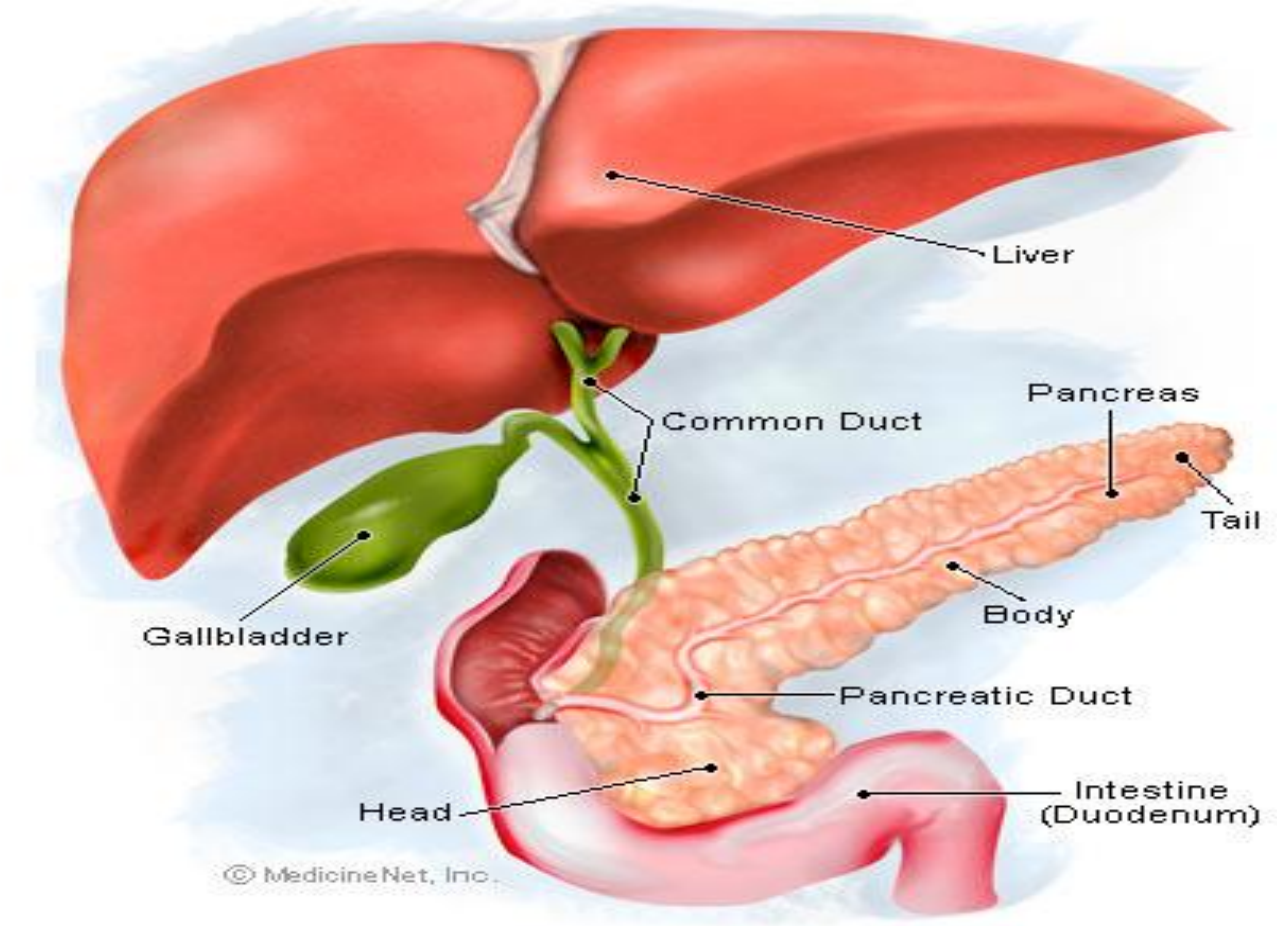
GIT Block

5th Lecture

Physiology of the Small Intestinal Motility and Secretion



PHYSIOLOGY TEAM – 430

This Lecture is done by :

Hanan AL-Amer – Faisal AL- Thunayan

Organized by : Layan Akkielah

– The small intestine:

- It is divided into duodenum, jejunum and ileum.
- The intestinal mucosa has:

1) **villi.**
2) **microvilli.**
3) **mucosal folds that increase the intestinal surface.**

Glands in small intestine:

Gland	Location
intestinal glands (crypts of Lieberkuhn) which secrete intestinal juice (succus entericus).	Between the bases of the villi
Brunner's glands	Submucosa (their ducts open at the base of crypts)

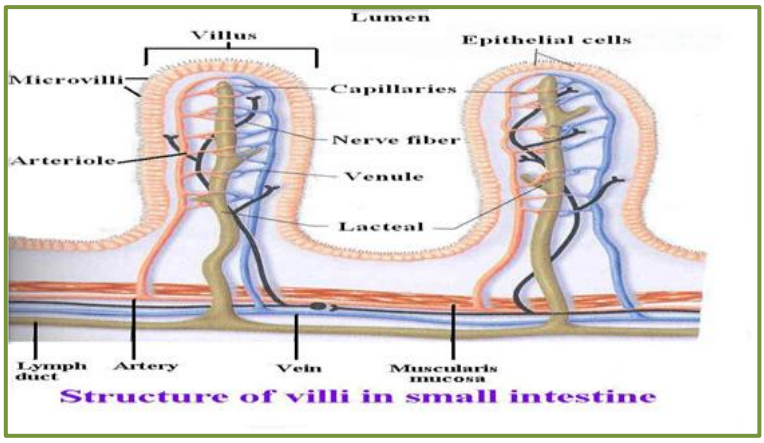
Crypts Of Lieberkuhn: are small pits which lie between the intestinal villi.

– The Villi

- The C.T core of villi contains a central arteriole that breaks up into capillaries that connect to venules, lymph vessel (lacteal), nerve fibers, smooth muscle cells.

The epithelial lining the villi includes:

1. Enterocytes which are digestive and absorptive columnar cells.
2. Mucous secreting goblet cells.
3. Few endocrine epithelial cells.

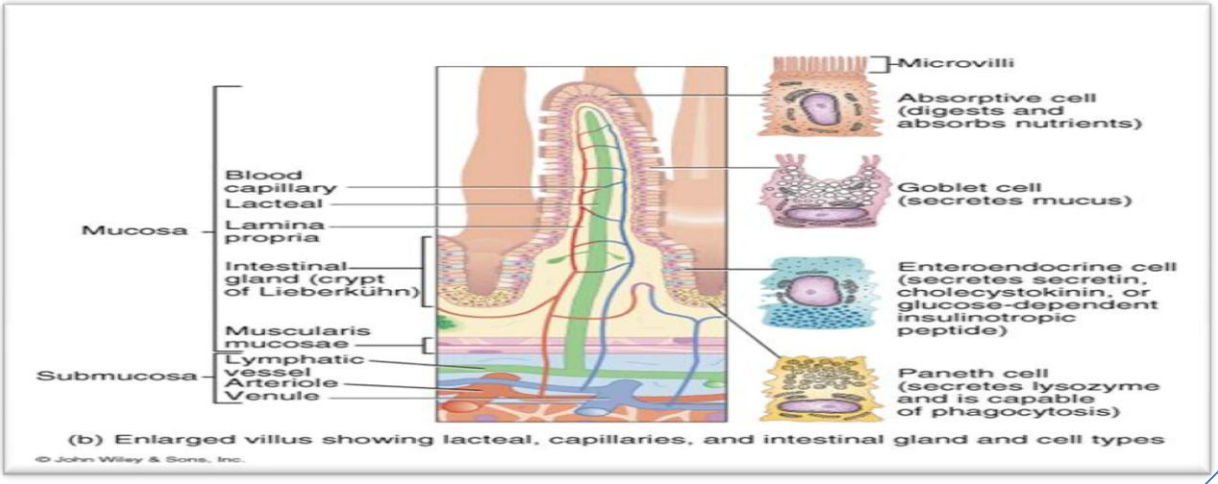


Structure of villi in small intestine

- **The lining epithelial cells of the crypts include:**

- Undifferentiated cells which migrate on to the villus and differentiate into enterocytes.
- Goblet cells.
- Epithelial endocrine cells.

