
بسم الله الرحمن الرحيم
السلام عليكم و رحمة الله و بركاته

Gastrointestinal Physiology

Lecture 5

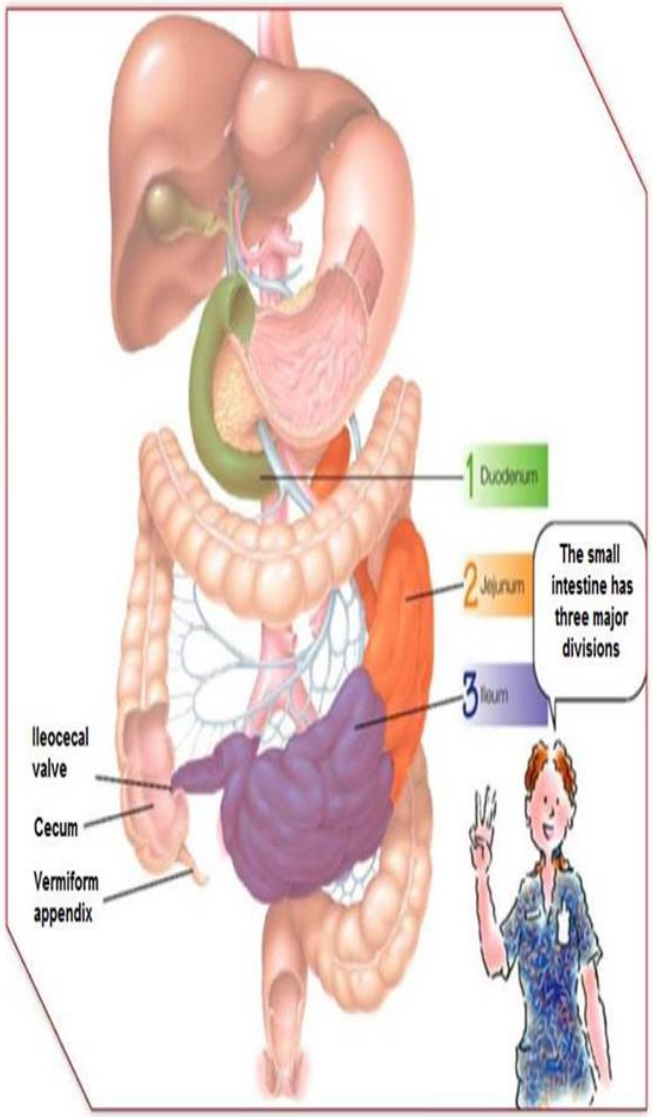
Physiology of the Small Intestine: Motility, Secretion and Absorption

Chapter 64; pages 812-814

Chapter 65; pages 830-831

Chapter 66: Pages 833-841

Dr. Hayam Gad
Associate Professor of Physiology, College of Medicine, KSU



Learning Objectives

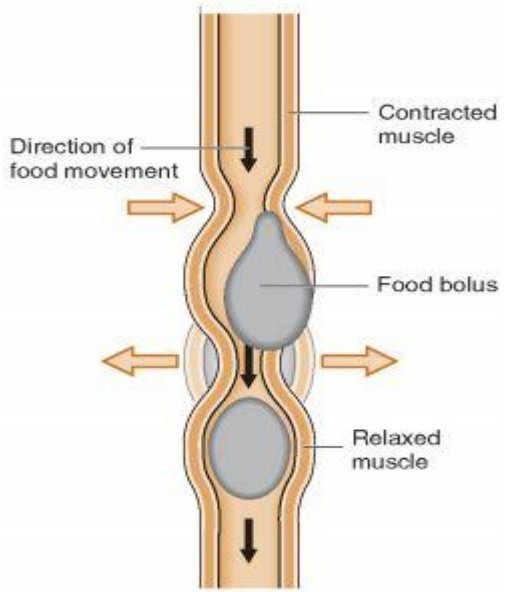
1. Motility in the small intestine.
2. Control of intestinal motility.
3. Secretions of the small intestine.
4. Digestion of carbohydrates, proteins and fats.
5. Basic principles of gastrointestinal absorption.
6. Absorption and secretion of electrolytes and water.

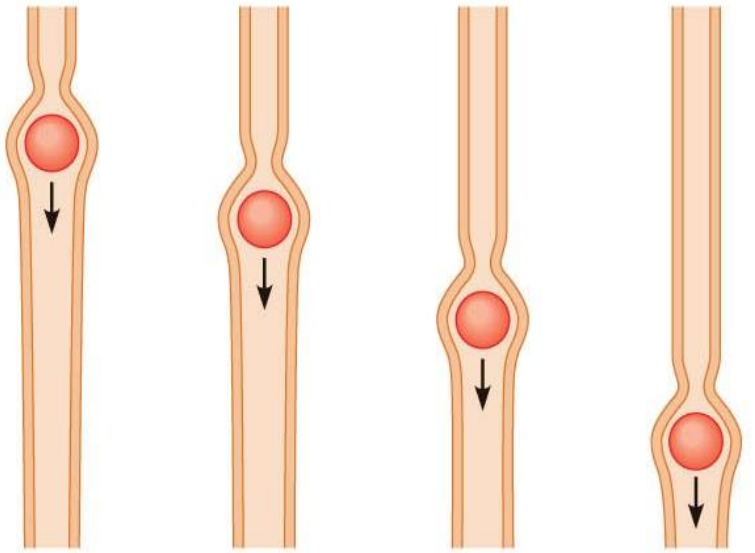
Motility in the Small Intestine

The movements of the small intestine can be divided into:

1. Propulsive Movement (Peristalsis)

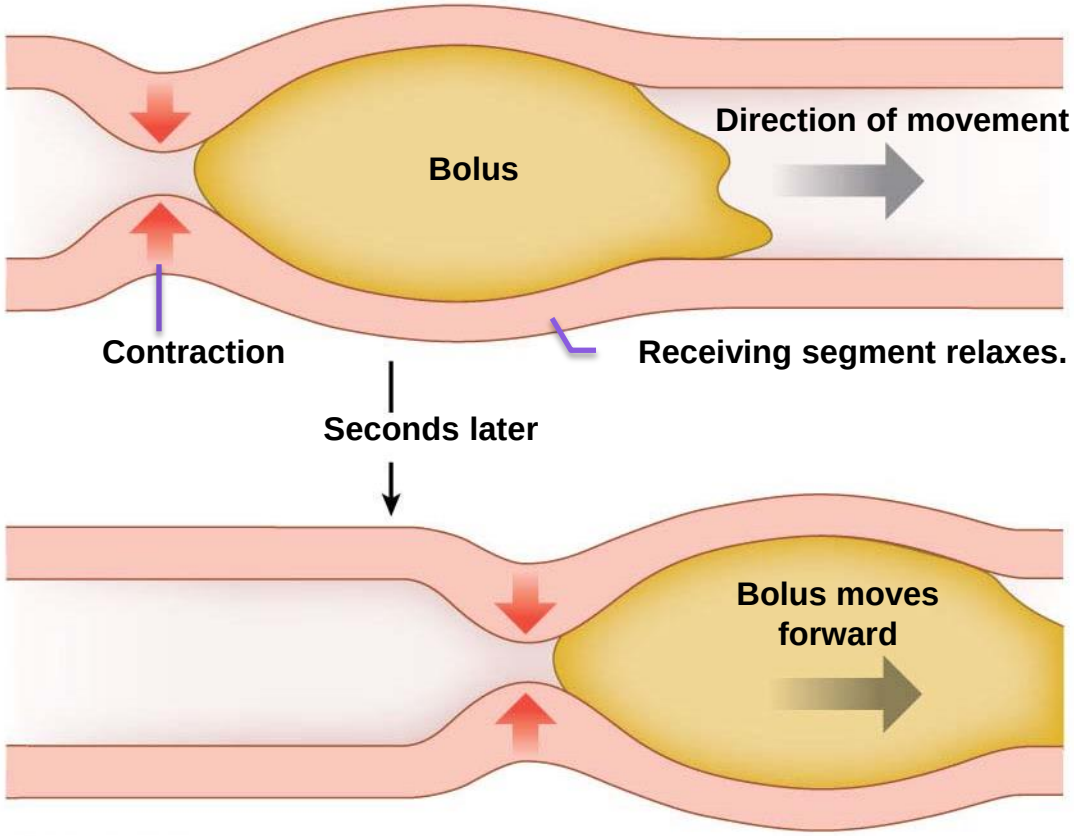
- Usual stimulus is distention.
- A contraction ring appears around gut, then moves forward.
- It organizes propulsion of material over variable distances.
- It is faster in the proximal intestine and slower in the terminal intestine (velocity 0.5 to 2.0 cm/sec), (3 to 5 hours are required for passage of chyme from the pylorus to the ileocecal valve).
- Myenteric plexus is important.
- They can be blocked by atropine.





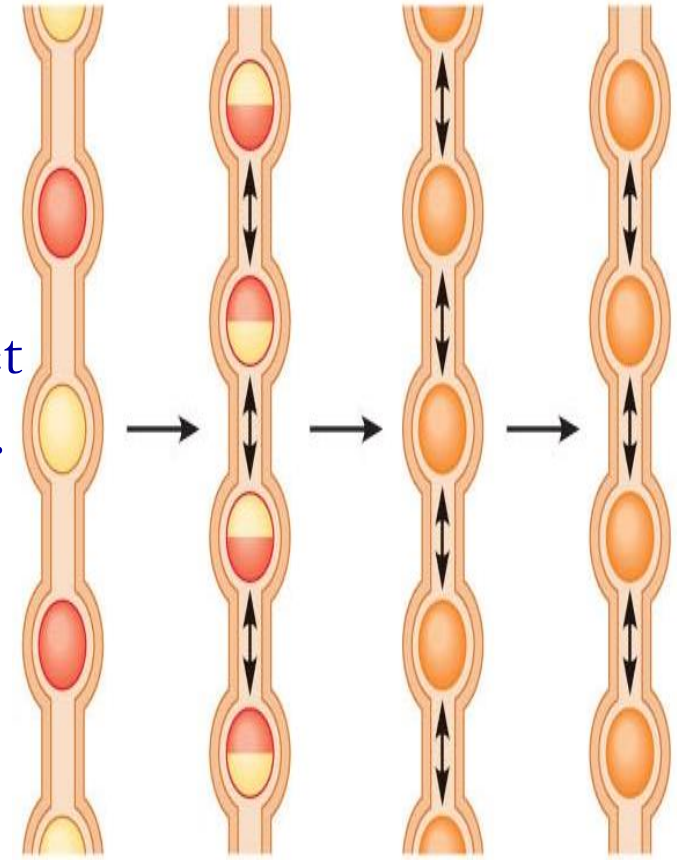
1. Propulsive Movement (Peristalsis)

- Propulsive segment ---contraction (circular M.)
  ---relaxation (longitudinal M.)
- Receiving segment ---contraction (longitudinal M.)
  ---relaxation (circular M.)



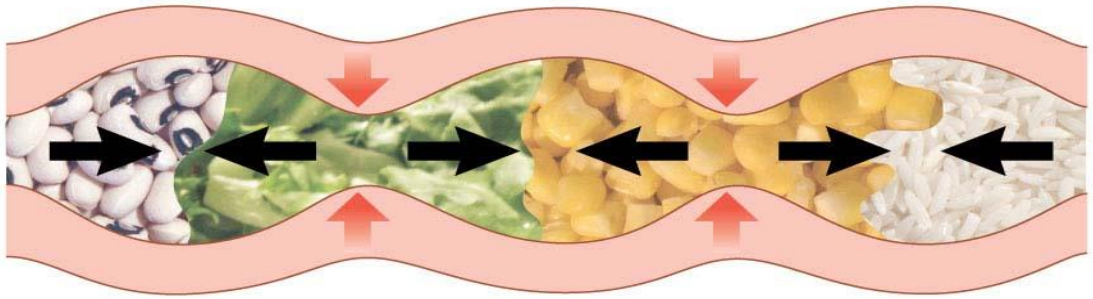
2. Mixing (Segmentation) Contractions

- A localized contraction of circular smooth muscles that constricts the intestine into spaced segments, and have the appearance of a chain of sausages.
- It last for fraction of min. As one set of segmentation contractions relaxes, a new set begins at points between the previous ones.
- Usual stimulus is distention.
- It is activated by enteric nervous system.
- They can be blocked by atropine.
- <u>The significance:</u>
  - Blend different juices with the chyme
  - Bring products of digestion in contact with absorptive surfaces

