

DIGESTIVE SYSTEM

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Topik perkuliahan

- Alokasi waktu: 100 menit
- Topik perkuliahan
 - 1. Mastikasi
 - 2. Deglutisi
 - 3. Absorpsi Makanan dalam saluran cerna

Sistem Digestivus

- = Sistem/traktus gastrointestinal , suatu portal dimana nutrisi (vit, mineral, cairan masuk ke tubuh), lemak, protein, KH dicerna menjadi unit yang bisa di absorbsi.
- Canalis/saluran yang terlibat : mulut, faring, esofagus, gaster, usus halus, usus besar.
- Organ digestif assessorius : gigi, lidah, kelenjar saliva, kandung empedu, hepar, pankreas.

Digestive System: Overview

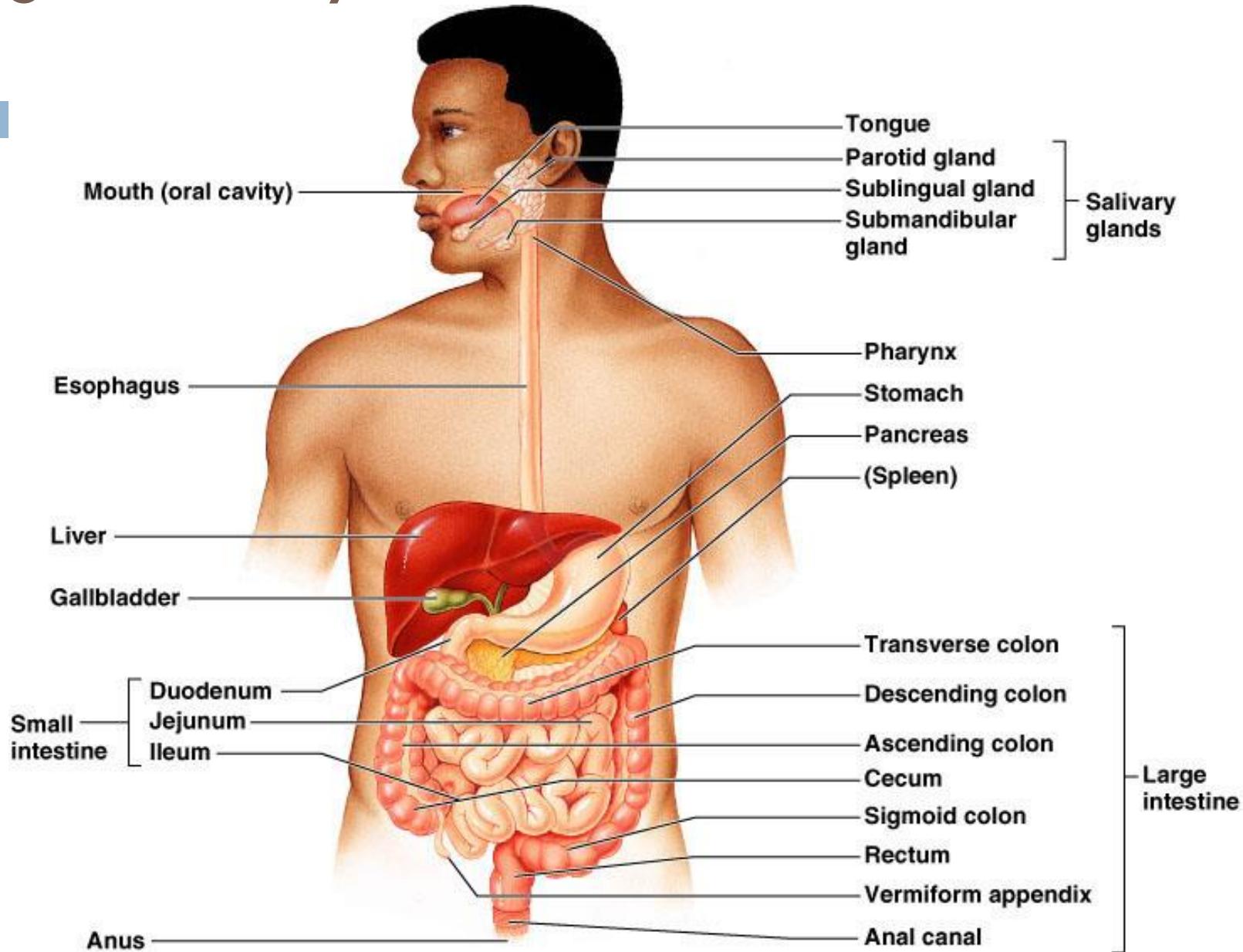
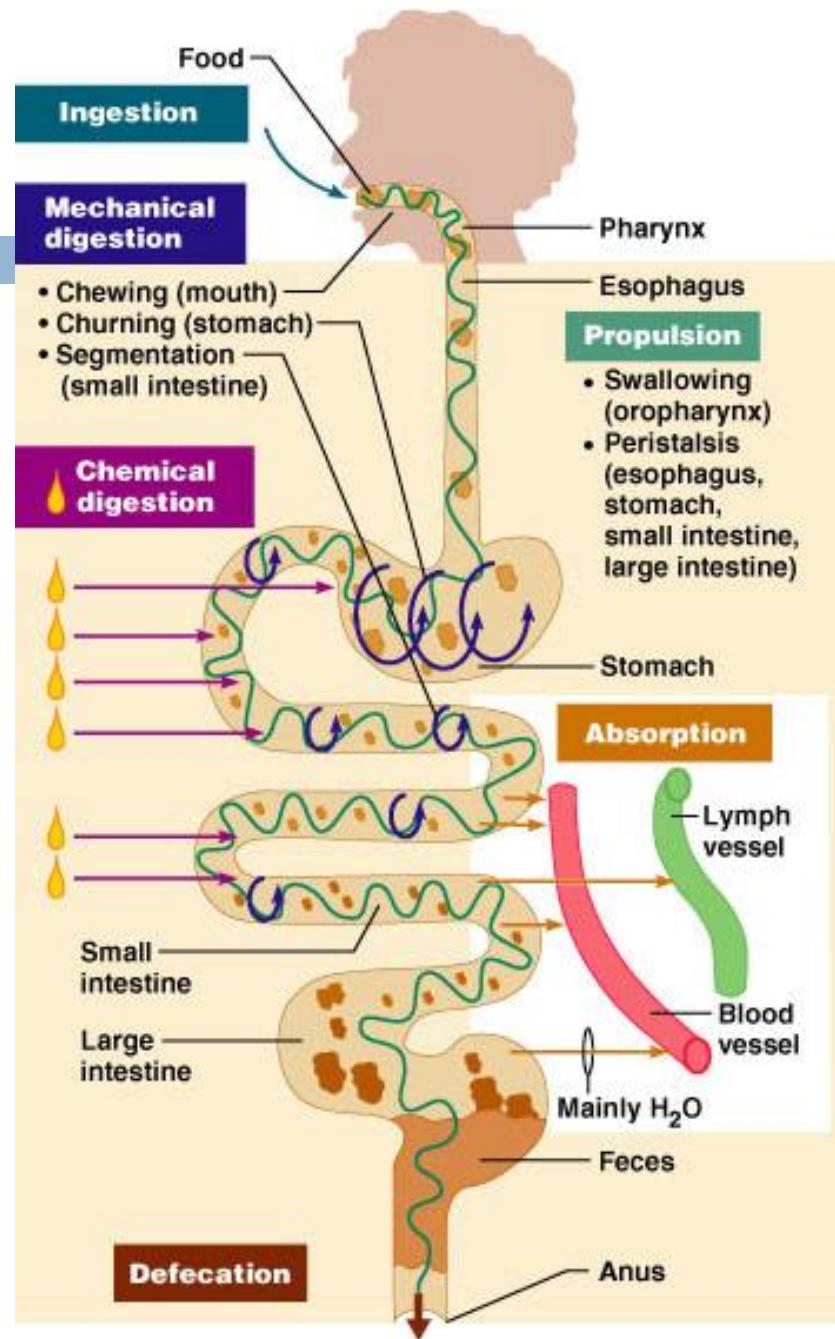


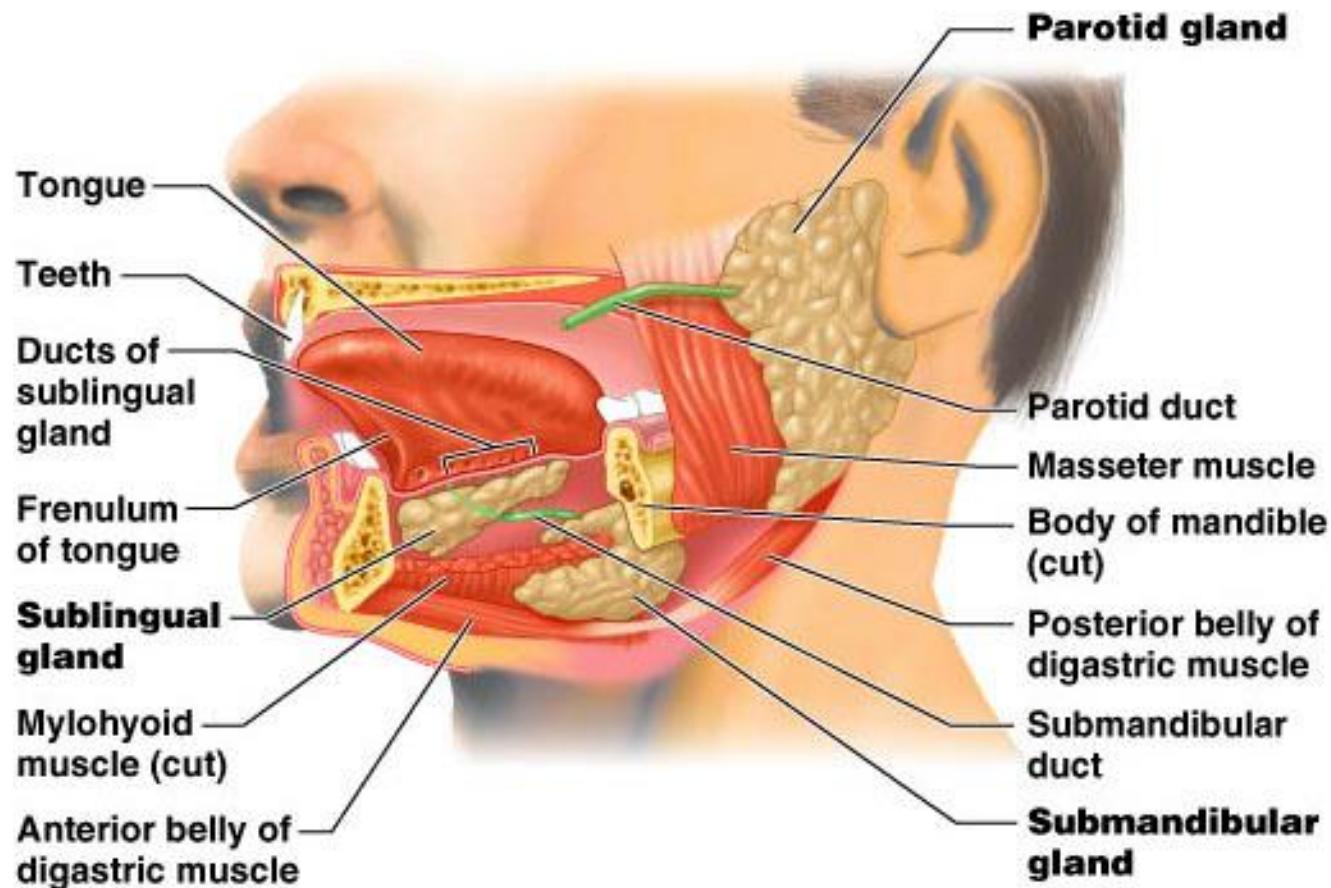
Figure 23.1

□ Terdapat 6 proses/aktivitas penting

- Ingesti
- Propulsi
- digesti mekanis
- digesti kimia
- Absorbsi
- dan defekasi



MULUT



(a)

Processes of the Mouth

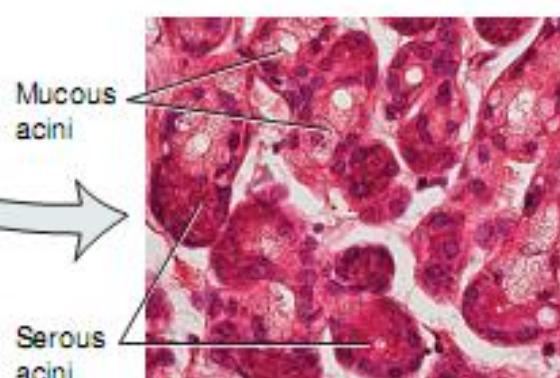
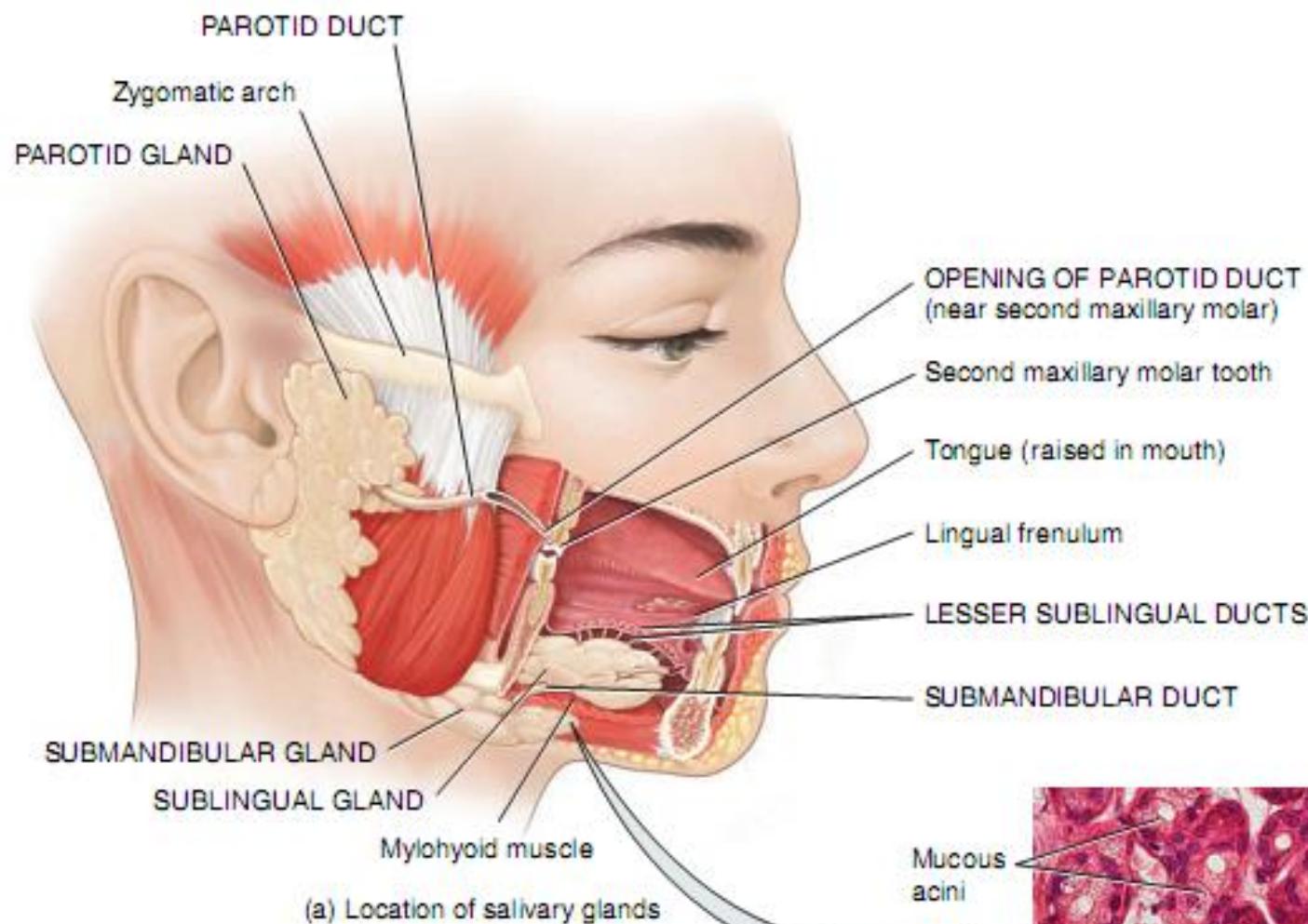
- Mastication (chewing) of food
- Mixing masticated food with saliva
- Initiation of swallowing by the tongue
- Allowing for the sense of taste

Ingesti-Mastikasi

- Proses memasukan makanan ke traktus digestivus
- Mastikasi : mengunyah makanan. Gigi incisivus memotong, molar menggiling makanan dan bercampur dengan saliva sebelum ditelan
- Penting utk : Mencerna semua jenis makanan terutama buah dan sayuran karena membran selulose harus dihancurkan sebelum dicerna.
- Saliva → agen pelumas
- Saliva → amilase utk cerna KH, dan lingual lipase utk cerna lemak
- Mencegah ekskoriasi traktus GI

Kelenjar Saliva

- Kkj. Parotis, submandibularis, sublingualis, bukalis
- Sekresi normal : 800- 1500 ml
- 2 tipe sekresi protein utama:
 - Serous → mengandung ptiallin (&amilase) → utk cerna serat
 - Mukus → musin , sbg pelumas & pelindung mukosa
- Kkj. Parotis → serous
- Submandibula + sublingualis → mukus & serous
- Bukalis → mukus



(b) Portion of submandibular gland

Saliva: Source and Composition

- Secreted from serous and mucous cells of salivary glands
- A 97-99.5% water, hypo-osmotic, slightly acidic solution containing
 - Electrolytes – Na^+ , K^+ , Cl^- , PO_4^{2-} , HCO_3^-
 - Digestive enzyme – Amilase
 - Proteins – mucin, lysozyme, defensins, and IgA
 - Metabolic wastes – urea and uric acid

Autonomic Influence on Salivary Secretion

- Pusat salivasi → saraf autonom → mengontrol derajat jumlah saliva
- Both sympathetic and parasympathetic stimulation increase salivary secretion, but the quantity and characteristics differ.
- Parasympathetic stimulation → peran dominan dalam sekresi saliva → saliva yang watery dan kaya enzim
- Sympathetic stimulation → produksi saliva kental yang sedikit dan kaya mucus.
- Because sympathetic stimulation elicits a smaller volume of saliva, the mouth feels drier than usual when the sympathetic system is dominant, such as in stressful situations.

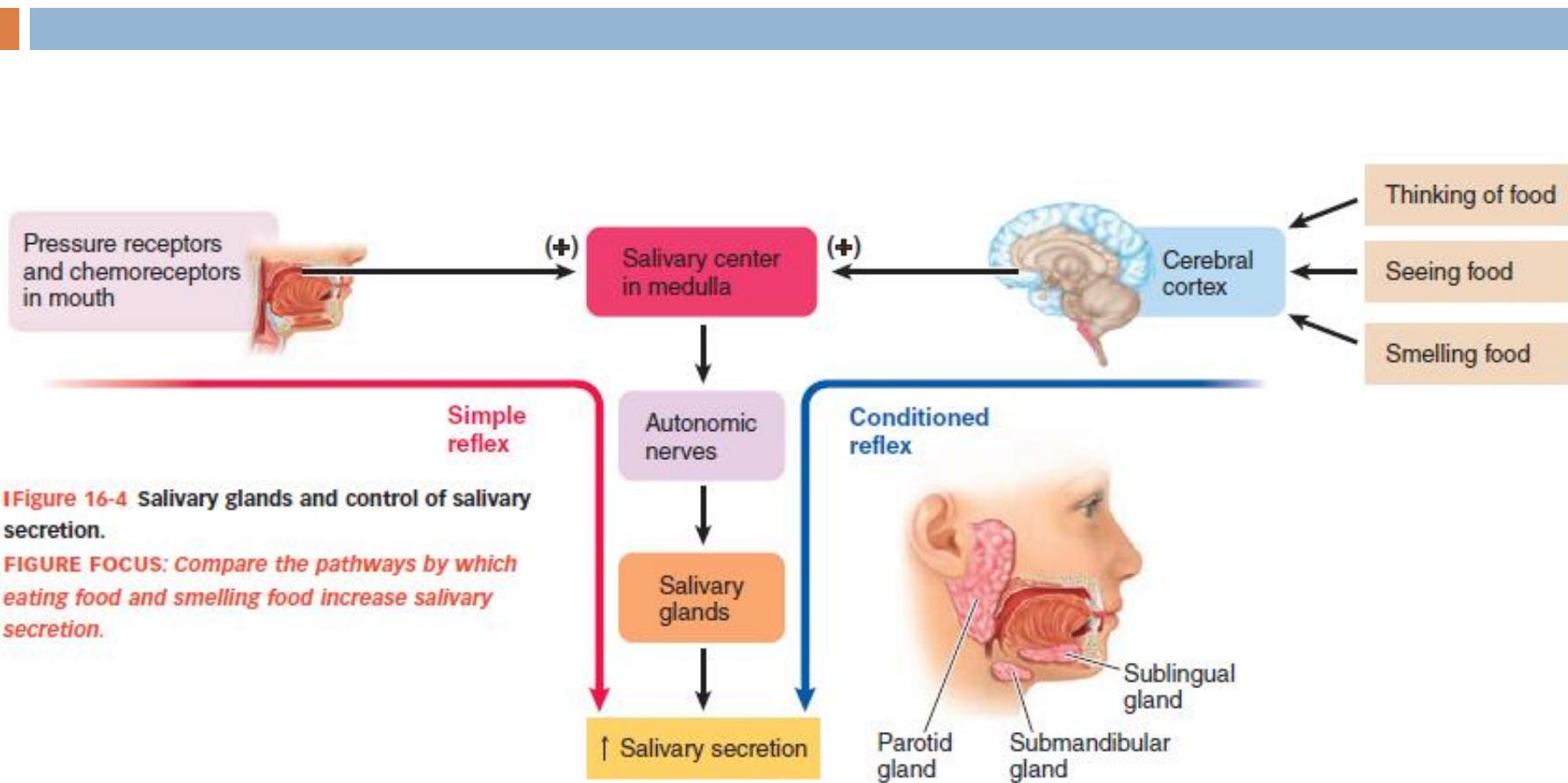


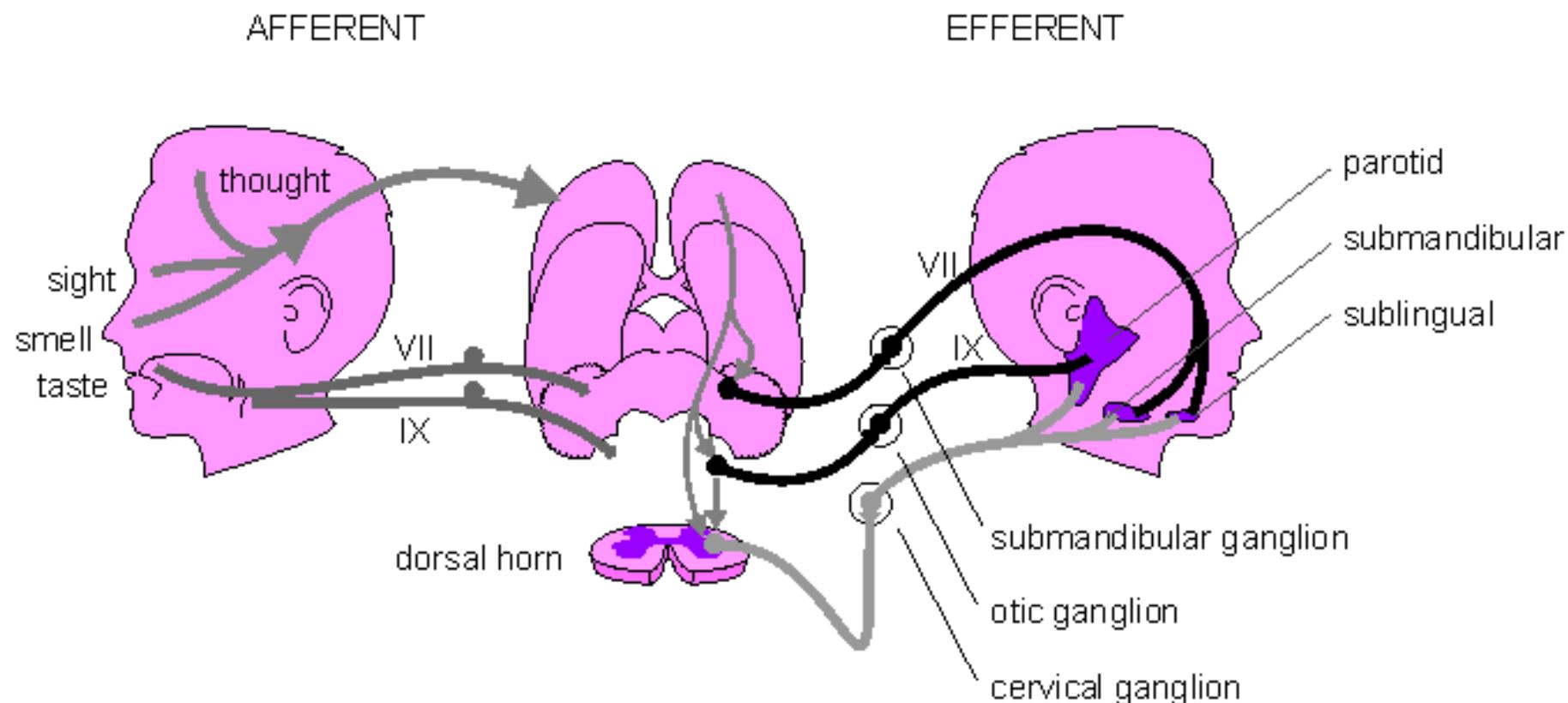
Figure 16-4 Salivary glands and control of salivary secretion.

