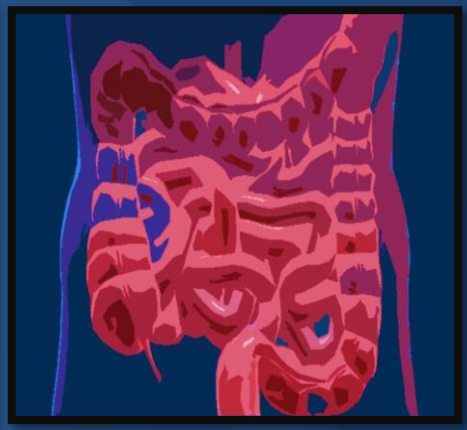
Physiology Team

LECTURE 5

Physiology of the Small Intestine: Motility and Secretion

GASTOINTISTINAL TRACT

Thanks for Cooperation:
Mohammed Al-Gammass
Eman Al-Bedaie



DONE BY:
Fay Alruwais - Najoud AlOtaibi

REVISED BY:
Mohammed Al-Sari

DESIGNED BY:
Khulood Al-Raddadi

OBJECTIVES

Physiology Team

At the end of this lecture, student should be able to describe:

- Motility in the small intestine.
- Control of intestinal motility.
- Secretions of the small intestine
- Digestion of carbohydrates, proteins and fats.
- Basic principles of gastrointestinal absorption.
  - ✓Absorption of carbohydrates
  - ✓Absorption of proteins
  - ✓Absorption of fats
  - ✓Absorption of vitamins
  - ✓Absorption and secretion of electrolytes and water

MIND MAP

Physiology of Small intestine

Physiology Team

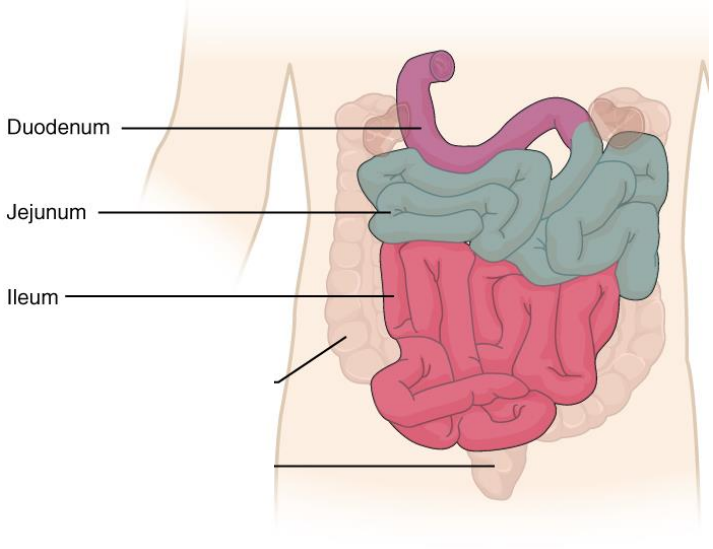
- Motility of small intestine
  - Segmenting (Mixing) contractions
  - Propulsive (Peristalsis) contractions
  - Migrating motor complex
  - Antiperistalsis
  - Peristaltic rush
  - Villi movement
- Control of intestinal motility
  - Neural Factors
  - Hormonal Factors
- Secretion & control of small intestine
  - Brunner's Glands in the Duodenum = Secretion of Mucus.
  - Crypts of Lieberkühn = Secretion of Succus Entericus. ((which is Intestinal Juice))
- Digestion of:
  - Carbohydrates
  - Proteins
  - Fats
- Absorption of:
  - Carbohydrates
  - Proteins
  - Fats
  - Vitamins
- Absorption & secretion of electrolytes & water
  - Absorption of Na+
  - Absorption of Cl-
  - Absorption & secretion of K+
  - Absorption of Ca++
  - Secretion of Bicarbonates ions
- Hormonal control of electrolytes absorption & secretion
  - Glucocorticoid
  - Somatostatin
  - Epinephrine
  - Aldosterone
  - Catecholamines

Motility In The Small Intestine

Physiology Team

Divisions of the Small Intestine:

1. Duodenum
2. Jejunum
3. Ileum



Motility in the Small Intestine :

The movements of the small intestine can be divided into:

- *Segmenting (Mixing) contractions*
- *Propulsive contractions (Peristalsis)*
- *Migrating motor complex*
- *Antiperistalsis*
- *Peristaltic rush*

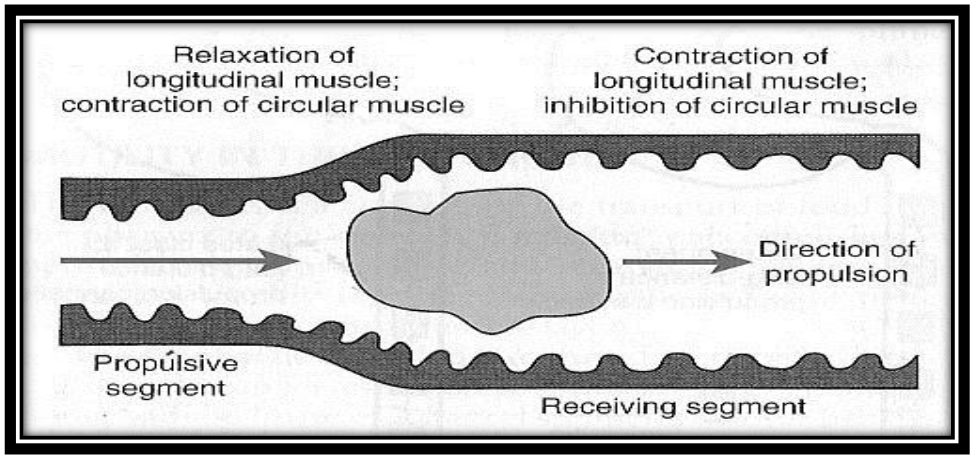
This video may help in general understanding of motility in the small intestine