- **The enterocytes have microvilli which are covered by a layer of glycocalyx (polysaccharide and protein) that adsorbs pancreatic enzymes and place the final products of digestion in a proper position for absorption.**



– **Types of potentials of smooth muscles of the small intestine:**

1. Basal electrical rhythm.
2. Action potential spike.

– **The movements of the small intestine can be divided into:**

1. Mixing Contractions. (Segmentation Contractions)
2. Propulsive Contractions
3. Migrating Motor complex.
4. Antiperistalsis
5. Peristaltic Rush
6. Movement of the villi

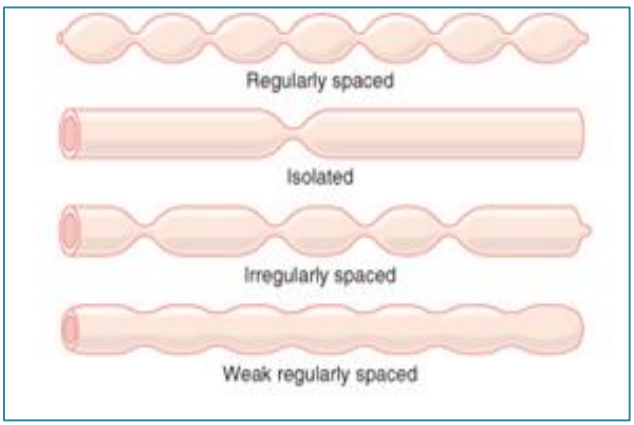
1) ***Mixing Contractions (Segmentation Contractions):*** (mentioned in the first lecture)

- They are ring-like contractions of circular muscle layer appearing at regular intervals along a length of small intestine and their function to mixed digestive food.
- Soon they disappear and are replaced by another set of ring contractions, arranged such that the parts that were contracted become relaxed.
- They persist after extrinsic denervation, but disappear after destroying the intrinsic nerve plexus in small intestine.

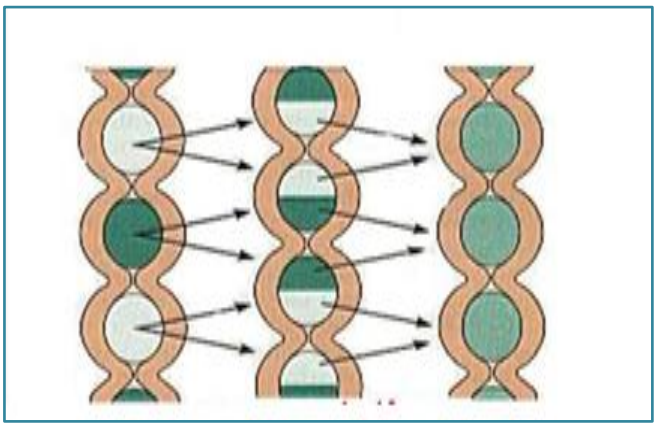
- **Other important purposes for mixing contractions**

➢ Blend different juices with the chyme

➢ Bring products of digestion in contact with absorptive surfaces. (Bringing chyme closer to the mucosa to get absorbed).



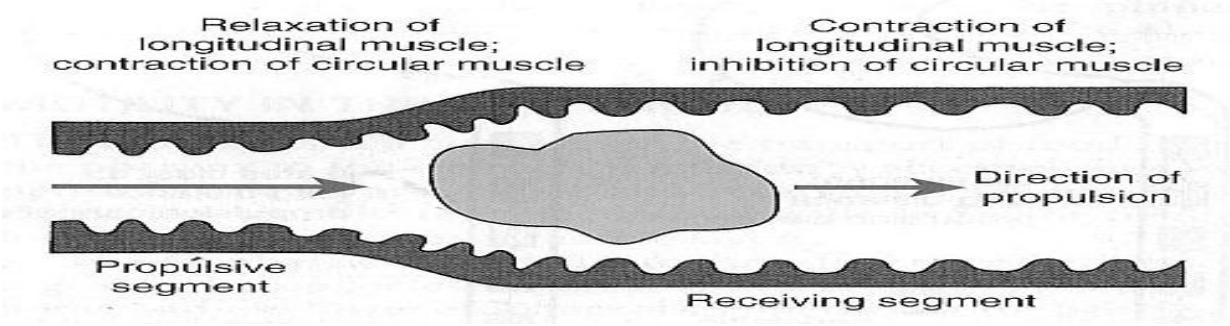
When these muscles contract, they give the appearance of a chain of sausages



Segmentation Contractions (Mixing)

2) *Propulsive Movements or Peristalsis movement*: (was mentioned in the first lecture but it is more detailed here)