FIGURE FOCUS: Compare the pathways by which eating food and smelling food increase salivary secretion.

Neural Control of Salivation

- The primary stimulus for salivation is **taste** – **afferent** input is carried to the **solitary nucleus in the medulla** via N. **VII** and N. **IX**. Input from other senses, such as **smell** and **sight** are also integrated in the solitary nucleus.
- Parasympathetic **efferent** pathways for the **sublingual** and **submandibular** glands are from N. **VII** via the **submandibular ganglion** and for the parotid gland from the **N.IX** via the **otic ganglion**. These pathways regulate fluid secretion by releasing **ACh** at the surface of the salivary gland **acinar cells**.

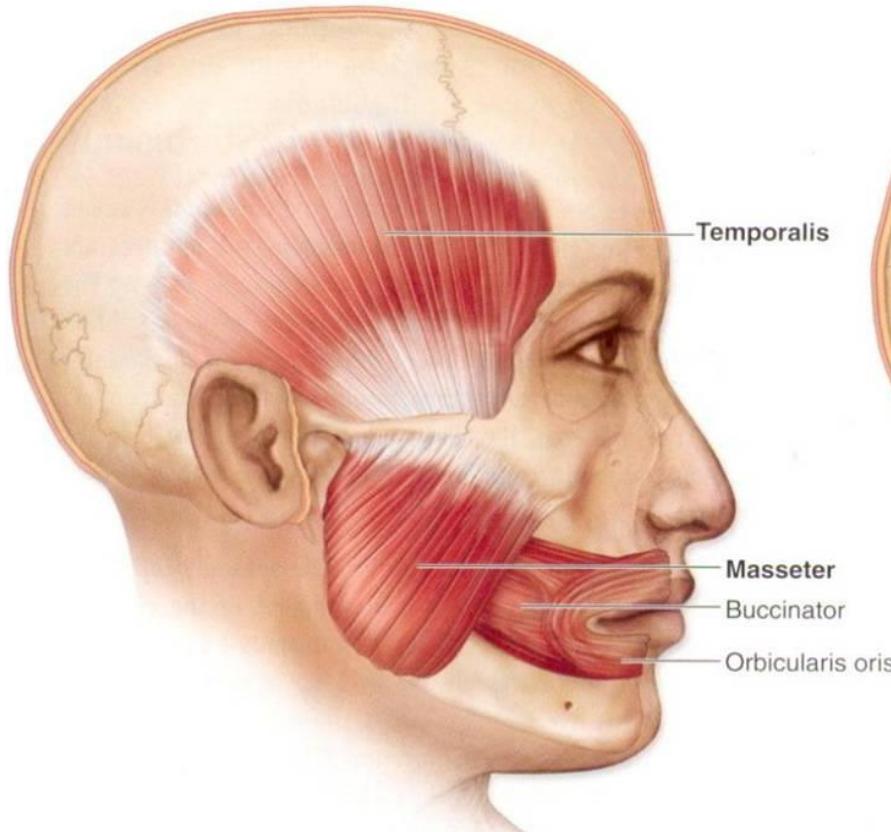
Neural Control of Salivation



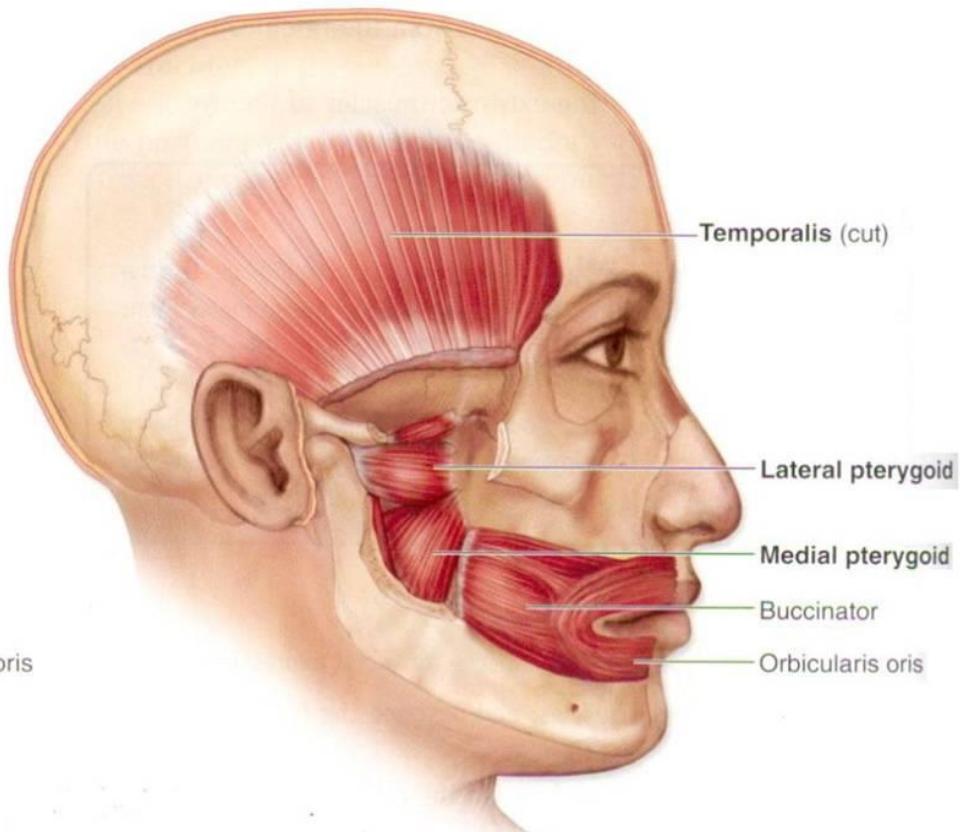
Black line → parasympathetic nerve
Grey line → sympathetic nerve

Otot mastikasi

otot	origo	insertio	persarafan	fungsi
m. temporalis	Dasar fossa temporalis dan permukaan dalam fascia temporalis	Ujung dan permukaan medial proc. Coronoideus dan tepi anterior ramus mandibulae	Nn. temporales profundi n. mandibularis (V3)	Mengangkat mandibulae, mengatupkan kedua rahang, serabut post. Menarik mandibula ke belakang setelah protrusi
m. masseter	Tepi bawah and permukaan medial arcus zygomaticus	Permukaan lateral ramus mandibulae dan proc. Coronoideus	n. mandibularis lewat nervus massetericus yang memasuki permukaan dalam m. masseter	Elevasi dan protrusi mandibula
m. pterygoideus lateralis	Cap. Superior : facies infratemporalis dan crista infratemporalis ala mayor os sphenoidalis Cap. Inferior : facies lateralis lamina lateralis proc. Pterygoideus	Collum mandibulae, discus articularis, capsula artic. Temporomandibularis	n. mandibularis lewat n. pterygoideus lateralis	Protrusi mandibula dan depresi dagu, gerak mandibula dari sisi ke sisi
m. pterygoideus medialis	Cap. Profundum : facies medialis lamina lateralis proc. Pterygoideus Cap. Superficiale : tuber maxilla	Permukaan medial ramus mandibulae di bawah for. mandibulae	N. mandibularis lewat n. pterygoideus medialis	Membantu elevasi mandibula untuk mengatupkan rahang, gerak menggiling, protrusi mandibula.



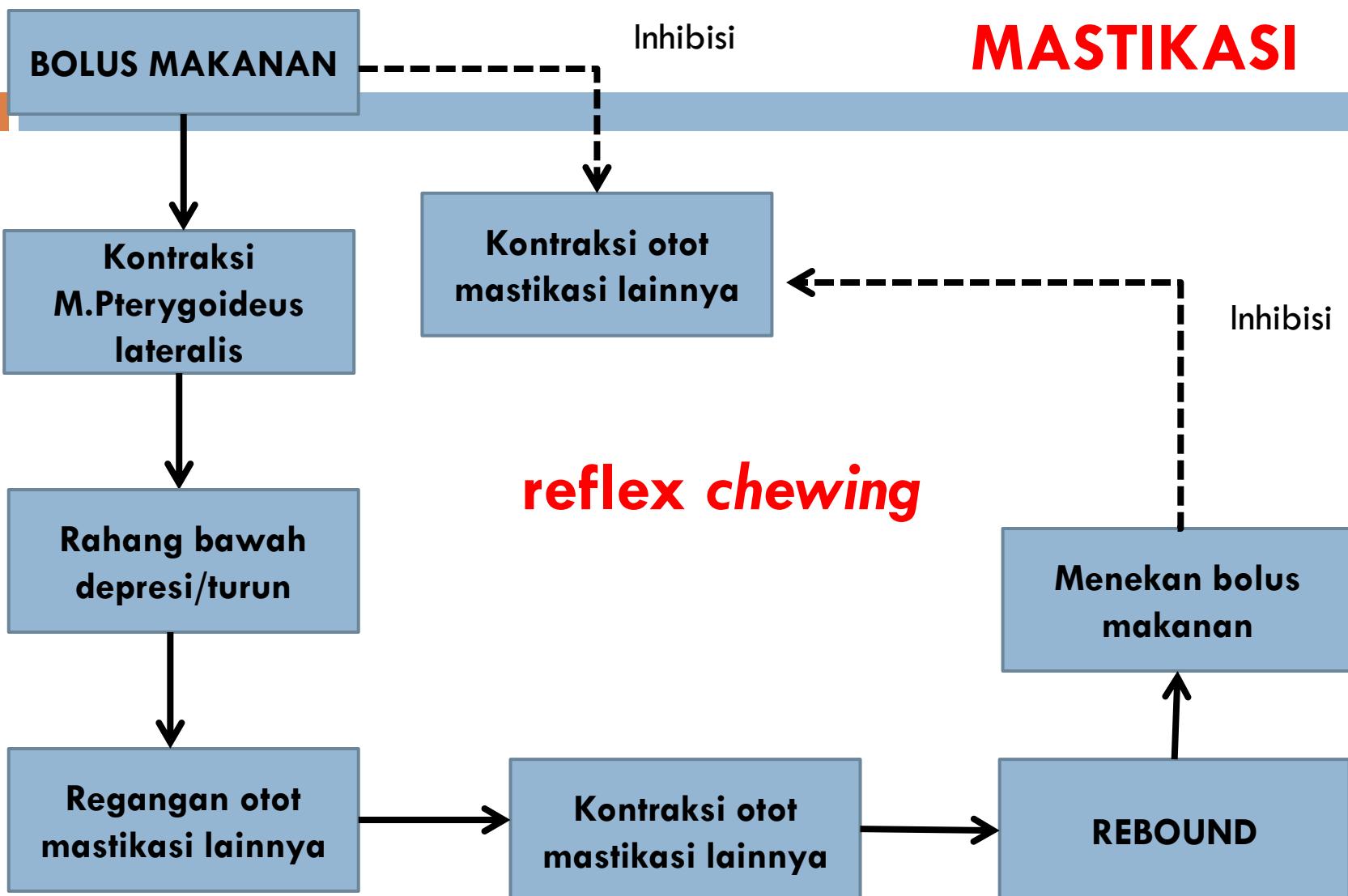
(a) Superficial lateral view



(b) Deep lateral view

- Proses pengunyahan terdiri dari beberapa tahap yaitu tahap membukanya mandibula, tahap menutupnya mandibula dan tahap berkontaknya gigi dengan makanan dan gigi antagonisnya
- Otot tambahan yaitu *m.mylohyoideus*, *m.digastrikus*, *m.geniohyoideus*, *m.stylohyoideus*, *m.infrahyoideus*, *m.bucsinator* dan *labium oris*.

MEKANISME MASTIKASI



- Gerakan mandibula selama proses pengunyahan dimulai dari gerakan membuka mandibula yang dilakukan oleh kontraksi **muskulus pterygoideus lateralis**. Pada saat bersamaan muskulus temporalis, muskulus masseter dan muskulus pterygoideus medialis tidak mengalami aktifitas atau mengalami relaksasi. Makanan akan masuk kerongga mulut dan disertai dengan proses menutupnya mandibula. Gerakan menutup mandibula disebabkan oleh kontraksi muskulus temporalis, muskulus masseter dan muskulus pterygoideus medialis, sedangkan muskulus pterygoideus lateralis mengalami relaksasi. Pada saat mandibula menutup perlahan, muskulus temporalis dan muskulus masseter juga berkontraksi membantu gigi geligi agar berkontak pada oklusi yang normal.
- Muskulus digastricus juga mengalami potensial aksi dan berkontraksi pada saat mandibula bergerak dari posisi istirahat ke posisi oklusi. Muskulus digastricus berperan dalam mempertahankan kontakgigi geligi.

Materi 2

Deglutasi / Swallowing / Penelan

Dibagi 3:

- fase volunter (disadari), mengawali proses penelan
- fase faringeal (involuntary), lewatnya makanan di faring
- fase esofageal (involuntary), membawa makanan dari faring ke lambung

Fase volunteer

- “secara sadar” makanan yang siap ditelan ditekan/digulung ke arah posterior menuju faring oleh lidah.

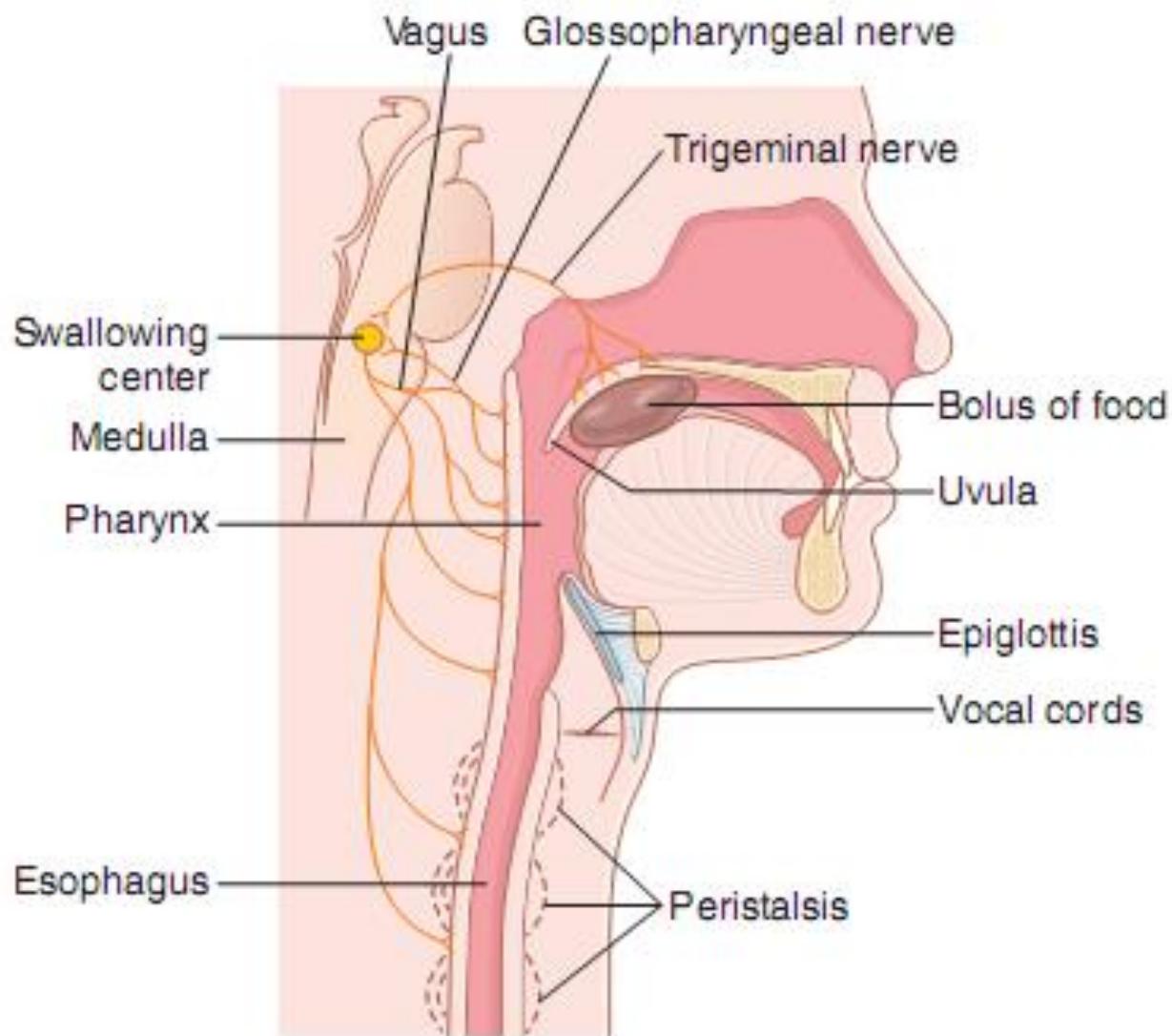


Figure 64-1. Swallowing mechanism.

Fase faringeal involunter

- Bolus merangsang daerah reseptor menelan diseluruh pintu faring, khususnya tiang-tiang tonsil dan impuls dari sini berjalan ke batang otak → cetuskan kontraksi otot faringeal
- Tahap mekanis faring secara singkat : trakea tertutup, esofagus terbuka, gelombang peristaltik cepat dari faring mendorong bolus ke esofagus
- Terjadi <2 detik.

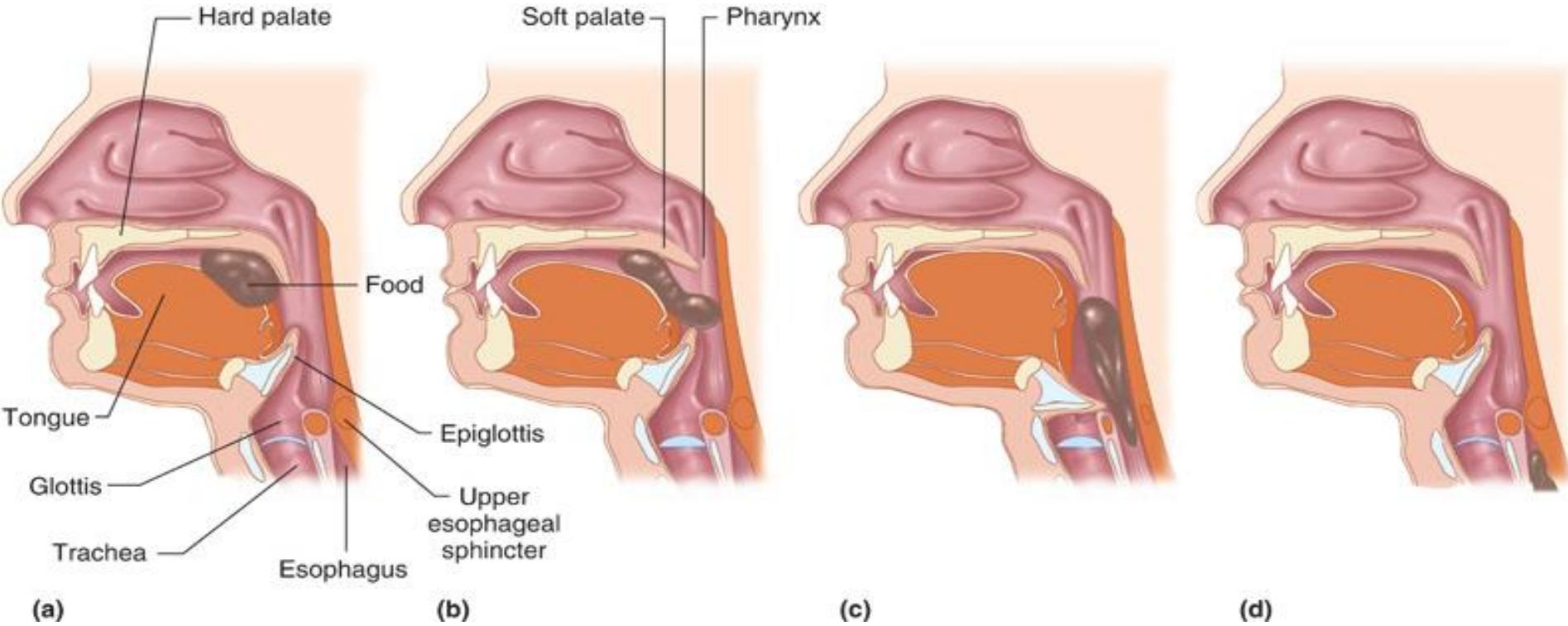
Pengaturan saraf

- Impuls sensoris (posterior mulut dan faring) → serabut saraf **sensoris N. V** dan **N. IX** → **medula oblongata** (berhubungan dg traktus solitarius)
- Pusat menelan/deglutisi mengatur proses penelanian secara keseluruhan berada di **medula oblongata dan pons bagian bawah**
- Impuls motorik → serabut **N. V, IX, X, XII** , beberapa serabut **servikal superior** → faring dan esogafus bagian atas

Fase esofageal

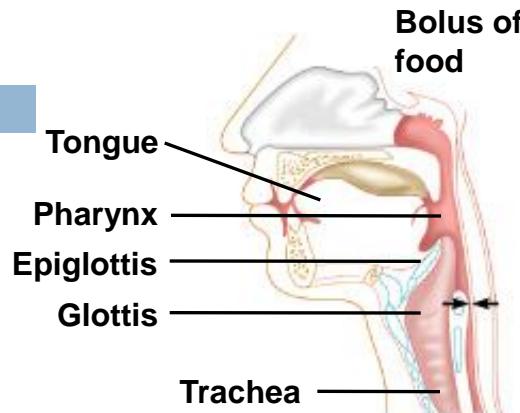
- Esofagus berfungsi menyalurkan makanan dari faring ke lambung
- 2 tipe gerakan peristaltik : primer dan sekunder
- Peristaltik primer : kelanjutan gelombang peristaltik dari faring
- Peristaltik sekunder : karena peregangan esofagus oleh makanan yang tertahan berlanjut sampai makanan dikosongkan ke lambung. Terjadi bila peristaltik primer gagal mengosongkan makanan di esofagus

- Otot faring dan 1/3 atas esofagus → otot lurik, gelombang peristaltik diatur oleh impuls saraf rangka **N. IX** dan **N.X**
- 2/3 bagian bawah esofagus → otot polos, persarafan oleh **N. X** yg bekerja melalui hubungannya dengan plexus mienterikus

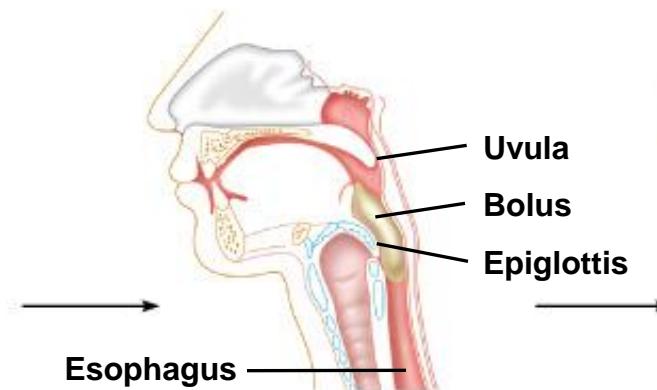


The swallowing reflex is coordinated by the medulla oblongata, which stimulates the appropriate sequence of contraction and relaxation in the participating skeletal muscle, sphincters, and smooth muscle groups.