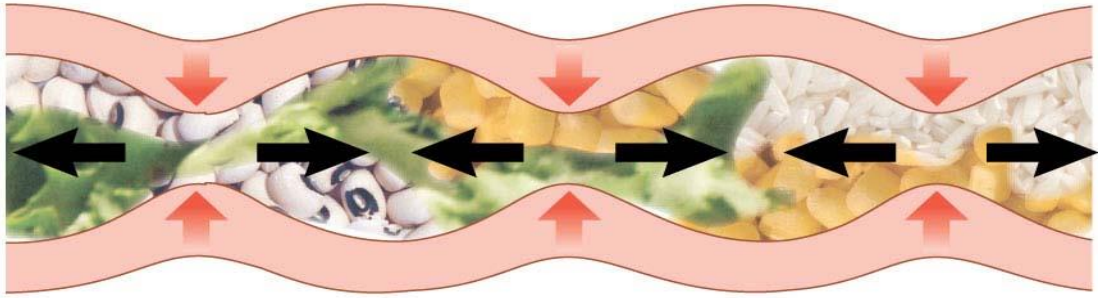


2. Mixing (Segmentation) Contractions

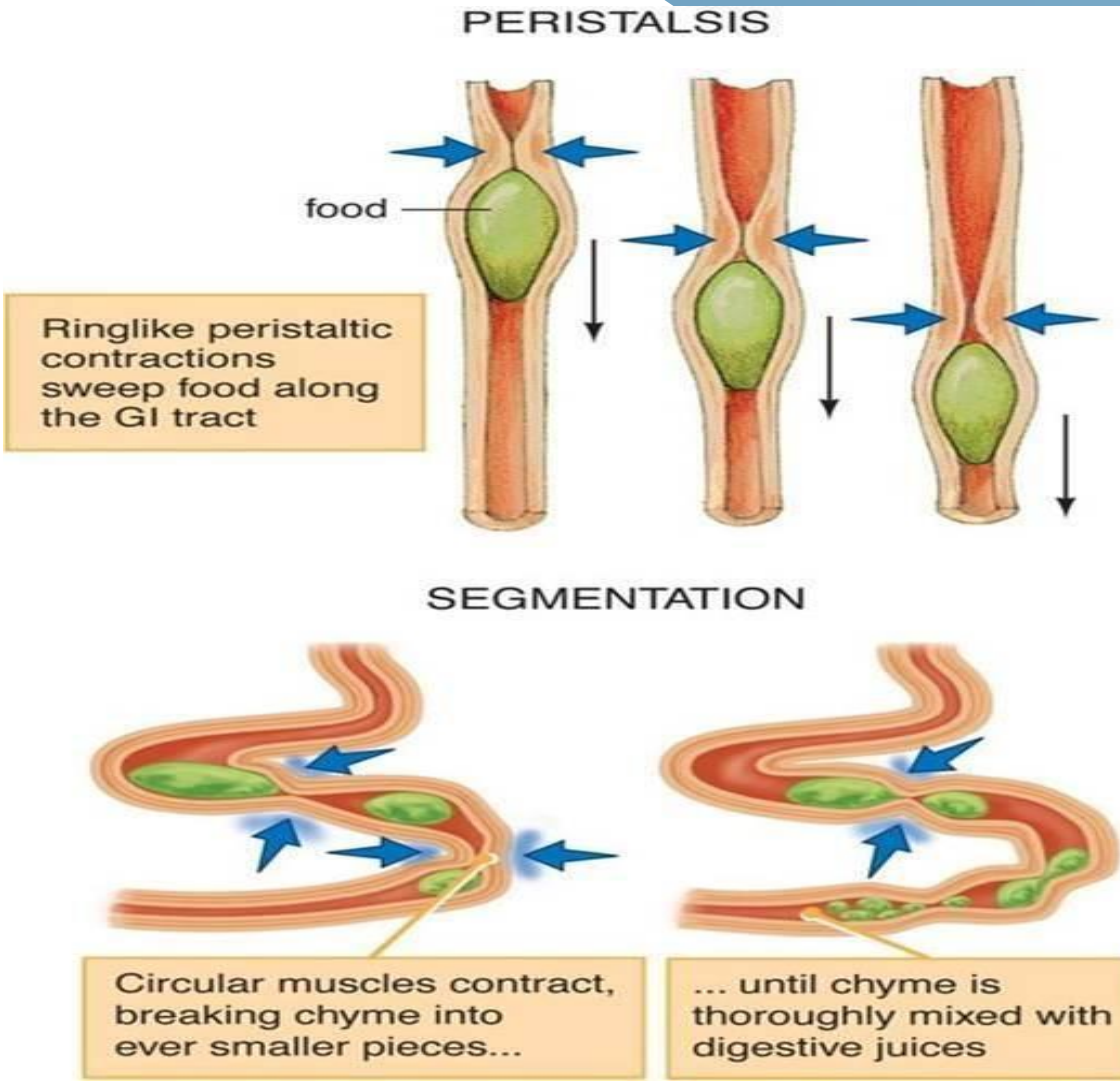
Segmental contractions are responsible for mixing.



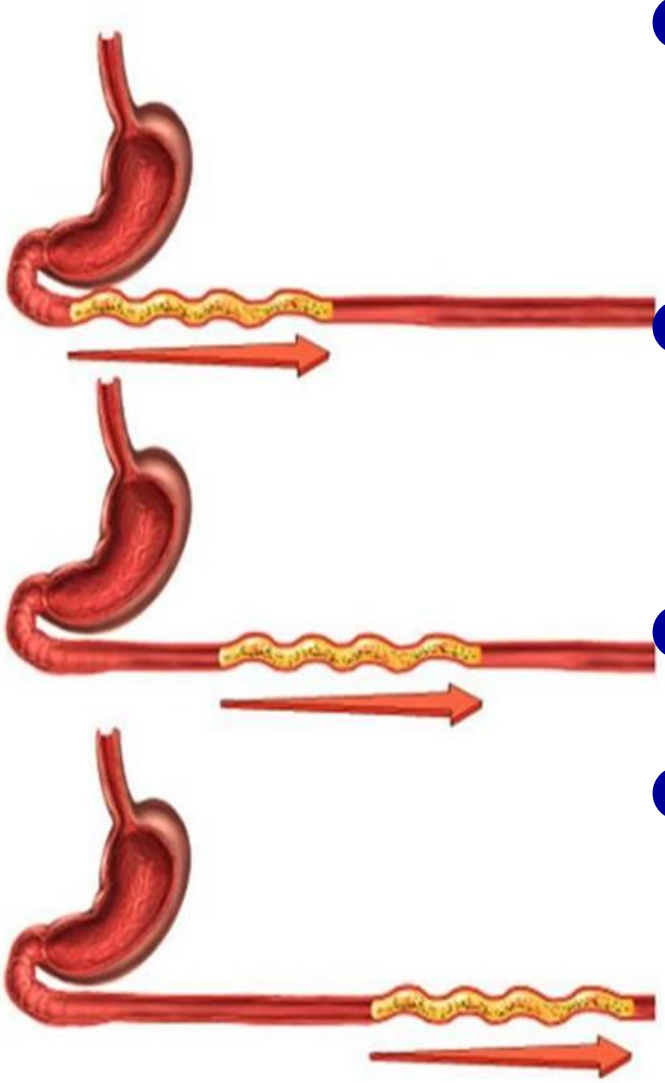
Alternate segments contract, and there is little or no net forward movement.



Peristalsis versus segmentation



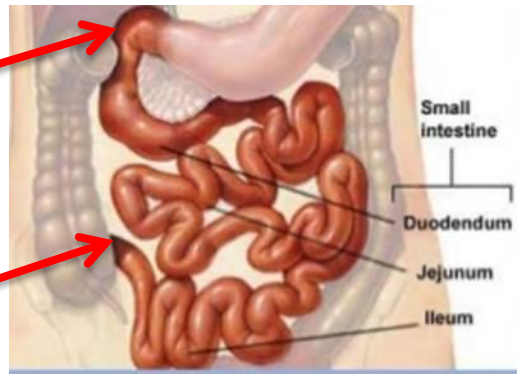
3- Migrating Motor Complex (MMC)



- Bursts of depolarization accompanied by peristaltic contraction that begins in empty stomach during interdigestive period (after absorption occurs)
- Travels a long whole length of small intestine to reach ileocaecal valve after 1.5-2 h. When it disappears, a new wave of MMC starts.
- Activity of MMC terminates as soon as food is ingested.
- Function of MMC is to sweep material (undigested food residues, dead mucosal cells and bacteria) into colon, keeping the small intestine clean.

4- Antiperistalsis

- A wave of contraction in the alimentary canal that passes in an oral (i.e. upward or backwards) direction and propel the chyme in the opposite direction.
- Occurs between:-
  - Stomach and duodenum to allow more time for neutralization of chyme.
  - Ileum and caecum to allow time for absorption.

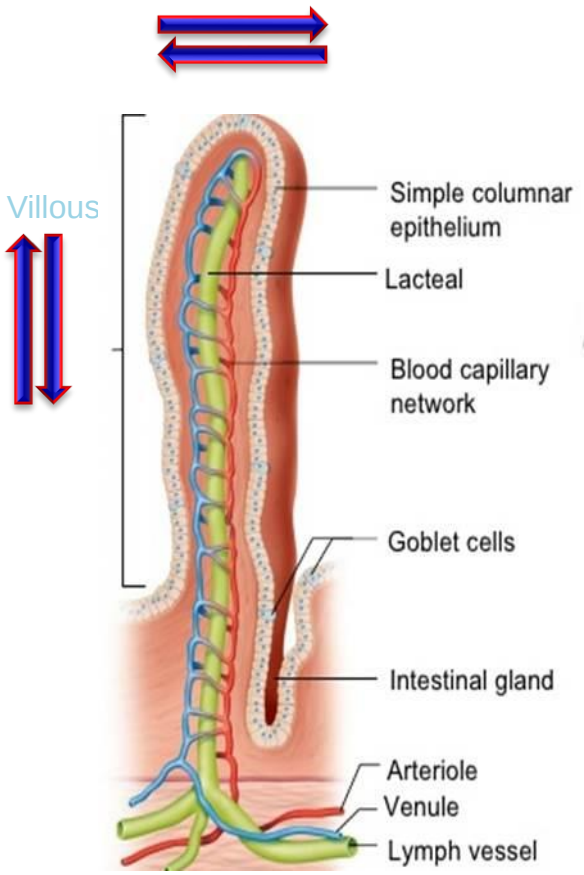


5- Peristaltic rush

- Powerful rapid peristalsis due to intense irritation of intestinal mucosa (as in infectious diarrhea).
- Initiated mainly by extrinsic nervous reflexes to brain stem and back to gut.
- Sweeps the contents of intestine into the colon without much absorption leading to diarrhea and thereby relieving the small intestine of irritative chyme or excessive distension.

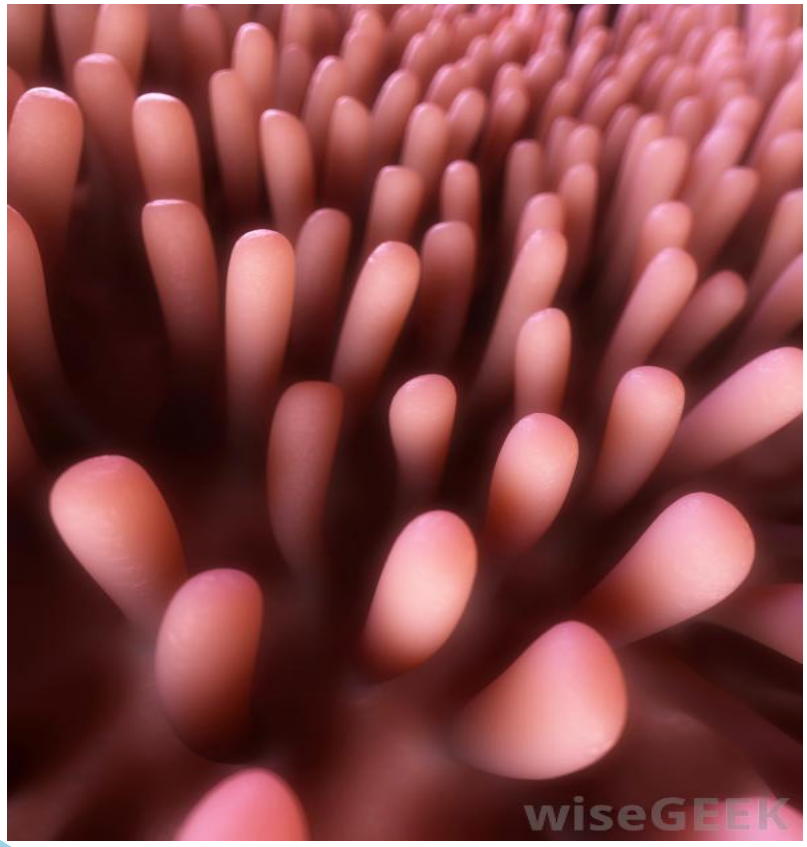
Movements of the Villi

- Initiated by local nervous reflexes in response to chyme in small intestine.
- Consists of fast shortening and slow lengthening as well as side to side movements.
- Stimulated by villikinin hormone released by intestinal mucosa when it comes in contact with digestive products.
- Facilitate absorption and lymph flow from central lacteals into lymphatic system.



