



PHYSIOLOGY OF THE SMALL INTESTINE

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- Further explanation

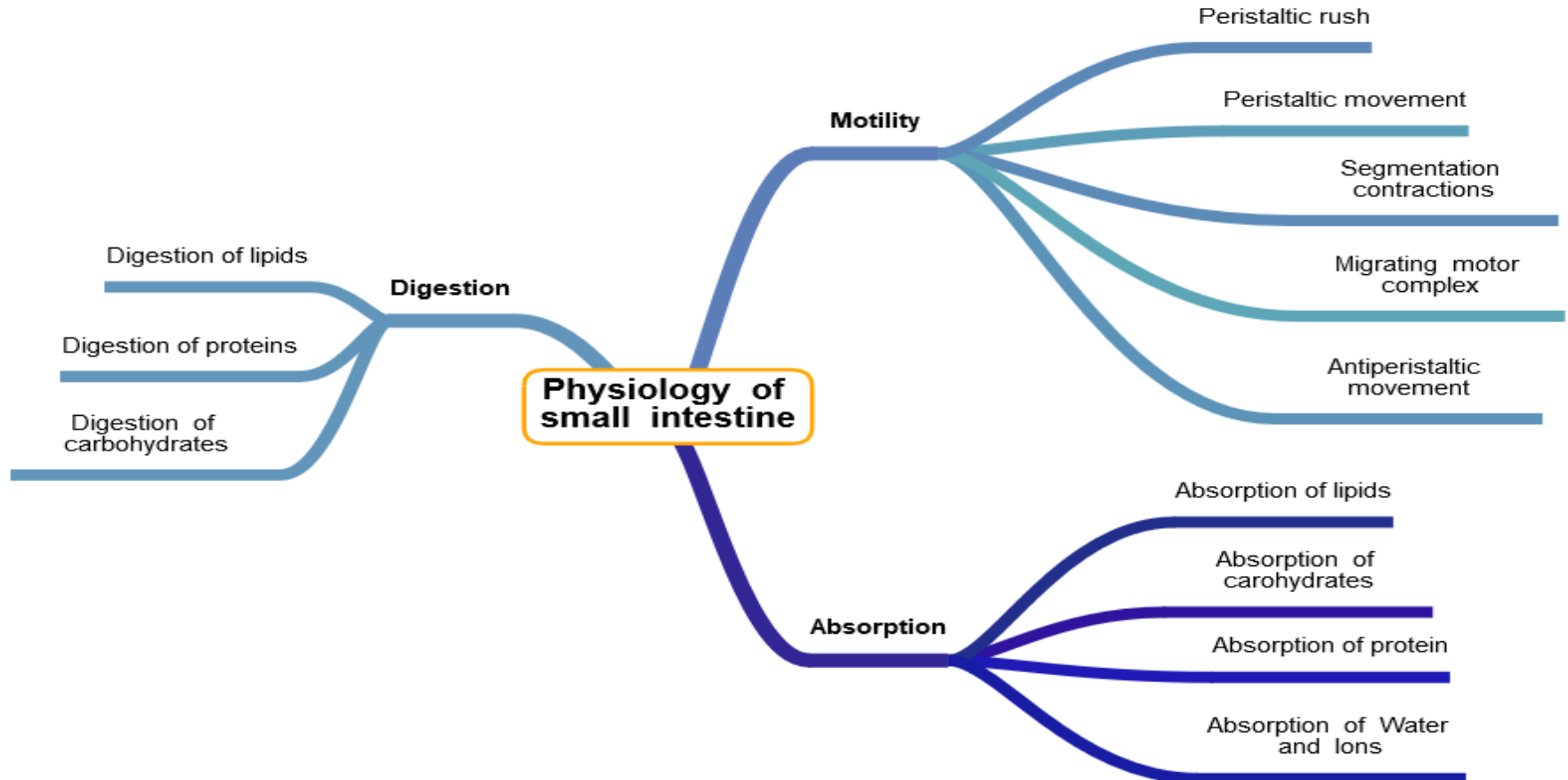


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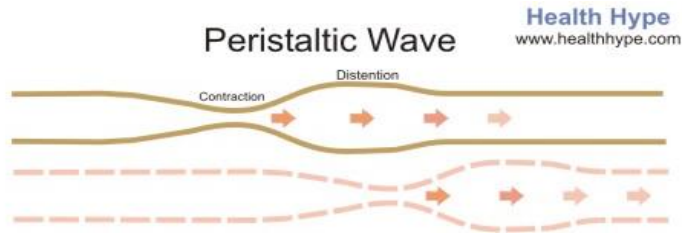


MOTILITY OF THE SMALL INTESTINE

(Intestinal motility is achieved by six types of movements)



1



Contraction ring appears around the gut and moves forward through the alimentary tract.

