Mechanical Process of Digestion

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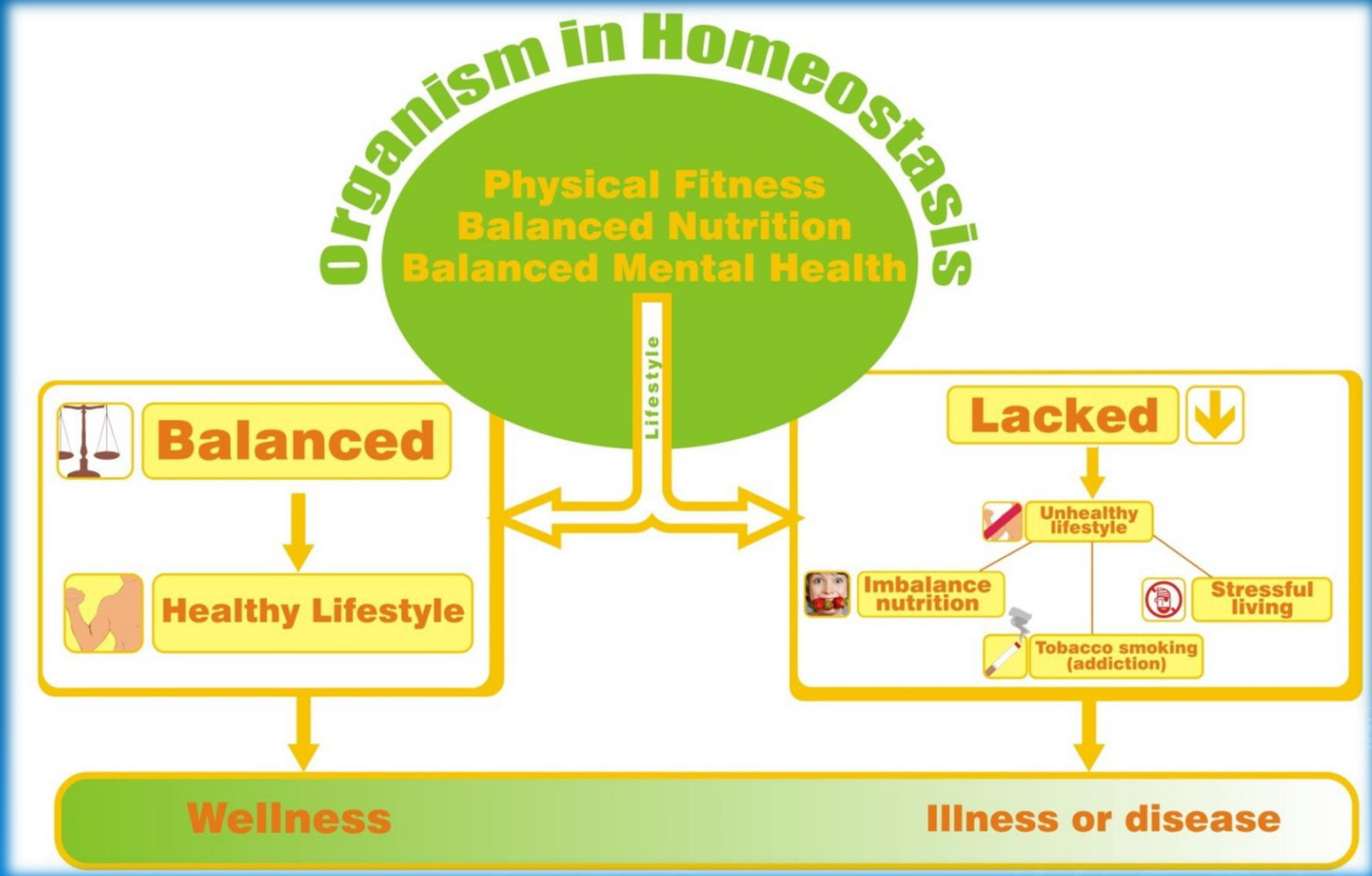
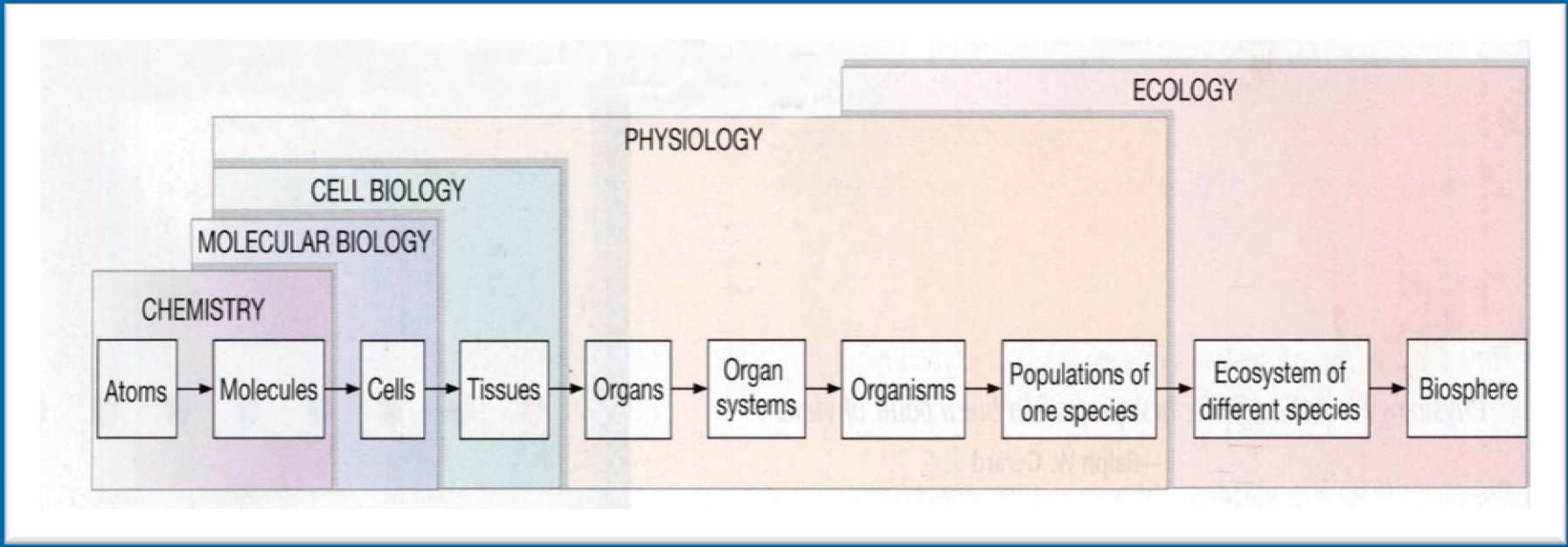
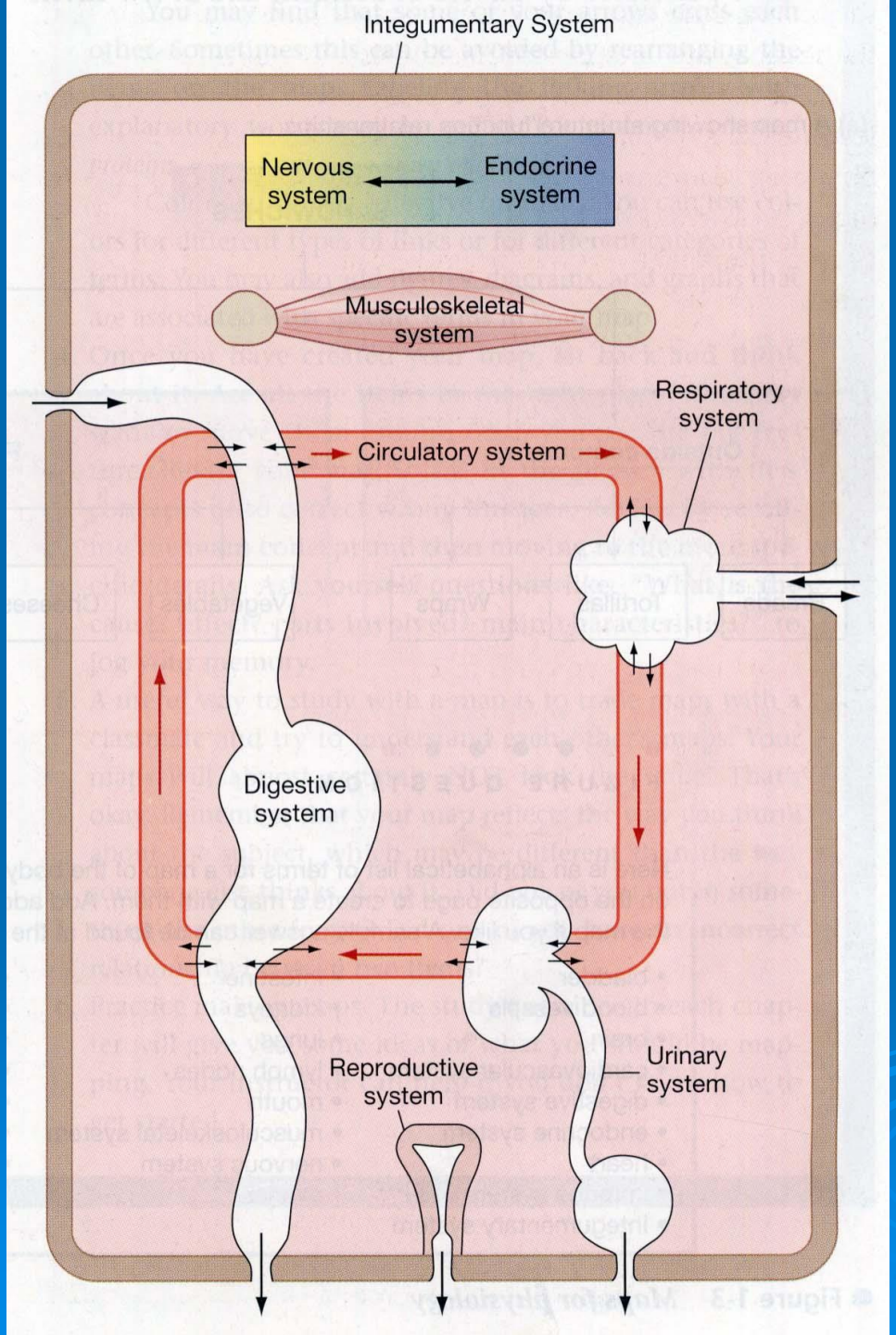

Organism in Homeostasis
Physical Fitness
Balanced Nutrition
Balanced Mental Health
Lifestyle
Balanced
Healthy Lifestyle
Lacked
Unhealthy lifestyle
Imbalance nutrition
Stressful living
Tobacco smoking (addiction)
Wellness
Illness or disease

Level of Organisation

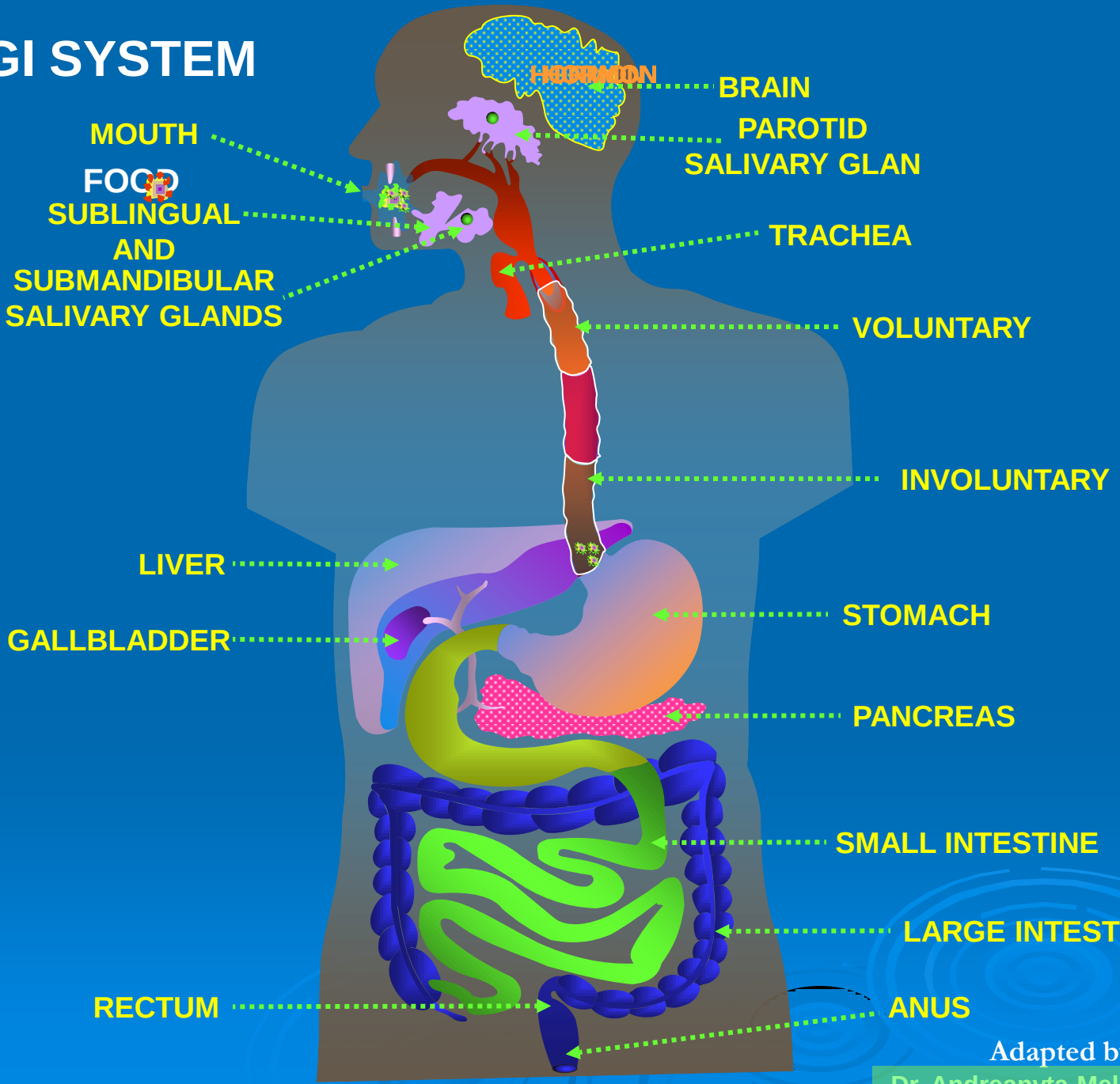



Integumentary System
Nervous system
Endocrine system
Musculoskeletal system
Respiratory system
Circulatory system
Digestive system
Reproductive system
Urinary system

DIGESTIVE SYSTEM

- The three fundamental processes that take place are:
  - **Secretion:** Delivery of enzymes, mucus, ions and the like into the lumen, and hormones into blood.
  - **Absorption:** Transport of water, ions and nutrients from the lumen, across the epithelium and into blood.
  - **Motility:** Contractions of smooth muscle in the wall of the tube that crush, mix and propel its contents.

THE GI SYSTEM



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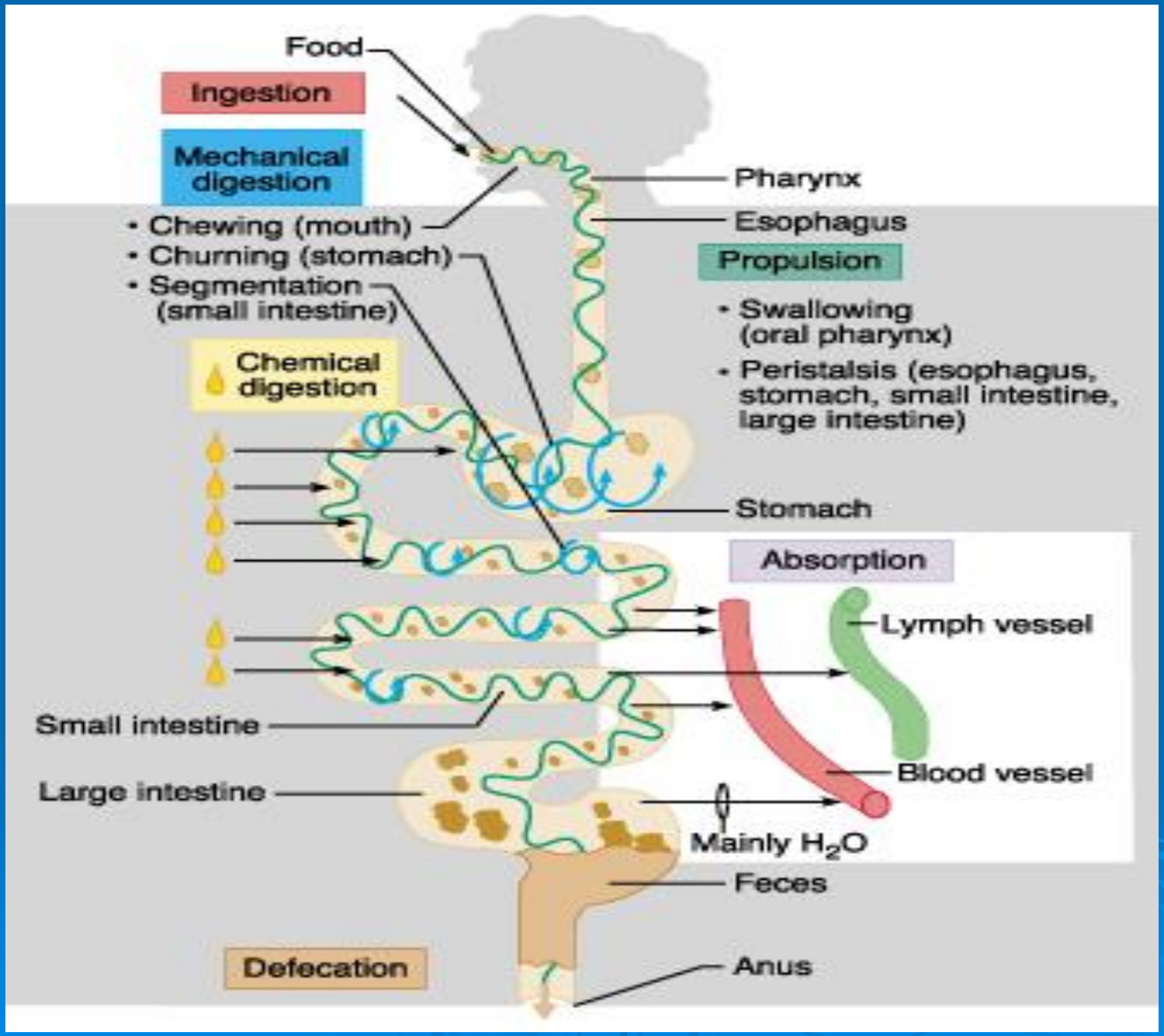
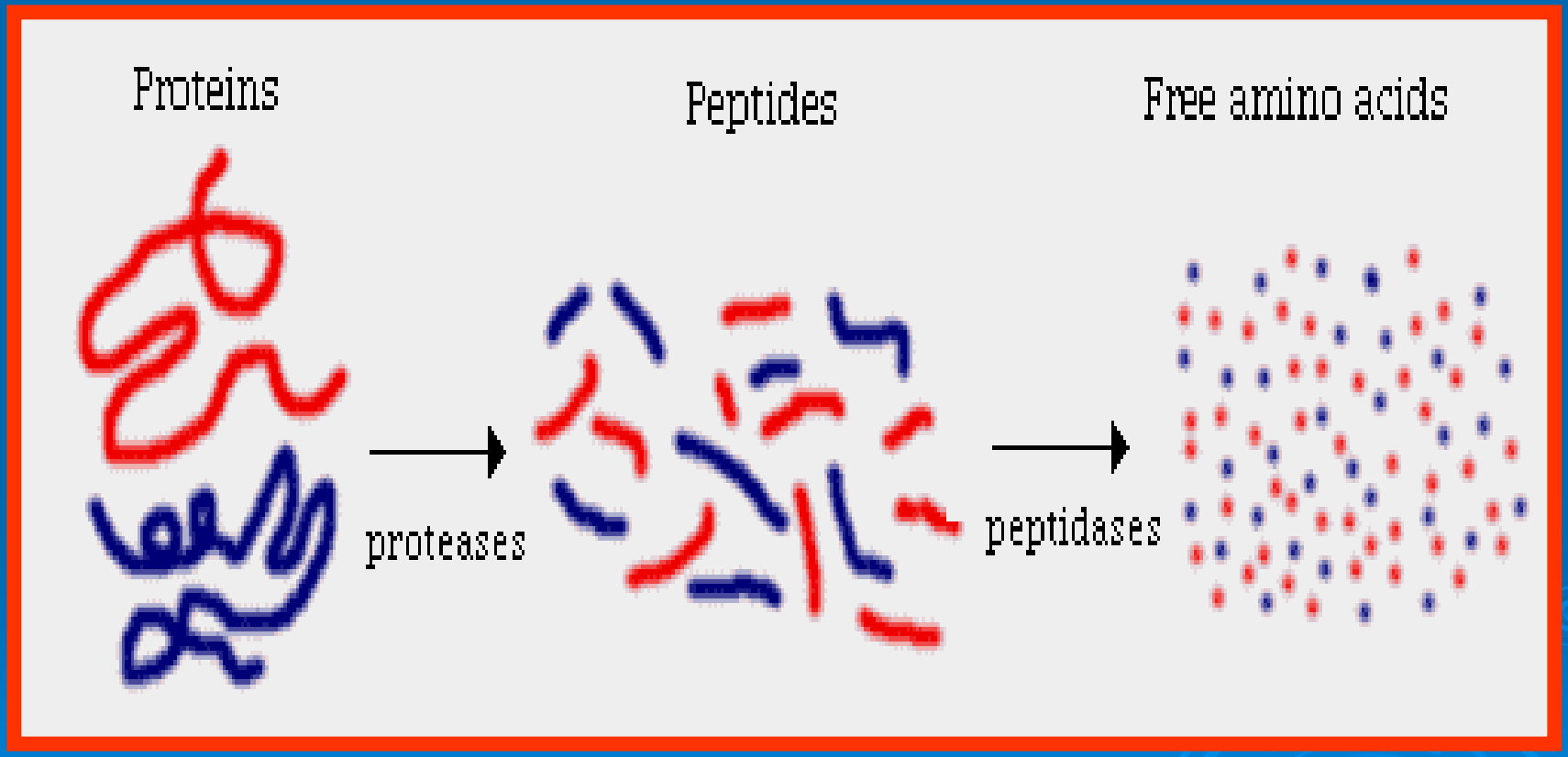
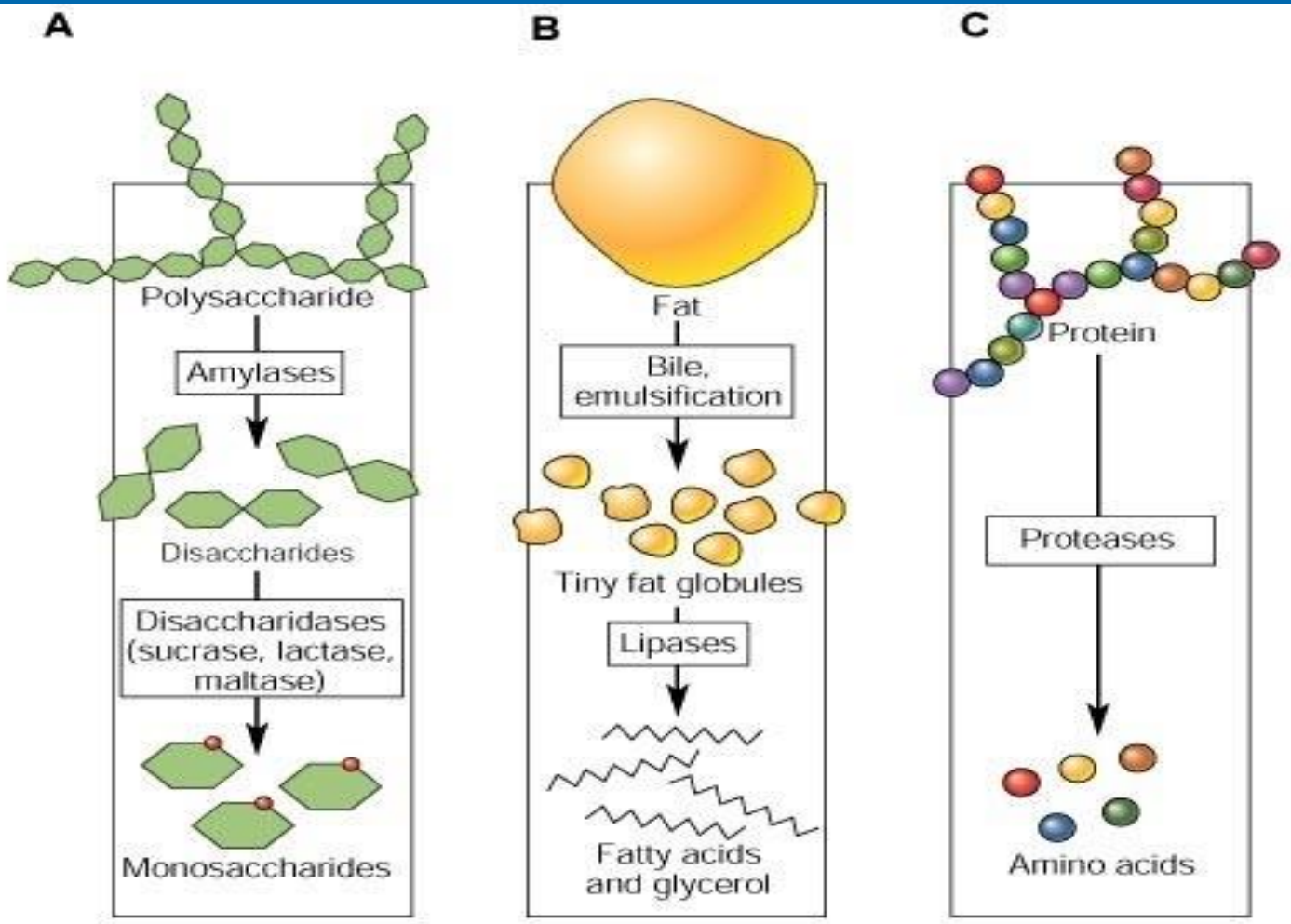

Food
Ingestion
Mechanical digestion
• Chewing (mouth)
• Churning (stomach)
• Segmentation (small intestine)
Chemical digestion
Pharynx
Esophagus
Propulsion
• Swallowing (oral pharynx)
• Peristalsis (esophagus, stomach, small intestine, large intestine)
Stomach
Absorption
Lymph vessel
Small intestine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

FROM MACROMOLECULES INTO MONOMERS



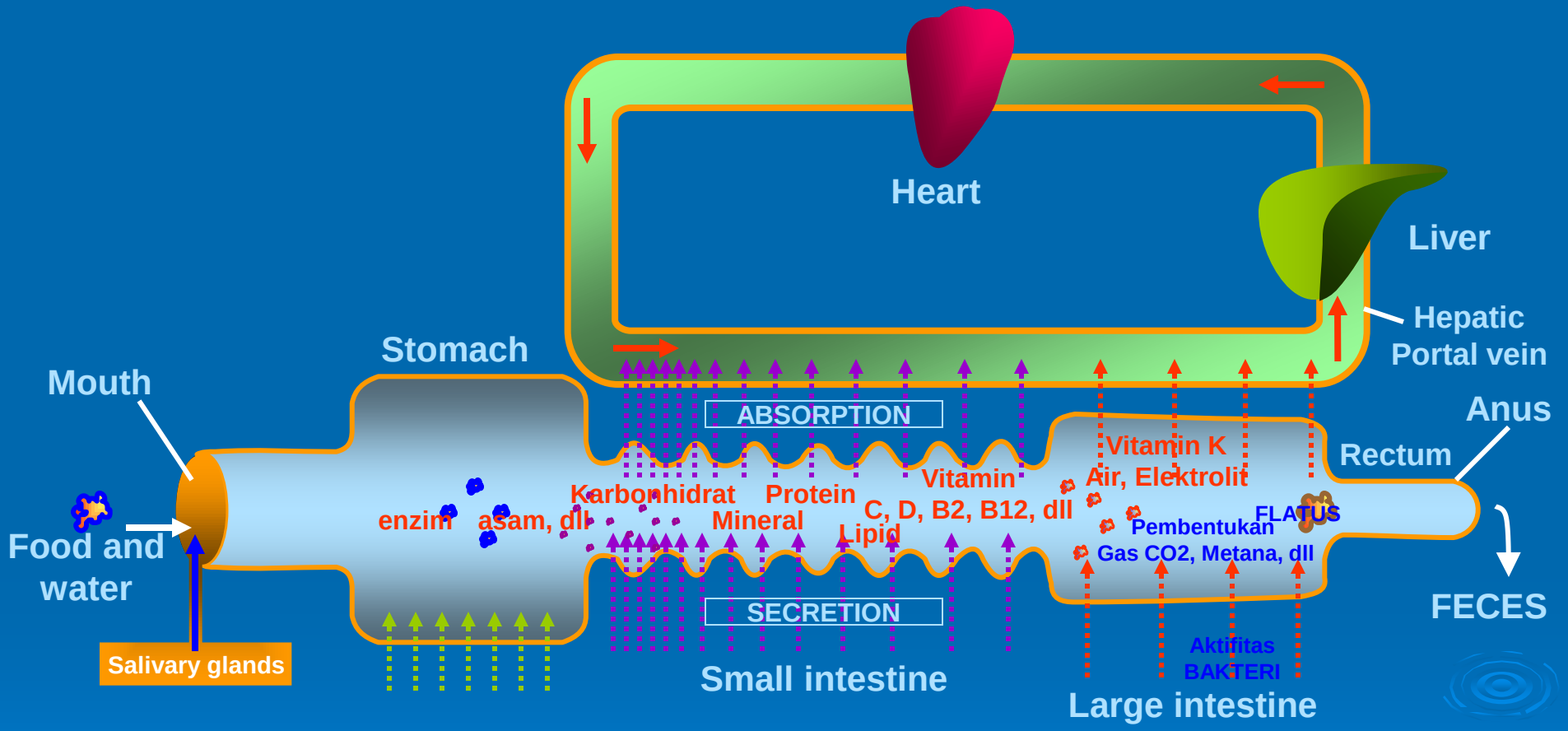
----- + H2O ----------→ -----OH + H-

MACROMOLECULES:	→→→	**MONOMERS:**
Carbohydrates		
polysaccarides		Monosaccharides
maltose		2 glucose
lactose		glucose + galactose
sucrose		glucose+fructose
starch		maltose
Proteins		Amino Acids (AA)
		peptides
Fats		
Tryglycerides		Monoglycerides+ FFA
Phospholipids		Lysophospholipids + FFA



From Herlihy B, Maebius NK: The human body in health and illness, Philadelphia, 2000, Saunders, p 407.