1. Mixing (Segmentation) Contractions:

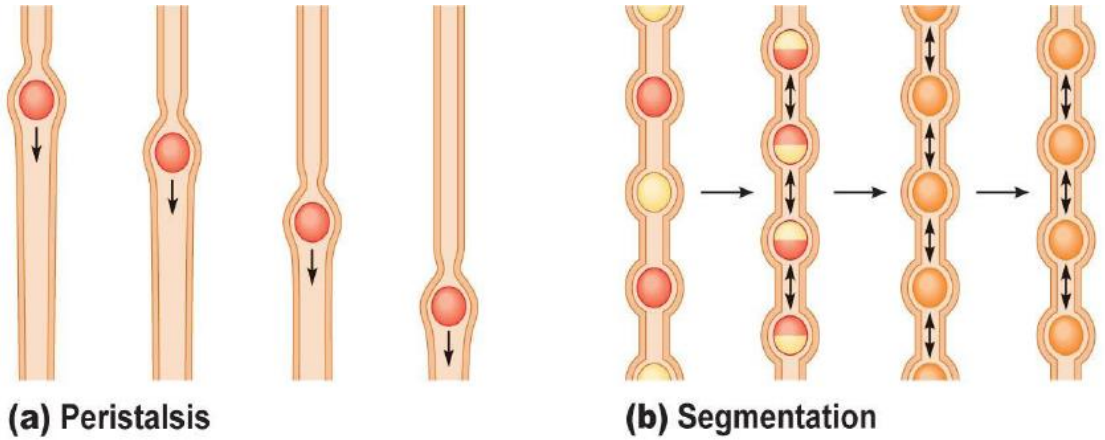
- When a portion of small intestine becomes distended, ENS activates segmentation contractions to divide the intestine into spaced segments which last for fraction of min, and have the appearance of a chain of sausages.
- As one set of segmentation contractions relaxes, a new set begins at points between the previous ones.
- Atropine blocks ENS excitatory activity => weak contractions.
- Importance of segmentation contractions:
  - ✓Blend different juices with the chyme
  - ✓Bring products of digestion in contact with absorptive surfaces.

2. Propulsive Movements (Peristalsis)

- Organizes propulsion of material over variable distances.
- Usual stimulus is distention.
- Myenteric plexus is important for these movements.
- They are faster in the proximal intestine and slower in the terminal intestine (velocity 0.5 to 2.0 cm/sec averaging 1cm/min), *3 to 5 hours are required for passage of chyme from the pylorus to the ileocecal valve.*
- They can be blocked by the drug atropine.



Motility In The Small Intestine



3- Migrating motor complex (MMC):

- It is bursts of depolarization accompanied by peristaltic contraction that begins in empty stomach during interdigestive period, travels along the small intestine to reach ileocaecal valve after 1.5-2 hrs, where it disappears and a new wave of starts.
- Activity stops as soon as food is ingested.
- Propels any remnants in stomach & small intestine into the colon.

4- Antiperistalsis:

In the opposite direction (from anus to mouth) occurs between stomach and duodenum to allow more time for neutralization of chyme and between ileum and caecum to allow time for absorption.

(Also occurs during vomiting).

5- Peristaltic rush: (Doesn't normally occur)

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

Movement Of The Villi

Physiology Team

The villous movement consists of :

1. fast shortening and slow lengthening.
2. side to side movements.

• Villous contractions are initiated by local nervous reflexes in response to chyme in small intestine.

• They are stimulated by villikinin hormone (specific hormone for the movement of the villi) released by intestinal mucosa when it comes in contact with digestive products.

• They facilitate absorption and lymph flow from central lacteals into lymphatic system. (help in ↑ lymph flow)

Control Of Intestinal Motility

Physiology Team

1- Neural factors:

- **Vagal (parasympathetic)** excitation increases intestinal and villous movements.
- **Sympathetic** excitation decreases intestinal and villous movements.

Gastroileal reflex *(initiated from the stomach and affect the ileum)* is initiated by gastric distension. 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. This reflex is mediated by vagus nerve .

2- Hormonal factors:

- **Gastrin, CCK, insulin and serotonin** stimulate intestinal motility.
- **Gastrin and CCK** relax ileocaecal sphincter. *(have an action like vagus nerve by relaxing ileocaecal sphincter and stimulating intestinal motility, CKK decrease stomach motility but increase intestinal motility)*
- **Motilin** secreted from duodenum stimulates intestinal motility and regulate MMC.
- **Secretin and glucagons** inhibit intestinal motility and contract ileocaecal sphincter. *(similar to sympathatic action)*
- **Villikinin** stimulates movement of the villi.

