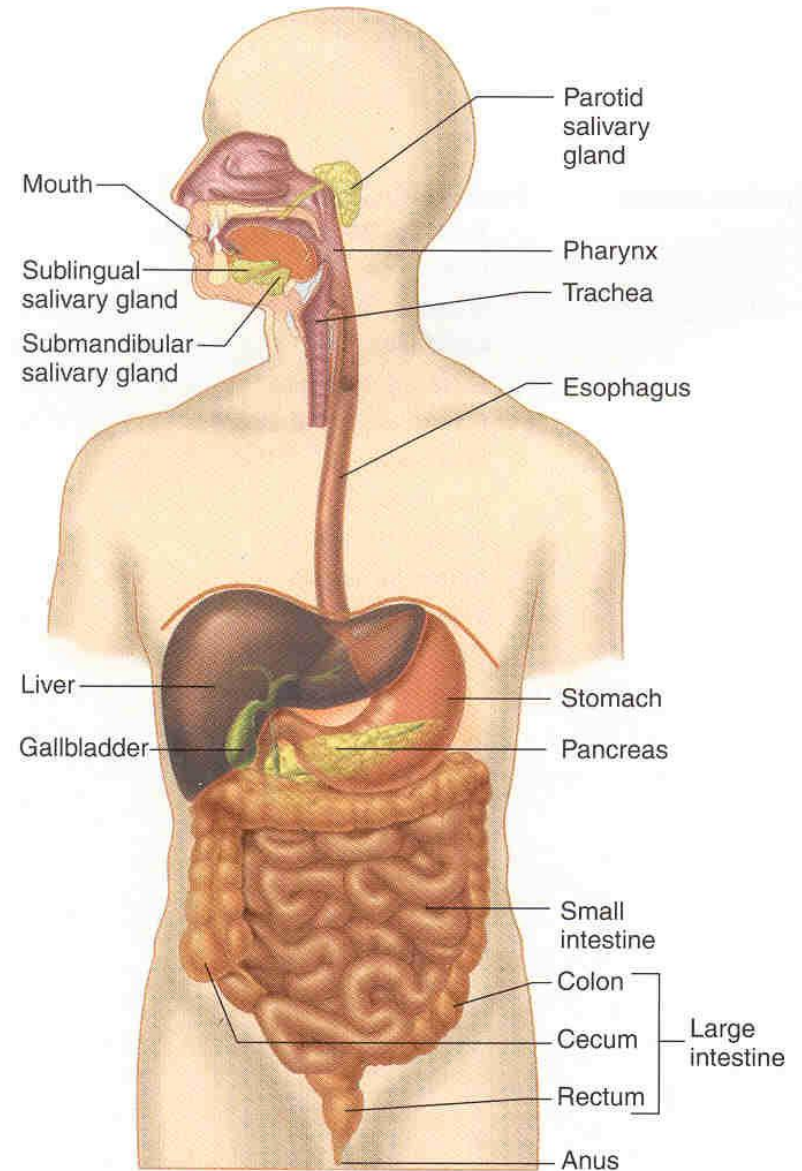


Digestive System

Tim Anfisman
FFUP



Organs of GI tract

Mouth

Pharynx

Trachea

Esophagus

Diaphragm

Stomach

Small intestine

Colon

Vermiform appendix

Rectum

Anus

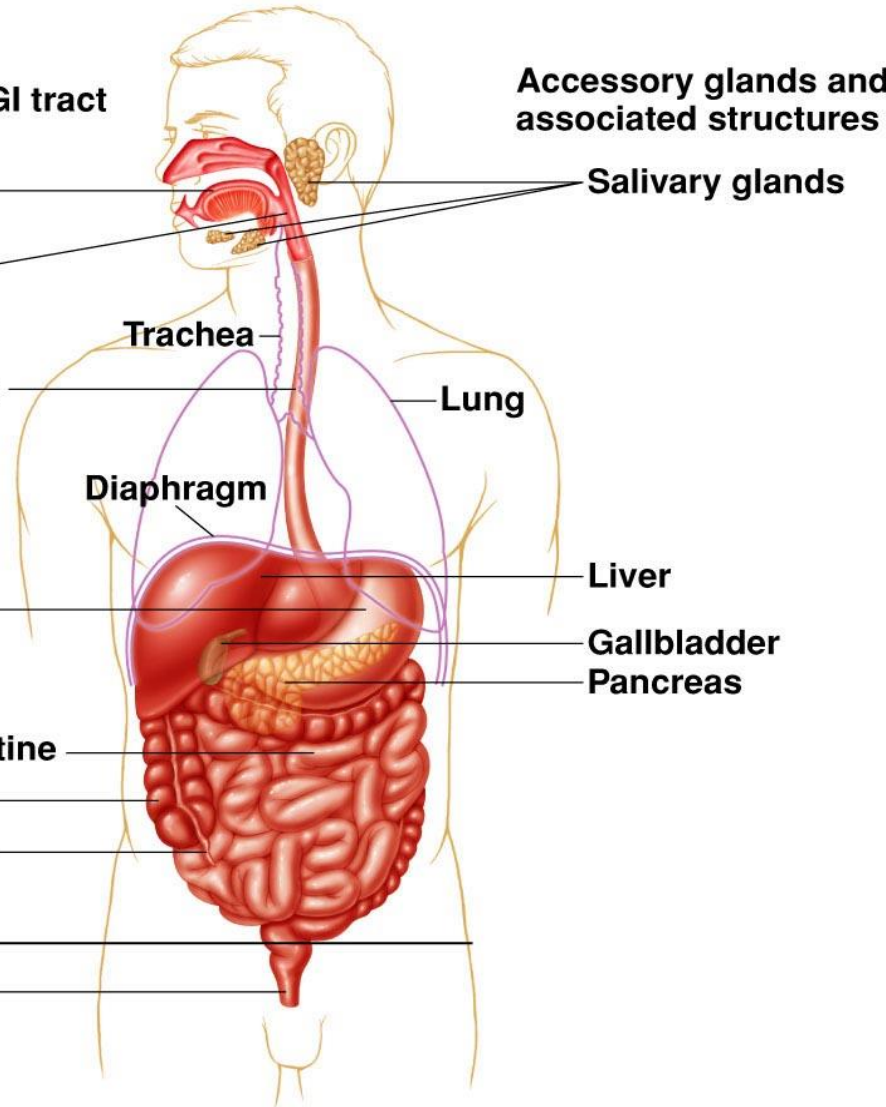
Accessory glands and associated structures

Salivary glands

Lung

Liver

Gallbladder
Pancreas



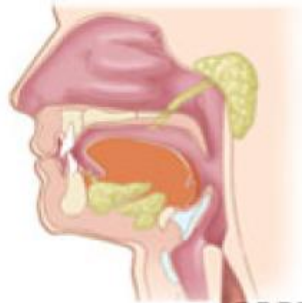
ANATOMI SISTEM PENCERNAAN

Functions of the GI system

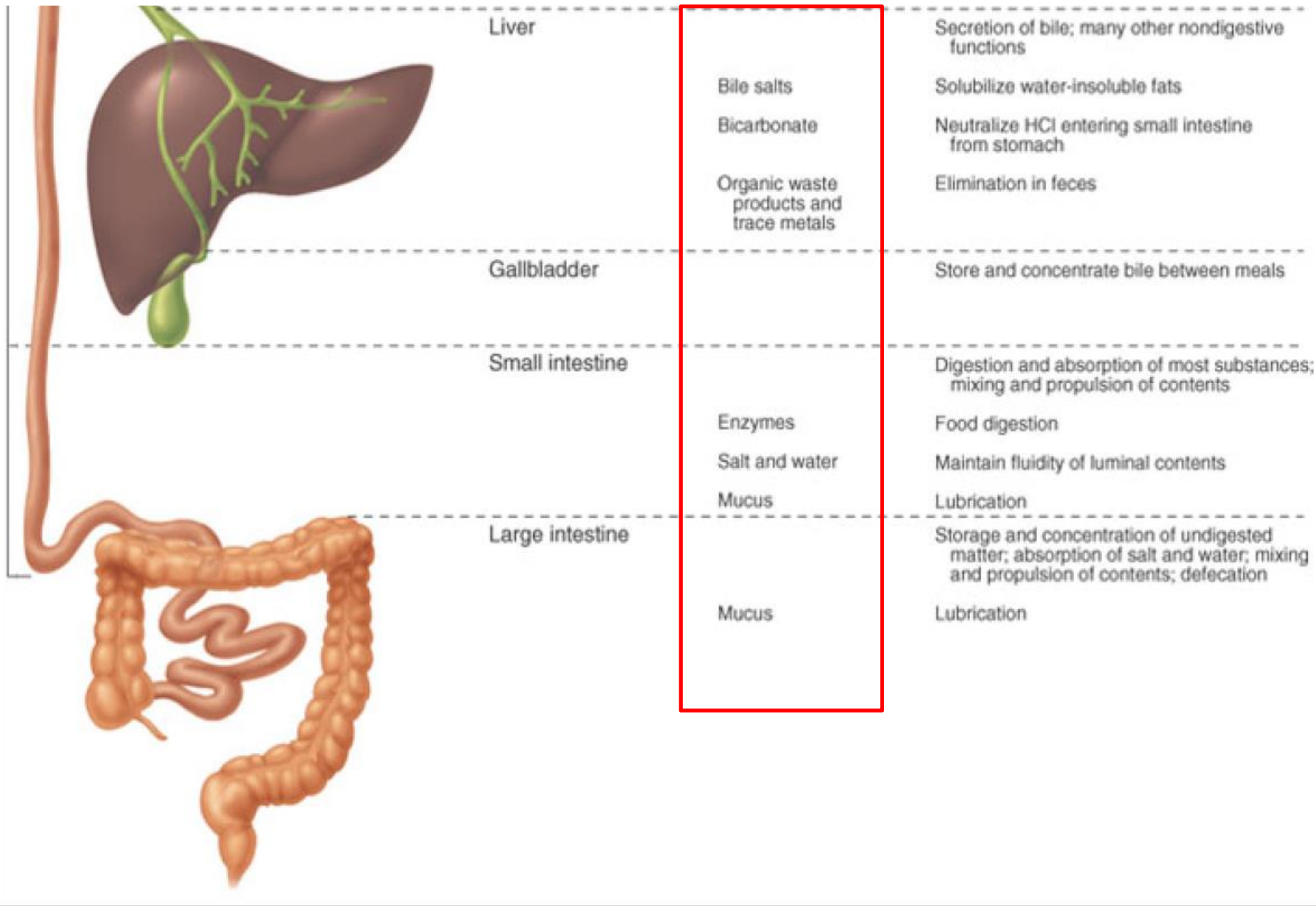
- Food transportation
- Digestion:
 - a. Mechanical digestion: breaking food in small particles so they are easily broken down by enzymes → mouth and stomach
 - b. Chemical digestion: pancreas and duodenum
- 3. Nutrient absorption: small intestine
- 4. Water reabsorption: colon
- 5. Excretion of food residue

Functions of the GI system

1. Food transportation
2. Digestion:
 - a. Mechanical digestion:
breaking food in small
particles so they are easily
broken down by enzymes
→ mouth and stomach
 - b. Chemical digestion:
pancreas and duodenum
3. Nutrient absorption: small
intestine
4. Water reabsorption: colon
5. Excretion of food residue



Organ	Exocrine secretions	Functions
Mouth and pharynx Salivary glands	Salt and water Mucus Amylase	Chewing begins; initiation of swallowing reflex Moisten food Lubrication Polysaccharide-digesting enzyme
Esophagus	Mucus	Move food to stomach by peristaltic waves Lubrication
Stomach	HCl Pepsins Mucus	Store, mix, dissolve, and continue digestion of food; regulate emptying of dissolved food into small intestine Solubilization of food particles; kill microbes; activation of pepsinogens to pepsins Protein-digesting enzymes Lubricate and protect epithelial surface
Pancreas	Enzymes Bicarbonate	Secretion of enzymes and bicarbonate; also has nondigestive endocrine functions Digest carbohydrates, fats, proteins, and nucleic acids Neutralize HCl entering small intestine from stomach



Liver

Bile salts
Bicarbonate
Organic waste products and trace metals

Secretion of bile; many other nondigestive functions
Solubilize water-insoluble fats
Neutralize HCl entering small intestine from stomach
Elimination in feces