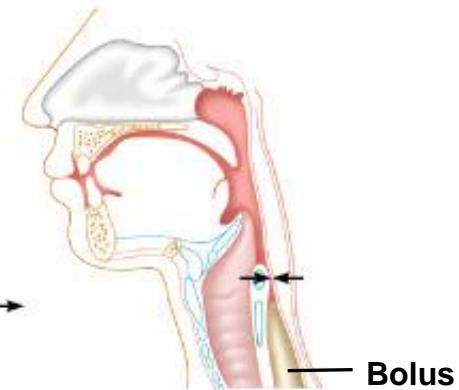
Deglutition (Swallowing)



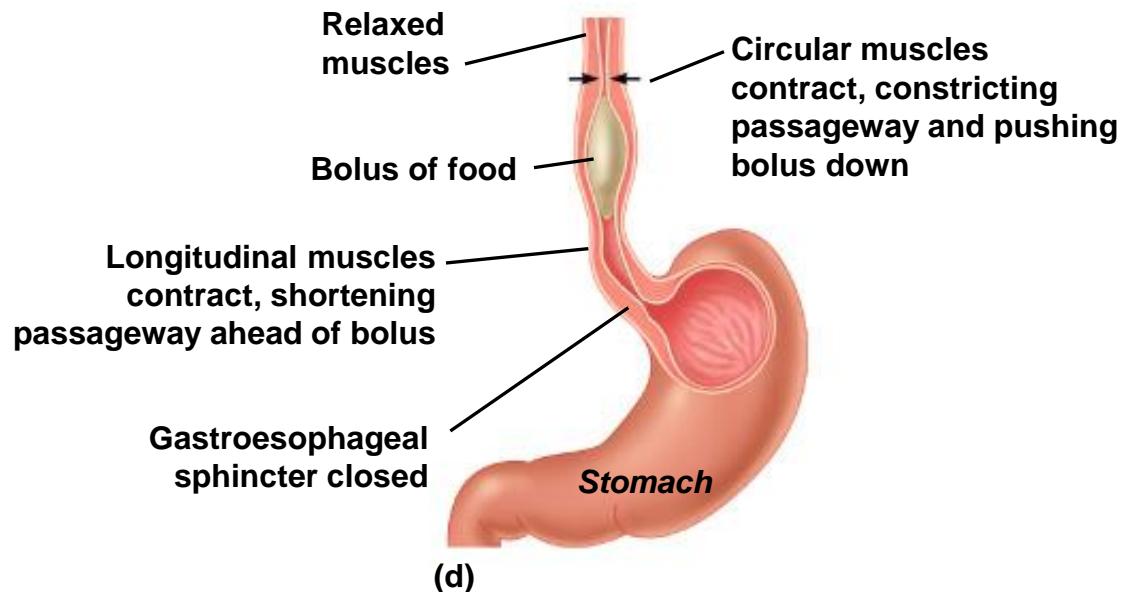
(a) Upper esophageal sphincter contracted



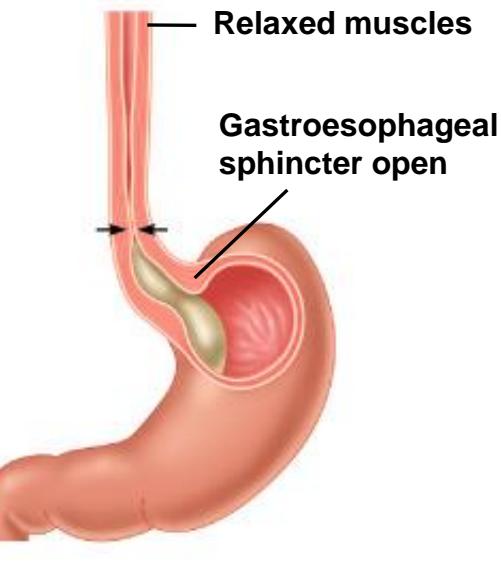
(b) Upper esophageal sphincter relaxed



(c) Upper esophageal sphincter contracted



(d)



(e)

Materi 3

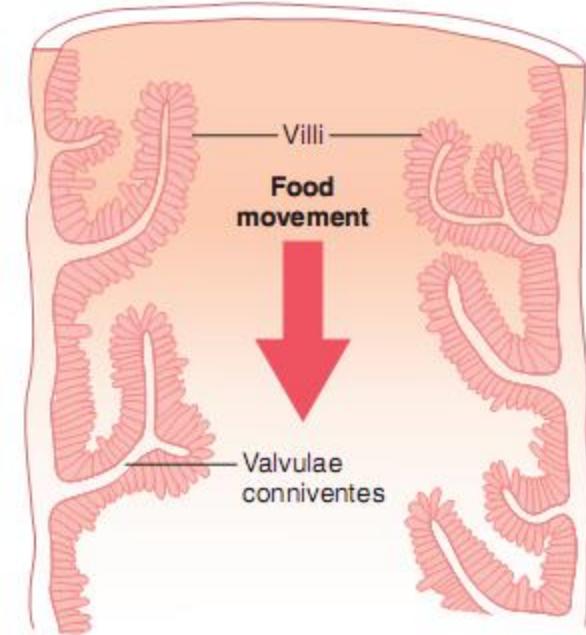
- **FAAL DIGESTI DAN ABSORBSI**
 - **Mulut → Amilase saliva**
 - **Lambung**
 - **Usus halus**
 - **Usus besar**
- **Karbohidrat**
- **Protein**
- **Lemak**
- **Air, vitamin, mineral**

Dasar anatomi Absorpsi

Valvula koniventes (Lipatan Kerckring)

Letak : seluruh permukaan usus halus

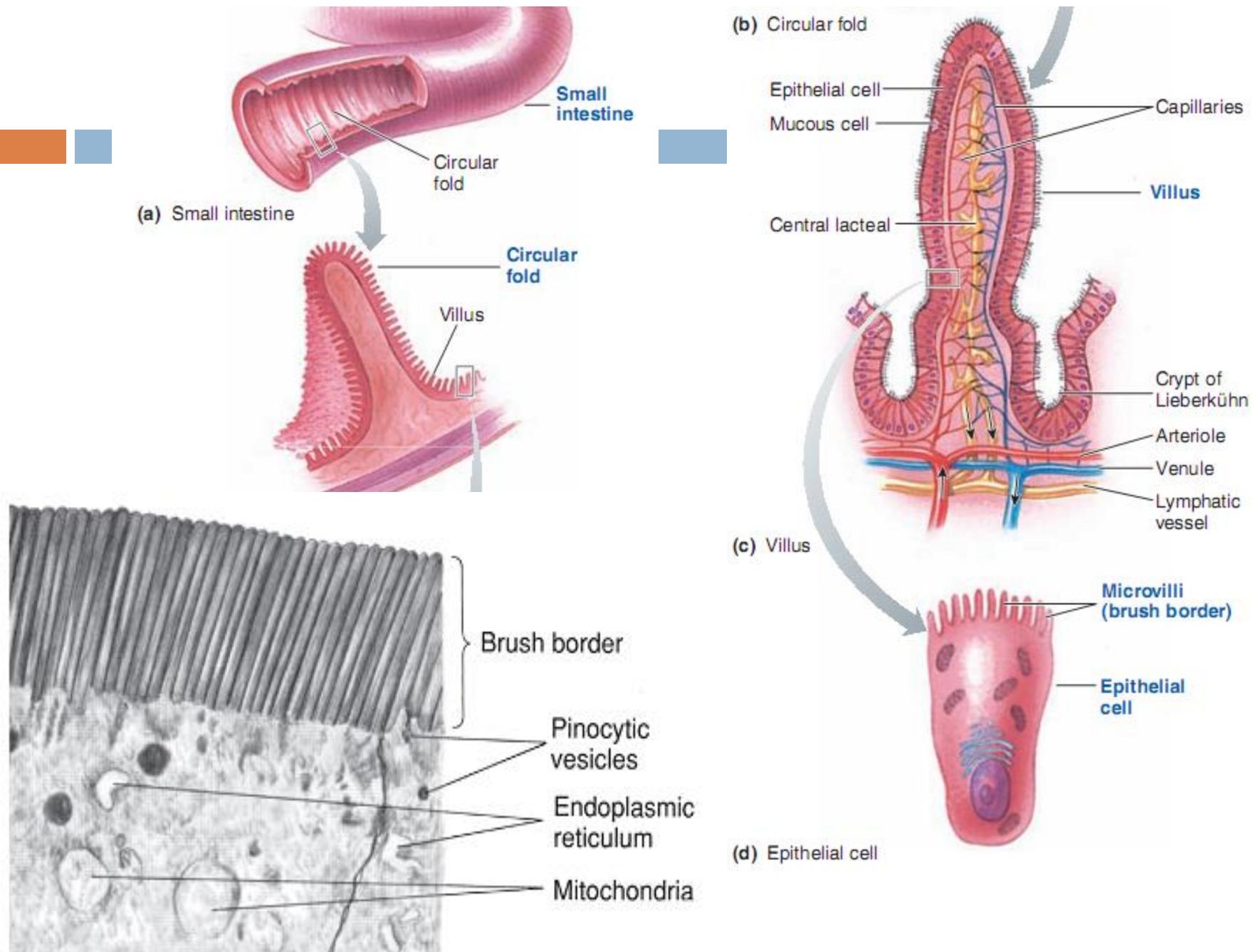
↑ Abs hingga 3X lipat



Valvula koniventes (Lipatan Kerckring) tertutup oleh vili yang rapat

↑ Abs hingga 10X lipat

1 sel epitel usus t.d
1000 mikrovili / brush border ($p 1 \mu\text{m}$, $\theta 0,1 \mu\text{m}$)
Mikrovili → ↑ Abs 20X lipat



Valvula koniventes + vili + mikrovili → ↑ Absorpsi
1000 X lipat



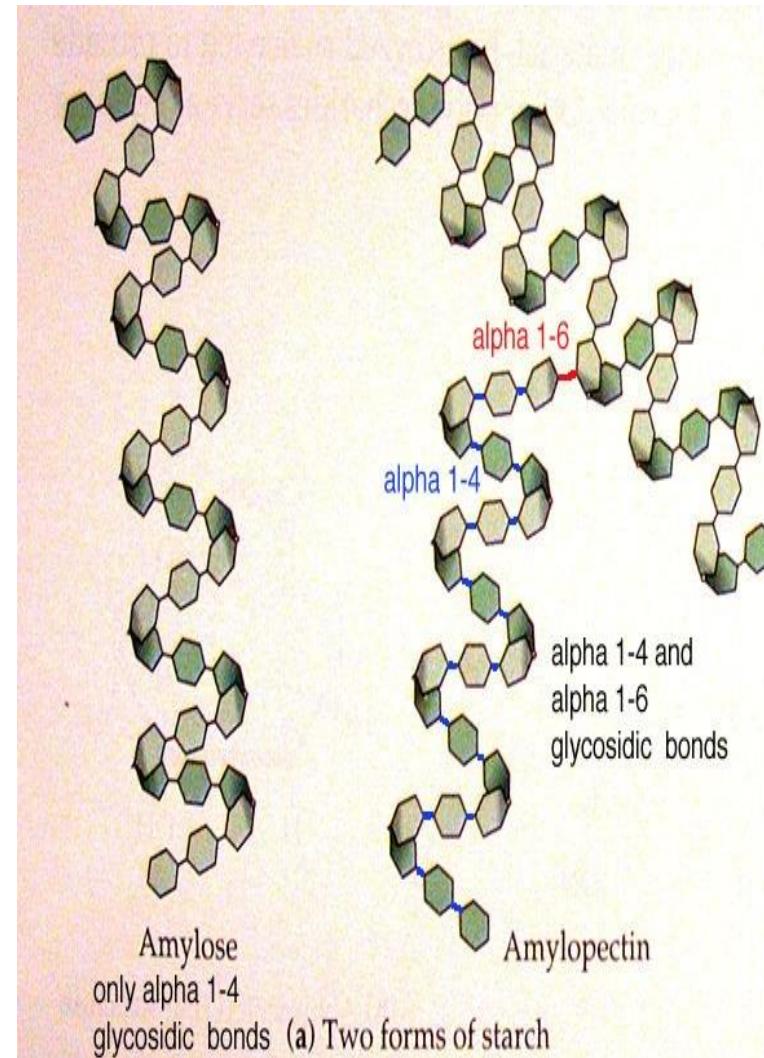
Luas Permukaan Total,
 250 m^2

Absorpsi Dalam Usus Halus

- Abs dalam usus halus → beberapa ratus KH, 100 g atau lebih lemak, 50-100 g asam amino, 50-100 g ion, 7-8 L air.
 - Abs. Air
 - Abs. Ion Na^+
 - Abs. Ion Cl^-
 - Abs. Ion Bikarbonat CO_3^{2-}
 - Abs. Ion lain

Digestive Processes in the Mouth

- Ingesti
- Mastikasi
- Amilase saliva → menghidrolisis ikatan α 1-4 glikosida
- Molekul KH/zat tepung masih dalam ukuran yang besar
- Protein, lemak, dll → tidak mengalami pencernaan di mulut

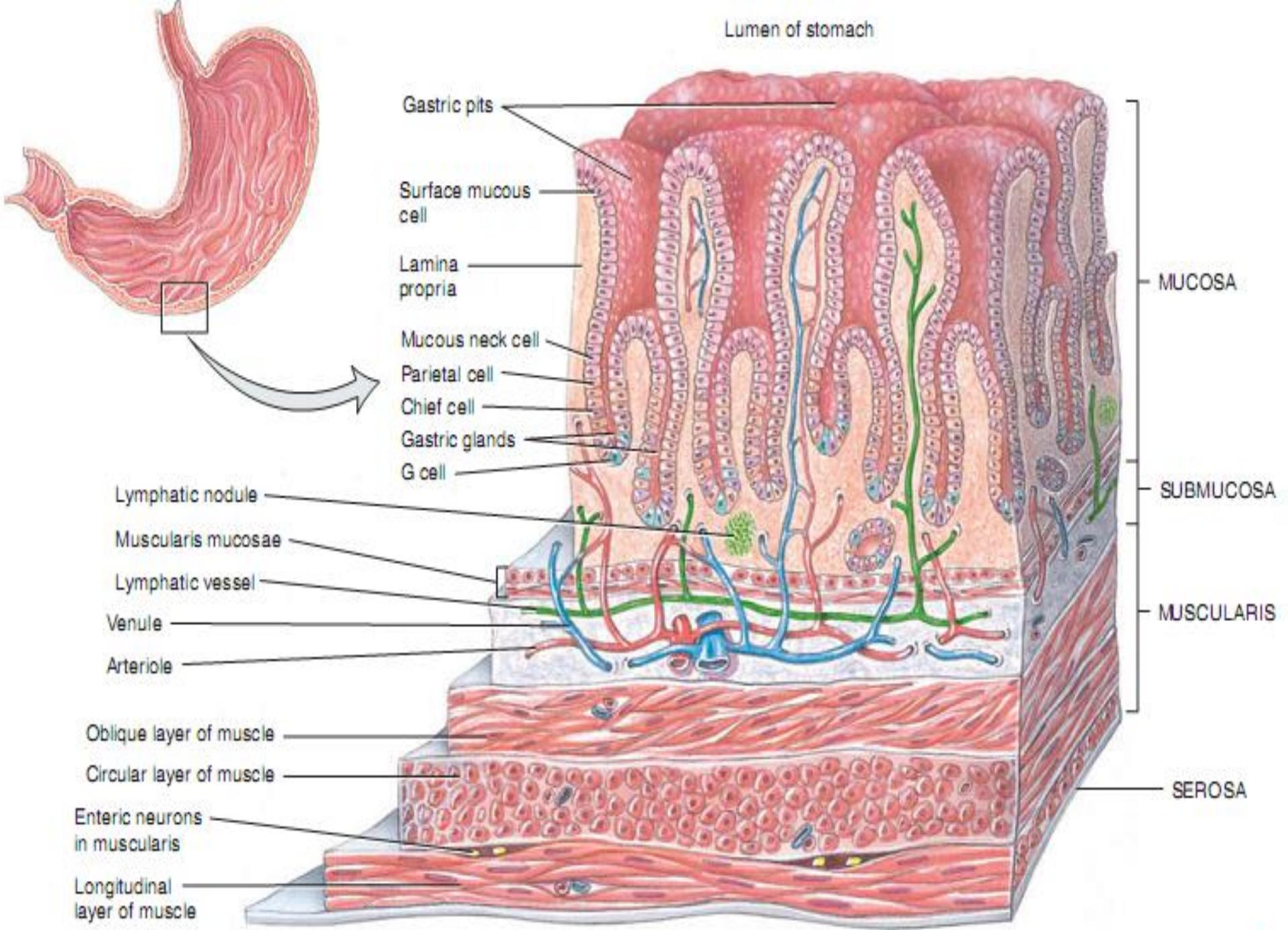


Digestion in the Stomach

- The stomach:
 - Holds ingested food
 - Degrades this food both physically and chemically
 - Delivers chyme to the small intestine
 - Digestion of Starch/carbohydrate and Protein
- Stomach Juice :
 - Pepsinogen
 - HCl
 - Mucus
 - Intrinsic factor → for absorption of vit.B12

Lambung

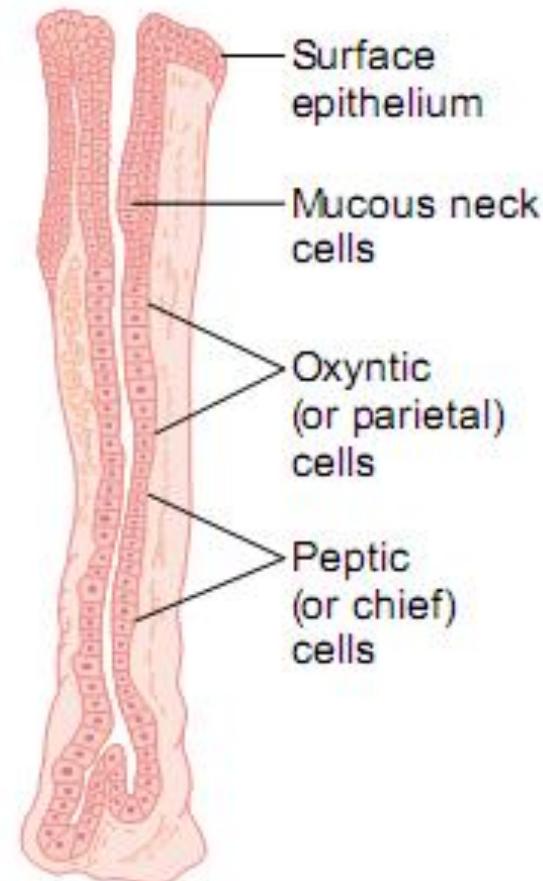
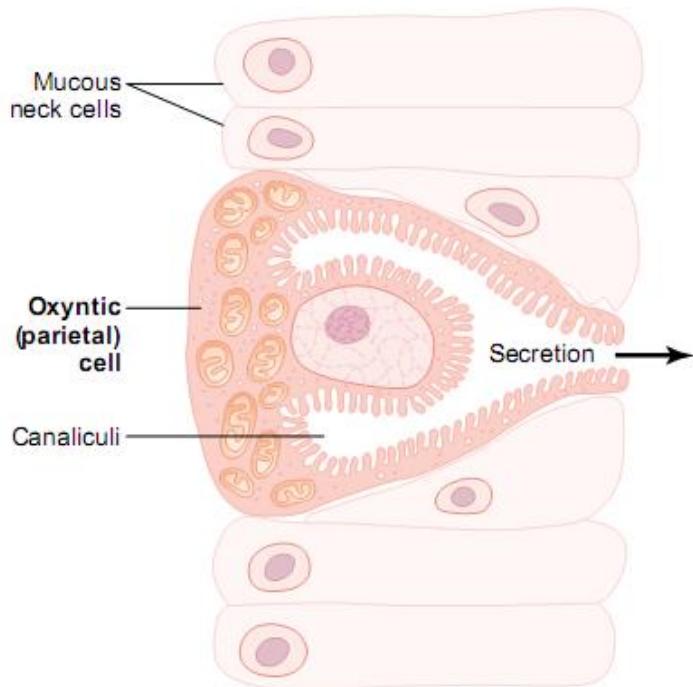
- Karakteristik sekresi lambung:
 - Mukosa lambung memiliki 2 tipe klj. Tubular
 - 1. kelenjar oxyntic (klj.gastrik) → terutama di corpus & fundus
Sekresi HCl, pepsinogen, fx.intrinsik, & mucus
 - 2. kelenjar pylorik → di antrum pilorikum
Sekresi mucus utk pelindung pilorus dari as.lambung, & sekresi gastrin

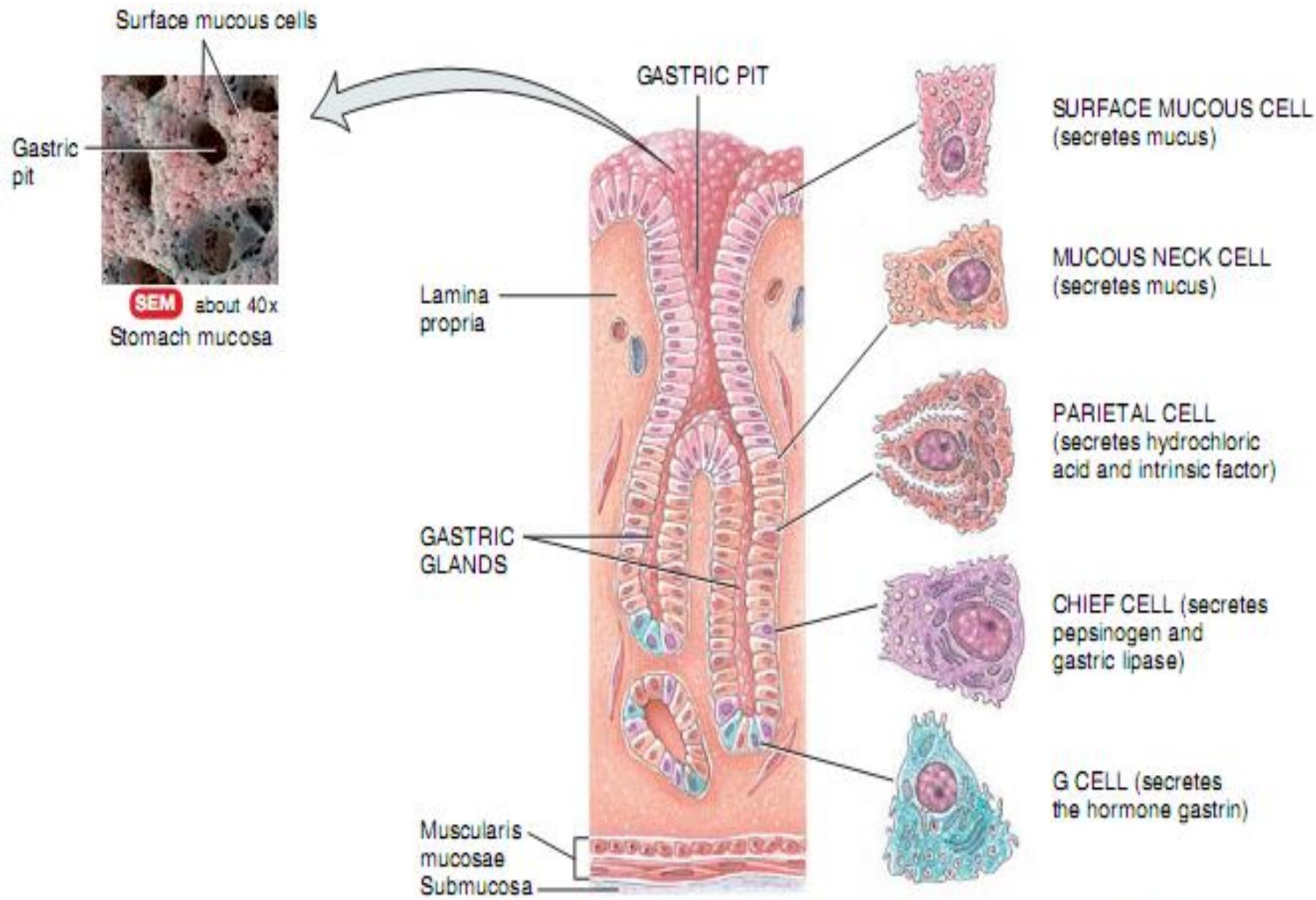


Sekresi dari Klj. Oxyntic

□ 3 tipe sel klj.oxyntic:

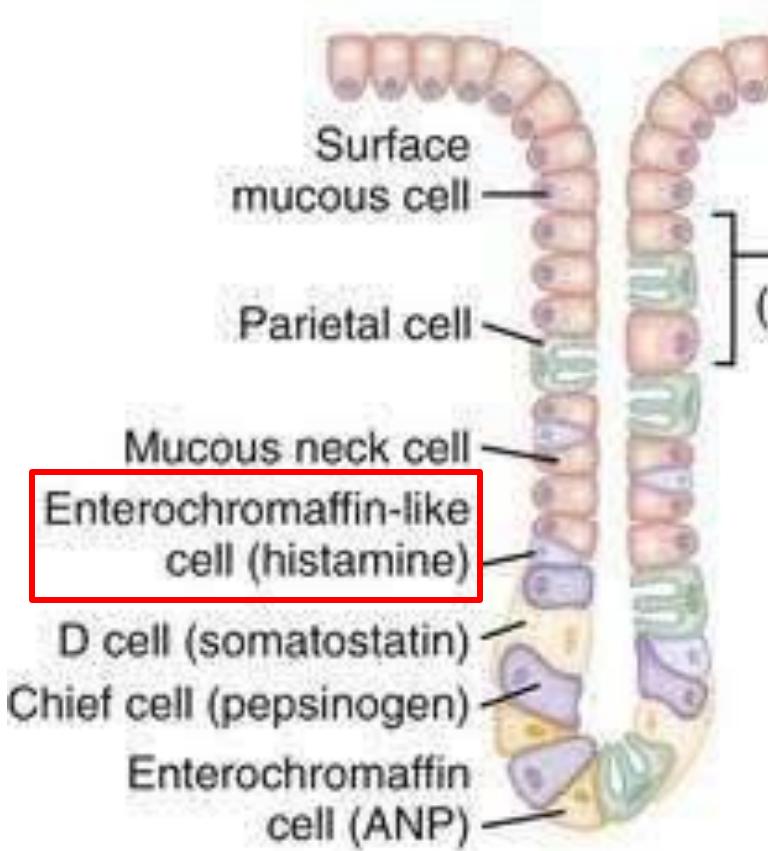
- Mucuos neck cell → mukus
- Peptic/chief cell → pepsinogen
- Parietal/oxyntic cell → HCl dan fx intrinsik



