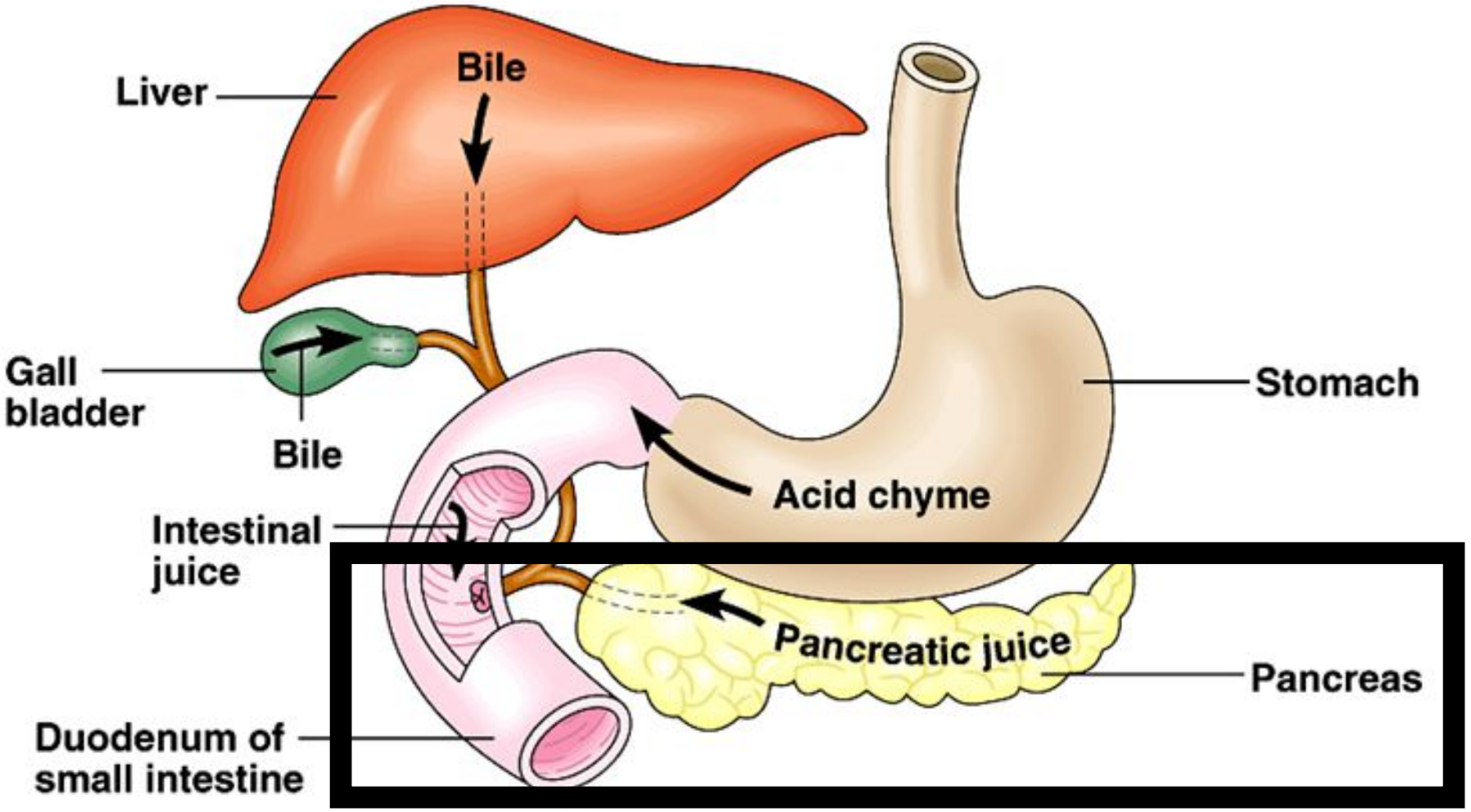
Intestinal Phase (hours)

- **Function:** Control rate of chyme entry into duodenum

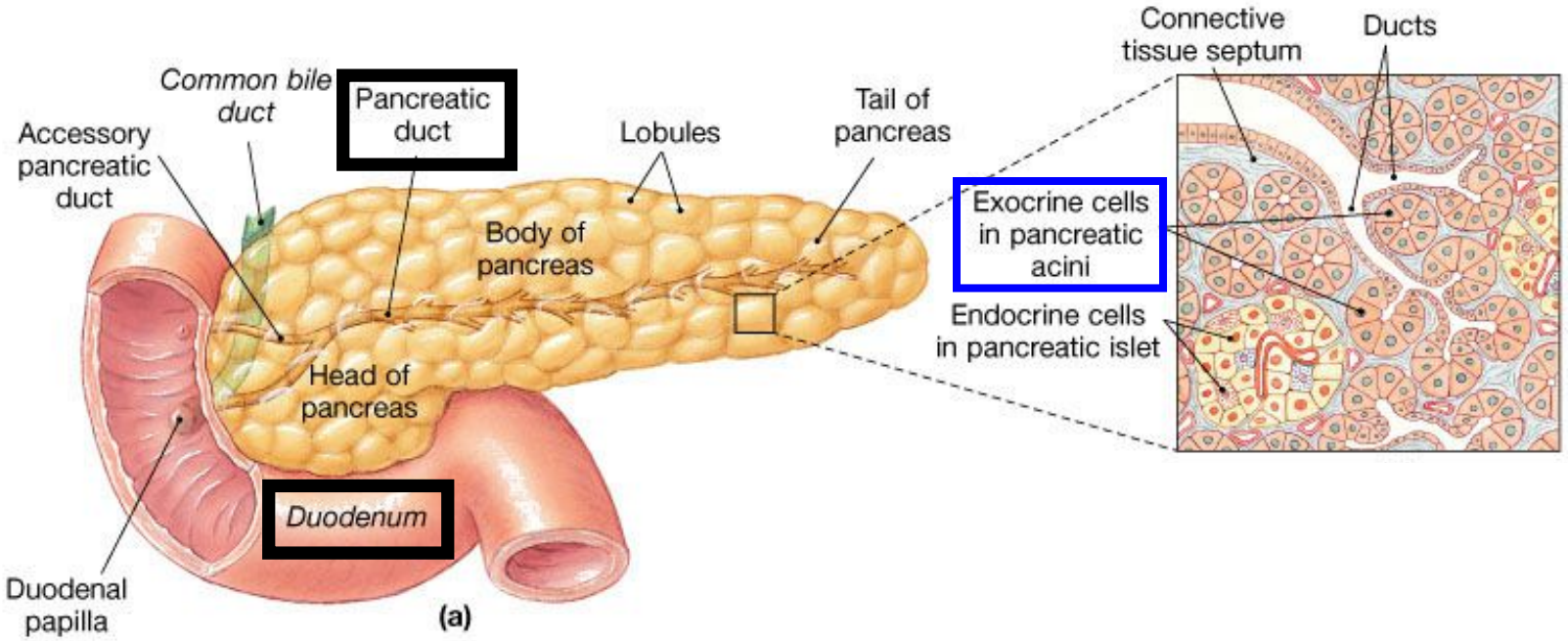


Pancreas

- **Pancreatic juice** (chemical digestion)



Pancreas



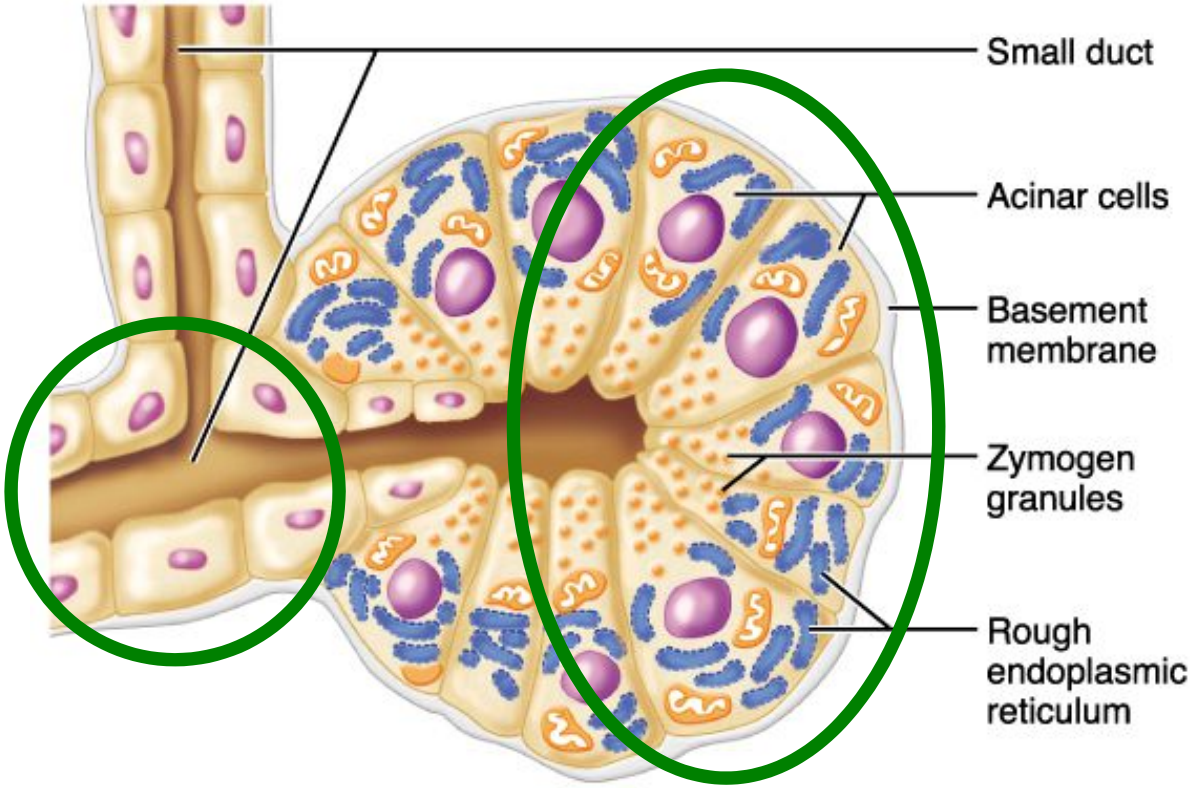
Exocrine function:

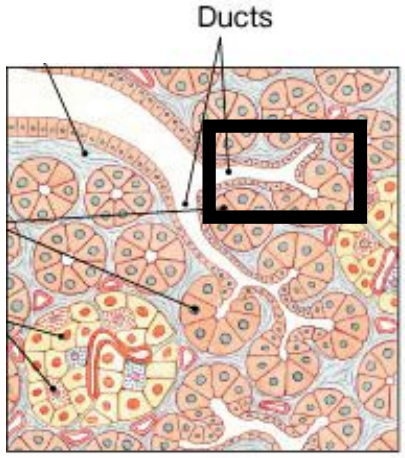
- Secretes pancreatic juice

Endocrine function:

- Release insulin & glucagon

Pancreatic Juice





Ductal cells

Bicarbonate (HCO_3^-)

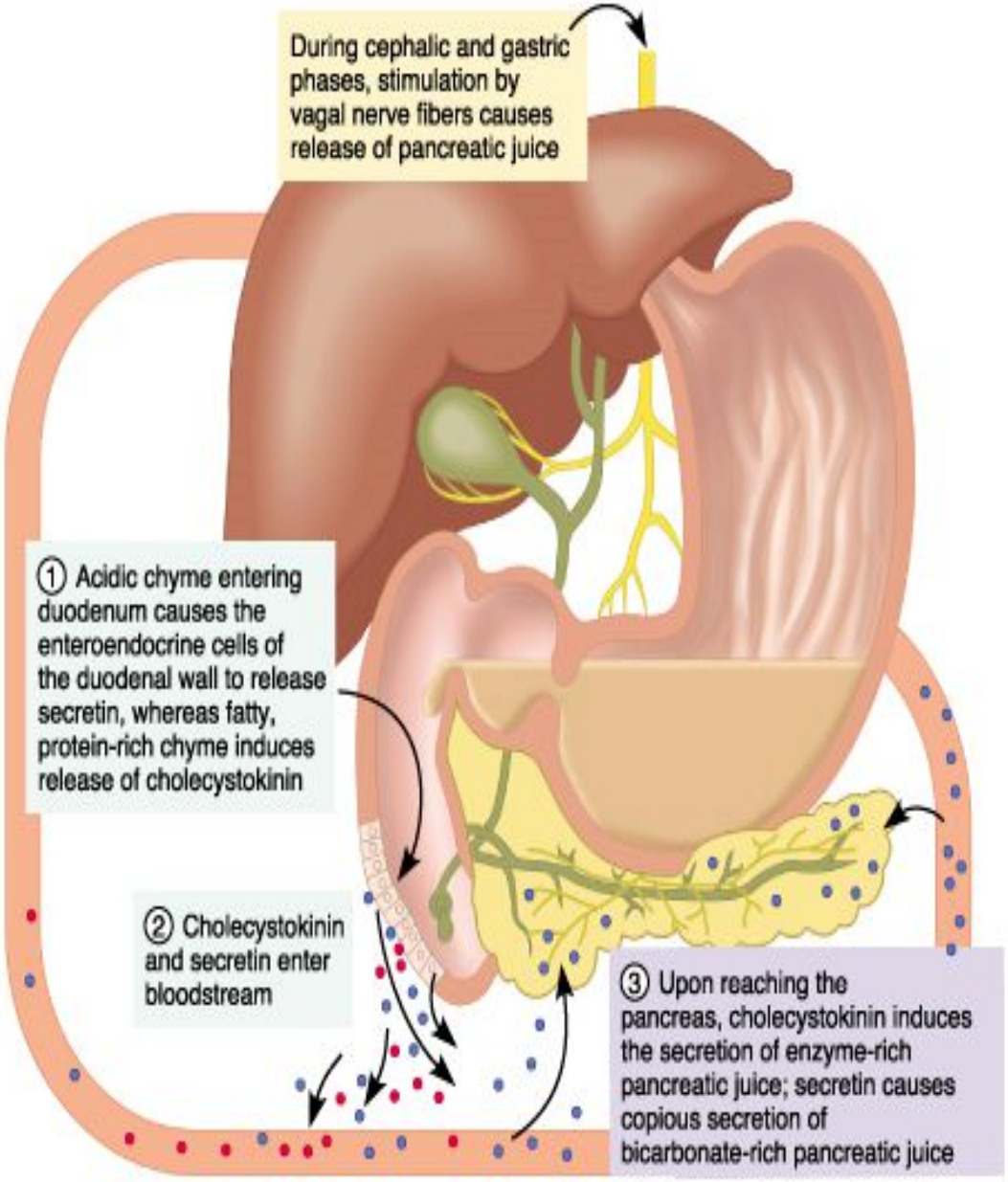
- Neutralizes gastric acid
- Provides optimal pH for pancreatic enzymes to work in small intestine

Acinar cells

Enzymes

- Amylase / Lipases / Nucleases (active)
- Trypsinogen / Chymotrypsinogen (inactive)

Regulation of Pancreatic Secretion



Chyme stimulates duodenum to release the hormones secretin & cholecystokinin into blood

Secretin

→ **Pancreas** secretes HCO_3^--rich juice

Cholecystokinin

→ **Pancreas** secretes enzyme-rich juice

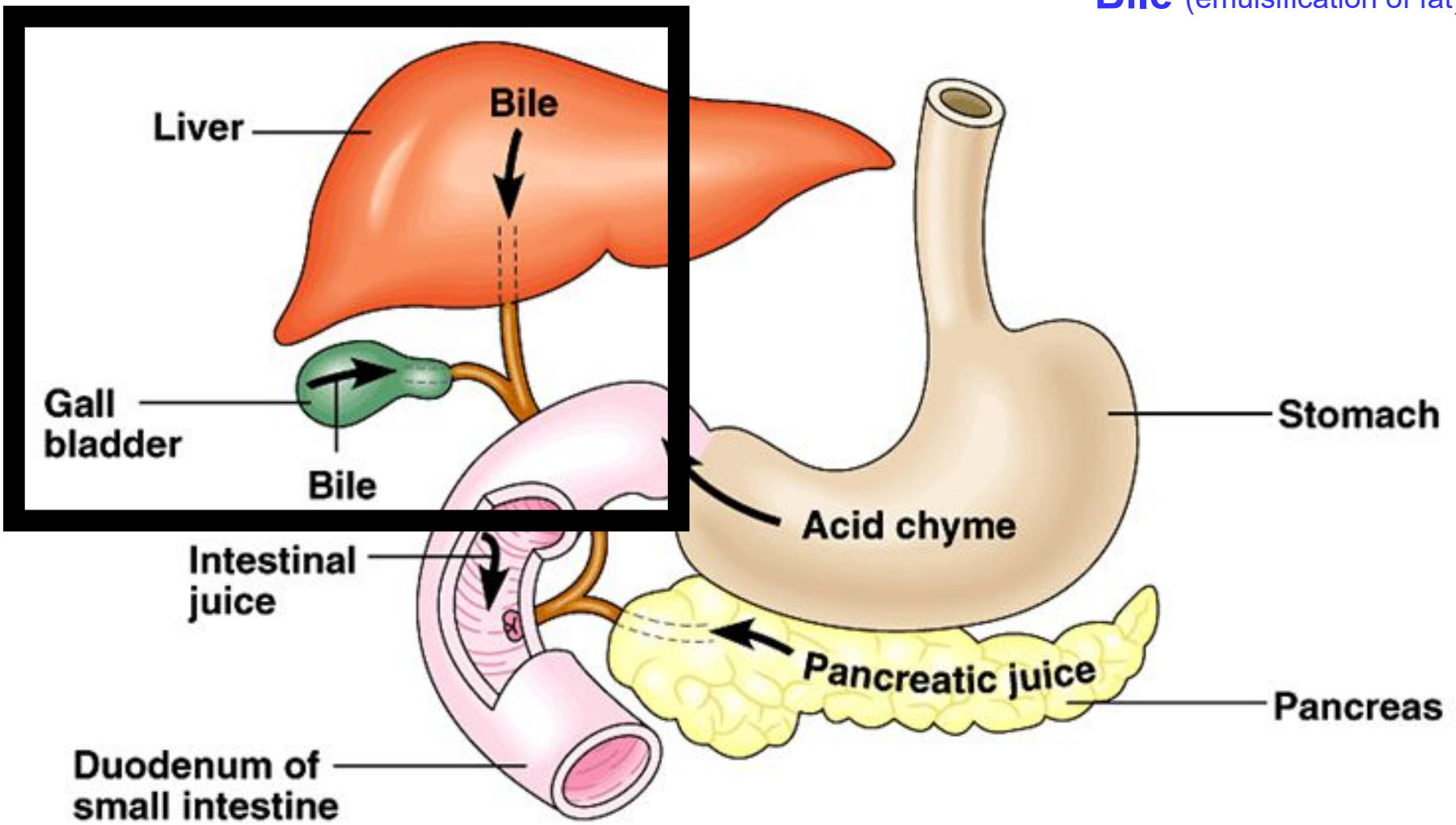
Activation of vagus nerve

→ **Pancreas** secretes

Pancreatic juice enters duodenum

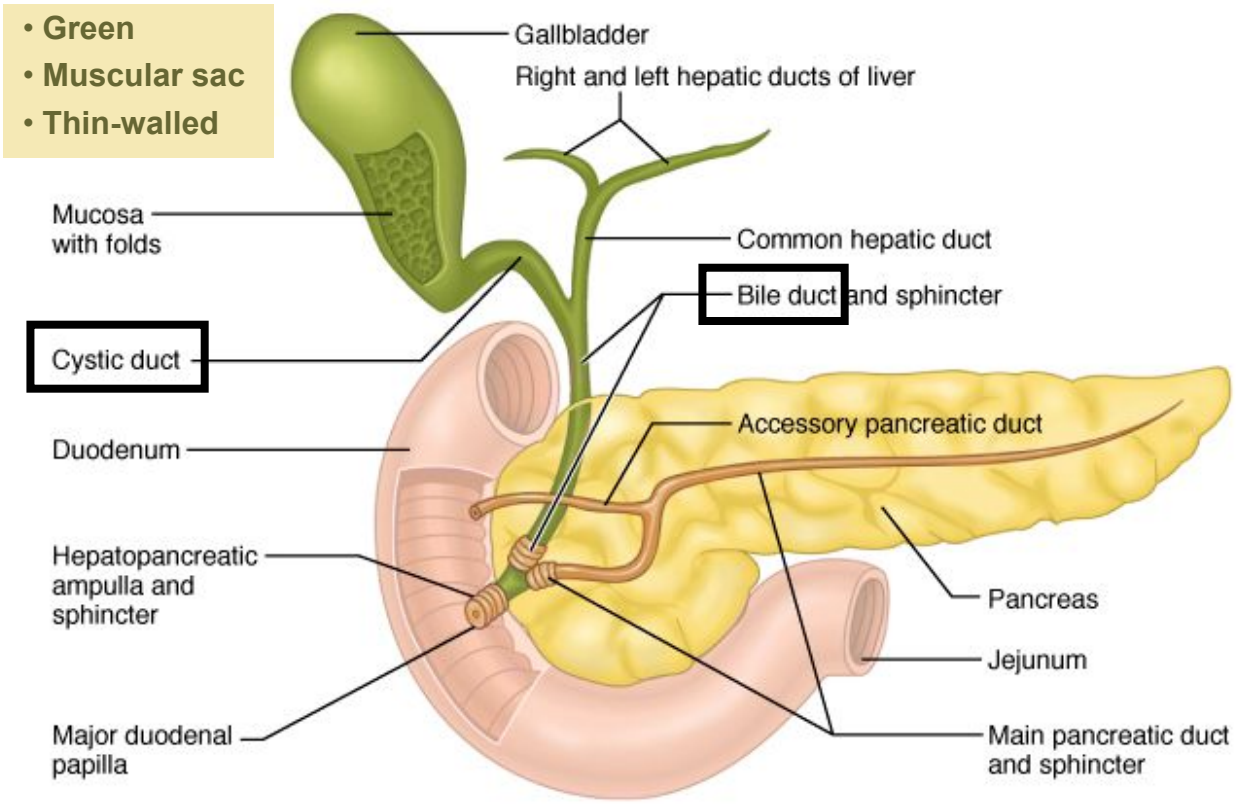
Liver & Gall Bladder

- **Bile** (emulsification of fat)