- Occur in any part of the small intestine.
- Usually stimulated by **Distention**, It usually travels in an oral-caudal direction.
- At a velocity of 0.5 to 2.0 cm/sec or between 2-25 cm/sec.
- They are faster in the **proximal** intestine and slower in the terminal intestine.
  (because once we reach the terminal ileum we need enough time to get the materials back via different transport mechanisms, to give them time to get back to the portal circulation)
- They normally are very weak after traveling only 3 to 5 centimeters.
- Net movement along the small intestine normally **averages** only 1 cm/min → So 3 to 5 hours are required for passage of chyme from the pylorus to the ileocecal valve.
- Organizes propulsion of chyme over variable distances within the intestinal lumen.
- **Myenteric plexus** is important for Propulsive movements (it controls propulsive movement)
- Mechanism of propulsive movements:



N.B.
Circular muscles contract → constricting passageway and pushing chyme forward
Longitudinal muscles contract → shortening passageway ahead of chyme
So we can say Peristalsis movement consists of a travelling wave of contraction above the bolus preceded by relaxation at the bolus site and below.

- People who don't have enough propulsive movement they're susceptible to have constipation.
- Atropine (cholinergic blocker) depresses these movements → Constipation

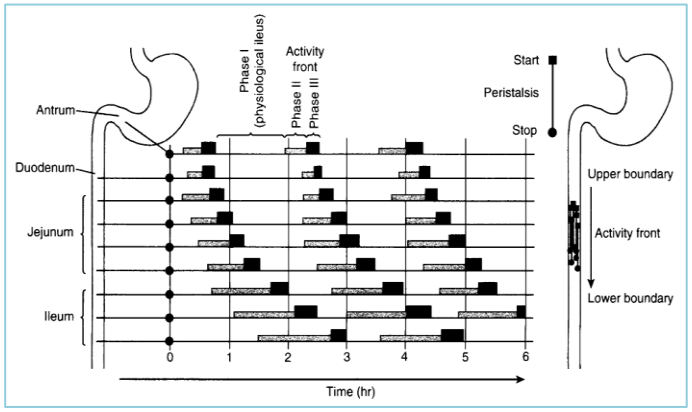
3) *Migrating Motor complex (MMC):*

- MMC are movements in the "Interdigestive State" in the stomach & small intestine.

> **Digestive state:**
> When nutrients are present and digestive process are ongoing
> **Interdigestive state :**
> When the digestion and absorption of nutrients are completed, **2-3 hours after a meal**

- It is bursts of depolarization accompanied by peristaltic contractions separated by longer quiescent periods
- travels a long whole length of small intestine to reach ileocaecal valve after 1.5-2 h. where it disappears. A new wave of MMC starts.
- The activity of MMC terminates as soon as food is ingested.
- It happens during **fasting**, conscious and sleep stages.
- Begins at distal stomach (**antral pump region**) to the **ileum** → The antral contraction to propel the remaining materials bigger than **7mm**.

> **Quiescent**: potential but there's no activity



- **Every contraction** consists of the upper boundary (**starting point,** antral pump region), lower boundary (**the stop point** at which the contraction finishes, Ileum) and the activity front.

> **Activity front** = the contracted segment

- **The cycle of MMC consists of three phases:**

1. **absence of contraction**. (quiescent period).
2. **irregular contraction**. (Activity Front).
3. **a burst of regular large amplitude contraction**.

- It takes 80-120 min for one activity front (from the antrum to the ileum)
- the speed of the activity front is :
  Duodenum → 3-6 cm/min
  Ileum → 1-2 cm/min
- **MMC** are organized by enteric nervous system (ENS) and:

➢ Stimulated by motilin → It gets released when we don't have food in the digestive tract "during fasting"

➢ Inhibited by CCK and Gastrin → get released when we have fatty acids or distended stomach, which means when we're not fasting.

- MMC keep cycling till they are ended by ingestion of food (presence of a meal in the upper digestive tract) → Vagal efferent → signals to ENS → interrupt the MMC and initiate mixing movements during ingestion of a meal.

  So if the vagus nerves are cut there will be no interruption of (MMC) " The Interdigestive State " unless a large quantity of mall is ingested, and still the interruption is often incomplete.