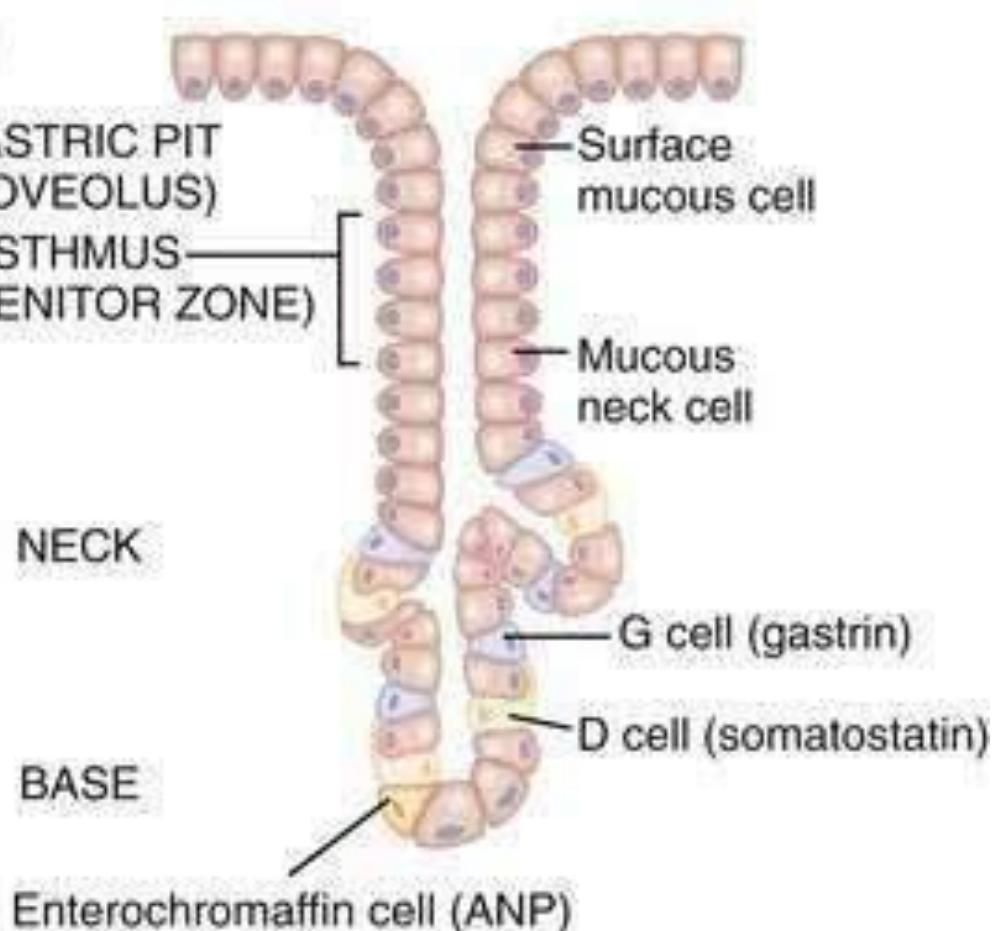


(b) Sectional view of the stomach mucosa showing gastric glands and cell types

OXYNTIC GLAND



PYLORIC GLAND



Digestion of Carbohydrate

- Enzim amilase saliva tidak akan aktif karena keasaman yg tinggi di lambung
- Tidak ada enzim lambung untuk menghidrolis ikatan glikosida KH
- HCl di lambung menyebabkan Sucrosa → fruktosa dan glukosa

Digestion of Protein

- Di lambung, protein dihidrolisis oleh enzim pepsin
→ polipeptida rantai panjang.



protein



Regulasi sekresi pepsinogen

- Di sekresi oleh sel peptic/chief cell dalam klj.oxynitic
- Distimulasi oleh 2 sinyal:
 - 1) Ach yg dikeluarkan N.vagus atau dari plexus enterik gaster.
 - 2) adanya asam yang berada di lambung
 - As.lambung ↓ → Pepsin ↓
- Pepsinogen → prekursor dari enzim pepsin
Pepsinogen → peptide a+ intermediate protein A
Intermediate protein A → peptide b+intermediate protein B
Intermediate protein B → peptide n + **pepsin**

Stimulasi sekresi asam gaster/lambung

- Sel parietal di klj oxyntic (corpus gaster) adalah satu-satunya sel yang mensekresi HCl.
 - Sekresi HCl ini dikontrol oleh **sinyal endokrin dan saraf**.
 - Kinerja sel parietal sangat terkait dg **sel ECL** (enterochromafin-like cells) → fungsi utama: sekresi histamin
 - Sekresi dan formasi HCL oleh sel parietal secara langsung **bergantung jumlah histamin yang disekresi sel ECL**.
 - Sel ECL distimulasi melalui: 1) hormon **gastrin** (mukosa antrum gaster) yg keluar sbg respon thd makanan ber-protein. 2)**Ach** yg dikeluarkan oleh N.vagus yg mensarafi gaster dan mungkin substansi hormonal yg dikeluarkan oleh saraf enterik dinding lambung.

Stimulasi sekresi HCl oleh Gastrin

- Gastrin disekresi oleh sel-sel G (sel gastrin) yg berada di klj.pilorik (antrum pilorus)
- Sekresi gastrin distimulasi oleh adanya makanan yg mengandung protein. Makanan berprotein → gastrin → sel ECL (di corpus gaster) mensekresi histamin langsung kedalam klj.oxyntic → sekresi HCl

Sekresi faktor Intrinsik

- Substansi faktor intrinsik penting untuk absorpsi vit B.12 di ileum
- Disekresi oleh sel parietal bersamaan dengan HCl

Digestion in the Small Intestine

- Duodenum (most nutrients were absorb here)
- Jejunum
- Ileum
- Virtually all nutrient absorption takes place in the small intestine
- Pancreatic juice is needed
- Digestion of Carbohydrate and protein continue
- Secretion of Bile salt → for lipid digestion

PANKREAS

- Sekresi Pankreas

- Enzim digestif pankreas disekresi oleh asinus pankreas
- Na.Bic.nat disekresi dari **ductus** asinus
- Produk enzim dan Na.Bic.nat → duct.pankreatikus → papila vater yg dikelilingi sphincter oddi.
- Sekresi pankreas dikeluarkan sbg respon thd kimus.
Sekresinya bergantung isi kimus

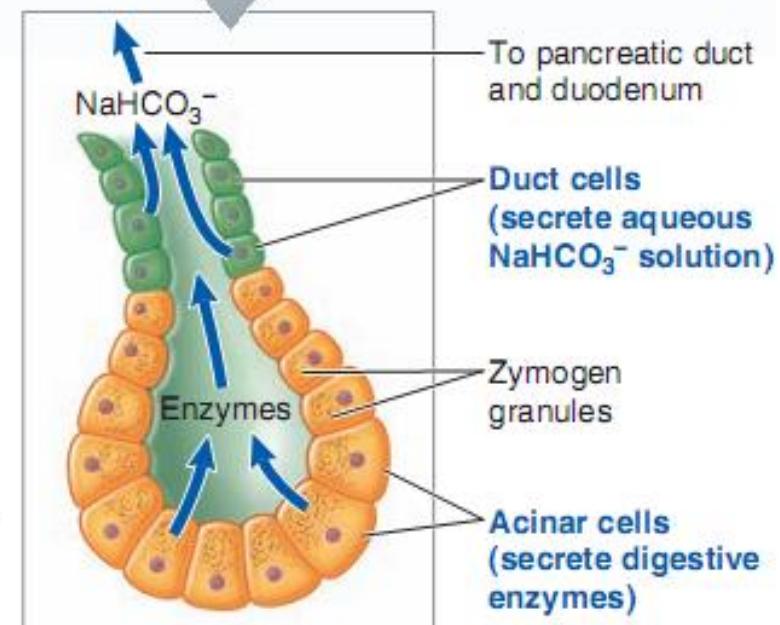
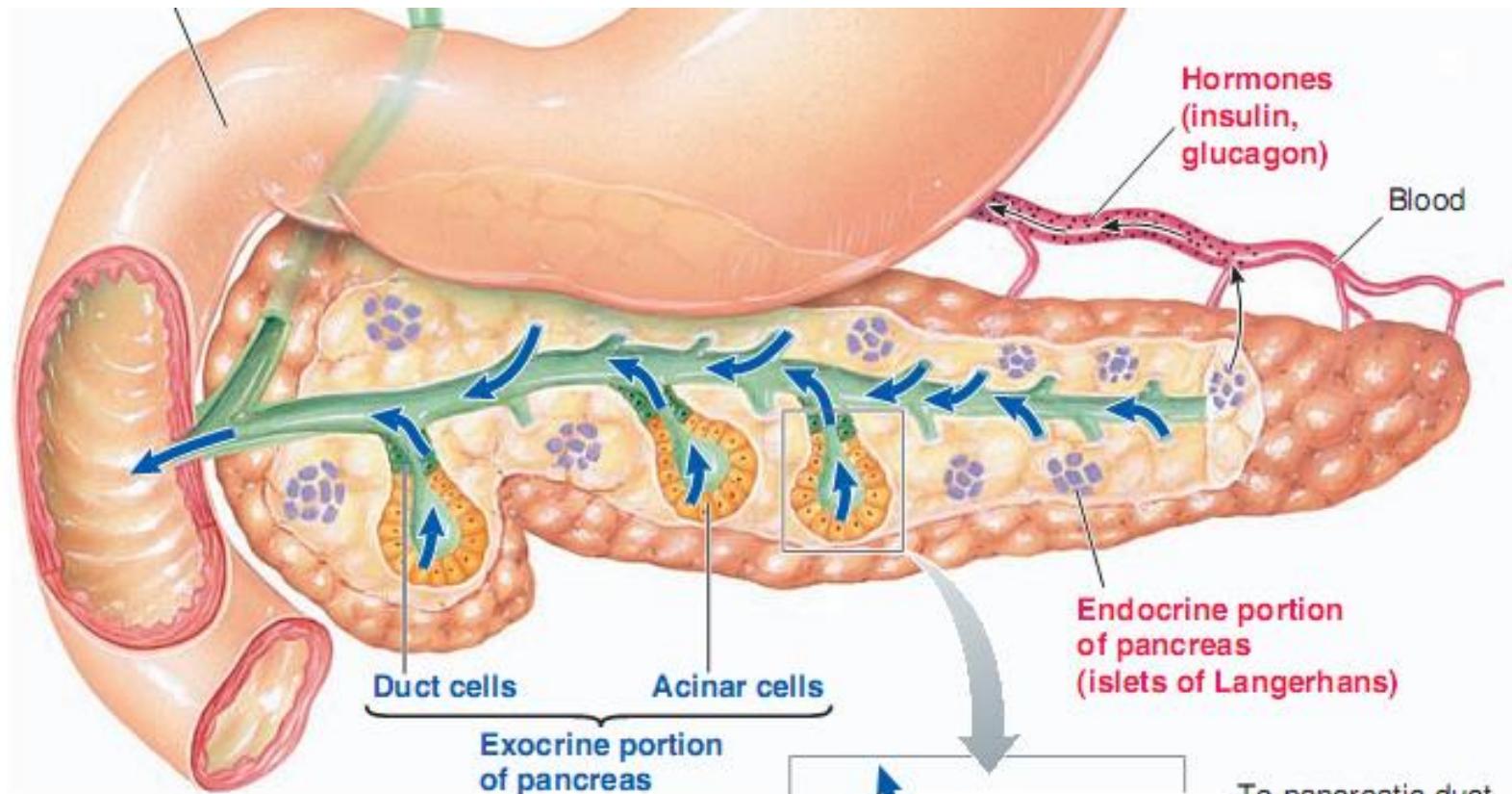


Figure 16-10 Exocrine and endocrine portions of the pancreas. The exocrine pancreas secretes into the duodenal lumen a digestive juice composed of digestive enzymes secreted by the acinar cells and an aqueous NaHCO_3^- solution secreted by the duct cells. The endocrine pancreas secretes the hormones insulin and glucagon into the blood.

Enzim digesti pankreas

Sekresinya mengandung multiple enzim untuk mencerna KH, protein, lemak dan sekresi Na.bic.nat

Enzim pankreas utk digesti protein :

- **Tripsin & chimotripsin** : protein → peptida
- **Carboxipolipeptidase** : peptida → a.amino

Enzim pankreas utk digesti KH :

- **Amilase pankreas** : hidrolisis ikatan α 1-4 glikosida → disakarida & trisakarida

Enzim pankreas utk digesti lemak:

- **Lipase pankreas** : lemak → as.lemak & monogliserida
- **Kolesterol esterase** : hidrolisis ester kolesterol
- **Fosfolipase** : fosfolipid → as. lemak

Sekresi pankreas dalam bentuk zymogen (tdk aktif) → tripsinogen, chimitripsinogen, procarboxyolipeptidase

- Akan aktif saat tersekresi di usus
- Enterokinase (enzim Brush border) mengaktifkan zymogen pancreas

Mukosa usus saat
bersentuhan dg kimis

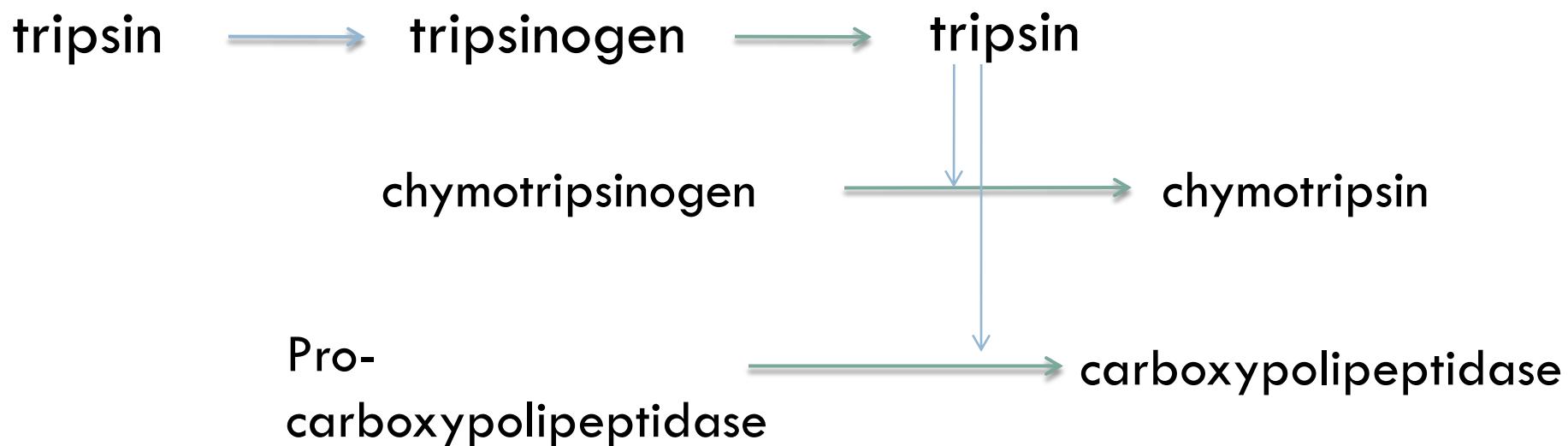


Enterokinase

Tripsinogen

Tripsin

- Tripsinogen juga diaktifkan scr autokatalitik



Sekresi inhibitor tripsin

- **Sel asinus pankreas** juga mensekresi substansi inhibitor tripsin secara bersamaan dg enzim2 proteolitik pankreas
- **Inhibitor tripsin** berfungsi **mencegah aktivasi** tripsin di dalam sel sekretorik, ductus, maupun asinus pankreas sehingga enzim2 proteolitik tidak akan mencerna pankreas

Mekanisme sekresi Na.Bic.Nat

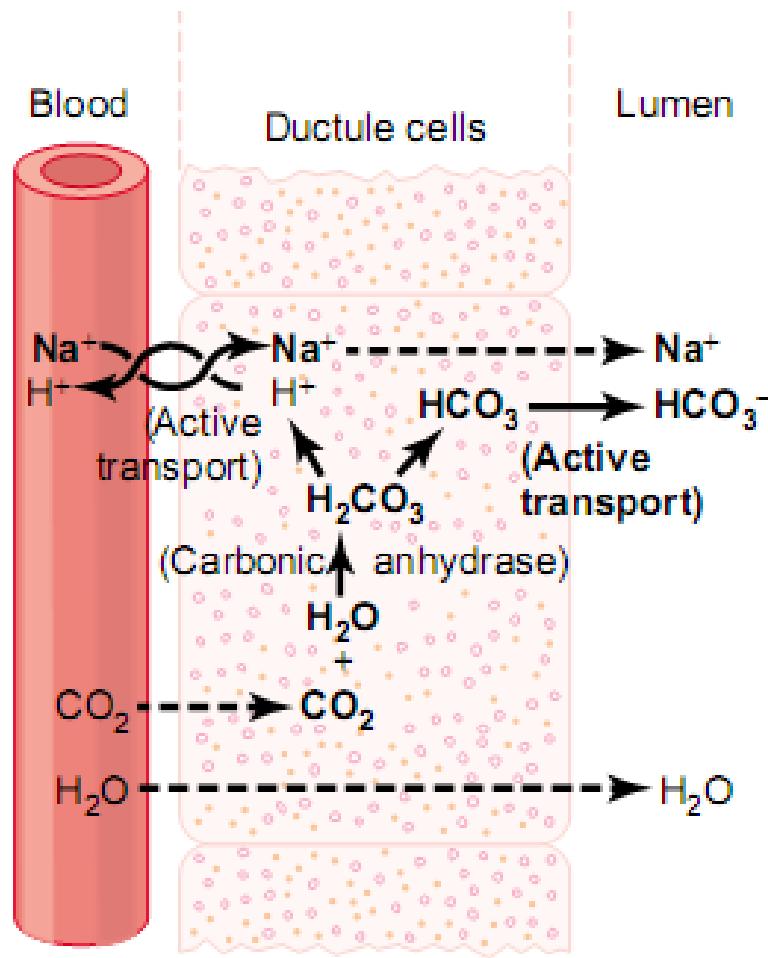


Figure 64-8

Secretion of isosmotic sodium bicarbonate solution by the pancreatic ductules and ducts.

Regulasi sekresi pankreas

3 stimuli dasar → sekresi pankreas:

1. **Ach** dari n.vagus parasimpatis dan saraf kolinergik sistem saraf enterik
2. **CCK** dari mukosa duodenum dan jejunum atas saat makanan lewat usus halus
3. **Secretin** dari mukosa duodenum dan jejunum atas saat makanan asam lewat usus halus

1-2 → stimulasi sel asinus pankreas utk sekresi enzim pencernaan dg H_2O dan elektrolit sedikit

3 → stimulasi sekresi air Na.Bic.Nat dalam jumlah banyak oleh epitel ductus

Air → mem-wash out enzim → alir ke duodenum

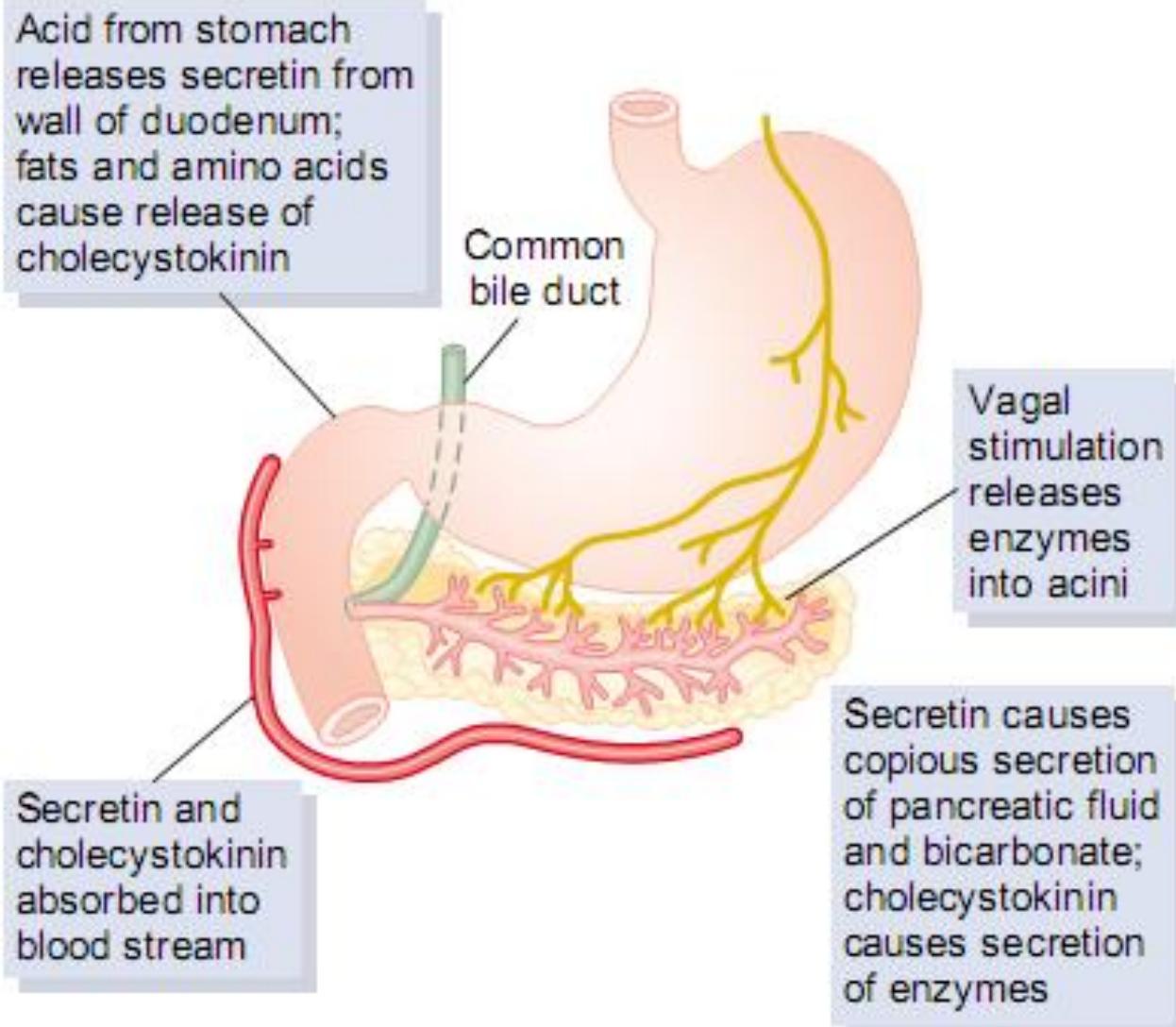
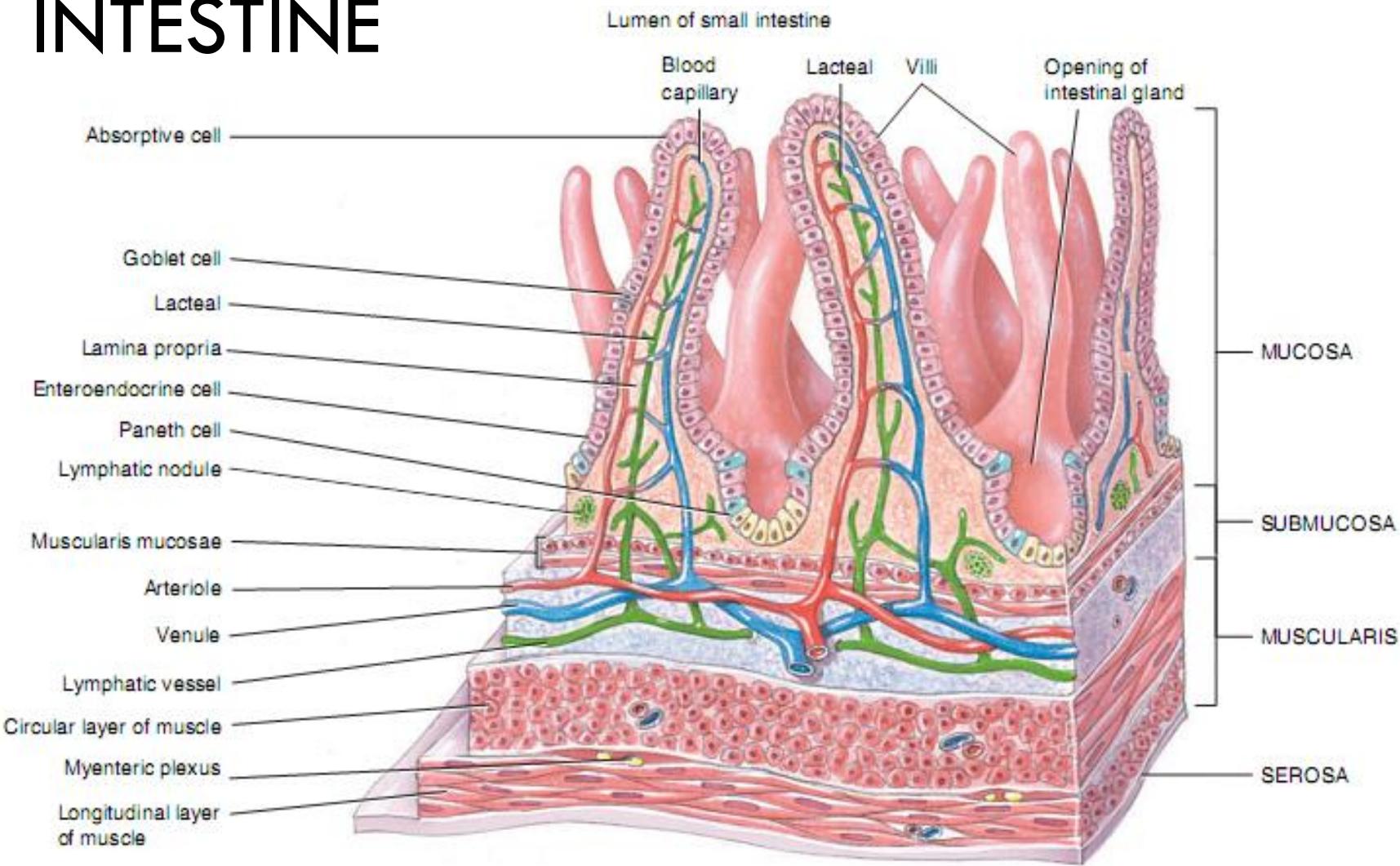