Gallbladder

Store and concentrate bile between meals

Small intestine

Enzymes
Salt and water
Mucus

Digestion and absorption of most substances; mixing and propulsion of contents
Food digestion
Maintain fluidity of luminal contents
Lubrication

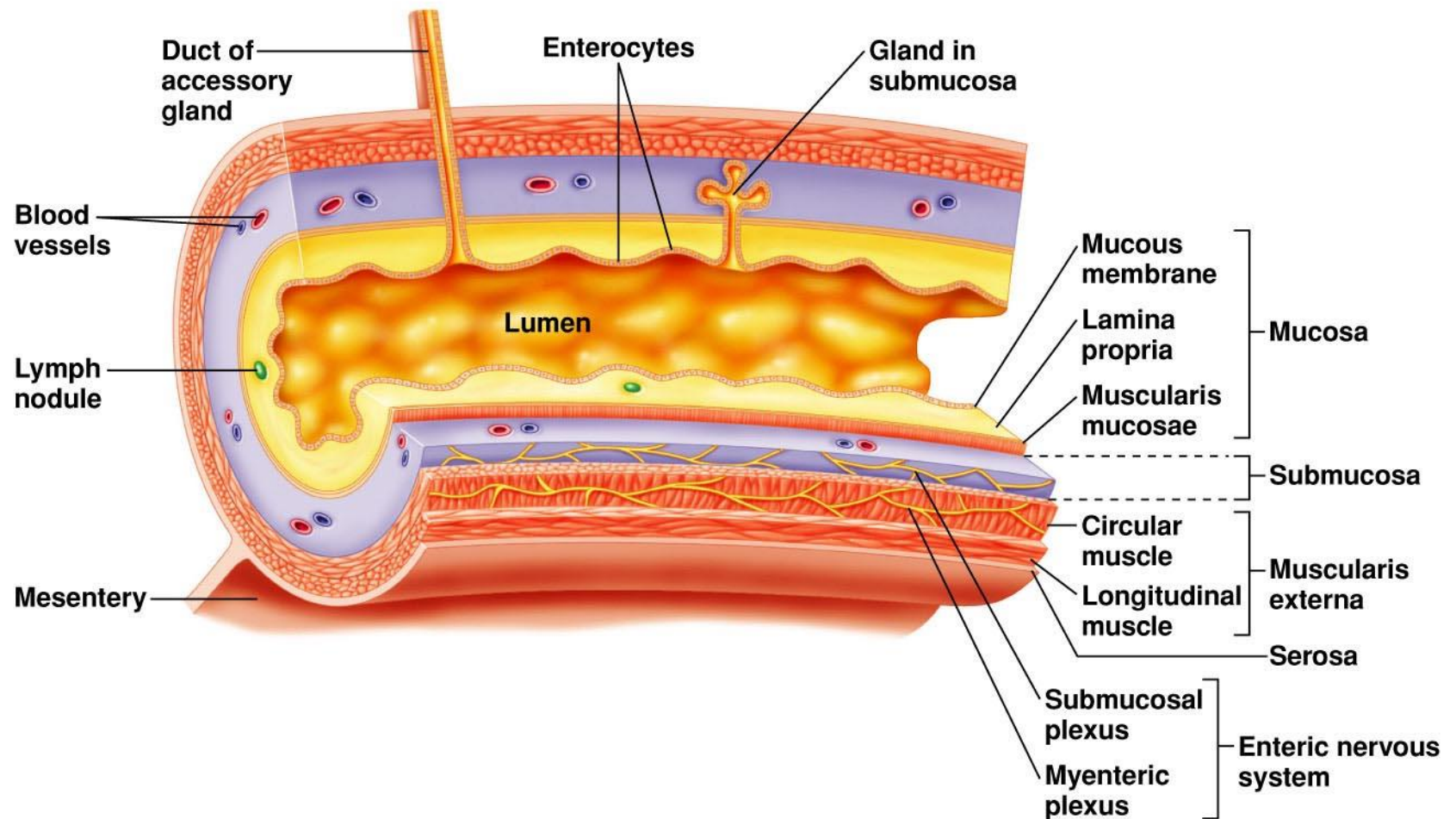
Large intestine

Mucus

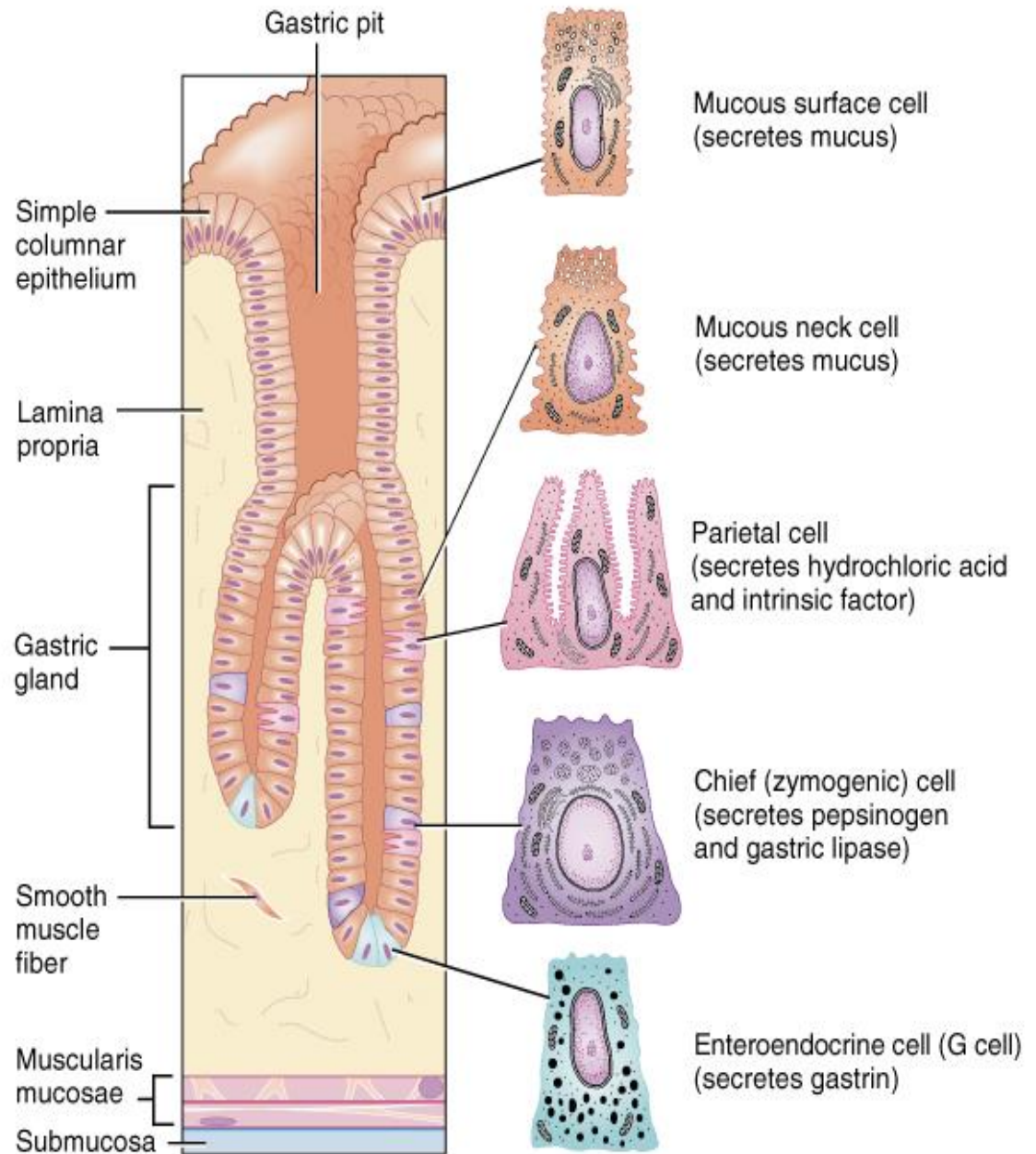
Storage and concentration of undigested matter; absorption of salt and water; mixing and propulsion of contents; defecation
Lubrication

Structure of the GI tract

- 1) Mucosa: epithelial cells (enterocytes) → role vary with location
 - lamina propria = layer of connective tissue under the epithelial, containing blood vessels, nerves and lymphatic vessels (Peyer's patches)
 - the muscularis mucosae: thin layer of smooth muscles
- 2) Submucosa: layer of connective tissue rich containing the submucosal plexus = Meissner's plexus
- 3) Muscularis externa – radial and longitudinal smooth muscles ; Auerbach plexus -- >in contact with Meissner's
- 4) Serosa:connective tissue continuing through the mesenteries (a thin membranes rich in blood and lymphatic capillaries) and the peritoneum (a double layer membrane surrounding the abdominal organs)



PERUT (STOMACH)



(b) Stomach mucosa showing gastric glands and cell types

PERUT (STOMACH)

Fig. 21-25

mainly in glands of fundus and body

Gastric mucosa	Cell Types	Substance Secreted	Stimulus for Release	Function of Secretion
	Mucous neck cell	Mucus	Tonic secretion; with irritation of mucosa	Physical barrier between lumen and epithelium
		Bicarbonate	Secreted with mucus	Buffers gastric acid to prevent damage to epithelium
	Parietal cells	Gastric acid (HCl)	Acetylcholine, gastrin, histamine	Activates pepsin; kills bacteria
		Intrinsic factor		Complexes with vitamin B ₁₂ to permit absorption
	Enterochromaffin-like cell	Histamine	Acetylcholine, gastrin	Stimulates gastric acid secretion
	Chief cells	Pepsin(ogen)	Acetylcholine; acid, secretin	Digests proteins
		Gastric lipase		Digests fats
	D cells	Somatostatin	Acid in the stomach	Inhibits gastric acid secretion
	G cells	Gastrin	Acetylcholine, peptides and amino acids	Stimulates gastric acid secretion

mainly in antral glands

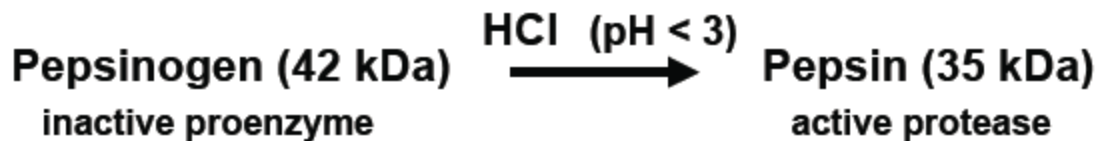
3. Composition of the Gastric Juice

Mucus cell

1. **Mucus:** Glycoprotein products found throughout entire GI tract. Primary function as lubricant, but can also have many other regionally specialized functions

