Lecture 6

PHYSIOLOGY TEAM

PHYSIOLOGY OF SMALL INTESTINE

Objectives :

1- **Intestinal motility + control**
2- **Intestinal secretion**
3- **Intestinal digestion**
4- **Intestinal absorption**

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First , Histology : Intestinal mucosa :

Including mucosal folds ,*villi and microvilli → ↑ surface of small intestine

*Microvilli covered by layer of glycoclex

Glycocalex → polysaccharide + protein

helps in :

-adsorption of the pancreatic enzymes

-place the final product of digestion in

وجود العلامة * بجانب بعض الكلمات للدلالة على انها تم تحديدها بالصورة الموجودة بالأسفل

the small intestine has 2 types of glands :

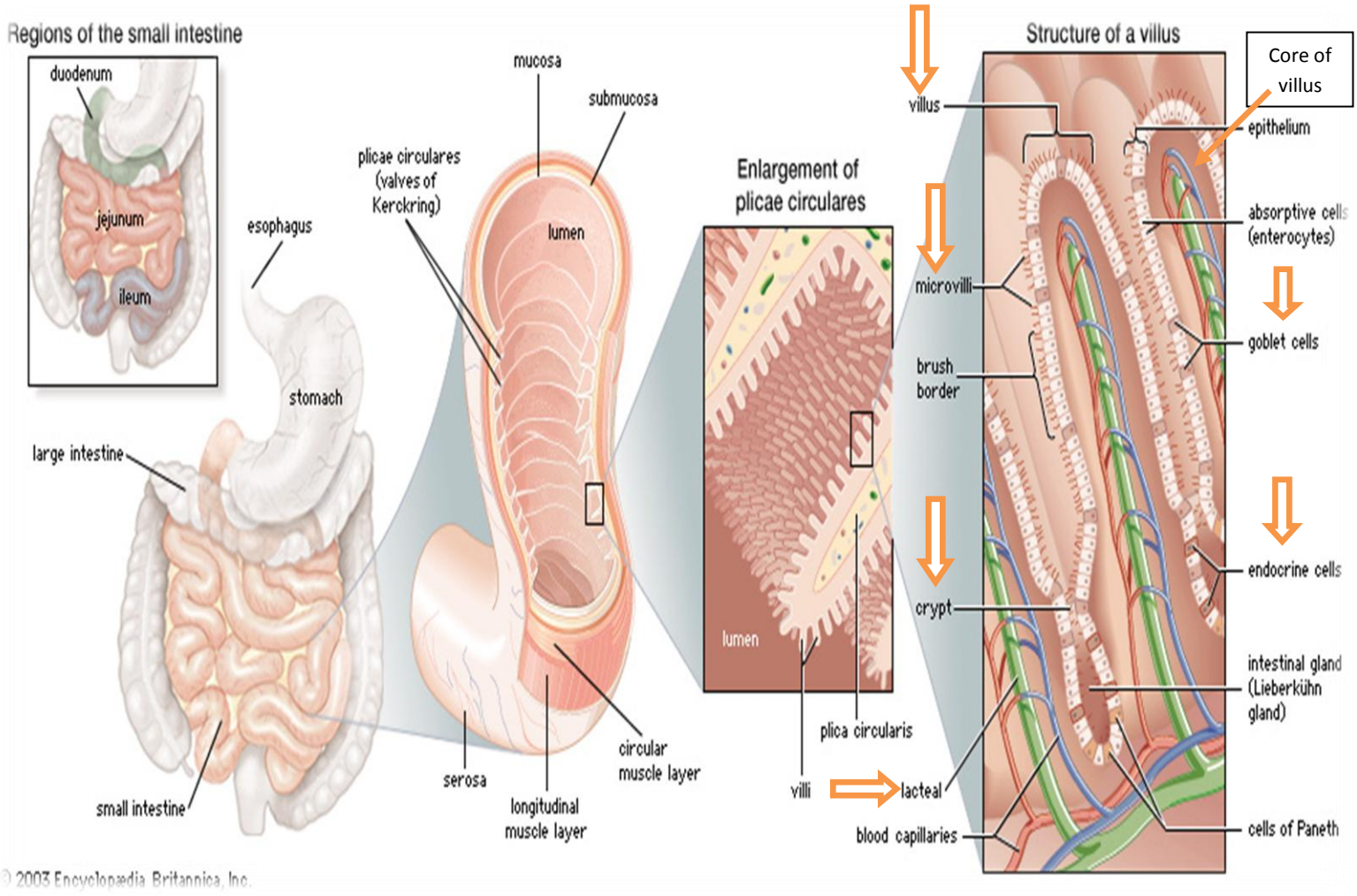
*crypts of Lieberkuhn	brunner`s gland
located between bases of the villi	located at the submucosa
secreting succus entericus	their ducts open at the base of crypts