Figure 64–10

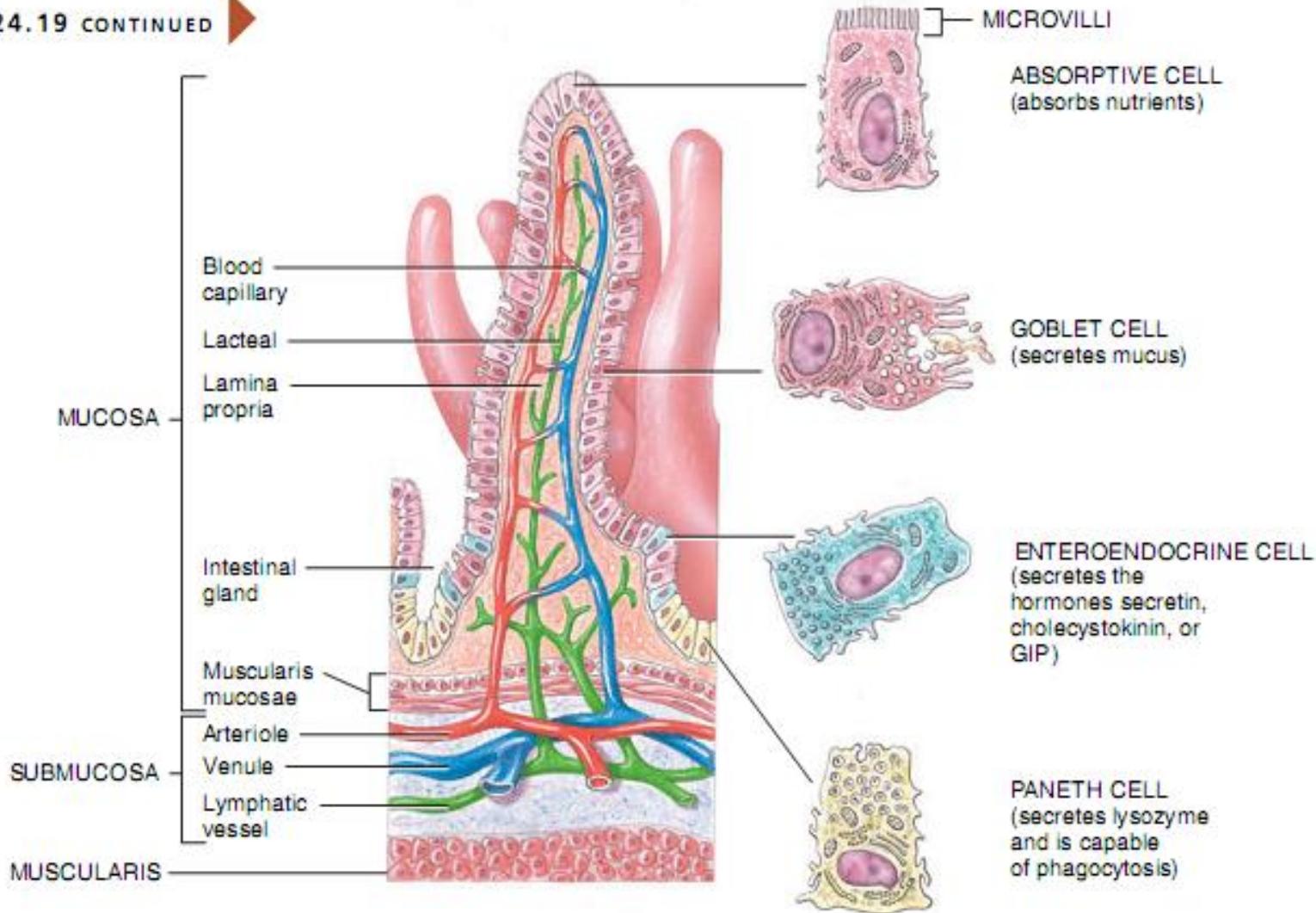
Regulation of pancreatic secretion.

INTESTINE



(b) Three-dimensional view of layers of the small intestine showing villi

24.19 CONTINUED



(c) Enlarged villus showing lacteal, capillaries, intestinal glands, and cell types

Sekretin menstimulasi sekresi ion

Bic.Nat

- Untuk menetralkan HCl lambung
- Disekresi oleh sel S di duodenum & jejunum → dalam bentuk **prosekretin** → kimis terutama asam yg banyak HCl (pH4,5-5.0) → ke duodenum → release & aktivasi **sekretin**
- Sekretin → sekresi ion HCO_3^- untuk netralkan asam (pH : $\text{NaCO}_3^- \pm 8$)

CCK

- Di keluarkan dari sel I di mukosa duodenum & jejunum atas
- In response to digestive products of fat, fatty acids, and monoglycerides in the intestinal contents.
- inhibits gastric motility and secretion,
- → rangsang sel asinus pankreas → sekresi enzim pencernaan (total sekresi ±70-80%)
- contracts the gallbladder & relaxation of sphincter Oddi, expelling bile → small intestine
- inhibits appetite to prevent overeating during meals by stimulating sensory afferent nerve fibers in the duodenum

Glucose-dependent insulinotropic peptide (also called gastric inhibitory peptide [GIP])

- is secreted by the *mucosa of the upper small intestine*
- mainly in response to fatty acids and amino acids but to a lesser extent in response to carbohydrate.
- mild effect in decreasing motor activity of the stomach → slows emptying of gastric contents to duodenum.
- also stimulates insulin secretion.

Motilin

- is secreted by the stomach and *upper duodenum* during fasting, and the only known function of this hormone is to *increase gastrointestinal motility*.
- Motilin is released cyclically and stimulates waves of gastrointestinal motility called *interdigestive myoelectric complexes* that move through the stomach and small intestine every 90 minutes in a person who has fasted.

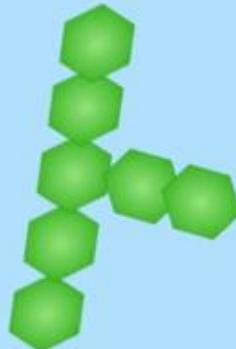
Digestion of Brush Border Enzyme

- Brush border enzyme → sintesis oleh sel absorptif usus halus, hasil digesti dari enzim akan dimasukan ke membran plasma mikrovili
- So, enzymatic digestion tjd di permukaan sel tersebut, tidak di lumen.
- Brush-border enzymes :
- 4 enzim pencerna KH (dextrinase, maltase, sucrase, and lactase)
- Enzim pencerna protein peptidases (aminopeptidase and dipeptidase)
- 2 enzim pencerna nucleotida: nucleosidases and phosphatases

Digestion of Polysaccharide

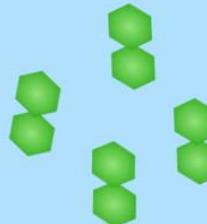
Short branched
polysaccharides

LIMIT
DEXTRINS



- Disaccharide
- Two glucose monomers

MALTOSE



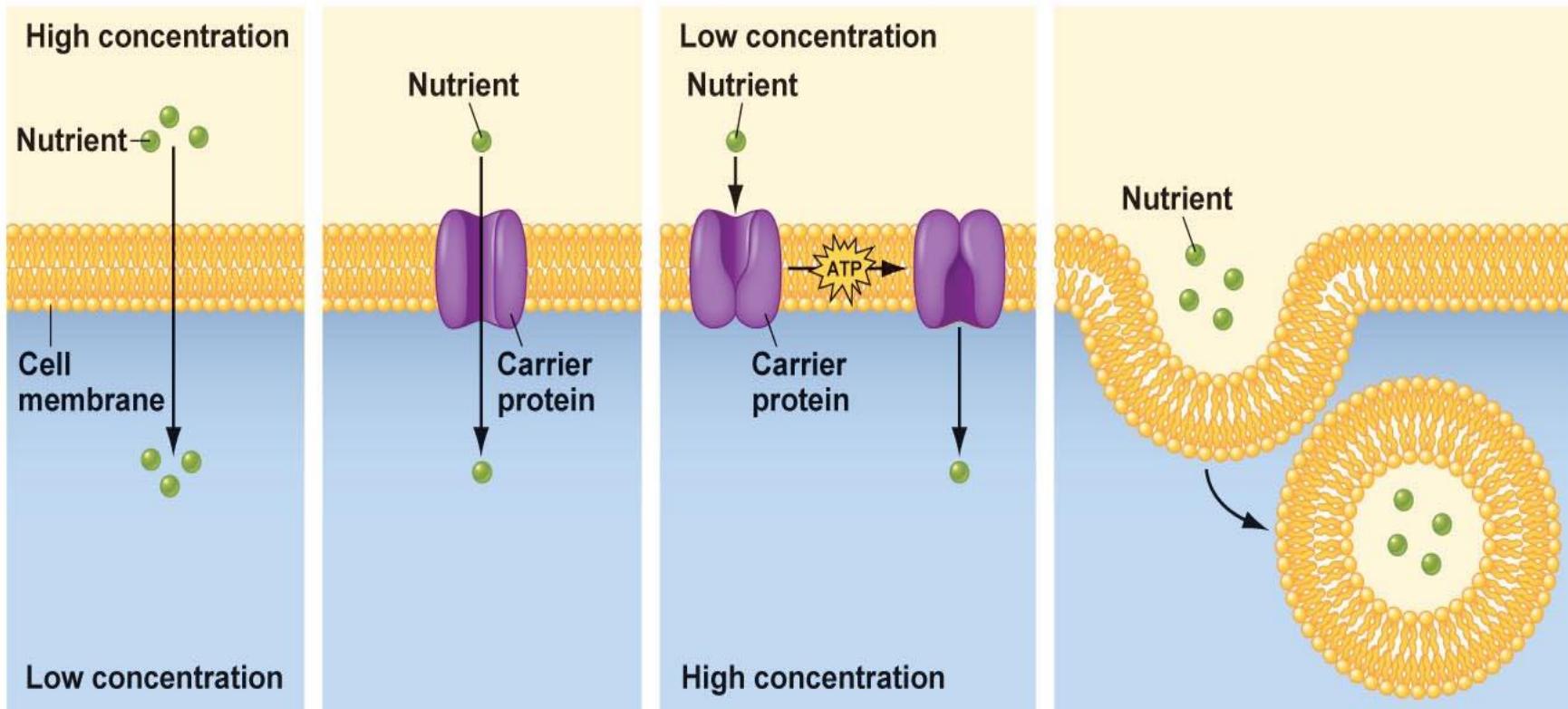
FURTHER DIGESTION

- Dextrinase: Limit Dextrins → Glucose
- Maltase: Maltose → 2 Glucose
- Sucrase: Sucrose → Fructose+Glucose
- Lactase: Lactose → Galactose+Glucose
- Glucoamylase: Polysaccharide → Glucose



- Majority of absorption takes place in the small intestine
 - Nutrients are absorbed via
 1. **Active transport** – nutrients move from low concentration to high concentration with the help of a carrier protein, energy is required
 2. **Sodium-glucose co-transport** – secondary active transport
 3. **Facilitated diffusion** – nutrients move from high concentration to low concentration with the help of a carrier protein; no energy is required
 4. **Endocytosis** – cell forms a vesicle to surround and engulf a nutrient
 5. **Passive diffusion** – nutrients move from high concentration to low concentration; no energy is required

Nutrient Absorption



a **Passive diffusion:** Nutrients pass through the cell membrane.

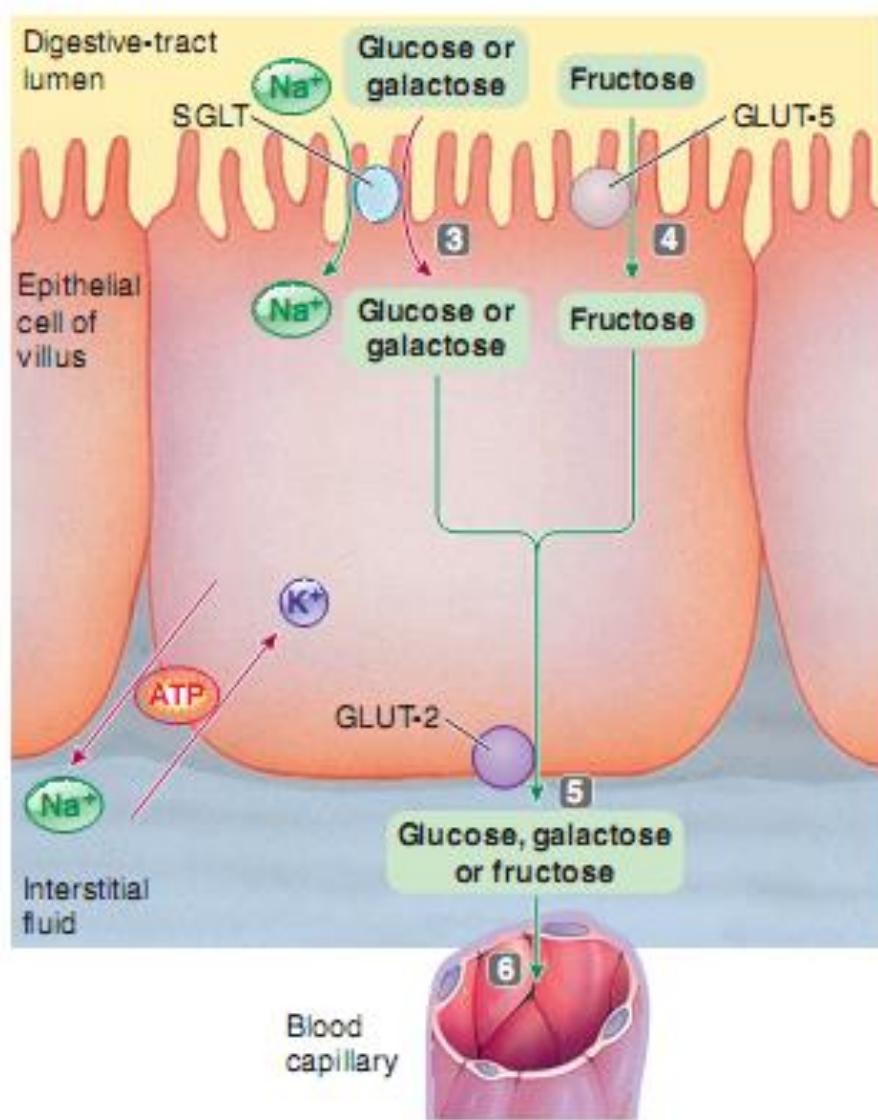
b **Facilitated diffusion:** Requires a specific carrier but no energy is needed to cross the membrane.

c **Active transport:** Requires both a carrier protein and energy to cross the cell membrane.

d **Endocytosis:** Whole molecules are engulfed by the cell membrane.

Absorption of Monosacaride in Small Intestine

- Glucose, galaktose are absorbed by sodium-glucose co-transport (SGLT/sod.glu linked transporter) in which 1 glucose enter the sell together with 2 Na^{2+}
- Fructose is absorb through facilitated diffusion



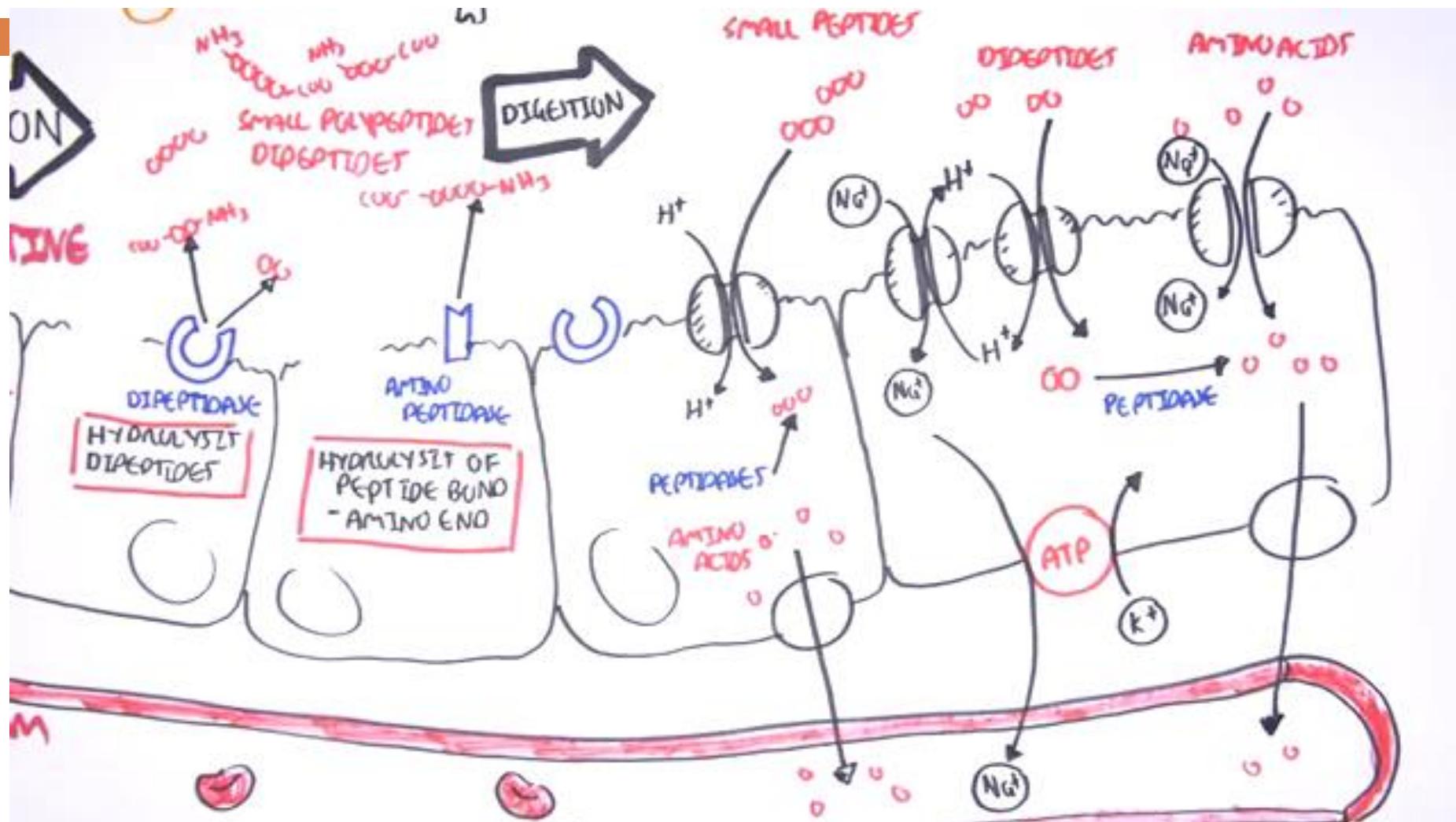
(b) Carbohydrate absorption

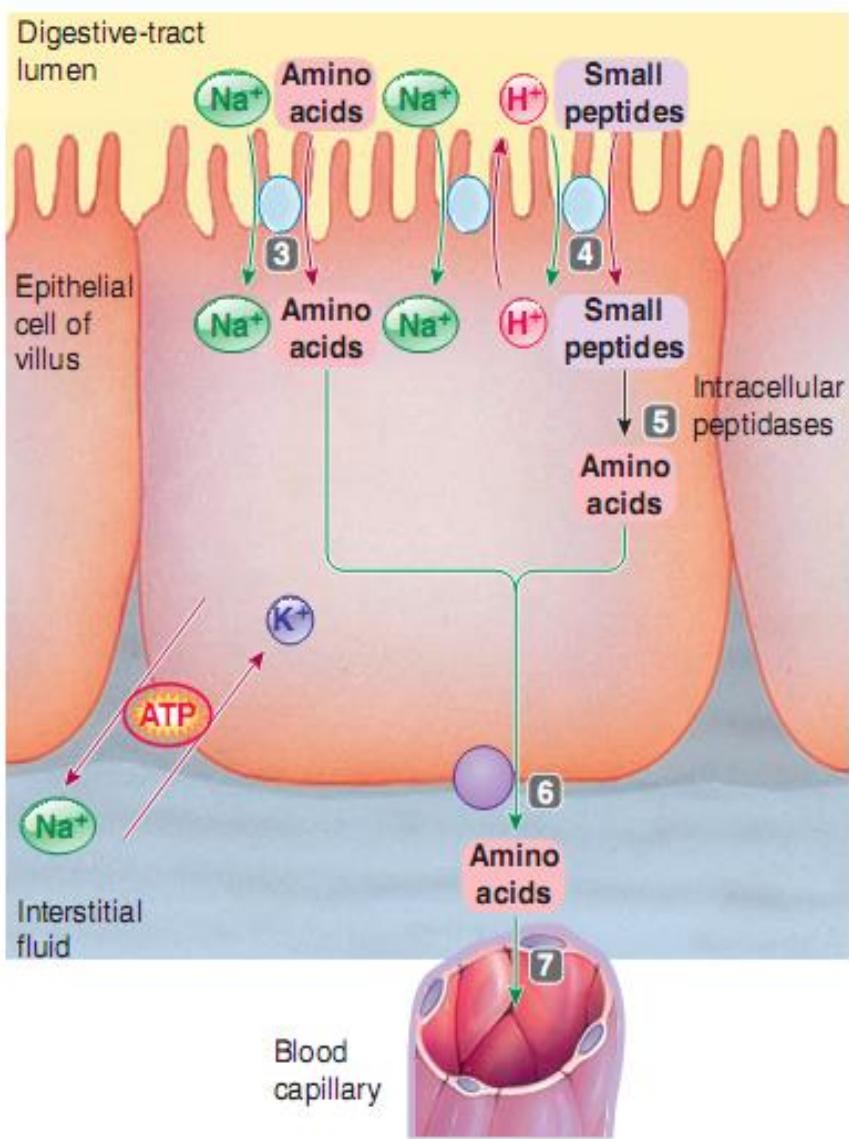
- 1 The dietary polysaccharides starch and glycogen are converted into the disaccharide maltose through the action of salivary and pancreatic amylase.
- 2 Maltose and the dietary disaccharides lactose and sucrose are converted to their respective monosaccharides by the disaccharidases (maltase, lactase, and sucrase-isomaltase) located in the brush borders of the small-intestine epithelial cells.
- 3 The monosaccharides glucose and galactose are absorbed into the epithelial cells by Na⁺- and energy-dependent secondary active transport (via the symporter SGLT) located at the luminal membrane.
- 4 The monosaccharide fructose enters the cell by passive facilitated diffusion via GLUT-5.
- 5 Glucose, galactose, and fructose exit the cell at the basal membrane by passive facilitated diffusion via GLUT-2.
- 6 These monosaccharides enter the blood by simple diffusion.