Chief cell

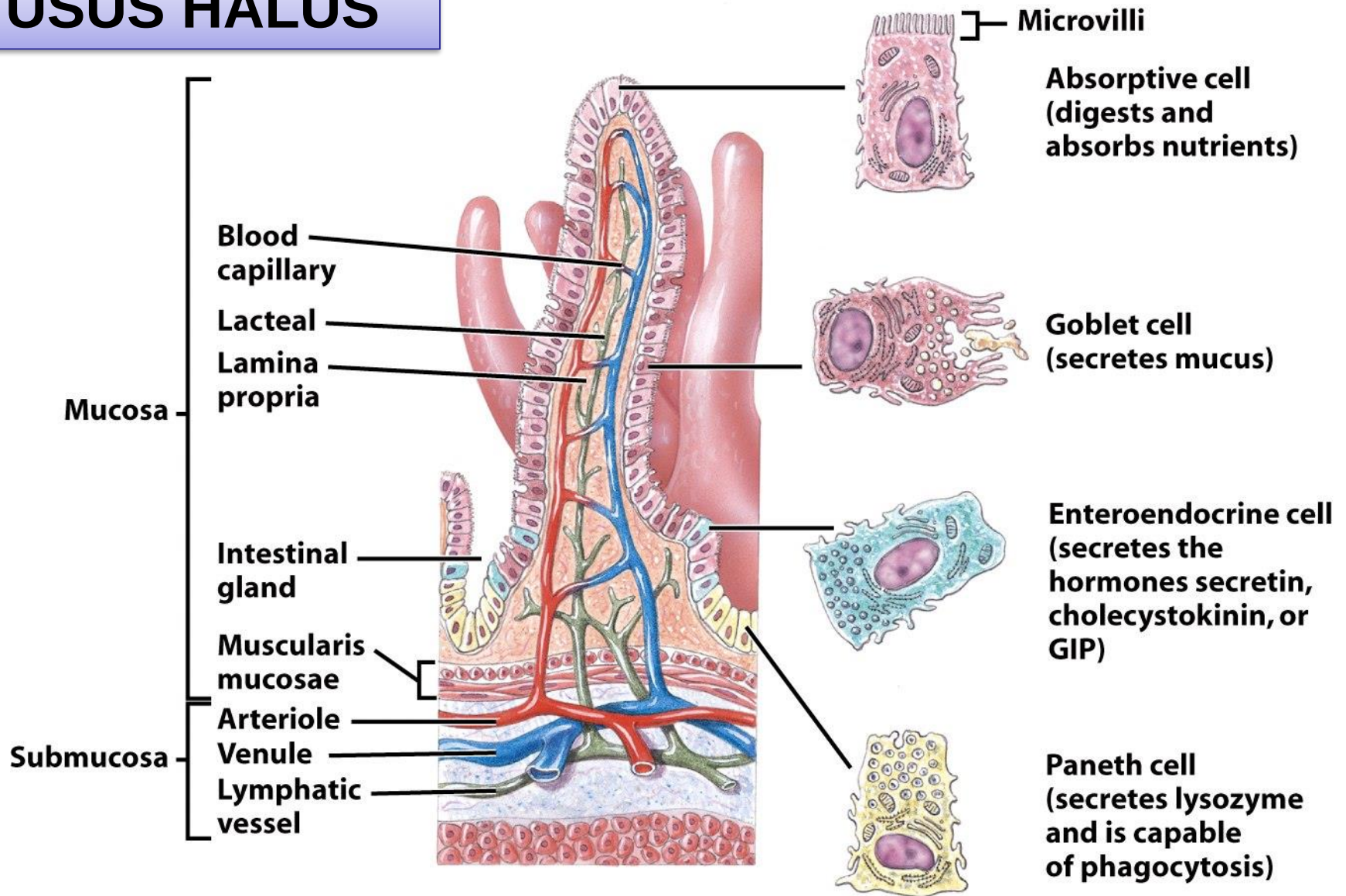
2. **Pepsinogen:** Proenzyme made by chief cells. As it encounters HCl in gland lumen, then continuing in the gastric lumen:



Parietal cell

- 3a. **Hydrochloric Acid:** denatures food; activates pepsinogen; dissolves bone; kills most bacteria
- 3b. **Intrinsic Factor:** Essential for absorption of Vitamin B₁₂

USUS HALUS



Enlarged villus showing lacteal, capillaries, intestinal glands, and cell types

USUS HALUS

Openings of
intestinal
glands

Lamina propria

Microvilli

Intestinal
gland

Absorptive cell
(absorbs water)

Goblet cell
(secretes mucus)

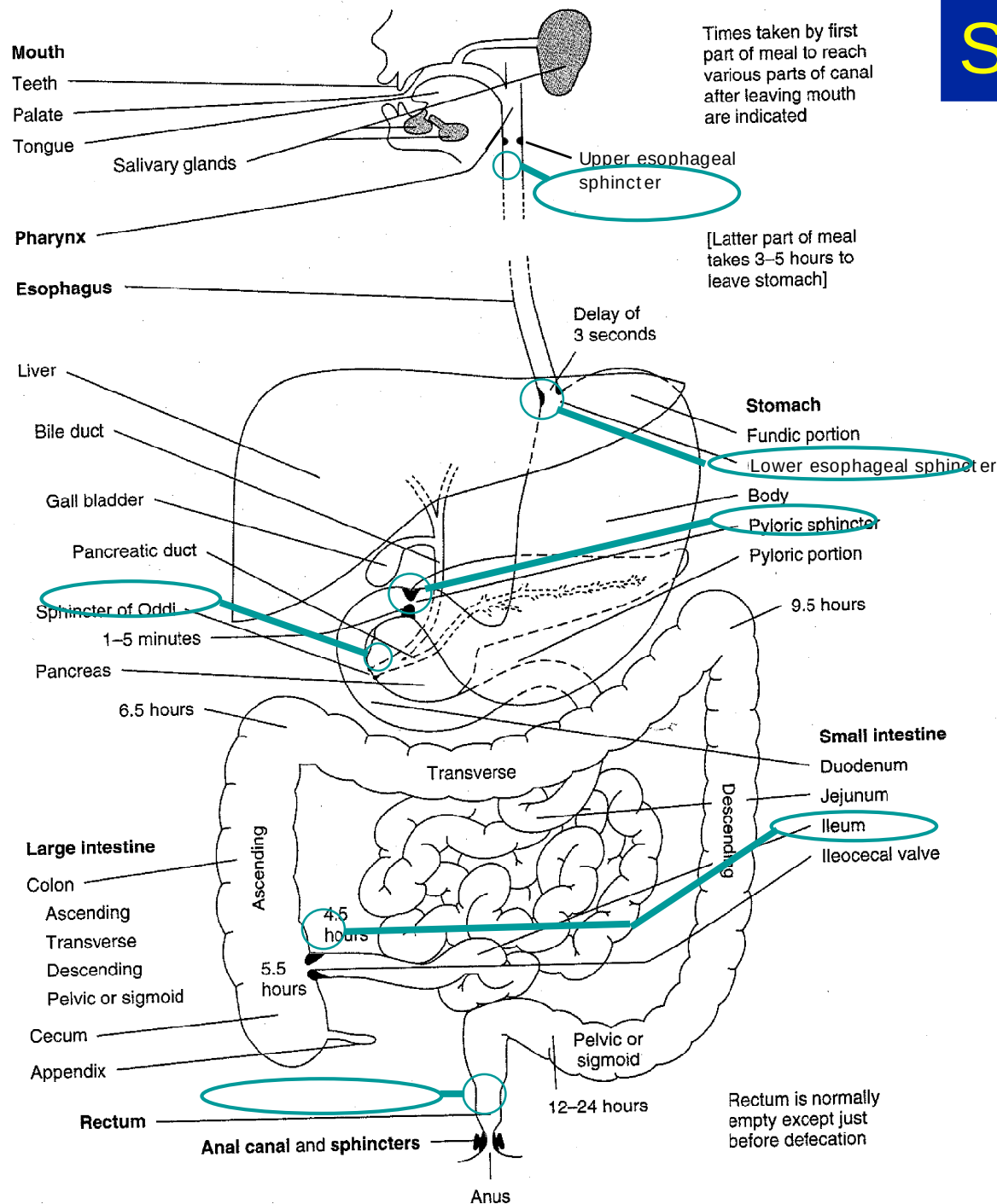
Muscularis
mucosae

Lymphatic
nodule

Submucosa

Sectional view of intestinal glands and cell types

Sphincters



Slow Waves & Action potentials are Forms of Electrical Activity in GI Muscles

Slow waves

- Unknown cause
- Responsible for triggering AP in G.I.
 - Interstitial cells of Cajal, ICCs (pacemaker)
 - Myenteric border
 - Submucosa border
- Occur at different frequency
 - stomach (3/min)
 - small intestine (duodenum, 12-18/min)
 - ileum & colon (6-10/min)
- May or may not accompanied by AP

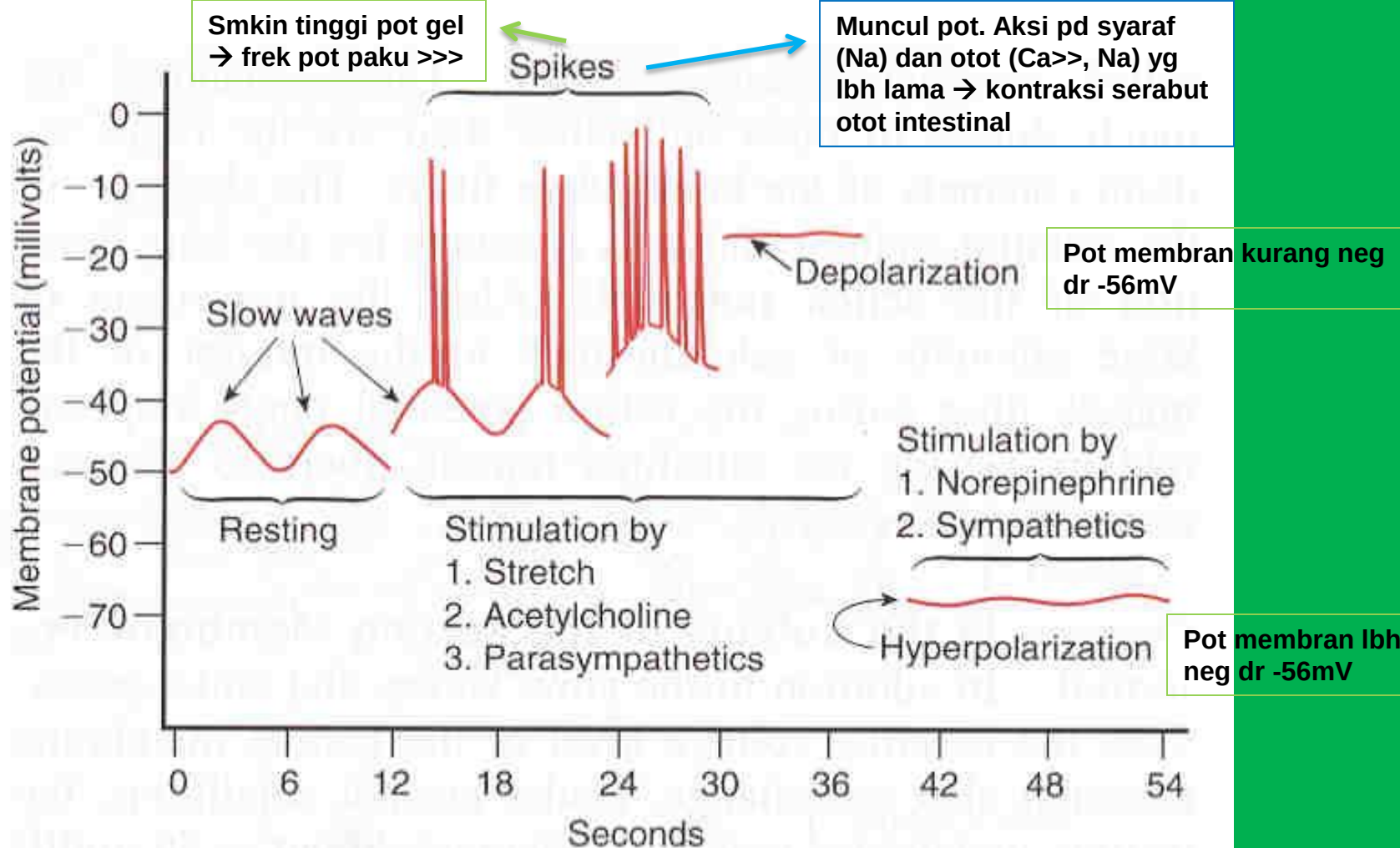


FIGURE 62-3

Membrane potentials in intestinal smooth muscle. Note the slow waves, the spike potentials, total depolarization, and hyperpolarization, all of which occur under different physiologic conditions of the intestine.

Slow Waves & Action potentials are Forms of Electrical Activity in GI Muscles

Factors that depolarize the membrane:

- Stretching of the muscle
- Ach
- Parasympathetic stimulation
- Hormonal stimulation

Factors that hyperpolarize the membrane:

- Norepinephrine
- Sympathetic stimulation





CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

Extrinsic Nerves →
Autonomic nervous system
(ANS)

- Parasympathetic
- Sympathetic

Intrinsic Nerves

- ENS



CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

Parasympathetic Nerves:

- Located in brain stem & sacral region
- Projection to the G.I. are preganglionic efferents
- Vagus & pelvic nerves
- Vagus nerves synapse with neurons of ENS in esophagus, stomach, small intestine, colon, gall bladder & pancreas
- Pelvic nerves synapse with ENS in large intestine
- Neurotransmitter is Ach
- Causes increase in GI secretion and motility by increasing the activity of ENS neurons.