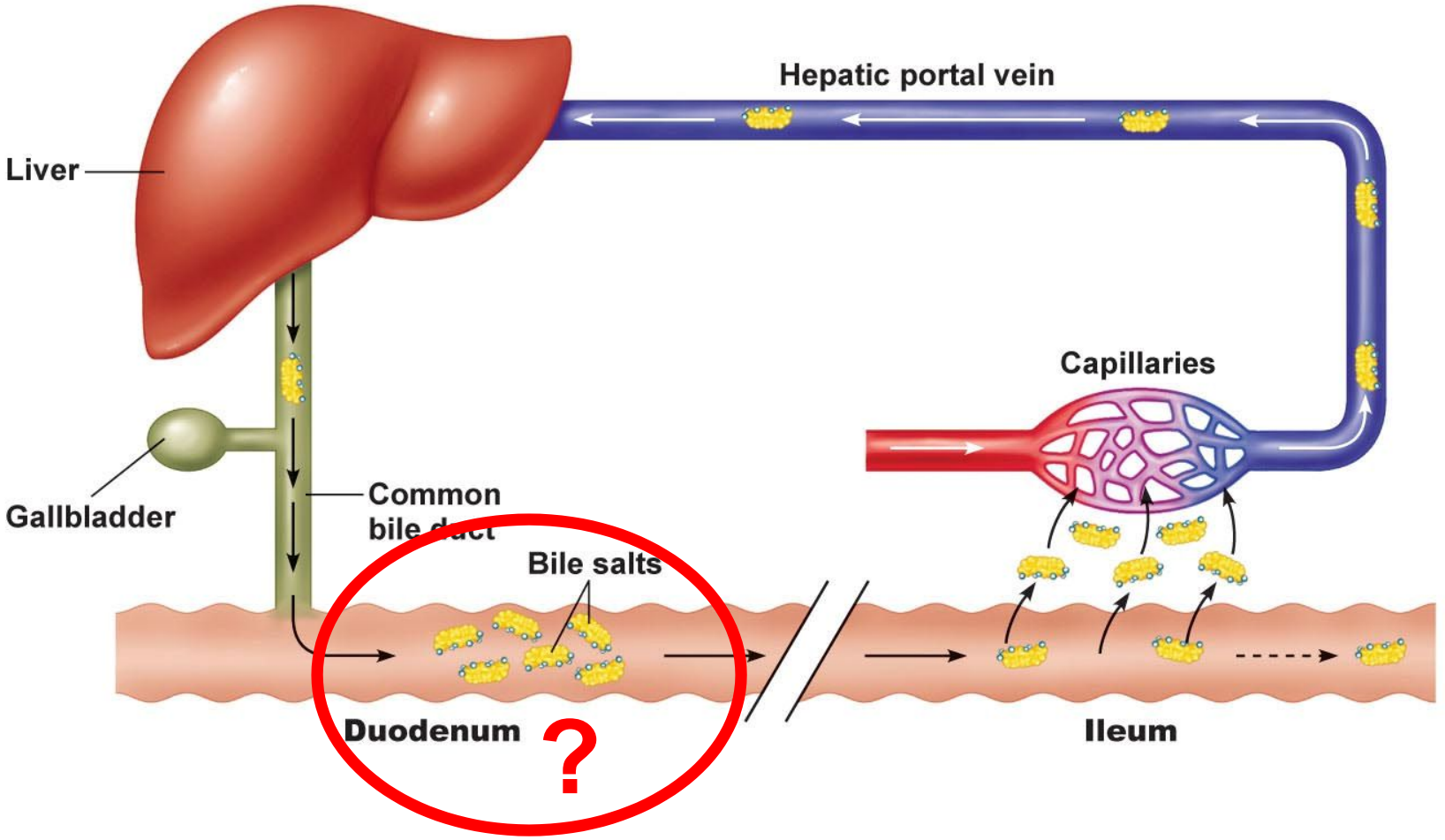
Bile Production & Release

- **Liver** produces **bile**
- **Gallbladder** **stores & concentrates** **bile**
  (by absorbing water during inter-digestive period)
- **Gallbladder** **releases** **bile** via **cystic duct** into **bile duct**



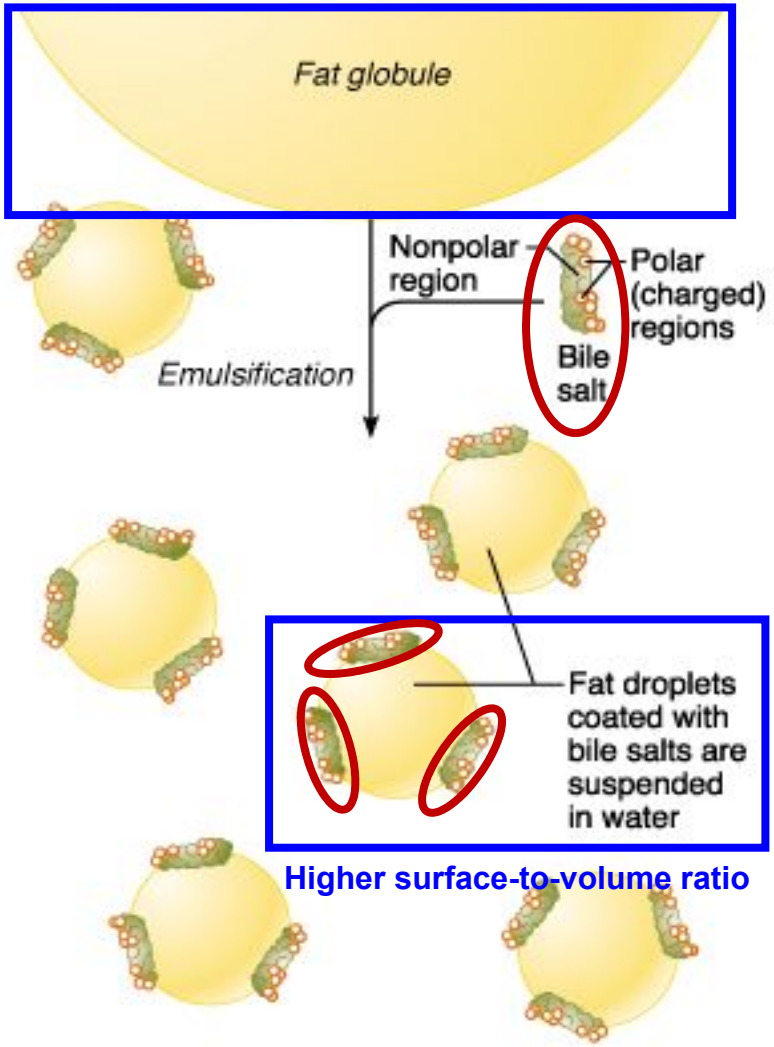
Bile Production & Release

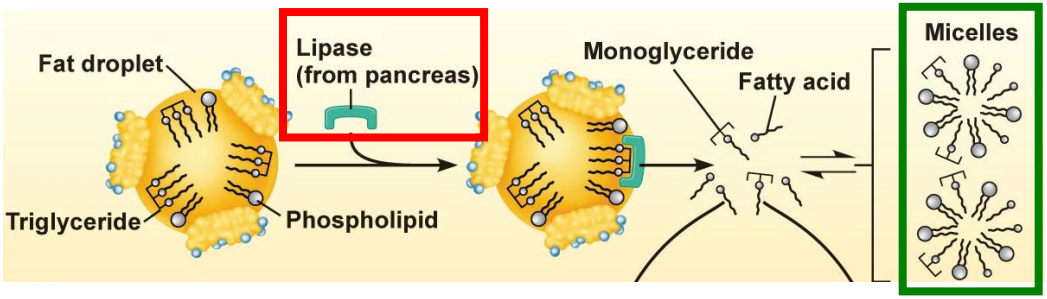
Bile salts are **absorbed in ileum** & **recycled by liver** via **enterohepatic circulation**