Usual stimulus is **distention**

- Organizes **propulsion** of material over variable distances.

They are **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).

It is activated by **enteric nervous system**.

They can be blocked by atropine.

2

Segmentation Contraction



A **localized contraction** of circular smooth muscles that constricts the intestine into spaced segments, last for fraction of min.

Usual stimulus is **distention**

- Blend different juices with the chyme
- Bring products of digestion in contact with absorptive surfaces

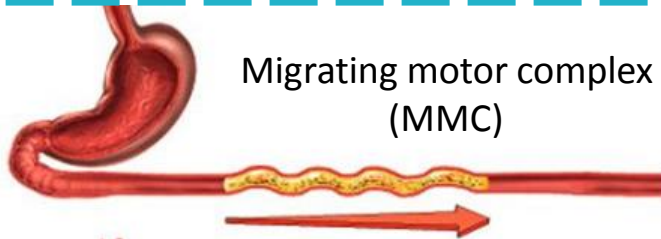
As one set of segmentation contractions relaxes, a new set often begins at points between the previous ones.

It is activated by **enteric nervous system**.

They can be blocked by atropine.

MOTILITY OF THE SMALL INTESTINE (CONT...)

3



Migrating motor complex (MMC)

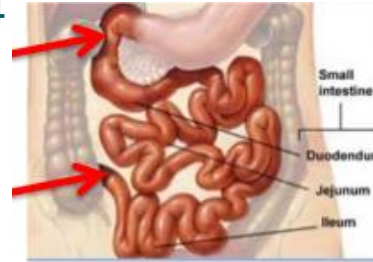
Bursts of depolarization accompanied by peristaltic contraction that begins in empty stomach during interdigestive period (after absorption occurs)

Travels a long whole length of small intestine to reach ileocecal valve after 1.5-2 h. where it disappears. A new wave of MMC starts.

Activity of MMC terminates as soon as food is ingested so Function of MMC is to **sweep material (undigested food residues, dead mucosal cells and bacteria) into colon and keeping the small intestine clean.**

Regulated by autonomic nerves and by release of motilin.

4



Antiperistalsis

A wave of contraction in the alimentary canal that passes in an oral (i.e. **upward or backwards**) direction and force the contents in the opposite direction to the normal.

Occurs normally 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.

MOTILITY OF THE SMALL INTESTINE

Neural control

- **Vagal excitation** increases intestinal and villous movements . (Gastrointestinal reflex is initiated by gastric distension : Impulses are conducted through myenteric plexus to initiate a fast peristaltic wave passing to the ileum. The ileocecal valve relaxes allowing chyme to pass into cecum. This reflex is mediated by vagus nerve)
- **Sympathetic excitation** decreases intestinal and villous movements.

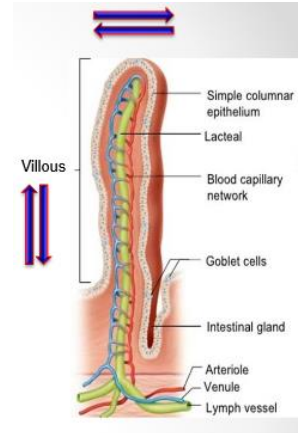
Hormonal control

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

6 Movement of Villi

Consists of tow types of movements :

- **fast shortening and slow lengthening**
- **side to side movements**



Facilitate absorption and lymph flow

from central lacteals into lymphatic system. Initiated by local nervous reflexes in response to Chyme in small intestine. Stimulated by **Villikinin** hormone released by intestinal mucosa when it comes in contact with digestive products.