Secretion Of The Small Intestine

Physiology Team

	Brunner's Glands	The Crypts of Lieberkühn
Location	located in the wall of the first few centimeters of the duodenum.	Small pits which lie between intestinal villi
Secretion	**Secretion of Mucus :** They secrete large amounts of **alkaline** mucus, which contains a large amount of **bicarbonate ions.** • Mucus protects the mucosa.	***Secretion of Intestinal Juices (Succus Entericus):*** 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.* 2. ***Enterocytes***→ A. *secrete large quantities of* ***H2O and electrolytes*** *and over the surfaces of adjacent villi.* B. ***reabsorb H2O, electrolytes & end products of digestion.***

Secretion Of The Small Intestine

Physiology Team

- ***Succus Entericus:*** (intestinal juice)

It is secreted from intestinal crypts.

- **Volume:** 1800 ml/day.
- **pH:** 7.5-8. (alkaline) It participates in the neutralization of acid chyme delivered from stomach. (important because the intestinal mucosa is not protected against HCL and to provide the optimal pH necessary for action of enzymes -pancreatic or intestinal)
- **Composition:** (in addition to water)
    - 0.6 % organic (mucus and enzymes)
    - 1 % inorganic substance. (electrolytes)
- Most of the enzymes are found in:
    - the **brush border.**
    - the **cytoplasm of the enterocytes** (intracellular digestion).

Secretion Of The Small Intestine

Physiology Team

- The enzymes that **secreted into the lumen** are:
  - enteropeptidase
  - amylase (pancreatic)
- Enterocytes of mucosa contain digestive enzymes (detailed in later slides):
  - Sucrase, maltase, isomaltase, and lactase for *splitting disaccharides into monosaccharides*.
  - Aminopeptidases, Oligopeptidases, Intracellular di- and tripeptidases for *splitting small peptides into amino acids*.
  - Small amounts of intestinal lipase for *splitting neutral fats into glycerol and fatty acids.*
  - Nucleotidases for *splitting nucleotides into purine and pyrimidine bases, phosphoric acid and pentose sugar.*

Control Of Secretion

Physiology Team

Brunner's gland secretion	Intestinal juice secretion
Is stimulated by: • **Hermonal: Secretin** (inhibitory to the motor function but stimulates secretion) • **Tactile** (tactile=coming of the chyme in contact with the mucosa) • **Neural:** vagal stimulation .	Is stimulated by: **A. Distension**, tactile and vagal stimulation. **B. Hermonal:** gastrin, secretin, CCK, glucagons, enterocrinin. **Sympathetic stimulation exerts an inhibitory effect.**

Digestion Of Carbohydrates

Physiology Team

Digestion by Pancreatic Amylase:

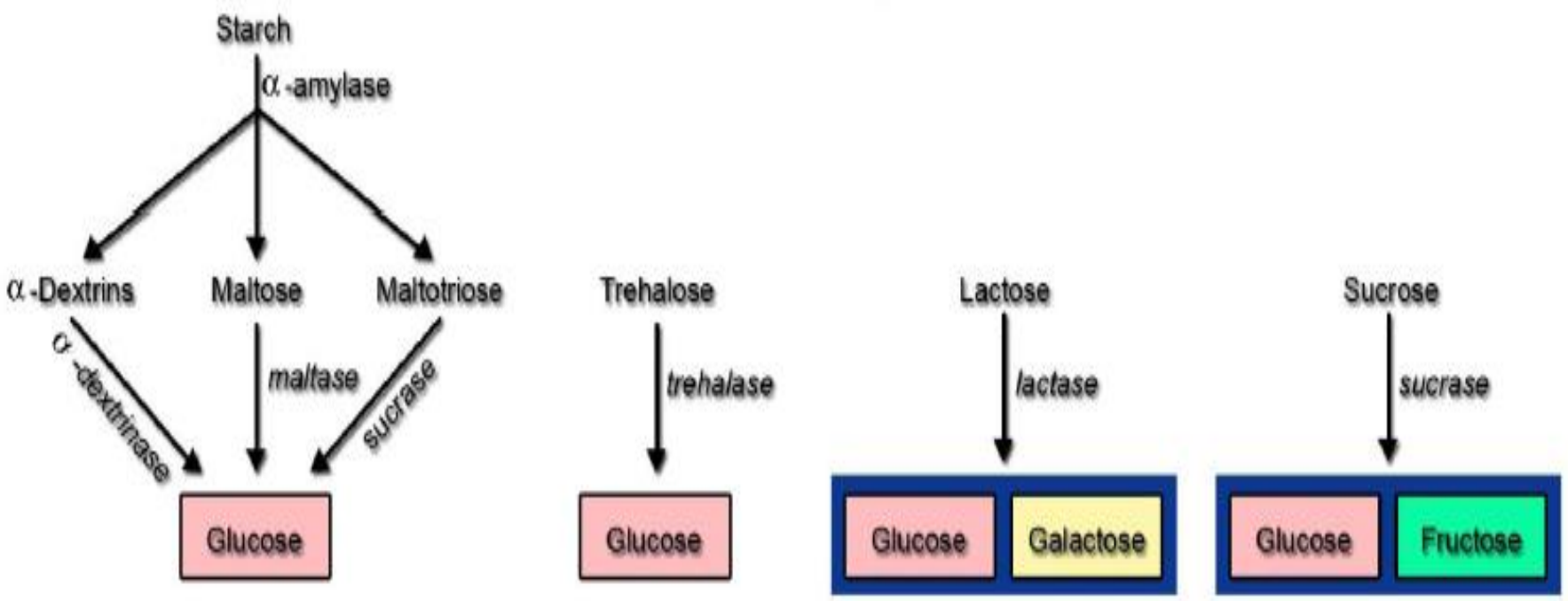
- Pancreatic α-amylase is almost identical with the α-amylase of saliva but more powerful. Within 15 to 30 minutes after the chyme mixes with pancreatic juice, all the carbohydrates will have become digested.
- The carbohydrates are almost totally converted into maltose or other very small glucose polymers before passing beyond the duodenum or upper jejunum.
- The enterocytes lining the villi of the small intestine contain four enzymes
  1. **Lactase**
  2. **Sucrase**
  3. **Maltase**
  4. **a-dextrinase**