- Intravenous feeding does not end the fasting pattern " MMC" (Because we can't stop MMC unless we have the food exists in the stomach or in small intestine)

- **Adaptive significance of MMC**

- Gallbladder contraction and delivery of bile to the duodenum is coordinated with the onset of MMC in the intraduodenal region
- Appears also to be a mechanism for cleaning **indigestible materials**. (materials that larger than 7mm)
- Plays a **housekeeper role** in preventing the overgrowth of microorganisms that might occur in the small intestine

- MMC Start when we are fasting, when there's no food in the digestive tract
- The function of MMC is to propel any remnants in stomach & small intestine into colon during the interdigestive period.
- Occur only between meals.

4) *Antiperistalsis:*

- In the opposite direction occur between stomach and duodenum to allow more time for neutralization of chyme and between ileum and cecum to allow time for absorption
- It might begin in the distal part of the small intestine (Ilium)
- The antiperistaltic wave travels backward up the intestine at a rate of 2 to 3 cm/sec.
- The role of **antiperistalsis** in vomiting:
- When the upper portions of GIT, especially the duodenum become overly **distended** → This **distention** becomes the exciting factor that initiates the actual vomiting act.

Neutralization: The interaction between an acid and a base that produces a solution that is neither acidic nor basic.
Chyme: The thick semifluid mass of partly digested food that is passed from the stomach to the duodenum

5) *Peristaltic rush*:

- Powerful rapid peristalsis due to severe irritation of intestinal mucosa as in infectious diarrhea.
- It is initiated mainly by extrinsic nervous reflexes to brain stem and back to gut.
- It sweeps the contents of intestine into the colon and thereby relieving the small intestine of irritative chyme or excessive distension.

6) Movement of the villi

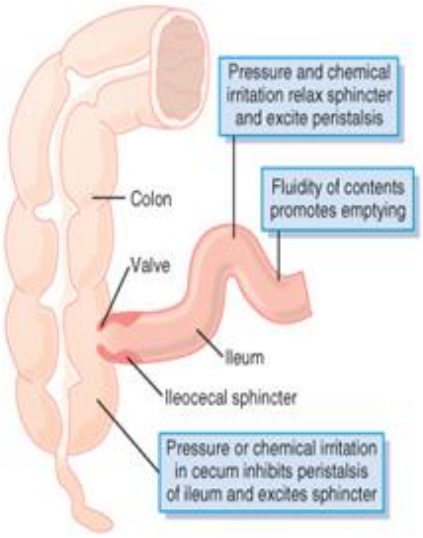
- The villous movement consists of fast shortening and slow lengthening as well as side to side movements.
- Villous contractions are initiated by local nervous reflexes in response to chyme in small intestine.
- They facilitate absorption and lymph flow from central lacteals into lymphatic system.
- They are stimulated by villikinin hormone released by intestinal mucosa when it comes in contact with digestive products.

– Control of intestinal movements

1. Neural factors

- **Ileocecal Valve :** Main function is to prevent the back flow of the fecal contents from the Colon to the Small Intestine
- **Feedback Control of the Ileocecal Sphincter (Valve):**

➢ controlled by reflexes from the cecum (When the cecum is distended → contraction of the ileocecal sphincter becomes more intense →ileal peristalsis is inhibited).
The purpose is to delay emptying of additional chyme into the cecum from the ileum (This reflex is mediated by Vagus nerve)



2- Hormonal factors :

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

– Intestinal secretion:

- Brunner'glands in the duodenum between the pylorus and ampulla (second part of duodenum) of vater secrete an alkaline fluid that contains mucus but no enzymes.
- Mucus protects the mucosa.
- Succus entericus(it is the intestinal juice)
- It is secreted from intestinal crypts
- **Volume:** 1800 ml/day.
- **PH:** 7.5-8.(alkaline to protect intestine mucosa cause it do not have much mucus secretion like stomach which protect it from the low PH) It participates in the neutralization of acid chyme delivered from stomach.
- **Composition:** 0.6 % organic(like enzymes which found in the brush broader or cytoplasm not in the lumen), 1 % inorganic substance(like calcium and potassium).
  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.