CONTROL
OF
DIGESTIVE
FUNCTIONS
BY
NERVOUS
SYSTEM

Sympathetic nerves:

- Located in thoracic & lumbar regions
- Neurotransmitter is NE
- NE increases sphincter tension
- Decrease GI secretion and motility by inhibiting neurons of the ENS.
- Emotions may slow digestions
→ stimulate sympathetic nerves

CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

Enteric Nervous System (minibrain)

- Has as many neurons as spinal cord
- Located close to the effector systems such as:
 - Musculature
 - Glands
 - Blood vessels (from esophagus to the anus)
- Consists of ganglia & fibers projecting to the effector systems

CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

Enteric Nervous System (minibrain)

Composes of two plexuses:

1. Myenteric plexus / *plexus of Auerbach*:
excitatory or inhibitory (outer plexus)

Mostly controls GI motility (movement)
→ frequency and strength of
contraction of muscularis

2. Submucosal plexus / *plexus of Meissner*
(inner plexus)

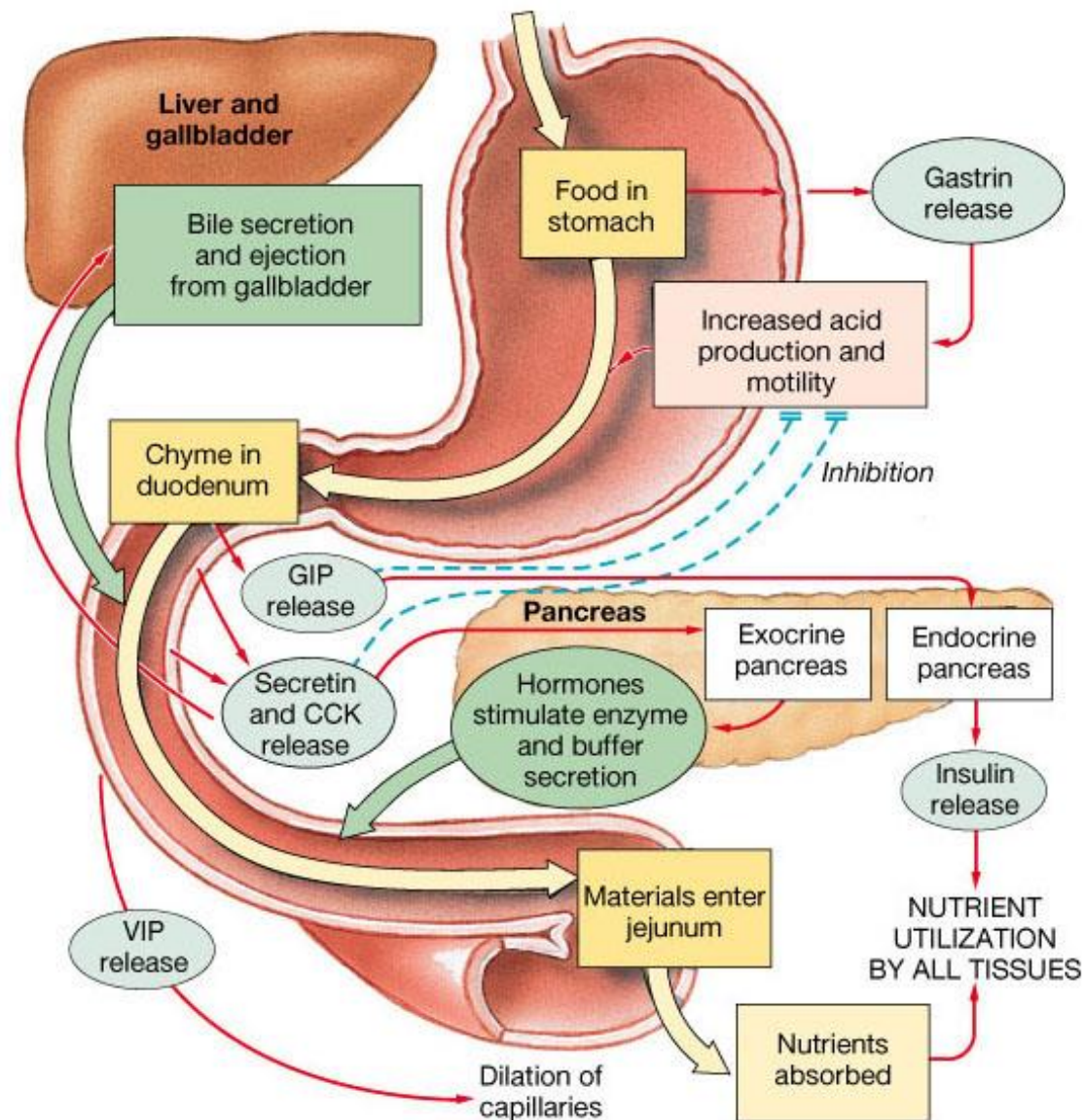
Motor neuron supply the secretory cells
of the mucosal epithelium → controlling
secretions of organs in GI tract

TABLE 8-2. Summary of Gastrointestinal Hormones

Hormone	Hormone Family	Site of Secretion	Stimuli for Secretion	Actions
Gastrin	Gastrin-CCK	G cells of the stomach	Small peptides and amino acids Distention of the stomach Vagal stimulation (GRP)	↑ Gastric H ⁺ secretion Stimulates growth of gastric mucosa
Cholecystokinin (CCK)	Gastrin-CCK	I cells of the duodenum and jejunum	Small peptides and amino acids Fatty acids	↑ Pancreatic enzyme secretion ↑ Pancreatic HCO ₃ ⁻ secretion Stimulates contraction of the gallbladder and relaxation of the sphincter of Oddi Stimulates growth of the exocrine pancreas and gallbladder Inhibits gastric emptying
Secretin	Secretin-glucagon	S cells of the duodenum	H ⁺ in the duodenum Fatty acids in the duodenum	↑ Pancreatic HCO ₃ ⁻ secretion ↑ Biliary HCO ₃ ⁻ secretion ↓ Gastric H ⁺ secretion Inhibits trophic effect of gastrin on gastric mucosa
Gastric inhibitory peptide (GIP)	Secretin-glucagon	Duodenum and jejunum	Fatty acids Amino acids Oral glucose	↑ Insulin secretion from pancreatic β cells ↓ Gastric H ⁺ secretion

TABLE 8-1. Neurotransmitters and Neuromodulators in the Enteric Nervous System

Substance	Source	Actions
Acetylcholine (ACh)	Cholinergic neurons	Contraction of smooth muscle in wall Relaxation of sphincters ↑ Salivary secretion ↑ Gastric secretion ↑ Pancreatic secretion
Norepinephrine (NE)	Adrenergic neurons	Relaxation of smooth muscle in wall Contraction of sphincters ↑ Salivary secretion
Vasoactive intestinal peptide (VIP)	Neurons of mucosa and smooth muscle	Relaxation of smooth muscle ↑ Intestinal secretion ↑ Pancreatic secretion
Gastrin-releasing peptide (GRP) or bombesin	Neurons of gastric mucosa	↑ Gastrin secretion
Enkephalins (opiates)	Neurons of mucosa and smooth muscle	Contraction of smooth muscle ↓ Intestinal secretion
Neuropeptide Y	Neurons of mucosa and smooth muscle	Relaxation of smooth muscle ↓ Intestinal secretion
Substance P	Cosecreted with ACh	Contraction of smooth muscle ↑ Salivary secretion



Kendali sekresi ludah



Deglution / Menelan

Makanan atau isi mulut dikumpulkan pada lidah dan didorong kearah belakang kedalam faring kontraksi faring mendorong kedalam kerongkongan

Pada saat menelan secara reflek terjadi hambatan pernafasan temporer dan penutupan glottis agar makanan tidak masuk kedalam tenggorokan

Kendali menelan

Tahap volunter dan involunter

Tahap Volunter —————> sadar dan dibawah kemauan

Tahap Involunter —————> otomatis dibawah kendali saraf otonom

➔ **Tahap faringeal** (bolus dari faring ke esofagus)

➔ **Tahap oesophageal** (bolus dari esofagus ke dalam perut)

Makanan secara sadar didorong ke belakang ke palatum oleh lidah

Palatofaringeal membentuk celah sagital

Nervus trigeminus

**Pita suara saling bertautan
Epiglotis bergerak kebelakang**

Medula oblongata

**Palatum mole
tutup nares posterior**

Laring ke atas

Oesofagus terbuka

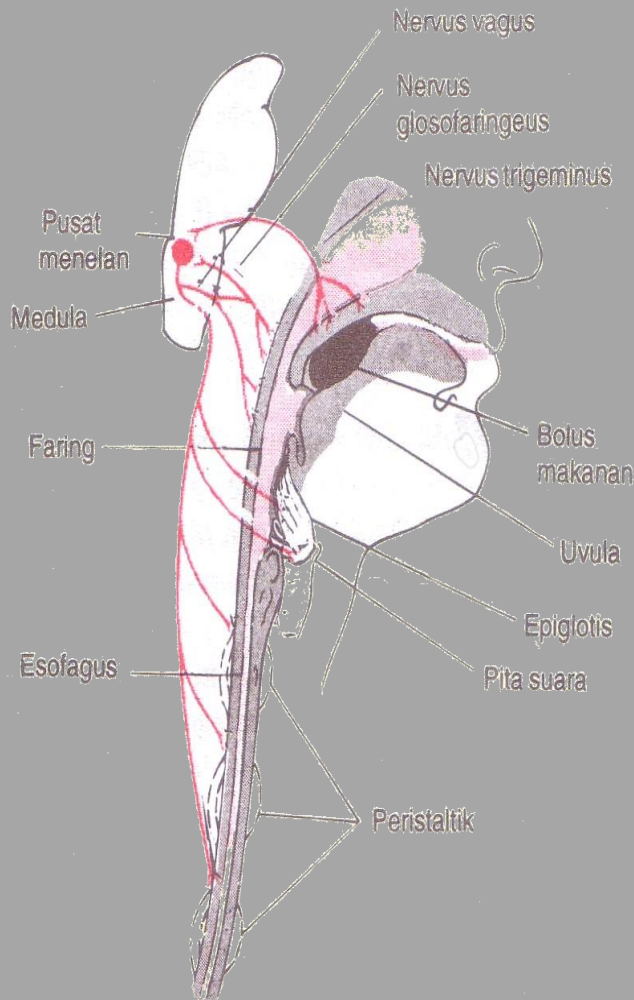
Nervus glosfaringeus

**Kontraksi peristaltik
Sfingter faringoesofageal**

Nervus vagus

**Peristaltik primer dan
Sekunder oesofagus**

Lambung

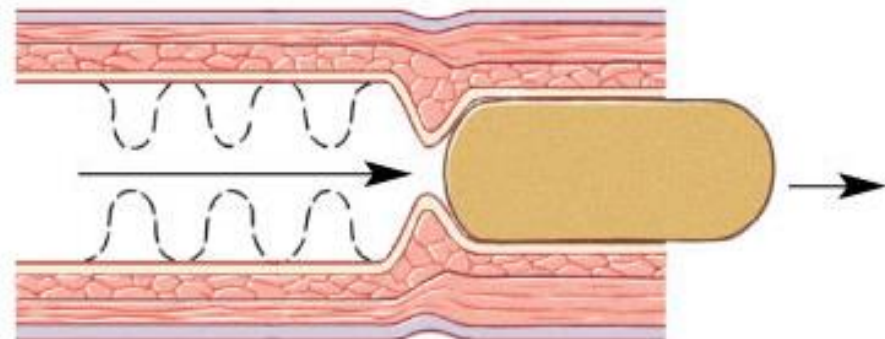
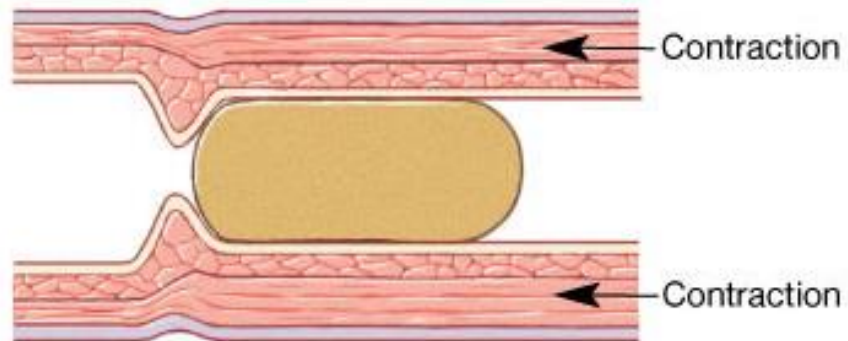
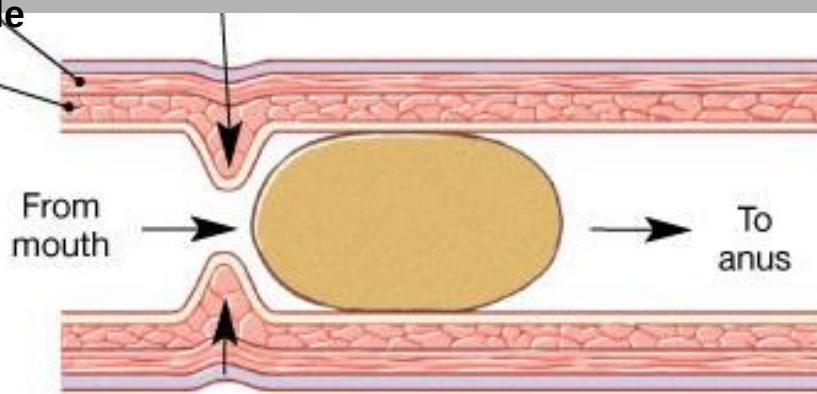