THE GI DIAGRAM



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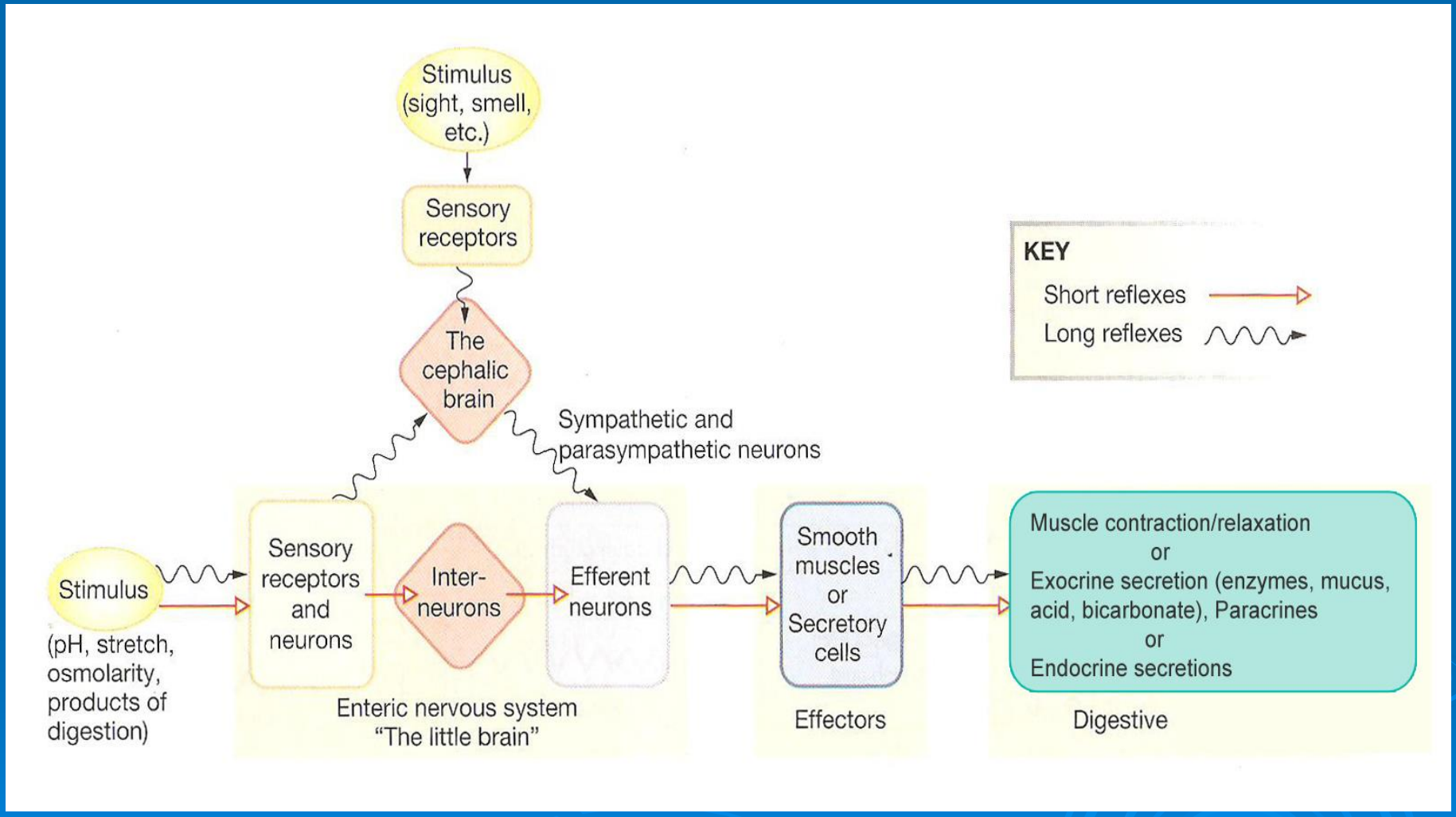
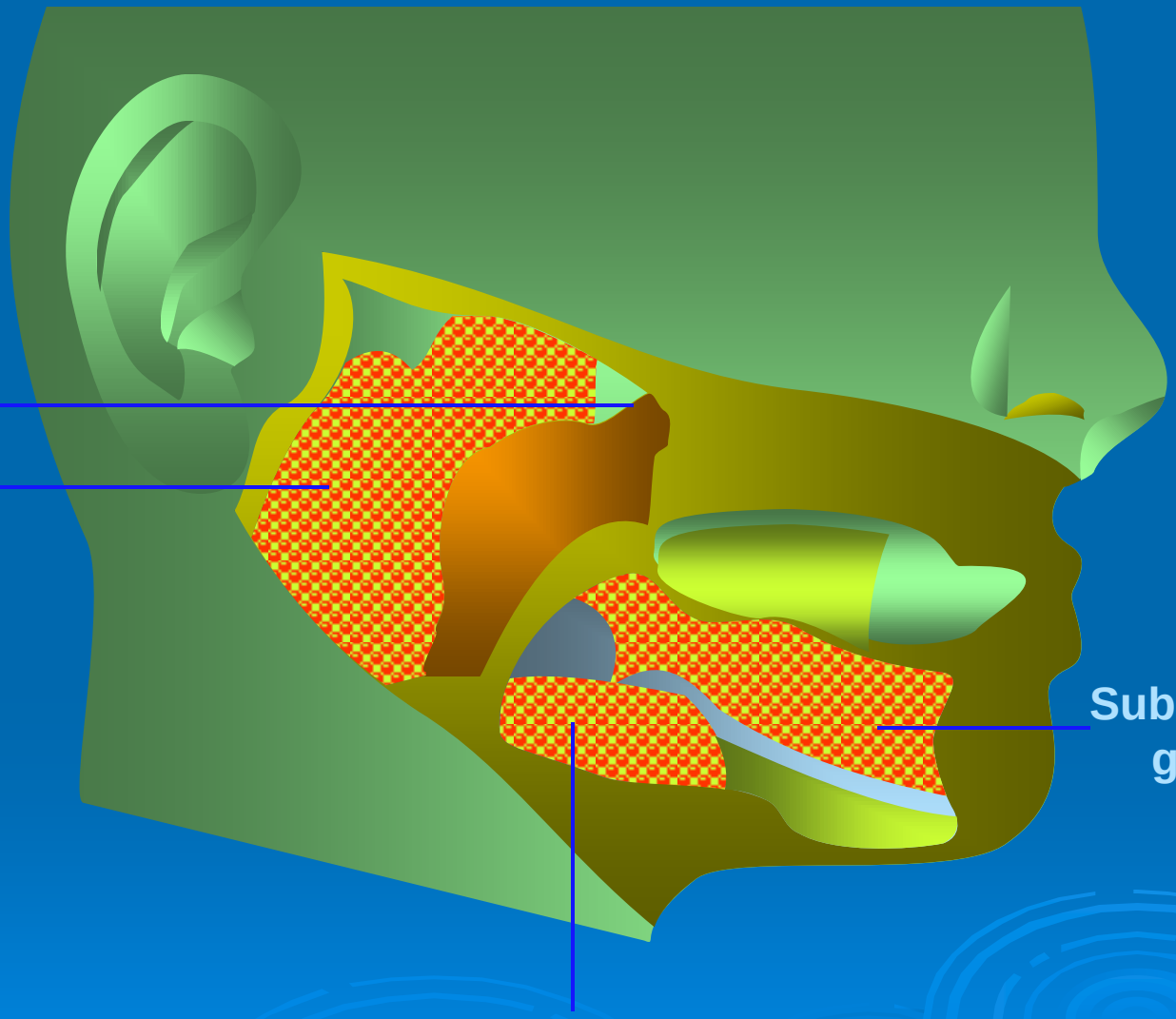
REGULATION OF GI FUNCTION

Complex regulation with overlapping pathways that involve:

- Neural
- Endocrines
- Local control mechanism (little brain; enteric nervous system)


Stimulus (sight, smell, etc.)
Sensory receptors
The cephalic brain
Sympathetic and parasympathetic neurons
KEY
Short reflexes
Long reflexes
Stimulus
(pH, stretch, osmolarity, products of digestion)
Sensory receptors and neurons
Inter-neurons
Efferent neurons
Enteric nervous system
"The little brain"
Smooth muscles or Secretory cells
Effectors
Muscle contraction/relaxation
or
Exocrine secretion (enzymes, mucus, acid, bicarbonate), Paracrines
or
Endocrine secretions
Digestive

NAMES AND LOCATION OF THE MAJOR SALIVARY GLAND IN THE HUMAN



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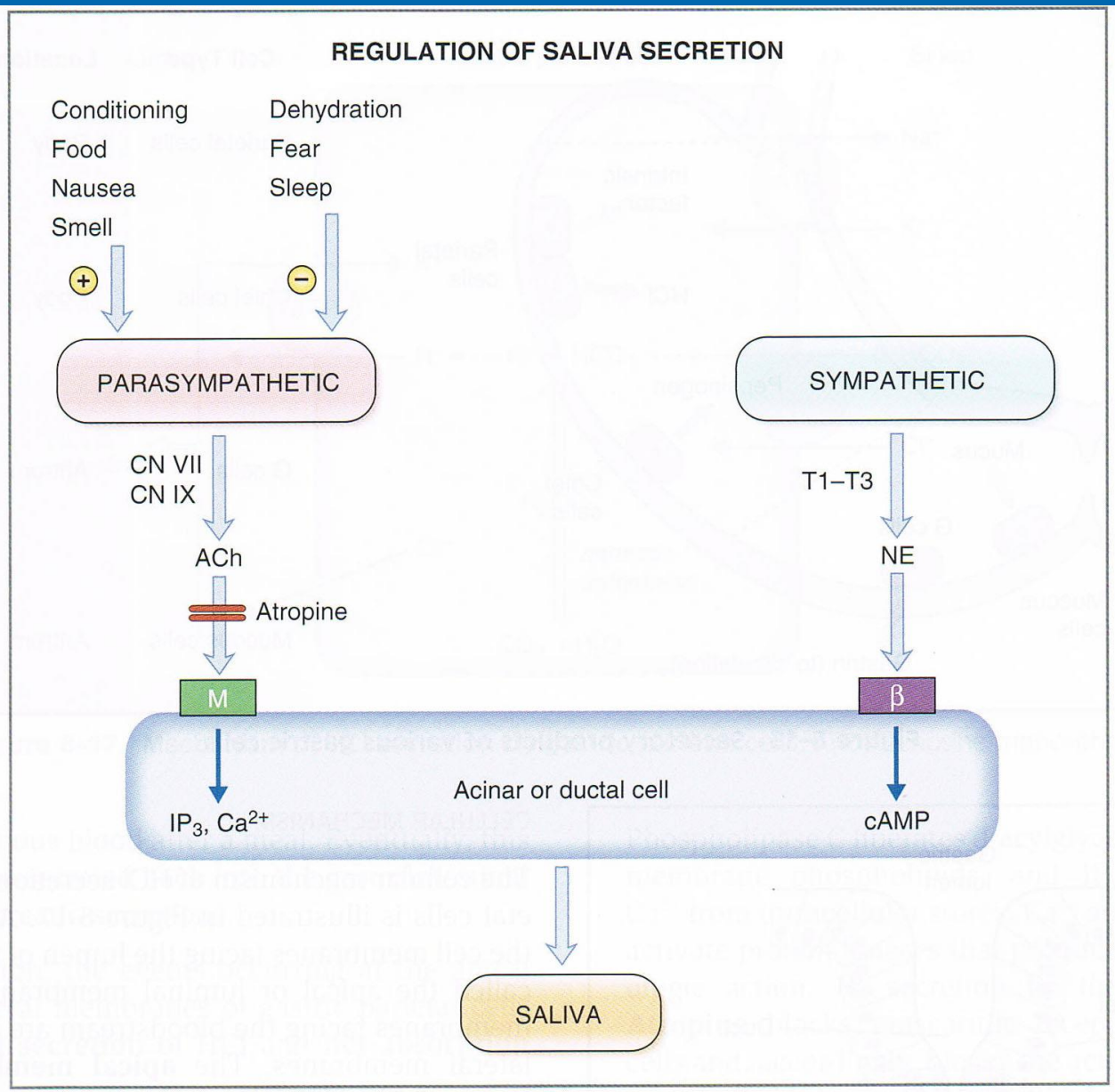
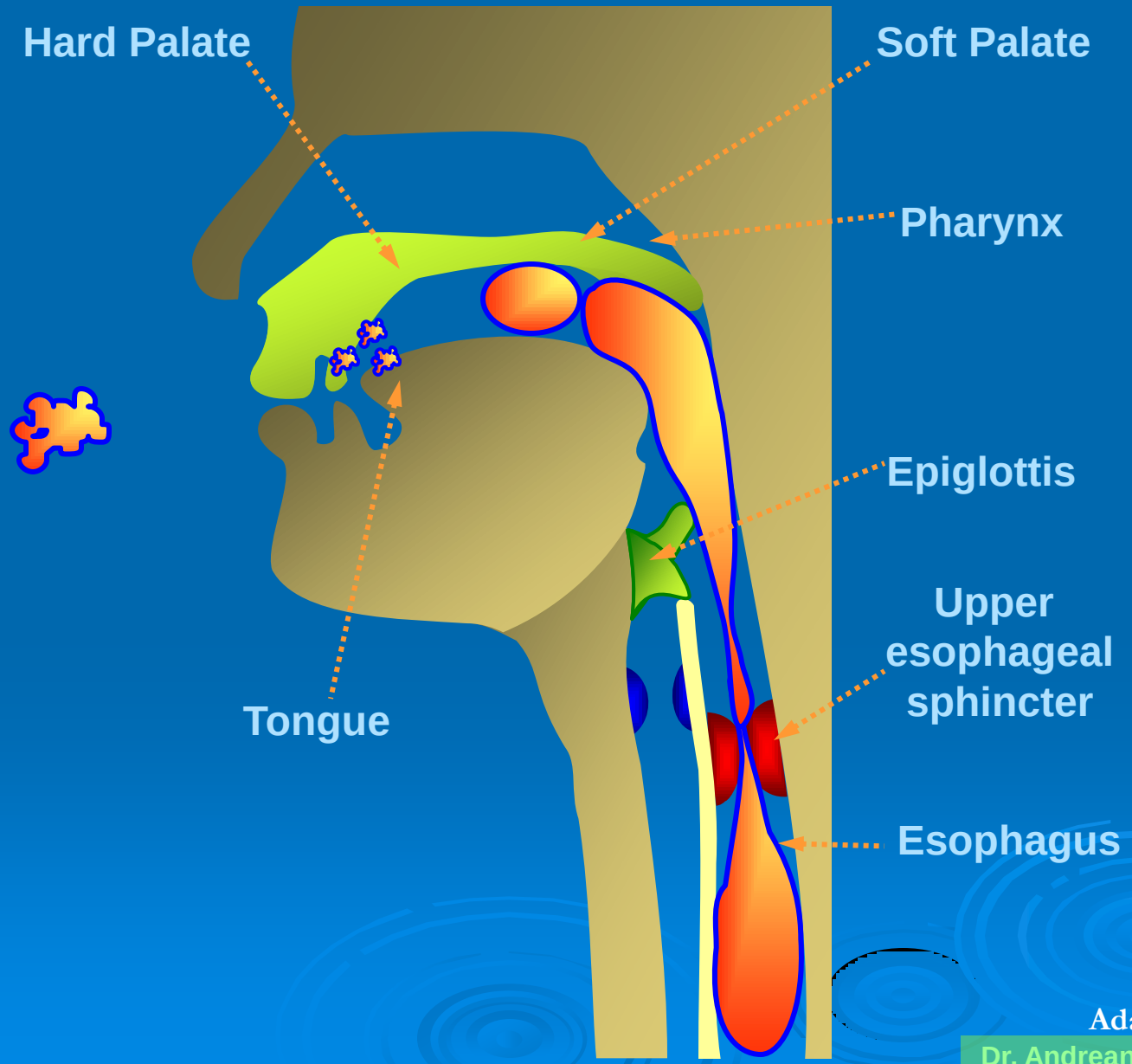


Figure 8–14 Regulation of salivary secretion by the autonomic nervous system. ACh, Acetylcholine; β, β receptor; cAMP, cyclic adenosine monophosphate; CN, cranial nerve; M, muscarinic receptor; NE, norepinephrine; T1–T3, thoracic segments.

MOVEMENTS OF FOOD THROUGH THE PHARYNX AND UPPER ESOPHAGUS DURING SWALLOWING



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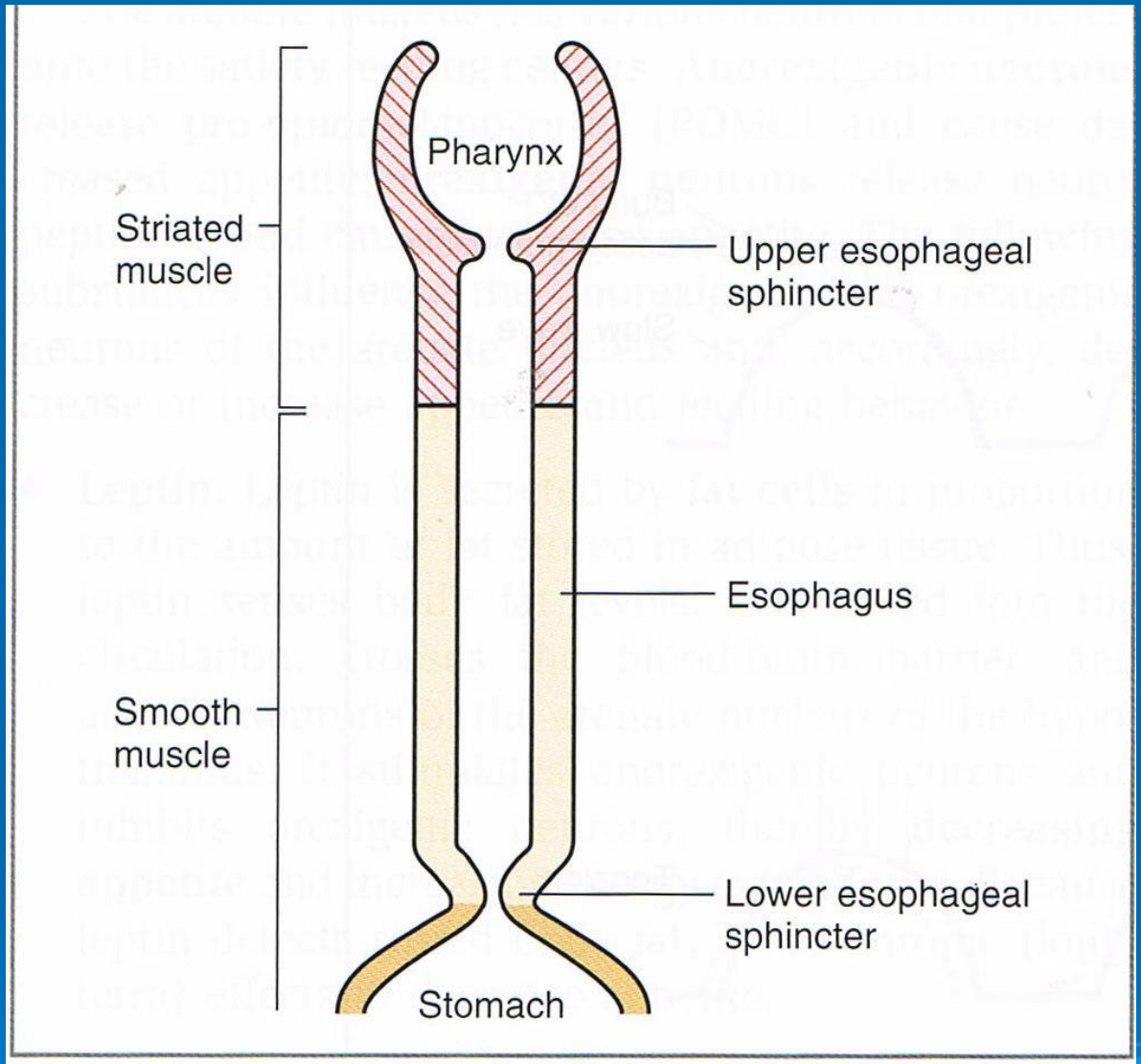
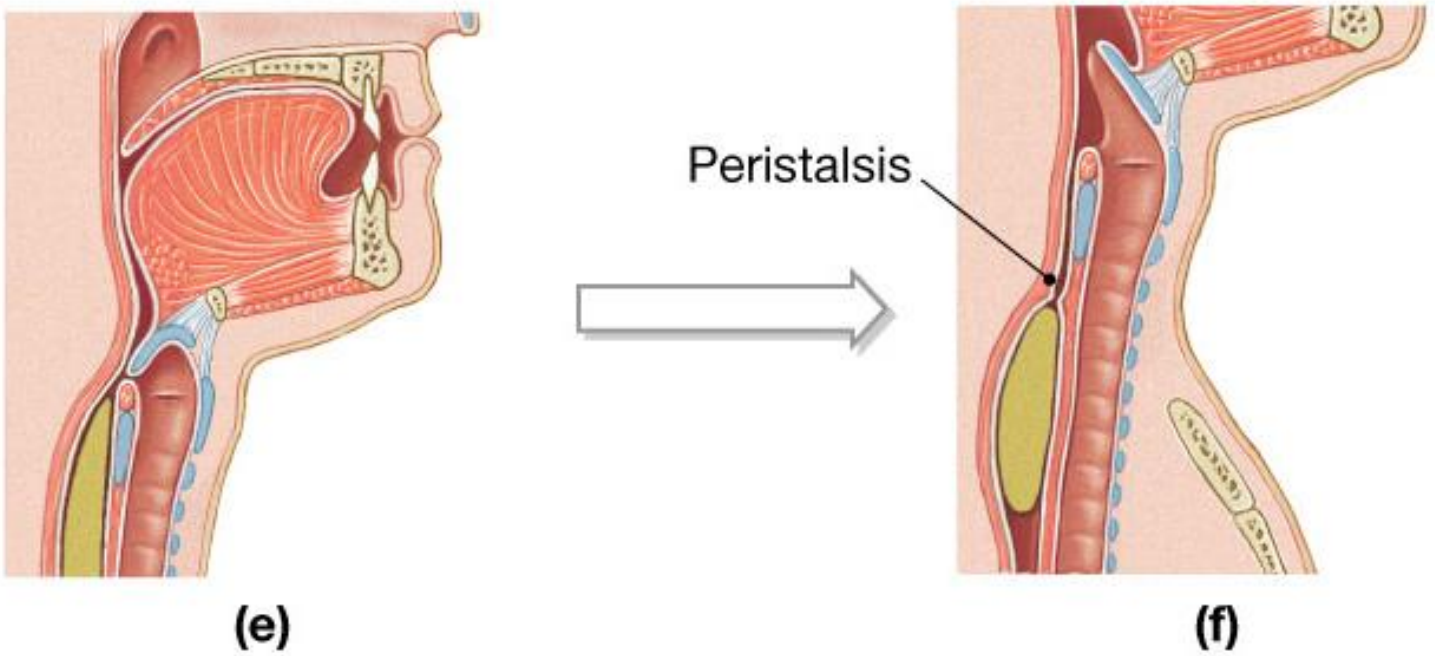
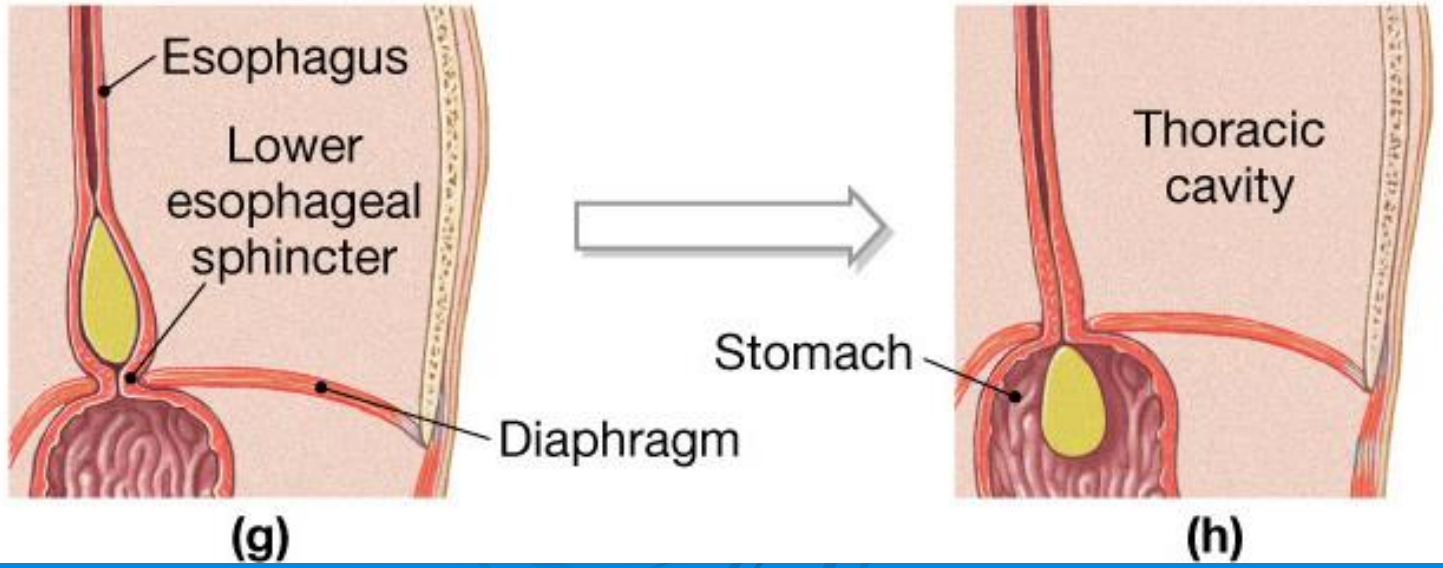


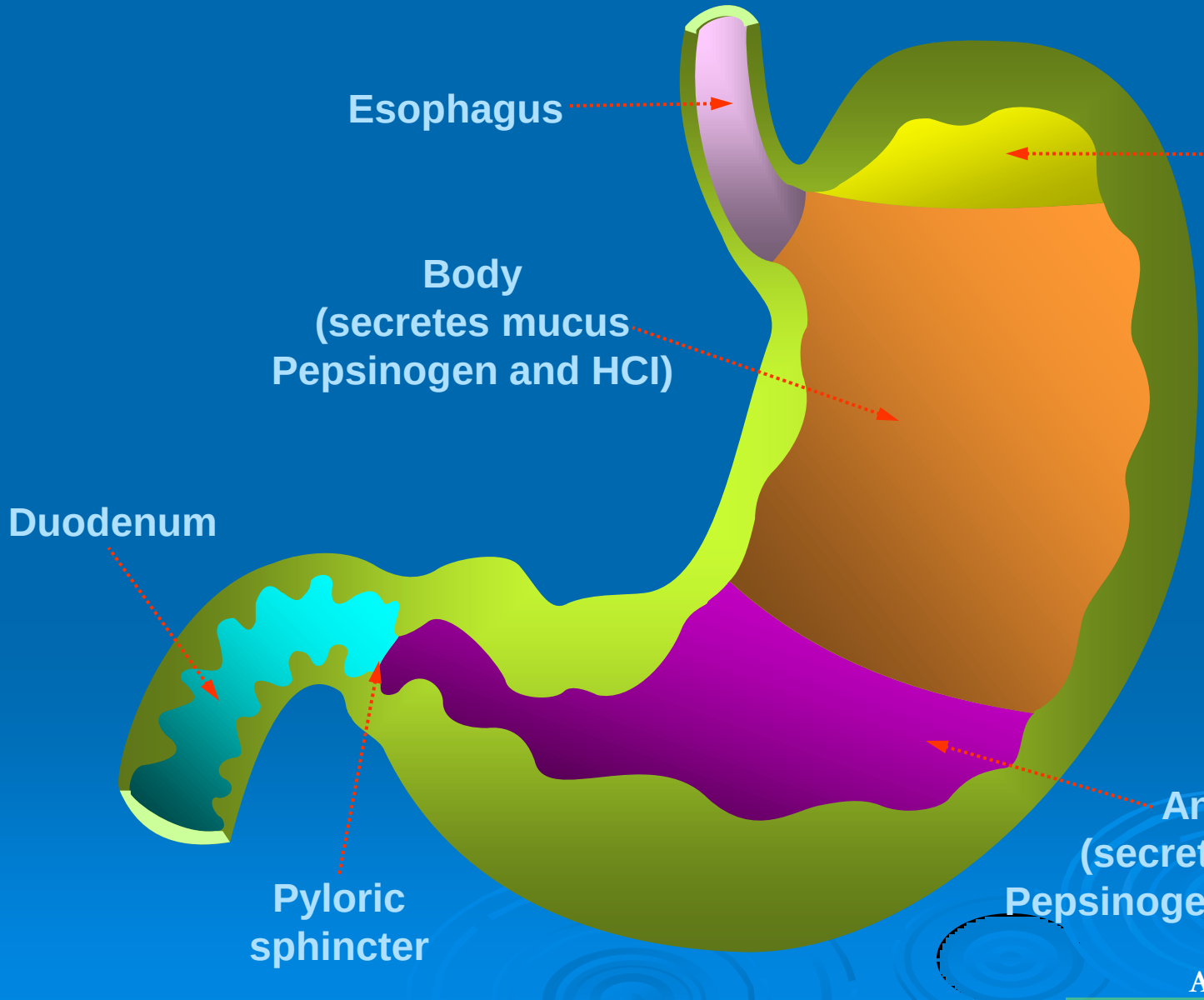
Figure 8–8 Structures of the upper gastrointestinal tract. The pharynx, upper esophageal sphincter, and upper third of the esophagus are composed of striated muscle. The lower two thirds of the esophagus and lower esophageal sphincter are composed of smooth muscle.