SECRETION OF THE SMALL INTESTINE

Brunner's glands of the duodenum

Brunner's glands : (submucosal glands) secrete large amounts of **alkaline mucus** ie. Contains large amounts of bicarbonate ions .

This mucus protects the mucosa from the acidic chyme coming from the stomach.

Brunner's glands are stimulated by :

- (1) irritating (tactile) stimuli on the duodenal mucosa
- (2) vagal stimulation
- (3) Secretin hormone

Brunner's glands are **inhibited** by sympathetic stimulation

Intestinal crypts secretions

Intestinal Juice (Succus Entericus) is secreted by the intestinal crypts which are small pits between the villi.
Volume: 1800 ml/day. pH: 7.5-8

It participates in **the neutralization** of acid Chyme delivered from stomach.

Composition: 0.6 % organic, 1 % inorganic substance

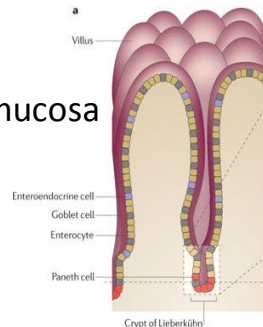
Most of the enzymes are found either in the brush border or in the cytoplasm of the **enterocytes**.

The enzymes that are actually secreted into the lumen are **Enteropeptidase** and **amylase**

stimulated by:

- (1) Distension, tactile and vagal stimulation.
- (2) Hormones as gastrin, secretin, CCK, glucagon, enterocrinin.

Sympathetic stimulation exerts an **inhibitory** effect.



DIGESTION IN THE SMALL INTESTINE

Carbohydrates

- The enterocytes contain four enzymes (lactase, sucrase, maltase, and α -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.

Proteins

A small percentage of proteins are digested to Amino Acids by the pancreatic juices. (which contains Enteropeptidase)

But most proteins remain as **dipeptides and tripeptides** (which will be digested intracellularly)

Most protein digestion occurs in the duodenum and jejunum by aminopeptidases, oligopeptidases, intracellular di and tripeptidases.

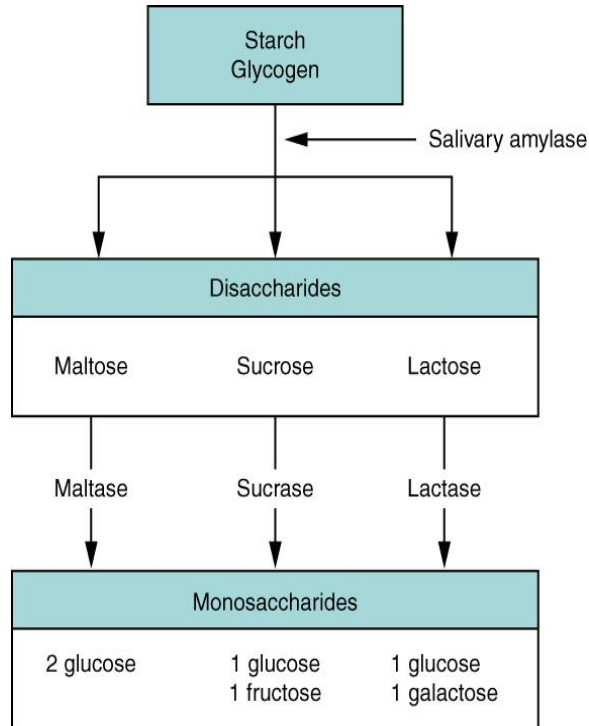
Lipids

- Bile salts and lecithin in the bile (type of phospholipids produced in the liver) help fat digestion by making the fat globules readily fragmentable with the water in the small intestine (**emulsification of fat**).