Longitudinal muscle
Circular muscle

**Kontraksi otot sirkularis
disamping massa
makanan**

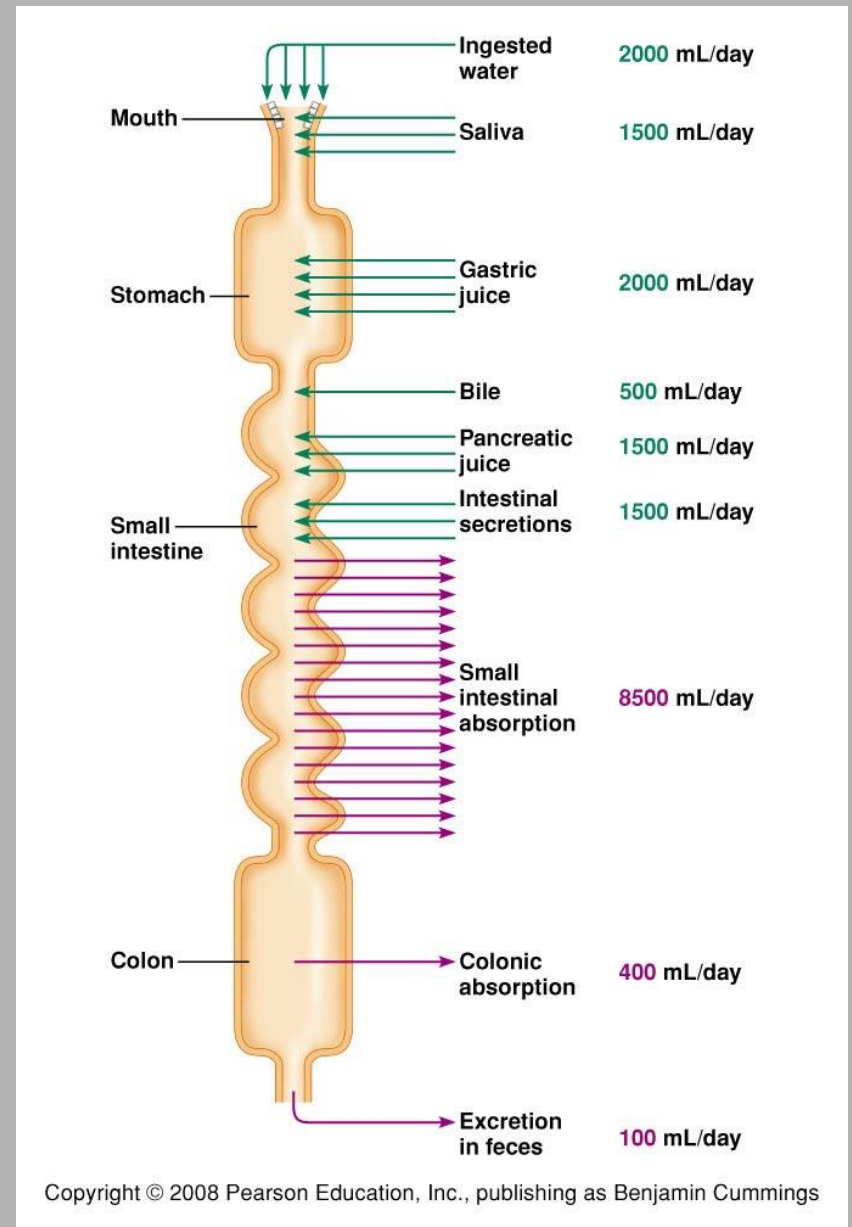
**Kontraksi otot
longitudinalis
mendorong kearah
depan dari massa
makanan**

**Kontraksi otot sirkularis
akan memaksa massa
makanan bergerak maju**



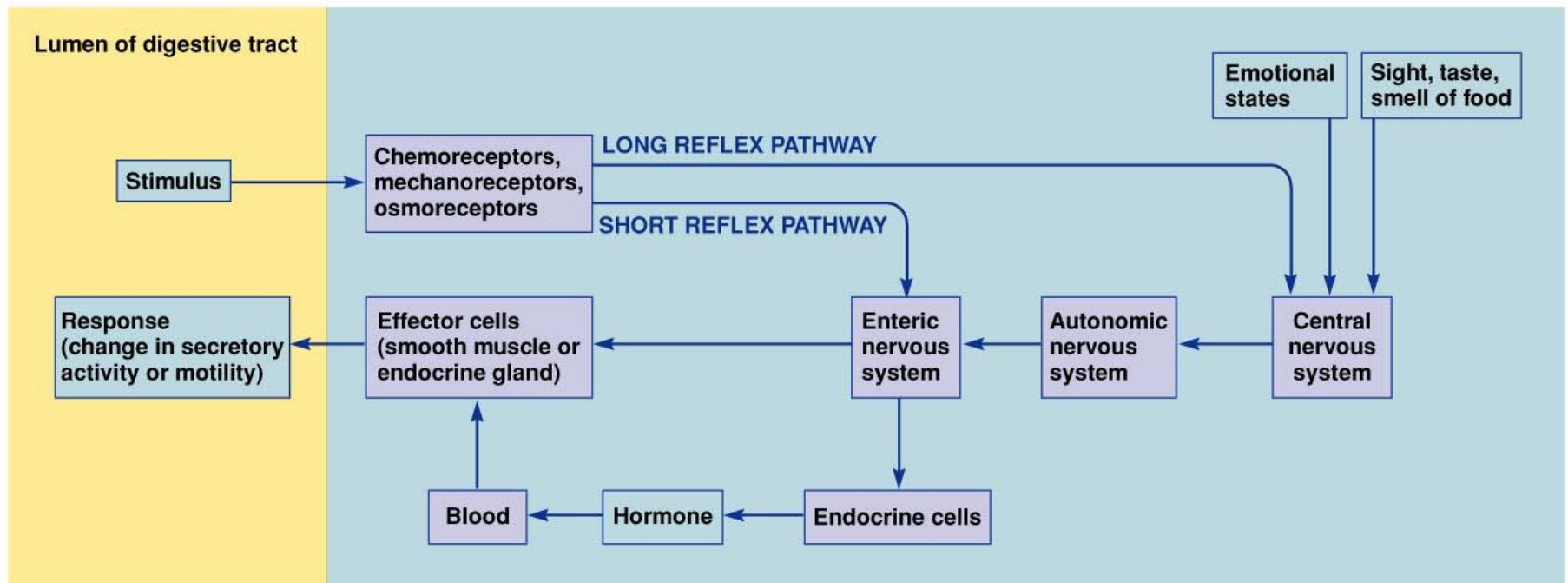
GI secretion and regulation

- Sensors: 3 different receptors:
 - mechanoreceptors: monitor state of distention
 - chemoreceptors monitor concentrations of substances in the lumen
 - osmoreceptors monitor osmolarity of lumen contents
- Integrating centers: CNS and enteric NS
- Effectors: endocrine, exocrine cells, smooth muscles



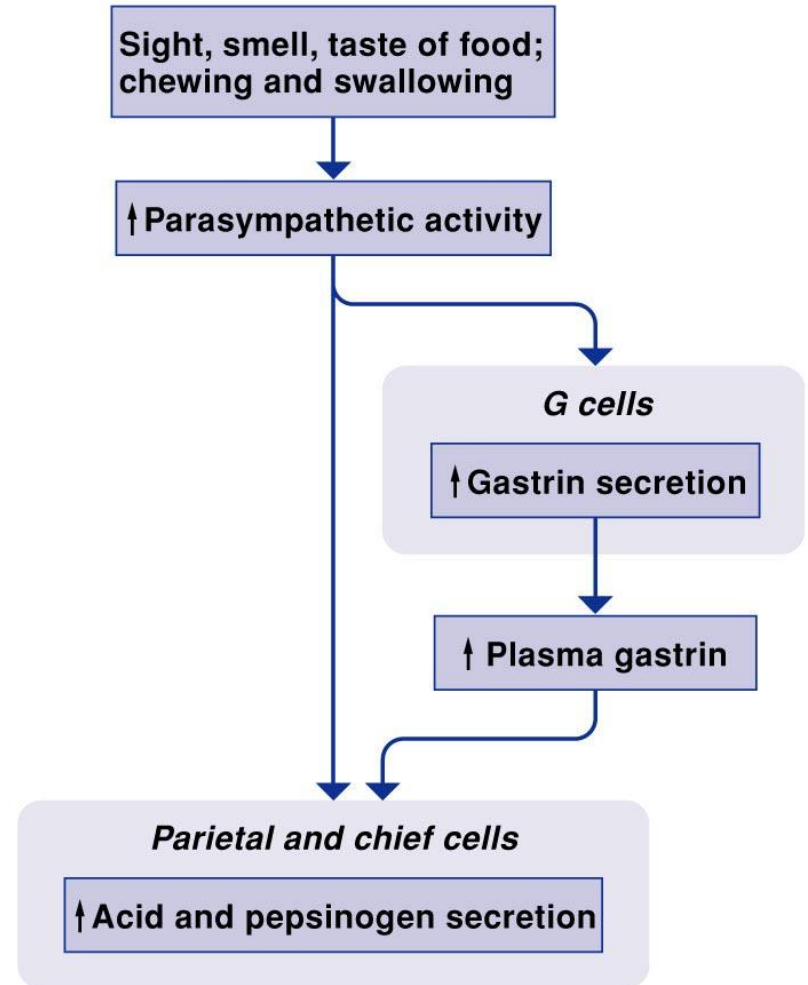
Control pathways

- Both hormonal and neural
- Short pathways: involves automatic regulation within the enteric system itself
- Long pathways: involves the CNS (somatic and autonomic)
- Three phases: cephalic, gastric and intestinal phases