ESOPHAGEAL PHASE





THE THREE REGIONS OF THE STOMACH : FUNDUS, BODY, AND ATRIUM



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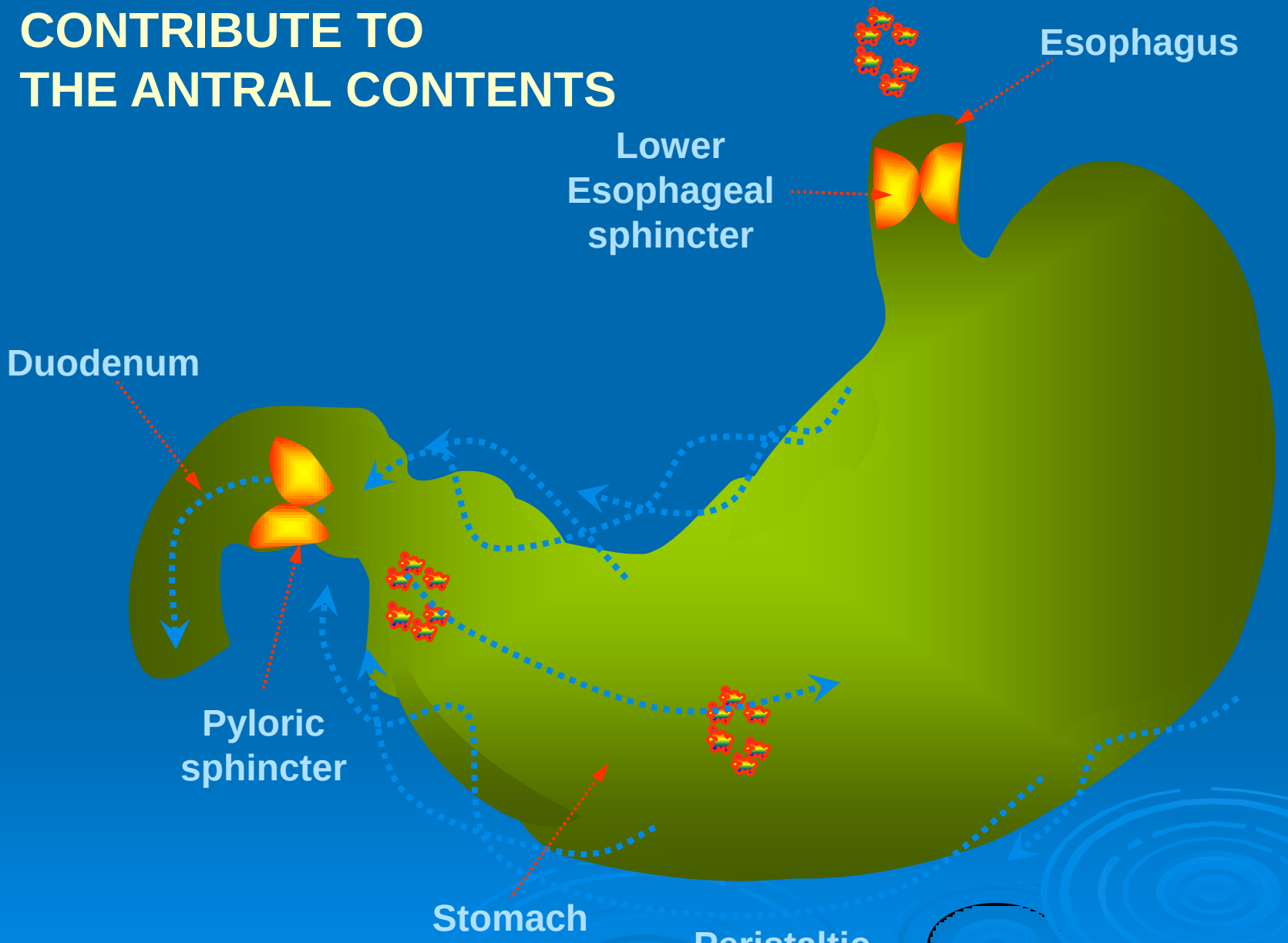
PERISTALTIC WAVES CONTRIBUTE TO THE ANTRAL CONTENTS



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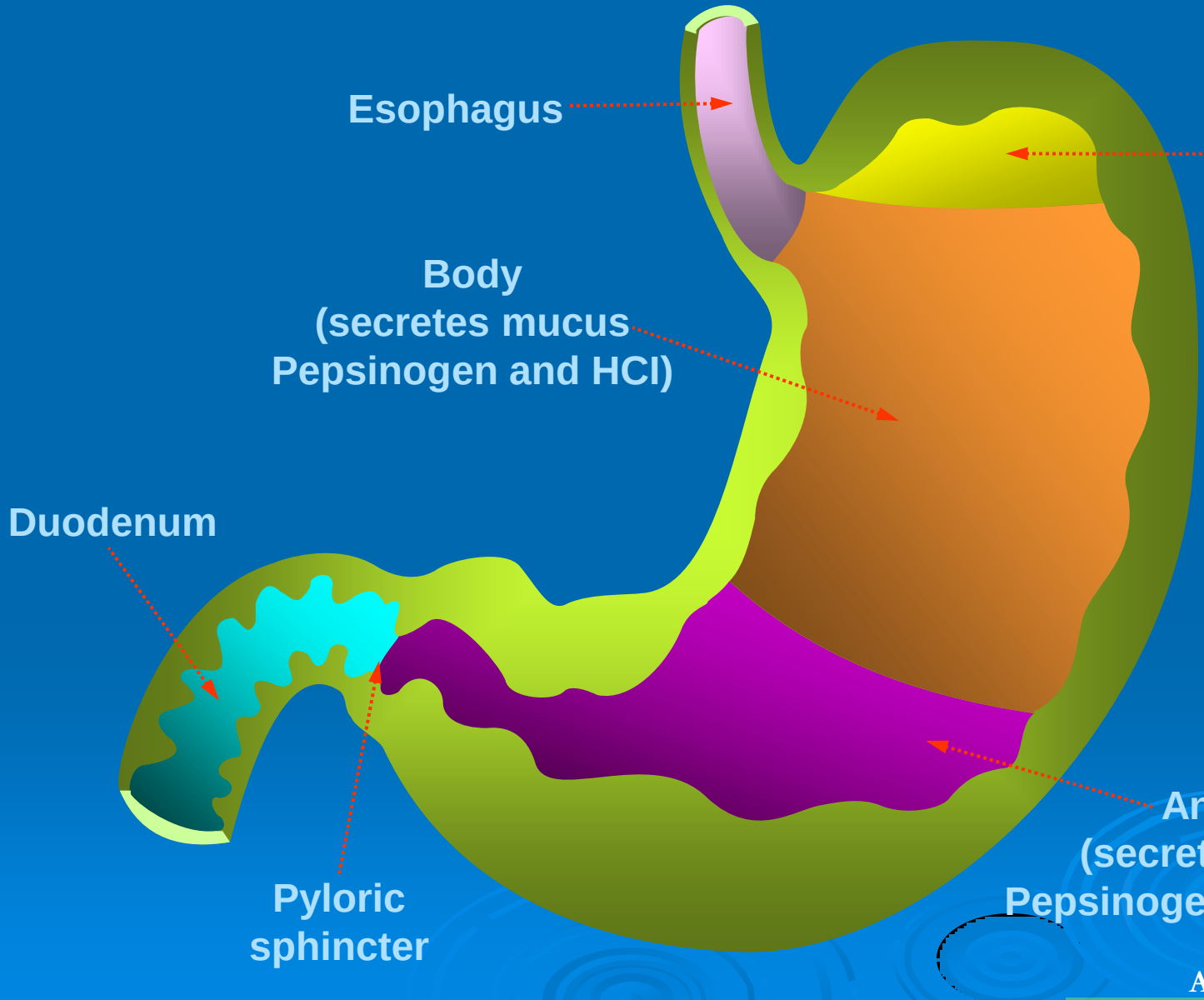
THE THREE REGIONS OF THE STOMACH : FUNDUS, BODY, AND ATRIUM



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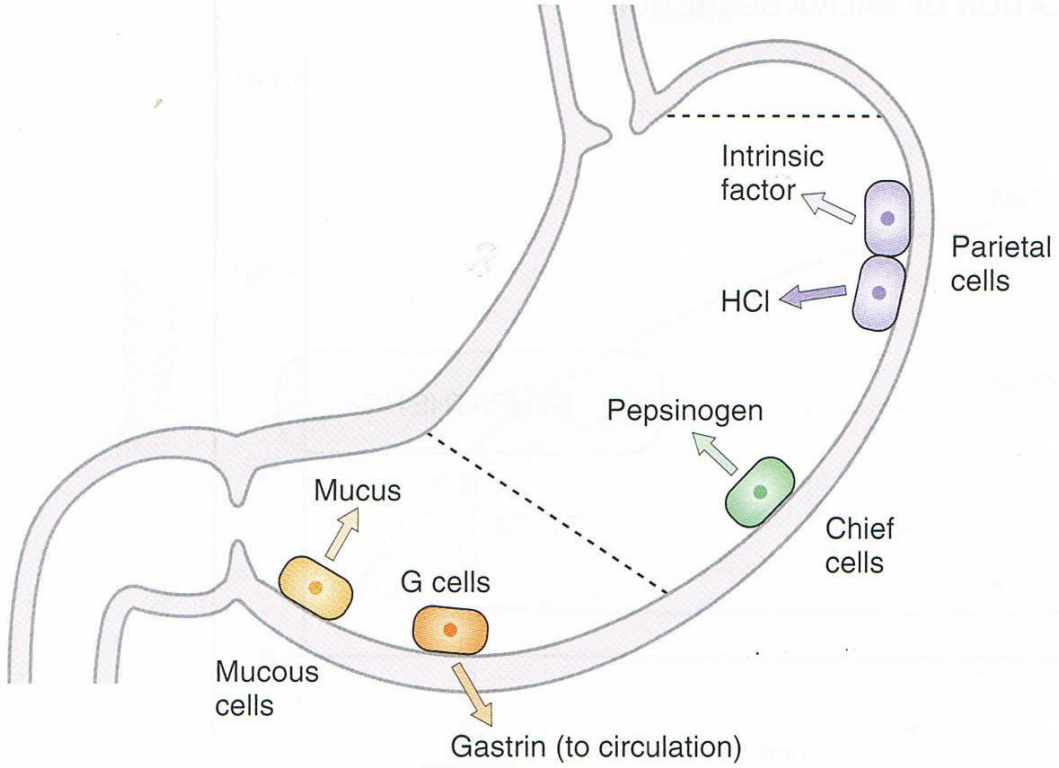
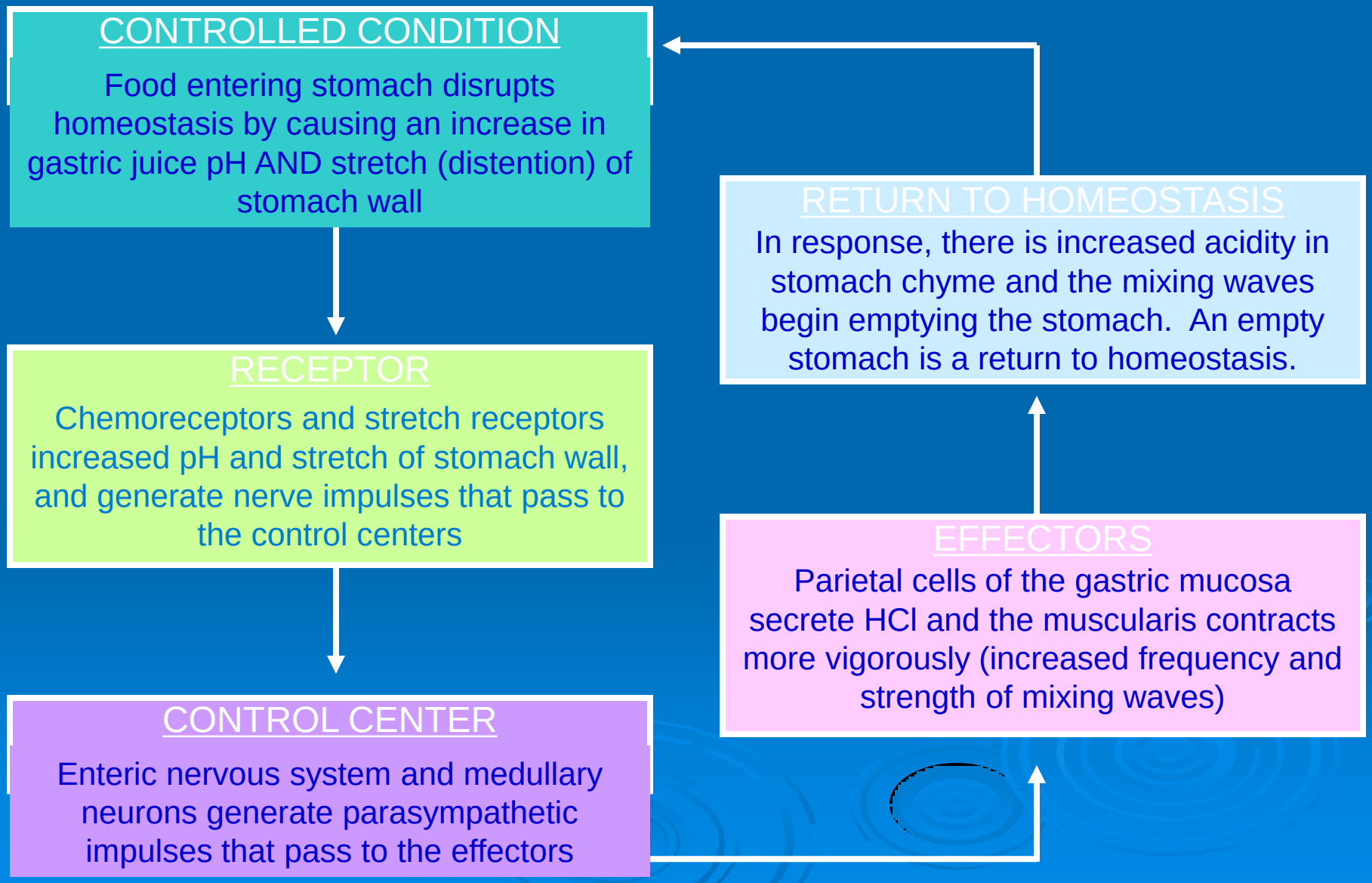


Cell Type	Location	Secretion
Parietal cells	Body	HCl Intrinsic factor
Chief cells	Body	Pepsinogen
G cells	Antrum	Gastrin
Mucous cells	Antrum	Mucus Pepsinogen

Figure 8–15 Secretory products of various gastric cells.

Negative Feedback of the Gastric Phase



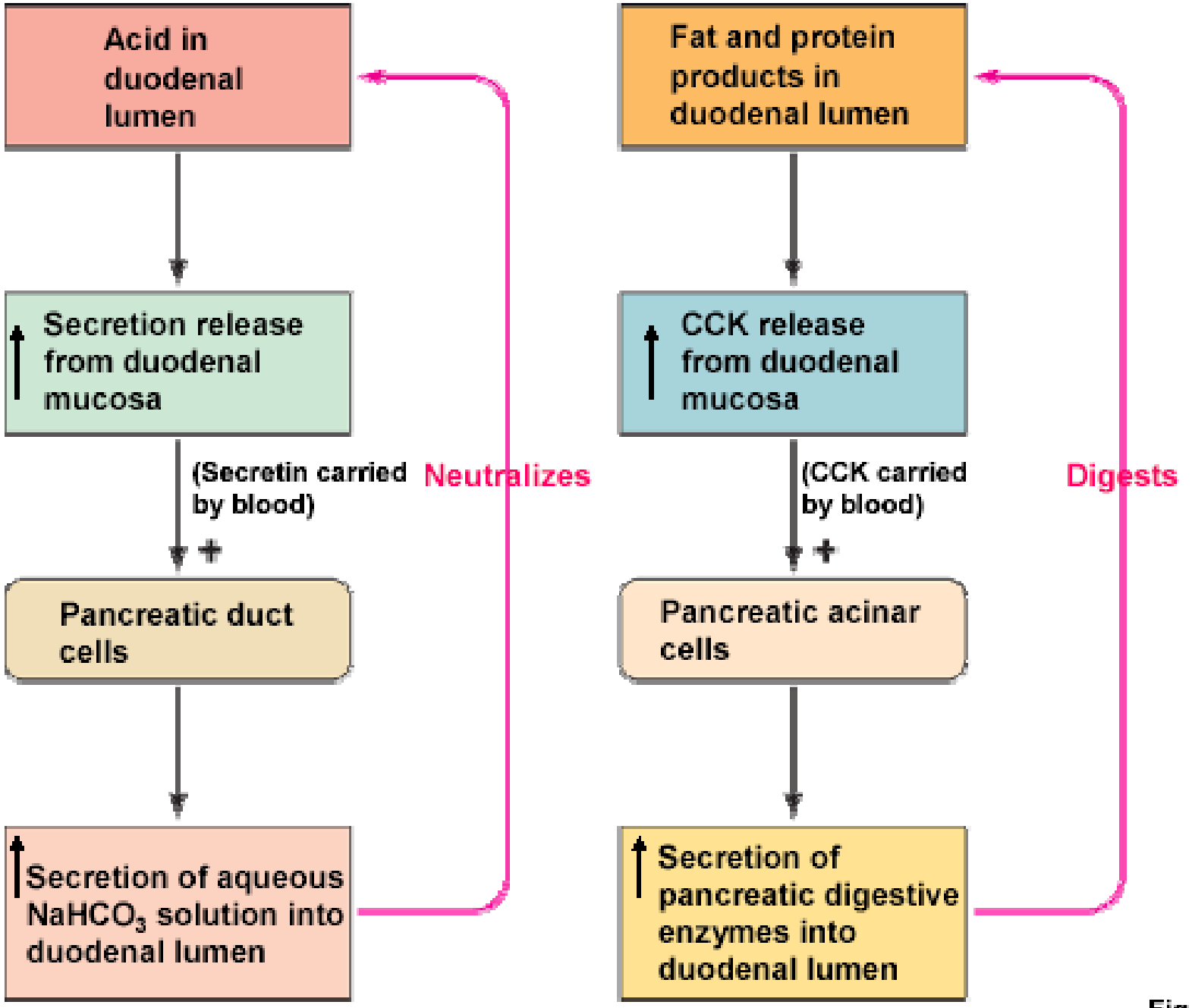
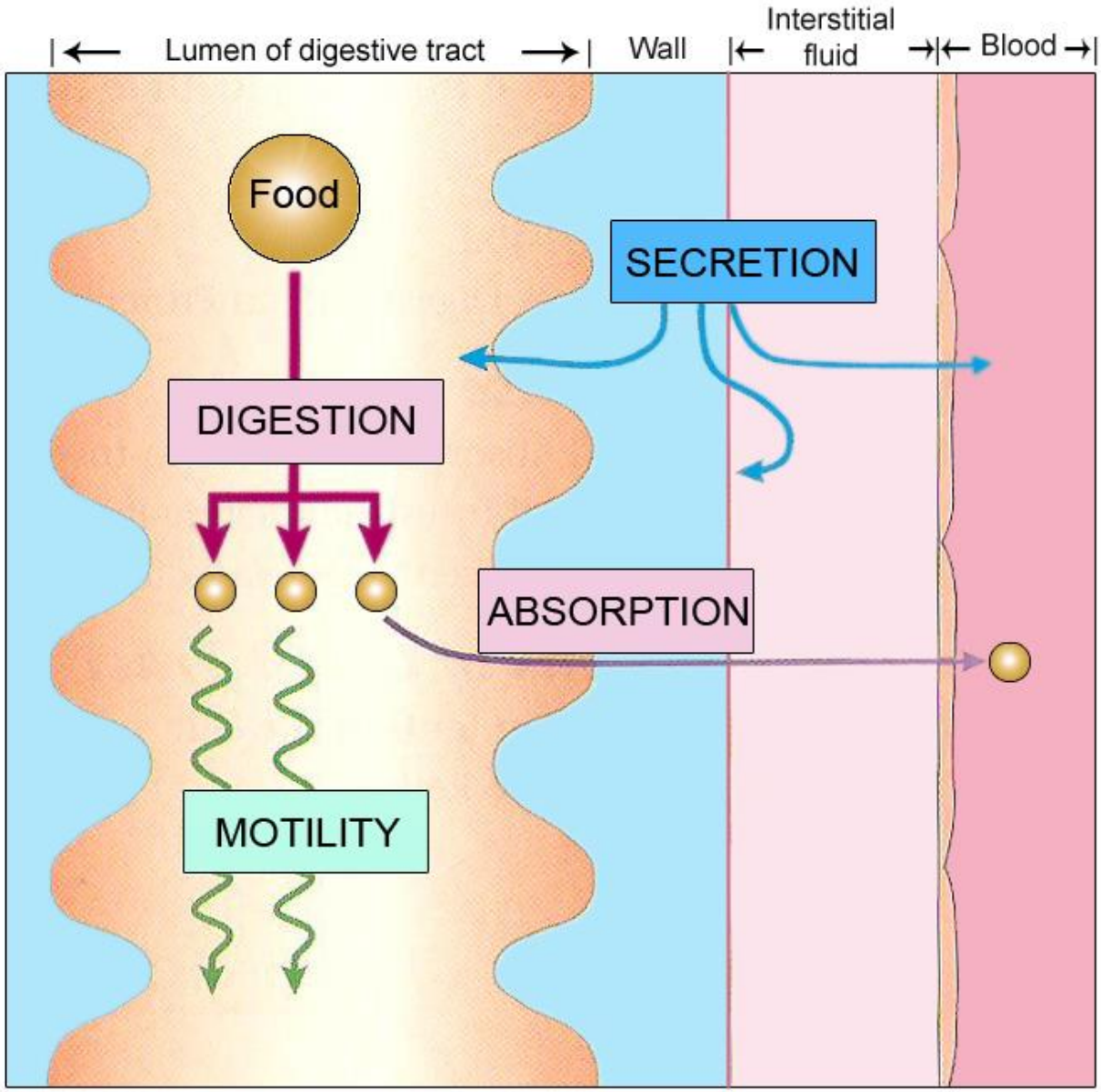
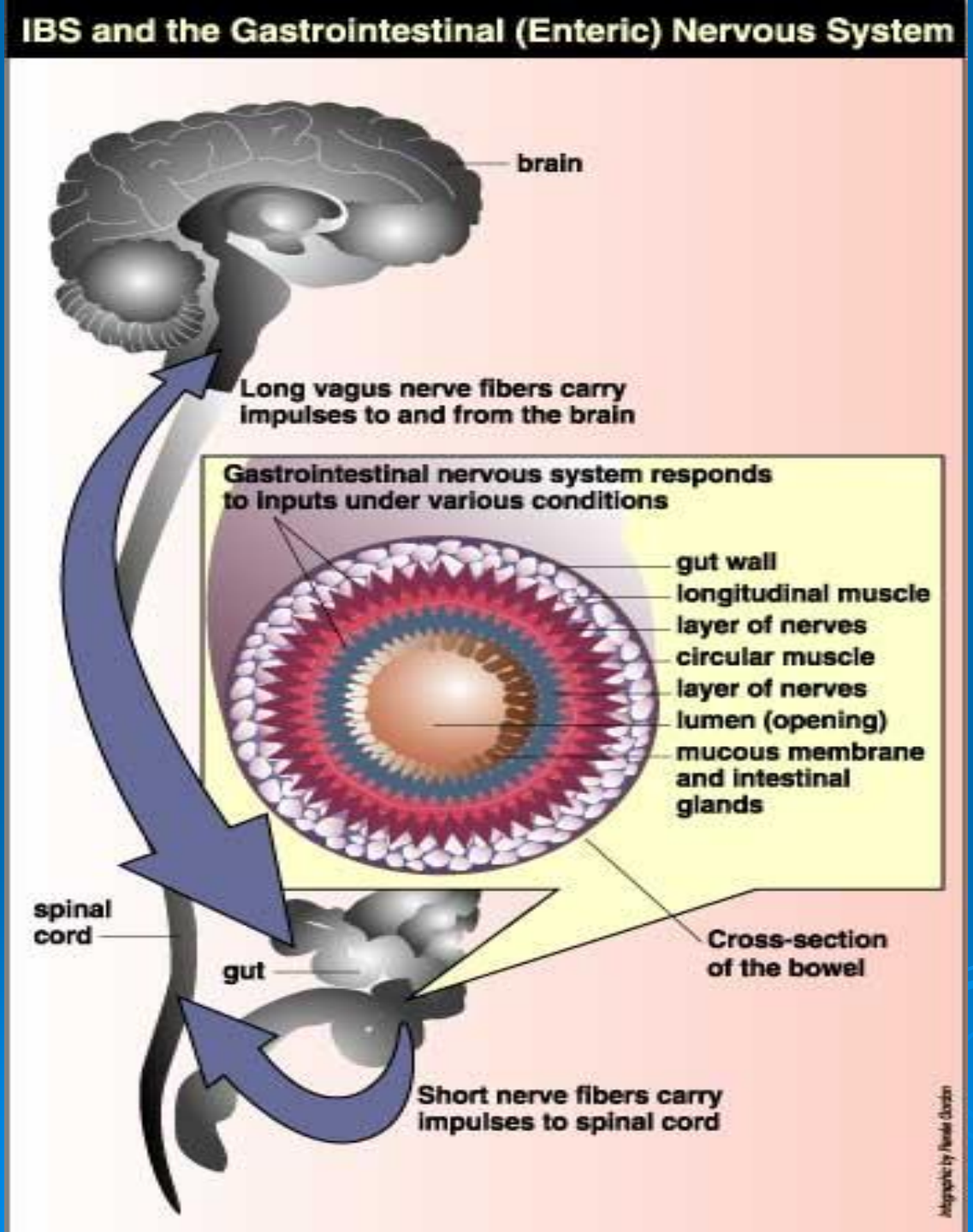
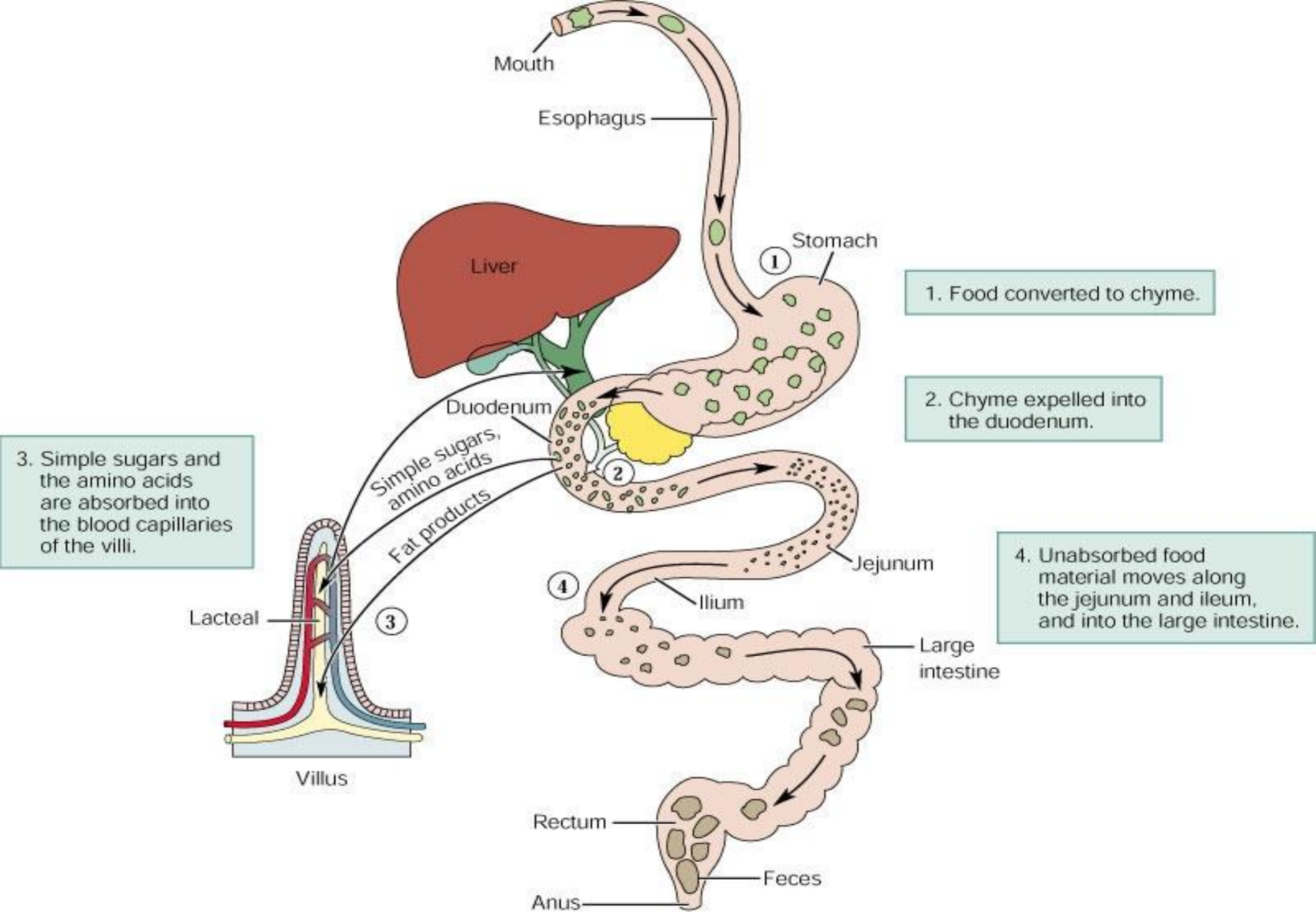


Fig. 15-12, p. 488


Lumen of digestive tract
Wall
Interstitial fluid
Blood
Food
SECRETION
DIGESTION
ABSORPTION
MOTILITY


IBS and the Gastrointestinal (Enteric) Nervous System
brain
Long vagus nerve fibers carry impulses to and from the brain
Gastrointestinal nervous system responds to inputs under various conditions
gut wall
longitudinal muscle
layer of nerves
circular muscle
layer of nerves
lumen (opening)
mucous membrane and intestinal glands
spinal cord
gut
Cross-section of the bowel
Short nerve fibers carry impulses to spinal cord