Action of Bile Salts

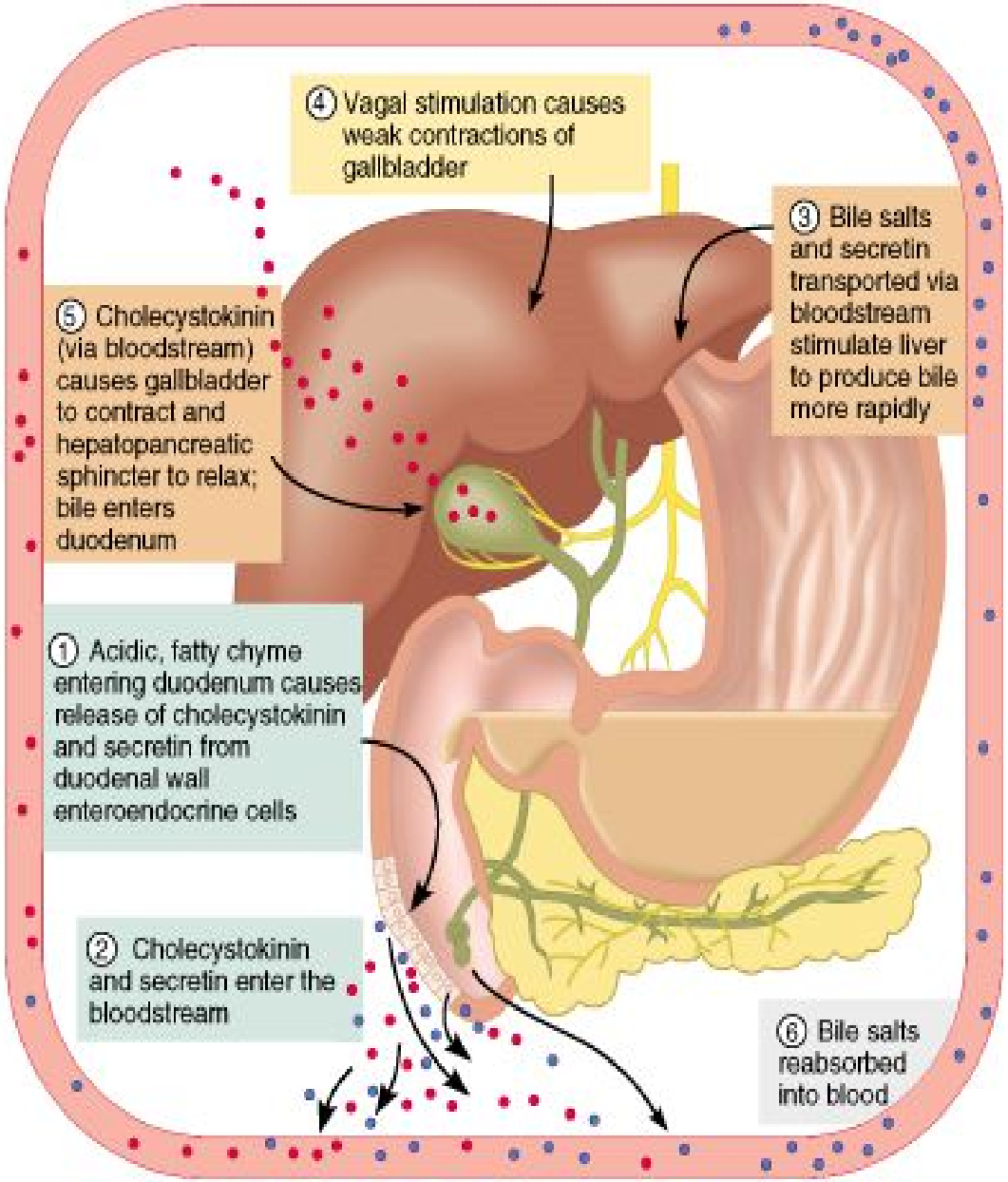
Bile salts emulsify **fat globules** into **droplets** that mix with water more readily





Pancreatic lipases digest triglycerides on the surface of lipid droplets, releasing fatty acids & monoglycerides (which form micelles).

Regulation of Bile Production & Release



Chyme stimulates duodenum to release the hormones secretin & cholecystokinin into blood

Secretin & **bile salts**

→ **Liver** produces bile

Cholecystokinin

→ **Gallbladder** contracts

→ **Hepatopancreatic sphincter** relaxes

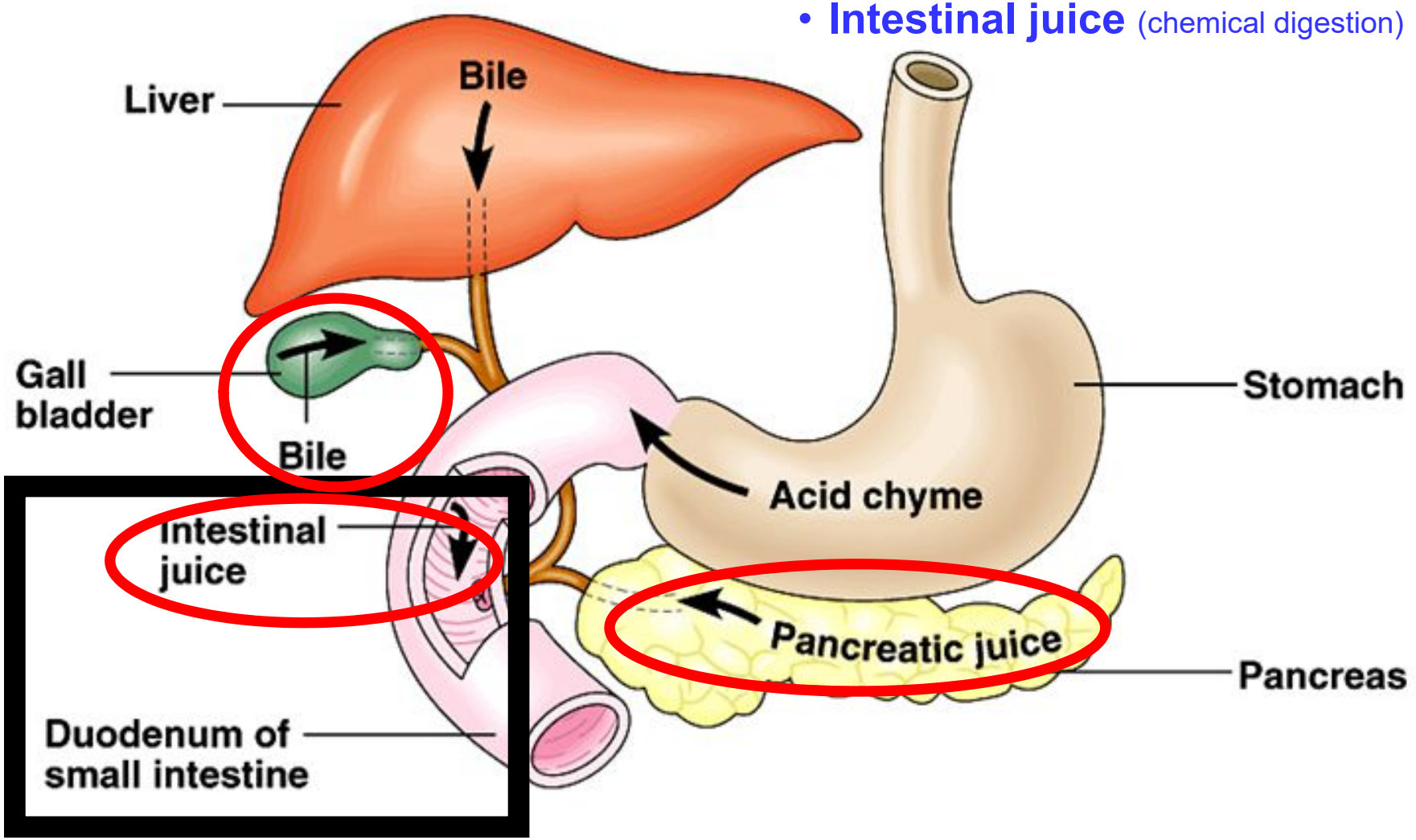
Activation of vagus nerve

→ **Gallbladder** contracts

Bile enters duodenum

Small Intestine

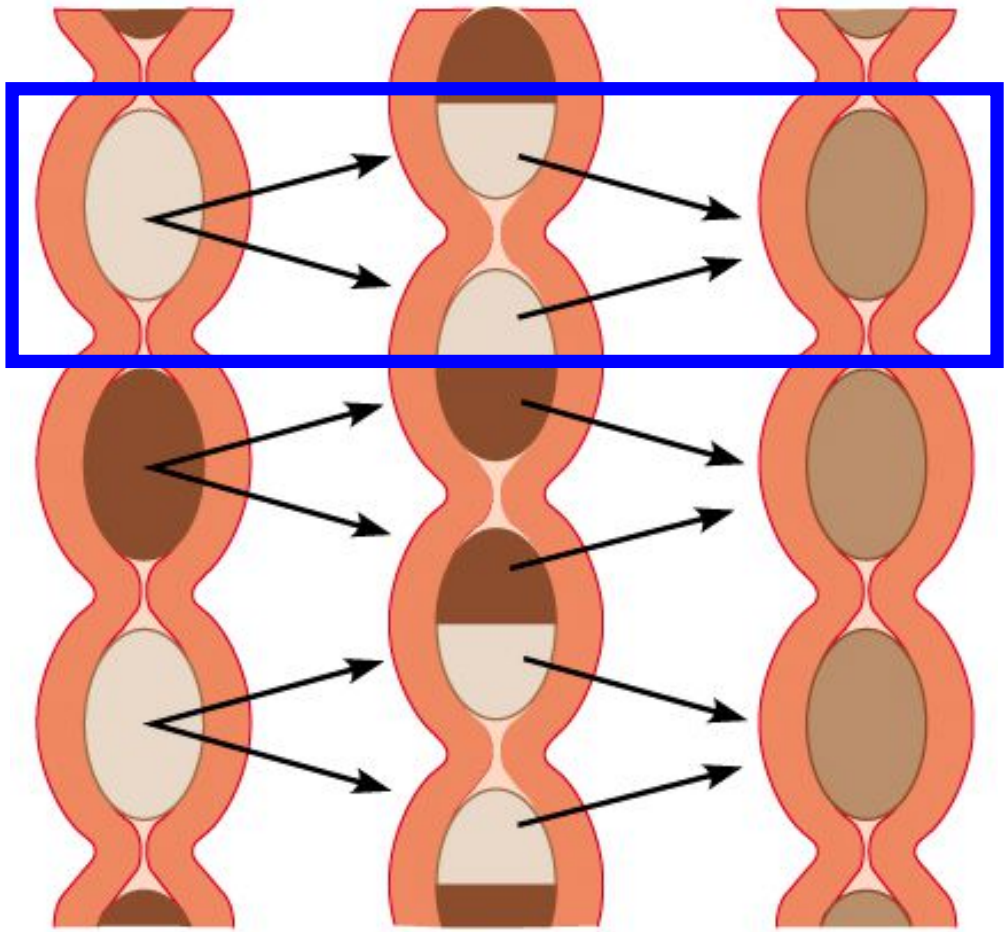
- **Segmentation** (mechanical digestion)
- **Intestinal juice** (chemical digestion)