Video for Movements of the Villi

- https://www.youtube.com/watch?v=JEuxi2k5tH0&ab_channel=AnnaZielinska



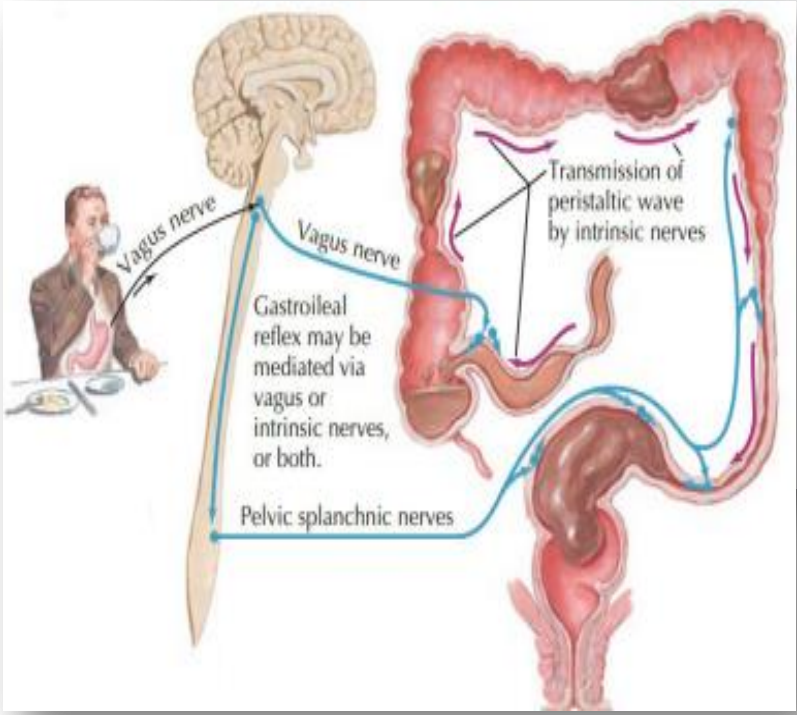
Control of Intestinal Motility

1- Neural Factors

- Vagal excitation increases intestinal and villous movements.
- Sympathetic excitation decreases intestinal and villous movements.

Gastroileal reflex

- Initiated by gastric distension.
- Mediated by vagus nerve.
- Impulses are conducted through myenteric plexus to initiate a fast peristaltic wave passing to the ileum.
- The ileocaecal valve relaxes allowing chyme to pass into cecum.



Control of Intestinal Motility (Cont.)

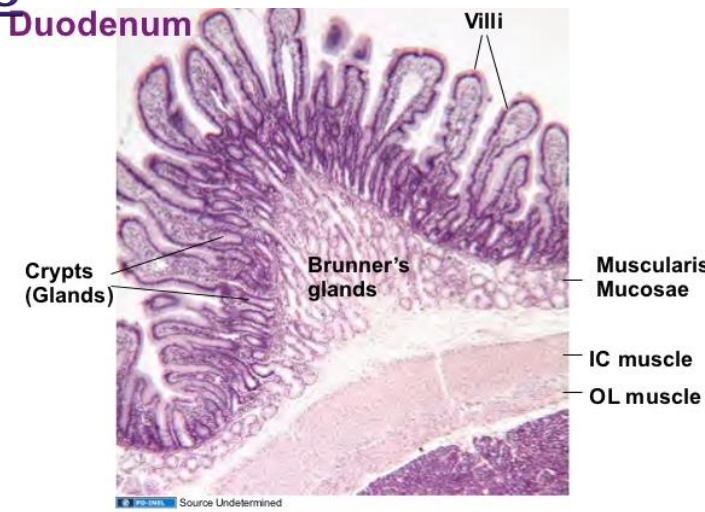
2- Hormonal Factors

- Gastrin, CCK, insulin and serotonin stimulate intestinal motility.
- Motilin secreted from duodenum stimulates intestinal motility and regulate MMC.
- Gastrin and CCK relax ileocaecal sphincter.
- Secretin and glucagon inhibits intestinal motility and contract ileocaecal sphincter.
- Villikinin stimulates movement of the villi.

Secretions of the Small Intestine

Secretion of Mucus by Brunner's Glands in the Duodenum

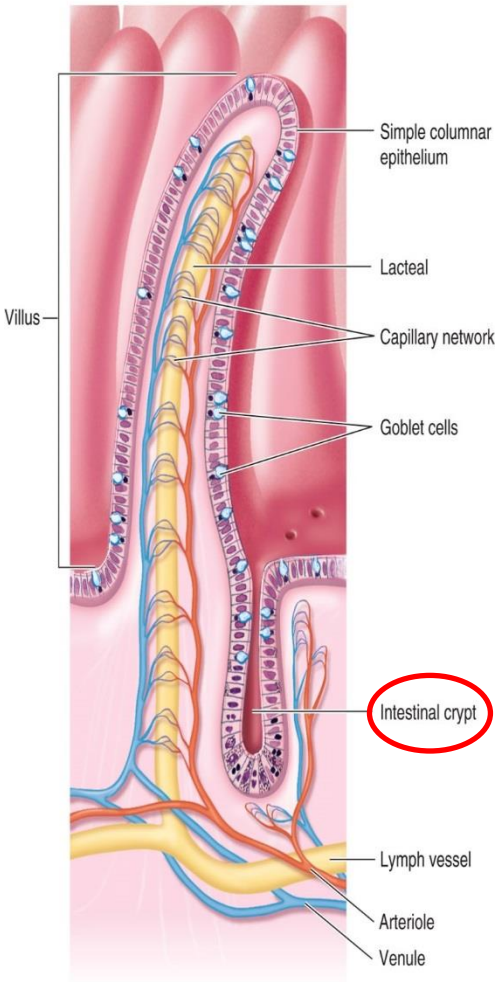
- ***Brunner's glands*** secrete large amounts of alkaline mucus, which contains a large amount of bicarbonate ions.
- Mucus protects the mucosa



(Brunner's glands are diagnostic for duodenum….)

Intestinal Juice (Succus Entericus)

- Secreted from intestinal crypts (small pits which lie between intestinal villi).
- pH: 7.5-8. It participates in the neutralization of acid chyme delivered from stomach.
- The surfaces of both the crypts and the villi are covered by an epithelium composed of 2 types of cells: (1) goblet cells, secrete mucus, and (2) enterocytes, **secrete** large quantities of H_2O and electrolytes and over the surfaces of adjacent villi, **reabsorb** H_2O, electrolytes & end products of digestion.



Control of Intestinal Secretion

Brunner's gland secretion

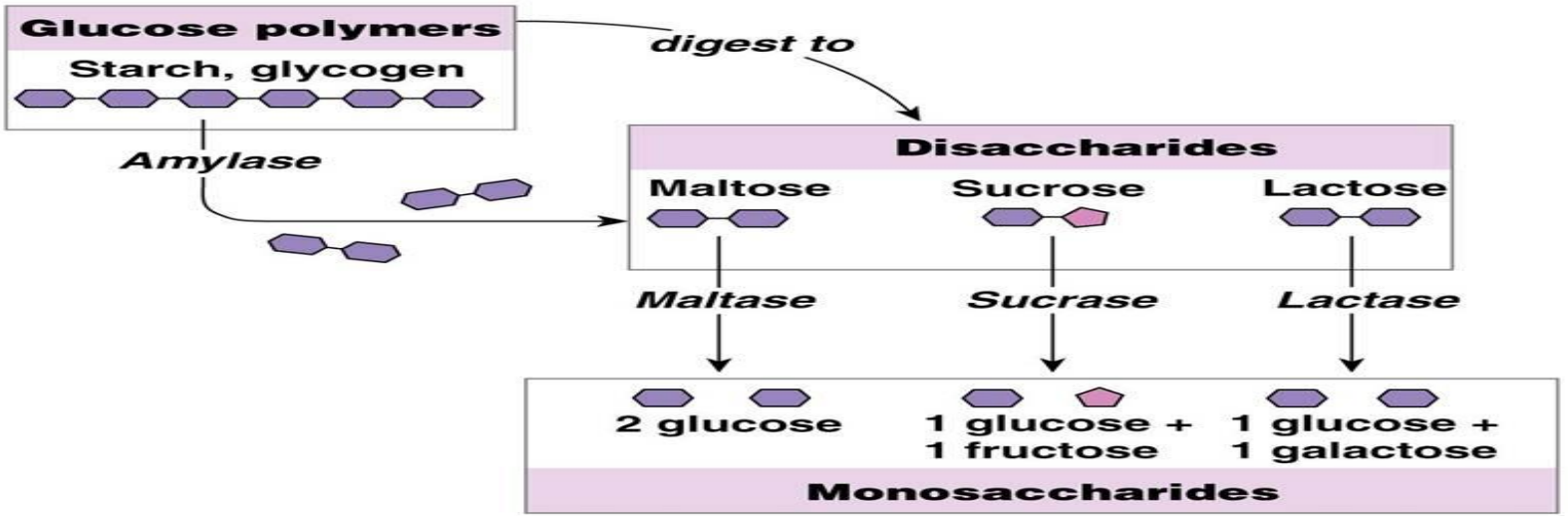
- **Stimulated by:**
  - Secretin
  - Irritating stimuli on the duodenal mucosa
  - Vagal stimulation
- **Inhibited by**
  Sympathetic stimulation

Intestinal juice secretion

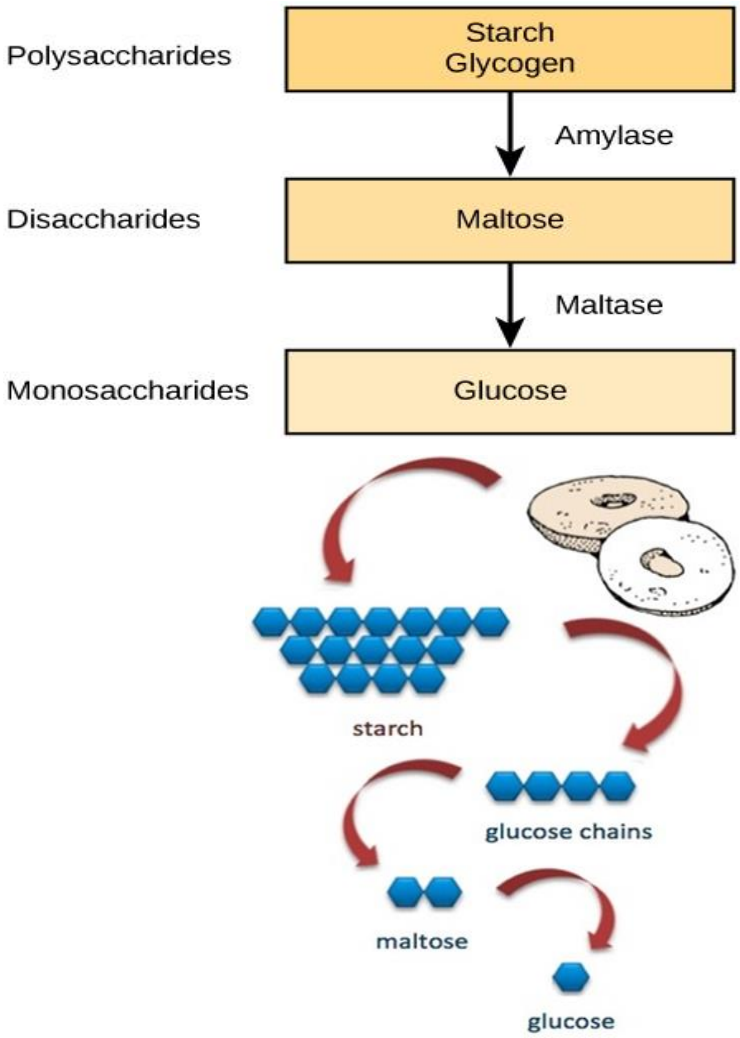
- **Stimulated by:**
  - Distension, tactile and vagal stimulation.
  - Hormones as: gastrin, secretin, CCK, glucagons, enterocrinin.
- **Inhibititd by**
  Sympathetic stimulation