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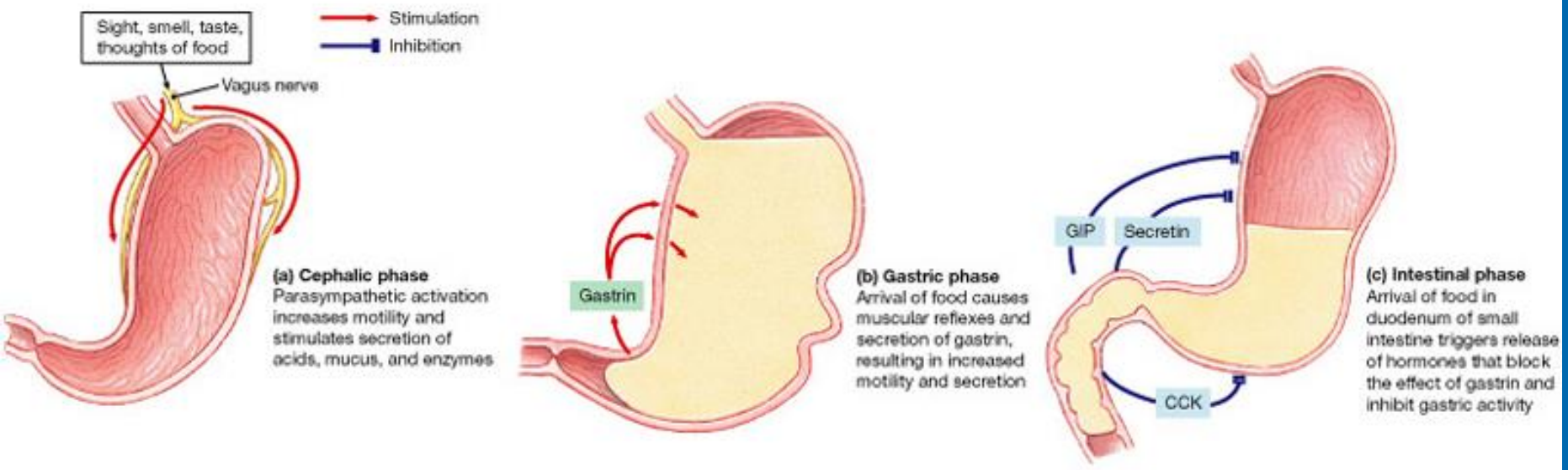
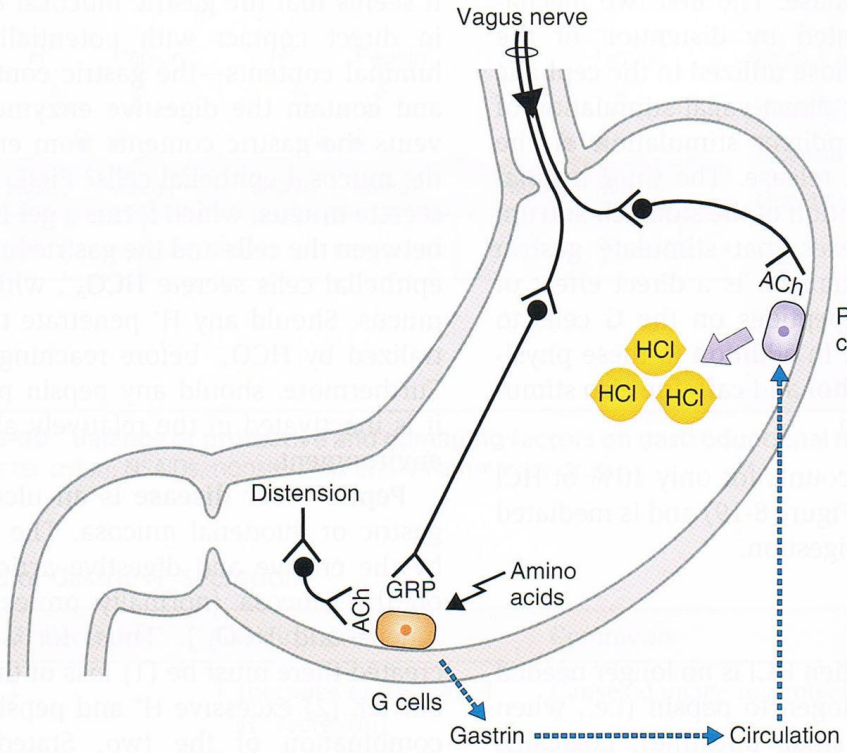
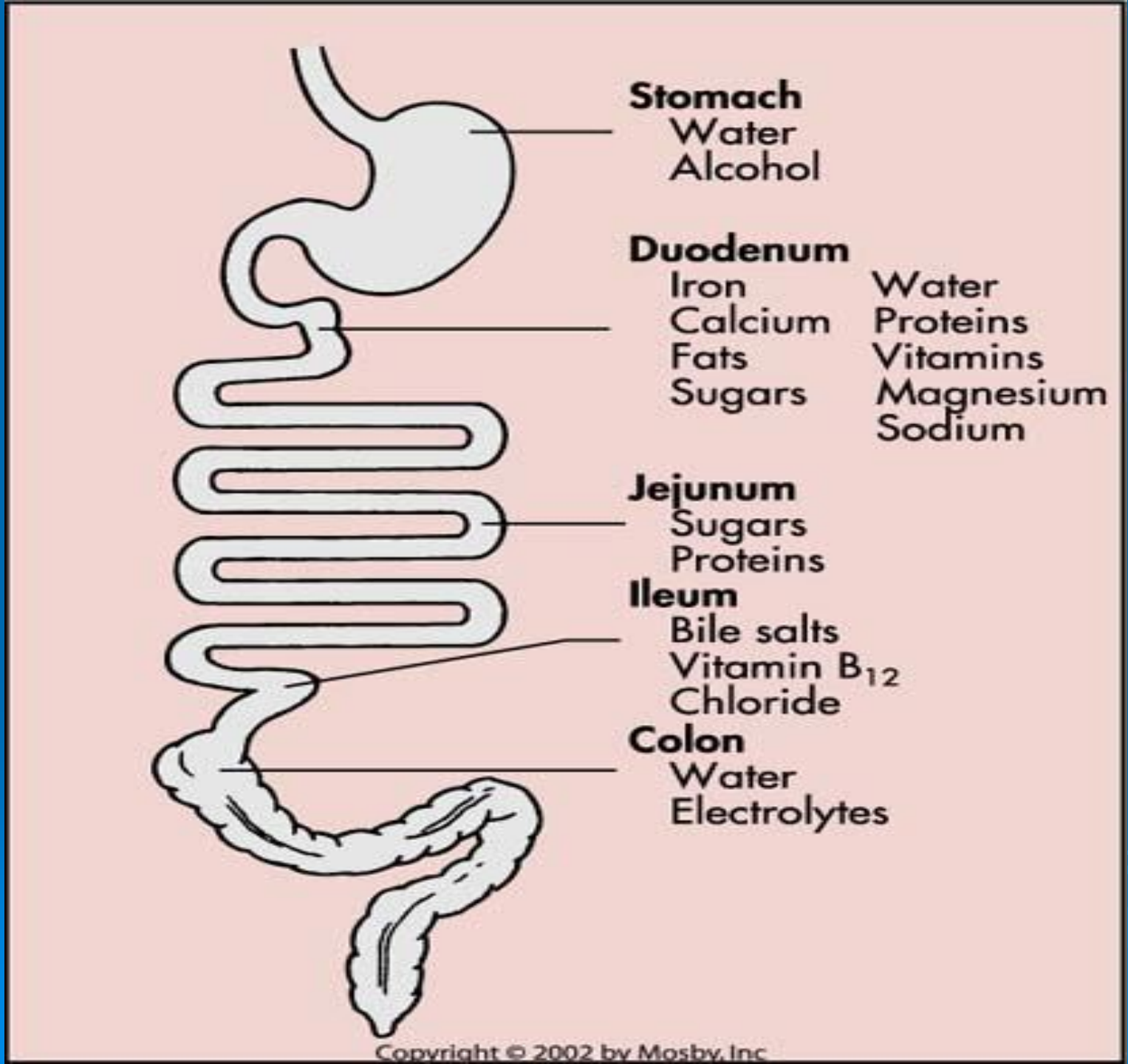

Sight, smell, taste, thoughts of food
Stimulation
Inhibition
Vagus nerve
(a) Cephalic phase
Parasympathetic activation increases motility and stimulates secretion of acids, mucus, and enzymes
Gastrin
(b) Gastric phase
Arrival of food causes muscular reflexes and secretion of gastrin, resulting in increased motility and secretion
GIP
Secretin
CCK
(c) Intestinal phase
Arrival of food in duodenum of small intestine triggers release of hormones that block the effect of gastrin and inhibit gastric activity

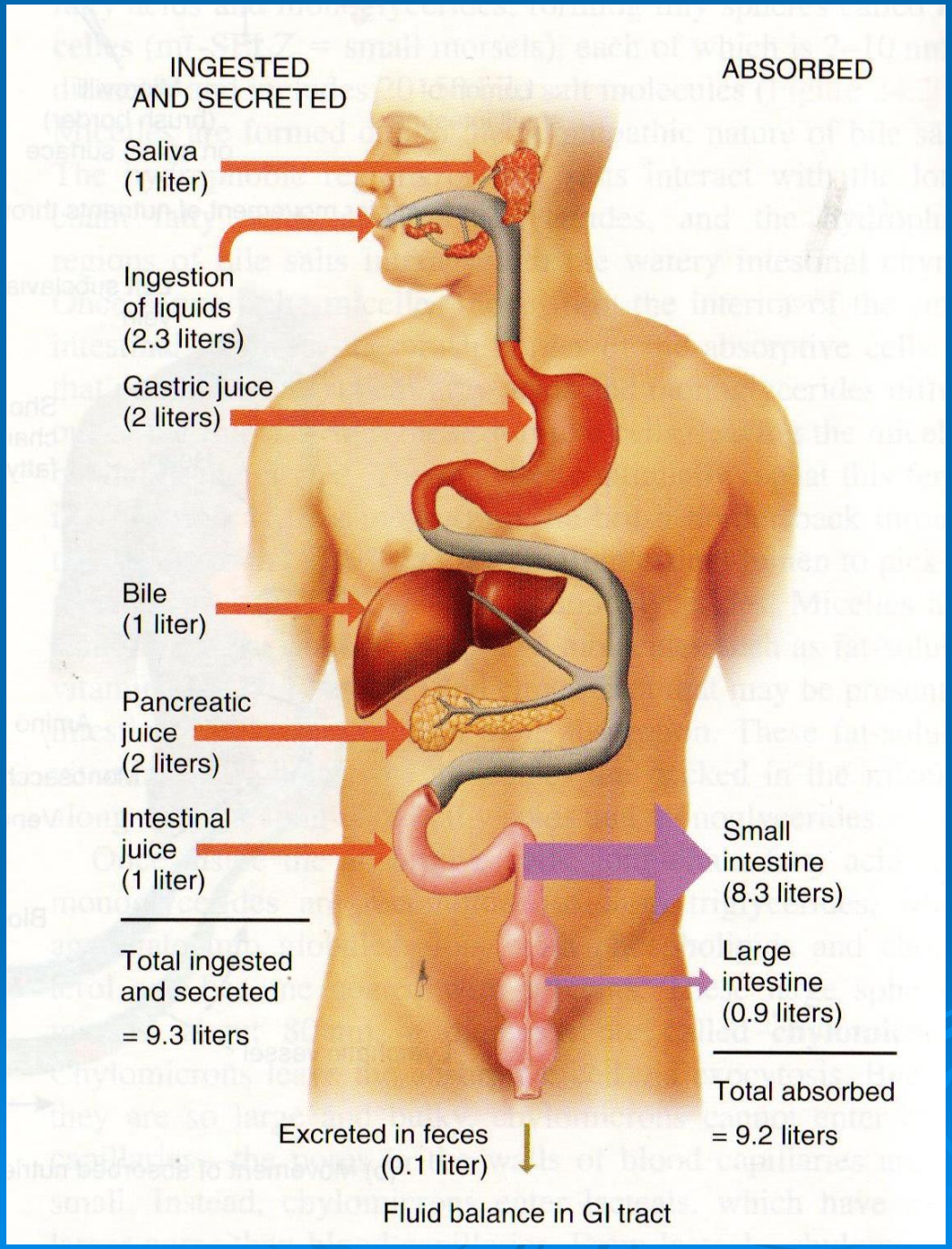
REGULATION OF HCl SECRETION



Phase	% of HCl Secretion	Stimuli	Mechanisms
Cephalic	30%	Smell, taste, conditioning	Vagus → parietal cell Vagus → gastrin → parietal cell
Gastric	60%	Distension	Vagus → parietal cell Vagus → gastrin → parietal cell
		Distension of antrum	Local reflex → gastrin → parietal cell
		Amino acids, small peptides	Gastrin → parietal cell

Figure 8–19 Regulation of HCl secretion during cephalic and gastric phases. ACh, Acetylcholine; GRP, gastrin-releasing peptide (bombesin).




INGESTED
AND SECRETED
ABSORBED
Saliva
(1 liter)
Ingestion
of liquids
(2.3 liters)
Gastric juice
(2 liters)
Bile
(1 liter)
Pancreatic
juice
(2 liters)
Intestinal
juice
(1 liter)
Total ingested
and secreted
= 9.3 liters
Small
intestine
(8.3 liters)
Large
intestine
(0.9 liters)
Total absorbed
= 9.2 liters
Excreted in feces
(0.1 liter)
Fluid balance in GI tract

Intestinal Movements

- Segmentation
  - Mixing mucous and enzyme
- Slow peristaltic contractions → to encourage absorption
- Local contractions (no CNS involvement)
- It takes appr. 5 hrs to digest & move chymus from duodenum to ileum

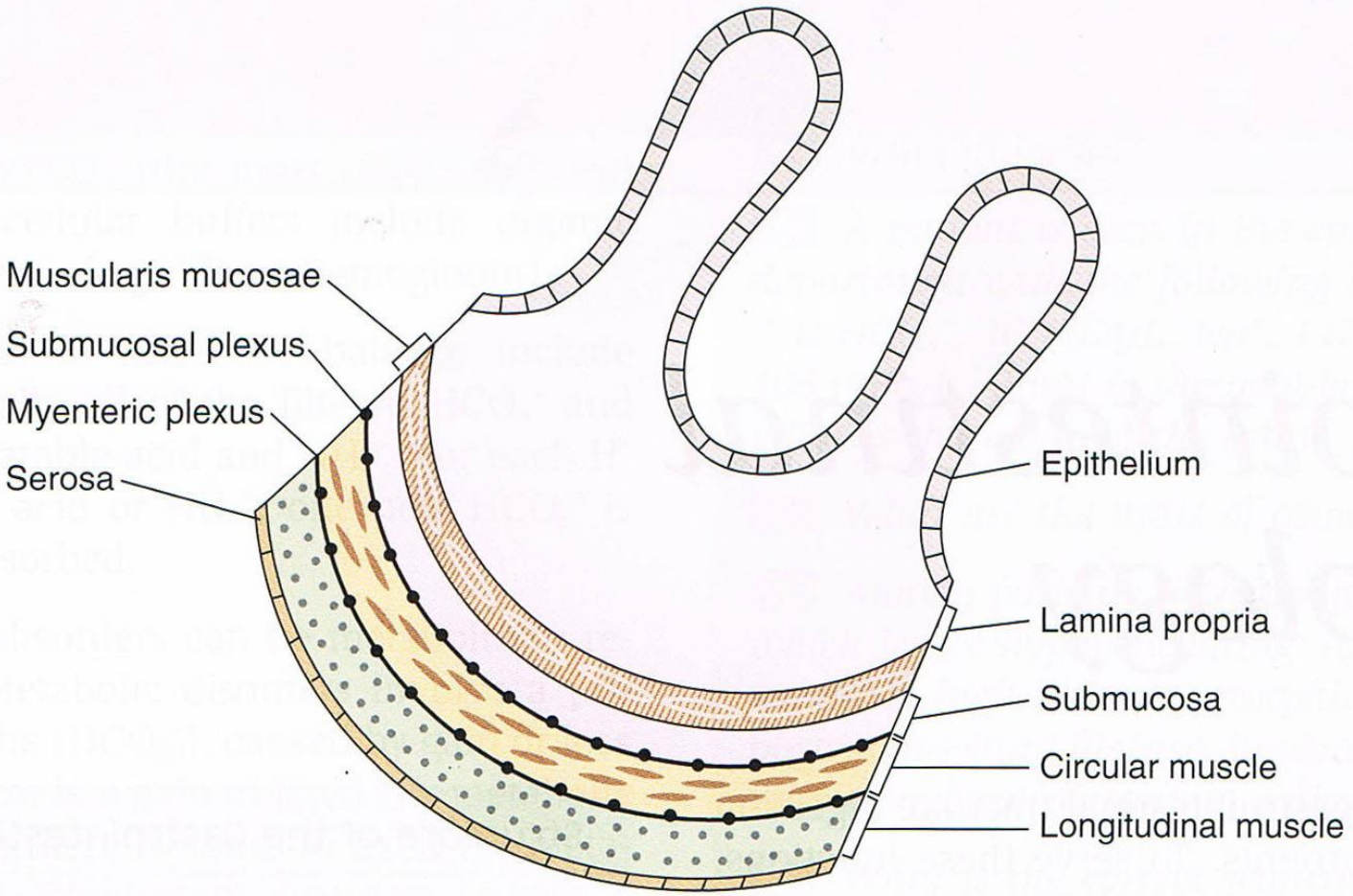
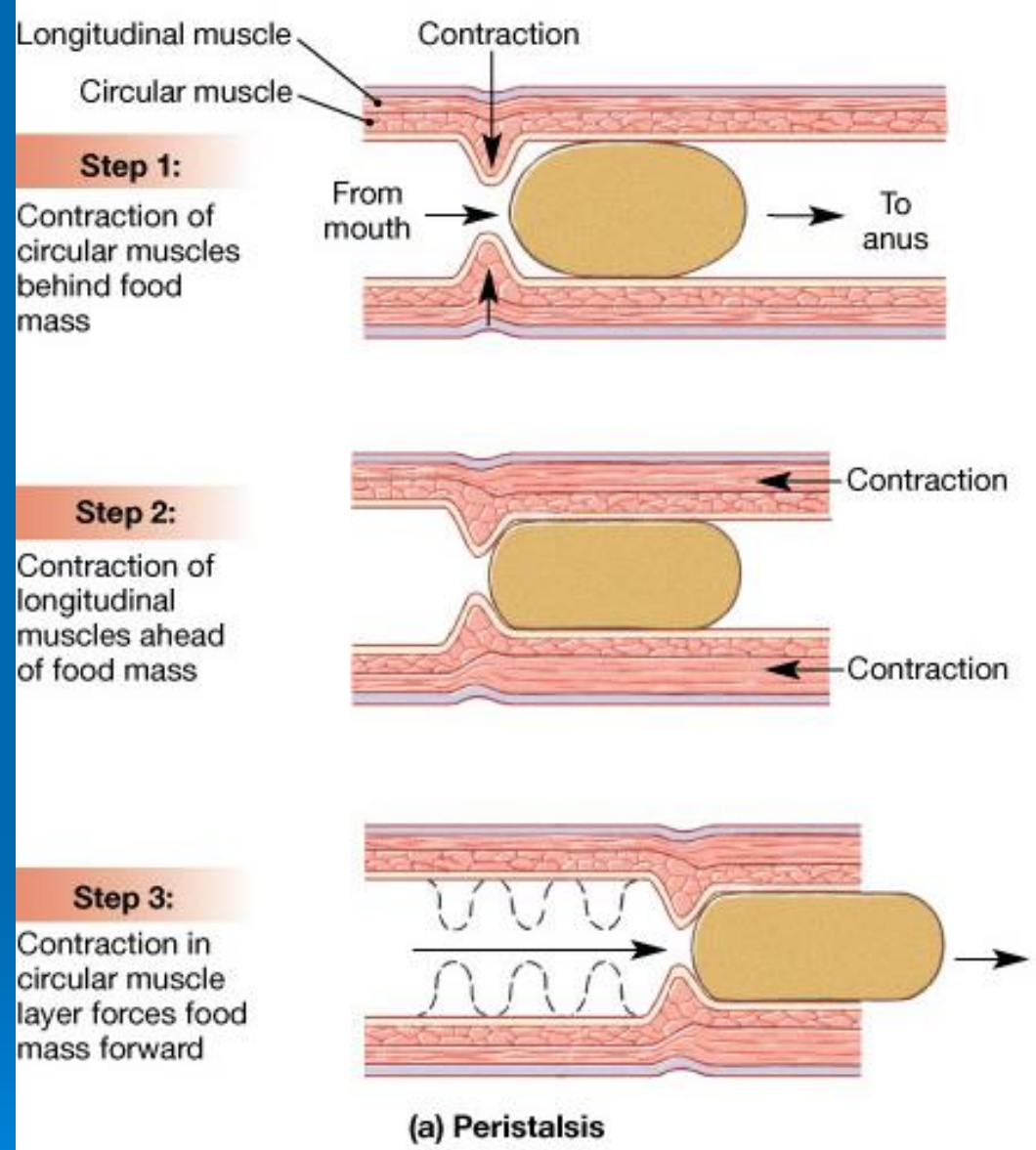
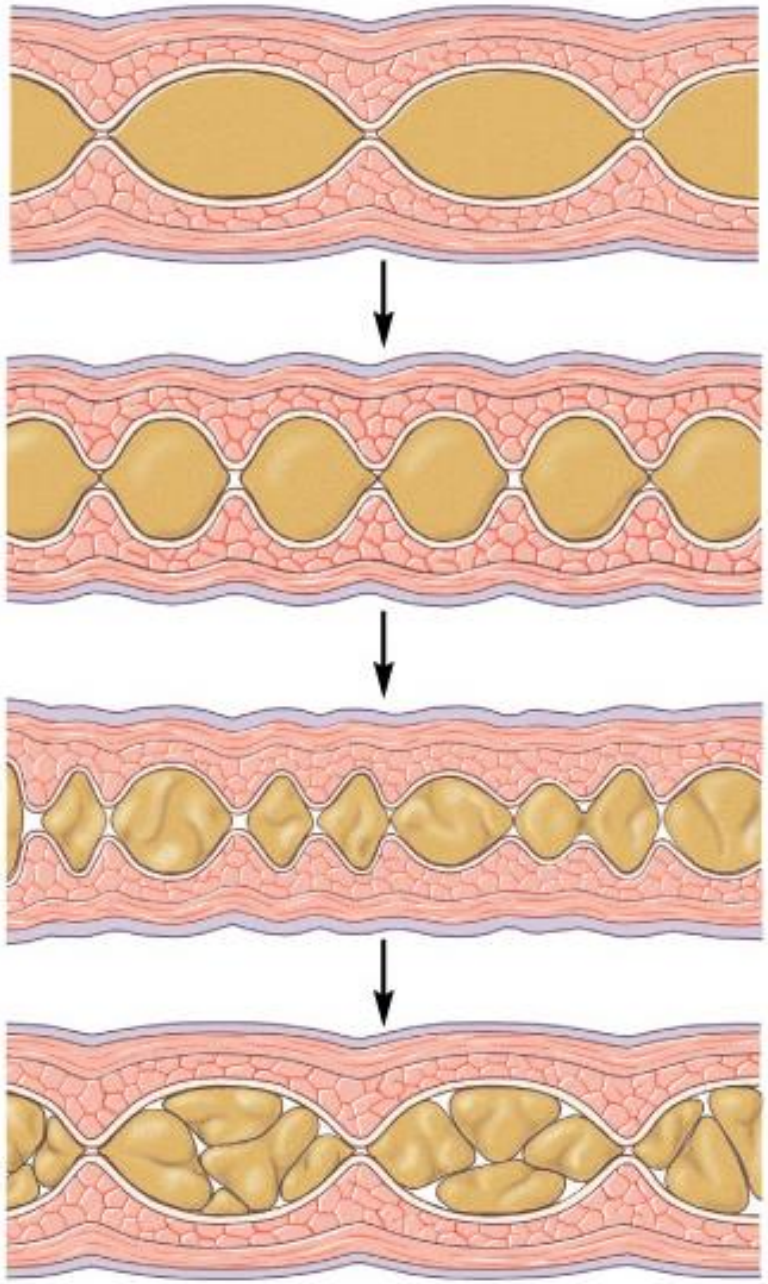


Figure 8–1 The structure of the wall of the gastrointestinal tract.



(a) Peristalsis



(b) Segmentation

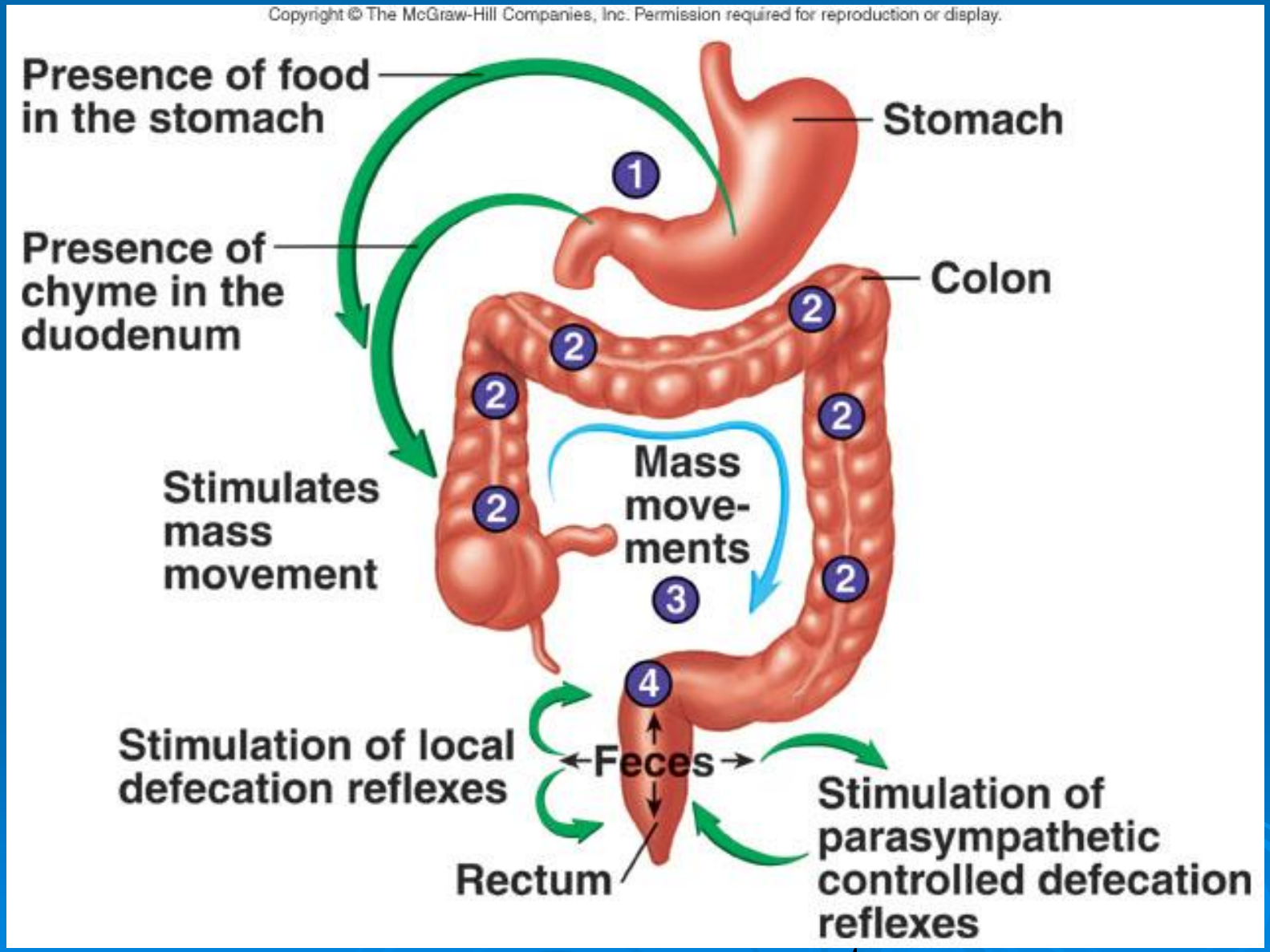
Colon Motility

→ pattern of motility

- Haustration (slow segmentation)
- Mass movement (slow peristaltic; 3-4 times/day)

Defecation

Distension of rectum **stimulates** sigmoid colon and smooth muscle of rectal wall → relaxation of internal sphincter muscle (outonomic nerve)
Defecation conducts when external sphincter muscle is relaxed



Gastrointestinal Hormones

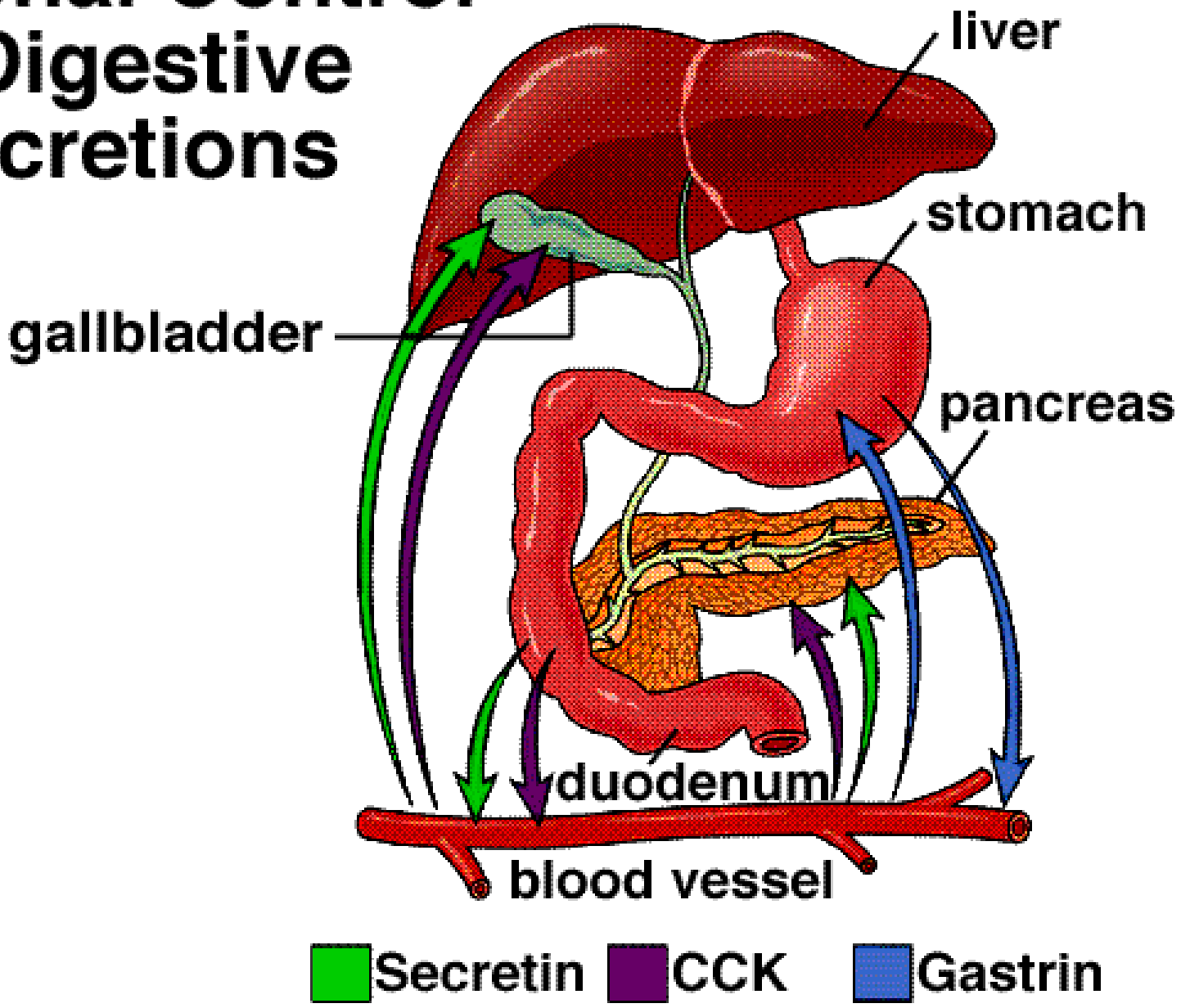
Gastrin

- **Origin: Stomach**
- **Stimulus: Food in stomach**
- **Function: Stimulates HCl & pepsinogen secretion, increases stomach motility**

Secretin

- **Origin: Duodenum**
- **Stimulus: Acid**
- **Function: Stimulates pancreatic secretions. Slows stomach motility and acid production**