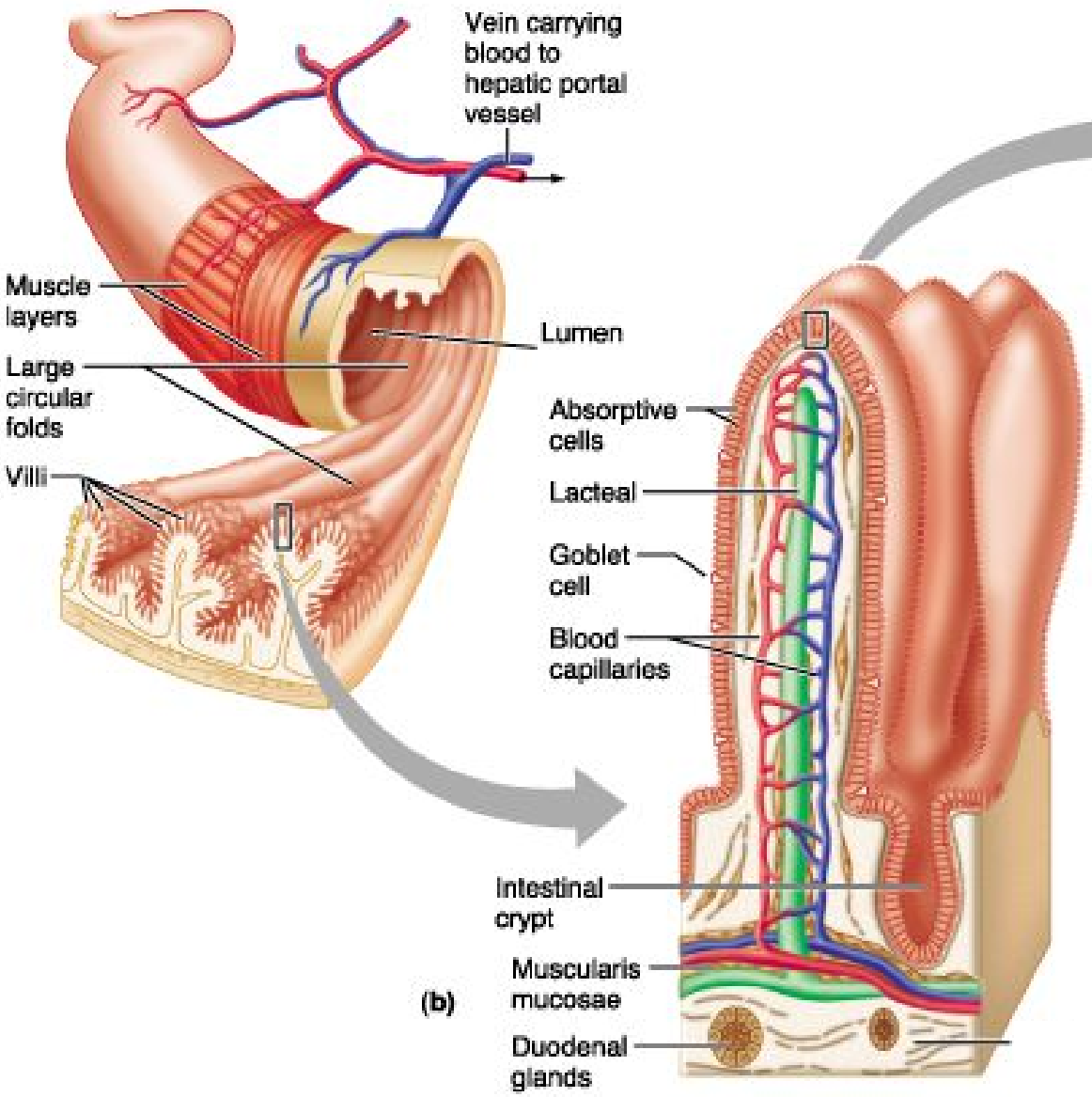
Most nutrients are absorbed in small intestine

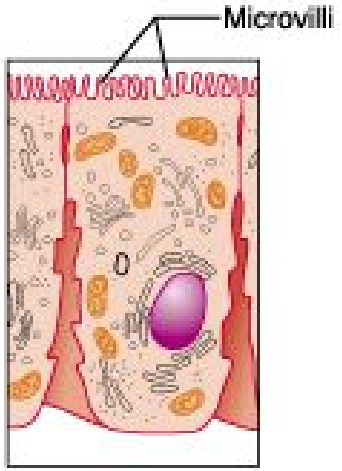
Segmentation

Churning & fragmentation of food substances



Intestinal Secretion





Brush border enzymes

(at apical membrane of absorptive cells lining small intestines)

Goblet cells

- **Mucus**

Brunner's glands (in duodenum)

- **Mucus** (thick, alkaline)

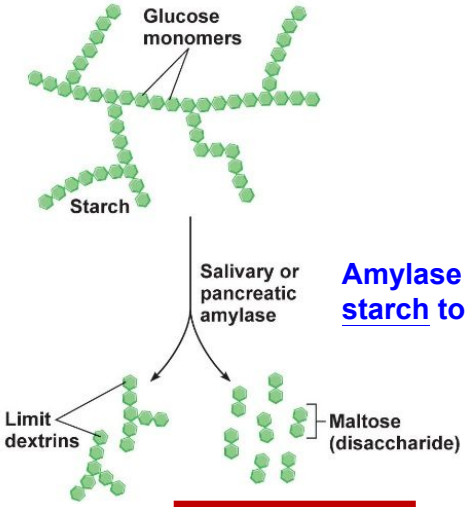
Intestinal crypt cells

Intestinal juice

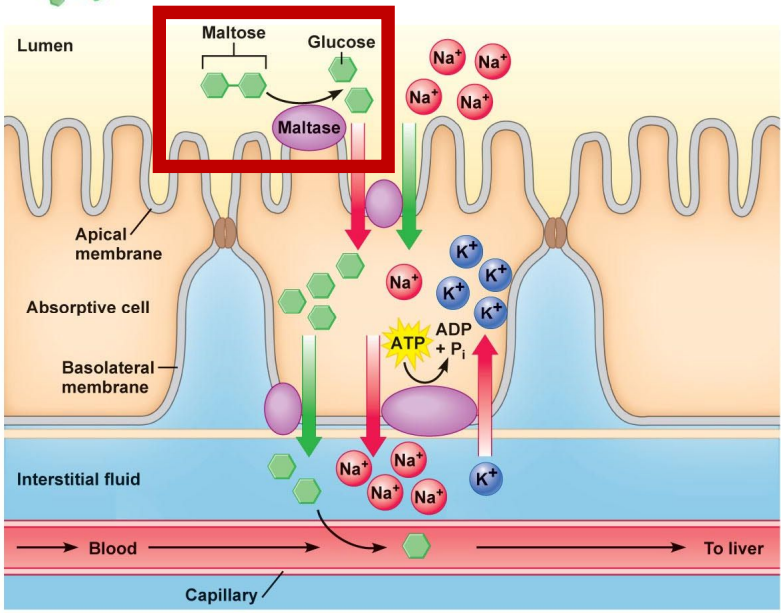
small amount of digestive enzymes

Intestinal Secretion

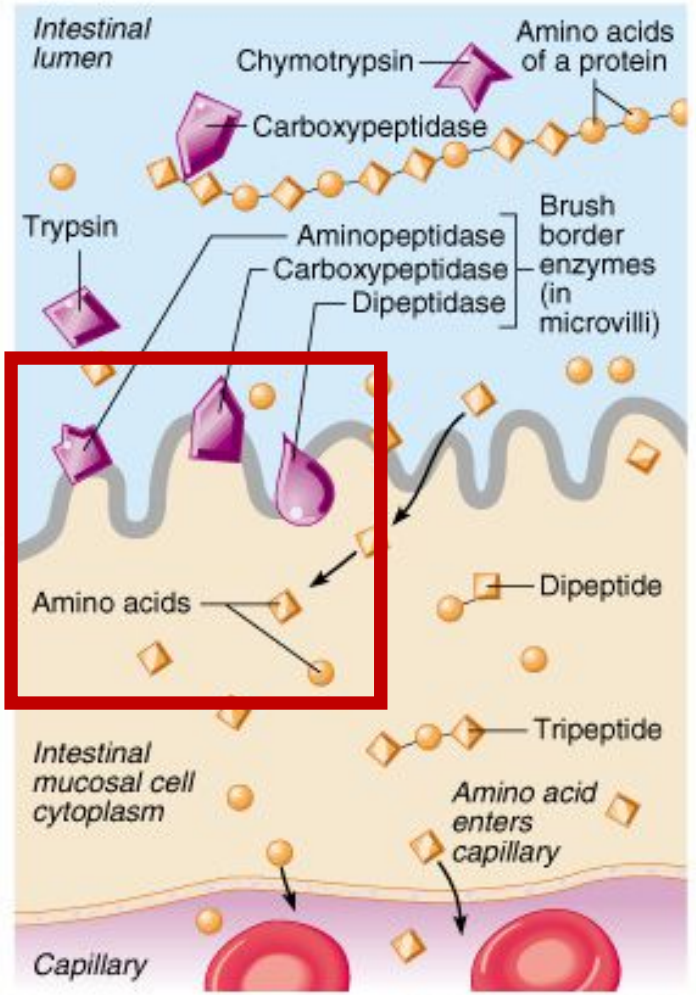
Brush border enzymes are required to complete digestion



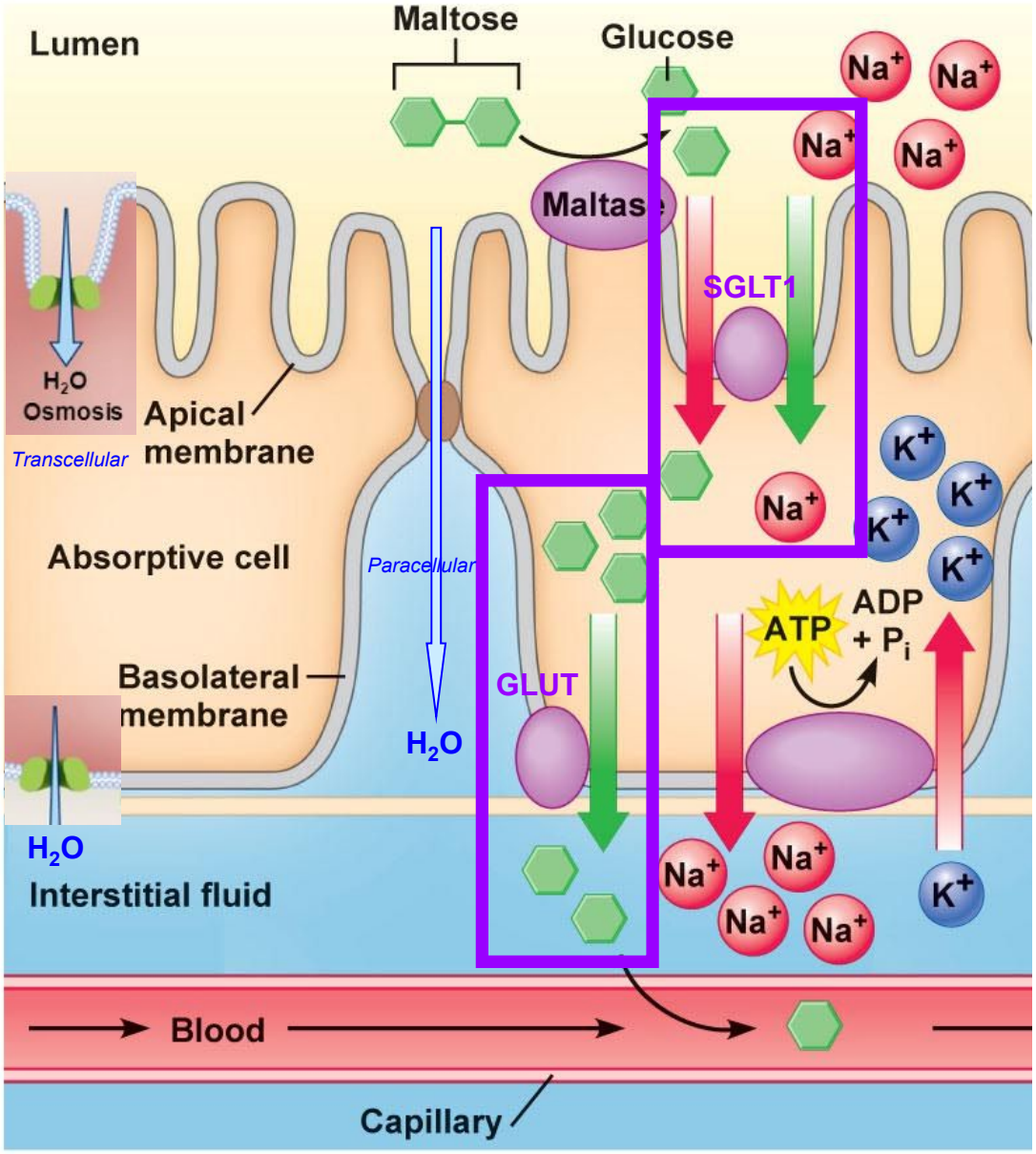
Amylase cannot break down starch to glucose monomers