❑ Which are capable of splitting the disaccharides lactose, sucrose, and maltose, plus other small glucose polymers, into their constituent monosaccharides (the absorptive form).

❑ **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

Physiology Team



Also Pentose which's come from the digestion of RNA and DNA

Digestion Of Proteins in Stomach

Males' Slide

Physiology Team

In the stomach:

- Digested by pepsin (active at pH 2 – 3).
- Pepsin also digests collagen protein of intracellular connective tissue in meat, thus allowing digestive enzymes to reach meat protein.
- Pepsin is responsible for only 10% – 20% of protein digestion.

Digestion of Proteins in Small Intestine

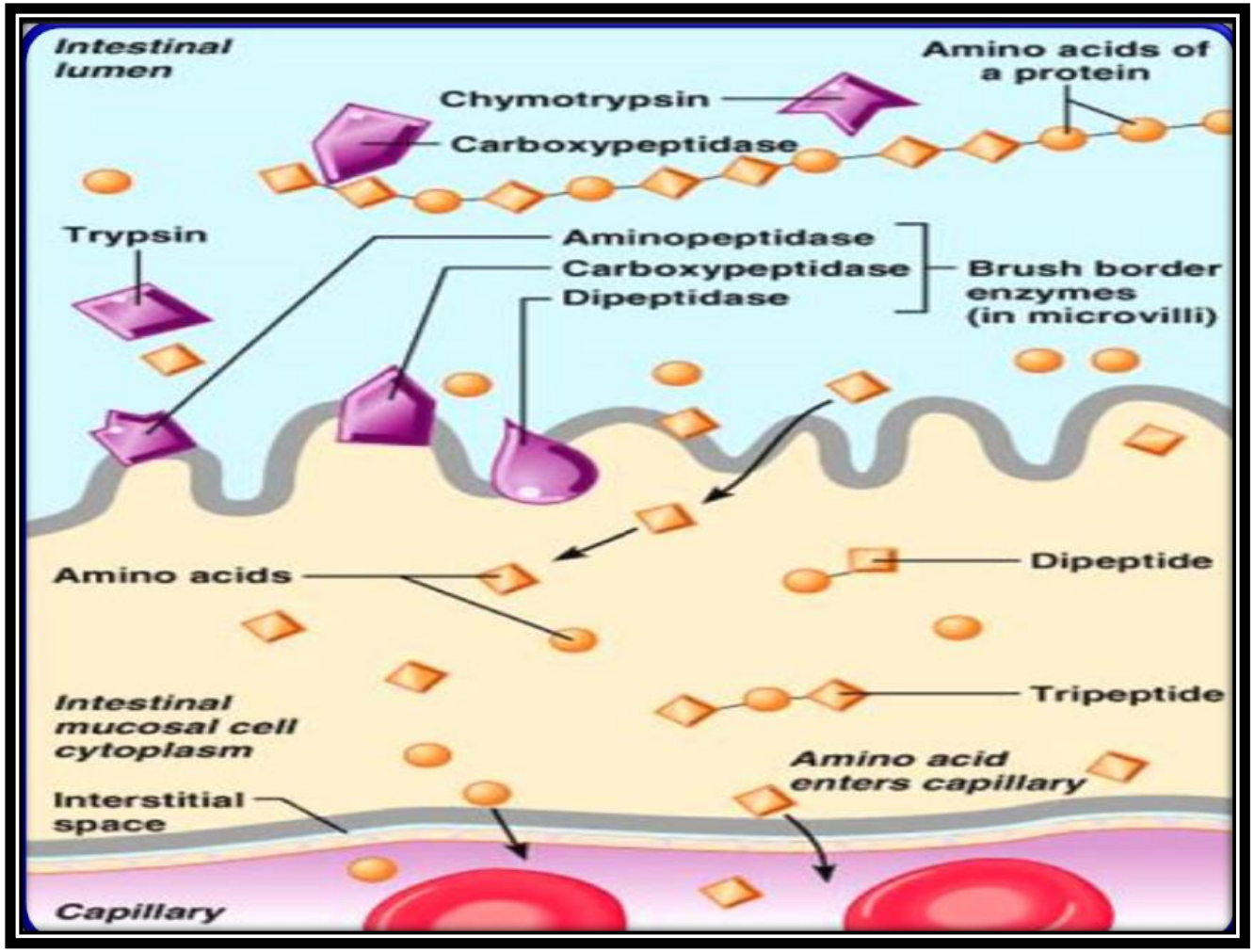
Physiology Team

• Only a small percentage of the proteins are digested all the way to their constituent AA (Amino acids) by the action of→ **pancreatic juices (trypsin, chemotrypsin & elastase)**.
Most 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.