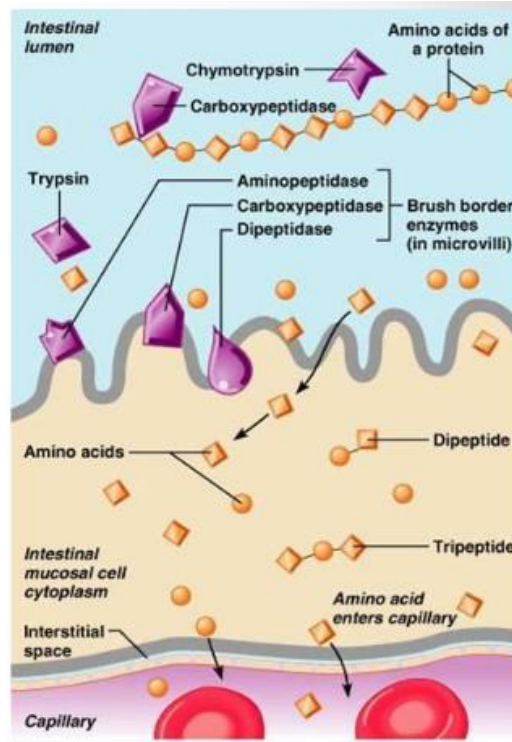
- Bile salts break the fat globules into very small sizes, so that the water-soluble digestive enzymes can act on the globule surfaces.

DIGESTION IN THE SMALL INTESTINE

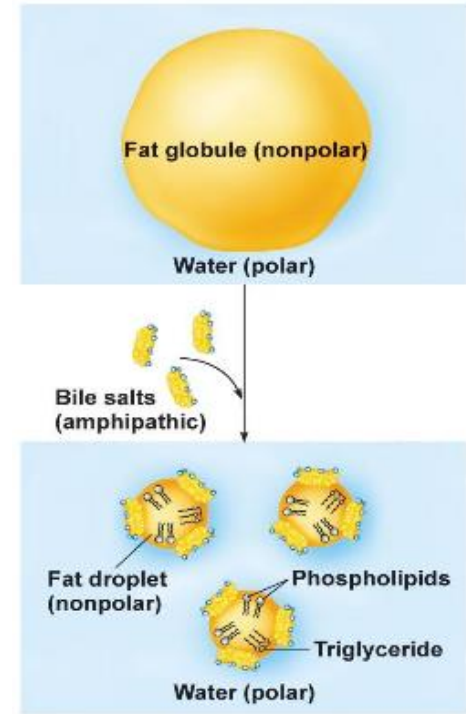
Carbohydrates



Proteins

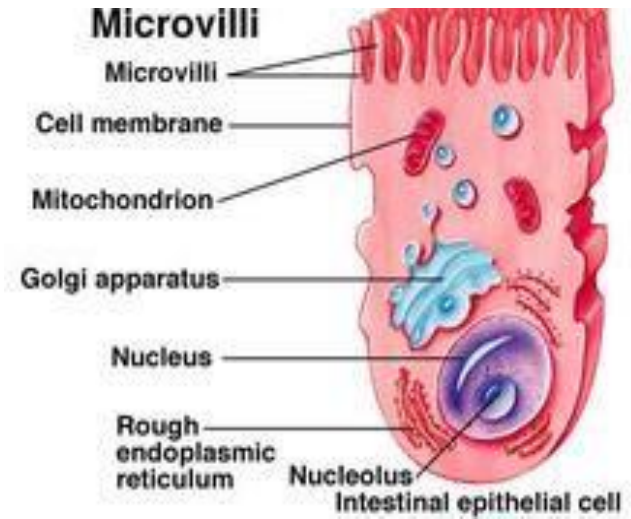
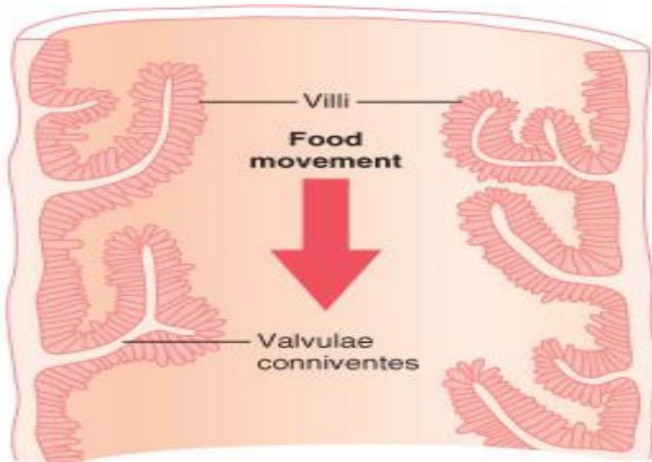