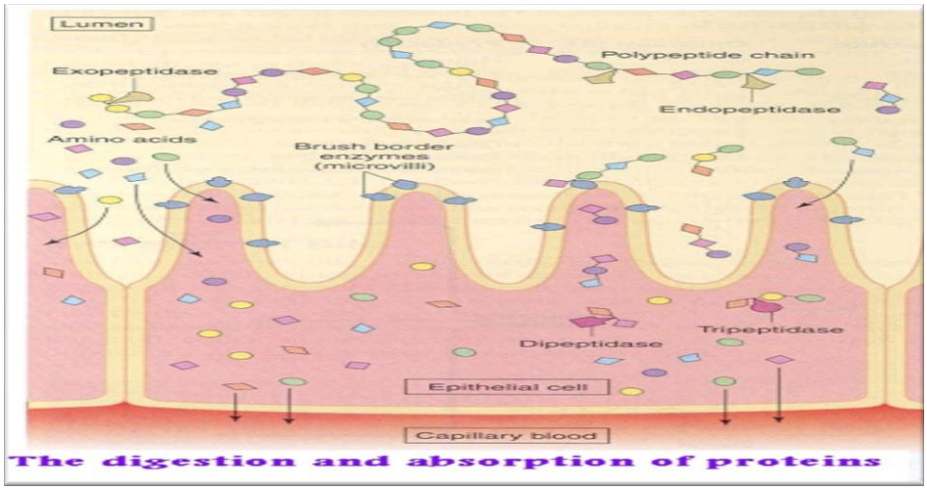
CCK is the leader of this hormones, it's more powerful

Intestine , bile and pancreas secretion are normally alkaline.

– Digestion in the small intestine:

1- **Protein digestion: start in stomach by pepsin enzyme → by pancreas enzyme → small intestine.**
Complete protein digestion occurs in the intestine by:-

a) Aminopeptidases: which split off terminal AA with free amino group. The resulting is a mixture of AA and oligopeptides.
b) Oligopeptidases: which break down oligopeptides into free AA.
c) Intracellular di and tripeptidases which break di and tripeptides into AA.



The digestion and absorption of proteins

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.

4- ***CHO digestion:***

no digestion of CHO it in the stomach.

i. Maltase splits maltose into 2 glucose
ii. Sucrase splits sucrose into glucose + fructose.
iii. 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(so it is help with constipation).

– Control of intestinal secretion:

1) Brunner's gland secretion is stimulated by secretin, tactile and vagal stimulation.
2) Intestinal juice secretion is stimulated by:
    i. Distension, tactile and irritating stimuli.
    ii. Hormones as gastrin, secretin, CCK, glucagon, enterocrinin.
    iii. Sympathetic stimulation exerts an inhibitory effect.

– Intestinal absorption:

- The small intestine is the main site of absorption of nutrients.
- For a substance to be absorbed, it must traverse an unstirred water layer (unmoved layer), a glycocalyx layer, the brush border, cytoplasm and the basal borders of the enterocytes and enters either a capillary into portal circulation or a lacteal into lymph, thoracic duct into systemic circulation.

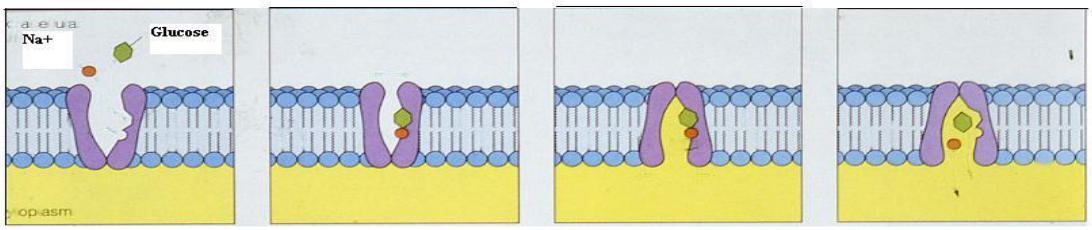
1- Absorption of CHO

It mainly occurs in the upper intestine.