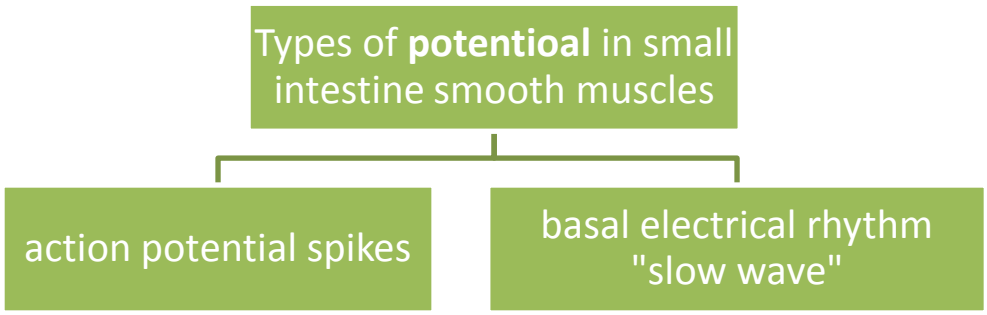
The core of the villi include(مكونات الخملة الداخلية) : central arteriole → capillaries →venules +*lacteal (lymph vessel) +nerve fiber +smooth muscles

Remember : enterocyte = columnar cells

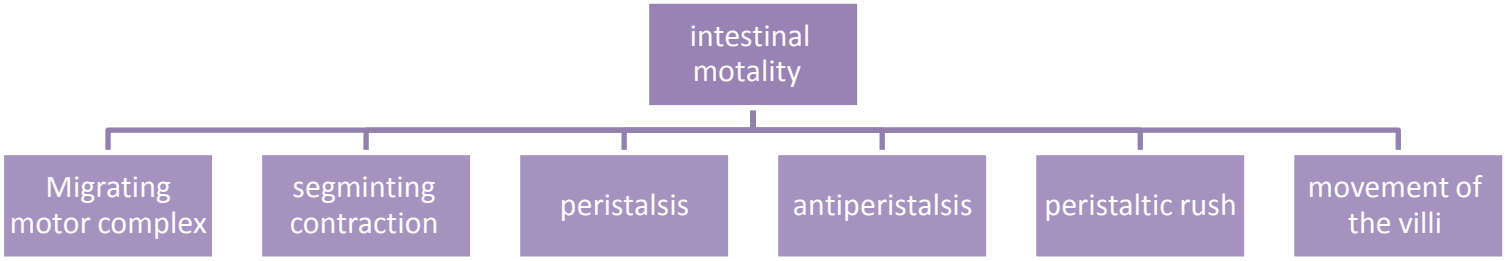
The lining epithelium of villi and crypts :

lining Epithelial of villi	Lining epithelial of crypts
Enterocytes(digestive + absorptive columnar cells)	Undifferentiated (migrates to villus and become enterocyte)
***Goblet cells (secrete mucos)**	Goblet cells
Few epithelial endocrine cells	*Epithelial endocrine cells