Hormonal Control of Digestive Secretions



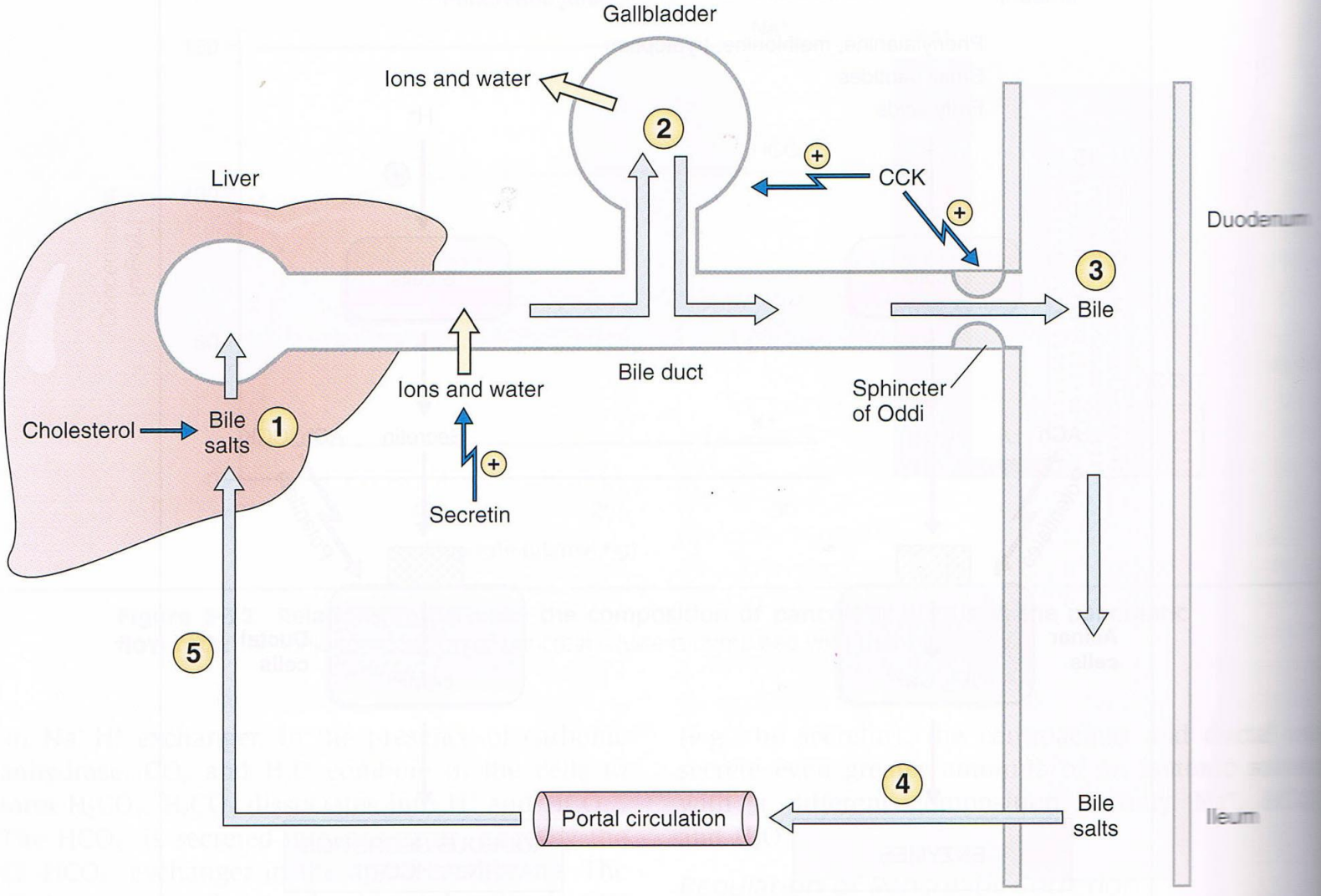
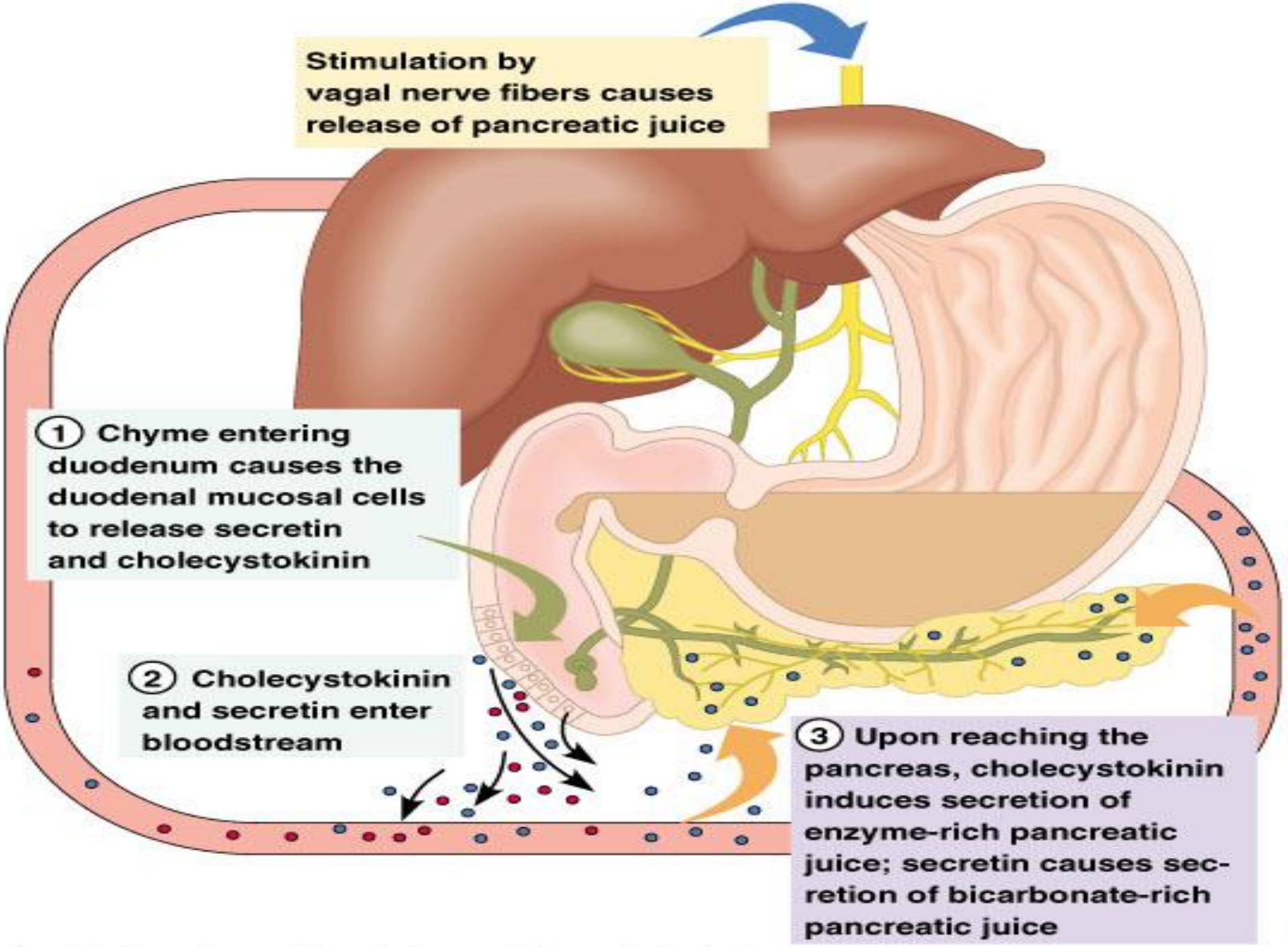
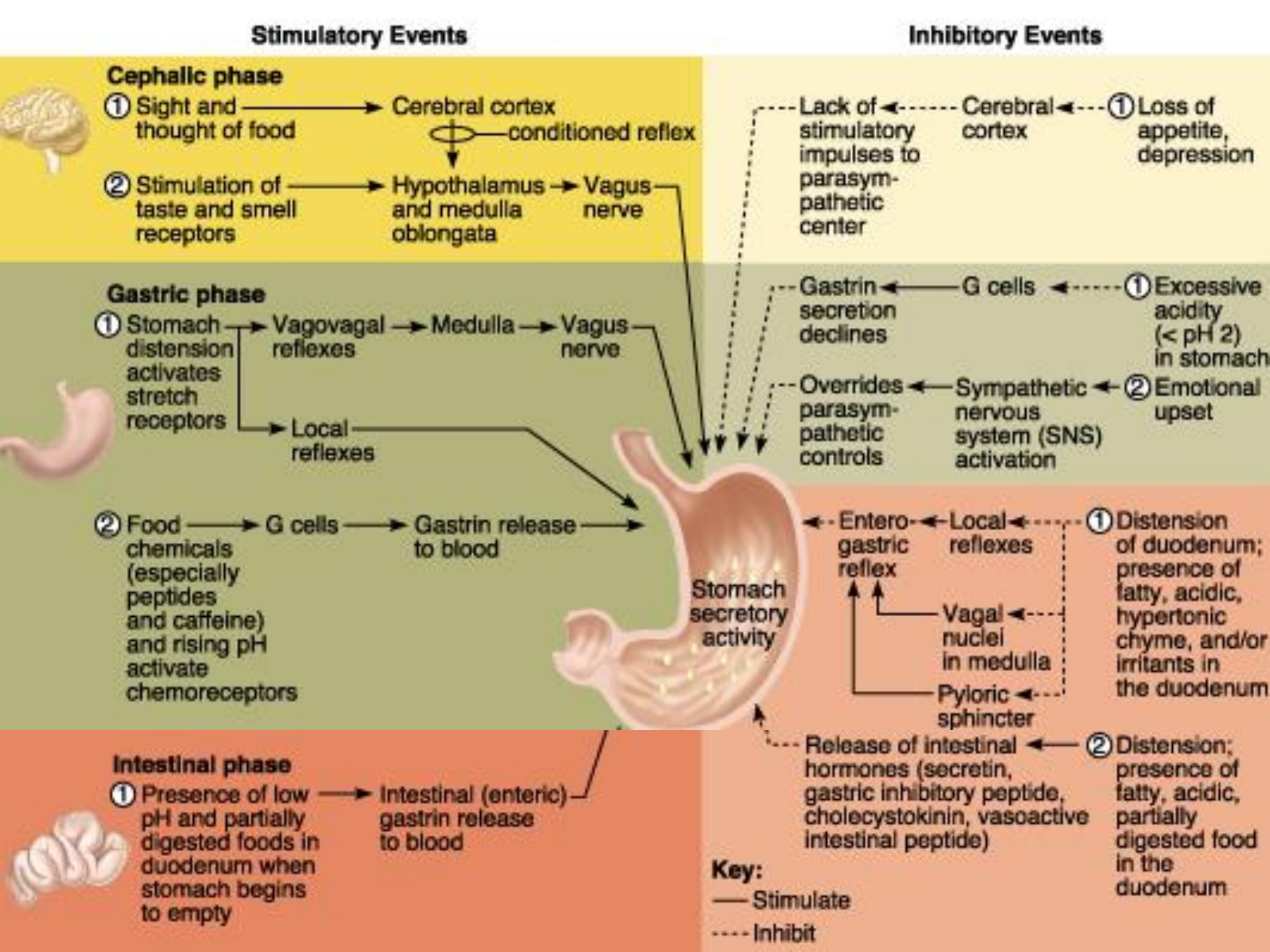


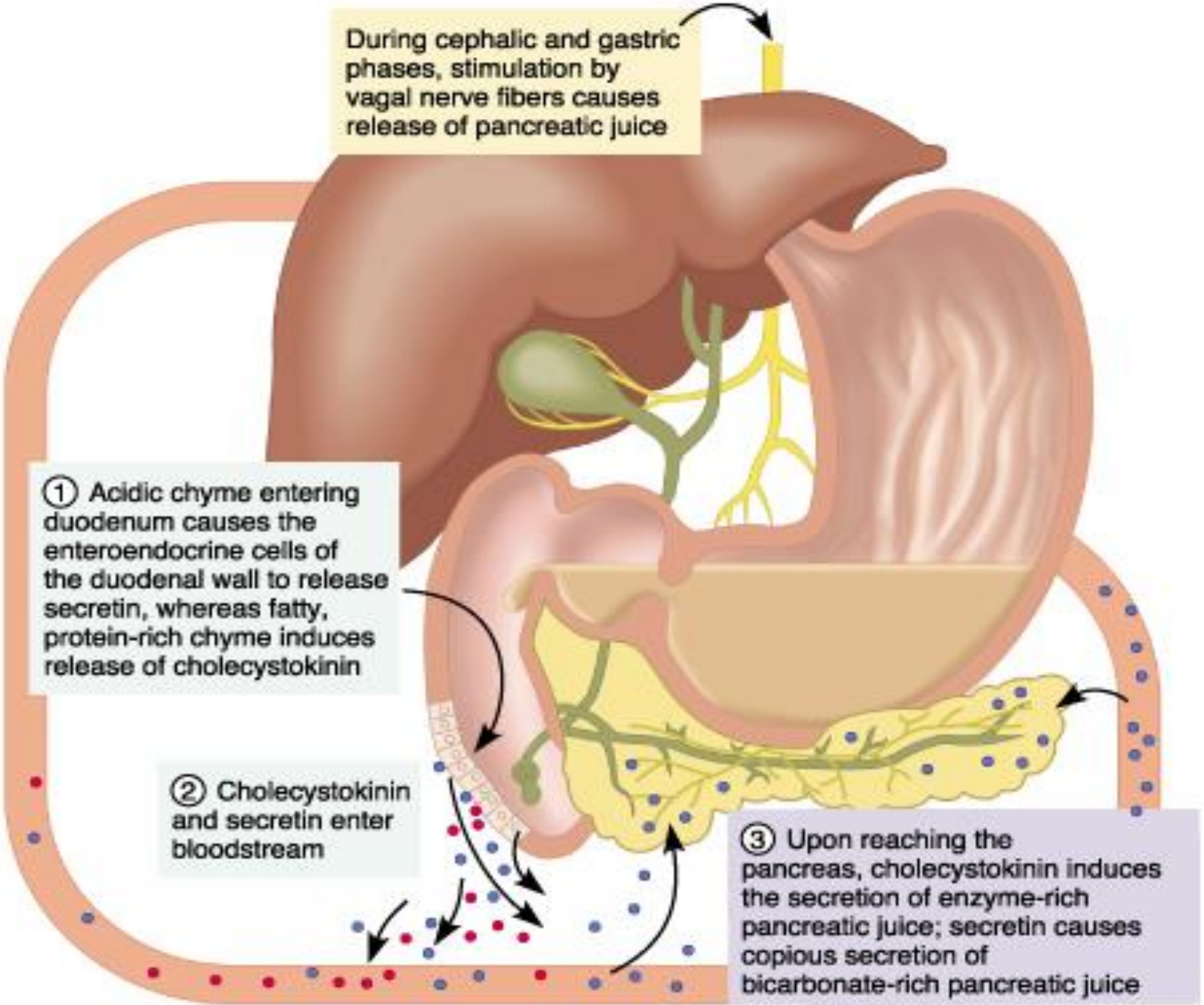
Figure 8–24 **Secretion and enterohepatic circulation of bile salts.** *Light blue arrows* show the path of bile flow; *yellow arrows* show the movement of ions and water. CCK, Cholecystokinin.

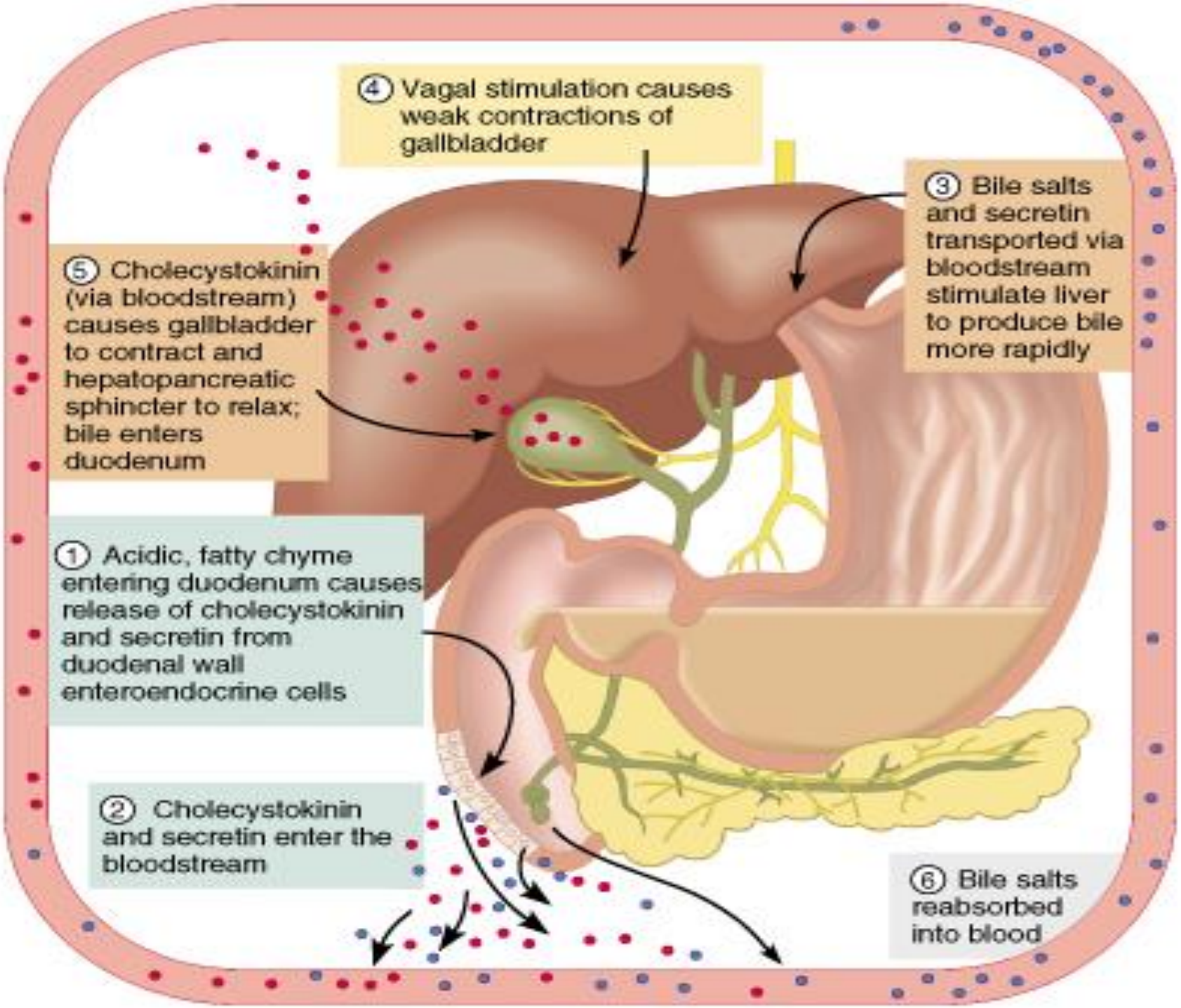
Table 24.3 Functions of the Gastrointestinal Hormones

Site of Production	Method of Stimulation	Secretory Effects	Motility Effects
Gastrin			
Stomach and duodenum	Distention; partially digested proteins, autonomic stimulation, ingestion of alcohol or caffeine	Increases gastric secretion	Increases gastric emptying by increasing stomach motility and relaxing the pyloric sphincter
Secretin			
Duodenum	Acidity of chyme	Inhibits gastric secretion; stimulates pancreatic secretions high in bicarbonate ions; increases the rate of bile and increases intestinal secretion; mucus secretion	Decreases gastric motility
Cholecystokinin			
Intestine	Fatty acids and other lipids	Slightly inhibits gastric secretion; stimulates pancreatic secretions high in digestive enzymes; and causes contraction of the gallbladder and relaxation of the hepatopancreatic ampullar sphincter	Decreases gastric motility
Gastric Inhibitory Polypeptide			
Duodenum and proximal jejunum	Fatty acids and other lipids	Inhibits gastric secretions	Decreases gastric motility




Stimulatory Events
Inhibitory Events
Cephalic phase
① Sight and thought of food
Cerebral cortex
conditioned reflex
② Stimulation of taste and smell receptors
Hypothalamus and medulla oblongata
Vagus nerve
Lack of stimulatory impulses to parasym-pathetic center
Cerebral cortex
① Loss of appetite, depression
Gastric phase
① Stomach distension activates stretch receptors
Vagovagal reflexes
Medulla
Vagus nerve
Local reflexes
Gastrin secretion declines
G cells
① Excessive acidity (< pH 2) in stomach
Overrides parasym-pathetic controls
Sympathetic nervous system (SNS) activation
② Emotional upset
② Food chemicals (especially peptides and caffeine) and rising pH activate chemoreceptors
G cells
Gastrin release to blood
Stomach secretory activity
Entero-gastric reflex
Local reflexes
① Distension of duodenum; presence of fatty, acidic, hypertonic chyme, and/or irritants in the duodenum
Vagal nuclei in medulla
Pyloric sphincter
Intestinal phase
① Presence of low pH and partially digested foods in duodenum when stomach begins to empty
Intestinal (enteric) gastrin release to blood
Release of intestinal hormones (secretin, gastric inhibitory peptide, cholecystokinin, vasoactive intestinal peptide)
② Distension; presence of fatty, acidic, partially digested food in the duodenum
Key:
Stimulate
Inhibit


During cephalic and gastric phases, stimulation by vagal nerve fibers causes release of pancreatic juice
① Acidic chyme entering duodenum causes the enteroendocrine cells of the duodenal wall to release secretin, whereas fatty, protein-rich chyme induces release of cholecystokinin
② Cholecystokinin and secretin enter bloodstream
③ Upon reaching the pancreas, cholecystokinin induces the secretion of enzyme-rich pancreatic juice; secretin causes copious secretion of bicarbonate-rich pancreatic juice


④ Vagal stimulation causes weak contractions of gallbladder
③ Bile salts and secretin transported via bloodstream stimulate liver to produce bile more rapidly
⑤ Cholecystokinin (via bloodstream) causes gallbladder to contract and hepatopancreatic sphincter to relax; bile enters duodenum
① Acidic, fatty chyme entering duodenum causes release of cholecystokinin and secretin from duodenal wall enteroendocrine cells
② Cholecystokinin and secretin enter the bloodstream
⑥ Bile salts reabsorbed into blood

Hormones are grouped into 2 families

Gastrin

- gastrin & CCK

Secretin

- Secretin, glucagon, glicentin, VIP,GIP

- Were grouped based on:
  - Similarity of chemical structures
  - Similarity of its function

GASTRIN Actions

- *in general*: stimulates gastric secretion & motility

1. Stimulates gastric acid secretion
2. Stimulates pepsin&intrinsic factor secretion by the stomach
3. Stimulates growth of gastric & intestinal mucosa (‘thropic action’)
4. Increase the tone of musculature of the LOS,stomach & small intestine
5. Stimulates insulin and glucagon secretion (after a protein meal)
6. Stimulates calcitonin secretion

CCK-PZ Actions

1. Contraction of gall bladder (→ cholecystokinin?)
2. Secretion of pancreatic juice rich in enzyme (→ pancreaozymin?)]
3. Augments the actions of secretin in producing an alkaline pancreatic juice
4. Increases the secretion of enterokinase from intestinal mucosa
5. Exert trophic effect on the pancreas
6. Inhibit gastric emptying
7. May enhance the motility of the small intestine and colon
8. Along with secretin, it augments the contraction of pyloric sphincter
9. Together with gastrin, stimulates glucagon secretion

SECRETIN Actions

1. Stimulates bicarbonate rich-watery alkaline pancreatic juice by increasing bicarbonate secretion of biliary tract
2. Increases bicarbonate secretion of biliary tract
3. Augments the action of CCK-PZ in producing pancreatic secretion of digestive enzymes
4. Decreases gastric acid secretion
5. May cause contraction of the pyloric sphincter
6. Increases insulin secretion; but inhibits glucagon secretion

Additional hormones in the digestive system regulate appetite

- **Ghrelin** is produced in the stomach and upper intestine in the absence of food in the digestive system and stimulates appetite.

- **Peptide YY** is produced in the GI tract in response to a meal in the system and inhibits appetite.
- Both of these hormones work on the brain to help regulate the intake of food for energy.

Nerve Regulators

Two types of nerves help to control the action of the digestive system.

Extrinsic (outside) nerves come to the digestive organs from the unconscious part of the brain or from the spinal cord.

They release a chemical called acetylcholine and another called adrenaline.

- **Acetylcholine** causes the muscle of the digestive organs to squeeze with more force and increase the "push" of food and juice through the digestive tract. Acetylcholine also causes the stomach and pancreas to produce more digestive juice.
- **Adrenaline** relaxes the muscle of the stomach and intestine and decreases the flow of blood to these organs.

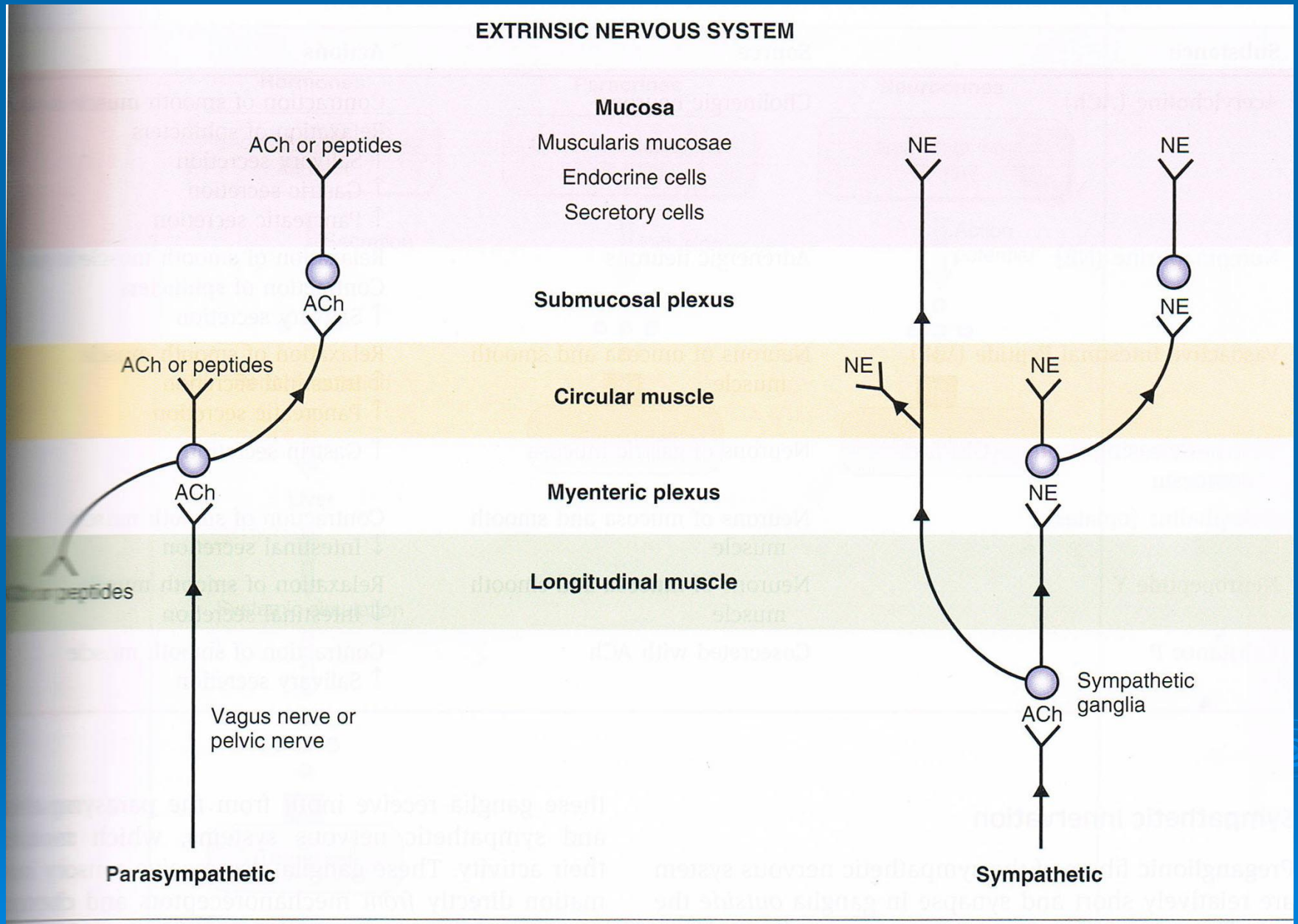


Figure 8–2 The extrinsic nervous system of the gastrointestinal tract. Efferent neurons of the parasympathetic and sympathetic nervous systems synapse in the myenteric and submucosal plexuses, in the smooth muscle, and in the mucosa. ACh, Acetylcholine; NE, norepinephrine.

Intrinsic nerves

Even more important, though, are the intrinsic (inside) nerves, which make up a very dense network embedded in the walls of the esophagus, stomach, small intestine, and colon.

The intrinsic nerves are triggered to act when the walls of the hollow organs are stretched by food.

They release many different substances that **speed up** or **delay** the movement of food and the production of juices by the digestive organs.