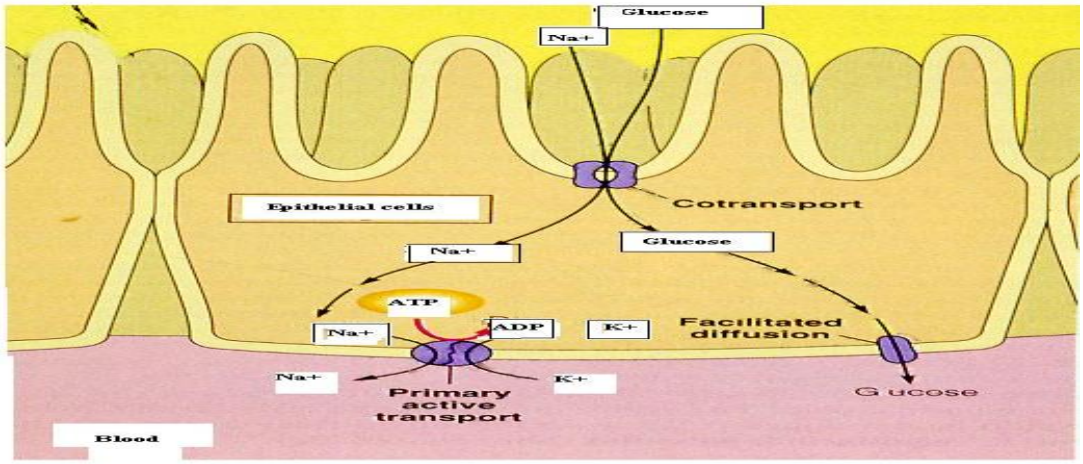
a. Glucose and galactose:

They are absorbed by 2ry active transport(need carrier) i.e. 2ry to the action of Na+-K+ ATPase. (Na transport with concentration not with active transport)
There is a membrane carrier protein in the brush border for cotransport of glucose (or galactose) and Na+ to inside of cell where they are released.
Glucose is further transported by facilitated diffusion(need carrier) across the basolateral membrane(then it is going into blood vessel) by another carrier.

A model for the cotransport of Na+ and glucose into a cell. This is secondary active transport, because it is dependent upon the diffusion gradient for Na+ created by the Na+/K+ pump.



The transport of glucose from intestinal lumen



b. **Fructose**
Transported by facilitated diffusion.

c. **Pentose**
Transported by passive diffusion and had slowest rate of absorption(cause there is no used of energy).

Type of CHO	Type of absorption
Glucose and galactose	2ry active transport facilitated diffusion
Fructose	facilitated diffusion
Pentose (slowest rate of absorption)	passive diffusion

2- Absorption of proteins

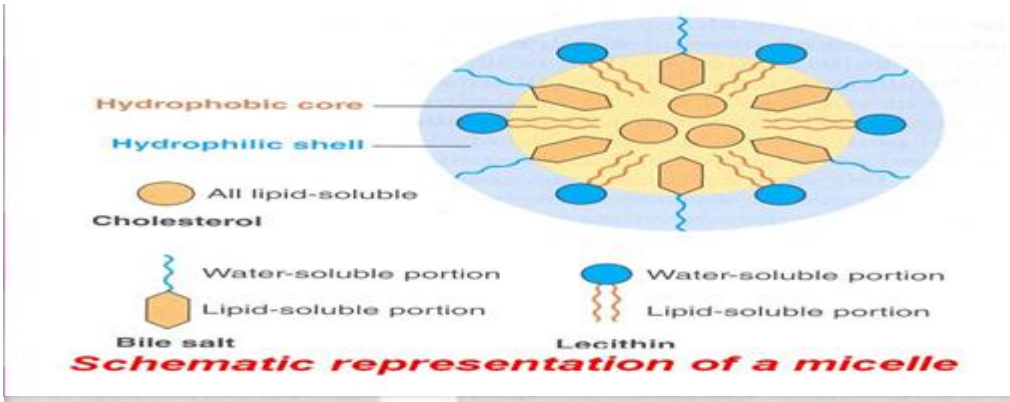
- It occurs in the upper intestine.
- D- AA are transported by passive diffusion.
- L- AA are transported by 2ry active transport.