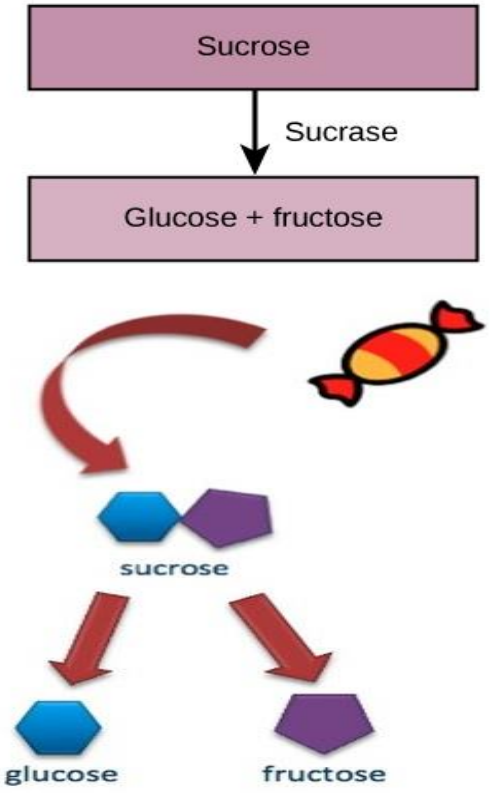
Digestion of Carbohydrates

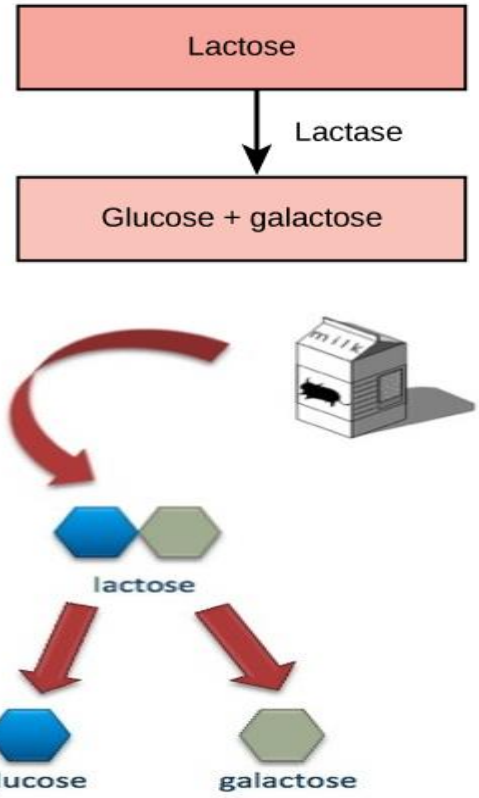
- The enterocytes contain four enzymes (maltase, sucrase, lactase and a-dextrinase), which are capable of splitting the disaccharides lactose, sucrose, and maltose, plus other small glucose polymers, into their constituent monosaccharides.
- These enzymes are located in the enterocytes covering the intestinal microvilli brush border, so that the disaccharides are digested as they come in contact with these enterocytes.



Digestion of Carbohydrates (Cont.)

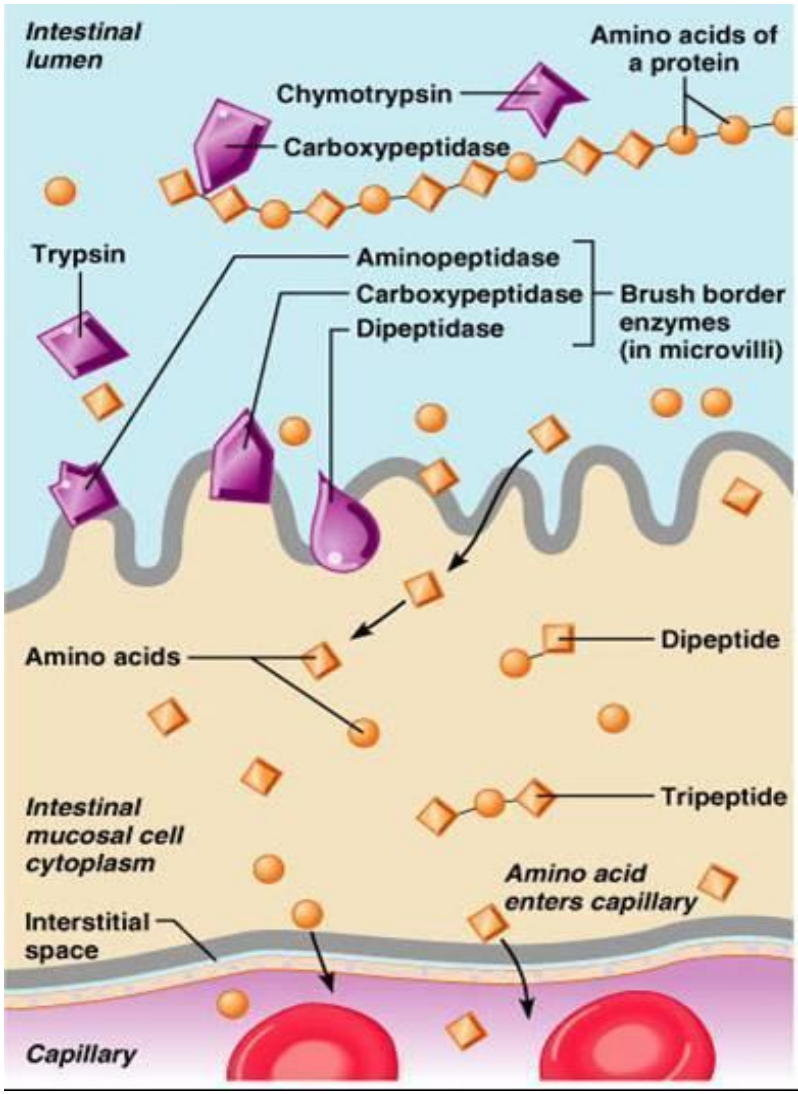






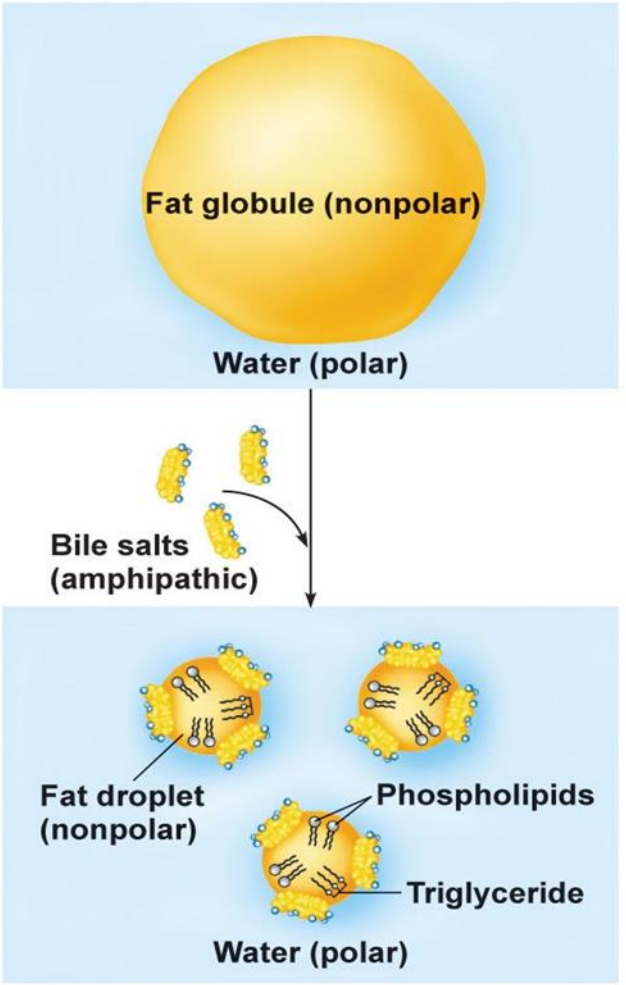
Digestion of Proteins

- A small percentage of proteins are digested to AA by the pancreatic enzymes.
- Most proteins remain as dipeptides and tripeptides
- Most protein digestion occurs in the duodenum and jejunum by aminopeptidases, oligopeptidases, intracellular di- and tripeptidases for splitting small peptides into amino acids.



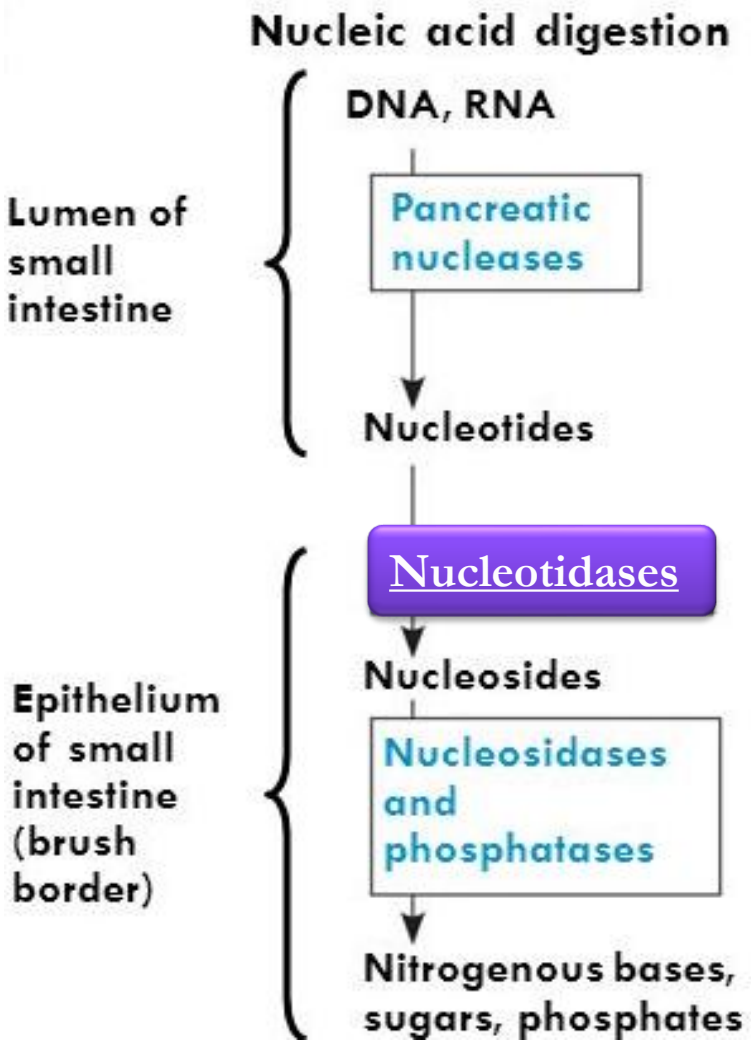
Digestion of Fats

- Less than 10 % of triglycerides is digested in the stomach by lipase.
- All fat digestion occurs in the small intestine.
- Bile salts and lecithin in the bile help fat digestion by making the fat globules readily fragmentable with the water in the small intestine (emulsification of fat).
- Bile salts break the fat globules into very small sizes, so that the water-soluble digestive enzymes can act on the globule surfaces.

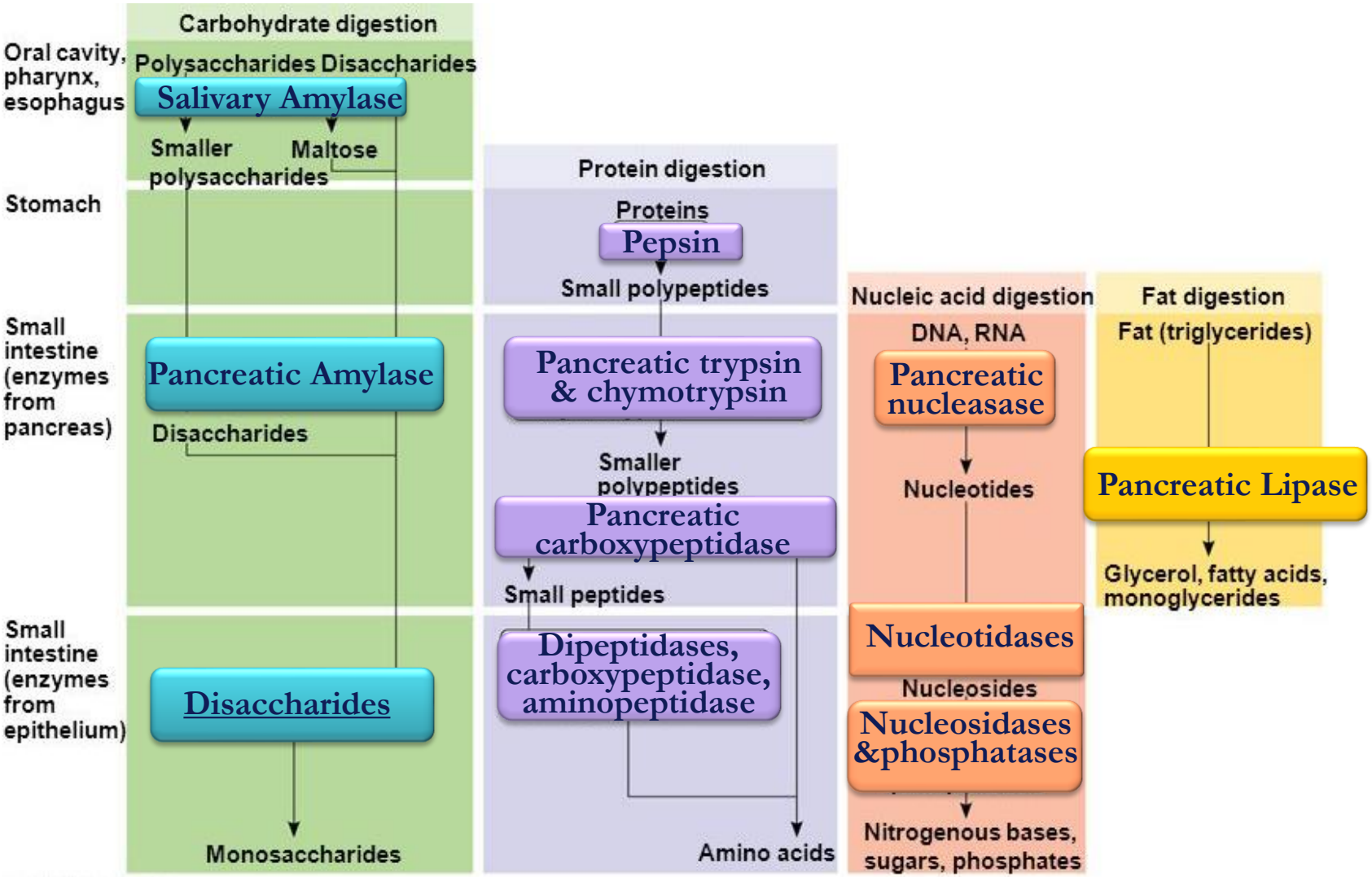


Digestion of Nucleotides

- Intestinal juice also contains **nucleotidases** for splitting nucleotides into nitrogenous bases (purine and pyrimidine), pentose sugar and phosphates.