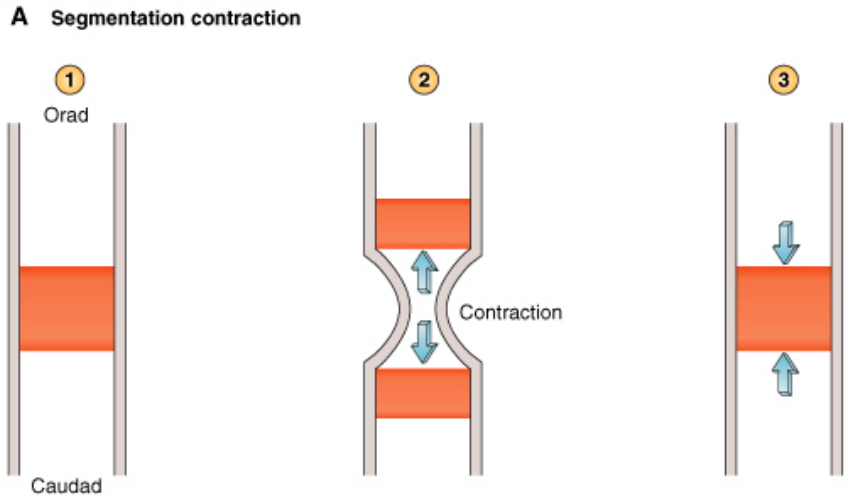
types and control of intestinal motility :

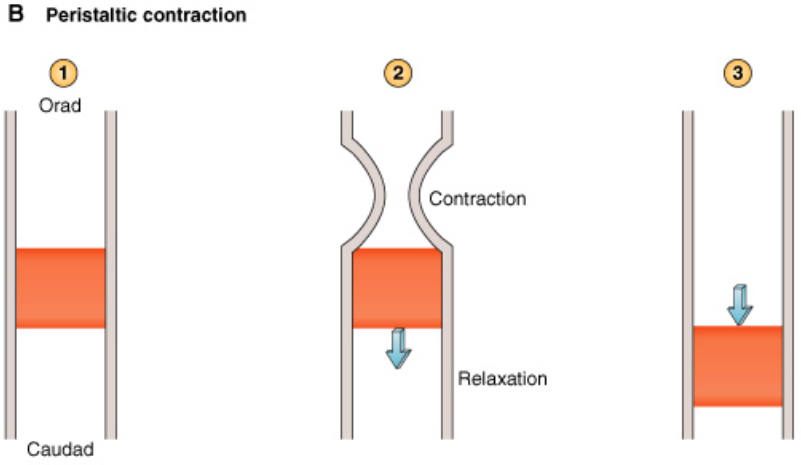


- All are initiated by ENS , except peristaltic rush by autonomic extrinsic nervous system.

The movement	Description	phases	activity	Function
1-Migrating motor complex	Bursts of depolarization followed by peristaltic contraction. Begins during interdigistive period in the empty stomach →to whole small intestine→iliocaecal valve then disappear	3 phases : 1-absence of contraction. 2-irregular contraction 3-burst of rigular , large amplitude contraction. هذه الحركة تاخذ وقتا طويلا للتأكد من خلو الأمعاء من الطعام	Terminates as soon as food is digested.	To remove any remnants in stomach and small intestine into the colon during interdigestive period.
2-segmenting (mixing) contraction "figure A below"	Ring =like contraction of the circular muscle layer along small intestine at regular intervals. When disappear a new wave of contraction begins so , the contracted part become relaxed and the relaxed part become contracted.		(activated by ENS) So, In extrinsic denervation →they persist If the intrinsic plexus destroyed → they disappear.	
3-peristalsis "figure B below"	Travlling wave of contraction above the site of bolus , preceded by relaxation at the bolus site and below . Usually in oral-caudal direction.		Controlled by intramural plexus It`s rate between 2-25cm/sec	

4-antiperistalsis	In opposite direction		Between stomach and duodenum →↑time for chime neutralization Between ileum &caecum →↑time for absorption
5-peristaltic rush	Powerful rapid peristalsis due to severe irritation of the intestinal mucosa Ex. infectious diarrhea	Initiated mainly by (extrisic nervous system) : (extrinsic nerve reflex)→brain stem →small intestine	Sweep contents of intestine to the colone to : -relive the small intestine from the irretatev chime -relive it from excessive distenation. و أيضا عند تناول الطعام الملوث مثلا , فعند دخوله للأمعاء يتم دفعه بسرعة كبية للتخلص منه مما يسبب الإسهال
6-movement of villi	fast shortening and slow lengthening as well as side to side movements.	-contractions are 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	They facilitate absorption and lymph flow from central lacteals into lymphatic system يعني الهدف منها ادخال الطعام داخل خلايا الامعاء وهضمه فيها ومن ثم انتقاله للاوعية الدموية واللمفاوية





Notes:

If the chyme is stuck → stimulate vomiting center

In relaxation → intestinal fold increase surface area → increases absorption

Propulsive contractions = peristalsis contraction "+note"