Trypsin & chymotrypsin cannot break down protein into amino acids

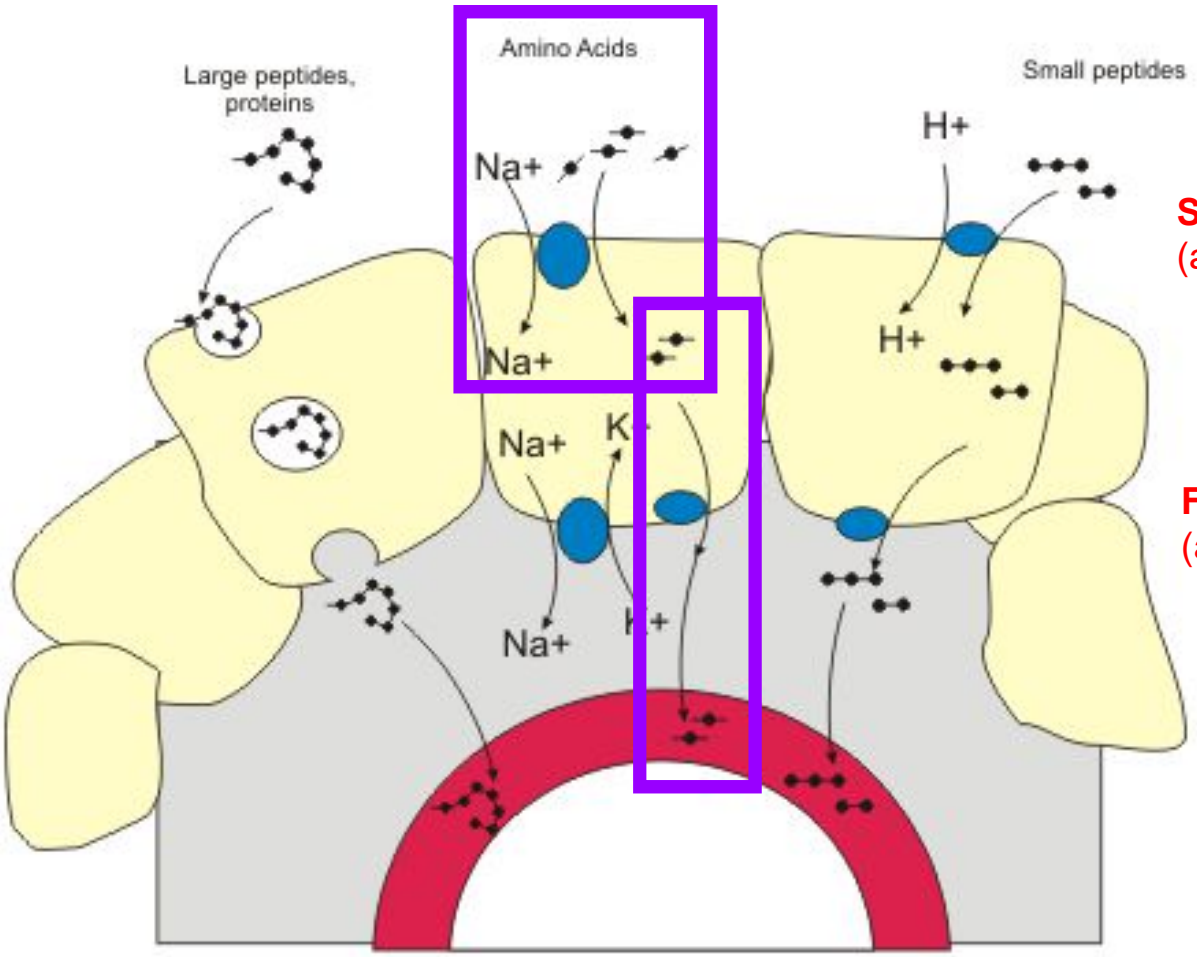


Absorption of Glucose / Sodium / Chloride / Water



1. Na^+-K^+ ATPase maintains low Na^+ concentration using energy (primary active transport)
2. Concentration difference between luminal & intracellular Na^+ allow absorption of Na^+ (diffusion), together with absorption of glucose via Na^+-glucose cotransporter (secondary active transport) into enterocytes
3. Glucose leaves enterocytes via glucose transporter (facilitated diffusion)
4. Na^+ is removed from enterocytes by Na^+-K^+ ATPase
5. Accumulation of glucose & Na^+ in interstitial fluid (high osmolality) causes water absorption (osmosis)
6. Accumulating glucose, Na^+ & water in interstitial space enter capillaries (diffusion / osmosis)
7. Chloride absorption is coupled to Na^+ absorption (by following electrochemical gradient established by Na^+)

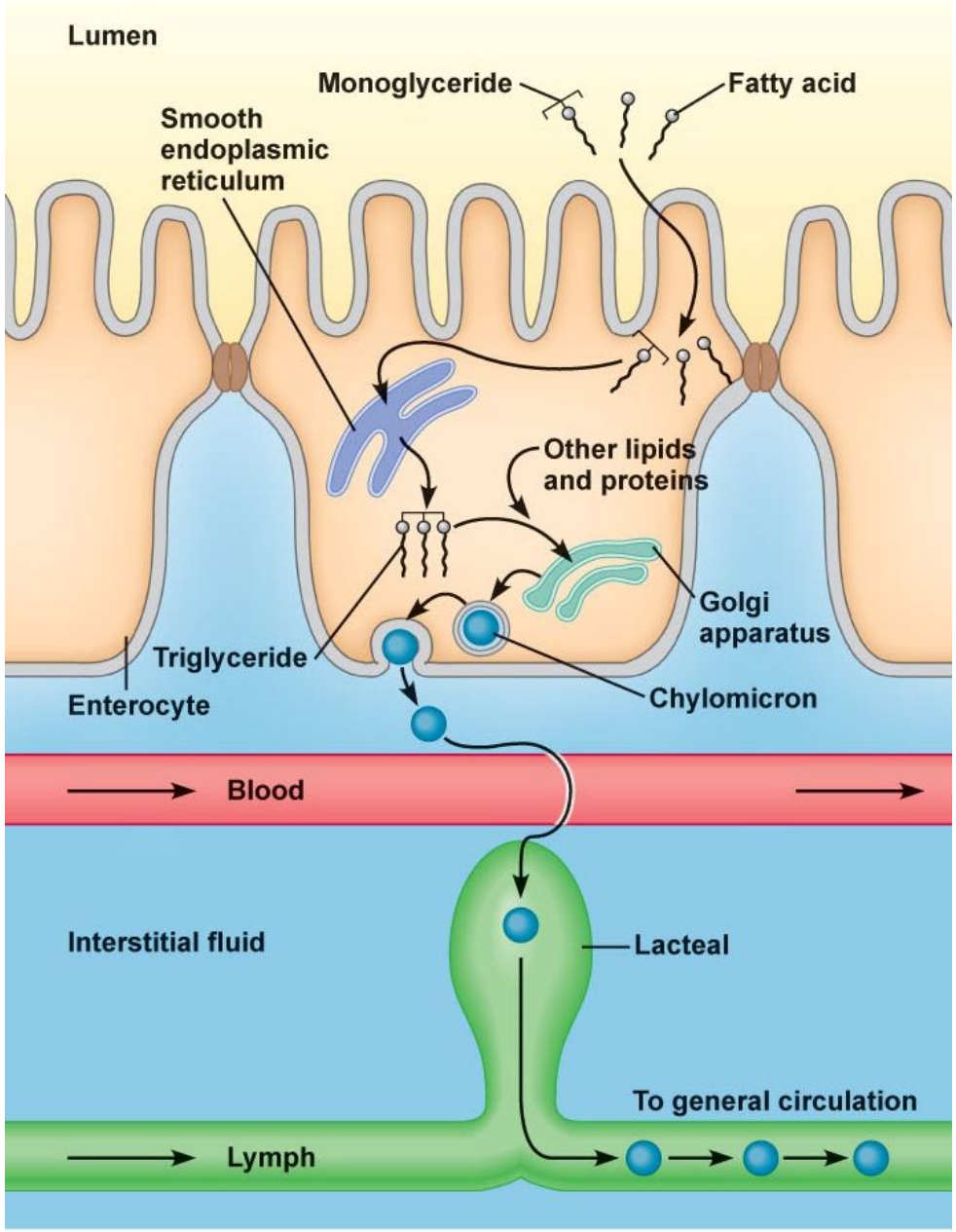
Absorption of Amino Acids



Secondary active transport
(across apical membrane)

Facilitated diffusion
(across basolateral membrane)

Absorption of Fatty Acids



1. **Free fatty acids & monoglycerides** enter **enterocytes** by **simple diffusion**
2. **Triglycerides** are re-synthesized & combined with proteins to form **chylomicrons**
3. **Chylomicrons** are secreted across the basolateral membrane by **exocytosis**
4. **Chylomicrons** enter **lacteals**
5. **Chylomicrons** are transported by lymph to the **circulation**