Lipids



ABSORPTIVE SURFACE OF THE SMALL INTESTINAL

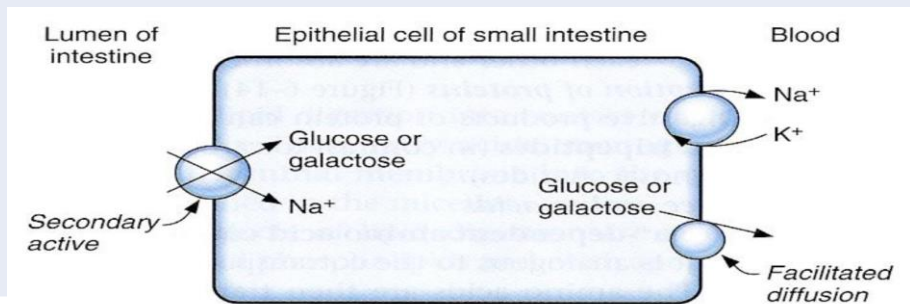
- The absorptive surface of the small intestinal mucosa, showing many folds called **valvulae conniventes** -well developed in the duodenum and jejunum- increase the surface area of the absorptive mucosa about **3-fold**.
- The presence of **villi on the mucosal surface** enhances the total absorptive area another **10-fold**.
- The **epithelial cell on each villus** is characterized by a brush border, consisting of as many as 1000 microvilli (increases the surface area another **20-fold**).



Absorption of carbohydrates

All the carbohydrates in the food are absorbed in the form of monosaccharides; only a small fraction are absorbed as disaccharides.

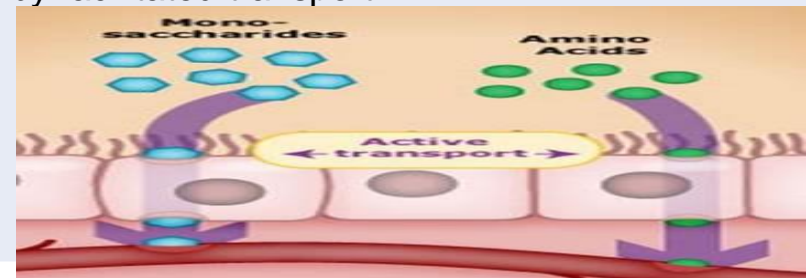
- Glucose and galactose absorption occurs in a cotransport mode with active transport of Na (2ry active transport) .
- Fructose is independent on Na⁺ but it transports in luminal membrane via facilitated diffusion.
- Pentose is transported by passive diffusion



Absorption of protein

Proteins are absorbed in the form of 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 FAT

- 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.

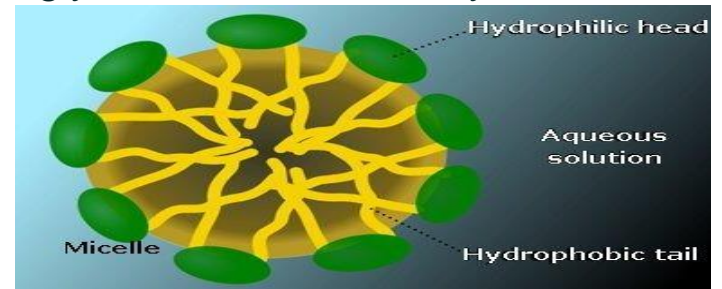
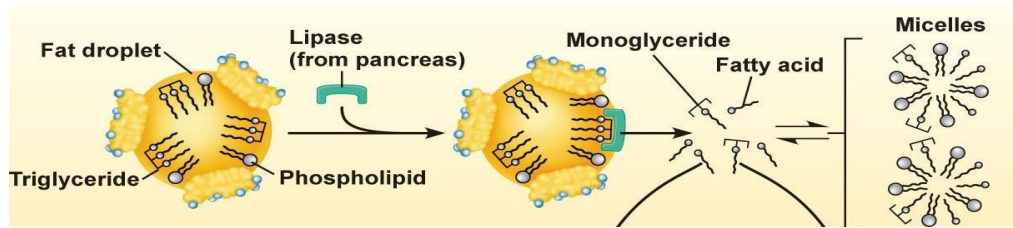
FORMATION OF MICELLES:

Bile salts are **amphipathic** molecules, each composed of a sterol nucleus (fat-soluble) and a polar group (water-soluble)

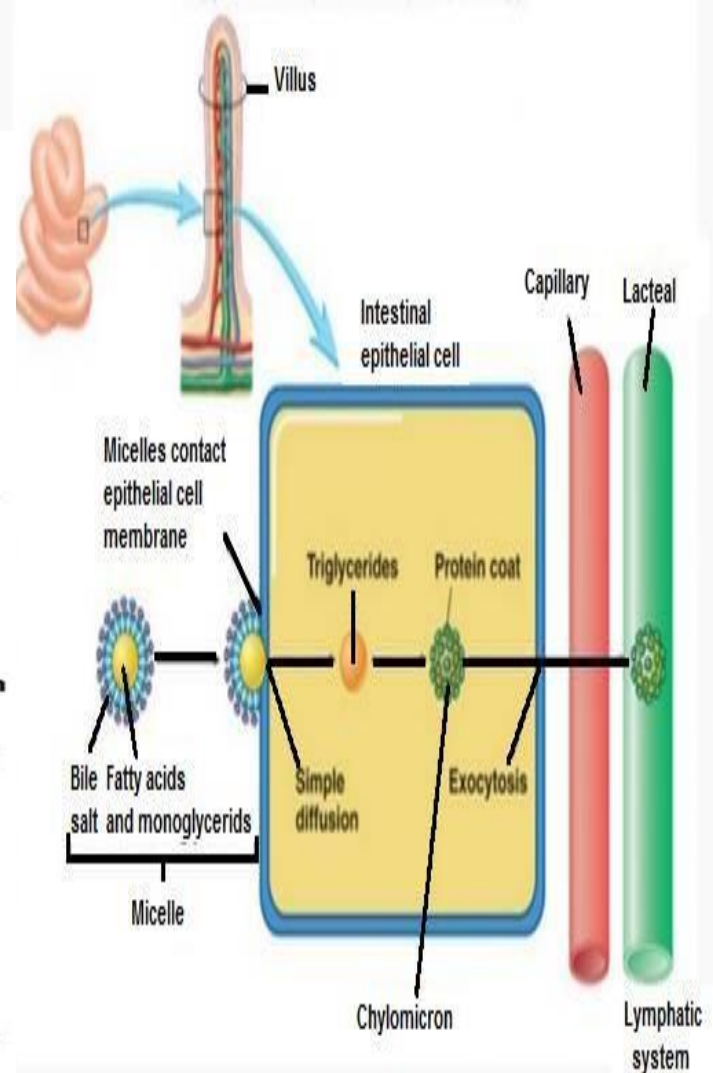
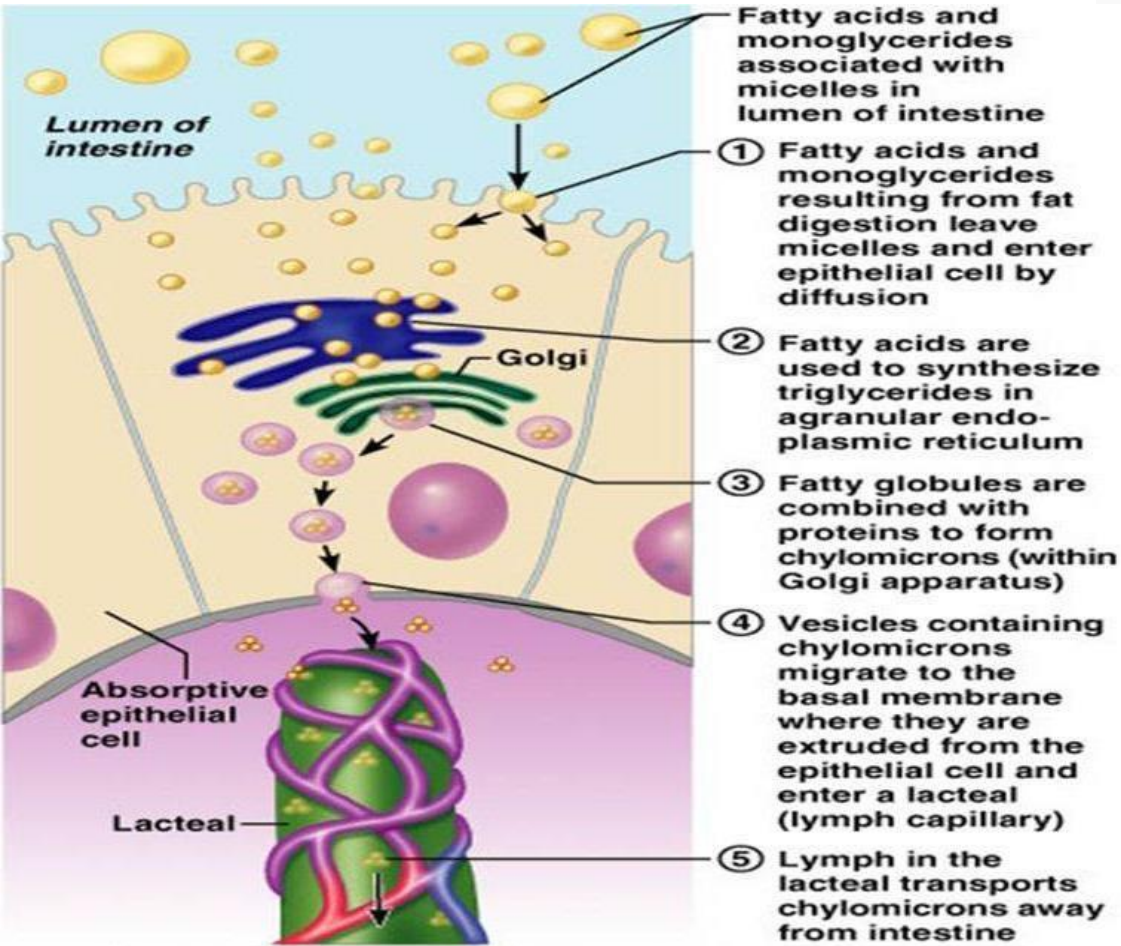
Micelles are small spherical, cylindrical globules 3 - 6 nm in diameter composed of 20 - 40 molecules of bile salts.