- ***They are faster in the proximal intestine and slower in the terminal intestine.***
- ***They normally are very weak after traveling only 3 to 5 centimeters,***
  - ***Net movement along the small intestine normally averages only 1 cm/min.***
  - ***This means that 3 to 5 hours are required for passage of chyme from the pylorus to the ileocecal valve.***

Anticholinergic Drugs (atropine) inhibit ENS → weak contraction

Control of intestinal movements

1- Neural factors

Vagal (Parasympathetic) excitation

increases

intestinal and villous movements

Sympathetic excitation

decreases

intestinal and villous movements.

1.entry of chyme into the stomach → stretch → (gastroenteric reflex) → conducted through mynteric plexuses → wall of small intestine → increase Peristaltic activity

2. Entry of chyme into the duodenum → stretch →(ileocaecal valve relaxes)**→ increase Peristaltic activity.**

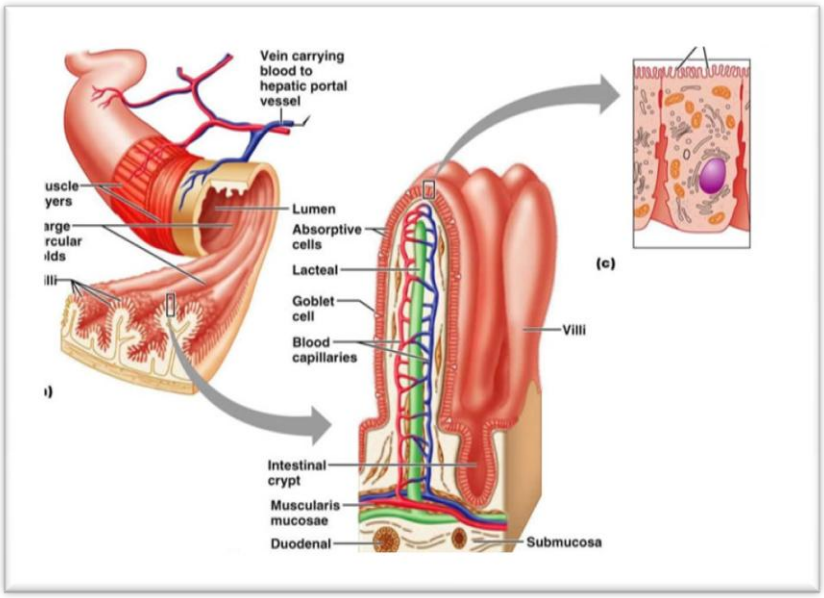
2- Hormonal factors

-Gastrin, CCK, insulin and serotonin stimulate intestinal motility. -Gastrin and CCK relax ileocaecal sphincter	-Secretin and glucagons inhibits intestinal motility -contract ileocaecal sphincter.	Motilin secreted from duodenum stimulates intestinal motility and regulate Migrating Motor Coplex	Villikinin (secreted from intestinal mucosa) stimulates movement of the villi.

The hormone which contract the muscle, the muscle of the hormone relax the sphincter ,

And the hormone which relax the muscle, contract the sphincter .

Secretion of Intestinal Digestive Juices by the Crypts of Lieberkühn



Small pits which lie between the intestinal villi.

- The surfaces of both the crypts and the villi are covered by an epithelium composed of two types of cells:

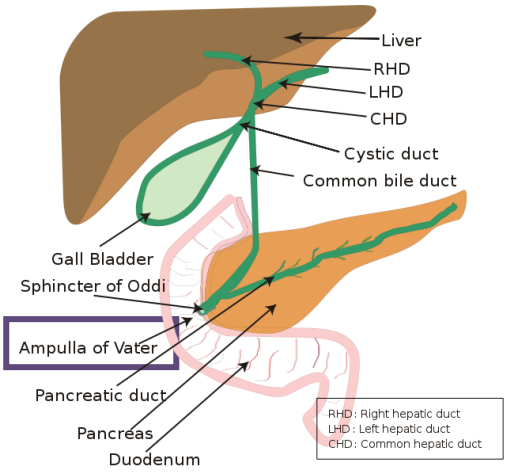
(1) **Goblet** *cells,* which secrete *mucus*,

(2) **Enterocytes**

In the crypts → secrete large quantities of water and electrolytes

In the villi → reabsorb the water and electrolytes along with end products of digestion

Intestinal secretion



1 - Brunner'glands

in the **duodenum** between the pylorus and **ampulla of vater*** ,,
in submucosa layer ..