- **Aminopeptidase work on peptide chain with amino acid terminal.**
- **Oligopeptidases work on peptides with small chains.**
- **di and tripeptides are absorpted as such and digested Intracellulary by di and tripeptidases.**

Digestion Of Proteins

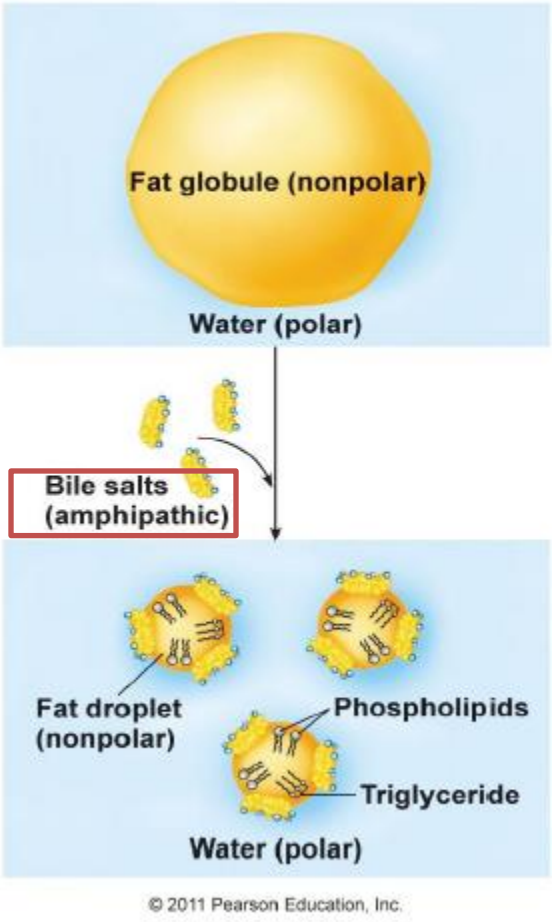
Physiology Team



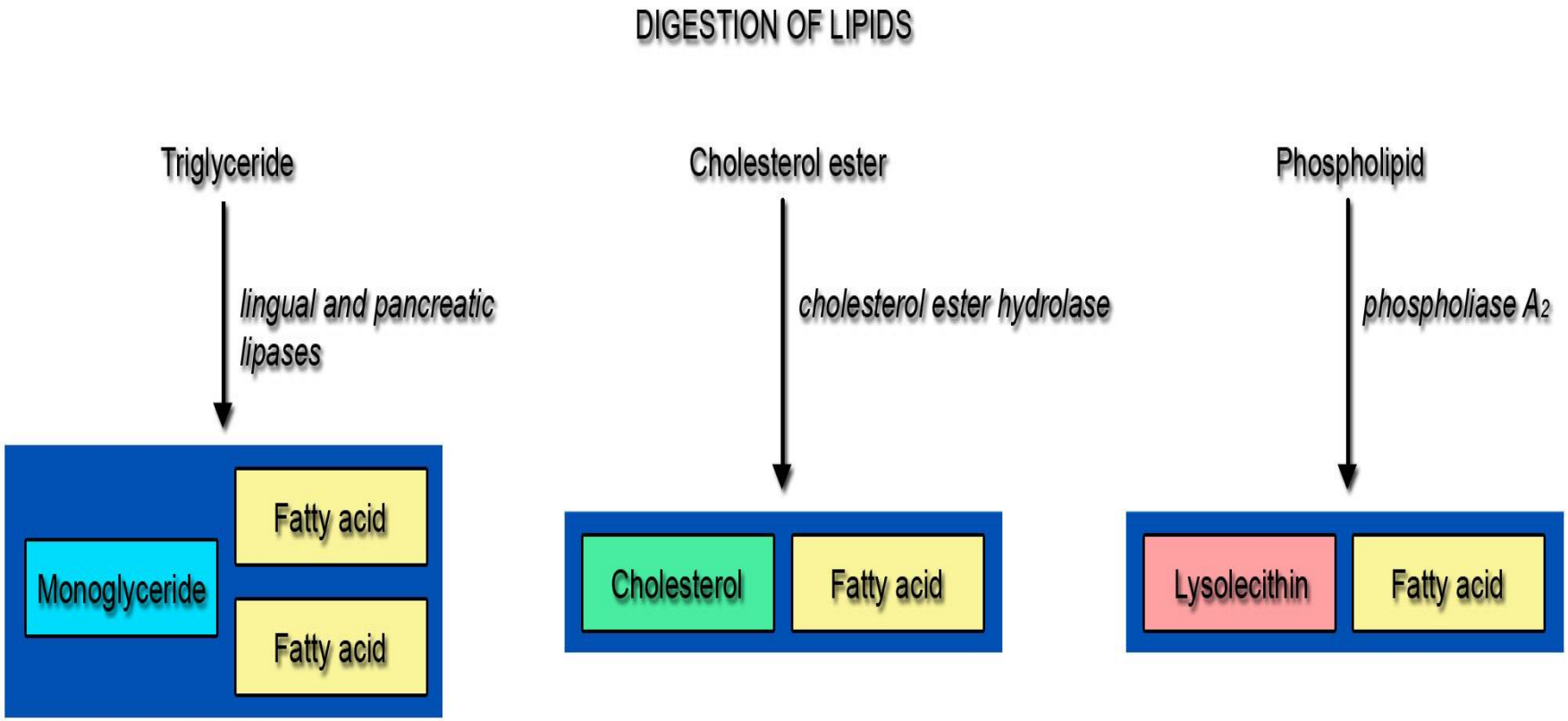
Digestion Of Fats

Physiology Team

- **Bile salts and lecithin** in bile allow fat globules to be easily broken into smaller pieces by intestinal agitation (emulsification), therefor making it easier for water soluble enzymes to act on globule surfaces.
- The most important enzyme in TG digestion is pancreatic lipase



Guyton: Bile salts decrease surface tension between fat particles, allowing the agitation in the intestine to break fat globules into small sizes. This is called emulsification.


DIGESTION OF LIPIDS
Triglyceride
lingual and pancreatic lipases
Monoglyceride
Fatty acid
Fatty acid
Cholesterol ester
cholesterol ester hydrolase
Cholesterol
Fatty acid
Phospholipid
phospholiase A2
Lysolecithin
Fatty acid

Basic Principles Of Gastrointestinal Absorption

Physiology Team

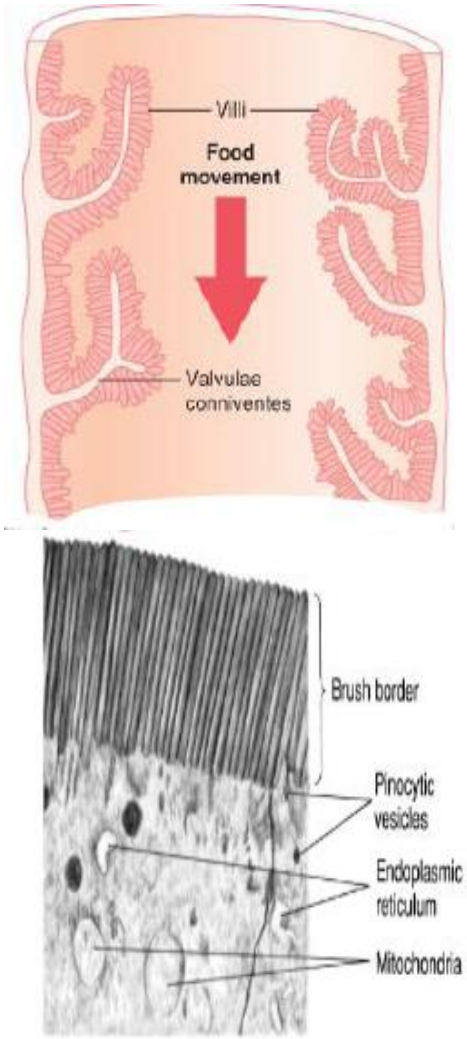
•***Absorptive Surface of the small intestinal wall***

The absorptive surface of the small intestinal mucosa, showing many folds called **valvulae conniventes**, is well developed in the duodenum and jejunum.

•They 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*).**



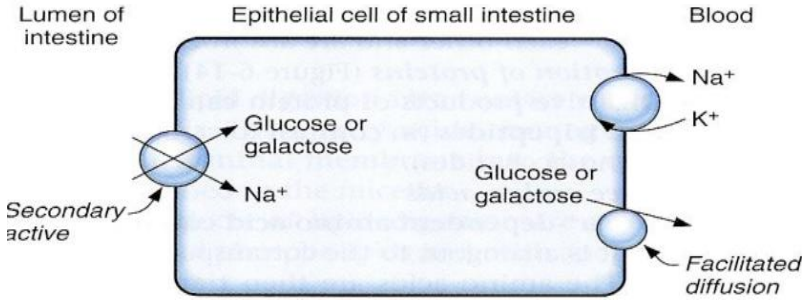
	Carbohydrates	Proteins	Fats	Vitamins