The polar parts are (-ve) charged, they allow the entire micelle globule to dissolve in the water of the digestive fluids.

The micelles act as a transport medium to carry the monoglycerides and free fatty acids to the brush borders of the intestinal epithelial cells.



STEPS OF FAT ABSORPTION



ABSORPTION OF VITAMINS

Fat-soluble vitamins	water-soluble vitamins
A, D, E, & K	C, B1, B2, B6, and folic acid B12 *
incorporated into micelles and absorbed along with other lipids	are absorbed by Na ⁺ -dependent cotransport mechanisms • * absorbed in the ileum and requires intrinsic factor

- Gastrectomy results in the loss of parietal cells and loss of intrinsic factor → pernicious anemia

ABSORPTION + SECRETION OF ELECTROLYTES AND WATER

Electrolytes and H₂O cross intestinal epithelial cells by: •

- 1- cellular
- 2-paracellular route

The permeability of the tight junctions varies with the type of epithelium •

1-Leaky epithelia are in the small intestine and gallbladder

2-A tight epithelium is in the colon



Secretion Of Electrolytes

K ⁺	HCO ₃ ⁻
K ⁺ secretion in the colon is stimulated by aldosterone (loss of K ⁺ in diarrhea causes Hypokalemia)	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.

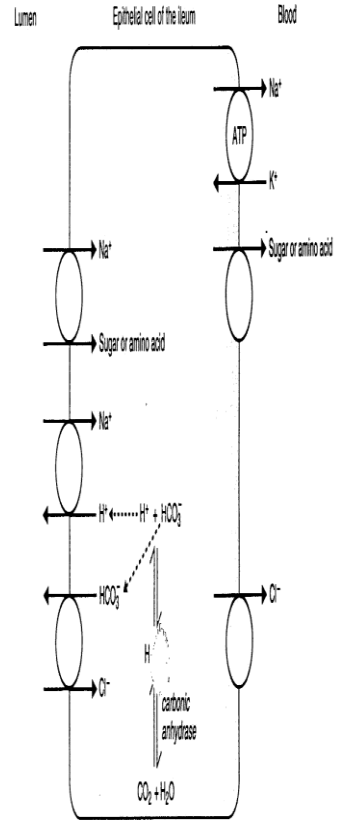
ABSORPTION OF ELECTROLYTES

Electrolytes	Absorption mechanism
Na ⁺	1-Passive diffusion 2-Na ⁺ -glucose or Na ⁺ -amino acid co-transport 3-Na ⁺ -Cl ⁻ exchange 4-Na ⁺ -H ⁺ exchange (The next step in the transport process is osmosis of water into the paracellular spaces because a large osmotic gradient has been created by the elevated concentration of ions in the paracellular space) NOTE : Aldosterone Greatly Enhances Na ⁺ Absorption, so almost no NaCl & water loss
Cl ⁻	accompanies Na ⁺ absorption by mechanisms: 1-Passive diffusion 2-Na ⁺ -Cl ⁻ cotransport 3- Cl ⁻ HCO ₃ ⁻ exchange
K ⁺	Passive diffusion
Ca ⁺⁺ absorption by enterocytes.	↓ Plasma Ca ⁺⁺ → Parathyroid hormone (it goes to kidney & activate Vit. D in order to absorb more Ca ⁺⁺ in intestine) 25-hydroxy-vitamin D3 (inactive) > In kidney> 1,25 dihydroxy-vitamin D3 (active). → Stimulates synthesis of Ca-binding protein and Ca-ATPase in enterocytes.

HORMONAL CONTROL OF ABSORPTION & SECRETIONS OF ELECTROLYTES

Hormones		Action
Glucocorticoid		absorption of H ₂ O & ions (small & large intestine)
Somatostatin		H ₂ O & ions absorption (ileum & colon)