- **the characteristic of the secretion of Brunner'glands is :** secrete an **alkaline** fluid that contains **mucus** but no enzymes.
- and the function of the Mucus is to protects the mucosa.

> **ampulla of vater*: site of opening of pancreatic & bile duct , they open by a single opening in the second part of duodenum**

2- intestinal crypts : secreting *Succus entericus*

the characteristic of this secretion :
Volume: 1800 ml/day.

PH: 7.5-8 **(Alkline).**

Composition:
- 0.6 % organic (**mucus & enzymes**)
- 1 % inorganic substance(**electrolytes**).

NOTE : **Most of the enzymes are found either in the brush border (luminal border)or in the cytoplasm of the enterocytes .**

What's the importans of this alkaline secretion ?
It participates in the neutralization of acid chyme delivered from stomach.
The aim of this neutralization is to protect the intestinal mucosa and prevent ulceration and provide the optimum PH
There are two other **alkaline secretions** participate in the neutralization : Pancreatic secretion and Bile

اغلب الانزيمات تكون داخل الخلايا في السايتوبلازم او على سطحها

لكن هناك انزيمان يمتيزان بوجودهما في القناة بسبب وظيفتهما :

Except : The enzymes that are actually **secreted into the lumen** are **enteropeptidase** and **amylase** . !!

Enteropeptidase = enterokinase

Must be in lumen because:

It convert trypsinogen → trypsin

"important in activation of proteolystic enzymes coming from pancreas"

Digestion in the small intestine

1- Protein digestion

Complete protein digestion occurs in the intestine by:-

a. Amino Acid free amino group → mixture of AA and oligopeptides

b. oligopeptides → free AA

c. di and tripeptides → AA

2- Nucleotidases

Which split nucleotides into purine and pyrimidine bases, phosphoric acid and pentose sugar.

3- Lipid digestion

By lipase which splits TG into MG + FA.

MG → monoglyceride FA → Free Fatty Acid

4- CHO digestion

a. Maltase splits maltose into 2 glucose
b. Sucrase splits sucrose into glucose + fructose.
c. Lactase splits lactose into glucose and galactose.

5- Dietary fibers

Include cellulose are not digested by pancreatic or intestinal enzymes, they are metabolized by intestinal bacteria to short chain fatty acids and gases. This stimulates intestinal motility.

Intestinal absorption

- The small intestine is the main site of absorption of nutrients.
- A substance must pass these layers to be absorbed:
  1. unstirred water layer
  2. glycocalyx layer
  3. brush border, cytoplasm and the basal borders of the enterocytes
  4. enters either a capillary into portal circulation or a lacteal into lymph, thoracic duct into systemic circulation.

1- Absorption of Carbohydrates (CHO)