KEY

- = Active transport
- = Symport
- = Facilitated diffusion
- = Simple diffusion

Digestion and absorption of Protein

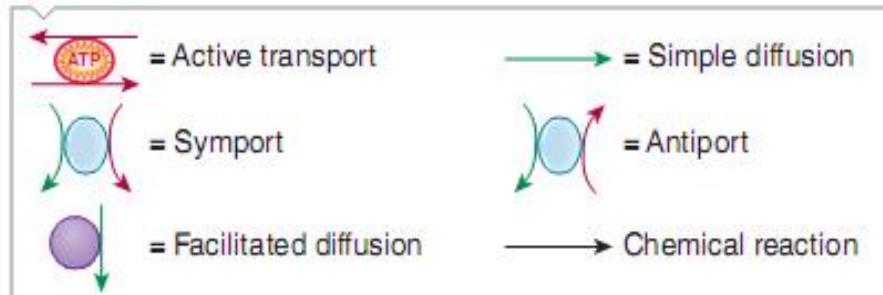




(b) Protein absorption

- Dietary and endogenous proteins are hydrolyzed into their constituent amino acids and a few small peptide fragments by gastric pepsin and the pancreatic proteolytic enzymes.
- Many small peptides are converted into their respective amino acids by the aminopeptidases located in the brush borders of the small-intestine epithelial cells.
- Amino acids are absorbed into the epithelial cells by means of Na^+ - and energy-dependent secondary active transport via a symporter. Various amino acids are transported by carriers specific for them.
- Some small peptides are absorbed by a different type of symporter driven by H^+ , Na^+ -, and energy-dependent tertiary active transport.
- Most absorbed small peptides are broken down into their amino acids by intracellular peptidases.
- Amino acids exit the cell at the basal membrane via various passive carriers.
- Amino acids enter the blood by simple diffusion. (A small percentage of di- and tripeptides also enter the blood intact.)

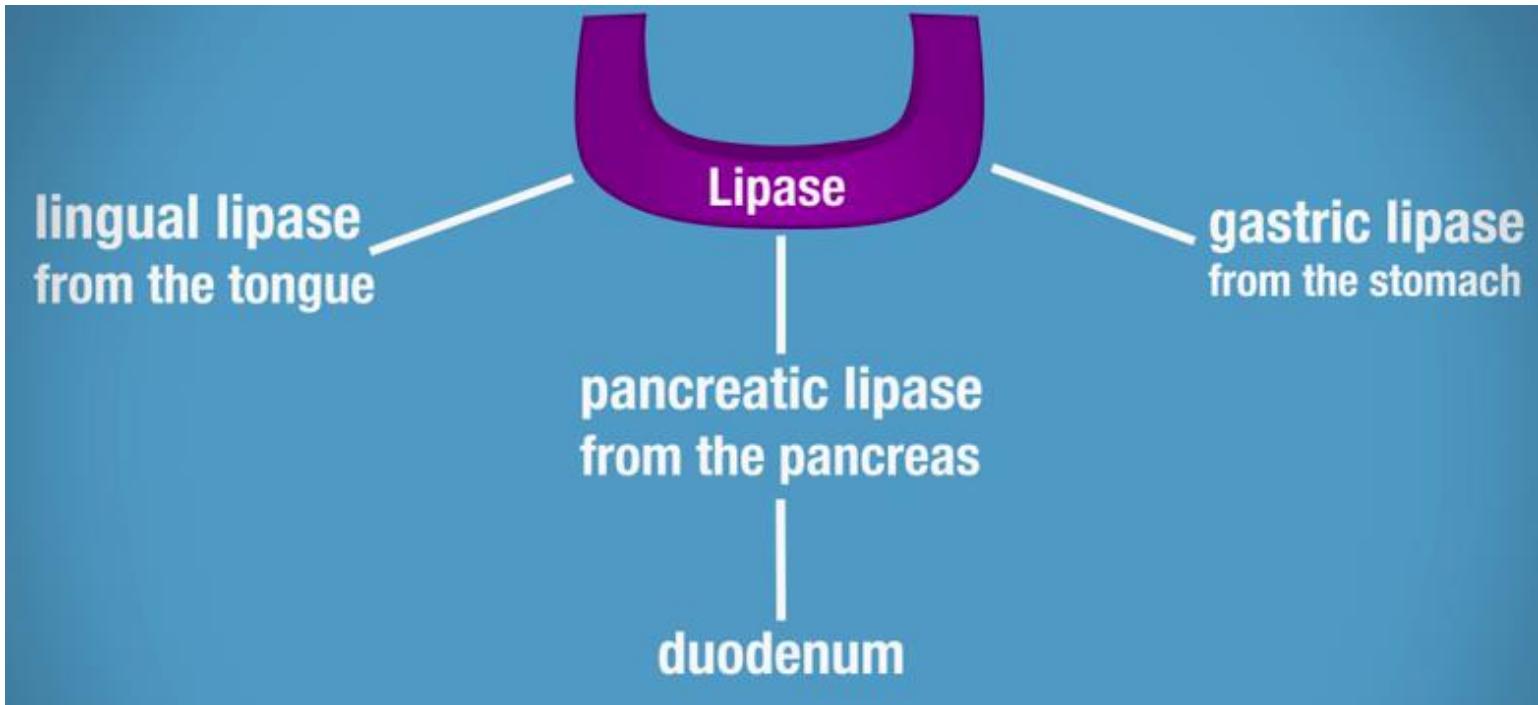
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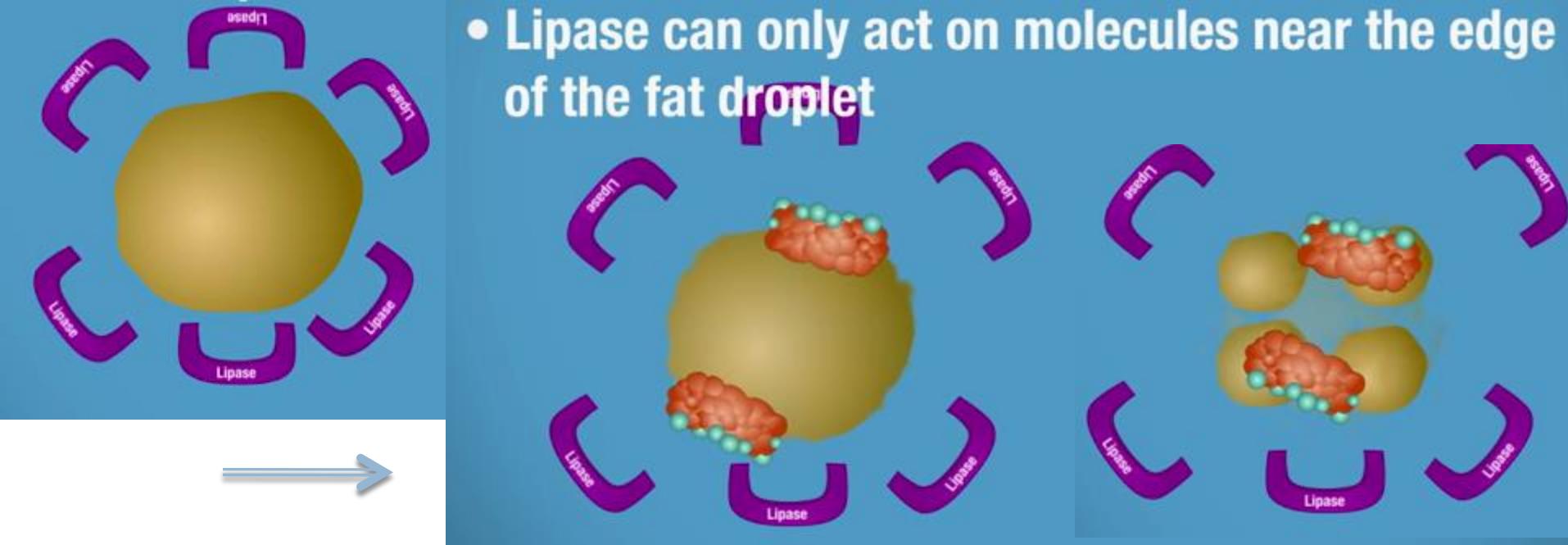
Digestion and absorption of Lipid

- **Lipids**
 - Typical diet consists of 25-160 grams of lipids
 - 90% triglycerides
 - Lipids have a problem in digestion and absorption
 - not water soluble
 - do not mix with stomach or intestinal contents
 - form fat droplets

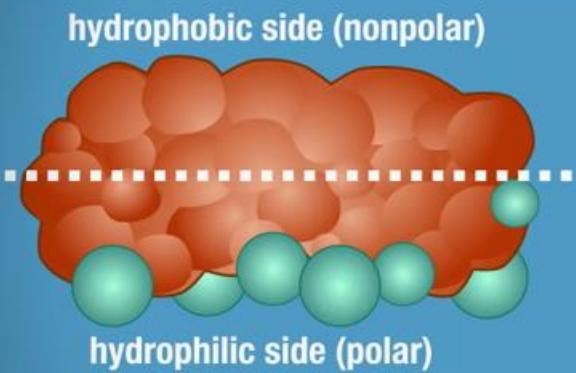




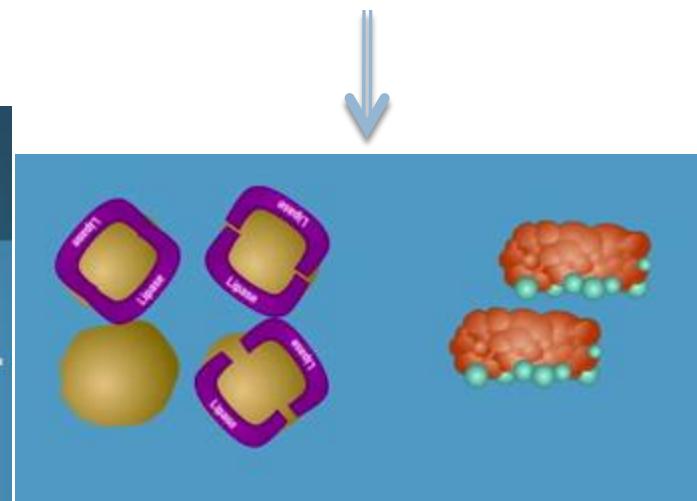
- Lipase can only act on molecules near the edge of the fat droplet

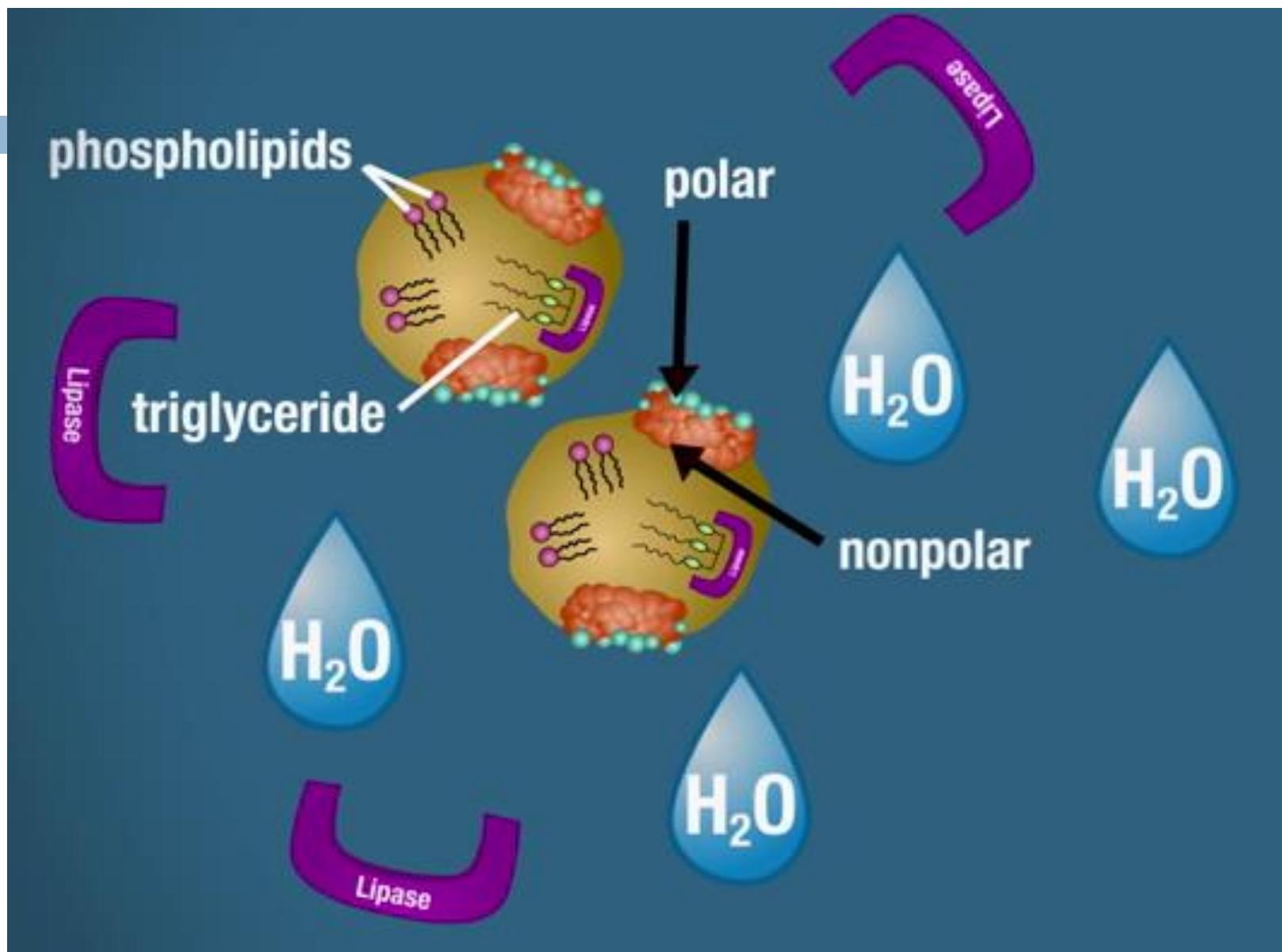


BILE SALTS

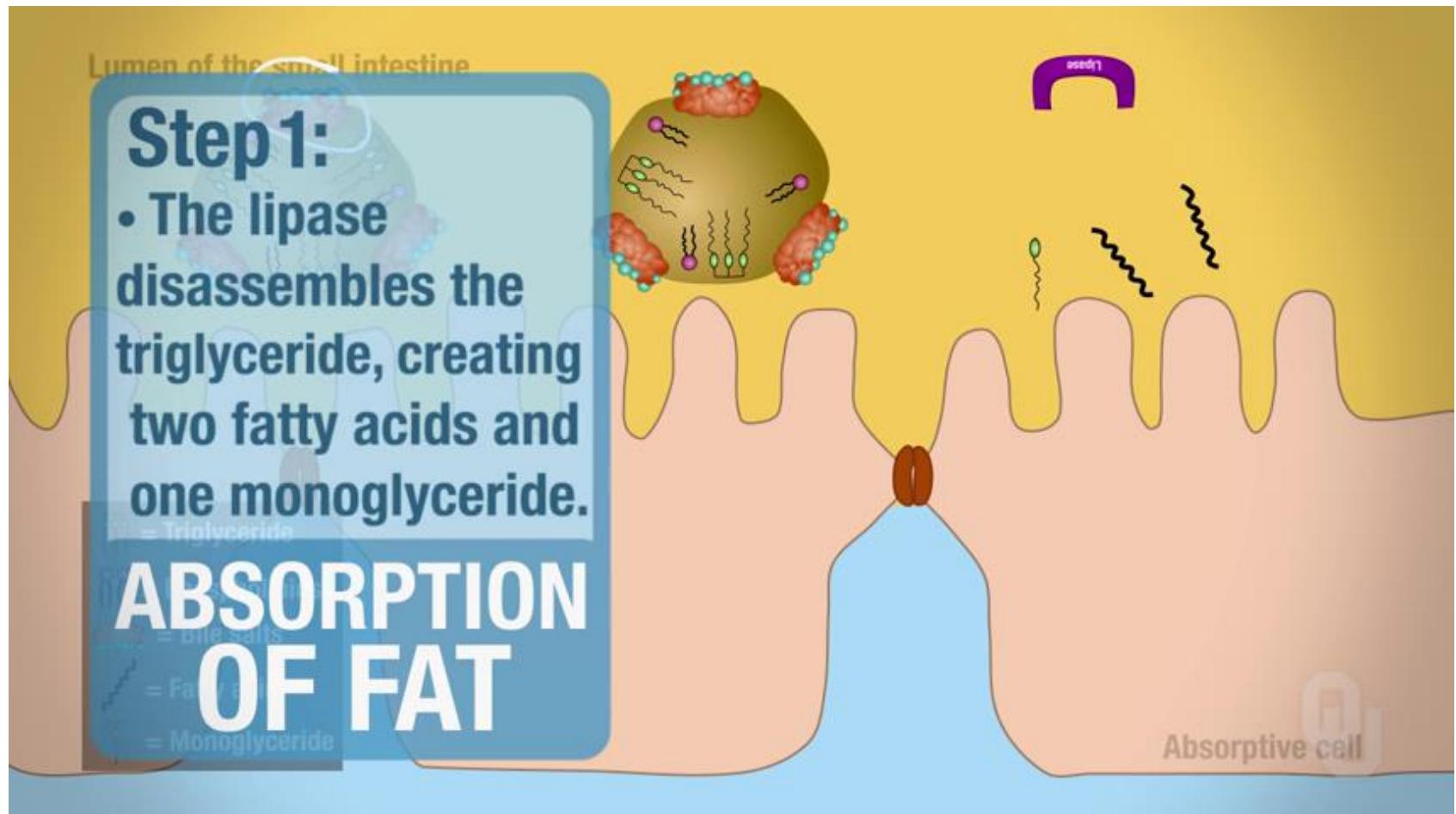


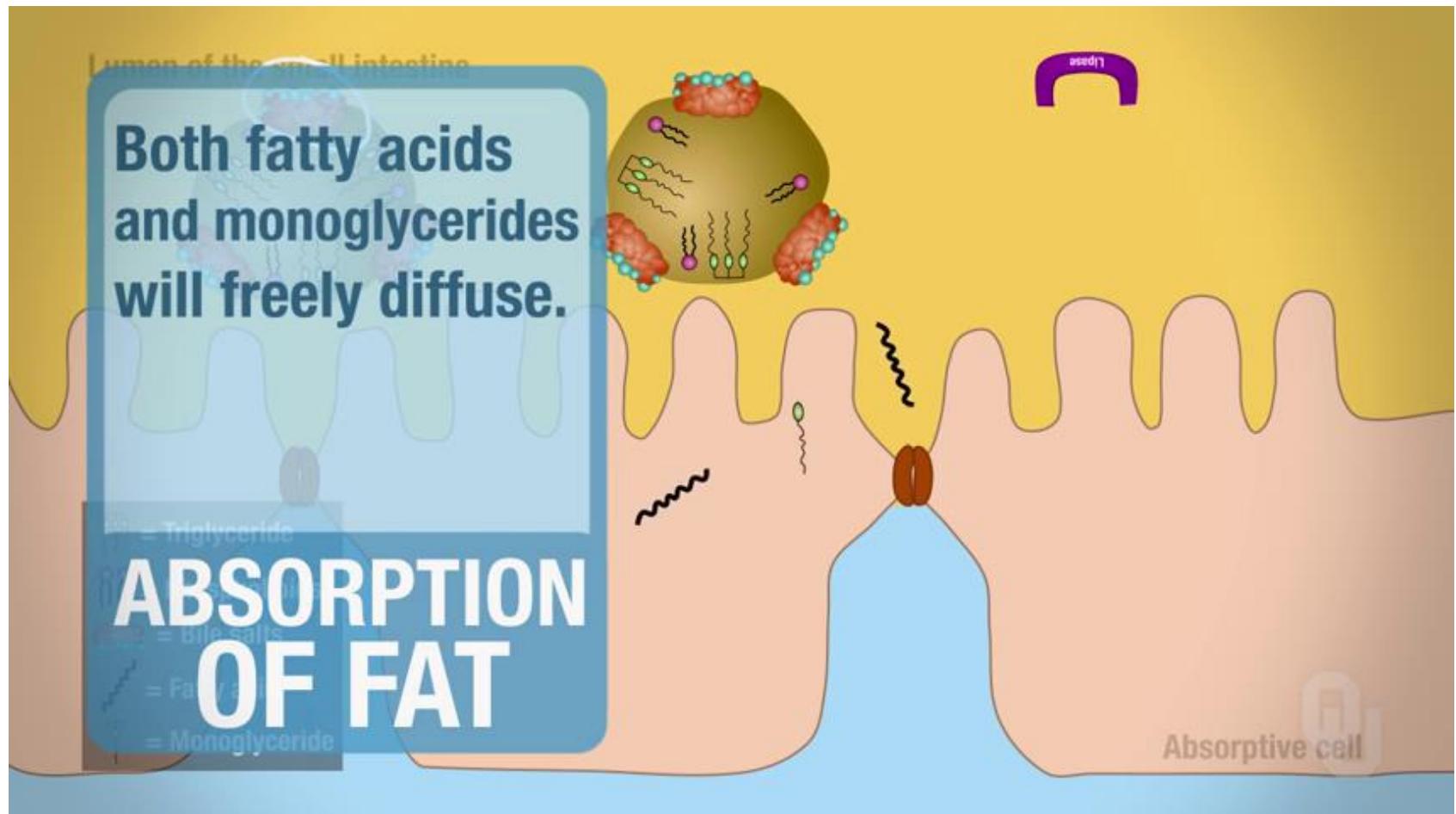
- Emulsification
- Synthesized in the liver from cholesterol
- Secreted in the bile to the duodenum
- Amphipathic molecule