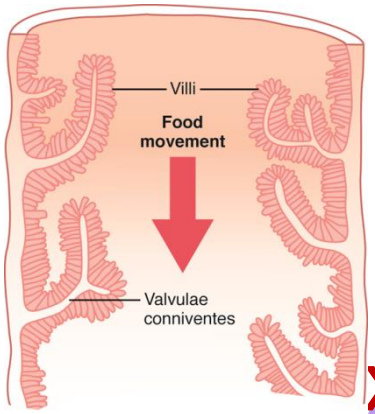
Digestive Enzymes: Could You Now Describe How a Happy Meal is Broken Down?



Basic Principles of Gastrointestinal Absorption

Absorptive Surface of the Small Intestinal mucosa

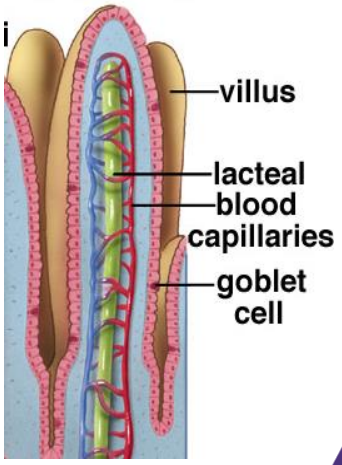
Three factors increase absorptive surface area of the small intestinal mucosa:-



3-fold

Mucosal folds (valvulae conniventes), well developed in the duodenum and jejunum.

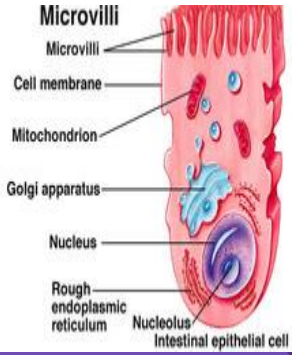
X



10-fold

The villi on the mucosal surface

X



20-fold

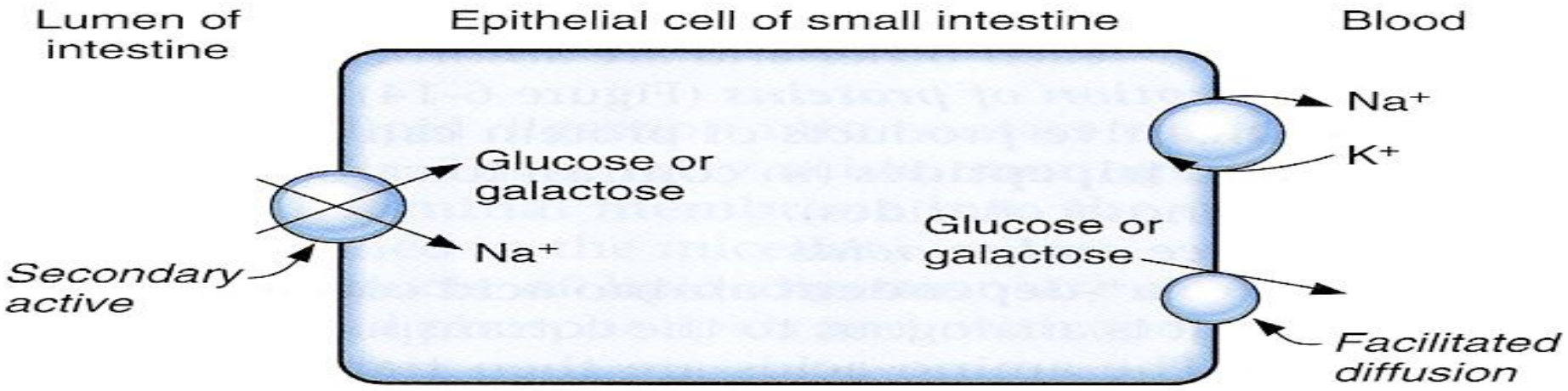
About 1000 microvilli on the epithelial cells of each villus (the brush border).

= 600-fold

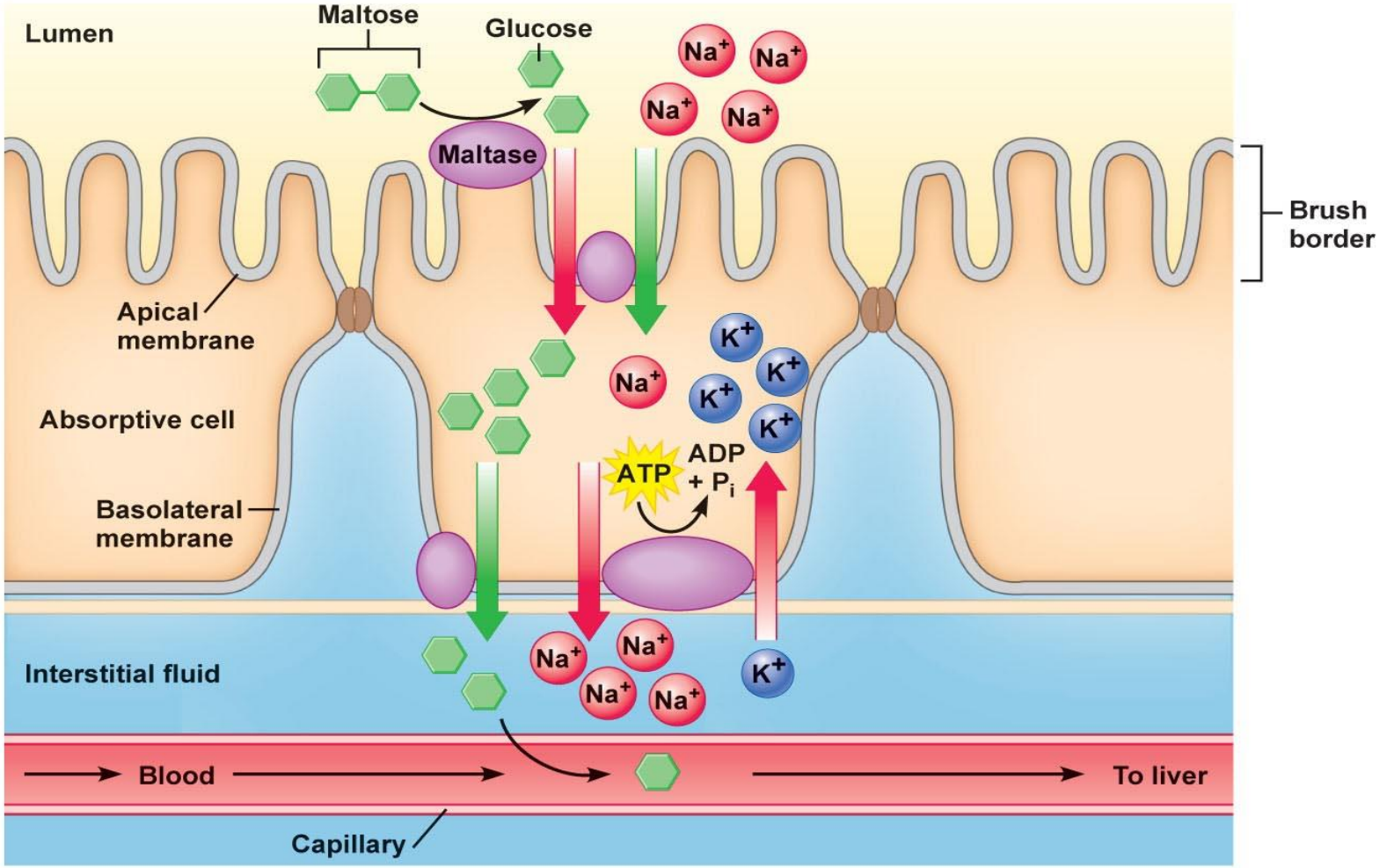
All these increase intestinal surface area (equivalent to a tennis court)

Absorption of Carbohydrates (Cont.)

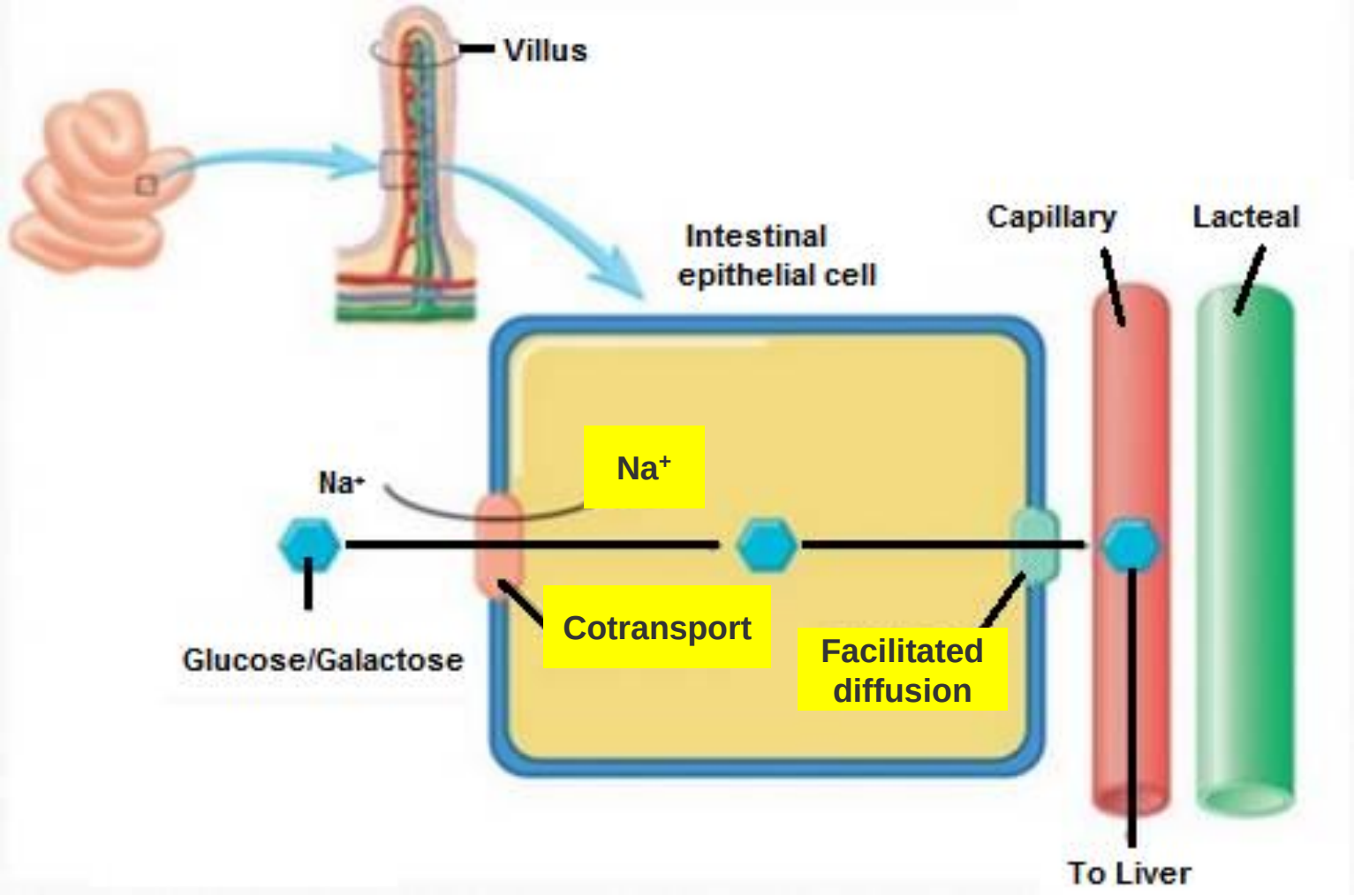
- All the carbohydrates in the food are absorbed in the form of monosaccharides; only a small fraction are absorbed as disaccharides.
- Glucose and galactose absorption occurs in a cotransport mode with active transport of Na^+ (2ry active transport) .
- Fructose is independent on Na^+ but it transports in lumenal membrane via facilitated diffusion.
- Pentose is transported by passive diffusion