It mainly occurs in the upper intestine as monosaccharides

A- Glucose and galactose

They are absorbed by secondary active transport

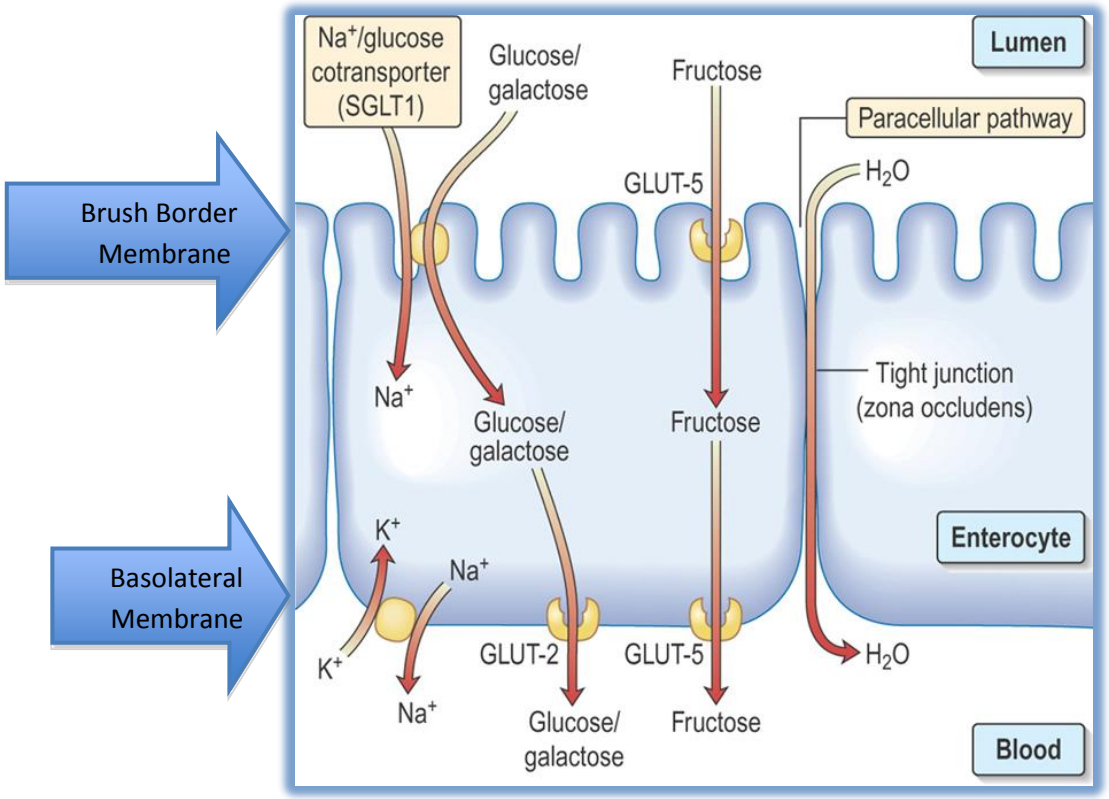
- **Primary Transport:** at the basolateral membrane, Na+/K+ ATPase decreases the Na+ in enterocyte
- **Secondary Transport:** a membrane carrier protein in the brush border for co-transport of glucose (or galactose) and Na+ to inside of cell where they are released. Glucose is further transported by facilitated diffusion across the basolateral membrane by another carrier.

B- Fructose

Transported by facilitated diffusion.

C- Pentose

Transported by passive diffusion and had slowest rate of absorption.



2- Absorption of water

A- The net daily absorption in the small intestine is 8 L/day (from GIT 7 L/day. Ingested water is 2 L/day). In the colon 1 l/day. The remainder (200 ml) is excreted in the stool.

B- About 98 % of water entering the lumen of GIT each day is absorbed. Water moves freely in and out of the lumen of small intestine depending on the osmotic pressure of its contents. Examples:

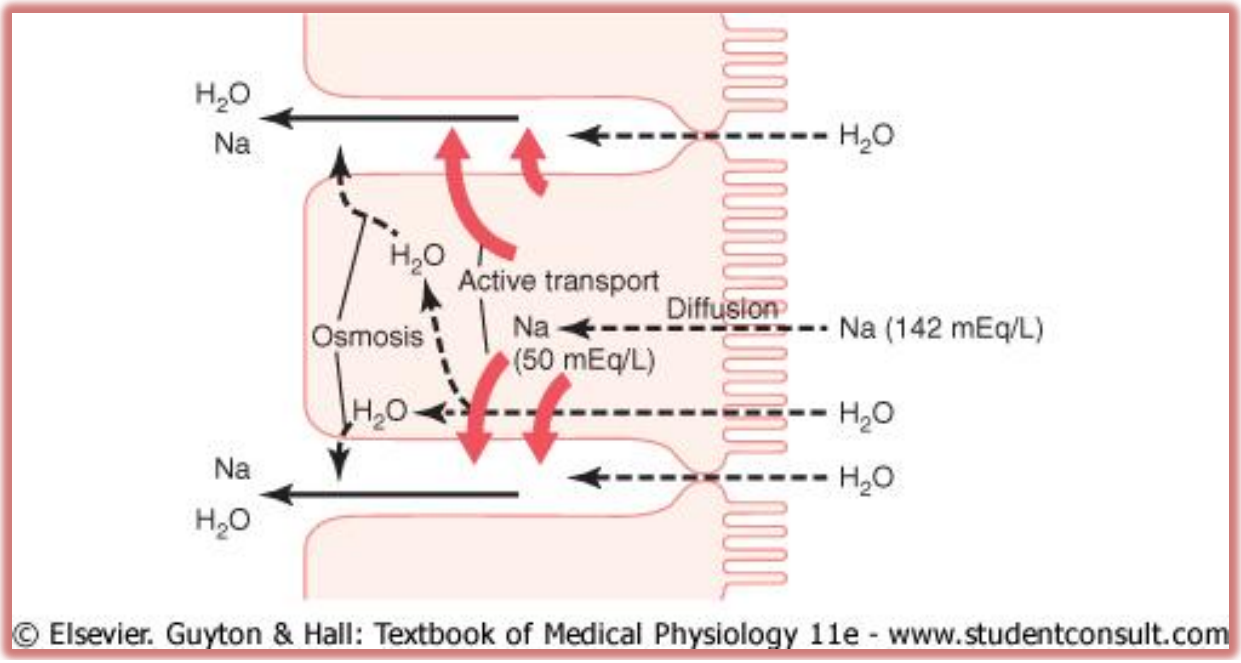
- Absorbed from the gut when chyme is diluted
- Returns to intestine when hyperosmotic solutions are present