Cephalic phase: salivary and gastric secretions

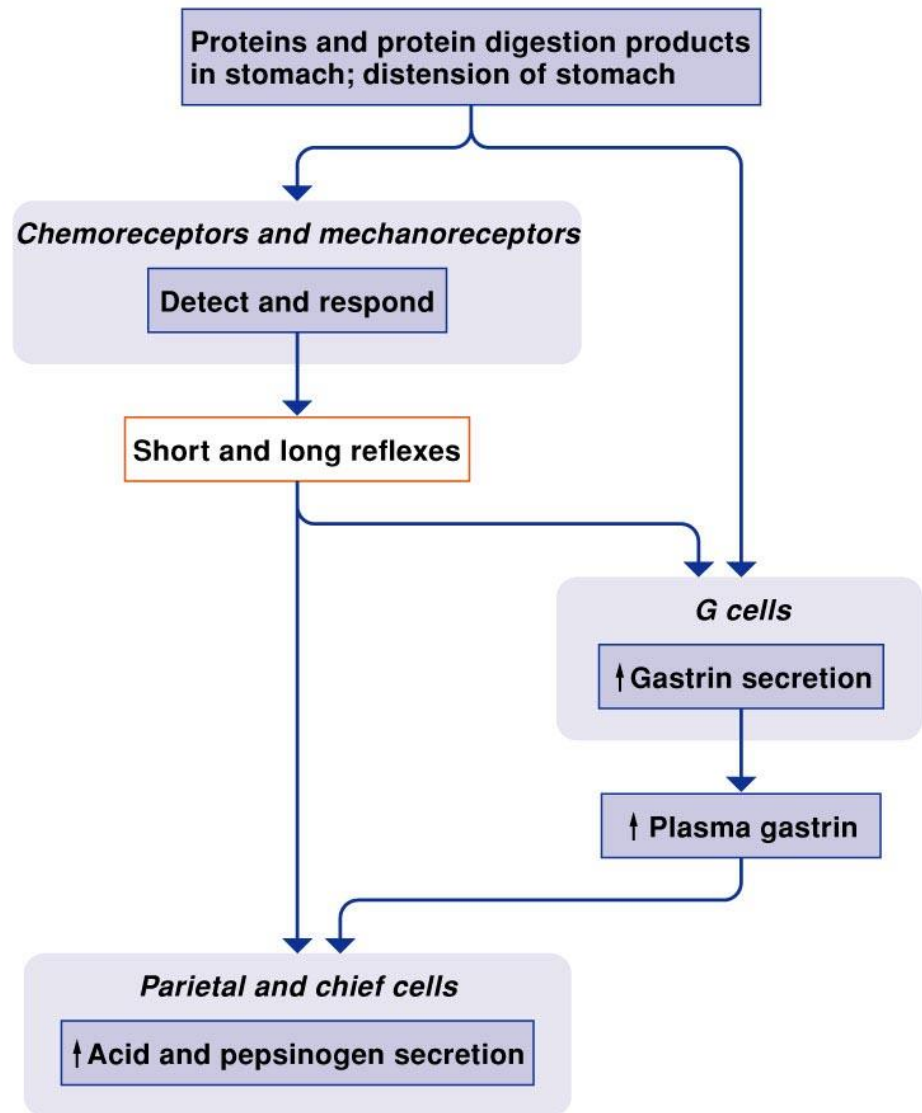
- Salivary secretion stimulated by parasympathetic NS by odors, sight, taste → saliva fluid and rich in enzymes
- Stimulated by sympathetic NS → thick secretion, rich in proteins
- Gastric secretion: increase acid and enzymes secretion in response to sight, smell and taste of food



(a) Cephalic-phase control of gastric secretion

Gastric phase

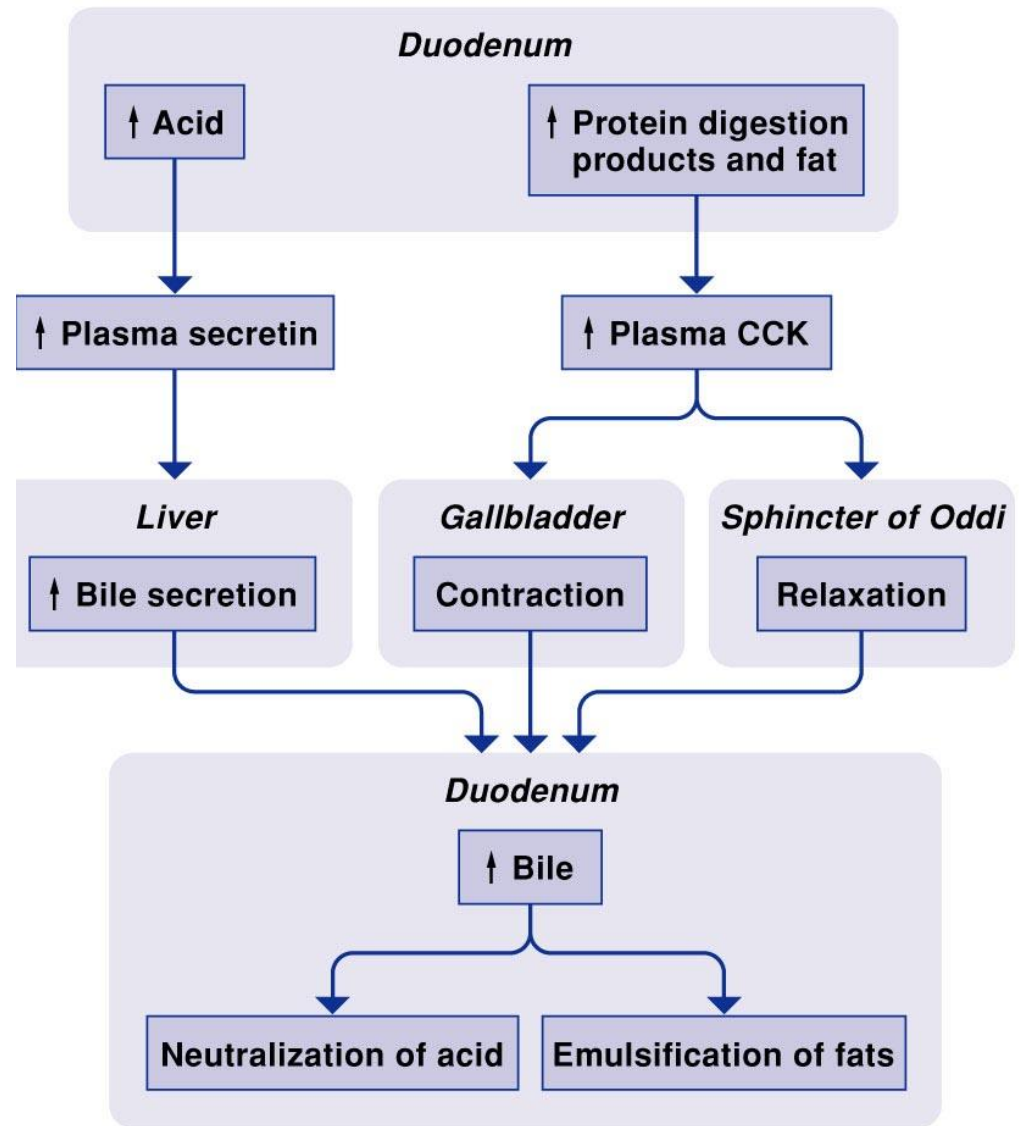
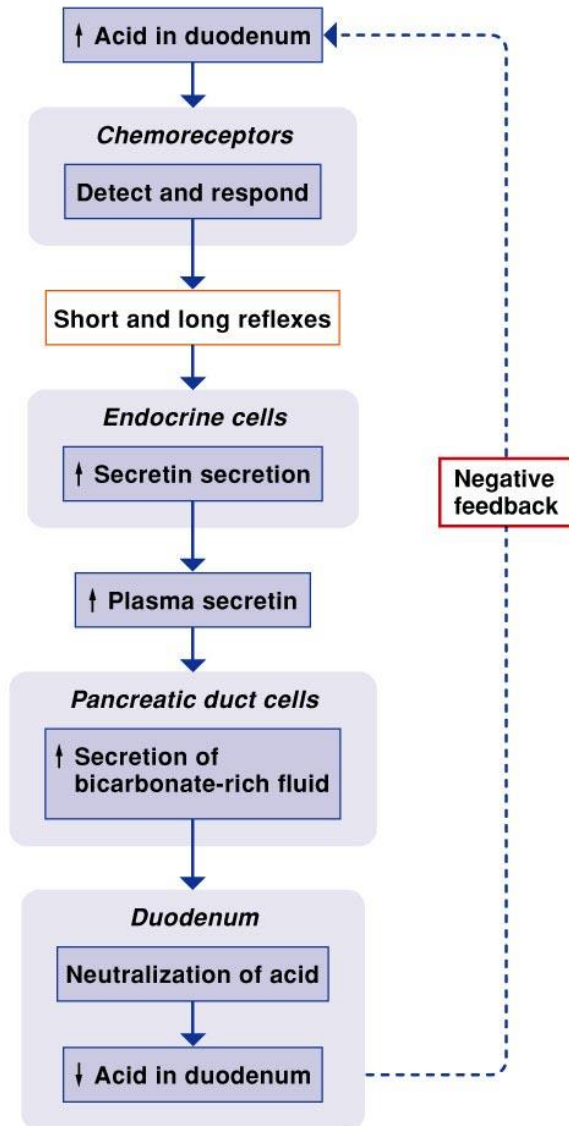
- Stimuli: presence of food in the stomach (both distention and nutrients)
- Stimulation of the parasympathetic NS and secretion of gastrin (hormone)
- Response: increased motility and juice secretion



(b) Gastric-phase control of gastric secretion

Intestinal phase

- Arrival of nutrients in duodenum → decreased gastric secretion and motility
- Promotes secretion of cholecystokinin (CCK) and secretin
 - CCK promotes:
 - increased pancreatic enzyme secretion
 - gallbladder contraction and sphincter of Oddi relaxation
 - secretin promotes:
 - bicarbonate ion secretion (pancreas)
 - bile secretion



Regulasi Sekresi

Usus Halus

Kelenjar Bruner:

Sekresi mukus :

bersifat basa untuk melindungi mukosa usus dari pengaruh – asam lambung (bersama dengan getah pankreas dan empedu)

Kripta Liëberkuhn

Sel Goblet

Sekresi encer (air dan elektrolit pH 7,5 – 8) dan mukus untuk melumasi–melindungi mukosa

Enterosit

Sekresi encer (air dan elektrolit pH 7,5 – 8)

Usus Besar

Banyak Kripta Liëberkuhn – vili

Sekresi >> mukus

Sel enterosit << enzim

Regulasi sekresi

Stimulasi Regional :

Rangsang taktil & iritasi o/ Kimus → Saraf Enterik → Motilitas Usus dan Sekresi

Rangsangan dibawah kendali Saraf Parasimpatis yaitu : N. Vagus (usus halus) ; N. Vagus serta N. Pelvikus (usus besar)

Hormonal :

Sekretin dan Kolesistokinin

Inhibisi :

Rangsangan Saraf Simpatis

Pankreas :

Kelenjar Endokrin : menghasilkan hormon insulin dan glukagon
(*pancreatic islet / pulau langerhans*)

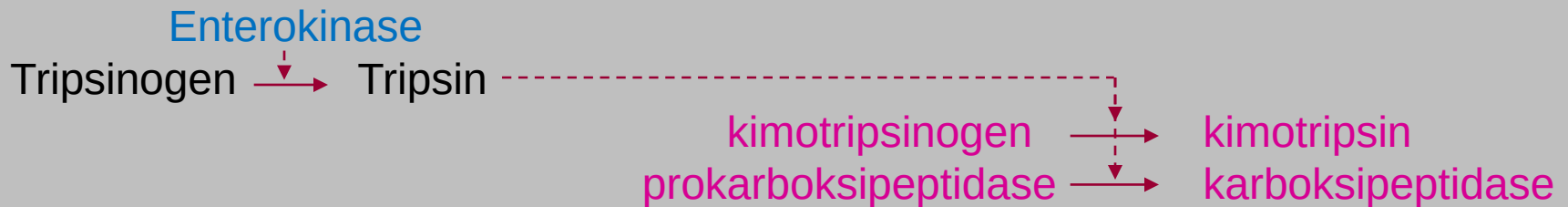
Kelenjar Eksokrin : menghasilkan ion bikarbonat dan berbagai enzim pankreas (*acinar cell*)