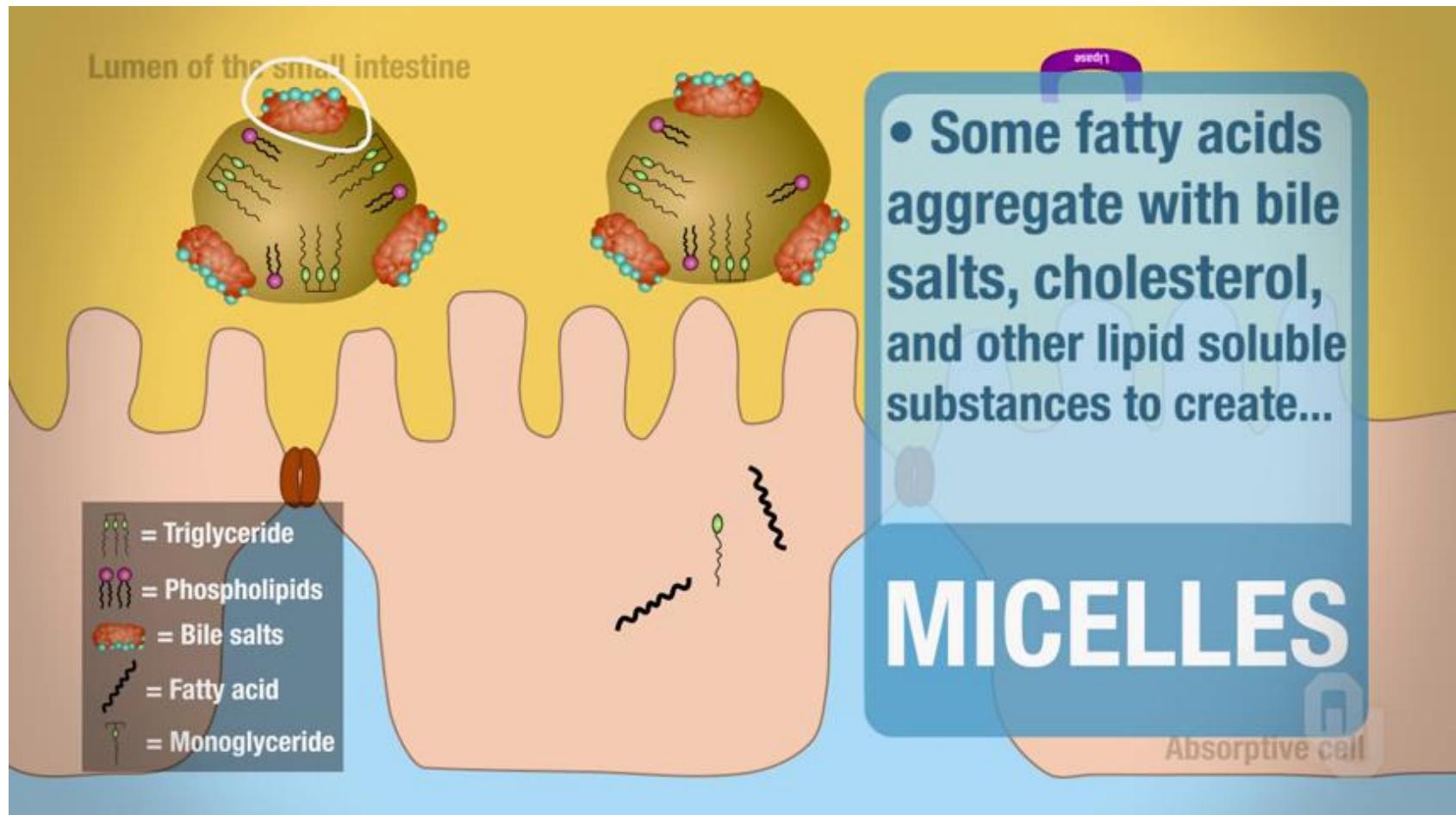




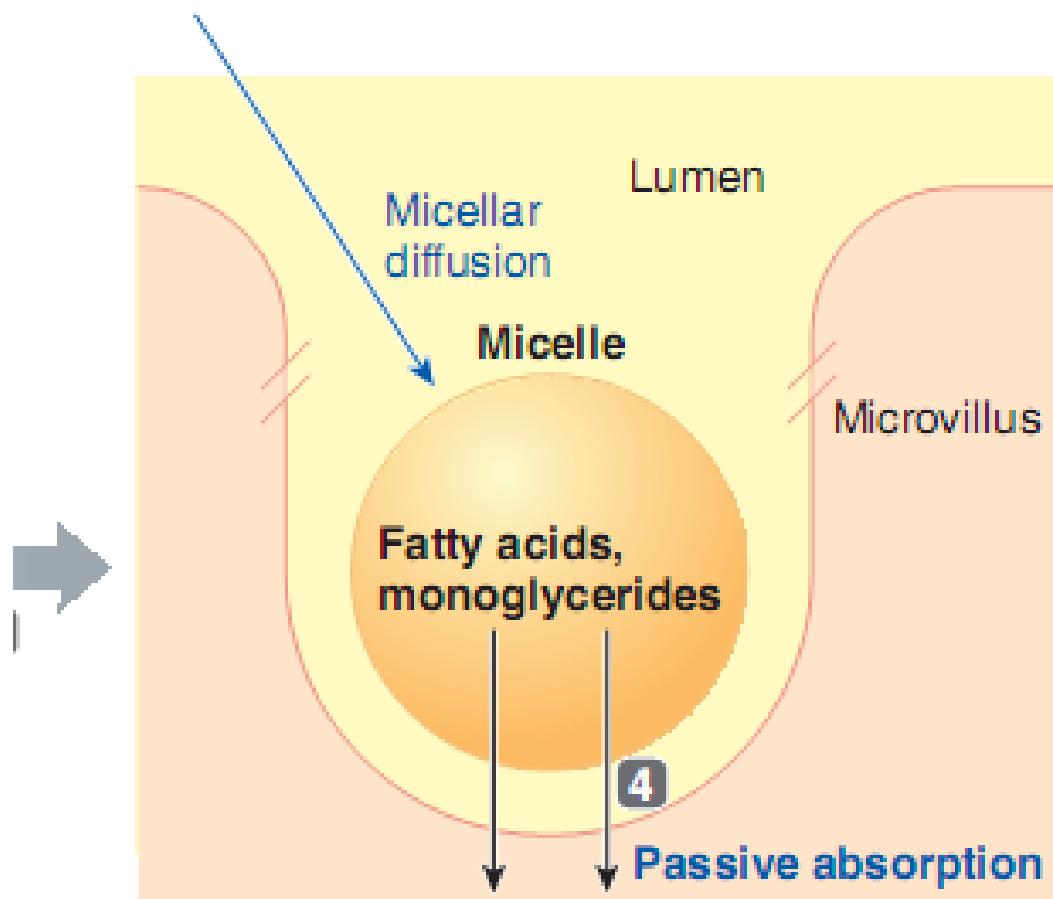
Absorption of lipid

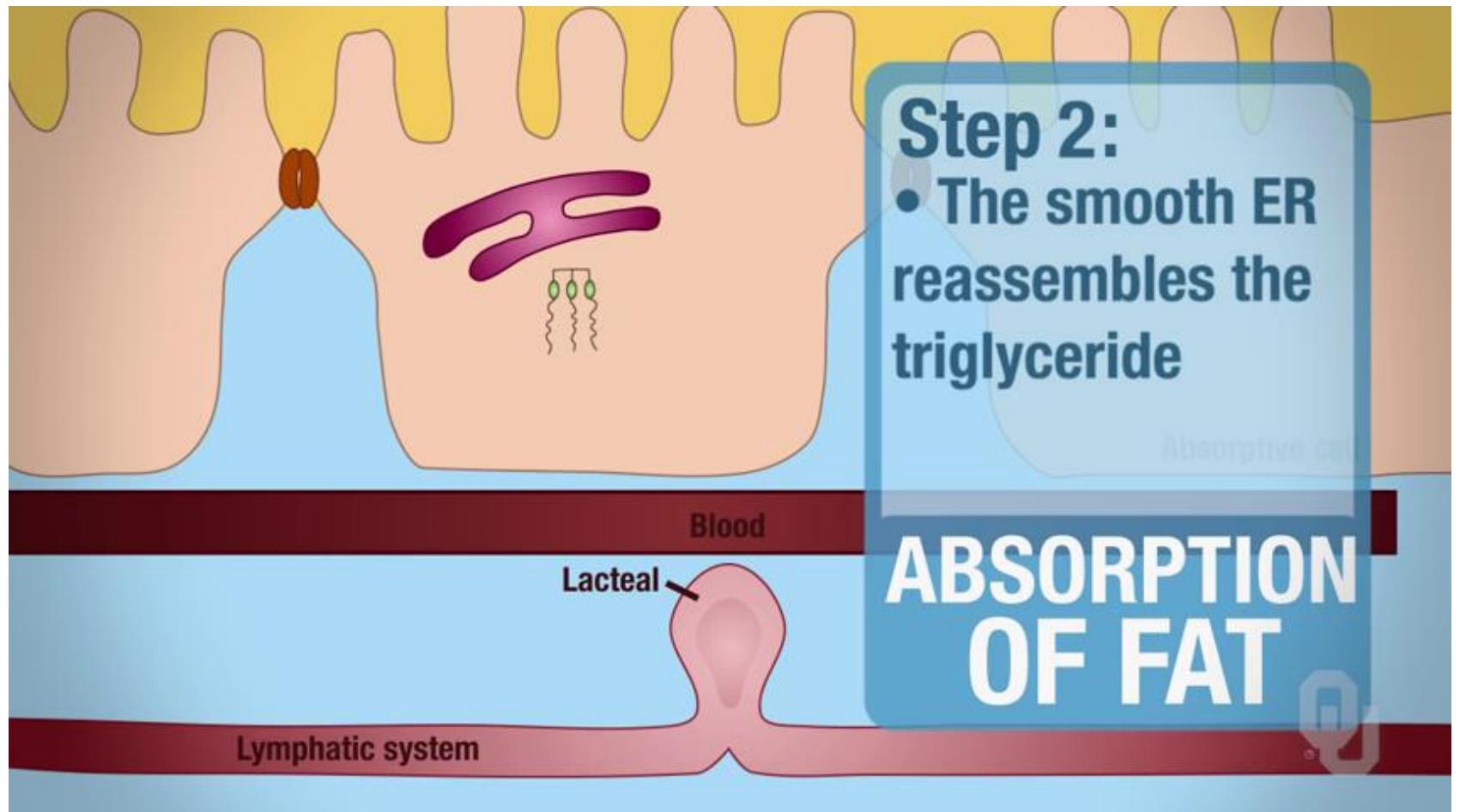


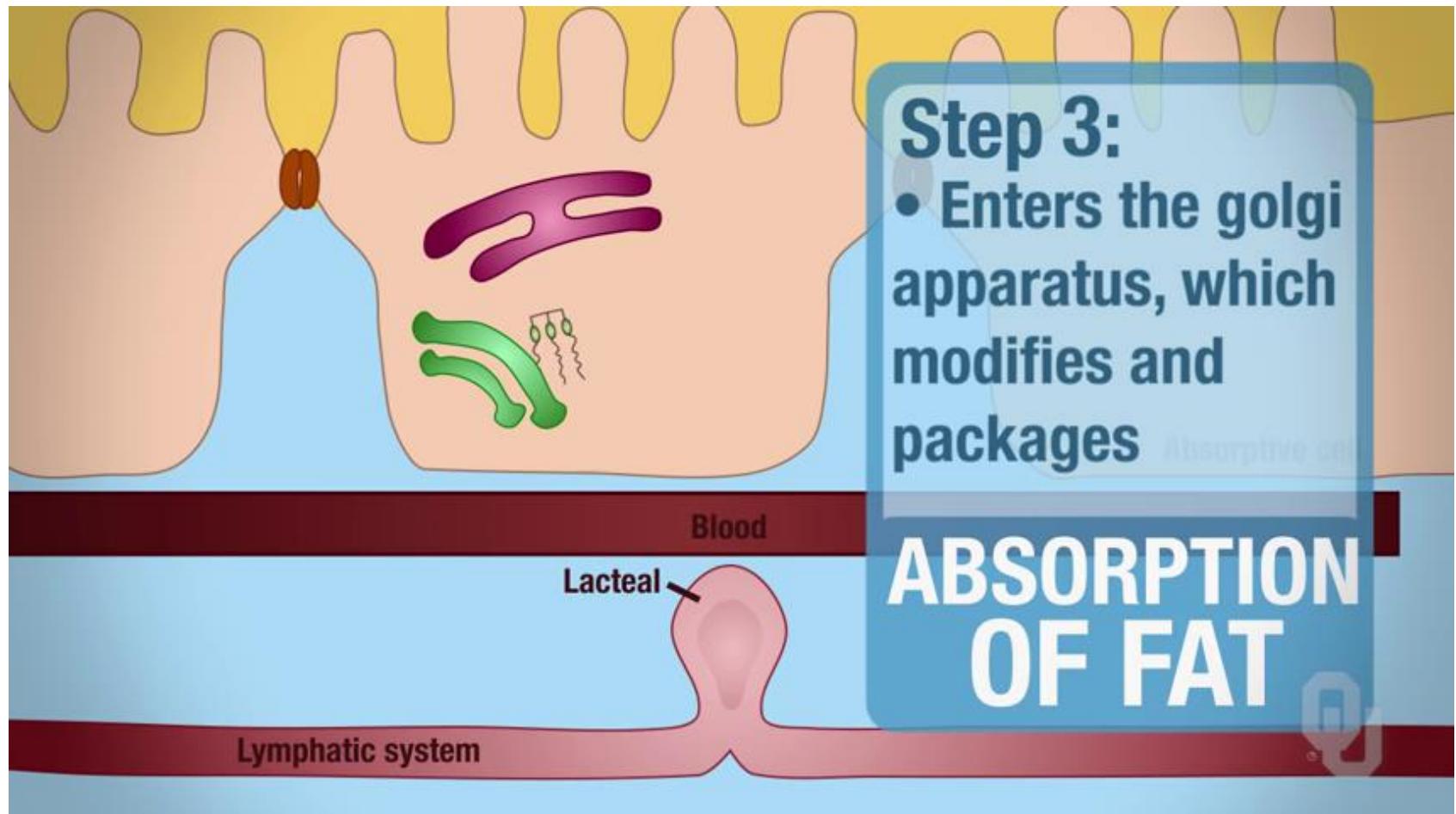


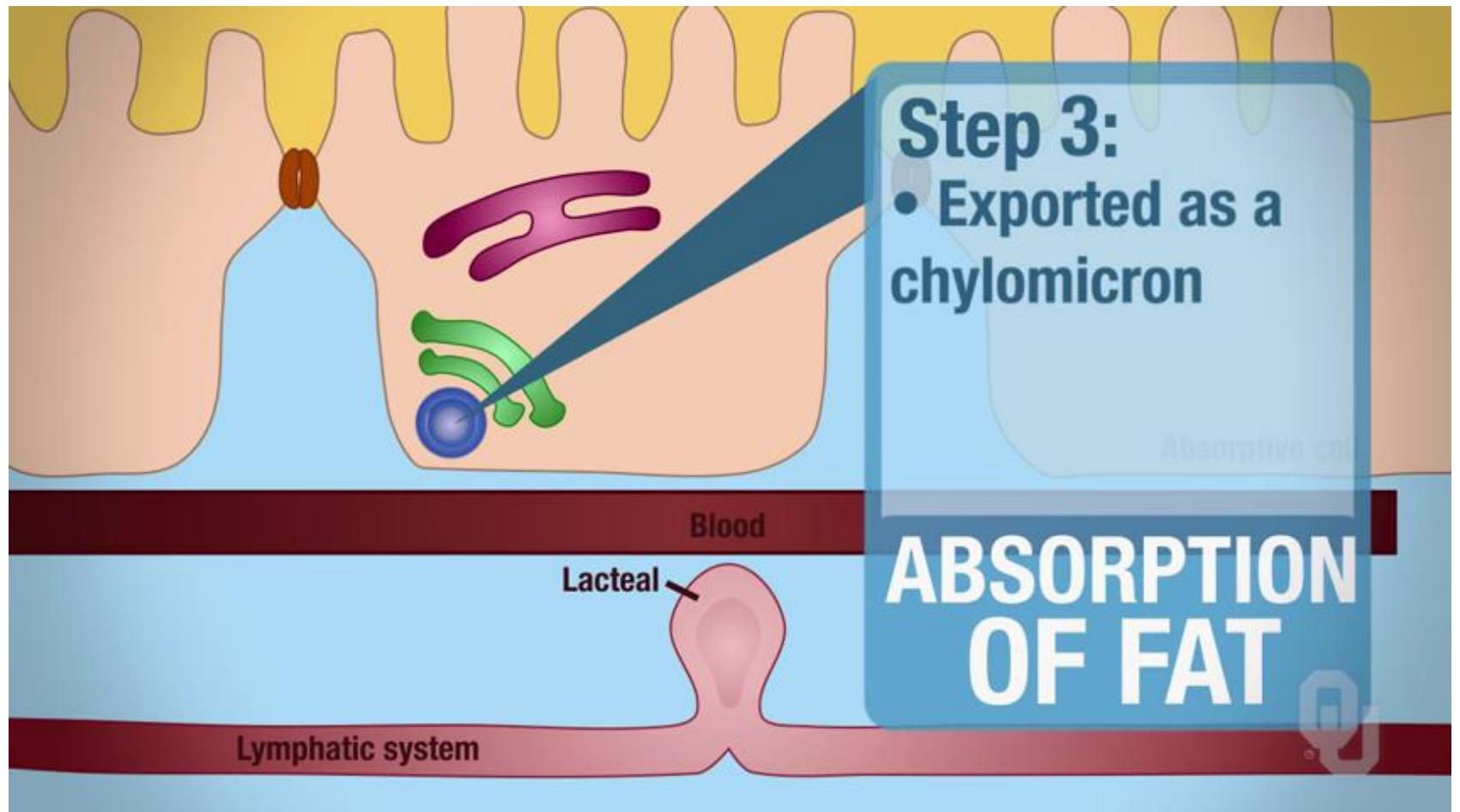


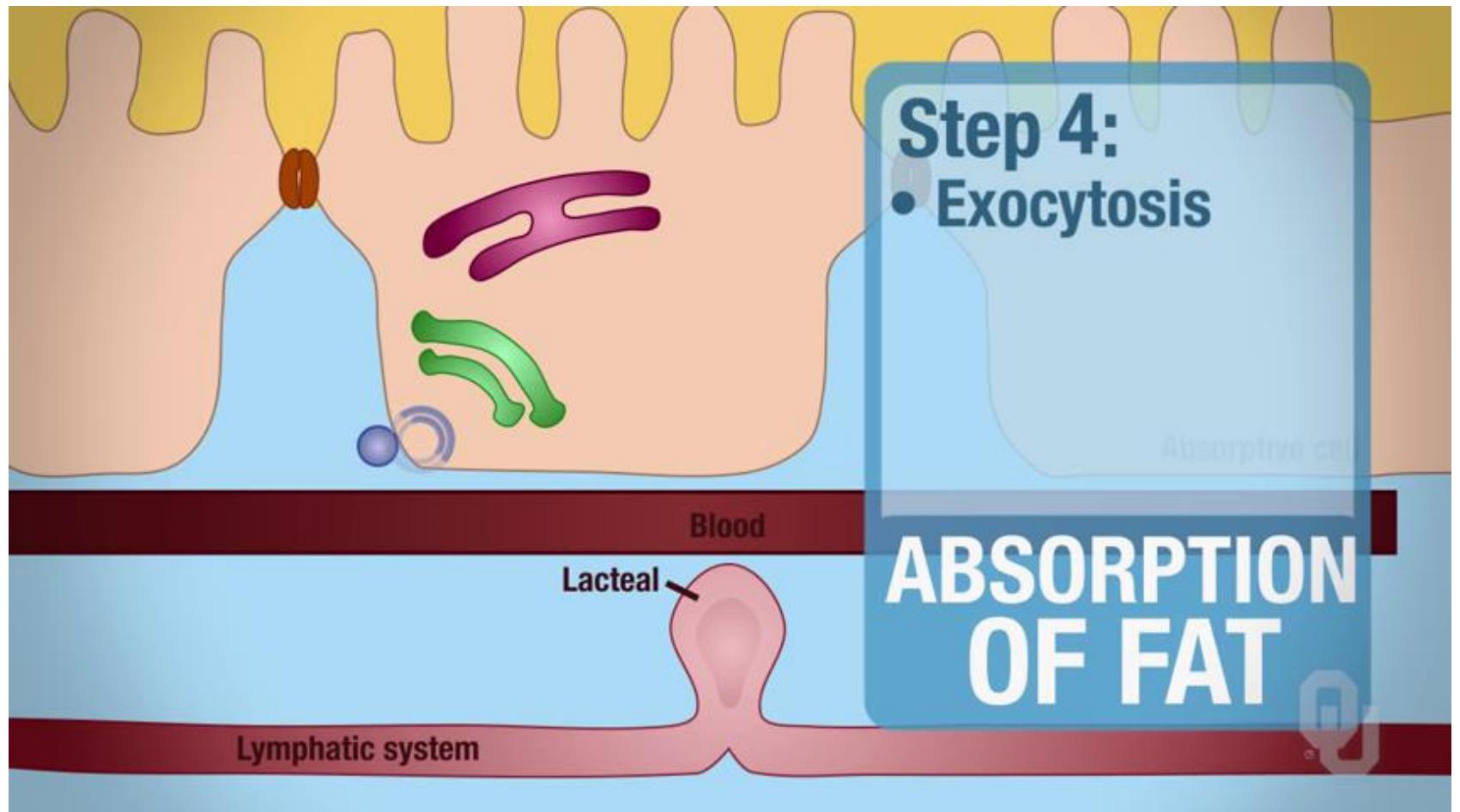
4 When a micelle approaches the absorptive epithelial surface, the monoglycerides and fatty acids leave the micelle and passively diffuse through the lipid bilayer of the luminal membranes.











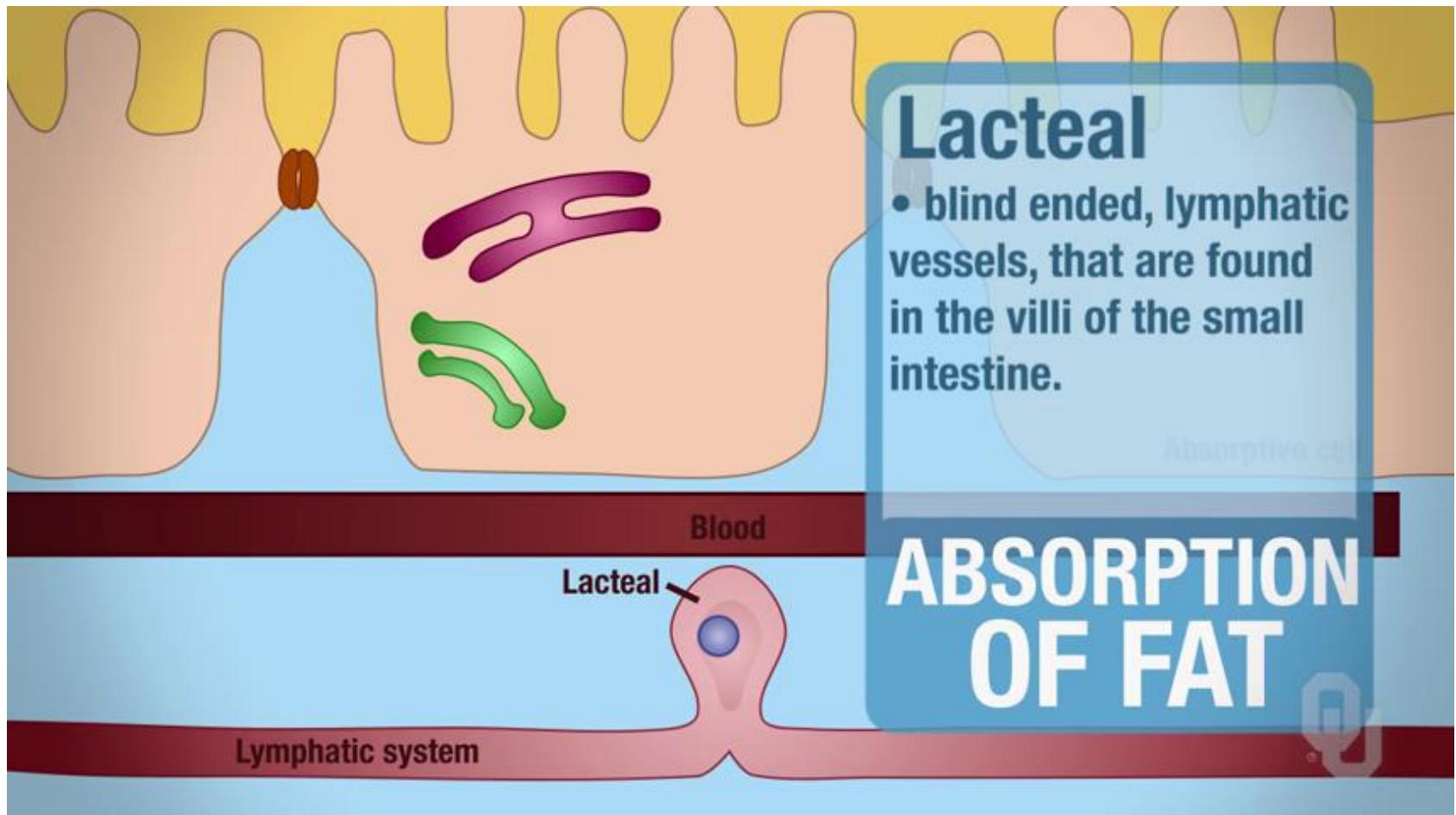
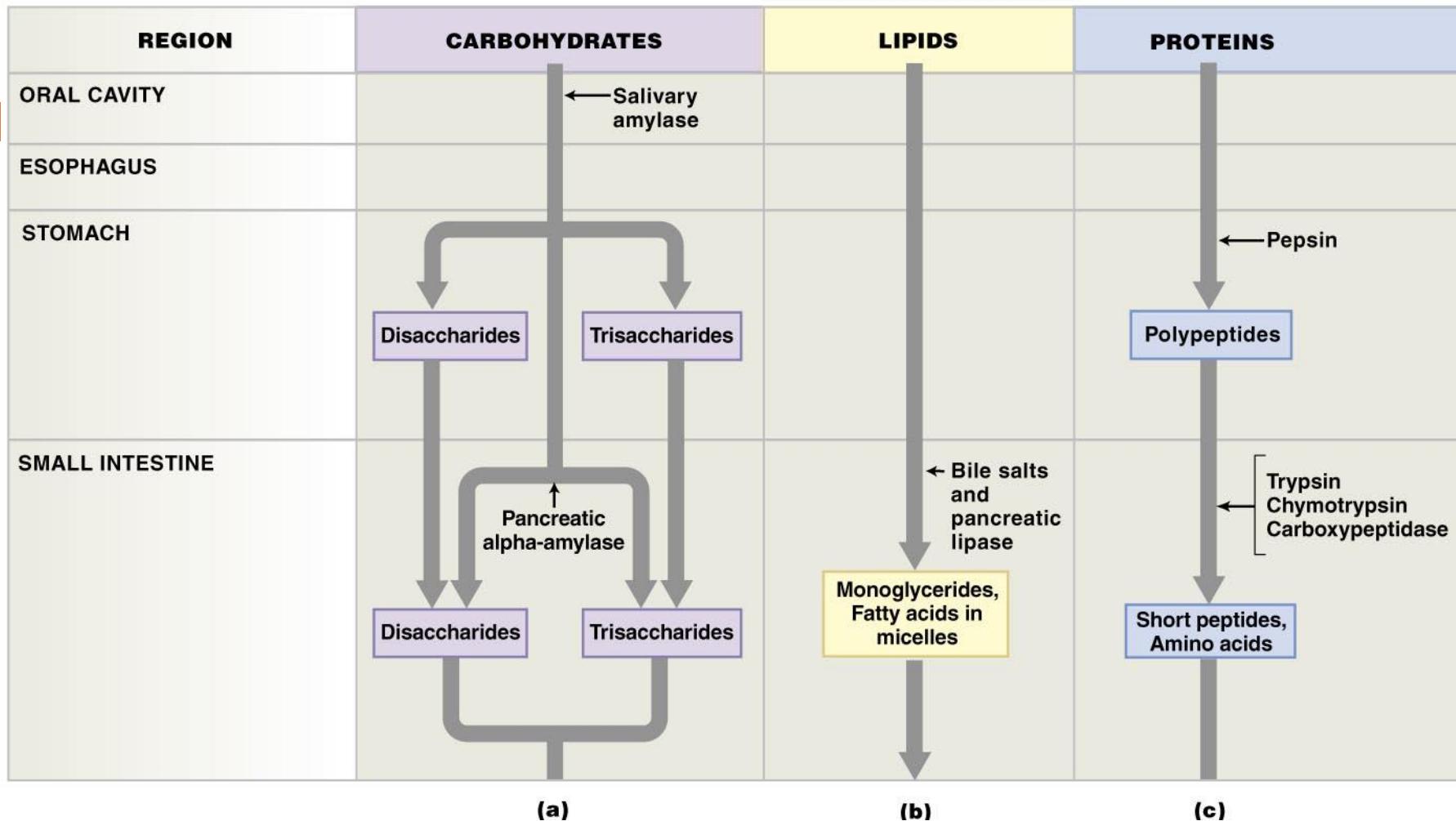
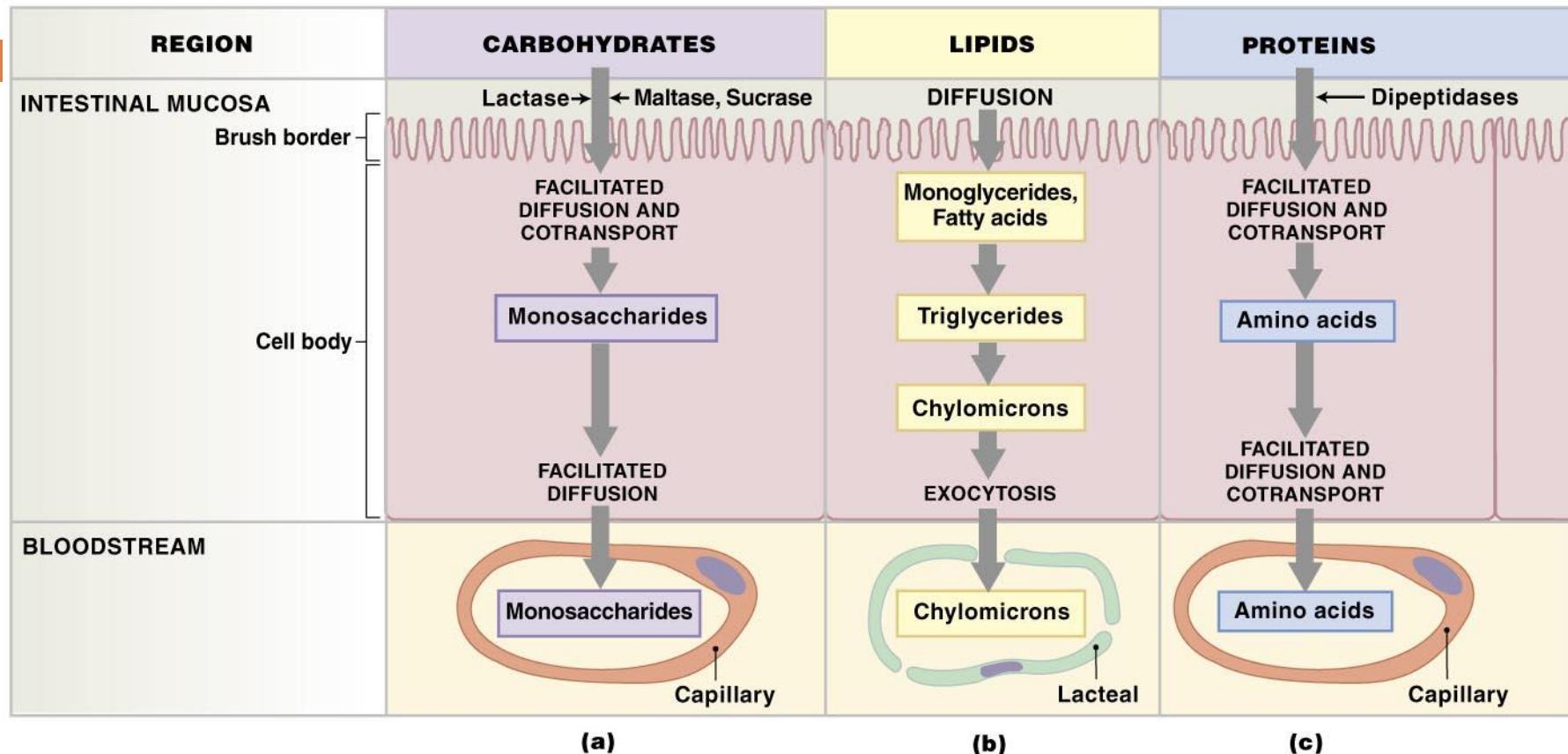