3- Na^+ absorption

A- **Passive diffusion**: at the brush border membrane, Na+ in the lumen moves passively across intestinal epithelium following water movement depending on osmotic gradient.

B- **Active Transport**: at the basolateral membrane, Na+ moves across the luminal border of the small intestine and colon along a concentration gradient created by Na^+/K^+ ATPase

C- **Result**: actively absorbed Na^+ facilitates absorption of glucose, AA and short chain FA.



4- K^+ absorption

A- K^+ moves across the intestinal epithelium by diffusion.

B- The net movement occurs into the lumen (as it is electronegative).

C- Small amount of K^+ is actively secreted into lumen as part of mucus.

5- Cl^- absorption

- Cl^- is actively absorbed in exchange for bicarbonate HCO^{-3}
- Result: makes lower intestinal contents alkaline.

6- Absorption of proteins

It occurs in the upper intestine.

A- **D-Amino acid** are transported by passive diffusion.

B- **L- Amino acid** are transported by secondary active transport (same as sodium co-transport of glucose)

C- **Di and Tripeptides** cross the brush border by active transport protein carrier. They are hydrolyzed by brush border and cytoplasmic oligopeptidases.

D- **Amino acids** leave the cell at the basolateral membrane by facilitated transport.

7- Absorption of vitamins

A- Absorption of **fat soluble vitamins (A, D, E, K)** is tied to that of fat. If fat absorption is deficient, absorption of fat soluble vitamins will be also defective.

B- Absorption of **vitamin B_{12} (water soluble vitamin)** requires the presence of intrinsic factor that stimulates endocytosis of vitamin B_{12}.

8- Absorption of fats:

It occurs mostly in the upper small intestine.

A- Absorption via Micelles:

- Fats are digested to form monoglycerides and free fatty acids
- Both of these digestive end products first become dissolved in the central lipid portions of *bile salt micelles*
- Molecules in the Micelles: outer layer is made of water soluble hydrophilic polar groups while the interior is made of fat soluble hydrophobic chains
- Long chain FA, monoglycerides, cholesterol and fat soluble vitamins are incorporated into the interior of the micelle.
- Result:
  - water insoluble compounds are made water soluble. (can be dissolved in chyme)
  - mixed micelle enters the unstirred water layer and makes contact with the brush border of enterocytes.

B- Direct Absorption

1) **Long chain FA, MG and cholesterol** enter the enterocytes by passive diffusion.
2) **FA and MG** are taken by the smooth endoplasmic reticulum and recombined to form new TG. They aggregate into globules along with the absorbed cholesterol and phospholipids.
3) **The phospholipids** arrange themselves in these globules with the fatty portion toward the center and the polar portion located on the surface. This makes the globule soluble within the fluids of the cell.
4) **Chylomicrons**: Small amount of B-lipoprotein coat part of the surface of each globule to form chylomicrons. It diffuses to side of the cell and is excreted by exocytosis into the central lacteal of villi, to lymph, then to thoracic duct.
5) **Short chain FA**: are absorbed directly into capillary blood of the villi to portal blood as they are more water soluble.