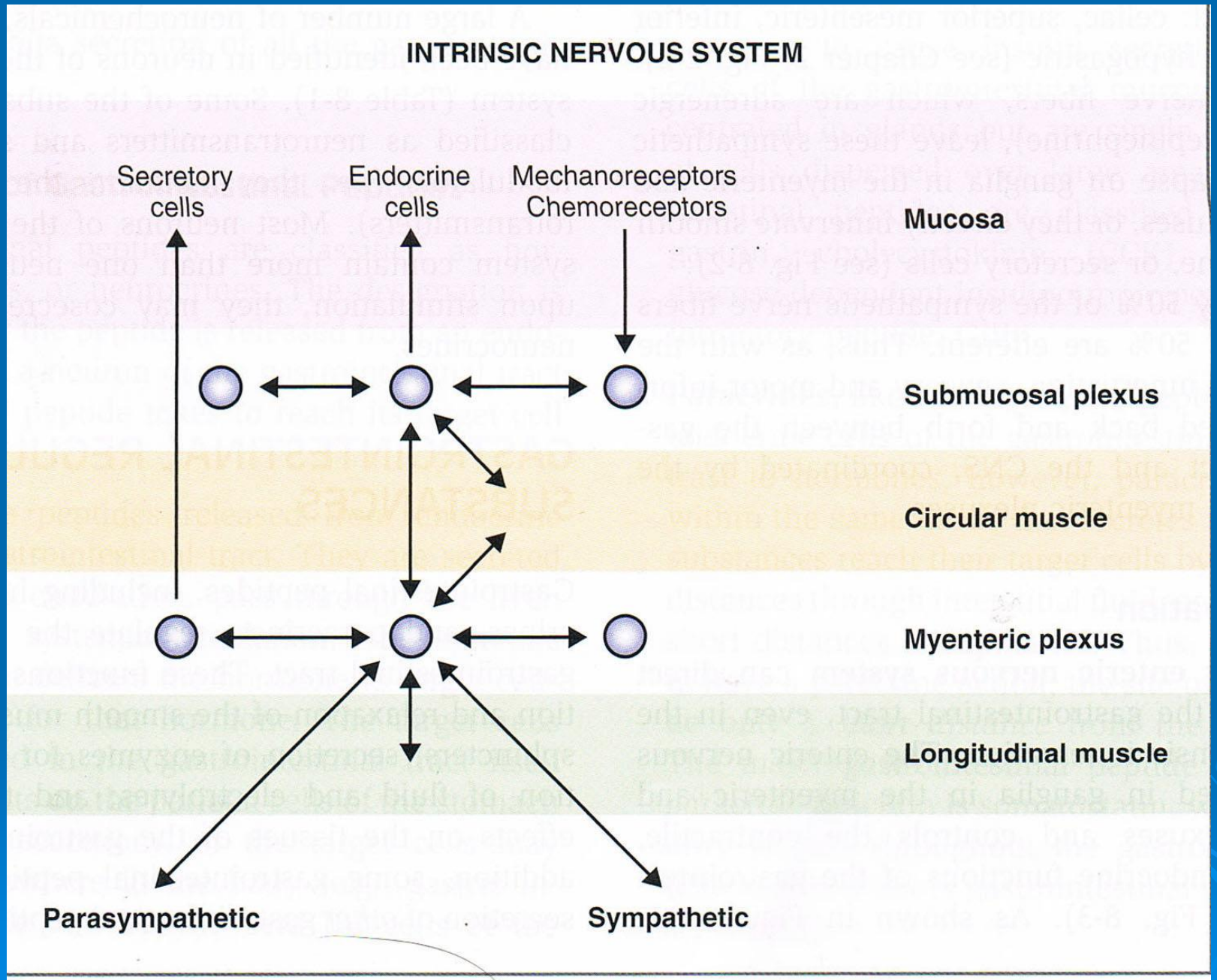
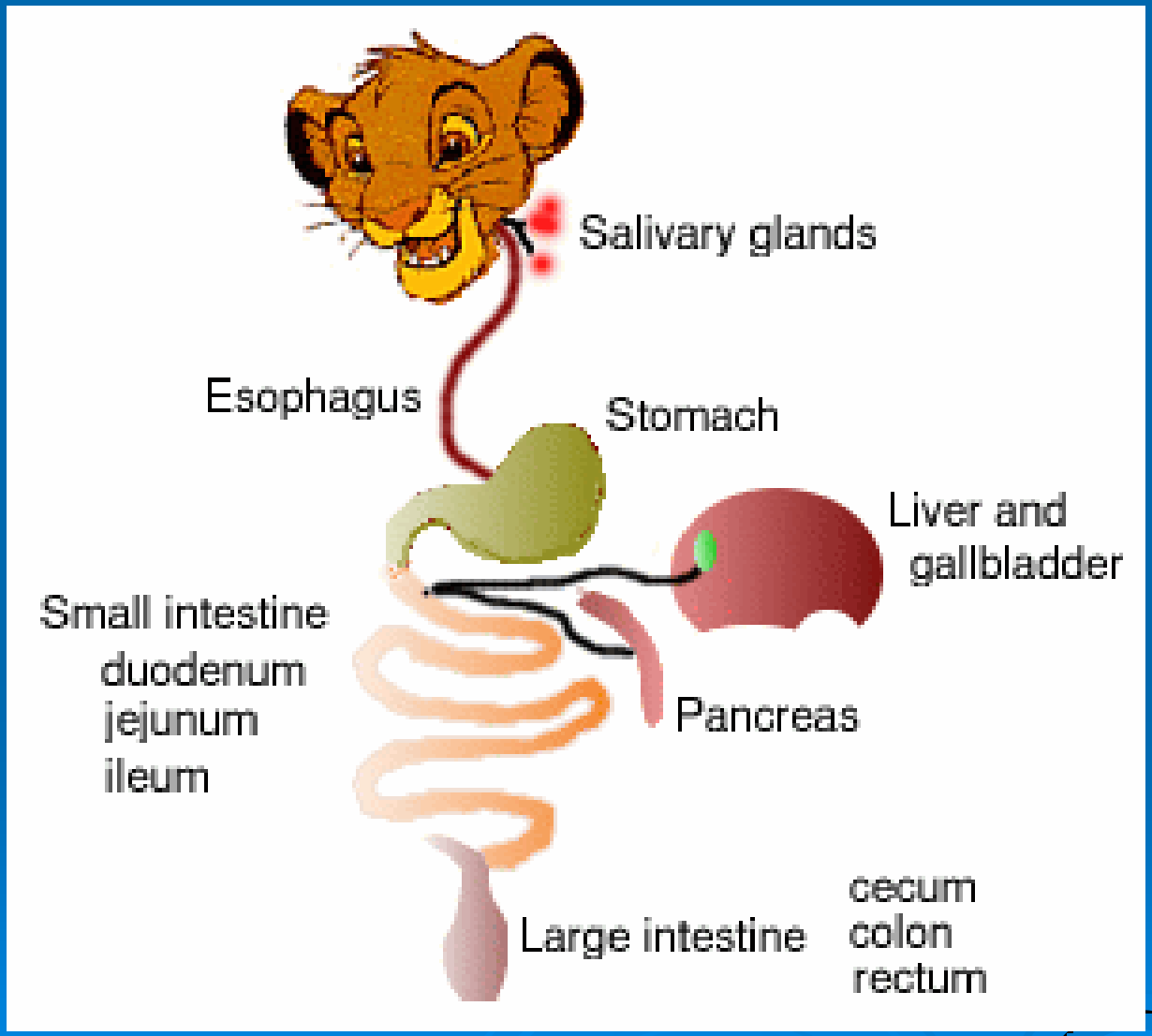


Figure 8–3 Intrinsic nervous system of the gastrointestinal tract.

why obesity?


Salivary glands
Esophagus
Stomach
Liver and gallbladder
Small intestine
duodenum
jejunum
ileum
Pancreas
Large intestine
cecum
colon
rectum

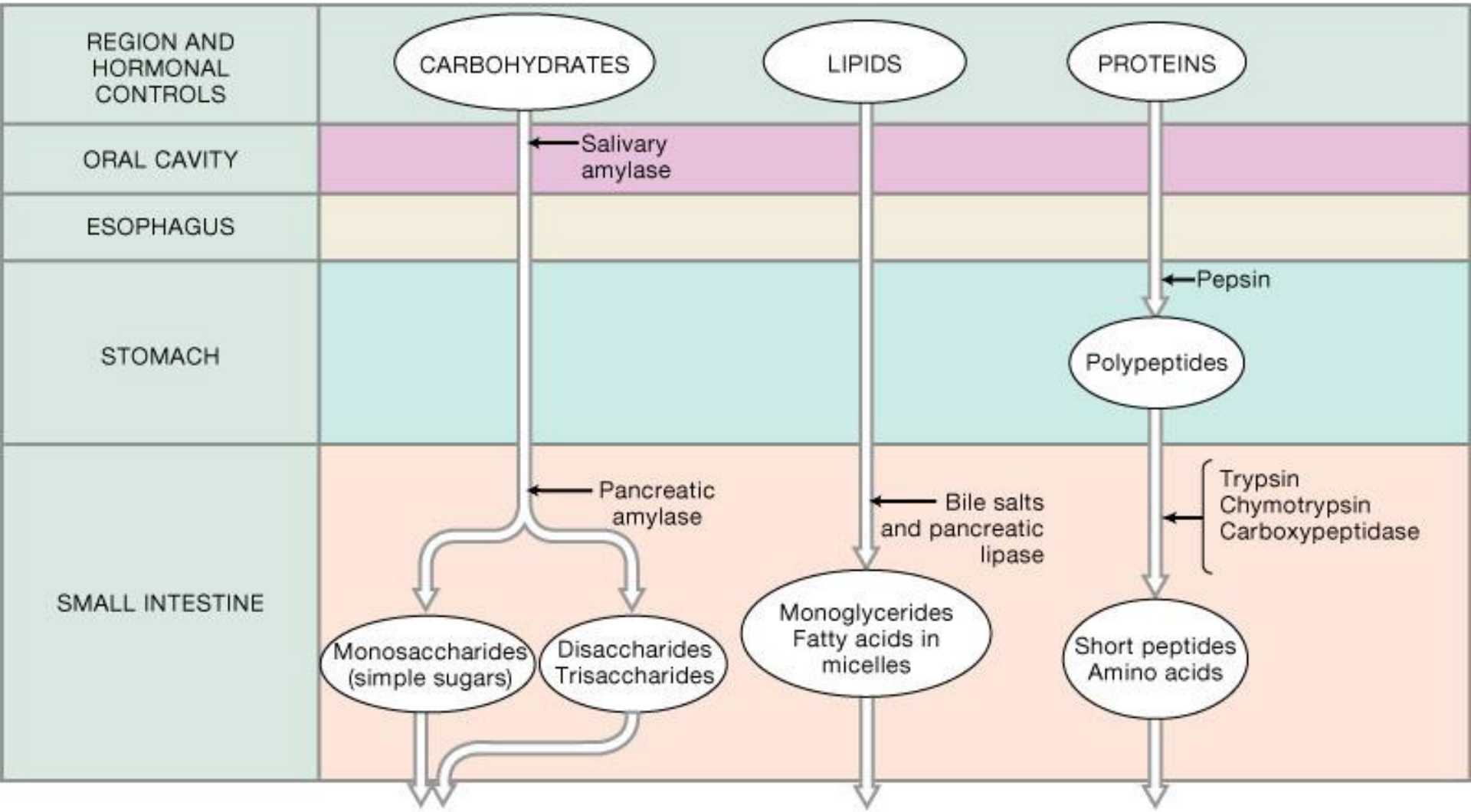
FOOD PROCESSING

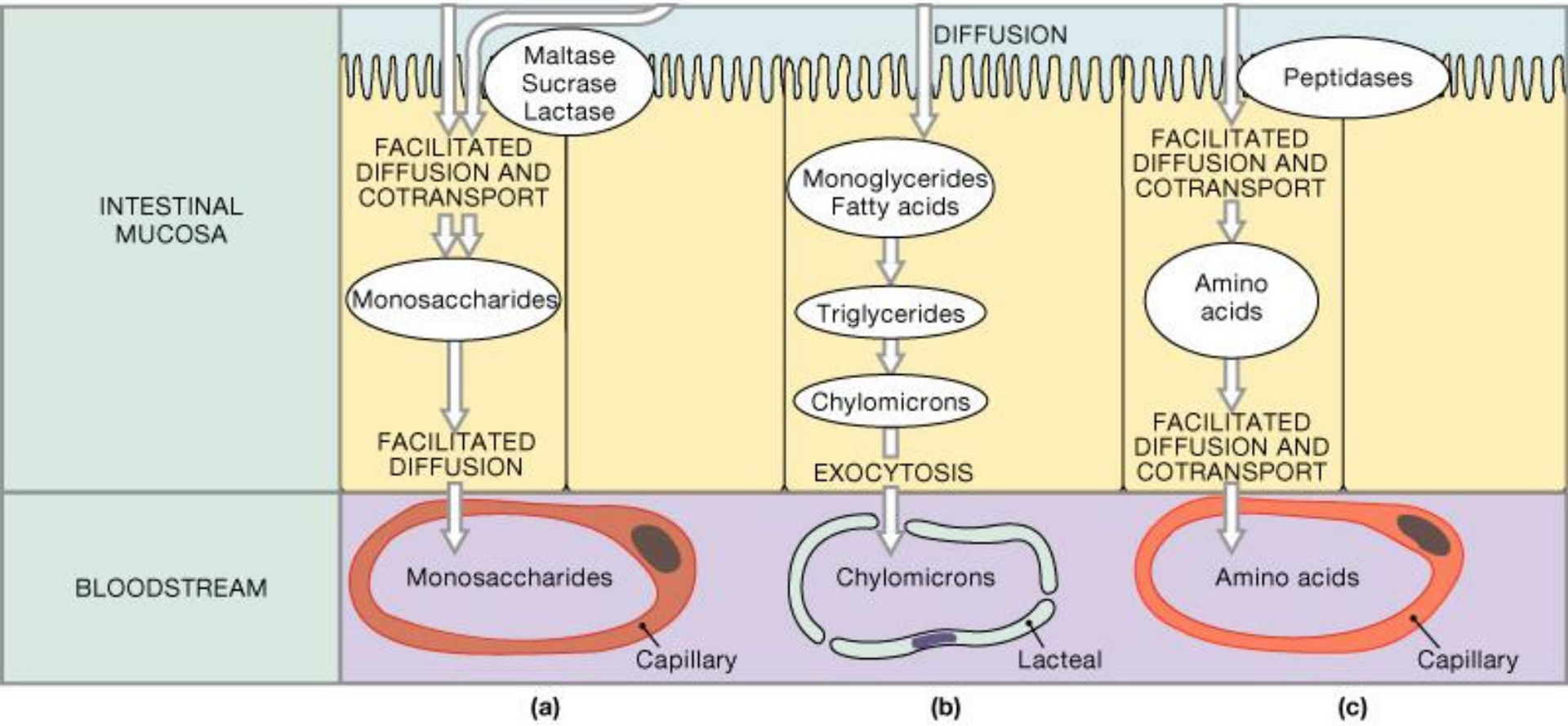
- Ingestion
- Digestion
- Absorption
- Elimination

Mechanical Breakdown

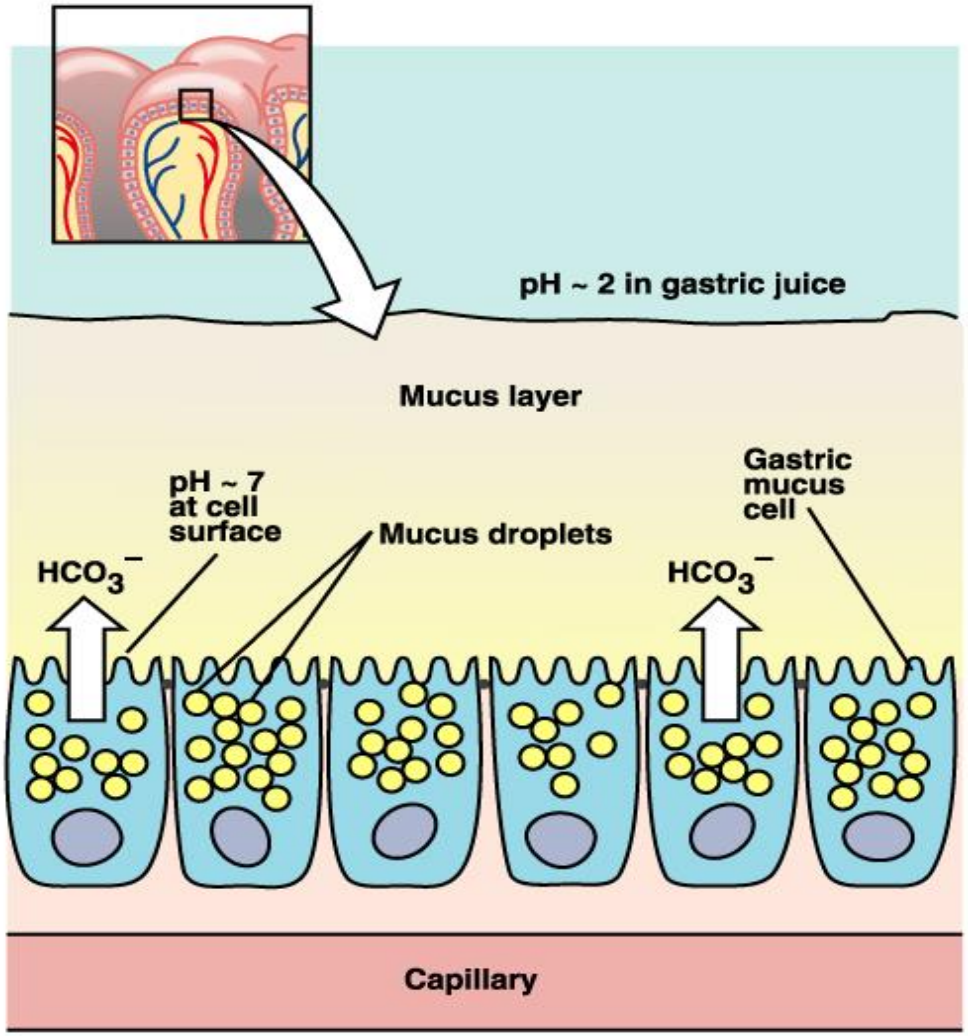
- Biting
- Chewing
- Grinding
- Emulsification

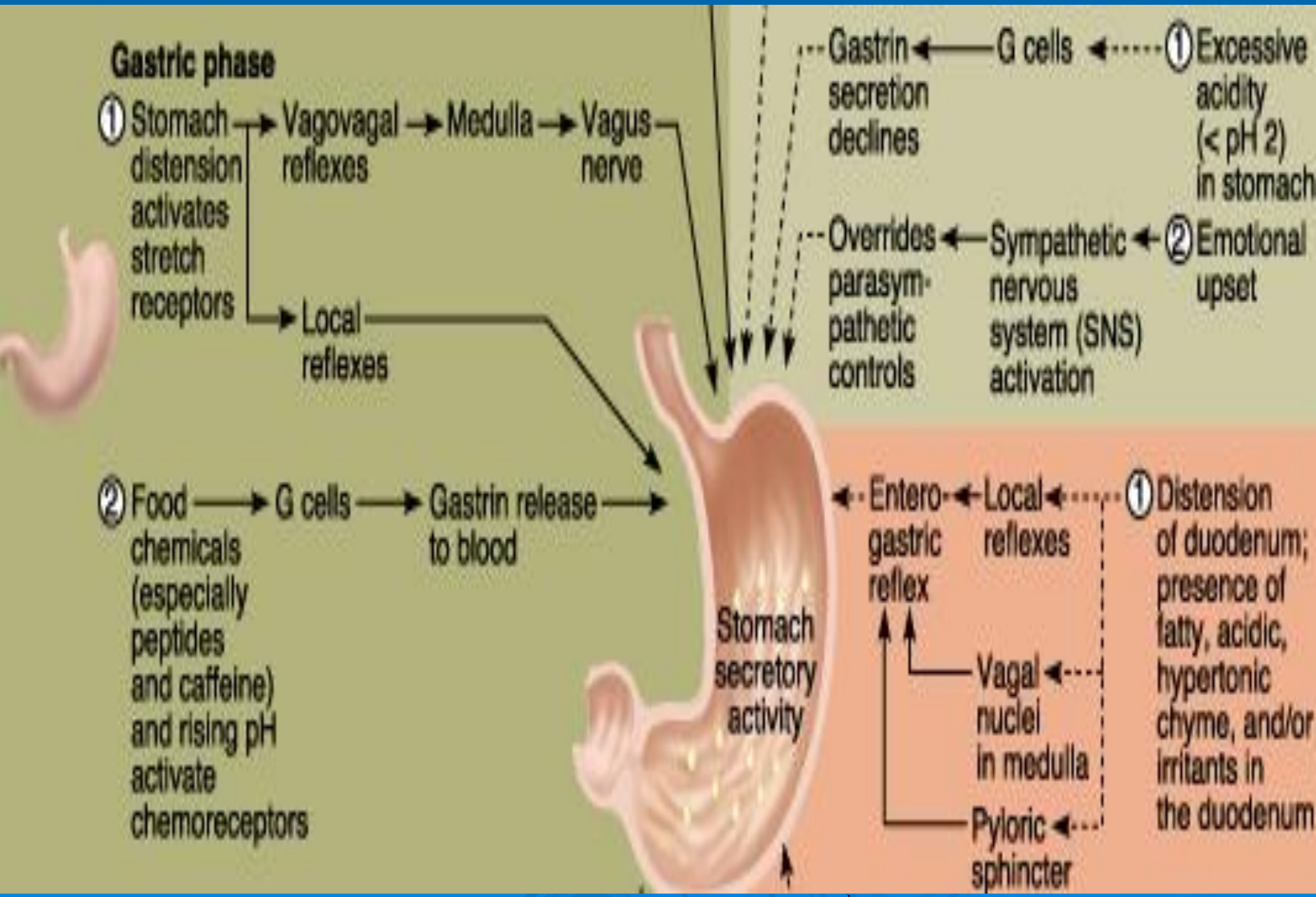
TO INCREASE surface area for enzymatic attack


REGION AND HORMONAL CONTROLS
CARBOHYDRATES
LIPIDS
PROTEINS
ORAL CAVITY
Salivary amylase
ESOPHAGUS
STOMACH
Pepsin
Polypeptides
SMALL INTESTINE
Pancreatic amylase
Bile salts and pancreatic lipase
Trypsin
Chymotrypsin
Carboxypeptidase
Monosaccharides (simple sugars)
Disaccharides Trisaccharides
Monoglycerides Fatty acids in micelles
Short peptides Amino acids


INTESTINAL MUCOSA
BLOODSTREAM
Maltase
Sucrase
Lactase
FACILITATED DIFFUSION AND COTRANSPORT
Monosaccharides
FACILITATED DIFFUSION
Monosaccharides
Capillary
(a)
DIFFUSION
Monoglycerides
Fatty acids
Triglycerides
Chylomicrons
EXOCYTOSIS
Chylomicrons
Lacteal
(b)
Peptidases
FACILITATED DIFFUSION AND COTRANSPORT
Amino acids
FACILITATED DIFFUSION AND COTRANSPORT
Amino acids
Capillary
(c)

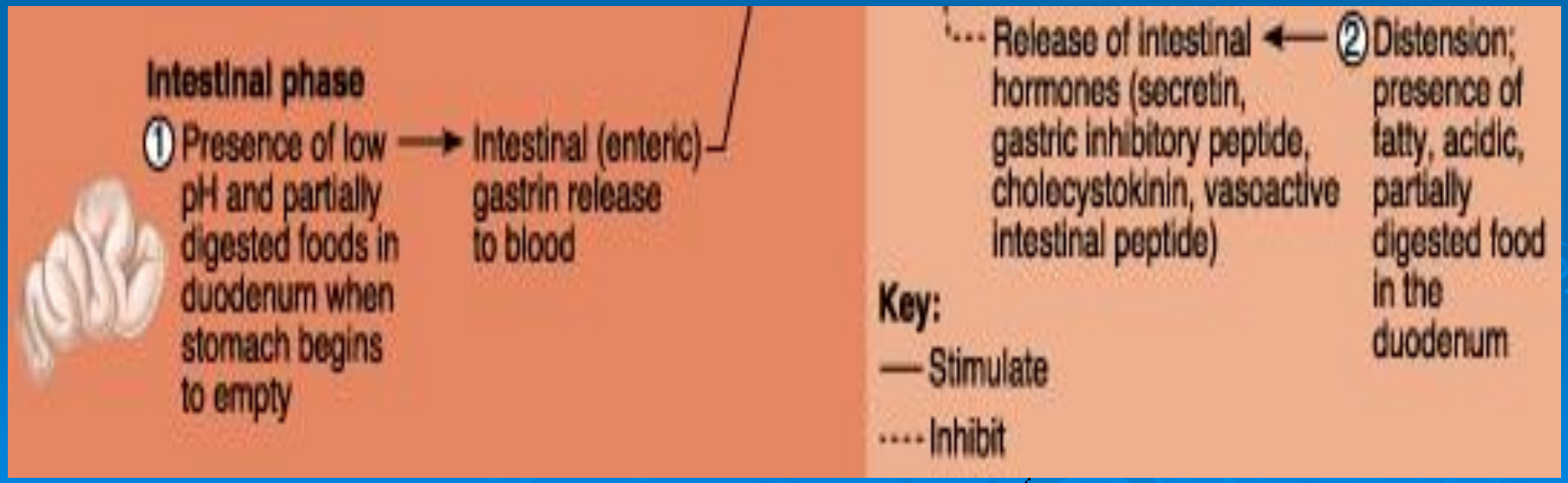
Sekresi lambung: - HCL
- pepsinogen
- Gastrin

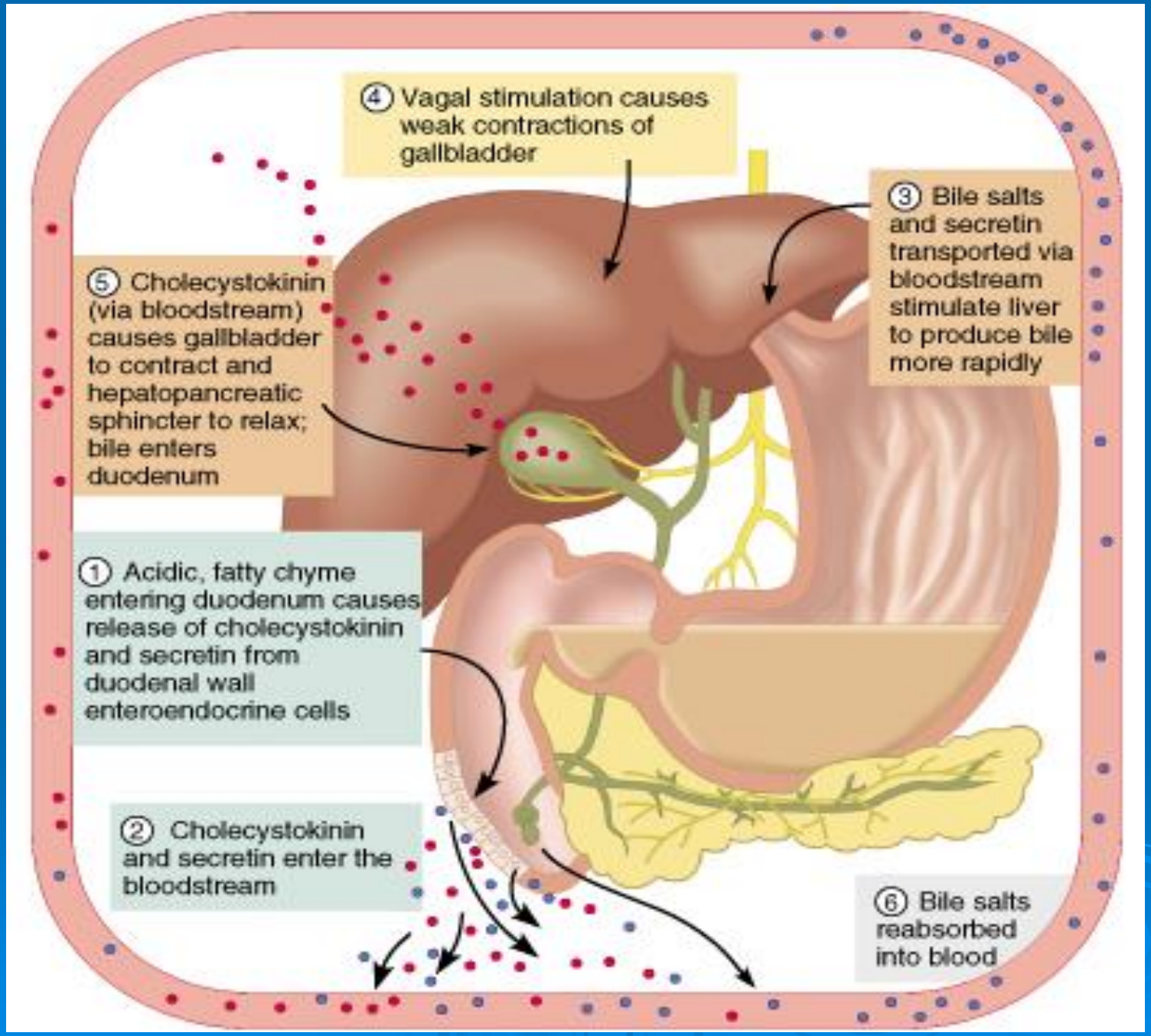



Gastric phase
① Stomach distension activates stretch receptors
Vagovagal reflexes
Medulla
Vagus nerve
Local reflexes
② Food chemicals (especially peptides and caffeine) and rising pH activate chemoreceptors
G cells
Gastrin release to blood
Gastrin secretion declines
G cells
① Excessive acidity (< pH 2) in stomach
Overrides parasympathetic controls
Sympathetic nervous system (SNS) activation
② Emotional upset
Stomach secretory activity
Entero-gastric reflex
Local reflexes
① Distension of duodenum; presence of fatty, acidic, hypertonic chyme, and/or irritants in the duodenum
Vagal nuclei in medulla
Pyloric sphincter

Sekresi di usus halus

- Kurang lebih 1.8 L
- Fungsi
  - → pelumas
  - → Buffer
  - → melarutkan enzym dari pankreas




④ Vagal stimulation causes weak contractions of gallbladder
③ Bile salts and secretin transported via bloodstream stimulate liver to produce bile more rapidly
⑤ Cholecystokinin (via bloodstream) causes gallbladder to contract and hepatopancreatic sphincter to relax; bile enters duodenum
① Acidic, fatty chyme entering duodenum causes release of cholecystokinin and secretin from duodenal wall enteroendocrine cells
② Cholecystokinin and secretin enter the bloodstream
⑥ Bile salts reabsorbed into blood

Sekresi Pankreas

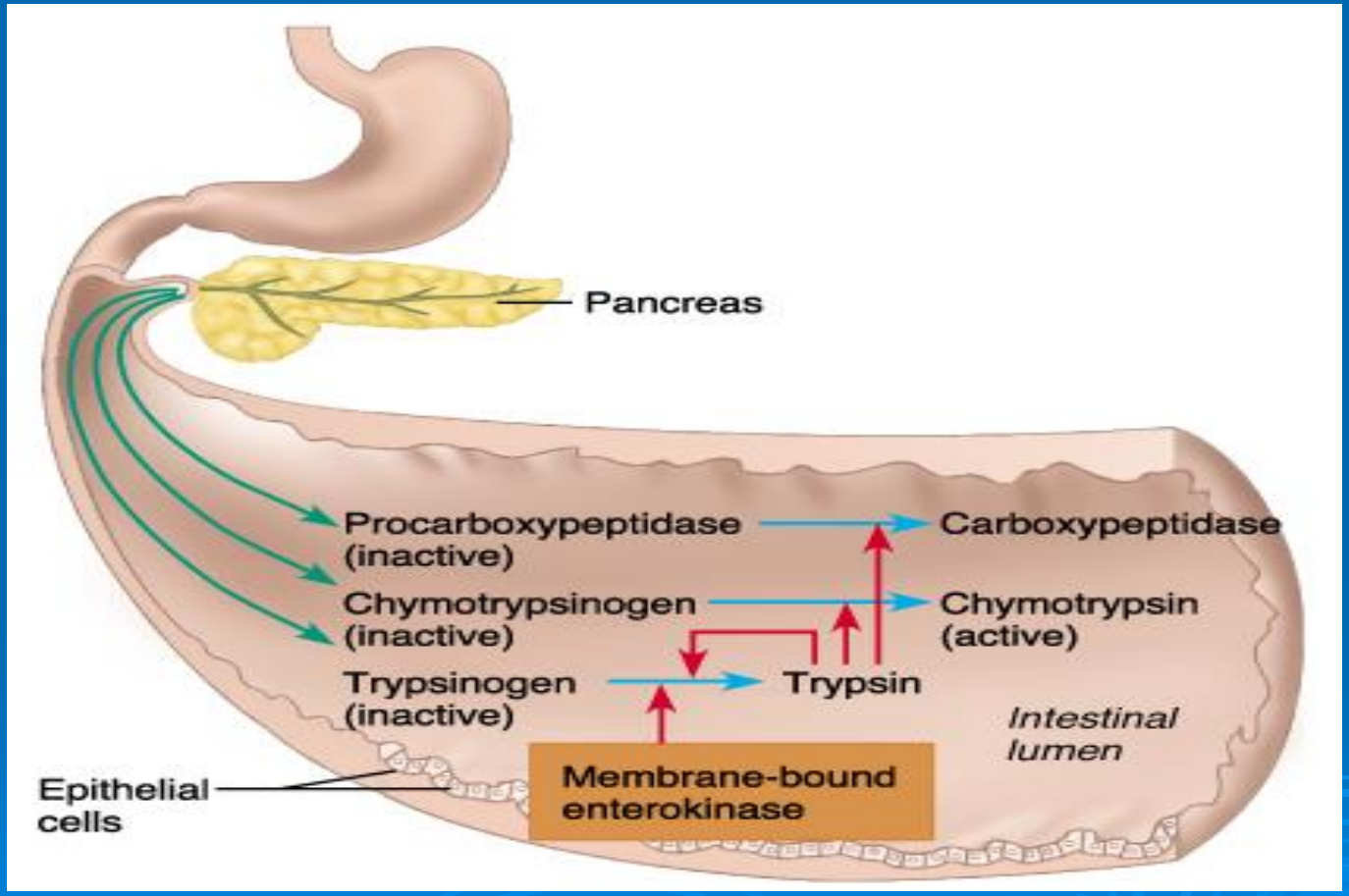


TABLE 24.4

Summary of Digestive Enzymes

ENZYME	SOURCE	SUBSTRATES	PRODUCTS
SALIVA			
Salivary amylase	Salivary glands.	Starches (polysaccharides).	Maltose (disaccharide), maltotriose (trisaccharide), and α-dextrins.
Lingual lipase	Lingual glands in the tongue.	Triglycerides (fats and oils) and other lipids.	Fatty acids and diglycerides.
GASTRIC JUICE			
Pepsin (activated from pepsinogen by pepsin and hydrochloric acid)	Stomach chief cells.	Proteins.	Peptides.
Gastric lipase	Stomach chief cells.	Triglycerides (fats and oils).	Fatty acids and monoglycerides.
PANCREATIC JUICE			
Pancreatic amylase	Pancreatic acinar cells.	Starches (polysaccharides).	Maltose (disaccharide), maltotriose (trisaccharide), and α-dextrins.
Trypsin (activated from trypsinogen by enterokinase)	Pancreatic acinar cells.	Proteins.	Peptides.
Chymotrypsin (activated from chymotrypsinogen by trypsin)	Pancreatic acinar cells.	Proteins.	Peptides.
Elastase (activated from proelastase by trypsin)	Pancreatic acinar cells.	Proteins.	Peptides.
Carboxypeptidase (activated from procarboxypeptidase by trypsin)	Pancreatic acinar cells.	Amino acid at carboxyl end of peptides.	Amino acids and peptides.
Pancreatic lipase	Pancreatic acinar cells.	Triglycerides (fats and oils) that have been emulsified by bile salts.	Fatty acids and monoglycerides.
Nucleases			
Ribonuclease	Pancreatic acinar cells.	Ribonucleic acid.	Nucleotides.
Deoxyribonuclease	Pancreatic acinar cells.	Deoxyribonucleic acid.	Nucleotides.
BRUSH BORDER			
α-Dextrinase	Small intestine.	α-Dextrins.	Glucose.
Maltase	Small intestine.	Maltose.	Glucose.
Sucrase	Small intestine.	Sucrose.	Glucose and fructose.
Lactase	Small intestine.	Lactose.	Glucose and galactose.
Enterokinase	Small intestine.	Trypsinogen.	Trypsin.
Peptidases			
Aminopeptidase	Small intestine.	Amino acid at amino end of peptides.	Amino acids and peptides.
Dipeptidase	Small intestine.	Dipeptides.	Amino acids.
Nucleosidases and phosphatases	Small intestine.	Nucleotides.	Nitrogenous bases, pentoses, and phosphates.