Pencerna protein

Tripsin, kimotripsin, karboksipeptidase, elastase dan nuklease

Tripsin dan Kimotripsin : protein $\rightarrow$ peptida

Karboksipeptidase : peptida $\rightarrow$ asam amino



Pencerna lemak

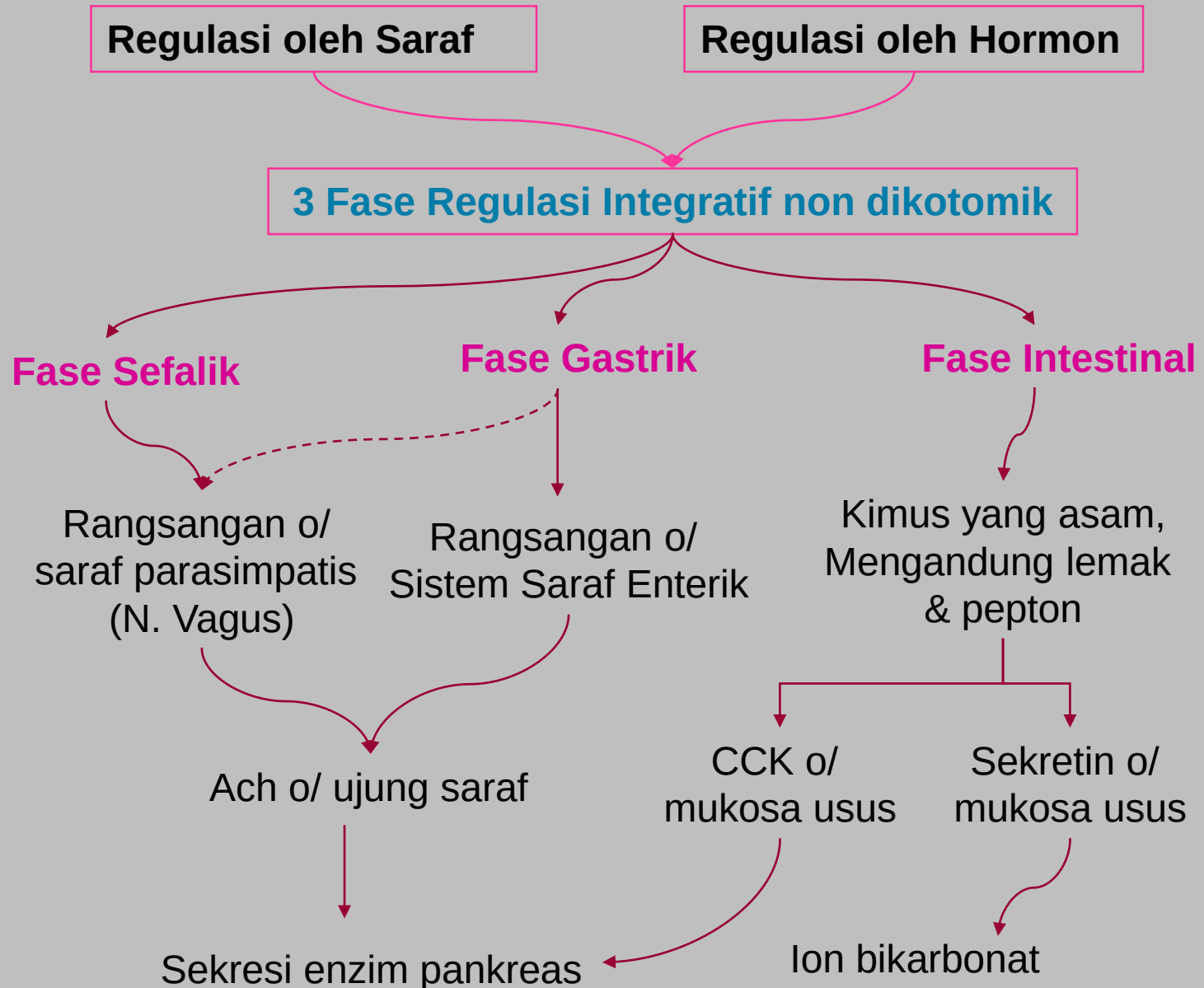
Lipase, fosfolipase dan kolesterol esterase

Pencerna karbohidrat

Amilase

Ion bikarbonat dan air : netralisasi kimus dari lambung yang asam

Regulasi Sekresi Getah Pankreas



Empedu disintesis di **hepatosit (sel hati)**, disimpan dan dipekatkan dalam **kandung empedu**

Fungsi Empedu : 1. berperan dalam pencernaan dan absorpsi lemak
2. sebagai sarana pengeluaran produk katabolisme dari hati
(**bilirubin dan kolesterol**)

Komposisi Empedu : Air, **Garam Empedu, Asam lemak**, Kolesterol, Bilirubin, **Lesitin**, Na^+ , K^+ , Ca^+ , Cl^- , HCO_3^-)

Prekursor garam empedu : **Kolesterol**  asam lemak : **asam kolik dan asam kenodeoksikolik**

Konjugasi dengan : **glisin & taurin**



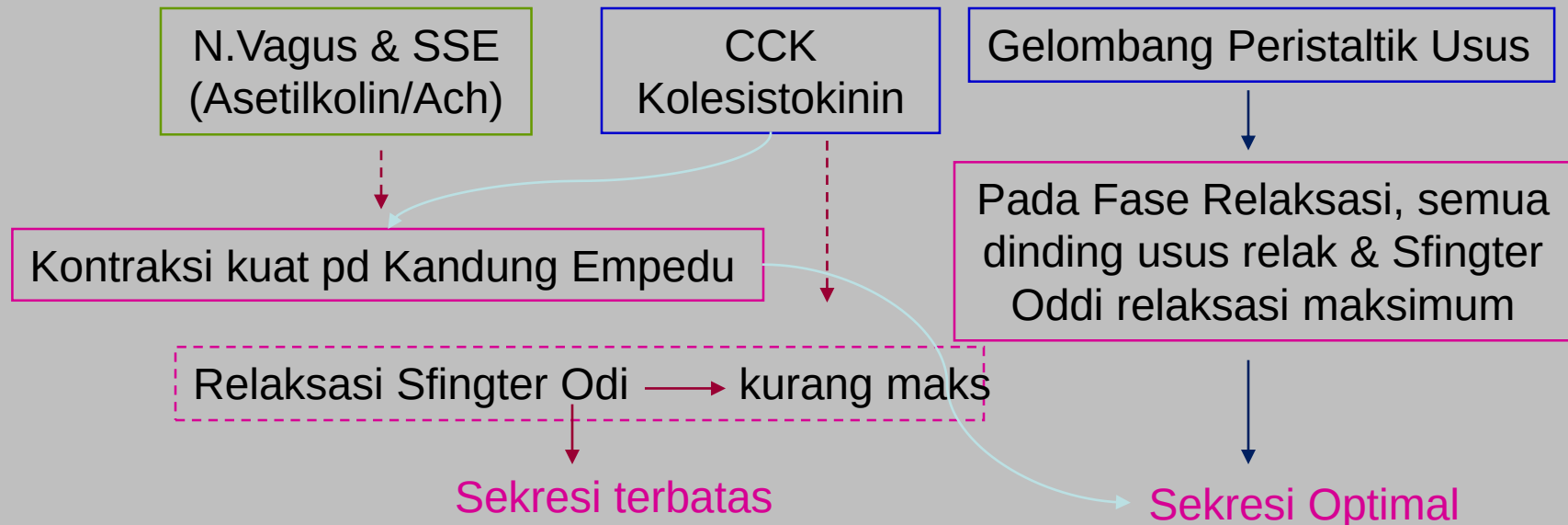
Garam empedu : **gliko/tauro-kolik**
gliko/tauro-kenodeoksikolik

- Fungsi Garam Empedu :**
1. Emulsifikasi lemak sehingga mudah beragitasi dalam GIT sehingga dapat mudah bereaksi dengan Lipase Pankreas
 2. Membantu transpor dan absorpsi asam lemak bebas dan monogliserida maupun turunan lemak lainnya dengan membentuk miselus (*micelus*)

Regulasi Sekresi Empedu

Empedu disintesis terus menerus → kandung empedu

Sekresi empedu dari kandung empedu → duodenum

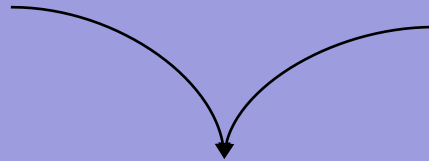


Regulasi Motilitas dan Transpor

USUS HALUS

**Kontraksi Segmentasi
(Gerakan Mencampur)**

**Kontraksi Peristaltik
(Gerakan Mendorong)**



Tidak dikotomis secara tegas

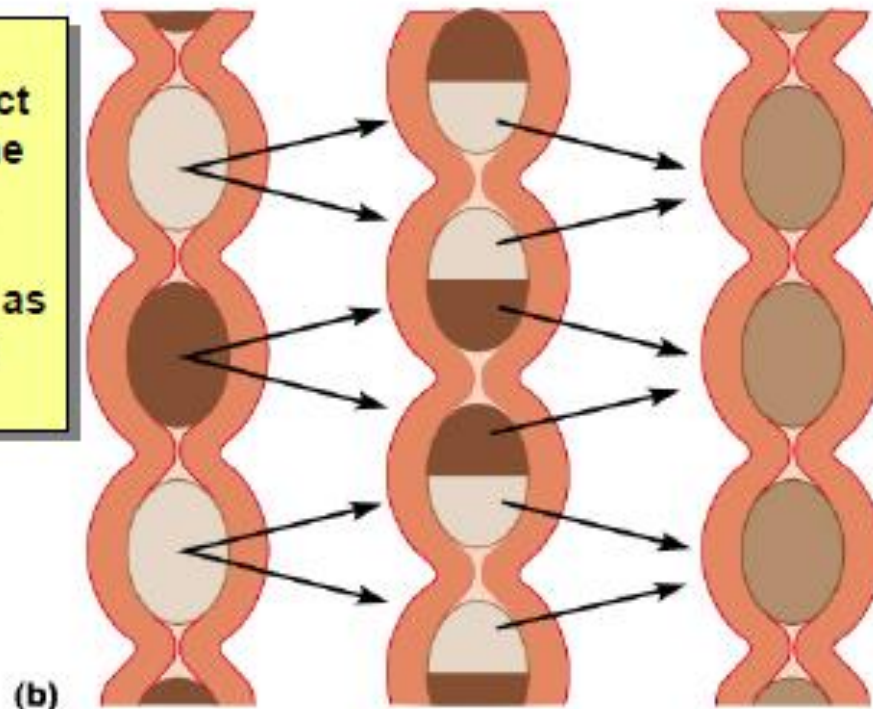
**Keduanya terjadi dibawah kendali Saraf Enterik pada
Pleksus Mienterikus melalui Refleks Gastroenterik (Gastroileal)**

**Gerakan Segmentasi merupakan gerakan seperti kontraksi cincin
(seperti meremas secara sirkularis) sehingga terbentuk interval tertentu**

**Gerakan Peristaltik merupakan gerakan mendorong akibat adanya regangan
sehingga terjadi gerakan sirkuler dibelakang titik perangsangan
dan berjalan sepanjang usus**

Segmentation

Circular muscles alternately contract and relax along the alimentary canal. This mixes and liquefies the food as well as helping to propel it along.

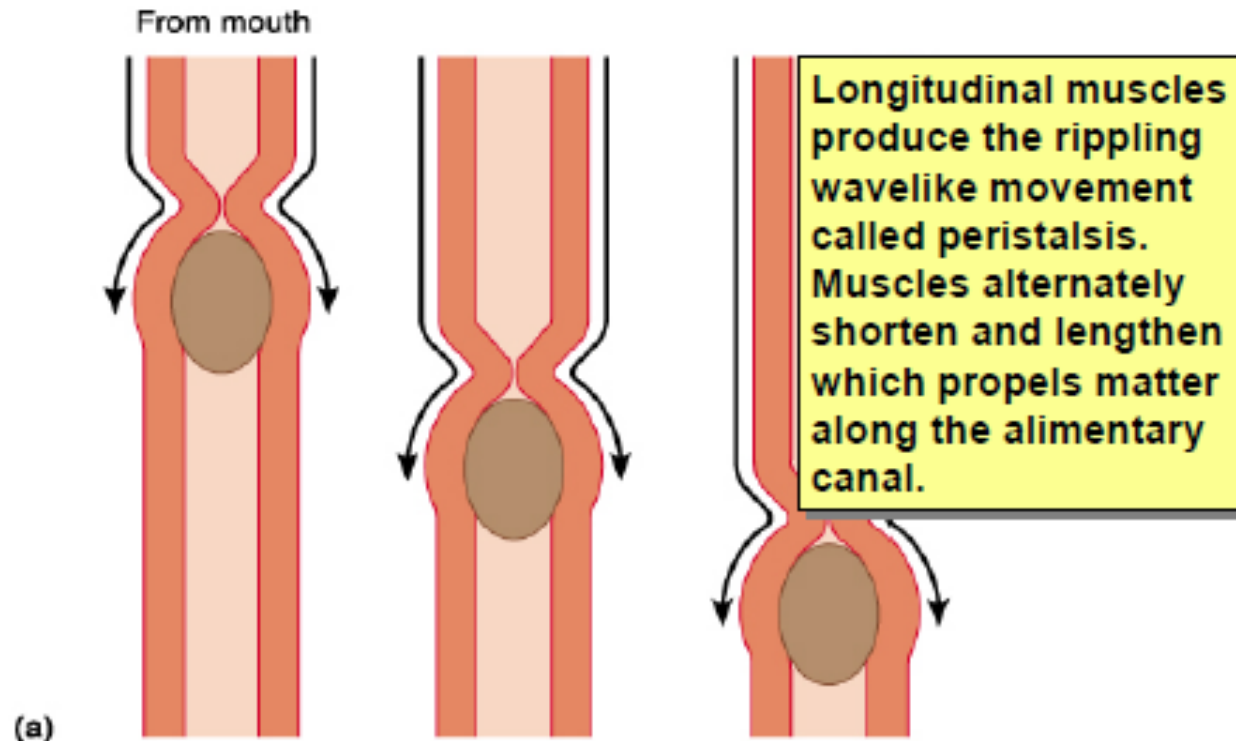


(b)

Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Segmentation is one of two muscular actions in the esophagus and it continues throughout most of the GI tract. It produces mixing of the contents and works together with peristalsis to move them along.