Absorption form	Mono-saccharides + small fraction Disaccharides	Dipeptides + Tripeptides + few free Amino Acids	Break down to Fatty acids + Monoglycerides then carried by bile micelles*	_____

How absorption occur + its mechanisms	#Glucose and Galactose → 2ry active transport with Na+
	
	#Fructose → facilitated diffusion on Na+ via lumenal membrane
	
	#Pentose → via passive diffusion
		#D- AA→ passive diffusion.
		#L- AA→ 2ry active transport.
		#Di and tripeptides →active transport protein carrier by crossing the brush border. They are hydrolyzed by brush border and cytoplasmic oligopeptidases.
		#AA → facilitated Transport by leaving the cell at the basolateral membrane.
			#In presence of bile micelles →about 97% of the fat is absorbed
			#In absence of the bile micelles → only 40 to 50% fat is absorbed.
			*Bile micelle: small spherical, cylindrical Globule of 20 - 40 molecules of bile salts**
			** Bile salts: amphipathic molecules, composed of {sterol nucleus (fat-soluble)} + {polar group (water-soluble), ((its –ive charge make entire micelle dissolve in water of GI fluids))}
			#Triglycerides aggregate into globules along with the absorbed cholesterol and phospholipids.
			#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.
				#Fat-soluble vitamins (A, D, E, & K) are absorbed along with other lipids → by micelles.
				#Water-soluble vitamins (C, B1, B2, B6, and folic acid) are absorbed →by Na+-dependent cotransport
				#Vitamin B12 is absorbed in the ileum and → requires intrinsic factor
				Gastrectomy = loss of parietal cells and loss of intrinsic factor → pernicious anemia!