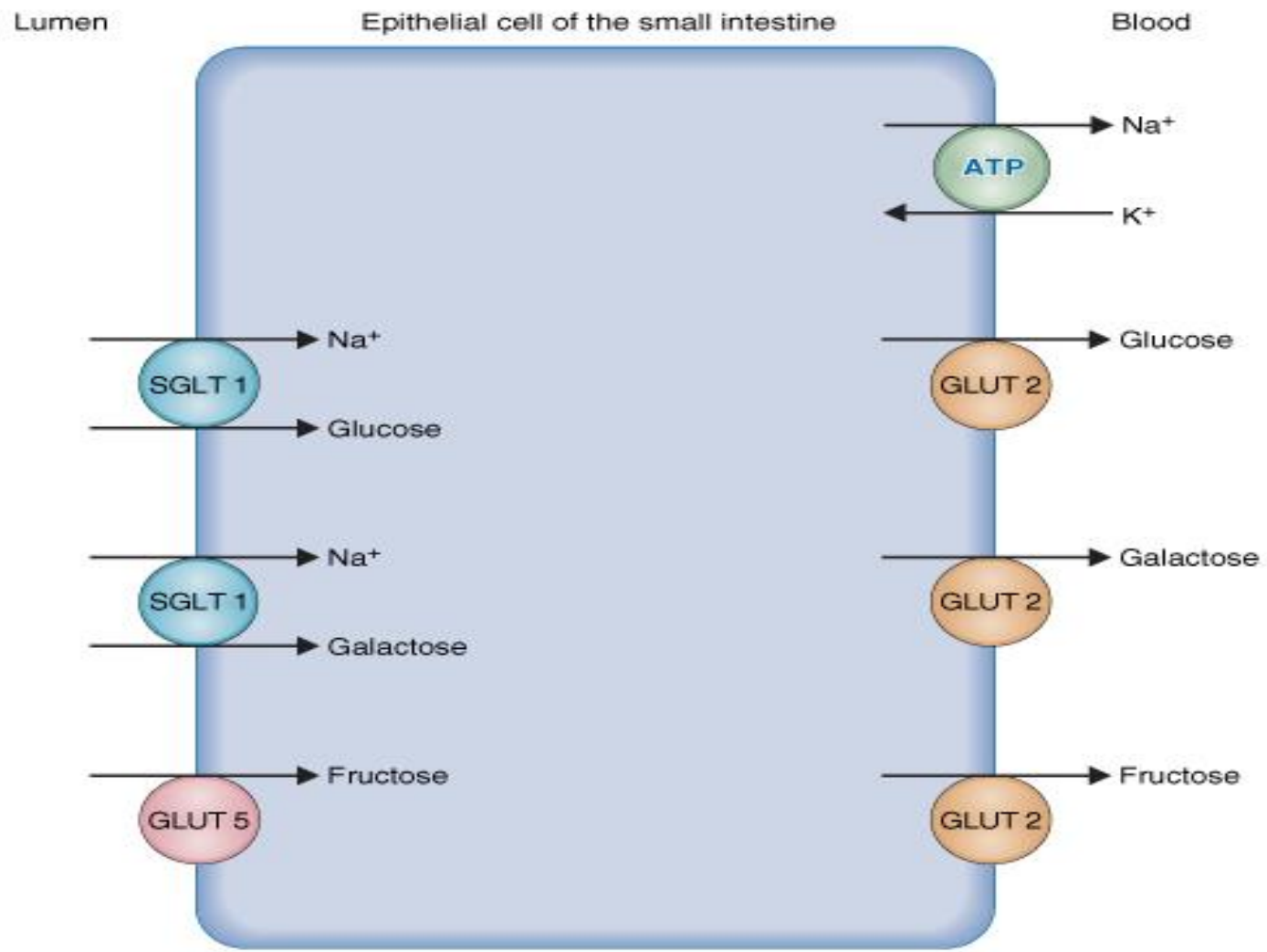
Absorption of Carbohydrates (Cont.)



Absorption of Carbohydrates (Cont.)



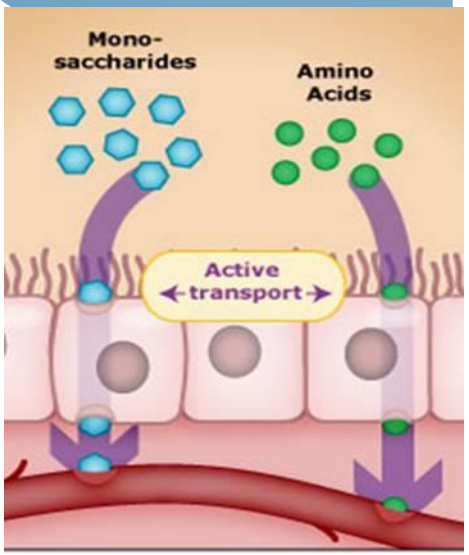
Absorption of Carbohydrates (Cont.)

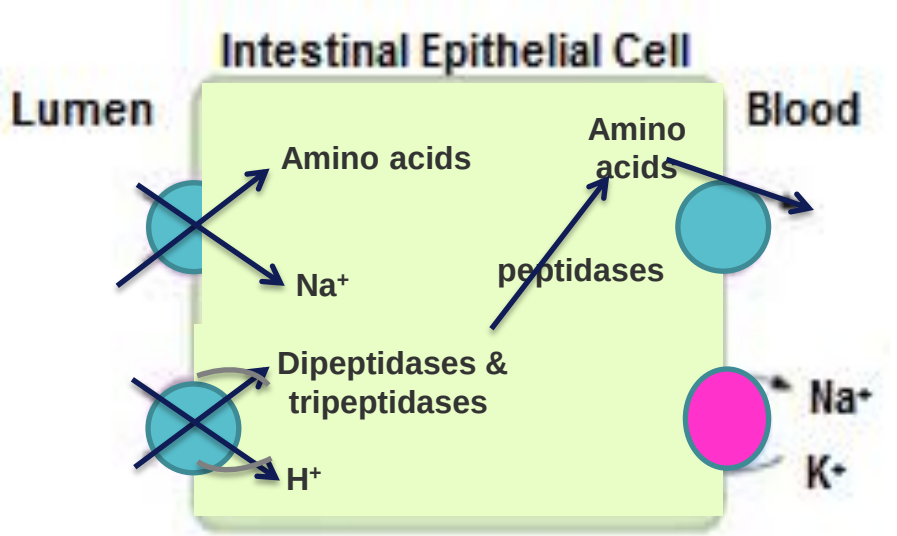


Absorption of Proteins

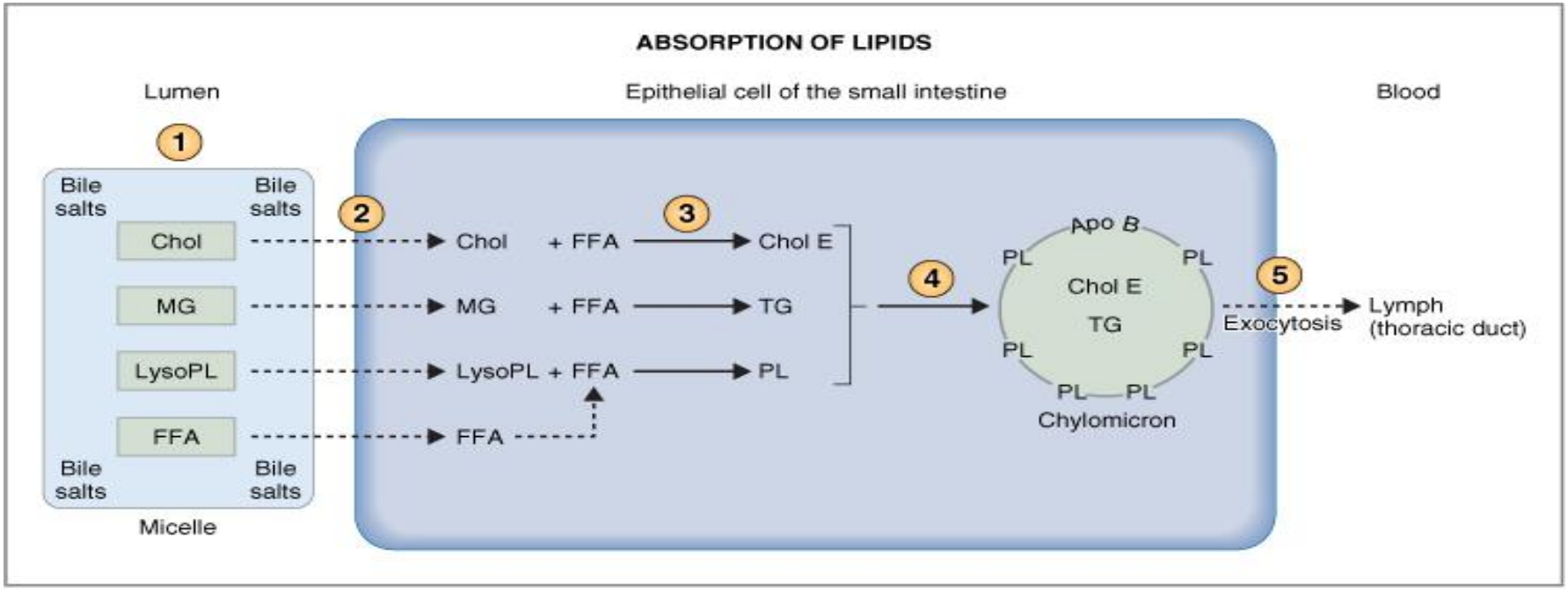
Proteins are absorbed as dipeptides, tripeptides, and a few free amino acids.

- D- AA are transported by passive diffusion.
- L- AA are transported by 2ry active transport.
- Di and tripeptides cross the brush border by active transport protein carrier. They are hydrolyzed by brush border and cytoplasmic oligopeptidases.
- AA leaves the cell at the basolateral membrane by facilitated transport.