Vitamin Absorption

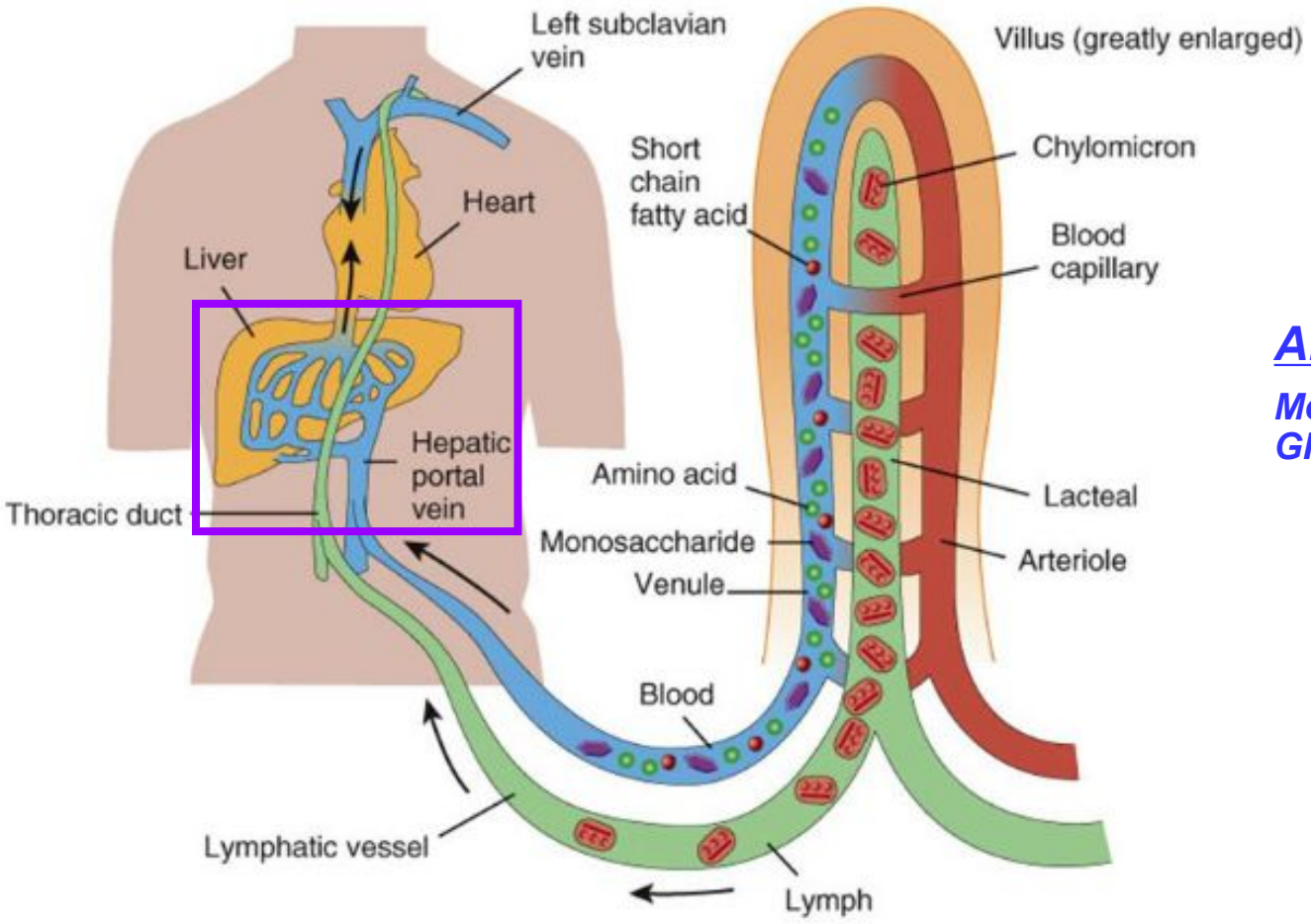
- **Fat-soluble vitamins (A, D, E, K) are absorbed similarly to dietary fats.**

[Taken up by micelles → transported into enterocytes by diffusion → packaged into chylomicrons to enter lacteals]

- **Water-soluble vitamins (B, C) are absorbed by diffusion or active transport.**
- **Vitamin B_{12} requires intrinsic factor (secreted by stomach) for absorption**

Vitamin	Method of Absorption
Fat soluble: A, D, E, K	Chylomicrons
Vitamin C (ascorbic acid)	Na^+-dependent brush border carriers
Biotin (B_7)	Na^+-dependent brush border carriers
Nicotinic acid (B_3)	Passive diffusion
Folic acid (B_9)	Na^+-independent brush border carriers
B_2 (riboflavin)	Na^+-dependent brush border carriers
B_1 (thiamine)	Na^+-independent brush border carriers
B_6 (pyridoxine)	Passive diffusion
B_{12} (cobalamin)	Translocation with intrinsic factor

Transport of Nutrients into Circulation



Absorption

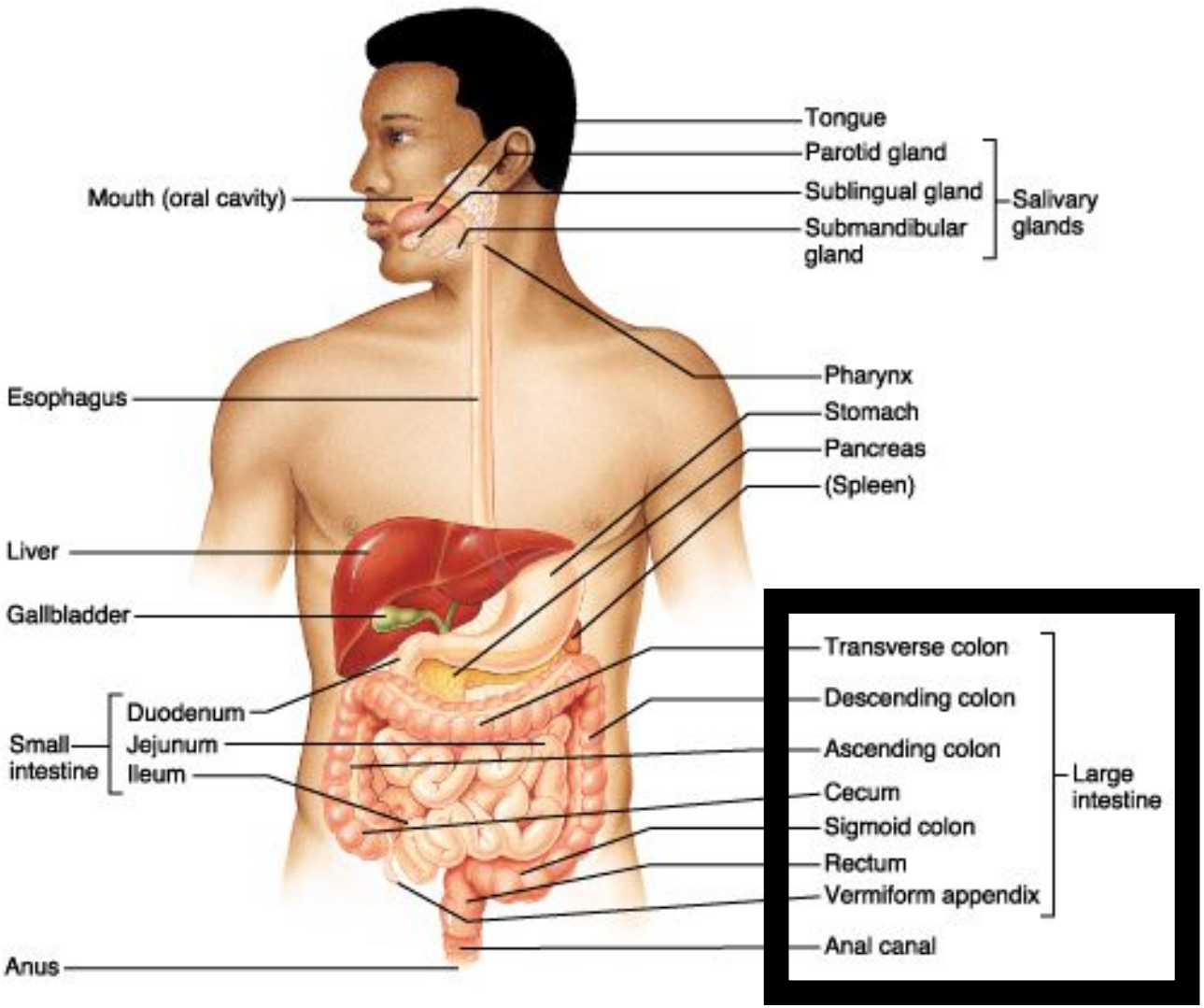
Movement of nutrients from GI tract to blood or lymph

Nutrients absorbed into bloodstream are transported to liver via hepatic portal vein