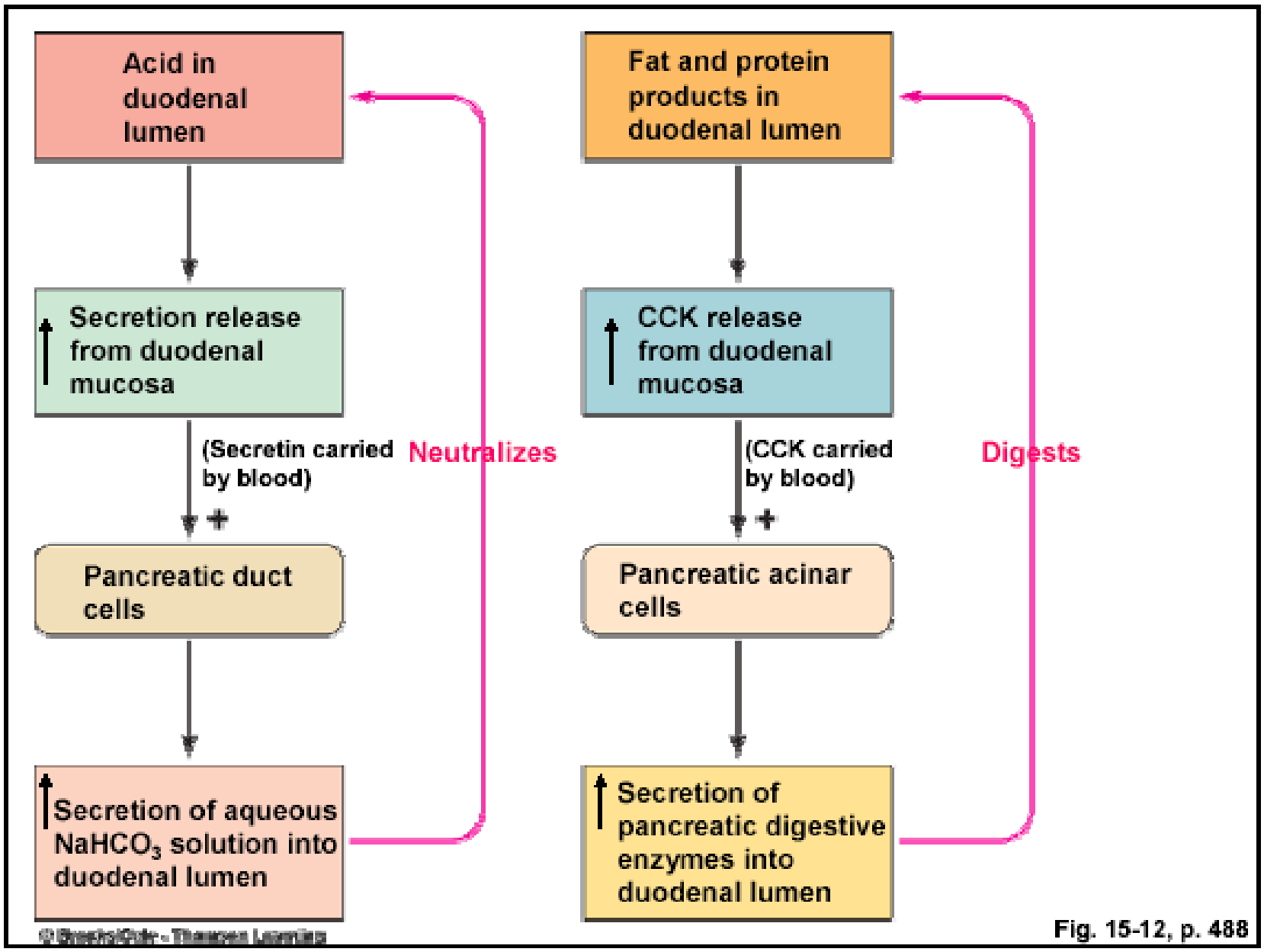
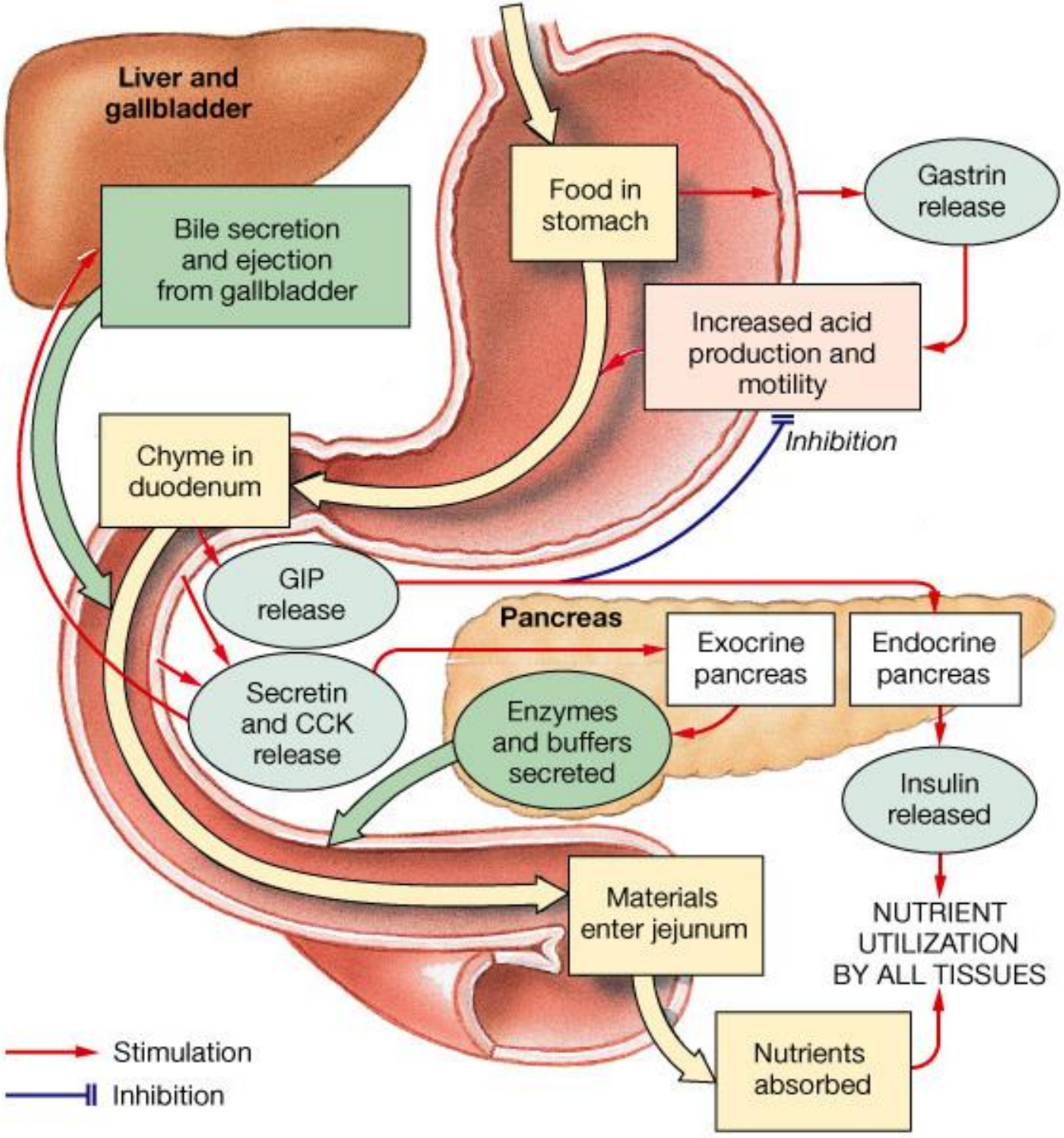
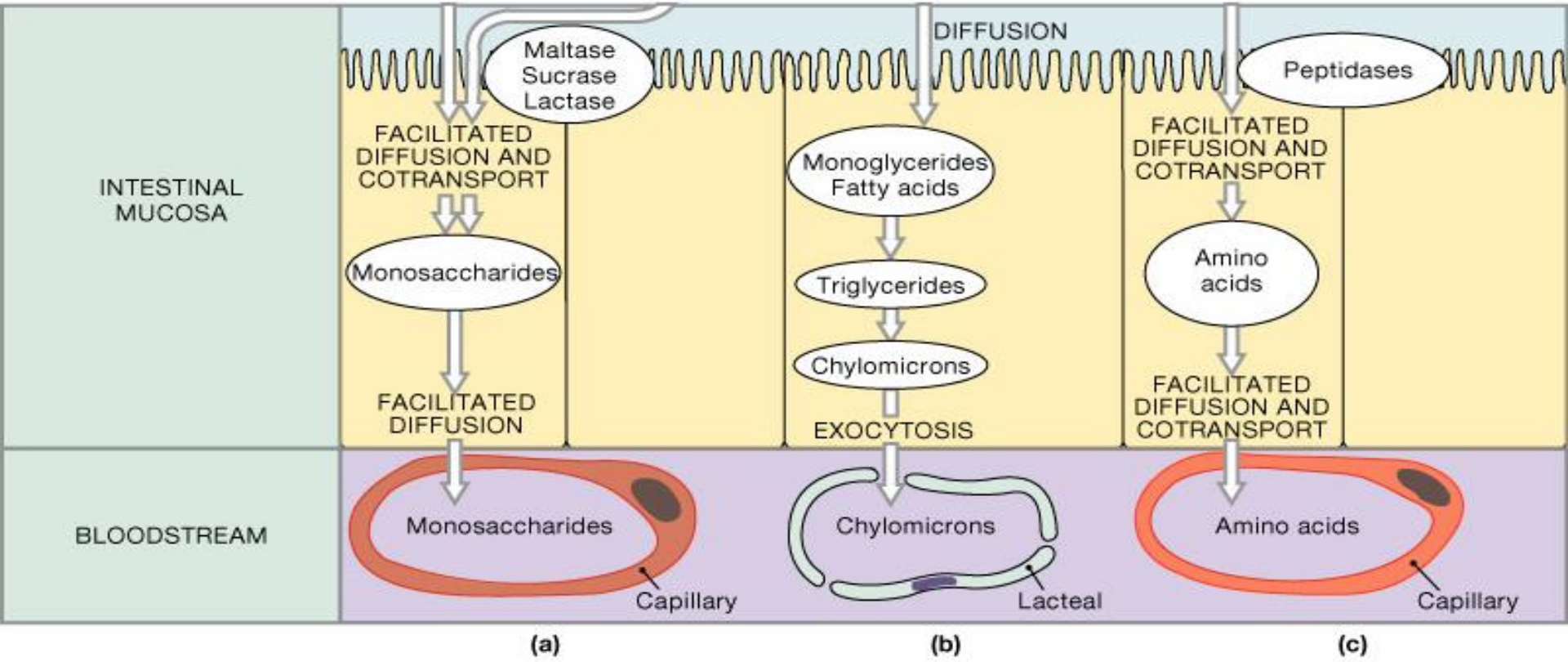


Fig. 15-12, p. 488


Liver and gallbladder
Bile secretion and ejection from gallbladder
Food in stomach
Gastrin release
Increased acid production and motility
Inhibition
Chyme in duodenum
GIP release
Pancreas
Exocrine pancreas
Endocrine pancreas
Secretin and CCK release
Enzymes and buffers secreted
Insulin released
Materials enter jejunum
NUTRIENT UTILIZATION BY ALL TISSUES
Nutrients absorbed
Stimulation
Inhibition

Absorbsi


INTESTINAL MUCOSA
BLOODSTREAM
Maltase
Sucrase
Lactase
FACILITATED DIFFUSION AND COTRANSPORT
Monosaccharides
FACILITATED DIFFUSION
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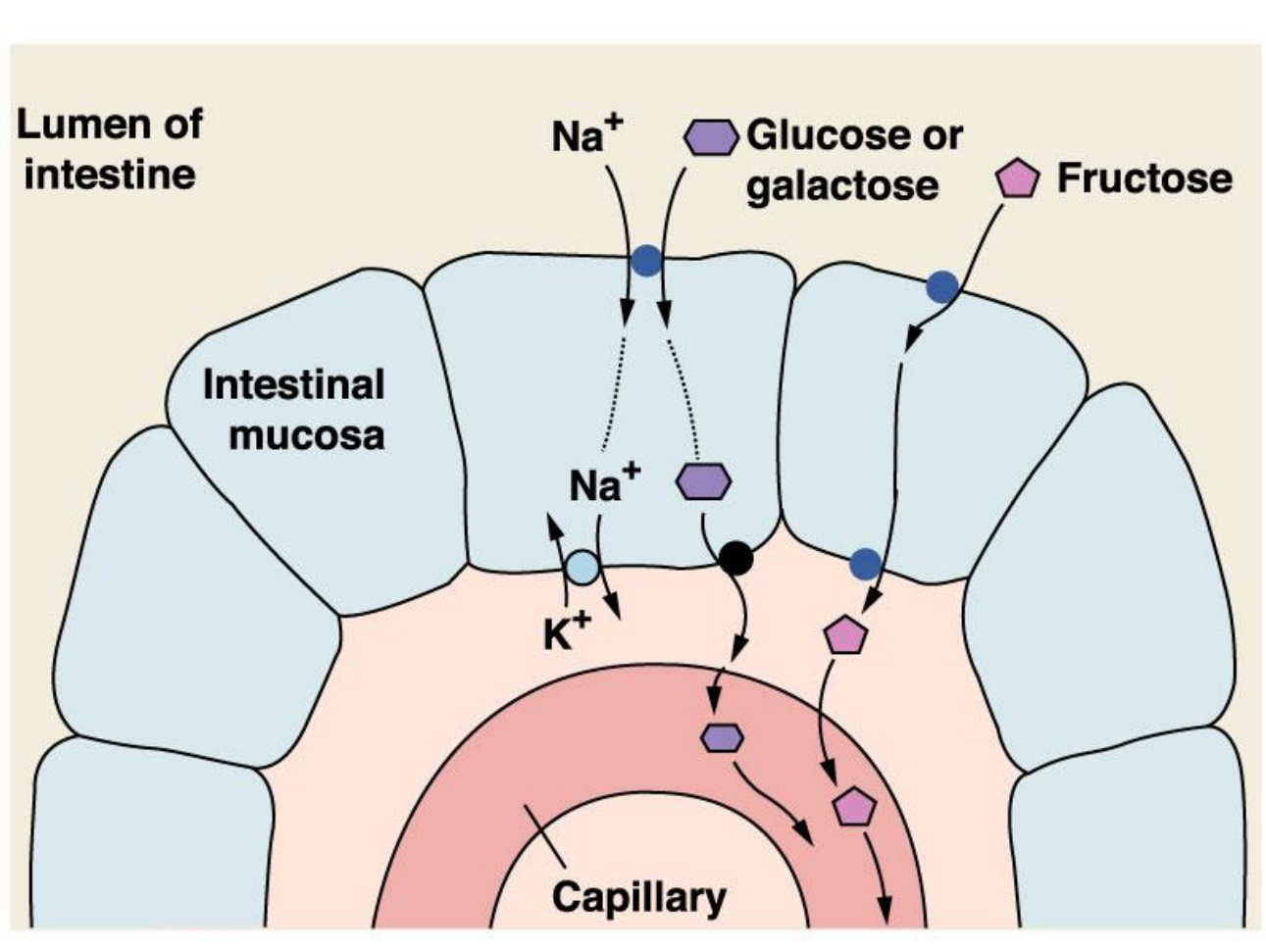
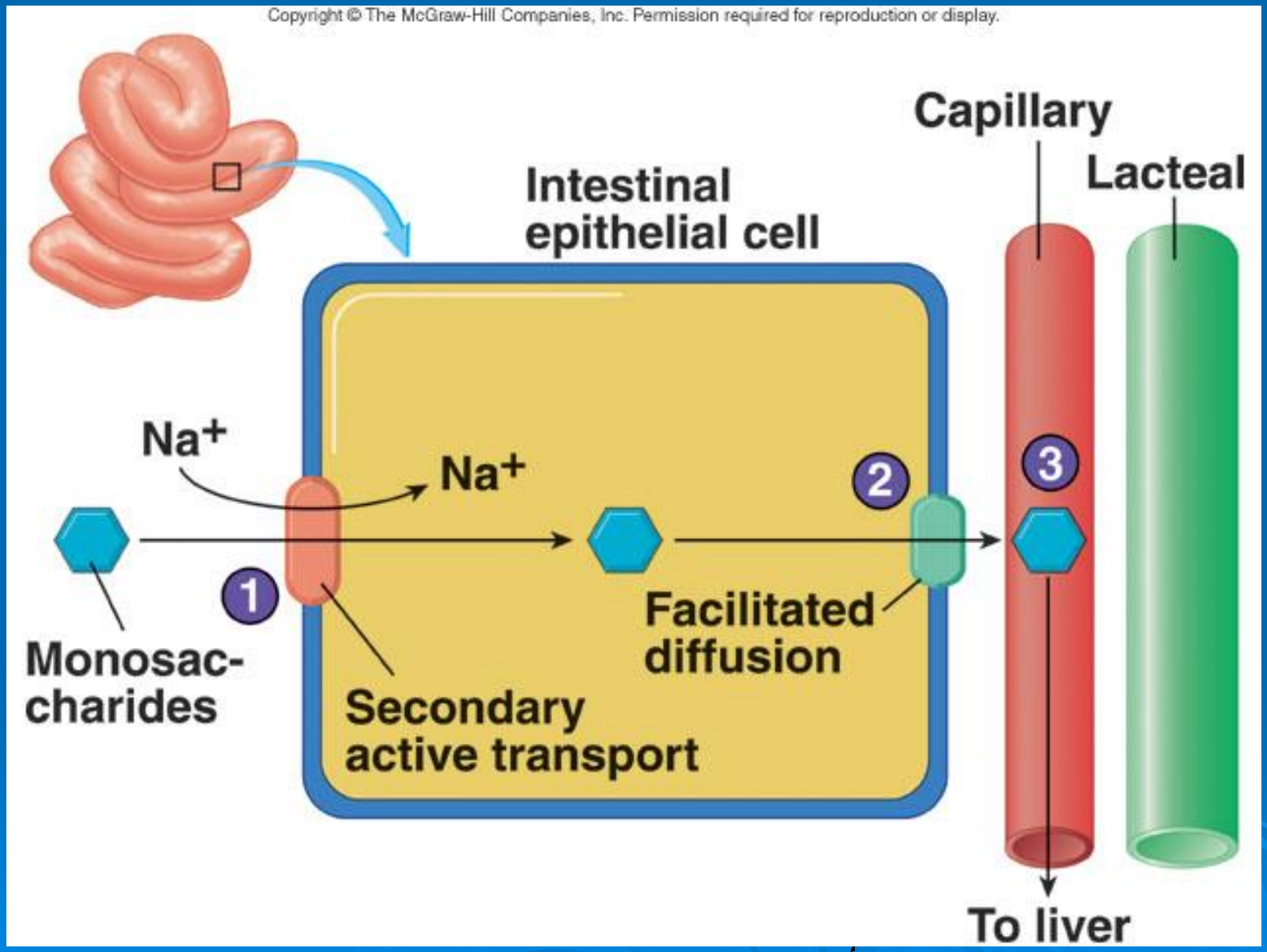
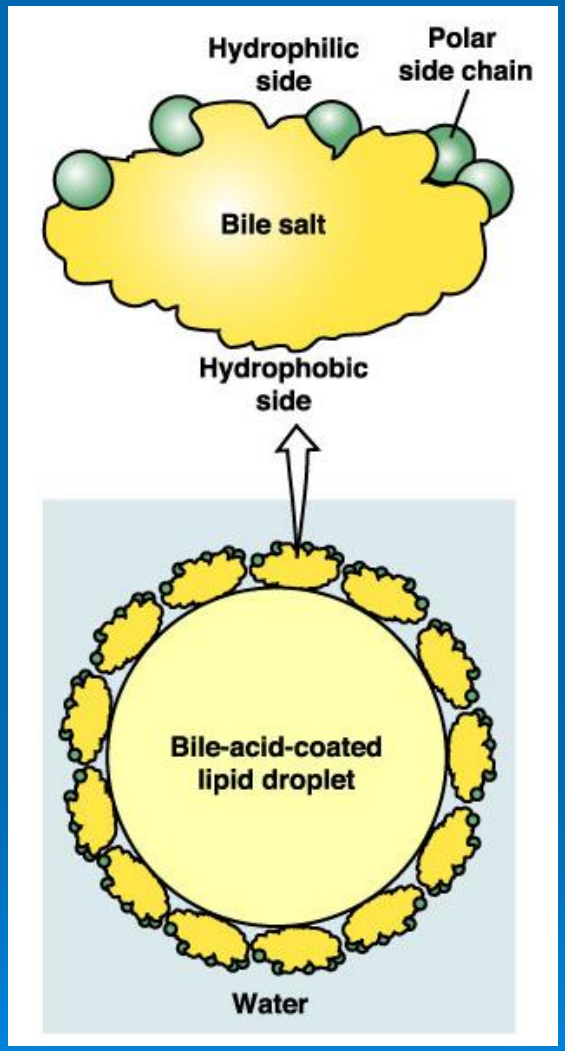
(a)
DIFFUSION
Monoglycerides
Fatty acids
Triglycerides
Chylomicrons
EXOCYTOSIS
Chylomicrons
Lacteal
(b)
Peptidases
FACILITATED DIFFUSION AND COTRANSPORT
Amino acids
FACILITATED DIFFUSION AND COTRANSPORT
Amino acids
Capillary
(c)