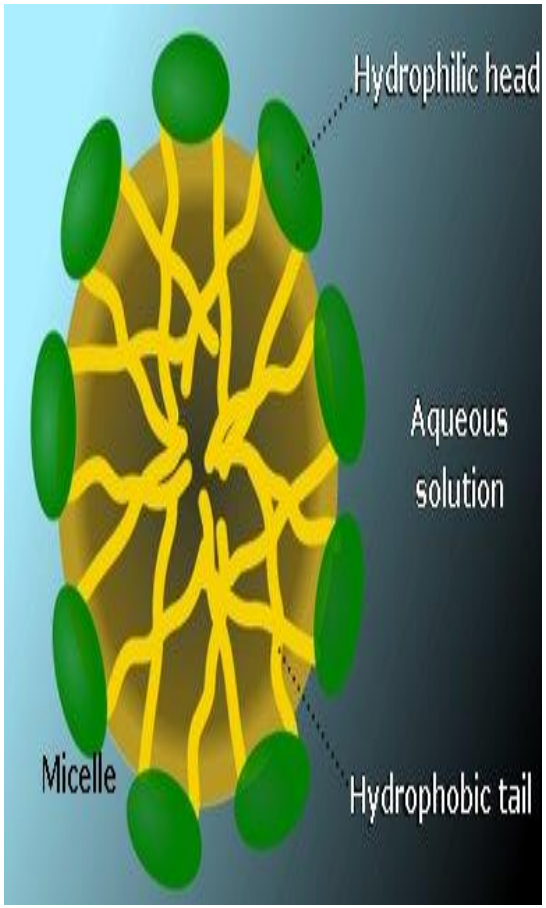
Absorption of Fats



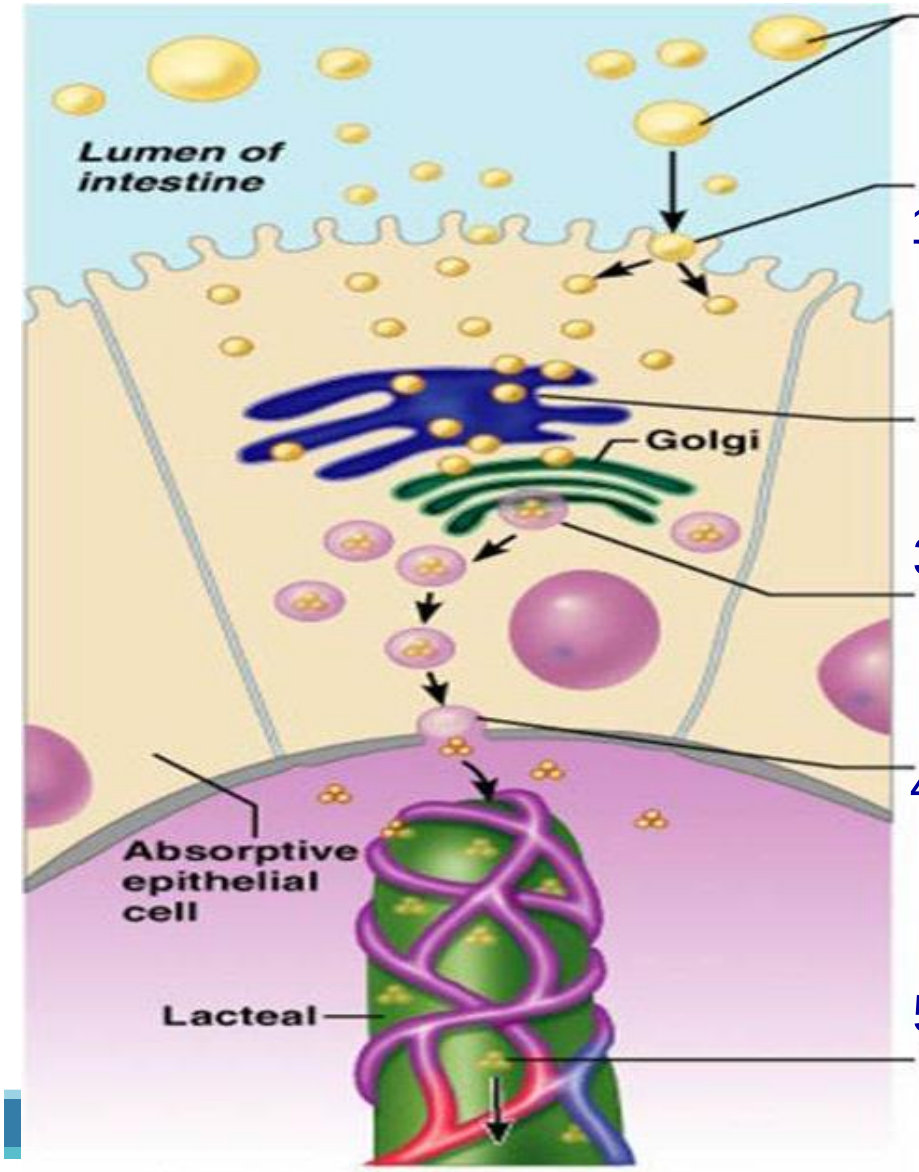
- In the presence of an abundance of bile micelles, about **97 %** of the fat is absorbed.
- In the absence of the bile micelles, only **40 to 50 %** can be absorbed.

Role of Micelles in Fat Absorption

- *B*ile salt are amphipathic molecules, each composed of a sterol nucleus (fat-soluble) and a polar group (water-soluble).
- The polar parts are (-) charged, they allow the entire micelle globule to dissolve in the water of the digestive fluids.
- *Micelles are* small spherical, cylindrical globules composed of 20 to 40 molecules of bile salts.
- Long chain FA, MG, cholesterol and fat soluble vitamins are incorporated into the interior of the micelle.
- In the presence of micelles, about 97 % of the fat is absorbed in the small intestine.
- The micelles carry FA & MG to the luminal borders of the intestinal epithelial cells.



Steps of Fat Absorption



Fatty acids (FA) & monoglycerides (MG) associated with the micelles in lumen of intestine.

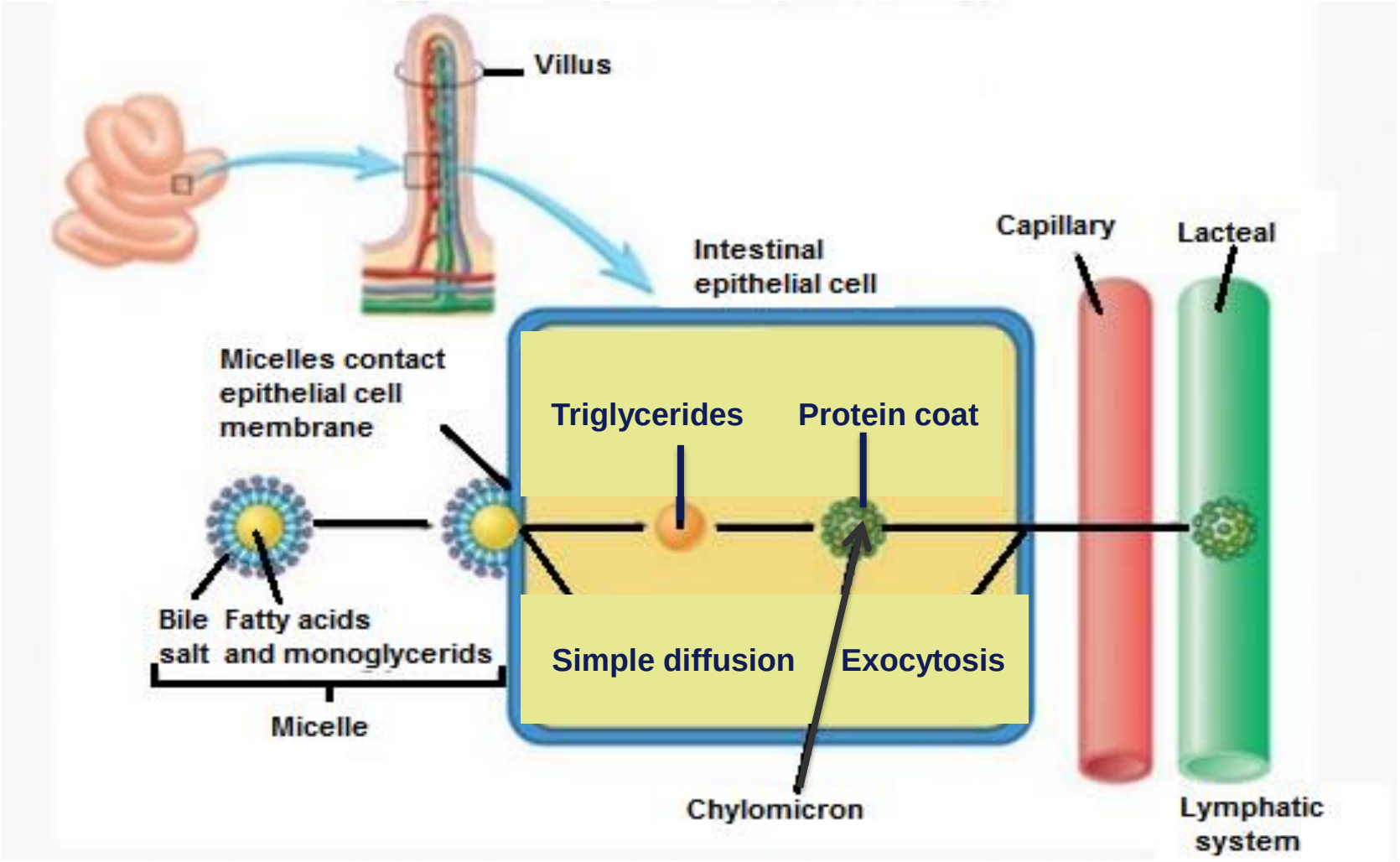
1) FA & MG leave micelles and enter epithelial cell by ***diffusion.***

2) FA are used to synthesis triglycerides in agranular endoplasmic reticulum.

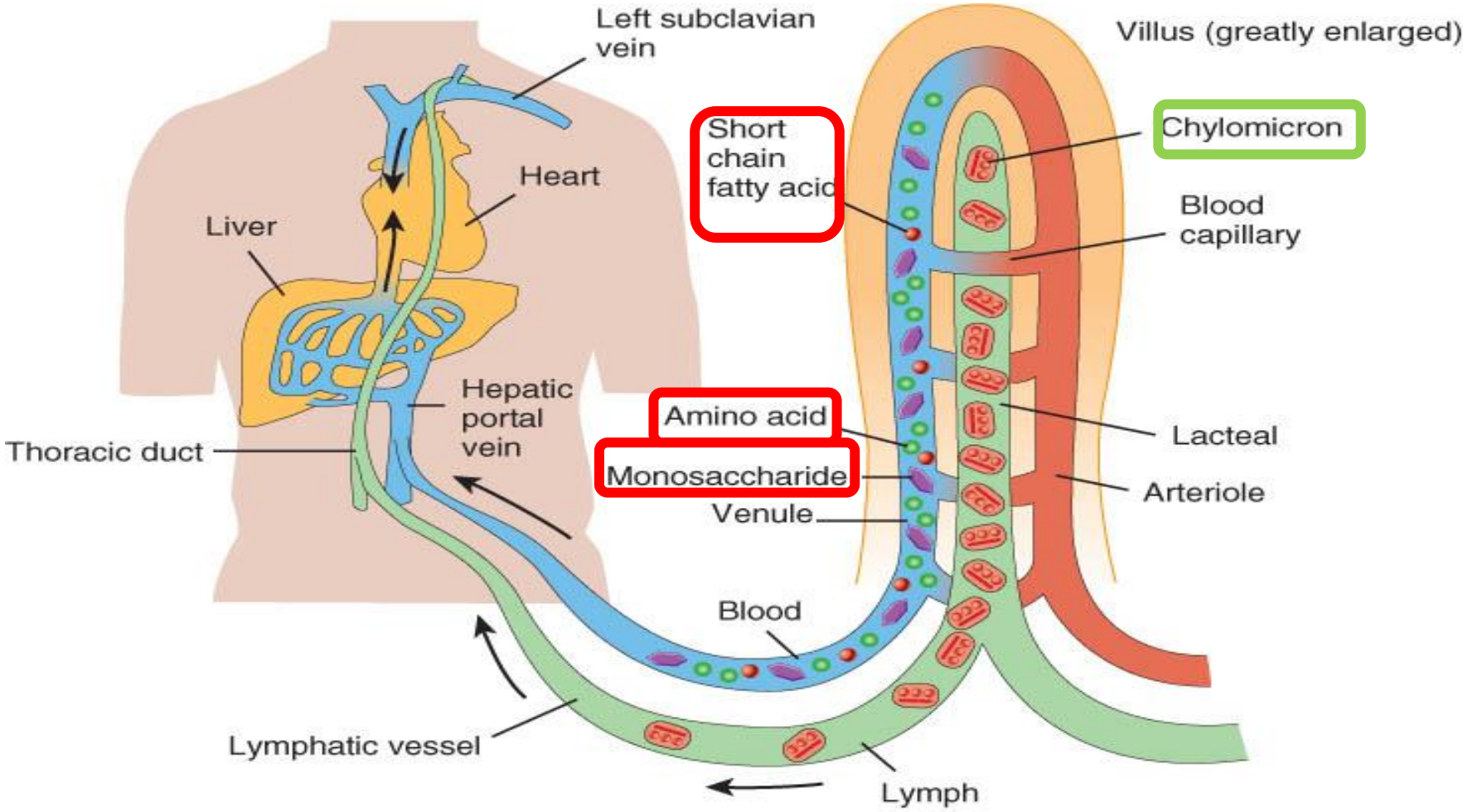
3) Fatty globules are combined with proteins to form ***chylomicrons*** within Golgi apparatus.

4) Vesicles containing chylomicrons leave epithelial cells by ***exocytosis*** and enter ***a lacteal*** (lymph capillary).

5) Lymph in the lacteal transport chylomicrons away from the intestine.


Villus
Intestinal epithelial cell
Capillary
Lacteal
Micelles contact epithelial cell membrane
Triglycerides
Protein coat
Bile salt
Fatty acids and monoglycerids
Micelle
Simple diffusion
Exocytosis
Chylomicron
Lymphatic system

Where will the absorbed nutrients go?