Large Intestine

Colon

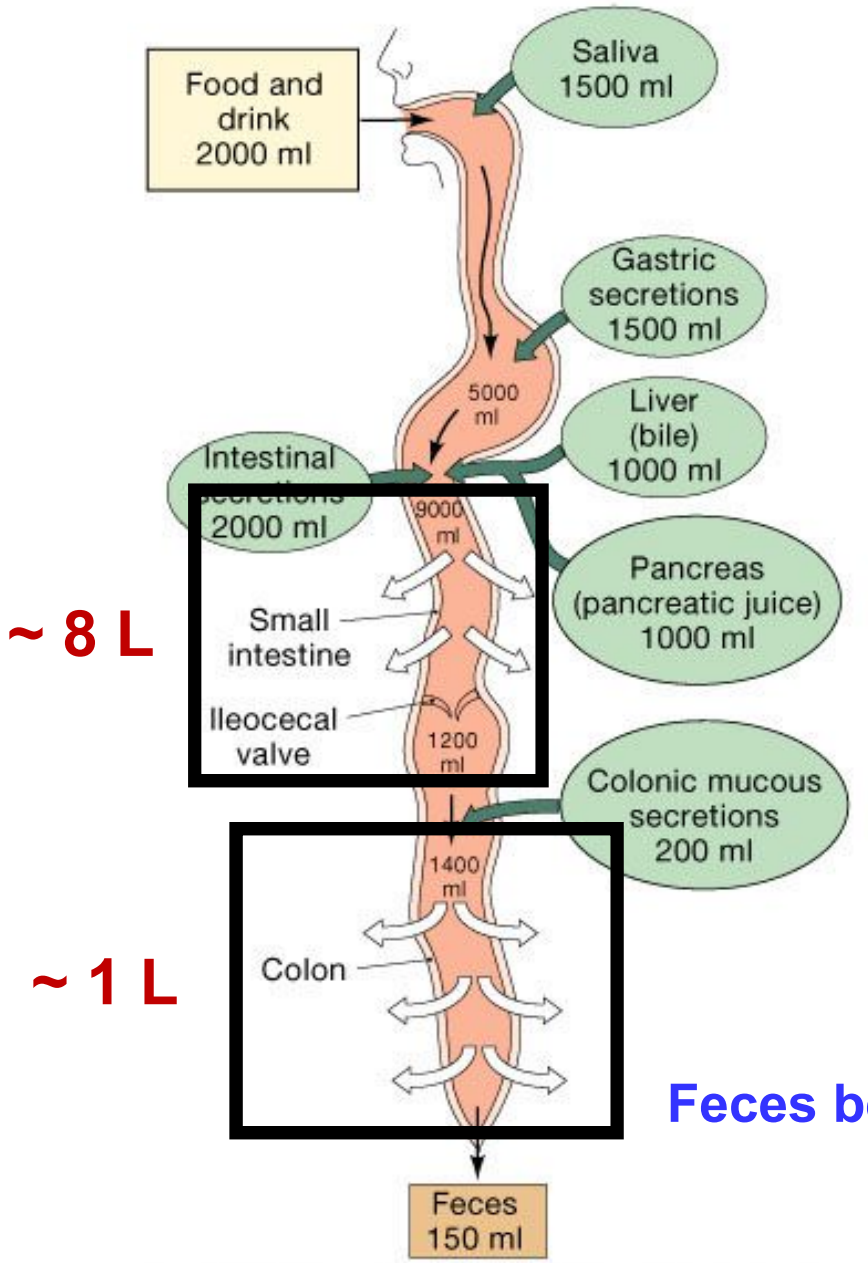
- Water absorption



Response:
Change in contractile or secretory activity

Water Absorption

>80% of water is absorbed in small intestine



~ 8 L

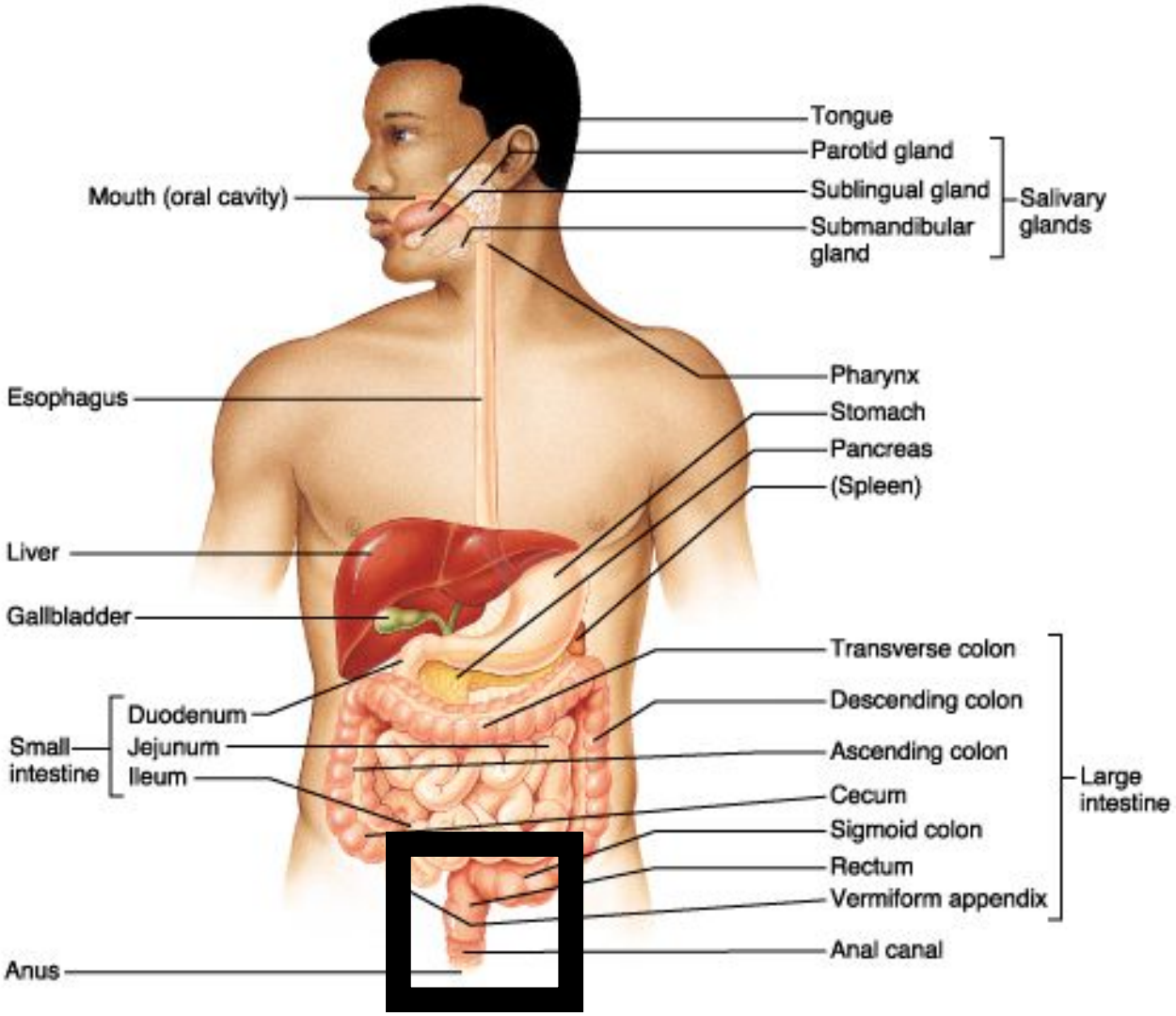
~ 1 L

Feces becomes compacted

Large Intestine

Rectum & Anus

- Feces storage
- Defecation

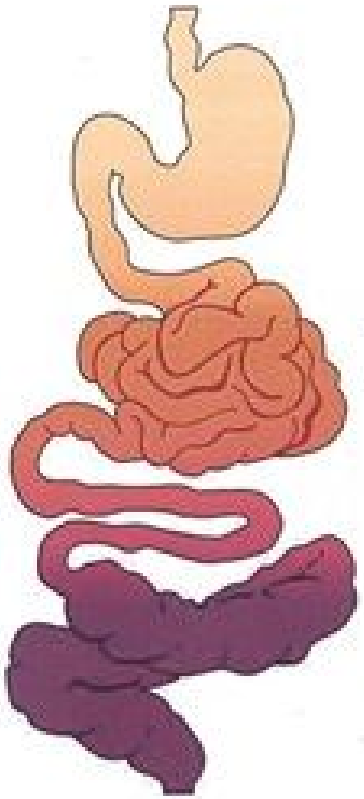


Response:
Change in contractile or secretory activity

Gut Flora

- **No. of cells in human body:** 10^{13} (10 trillion)
- **No. of micro-organisms in human gut:** 10^{14} (100 trillion) [> 500 species]

Stomach
$<10^3$ CFU/ml
Lactobacillus
Streptococcus
Staphylococcus
Enterobacteriaceae
Yeasts



Duodenum & Jejunum
10^2-10^5 CFU/ml
Lactobacillus, Streptococcus
Enterobacteriaceae
Staphylococcus, Yeasts

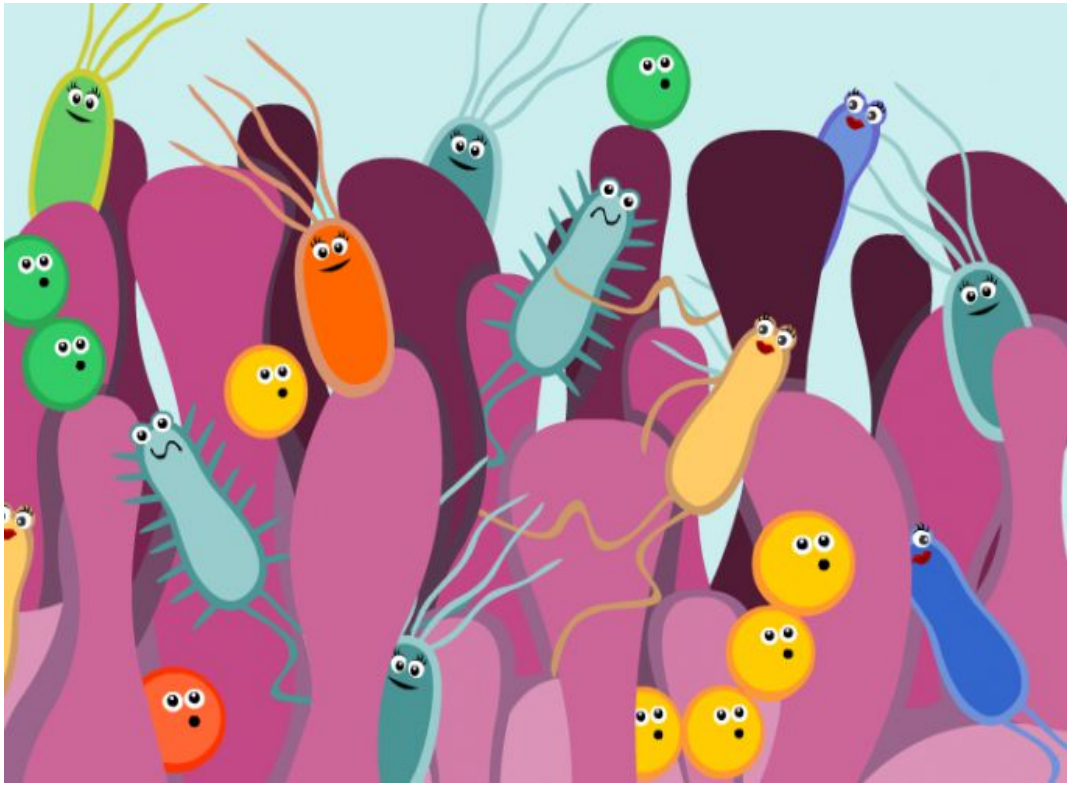
Ileum & Caecum
10^3-10^9 CFU/ml
Bifidobacterium
Bacteroides
Lactobacillus
Streptococcus
Enterobacteriaceae
Staphylococcus
Clostridium
Yeasts

Colon
10^{10}-10^{12} CFU/ml
Bacteroides, Eubacterium
Clostridium, Peptostreptococcus
Streptococcus, Bifidobacterium
Fusobacterium, Lactobacillus
Enterobacteriaceae
Staphylococcus, Yeasts

Gut Flora

Functions

- Control pathogens
- Synthesize vitamins B & K
- Synthesize enzymes & neurotransmitters
- Regulate metabolism
- Regulate immune system & inflammation



Key Points

Essential Activities of Digestive Process

Neural Control of GI Tract (Intrinsic vs. Extrinsic)

Mouth

- Regulation of salivation

Pharynx & Esophagus

- Swallowing
- Peristalsis

Stomach

- Regulation of gastric activities
  - Cephalic phase
  - Gastric phase
  - Intestinal phase

Regulation of Pancreatic Secretion

Regulation of Bile Production & Release

Action of Bile Salts

Small Intestine

- Segmentation
- Intestinal secretion & brush border enzymes
- Absorption of nutrients

Large Intestine

- Water absorption
- Defecation

Gut Flora