TABLE 16-3 Digestive Enzymes and Their Functions

ENZYME	SOURCE	OPTIMAL pH	TARGET	PRODUCTS
CARBOHYDRASES				
Amylase	Salivary glands, pancreas	6.7–7.5	Complex carbohydrates	Disaccharides and trisaccharides
Maltase, sucrase, lactase	Small intestine	7–8	Maltose, sucrose, lactose	Monosaccharides
LIPASES				
Pancreatic lipase	Pancreas	7–8	Triglycerides	Fatty acids and monoglycerides
PROTEASES				
Pepsin	Stomach	1.5–2.0	Proteins, polypeptides	Short polypeptides
Trypsin, chymotrypsin, carboxypeptidase	Pancreas	7–8	Proteins, polypeptides	Short peptide chains
Peptidases	Small intestine	7–8	Dipeptides, tripeptides	Amino acids
NUCLEASES				
	Pancreas	7–8	Nucleic acids	Nitrogenous bases and simple sugars





The Absorption of Vitamins

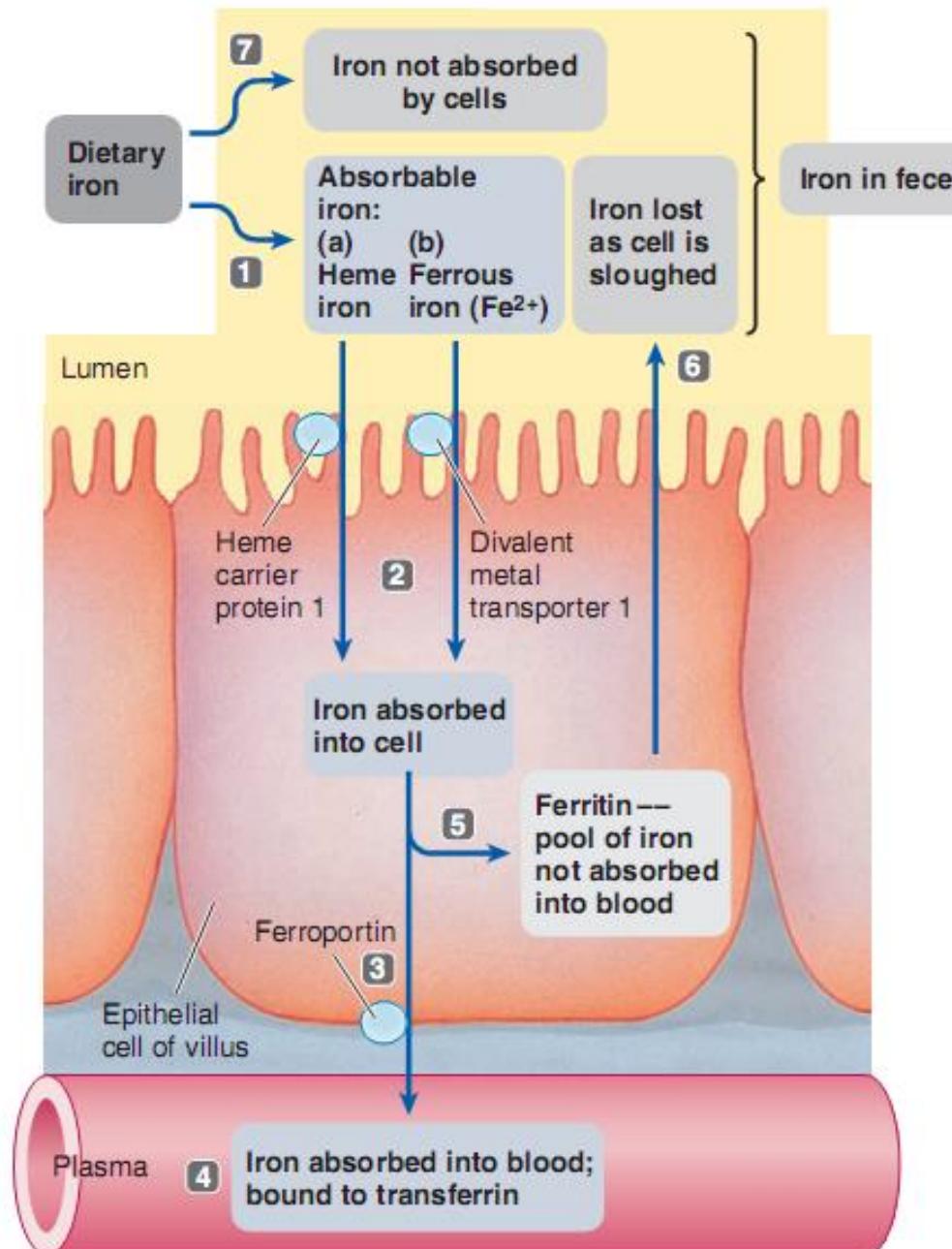
- Vitamins are organic compounds required in very small quantities
- Are divided into two major groups:
 - Fat-soluble vitamins
 - Water-soluble vitamins
- Water-soluble vitamins are primarily absorbed passively with water, whereas fat-soluble vitamins are carried in the micelles and absorbed passively with the end products of fat digestion.
- Vitamin B12 → must be in combination with gastric intrinsic factor for absorption by receptor mediated endocytosis in the terminal ileum.

Chemical Digestion: Nucleic Acids

- Absorption: active transport via membrane carriers
- Absorbed in villi and transported to liver via hepatic portal vein
- Enzymes used: pancreatic ribonucleases and deoxyribonuclease in the small intestines

Iron Absorption

- Iron is essential for hemoglobin production.
- The normal iron intake is typically 15 to 20 mg/day
- laki-laki → absorpsi 0.5 - 1 mg/day
- Wanita → absorb 1.0 - 1.5 mg/day. (Women need more iron because they periodically lose iron in menstrual blood flow.)



- 1 Only a portion of ingested iron is in a form that can be absorbed, either heme iron or ferrous iron (Fe^{2+}).
- 2 Iron is absorbed across the luminal membrane of small-intestine epithelial cells by different energy-dependent carriers for heme and Fe^{2+} .
- 3 Dietary iron that is absorbed into the small-intestine epithelial cells and is immediately needed for red blood cell production is transferred into the blood by the membrane iron transporter ferroportin.
- 4 In the blood, the absorbed iron is carried to the bone marrow bound to transferrin, a plasma protein carrier.
- 5 Absorbed dietary iron that is not immediately needed is stored in the epithelial cells as ferritin, which cannot be transferred into the blood.
- 6 This unused iron is lost in the feces as the ferritin-containing epithelial cells are sloughed.
- 7 Dietary iron that was not absorbed is also lost in the feces.

ABSORPSI AIR DAN MINERAL di TGI

□ Prinsip Dasar Absorpsi GI



- Absorpsi t.u di usus halus dan usus besar.
- Lambung tidak punya vili khas utk absorpsi dan tight junction berupa jar.ikat → sehingga absorpsinya buruk

Absorpsi Air

- Abs. isosmotik
 - Difusi air mengikuti hukum osmosis
 - Bila kimus encer → air osmosis ke darah vili melalui mukosa usus
 - Kimus hiperosmotik → H_2O ditransport dari plasma ke lumen
 - Kimus dibuat isosmotik dg plasma
 - Ketika ion-ion dan nutrien diabsorpsi, air dg isosmotik yang sama juga diabsorpsi

Absorpsi ion Na⁺

Na⁺ → transport aktif ke bagian basal dan sisi dinding sel → ruang paraseluler

Peningkatan konsentrasi ion di ruang paraseluler → osmosis H₂O

→ Masuk ke Pembuluh darah vilus

Aldosteron (klj.adrenal) → ↑ abs Na⁺ yg selanjutnya diikuti abs sekunder Cl⁻, H₂O, & zat lain.

Terutama di colon agar NaCl tidak hilang dalam feses

Penting saat dehidrasi!!

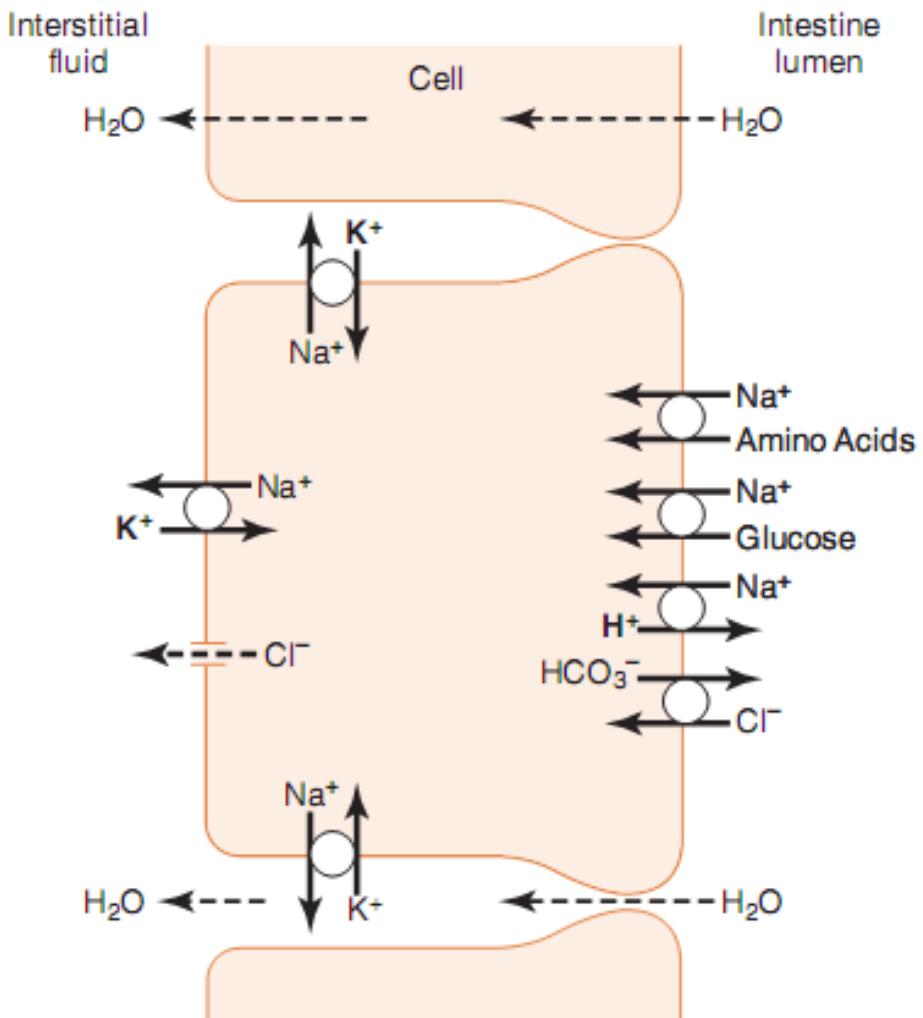


Figure 66-8. Absorption of sodium, chloride, glucose, and amino acids through the intestinal epithelium. Note also osmotic absorption of water (i.e., water "follows" sodium through the epithelial membrane).

Absorpsi Ion Cl⁻

- Di Jejenum dan Duodenum
- Berlangsung cepat dan difusi pasif
- Bergerak “mengikuti” gradien listrik ion Na⁺

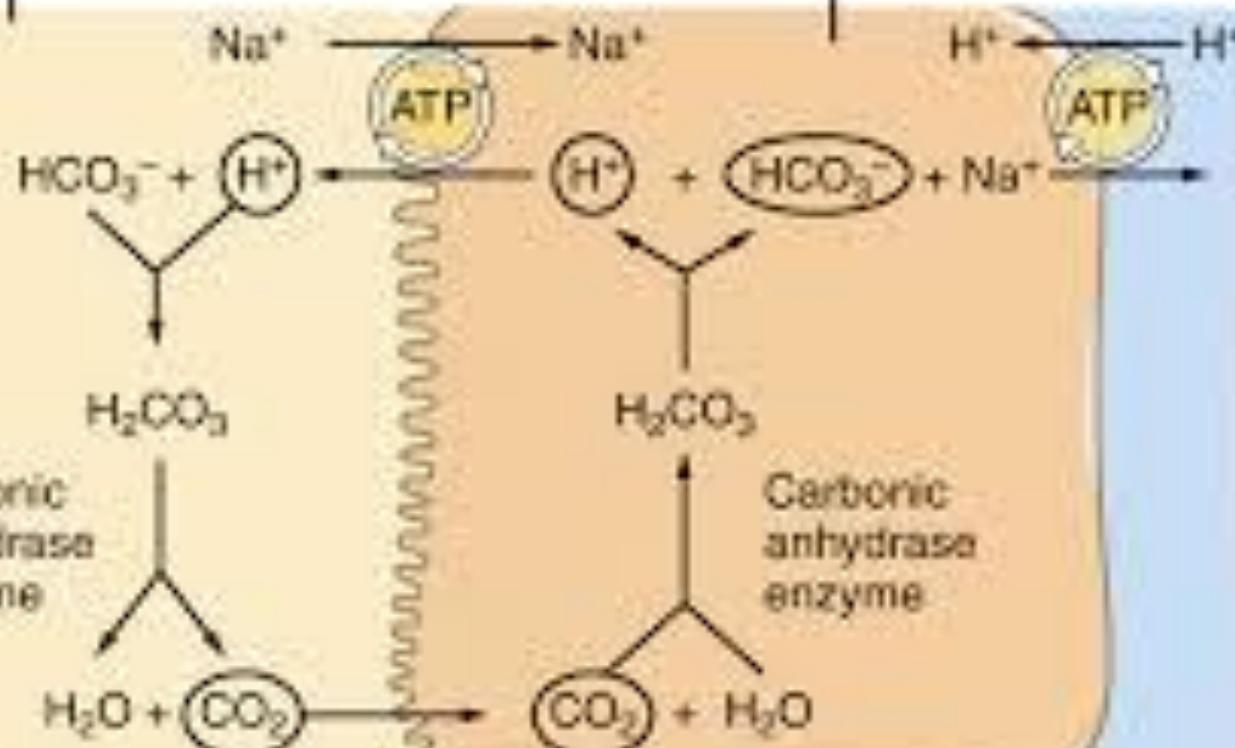
Absorpsi Ion HCO_3^-

- HCO_3^- banyak terdapat di usus karena sekresi pankreas utk menetralkan asam.
- Diabsorpsi secara tidak langsung dg cara
 - Na^+ diabsorpsi , ditukar dg sekresi H^+ ke lumen
 - H^+ bergabung dg $\text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3$ berdisosiasi $\rightarrow \text{H}_2\text{O} + \text{CO}_2$, H_2O tetap di lumen, CO_2 diabsorpsi ke darah \rightarrow keluar ke paru-paru

LUMEN

Sel Epitel

Bloodstream



Absorpsi ion lain

- Ca^{2+} , diabsorpsi t.u di duodenum, dikontrol oleh hormon paratiroid & vit.D
- K^+ , Mg^{2-} , phosfat → abs aktif lewat mukosa
- Ion bivalen → abs dalam jumlah sedikit
- Ion monovalen → abs dg mudah dan dalam jumlah besar

Mekanisme absorpsi dalam usus besar

- Terjadi di setengah proksimal colon (colon pengabsorpsi)
- Elektrolit dan H_2O melewati sel epitel usus dengan menembus sel maupun melewati celah antar sel (paraseluler)

- Permeabilitas *tight junction* (taut erat) antar sel epitel bervariasi
- Di usus besar → *tight junction* lebih erat → epitel lebih impermeable → mencegah difusi ion kembali ke lumen → memungkinkan mengabsorpsi Na lebih sempurna
- Absorpsi Na⁺ di usus besar terjadi dg melawan gradien konsentrasi yang jauh lebih tinggi dibanding usus halus terutama diperantarai oleh Aldosteron (karena Aldosteron ↑ transport Na)

- Sekresi HCO_3^- oleh vili ileum dan usus besar
 - Ion HCO_3^- disekresi ke lumen untuk ditukar dengan Cl^-
 - Mekanisme tsb tidak jelas, namun bergantung pada pertukaran protein dalam membran luminal sel epitel yang dengan kuat mengganti HCO_3^- dalam sel dengan Cl^- dalam lumen.
 - Apabila ion Cl^- dalam sel berlebih akan ditransport dg difusi pasif melewati membran basolateral sel epitel

- Absorpsi ion Na^+ dan Cl^- menciptakan gradien osmotik di sepanjang mukosa usus besar sehingga akan menyebabkan air terabsorpsi.
- Usus besar dapat mengabsorpsi max 5-7 L cairan dan elektrolit setiap hari, bila total cairan yang masuk ke usus besar atau melalui sekresi usus besar melebih jumlah tersebut → akan dibuang dalam bentuk diare

HOMEWORK

- Mechanism of gastric secretion? → SGD
- Reflexes in gastrointestinal tract?
- Peristaltic mechanism in each lumen?
- Mechanism of defecation?



THANK YOU

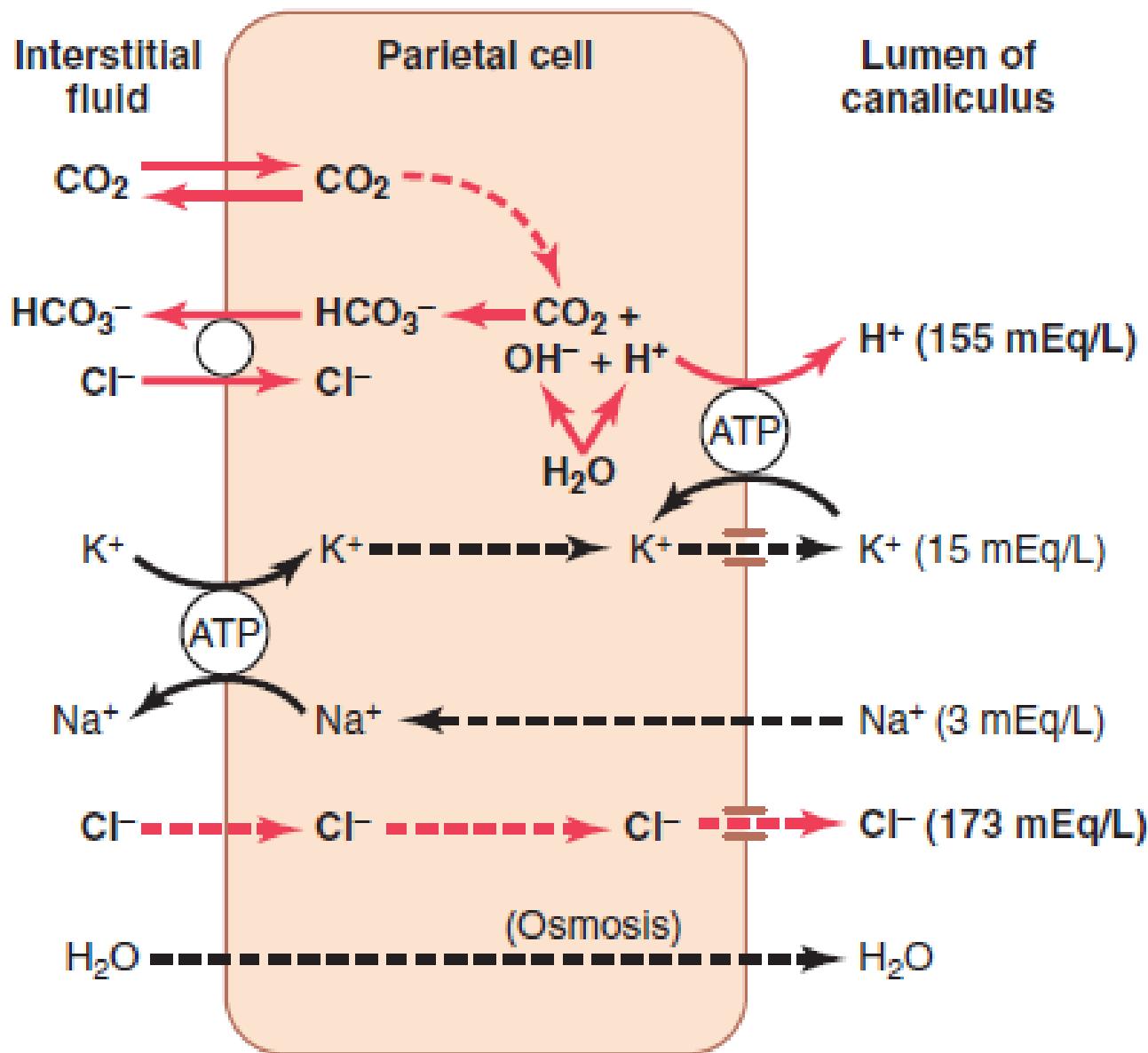


Figure 65-6. Postulated mechanism for secretion of hydrochloric acid. (The points labeled "ATP" indicate active pumps, and the dashed lines represent free diffusion and osmosis.)