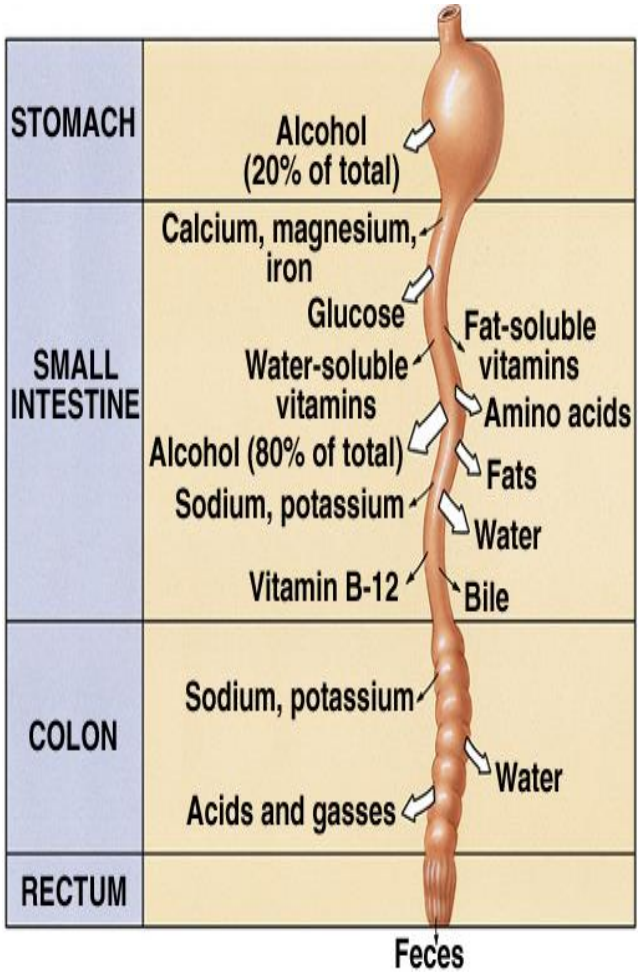


Absorption of Vitamins

a. Fat-soluble vitamins (A, D, E, & K) are incorporated into micelles and absorbed along with other lipids

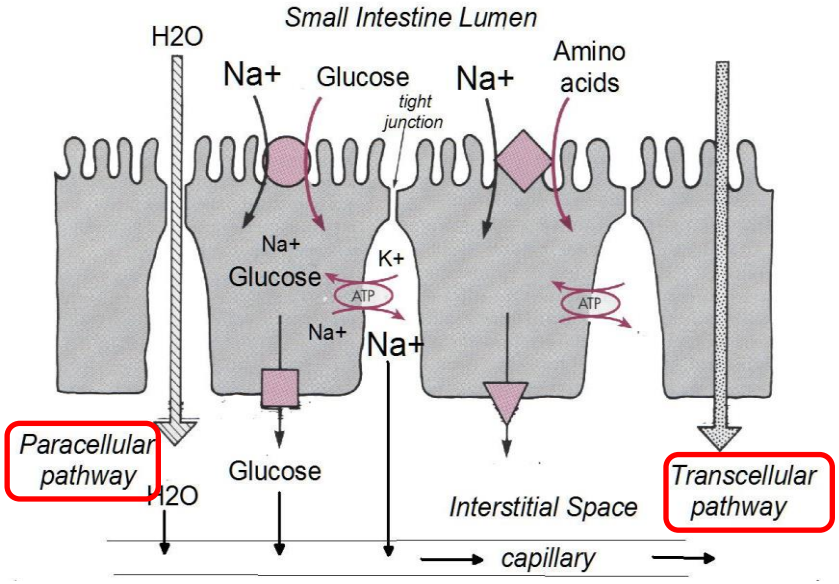
b. Most water-soluble vitamins (C, B_1, B_2, B_6, and folic acid) are absorbed by Na^+-dependent cotransport mechanisms

c. Vitamin B_{12} is absorbed in the terminal part of ileum and requires intrinsic factor
   - Ileal resection can cause vitamin B_{12} deficiency.
   - Gastrectomy results in the loss of parietal cells and loss of intrinsic factor
     → pernicious anemia



Absorption and Secretion of Electrolytes and Water

- Electrolytes and H_2O cross intestinal epithelial cells by either transcellular or paracellular route
- The permeability of the tight junctions varies with the type of epithelium
  - Leaky epithelia are in the small intestine and gallbladder
  - A tight epithelium is in the colon

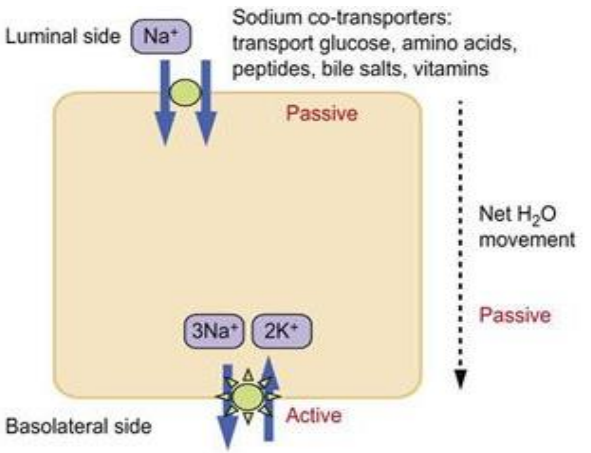


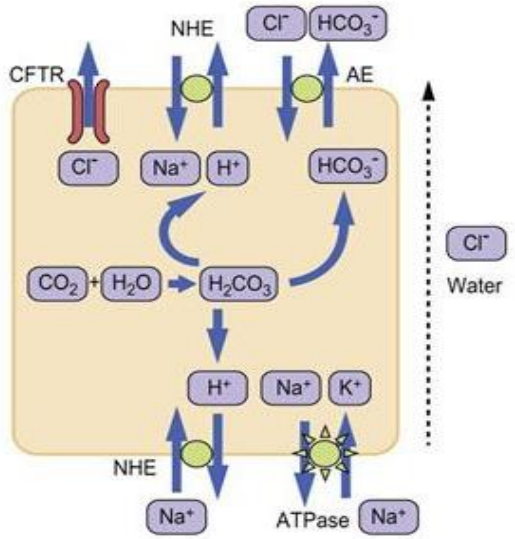
Absorption of Na^+

Na^+ moves into the intestinal cells by the following mechanisms:

1) Passive diffusion.
2) Na^+-glucose or Na^+-amino acid co-transport.
3) Na^+-Cl^- exchange.
4) Na^+-H^+ exchange.

- The next step is osmosis of water into the paracellular spaces.
- **Aldosterone Greatly Enhances Na^+ Absorption.** This effect is especially important in the colon because it allows virtually no loss of NaCl and water.





Absorption of Cl^-

Cl^- absorption accompanies Na^+ absorption by the following mechanisms:

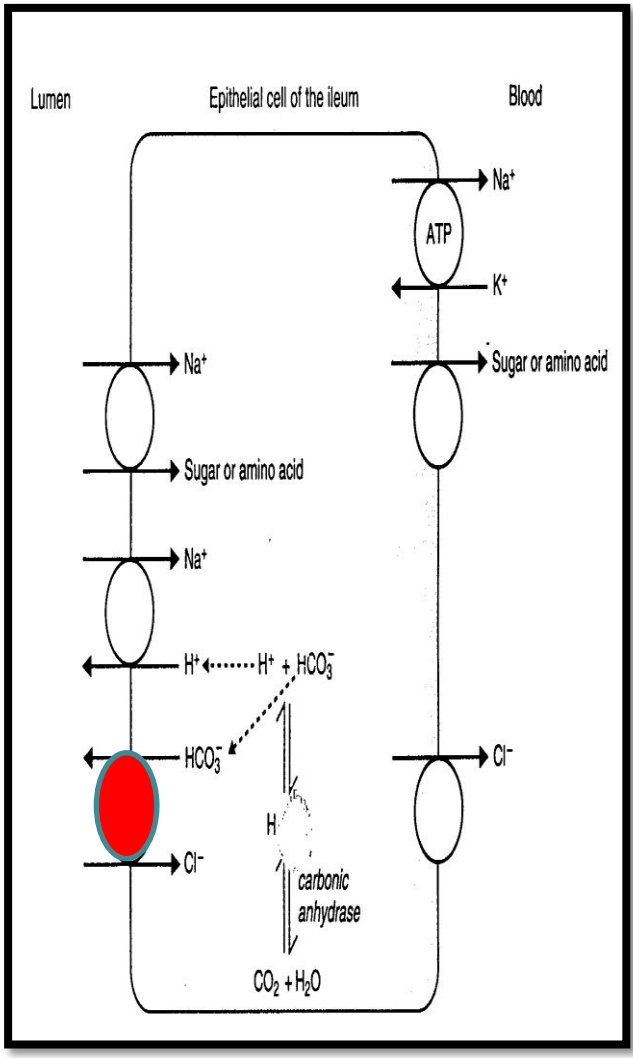
1) Passive diffusion
2) Na^+-Cl^- cotransport
3) Cl^--HCO_3^- exchange

Absorption and secretion of K^+

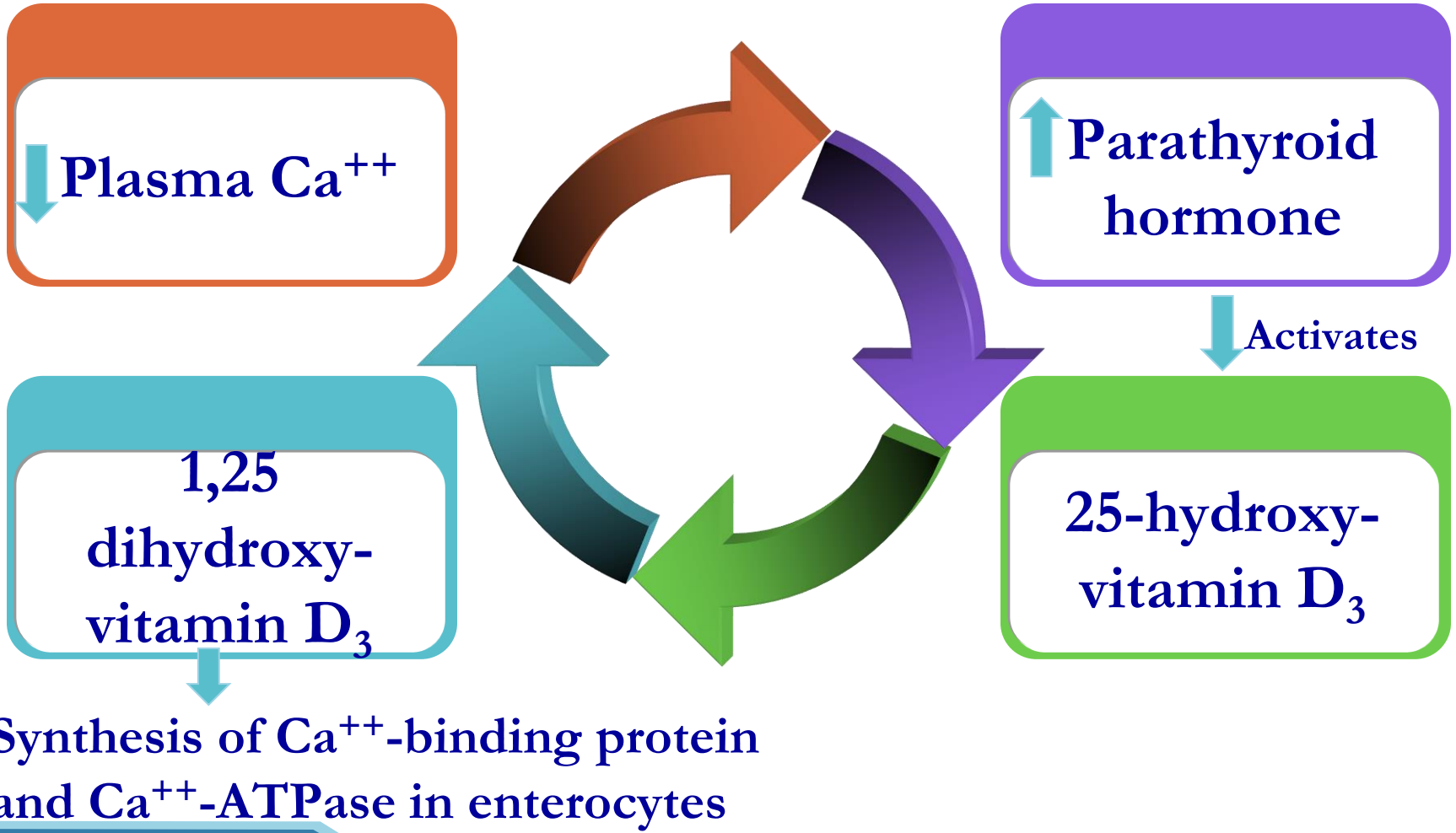
- ✓ K^+ is absorbed in the small intestine by passive diffusion
- ✓ K^+ secretion in the colon is stimulated by aldosterone
- ✓ Excessive loss of K^+ in diarrheal fluids causes hypokalemia

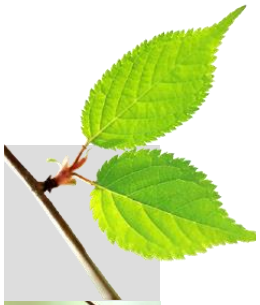
Secretion of HCO_3^- in the Ileum

- The epithelial cells on the surfaces of the villi in the ileum and large intestine have a special capability of secreting HCO_3^- in exchange for absorption of Cl^-.
- This provides alkaline HCO_3^- that neutralize acid products formed by bacteria in the large intestine.



Ca^{++} Absorption by Enterocytes






Thank
You!