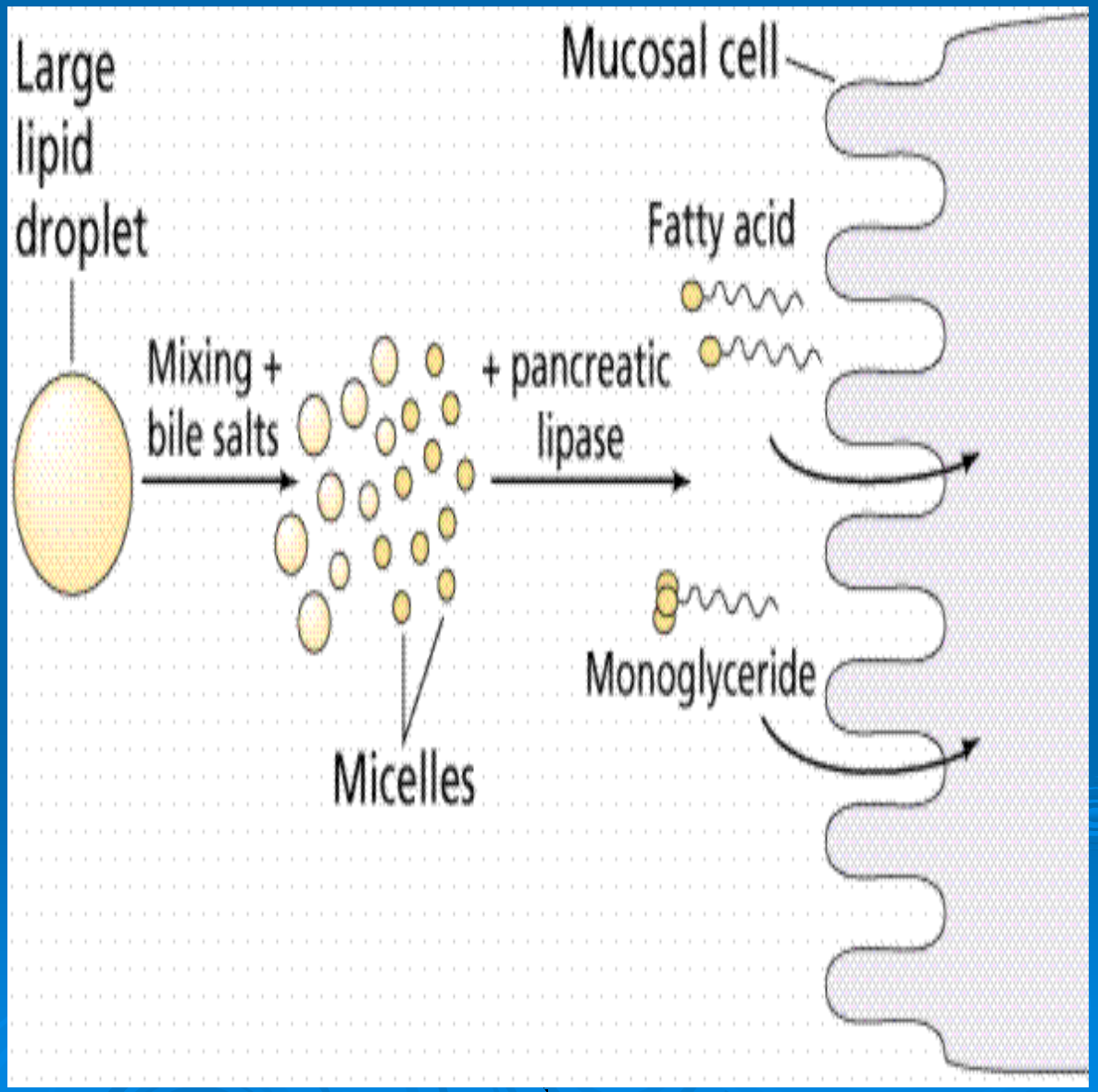
Absorbsi monosakarida

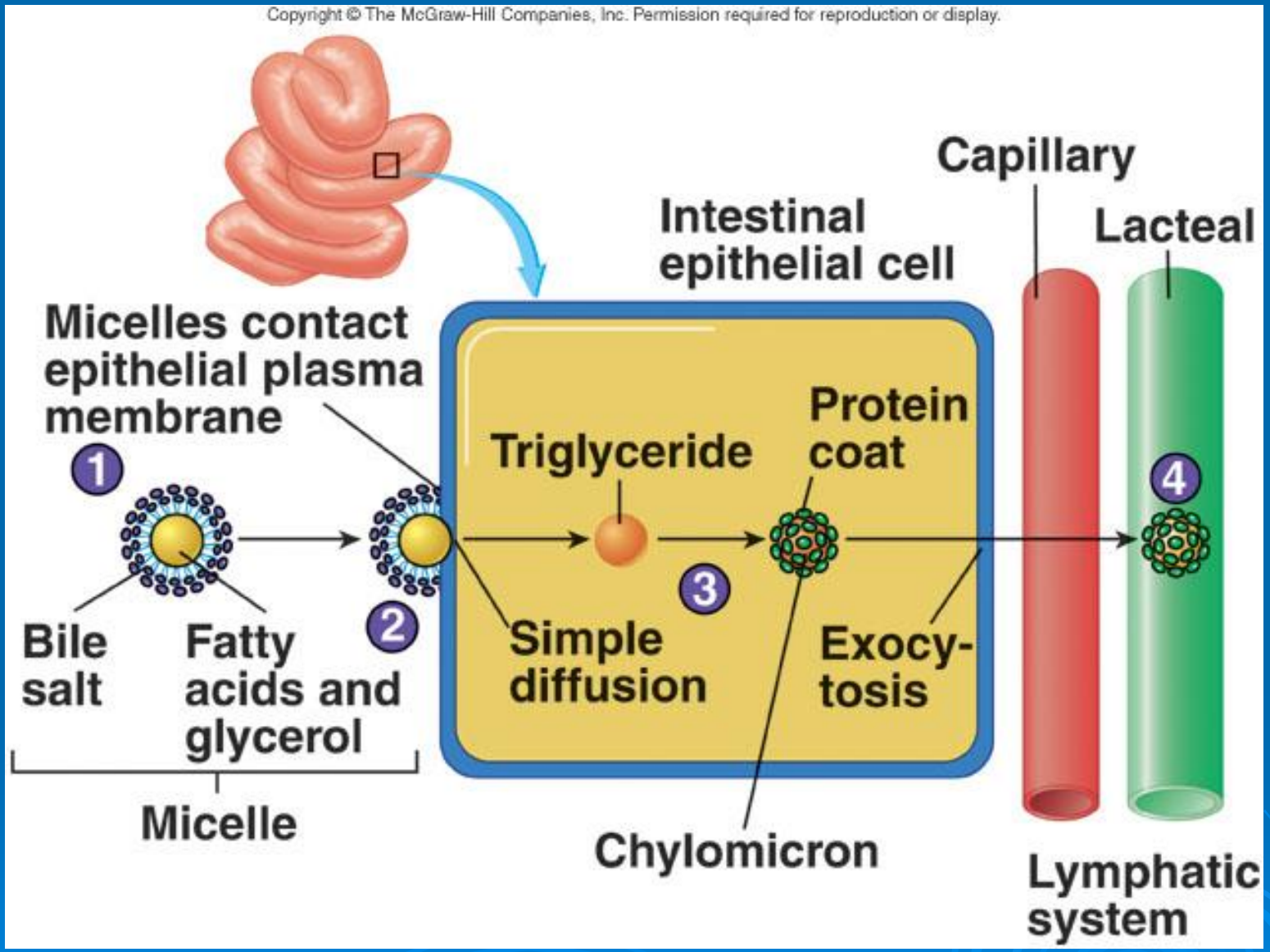


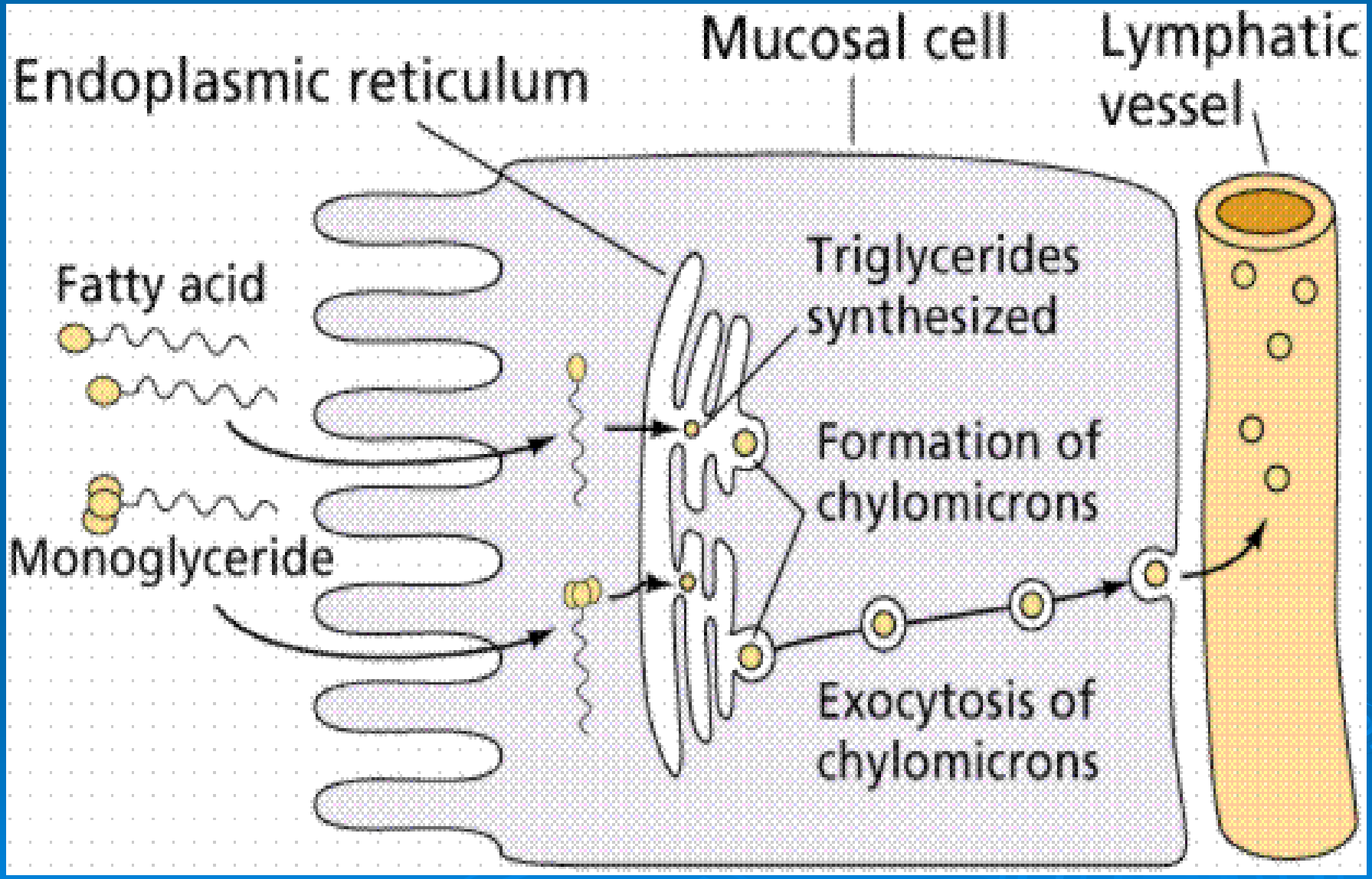


Absorbsi monogliserida dan asam lemak

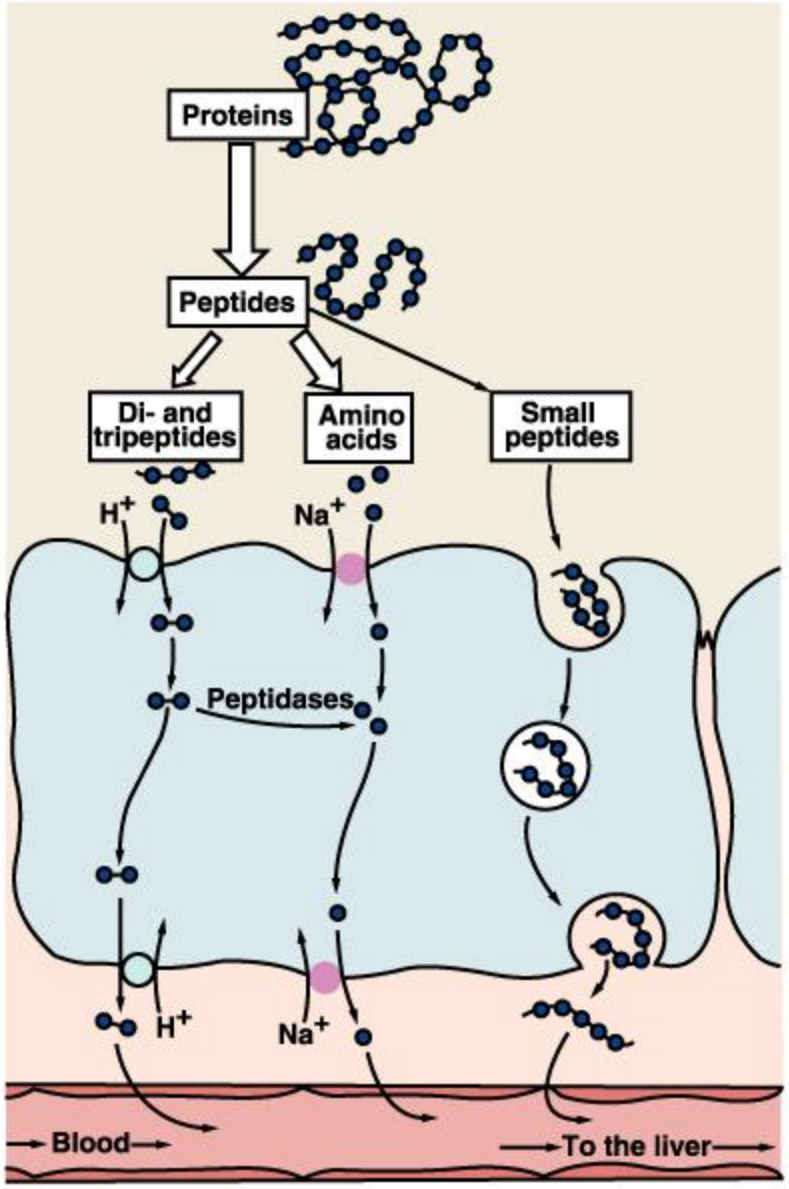


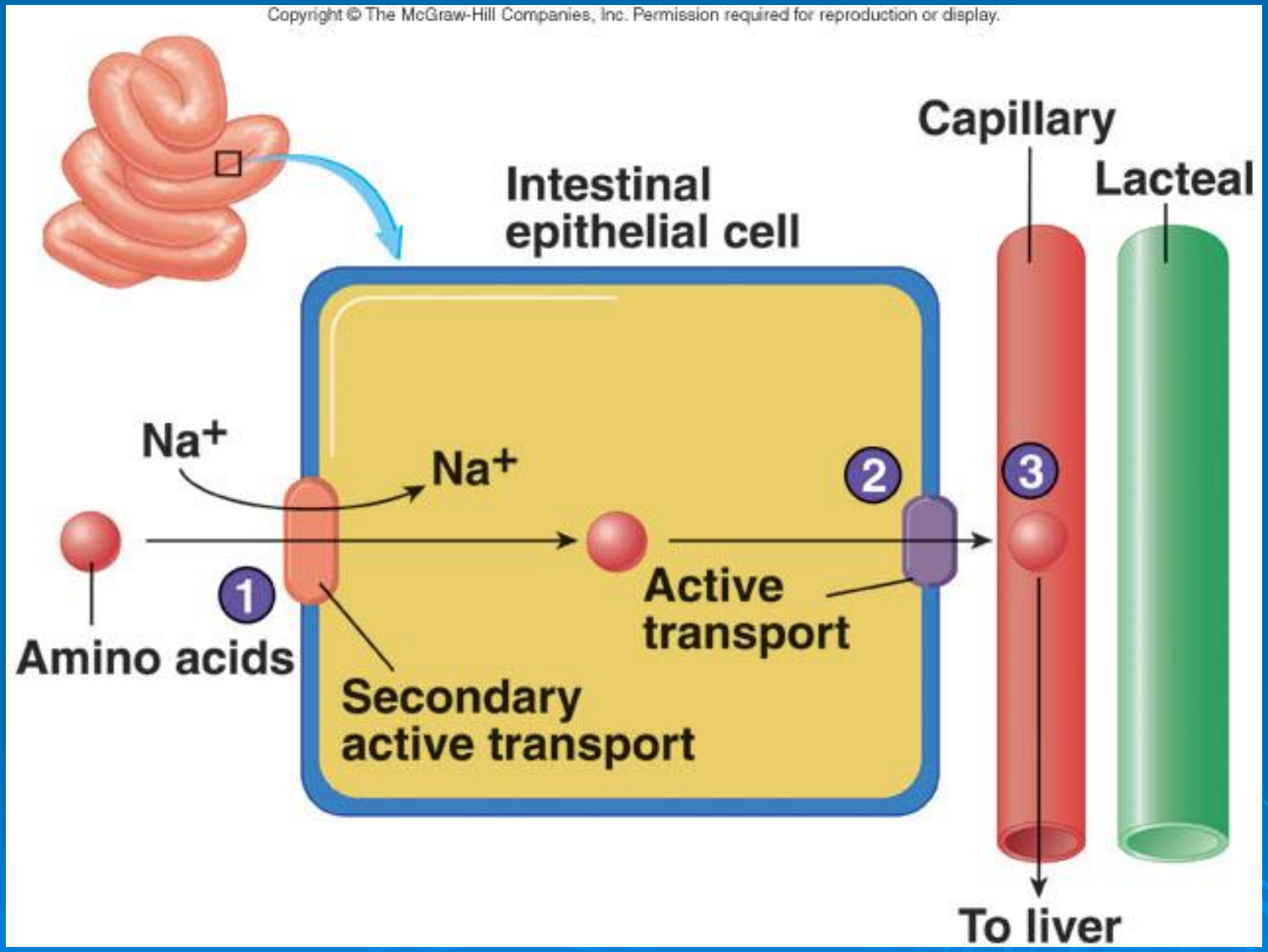





Endoplasmic reticulum
Mucosal cell
Lymphatic vessel
Fatty acid
Monoglyceride
Triglycerides synthesized
Formation of chylomicrons
Exocytosis of chylomicrons

Absorbsi asam amino





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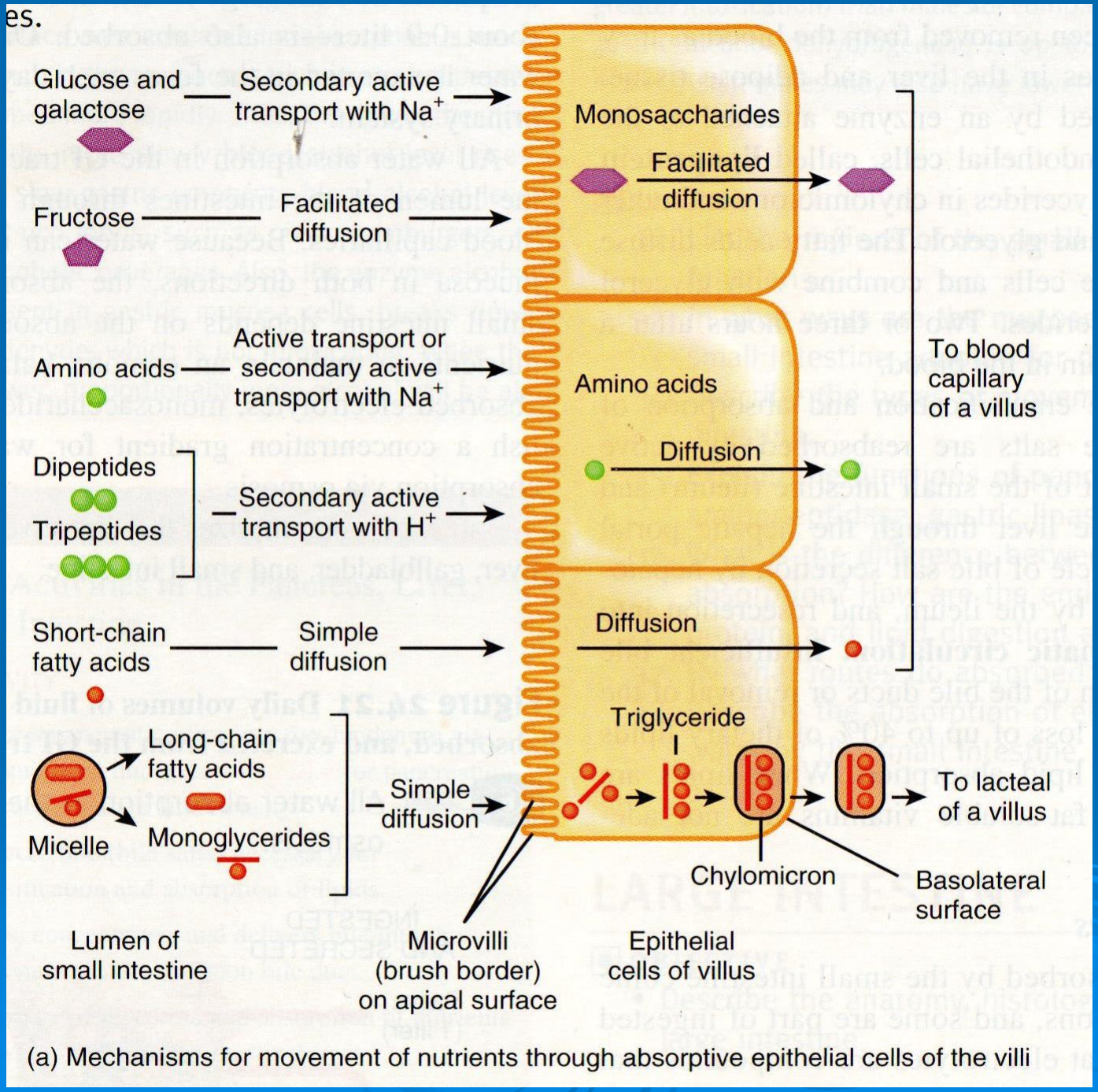
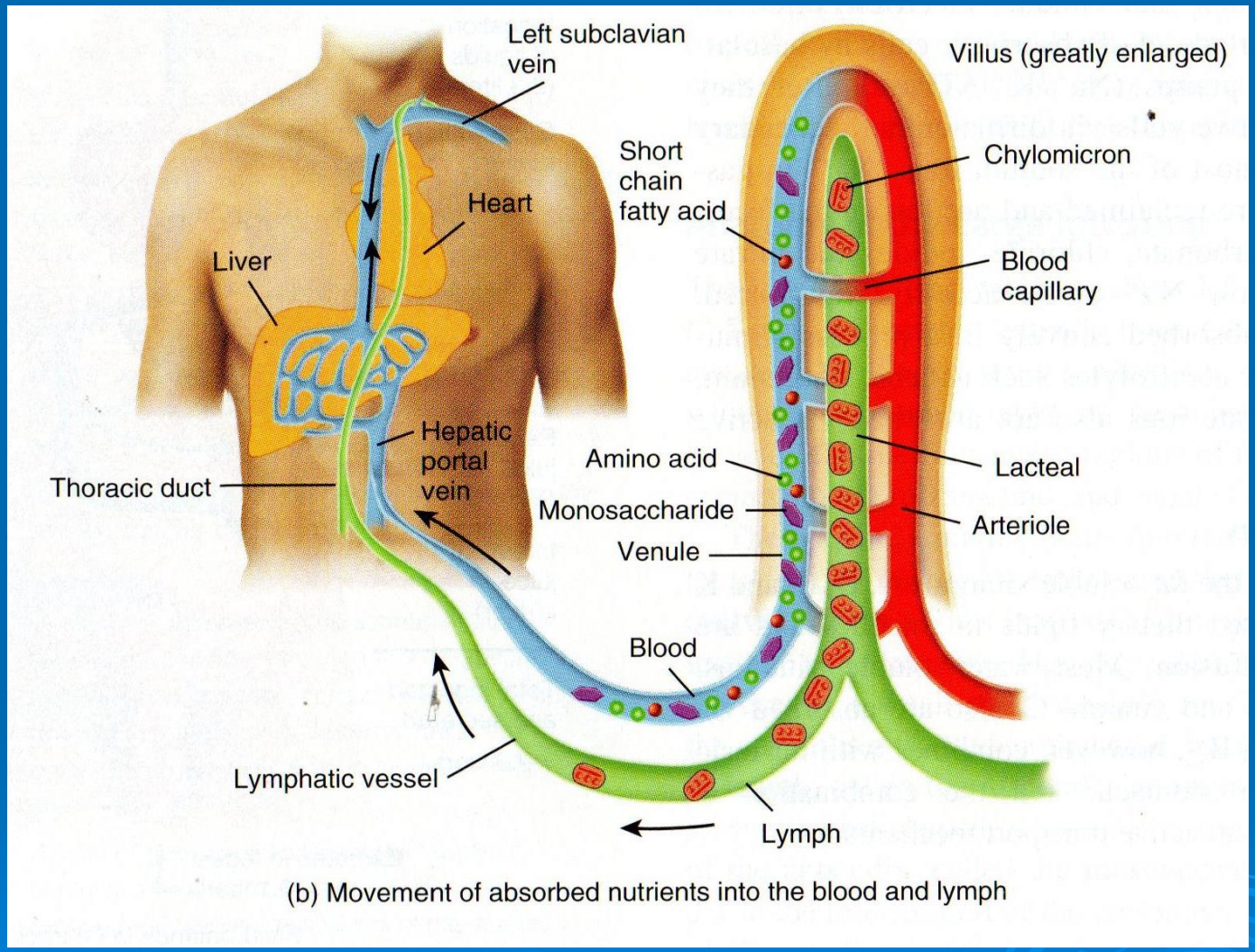


(a) Mechanisms for movement of nutrients through absorptive epithelial cells of the villi



(b) Movement of absorbed nutrients into the blood and lymph

Vitamin

→ Larut lemak (A, D, E, K): lewat bersama lipid

→ Larut air (B, C): masuk bersama air

B12 : faktor intrinsik di lambung mengikat B12 dan diabsorbsi di ileum

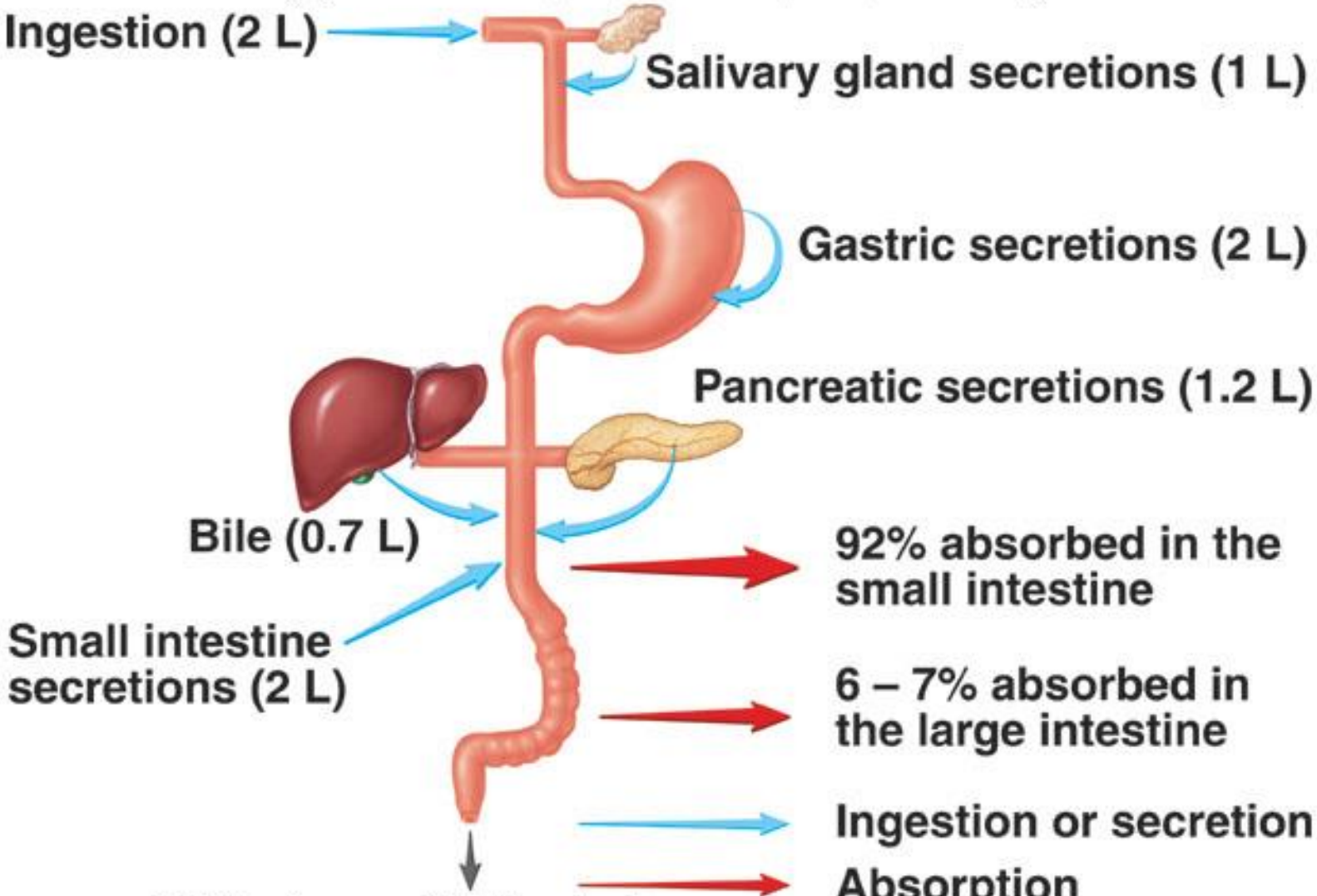
Air dan mineral

Mirip reabsobsi di tubulus ginjal dengan aktif transport Na, reabsorbsi air secara pasif mengikuti gradien osmotik

Normalnya 95% air masuk usus kecil sebelum masuk kolon

Cl mengikuti Na dari lumen GI ke dalam darah

→ Kalsium, potassium, magnesium, iodine, bicarbonate, iron



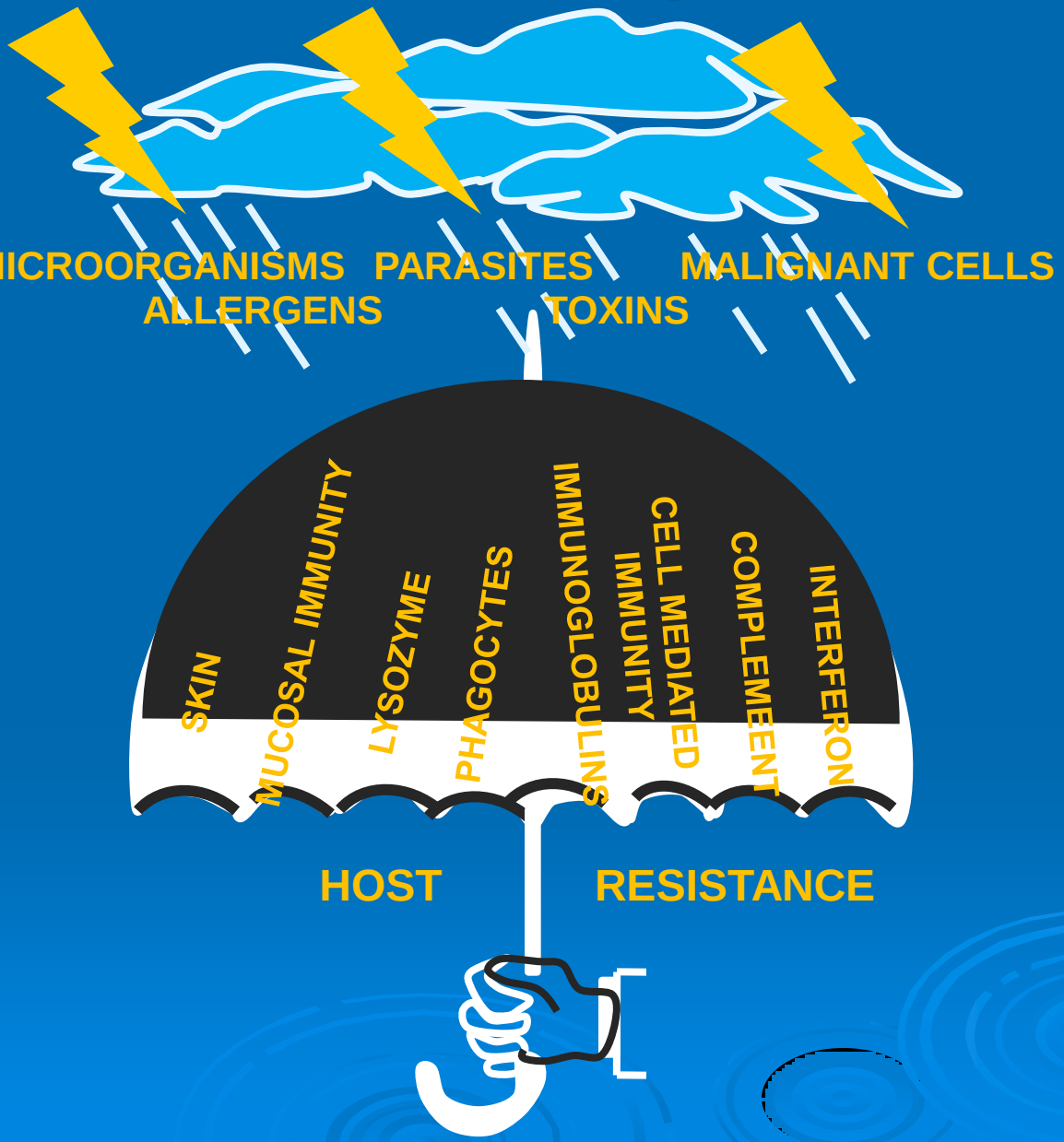
Absorbsi di kolon

- Reabsorbsi air
  - 1500 mL/hr di kolon; 1300 mL reabsorbsi
  - Feses terdiri: - 75% air
    - 5% bakteri
    - 20% undigested material, inorganic material, epitel

Reabsobsi garam empedu, vitamin, bilirubin, toxins

- Bile salts
  - Reabsorbsi, dibawa ke hepar
- Vitamin
  - Bakteri di kolon membentuk 3 vitamin
    - Vitamin K: fat soluble; diperlukan untuk sintesis faktor pembekuan di hati
    - Biotin: water soluble; diperlukan untuk metabolisme glukosa
    - Vitamin B_5: water soluble; diperlukan untuk biosintesis hormon steroid dan beberapa neurotransmiter

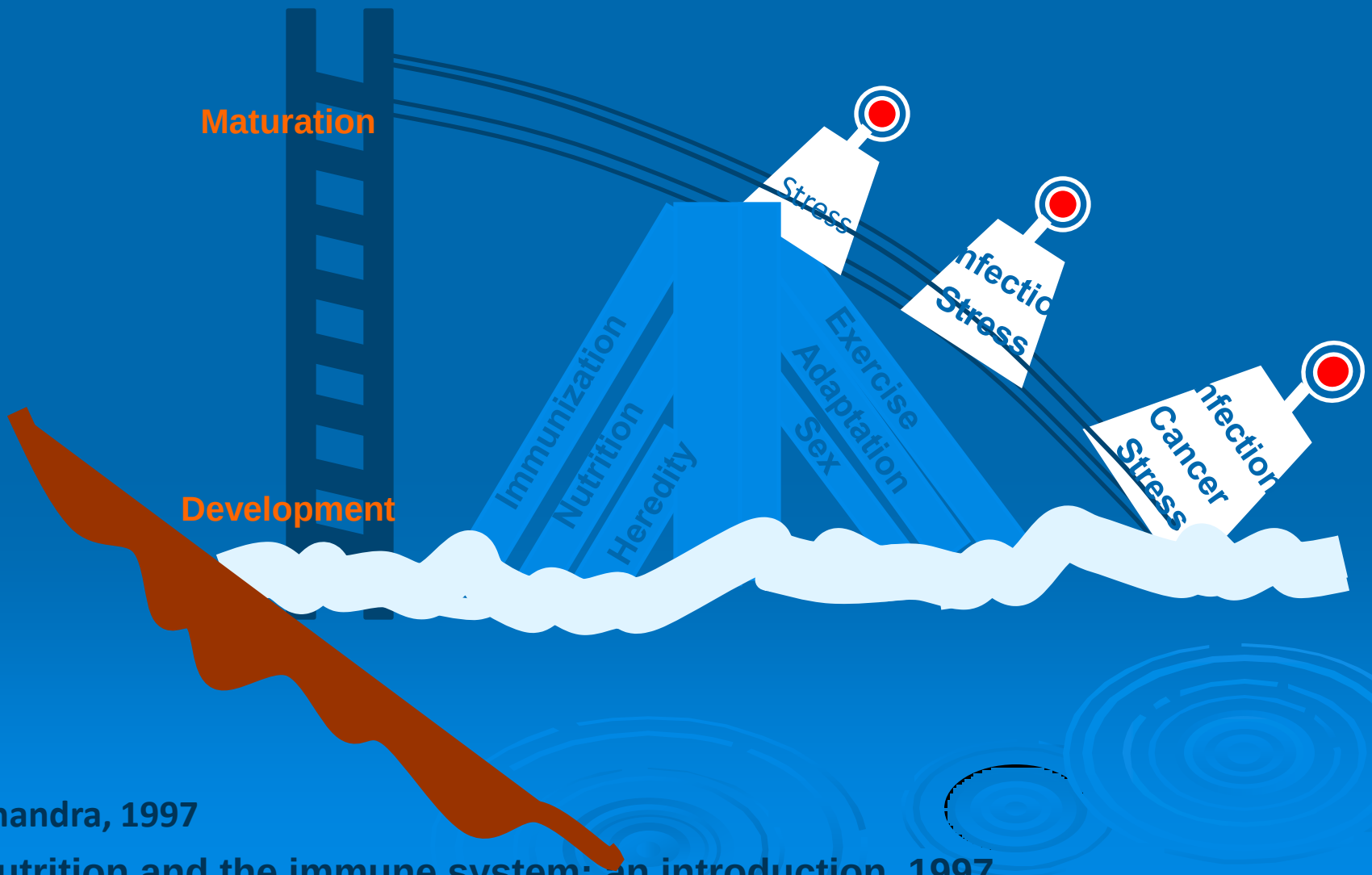
The Immune System



Chandra, 1997

Nutrition and the immune system: an introduction, 1997

Modifikasi Meliala, 2011



Chandra, 1997

Nutrition and the immune system: an introduction, 1997

Modifikasi Meliala, 2011


Enjoy learning adventure, it shall never end!