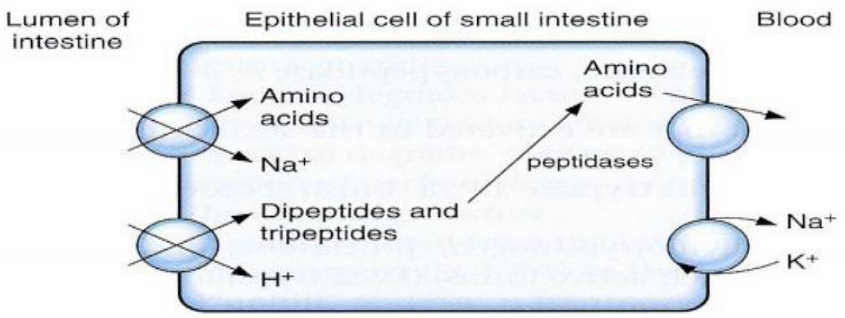
Basic Principles Of Gastrointestinal Absorption

Physiology Team

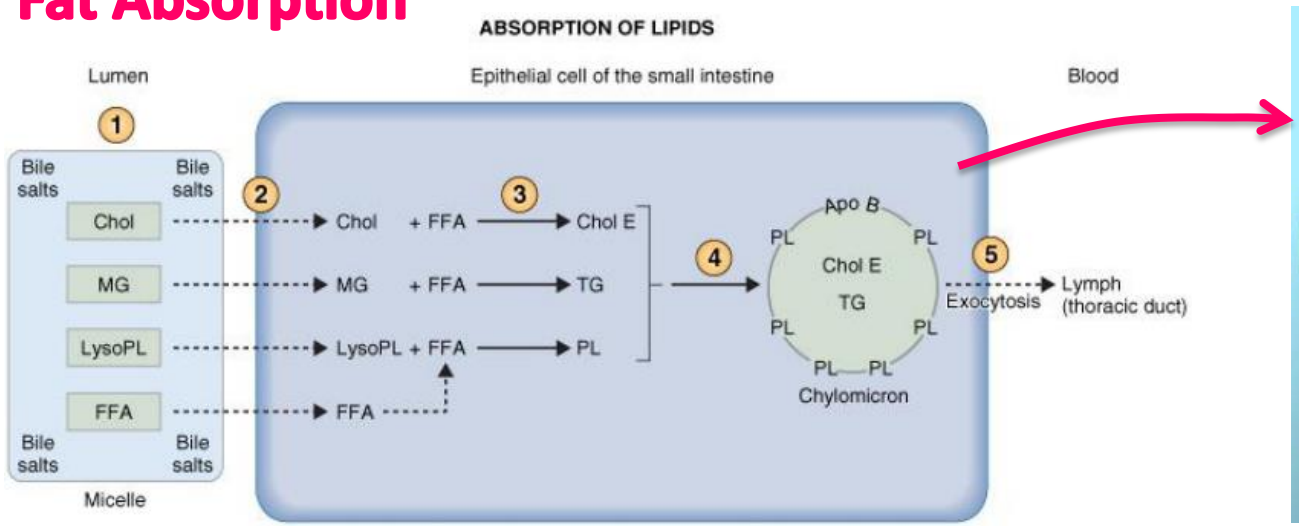
Carbohydrates Absorption

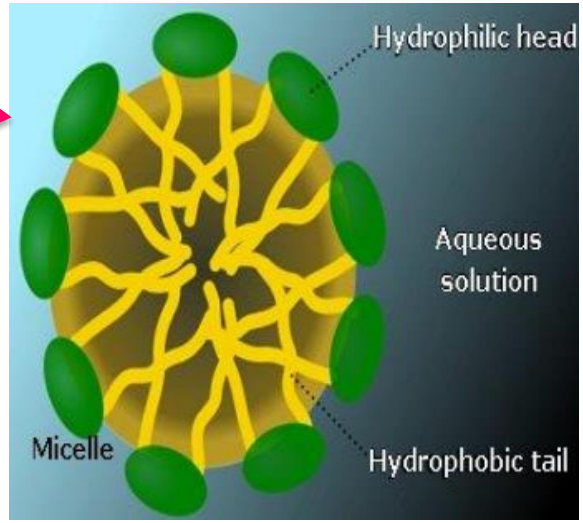


Proteins Absorption



Fat Absorption





Slides | Important | Females' Notes | Explanation | Males' Notes

Absorption & Secretions of electrolytes and water

Physiology Team

Absorption of	Absorption mechanisms
Na+	By : 1)Passive diffusion 2)Na+-glucose or Na+-amino acid co-transport 3)Na+-Cl- exchange 4)Na+-H+ exchange Next step, osmosis of water into the paracellular spaces, why? Because of large Na+ ions concentration in the paracellular space. ☺ (water follows to Na+). 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- -HCO3 exchange
K+	by passive diffusion ((loss of K+ in diarrhea causes Hypokalemia))

Secretion of	Reasons ?
K+	K+ secretion in the colon is stimulated also by Aldosterone!
HCO3 (bi-carbonate ions)	HCO3 secretion in ileum & large intestine exchange for Cl-. alkaline HCO3 that neutralize acid products by bacteria in the large intestine.