Epinephrine		NaCl absorption (ileum)
Aldosterone		synthesis of Na ⁺ channel (colon)
Catecholamines		Intestinal secretion

B Ileum



Answer key: 1-b 2-d 3-a 4-c 5-d 6-a 7-c

1- Which of the following participates in Emulsifications?

- A. Gastrin
- B. Lecithin
- C. Enteropeptidase
- D. Amylase

2-Peristalsis moves food material:

- A. In the stomach and small intestine only
- B. In the intestine only
- C. In the stomach only
- D. From the pharynx to the anal canal

3-Secretin is a hormone that :

- A. Stimulate the release of pancreatic juice
- B. Converts trypsinogen to trypsin
- C. Inhibits the action of pancreatic lipase
- D. Relaxes the pyloric sphincter

4- Obstruction of the bile duct will affect mostly the digestion of :

- A. Proteins
- B. Sugars
- C. Fat
- D. Nucleic acids

5- Which of the following is absorbed by passive diffusion?

- A. Glucose
- B. Maltose
- C. Fructose
- D. Pentose

6- Calcium binding proteins are synthesized in ...:

- A. Enterocytes
- B. Hepatocytes
- C. Bone marrow
- D. Muscles

7- Chloride is absorbed accompanied by which of the following ions ?

- A. Hydrogen ions
- B. Potassium
- C. Sodium
- D. Glucose

Q1: Describe the absorption of Vitamin B12.

Ans: Vitamin B12 is absorbed in the ileum and requires intrinsic factor.

Q2: What are the steps of fat absorption ?

Ans: 1- monoglycerides and fatty acids leave the micelles to diffuse into the epithelial cells of enterocytes.
2- triacylglycerides are synthesized from fatty acids by the endoplasmic reticulum
3- Triacylglyceride combines with apolipoproteins to form chylomicrons in Golgi apparatus .
4- chylomicrons then migrate from enterocytes to the lacteal lymph node which will transport them away.

Q3: Where and how are the Tripeptidases digested ?

Ans: intracellularly by brush border and cytoplasmic oligopeptidase.

Q4: What is the effect of sympathetic stimulation on secretions and motility ?

Ans: Inhibition of both

Q5: What is the effect of Gastrin on the GI tract ?

Ans: Stimulates intestinal motility and relax Ileocecal sphincter as well as it stimulate gastric secretions

Q6: What is the significance of antiperistalsis movement ?

Ans: between the Stomach and duodenum it allows more time for neutralization of chyme

Between the Ileum and caecum it allows time for absorption.

Thanks for checking our work

Good Luck

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