Peristalsis



Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Longitudinal muscle contraction produces peristalsis, the wave-like movements which, together with segmentation, propel the contents along the esophagus and GI tract. Most people use the term peristalsis to include both processes.

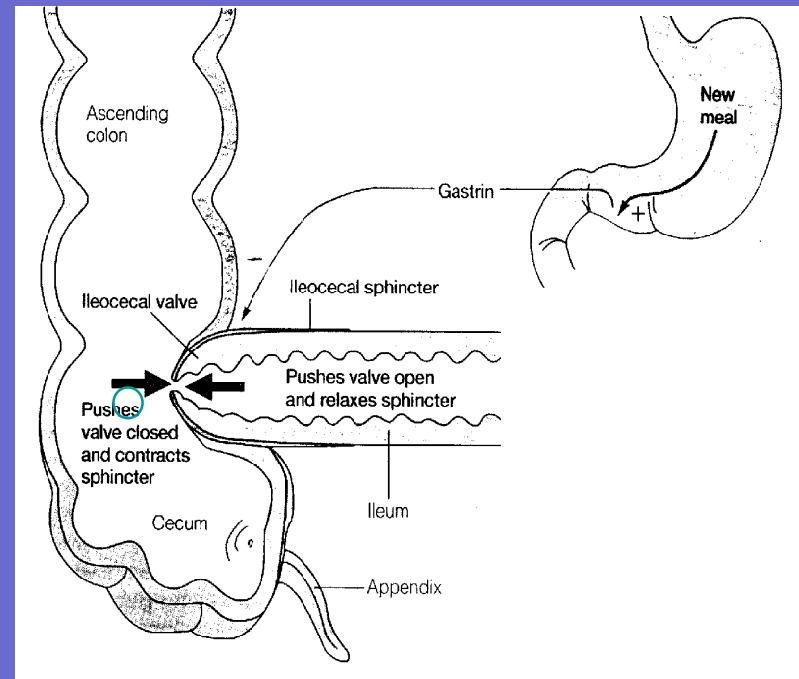
Emptying of the ileum

Ileocecal sphincter: normally closed. Short-range peristalsis in terminal ileum and distension relaxes IC sphincter --> small amount of chyme is squirted into the cecum.

Distension of cecum contracts IC sphincter.

Gastro-ileal reflex enhances ileal emptying after eating.

The hormone gastrin relaxes ileocecal sphincter.

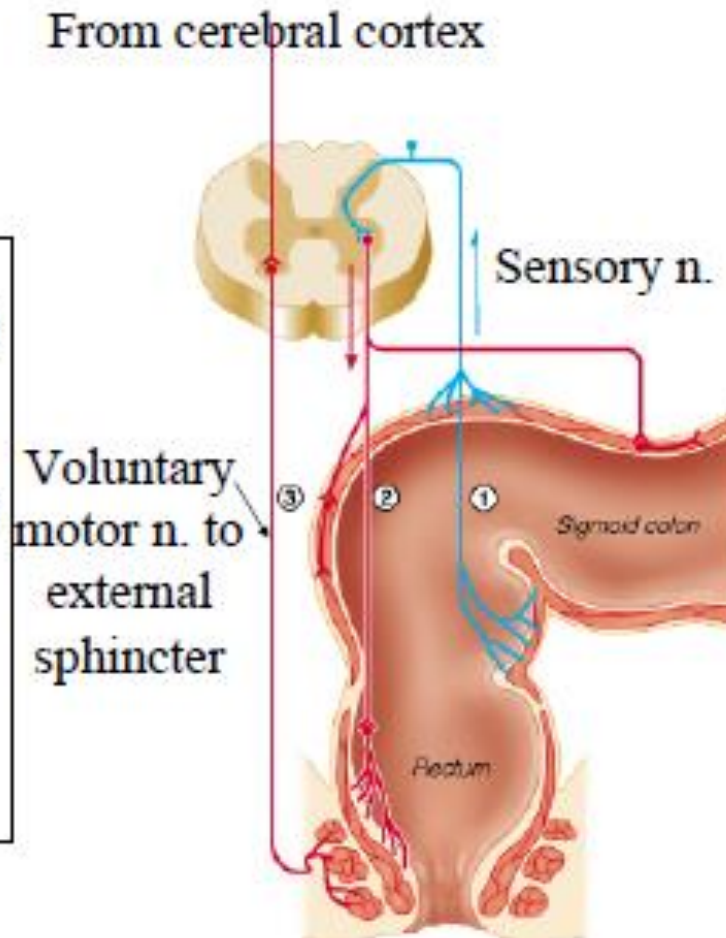


USUS BESAR

Serupa dengan usus halus, gerakan segmentasi = gerakan haustrasi, gerakan peristaltik dan gerakan massa (gerakan peristaltik pd daerah yang luas, terutama sepanjang pars desenden saat defekasi).

Defecation Reflex

- 1) Pressure in rectum from mass peristalsis sends afferent stimuli to spinal cord.
- 2) Parasympathetic stimuli cause contraction of rectal muscle and relaxation of internal anal sphincter.
- 3) Voluntary stimuli relax external sphincter and cause abdominal contraction.



Digesti dan Absorpsi

Sebagian besar atau bahkan seluruh proses digesti pada usus terjadi secara enzimatik

Karbohidrat : amilum, laktosa, glikogen, pektin, dekstrin dan berbagai derivat KH dalam daging

Amilase, laktase, maltase, sukrase, α - dekstrinase

Protein : pepsin, tripsin, kemotripsin, karboksipeptidase, proelastase, peptidase (aminopeptidase, dipeptidase)

Lemak : Lipase, ester kolesterol hirolase dan fosfolipase A₂

Absorpsi nutrisi dan reabsorpsi air maupun elektrolit (terutama natrium) terjadi di dalam usus (usus halus maupun usus besar)

Absorpsi terjadi melalui mekanisme transpor aktif, difusi dan solvent drag, kecuali lemak

Absorpsi air dan elektrolit (bikarbonat, natrium dan klorida)

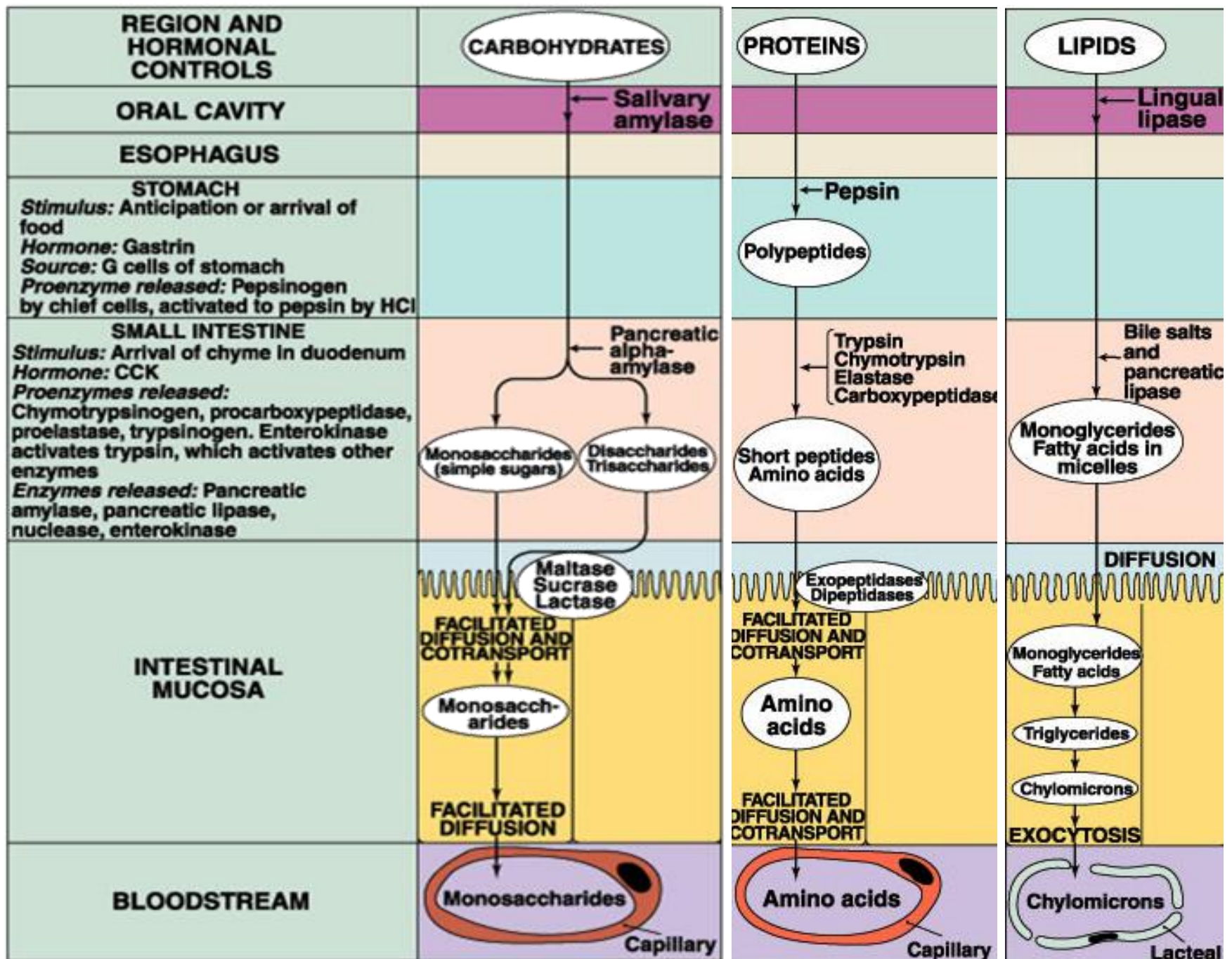
umumnya terjadi di bagian proksimal kolon sedang di bagian distal kolon umumnya bagian penyimpanan sebelum dikeluarkan

Di kolon banyak terdapat bakteri seperti *Escherichia coli*, *Enterobacter aerogenes*, *Bacterioides fragilis*, *Lactobacillus sp.* dan *Bifidobaacterium sp.* Mikroba tersebut memberikan keuntungan diantaranya dalam hal sintesis vitamin K, vitamin B12, tiamin, riboflavin serta memecah selulosa

Komposisi feses : $\frac{3}{4}$ air dan $\frac{1}{4}$ bahan padat yang terdiri dari :
30 % serat tidak tercerna
30 % bakteri mati
10 – 20 % lemak
10 – 20 % bahan inorganik
2 – 3 % protein

Warna dan bau disebabkan karena adanya :

- urobilin dan sterkobilin (hasil degradasi bilirubin) – (warna)
- indol, skatolmerkaptan dan H_2S serta zat lain hasil pemecahan bakteri yang khas (bau)



	Lumen of digestive tract	Mucosa	Interstitial fluid	Transport mechanism	Regulatory factors
IONS	Na^+			Diffusion, cotransport, or active transport	Increased when sodium-linked cotransport is under way; stimulated by aldosterone
	Ca^{2+}			Active transport	Stimulated by calcitriol and PTH
	K^+			Diffusion	Follows concentration gradient
	Mg^{2+}			Active transport	
	Fe^{2+}			Active transport	
	Cl^-			Diffusion or carrier-mediated transport	
	I^-			Diffusion or carrier-mediated transport	
	HCO_3^-			Diffusion or carrier-mediated transport	
	NO_3^-			Diffusion or carrier-mediated transport	
	PO_4^{3-}			Active transport	
	SO_4^{2-}			Active transport	
VITAMINS	Water-soluble vitamins (except B_{12})			Diffusion	Follows concentration gradient
	Vitamin B_{12}			Active transport	Must be bound to intrinsic factor prior to absorption
	Fat-soluble vitamins			Diffusion	Absorbed from micelles in company with dietary lipids