Absorption of	Absorption mechanism
Ca++ absorption by enterocytes.	When ↓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

Important

Physiology Team

Hormone	Absorption	In the
Catecholamines	↓ intestinal secretion	intestine
Glucocorticoid	↑ absorption of H2O & ions	(small & large intestine)
Epinephrine	↑ NaCl absorption	(ileum)
Aldosterone	↑ synthesis of Na+ channel	(colon)
Somatostatin	↑ H2O & ions absorption	(ileum & colon)

SUMMARY

Physiology Team

- Migrating motor complex (MMC) begins in an empty stomach during interdigestive period.
- Antiperistalsis motion occurs in the opposite direction between stomach and duodenum.
- **villikinin hormone** specific hormone **stimulate** the movement of the villi, released by intestinal mucosa.
- **Sympathetic excitation decreases** intestinal and villous **movement.**
- **Vagal excitation increases** intestinal and villous **movements**.
- T**he ileocaecal valve relaxes In the gastroileal reflex**
- **Gastrin, CCK, 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.**
- **Enterocytes secrete** large quantities of H2O and electrolytes and over the surfaces of adjacent villi and **reabsorb** H2O, electrolytes & end products of digestion.
- The enterocytes lining the villi of the small intestine contain four enzymes for the digestion of carbohydrates **(Lactase, Sucrase, Maltase, a-dextrinase)**
- Bile micelles helps in absorption of Fat by 97%, if absent fat absorbed by 40-50%.
- Lipids and B-lipoproteins are absorbed back to the lymph → then to thoracic duct.
- Fat-soluble vitamins absorbed with the lipids or fat.
- Water-soluble vitamins absorbed by Na+-dependent cotransport.
- Secretions of electrolytes in small intestine: K+ in colon, while HCO3 in ileum & large intestine.
- HCO3 secretion helps in neutralize large intestine form acids secreted by intestinal bacteria.

QUESTIONS

Physiology Team

Q1) Sympathetic excitation will :

A. increases intestinal and villous movement
B. relax ileocaecal sphincter
C. contract ileocaecal sphincter.
D. decreases intestinal and villous movement

Q2) Secretin and glucagons will:

A. Stimulate intestinal motility and contract ileocaecal sphincter.
B. inhibits intestinal motility and relax ileocaecal sphincter.
C. inhibits intestinal motility and contract ileocaecal sphincter.
D. Stimulate intestinal motility and relax ileocaecal sphincter.

Q3) Na+ absorption enhanced by which hormone :

A) Somatostatin B) Glucocorticoid
C) Aldosterone D) Parathyroid

Q4) D-AA protein is absorbed by which mechanism :

A) Active transport B) Passive diffusion
C) 2ry active transport D) Exchanging ions

1- D
2- C
3- C
4- B

QUESTIONS

Physiology Team

Q5) Villous movement consist of :

A- Fast shorting

B- Slow lighting

C- A+B

Q6) The movement of villi stimulated by :

A- CCK

B- Secrtien

C- Villikinin

Q7) Gastrien cause ……. While Secrtien cause …… of ileocaecal sphincter :

A- Relaxation , contraction

B- contraction , relaxation

C- Both cause relaxation

Q8) Brunner's gland located in the wall of :

A- Stomach

B- 1st part of duodenum

C- ileum

Q9) The Crypts of lieberkubn responsible for :

A- Intestinal juice secretion

B- Gastric juice secretion

C- non of the above

Q10) Most of protein digestion occurs in :

A- Stomach

B- Duodenum

C- Duodenum + Jejunum

Q11) The emulsification occurs for :

A- Carbohydrates

B- Fats

C- Proteins

5- C
6- C
7- A
8- B
9- A
10- C
11- B

Q12) The absorptive surface of small intestinal mucosa increase the surface area by:

A- 10- folds B- 20 – folds

C- 3- folds

Q13) The absorption of glucose and gelatos occur by:

A- 2ry active transport B- Facilitated diffusion

C- Passive diffusion

Q14) Fats excreted from the intestienal cells to the lacteal in the form of:

A-Cholesterol B- Chylomicrons

C- Phospholipids

Q15) Vit.B12 absorbed in:

A- Stomach B- Duodenum

C- ileum

12- C
13- A
14- B
15- C

THE END

Physiology Team

If there are any Problems or Suggestions,
Feel free to contact us:

Physiology Team Leaders

Mohammed Jameel & Shaimaa Al-Refaie

432Physiology@gmail.com

THANK YOU

IF YOU WANT TO SHARE ANY INFORMATION REGARDING PHYSIOLOGY OR ANY OTHER SUBJECT .. YOU CAN MENTION THIS ACCOUNT @MED432