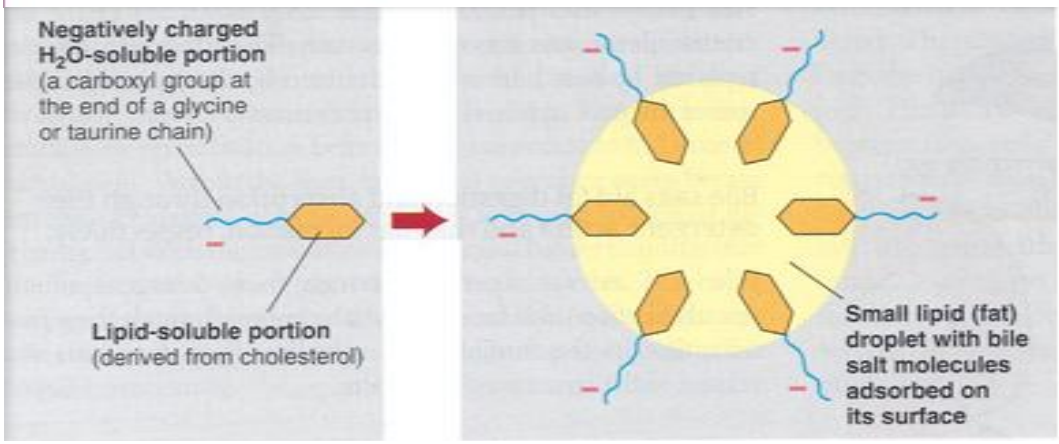
Note: D- AA L- AA are different isomers from protein.

- 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.

3- Absorption of fats

- It occurs mostly in the upper small intestine.
- Bile salts form micelles in which molecules are aggregated in such a way that water soluble hydrophilic polar groups are facing the outer side of the micelle, while fat soluble hydrophobic chains are facing the interior of the micelle.
- Long chain FA, monoglycerides, cholesterol and fat soluble vitamins are incorporated into the interior of the micelle. In this way water insoluble compounds are made water soluble.

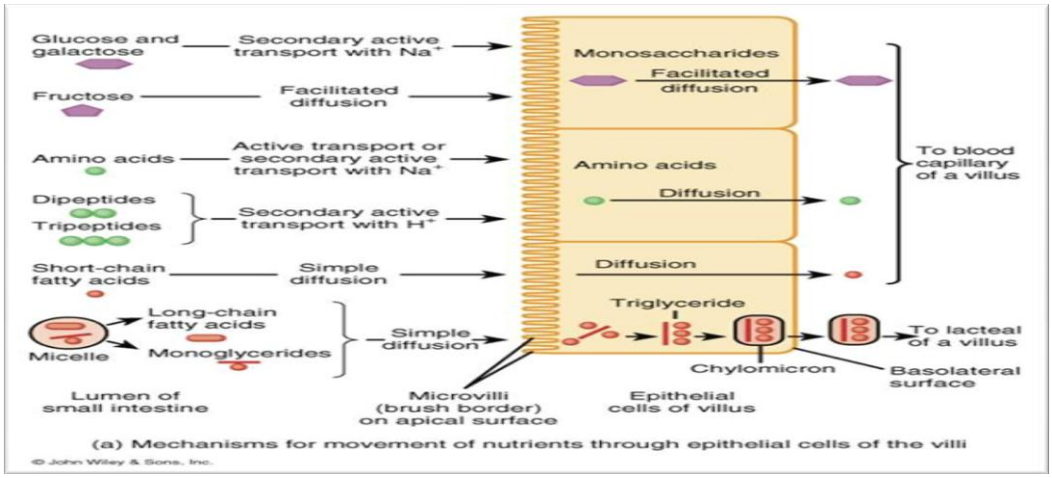




- The mixed micelle enters the unstirred water layer and makes contact with the brush border of enterocytes.
- Long chain FA, MG and cholesterol enter the enterocytes by passive diffusion.
- FA and MG are taken by the smooth endoplasmic reticulum and recombined to form new TG. They aggregate into globules along with the absorbed cholesterol and phospholipids.
- 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.
- 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.

Note: phospholipids make the job of bile salt by making chylomicrons

- Short chain FA are absorbed directly into capillary blood of the villi to portal blood as they are more water soluble.



4- 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 B12 (water soluble vitamin) requires the presence of intrinsic factor that stimulates endocytosis of vitamin B12.

5- Absorption of water

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

6- Na+ absorption

Na+ in the lumen moves passively in either direction across intestinal epithelium following water movement depending on osmotic gradient.

The other part moves across the luminal border of the small intestine and colon along a concentration gradient created by Na+ - K+ ATPase at the basolateral membrane. Such actively absorbed Na+ facilitates absorption of glucose, AA and short chain FA.

7- K+ absorption

K+ moves across the intestinal epithelium by diffusion with a net movement occurs into the lumen (as it is electronegative). Small amount of K+ is actively secreted into lumen as part of mucus.

8- Cl- absorption

Cl- is actively absorbed in exchange for HCO-3 which tends to make lower intestinal contents alkaline.