Physiology Team 439

MED439
KING SAUD UNIVERSITY

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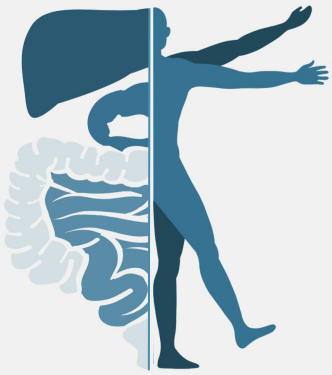


Small intestine motility & secretion

Objectives:

- 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 proteins.
  -Absorption fats.
  -Absorption vitamins
  -Absorption and secretion of electrolytes and water.

GI Motility of the Small Intestine - Ninja Nerd Lectures (Duration: 26:52 mins)

Videos Related to Carbohydrates:

Carbohydrates Digestion and Absorption Process (Duration: 3:45 mins)
Digestion and Absorption of Carbohydrates - Ninja Nerd Lectures (Duration: 38:06 mins)
Starch (Carbohydrate) Digestion and Absorption - Armando Hasudungan (Duration: 8:42 mins)

Videos Related to Fats:

Digestion and Absorption of Fats Part 1 (Duration: 4:19 mins)
Digestion and Absorption of Fats Part 2 (Duration: 4:13 mins)
Digestion & Absorption Of Lipids - Ninja Nerd Lectures (Duration: 46:00 mins)
Fat Digestion - Lipolysis & Lipid Transport - Dr Matt & Dr Mike (Duration: 23:27 mins)
Digestion, Mobilization, and Transport of Fats - Part I - KhanAcademyMedicine (Duration: 10:07 mins)
Digestion, Mobilization, and Transport of Fats - Part II -KhanAcademyMedicine (Duration: 14:45 mins)

Videos Related to Proteins:

Protein Digestion and Absorption - Armando Hasudungan (Duration: 10:36 mins)
Digestion & Absorption of Proteins - Ninja Nerd Lectures (Duration: 42:26 mins)

Color index:

- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

Editing File

Motility in the Small Intestine

The movements of the small intestine can be divided into :

1	Segmenting (Mixing) contractions.
2	Propulsive contractions (Peristalsis).
3	Migrating motor complex.
4	Antiperistalsis
5	Peristaltic rush.

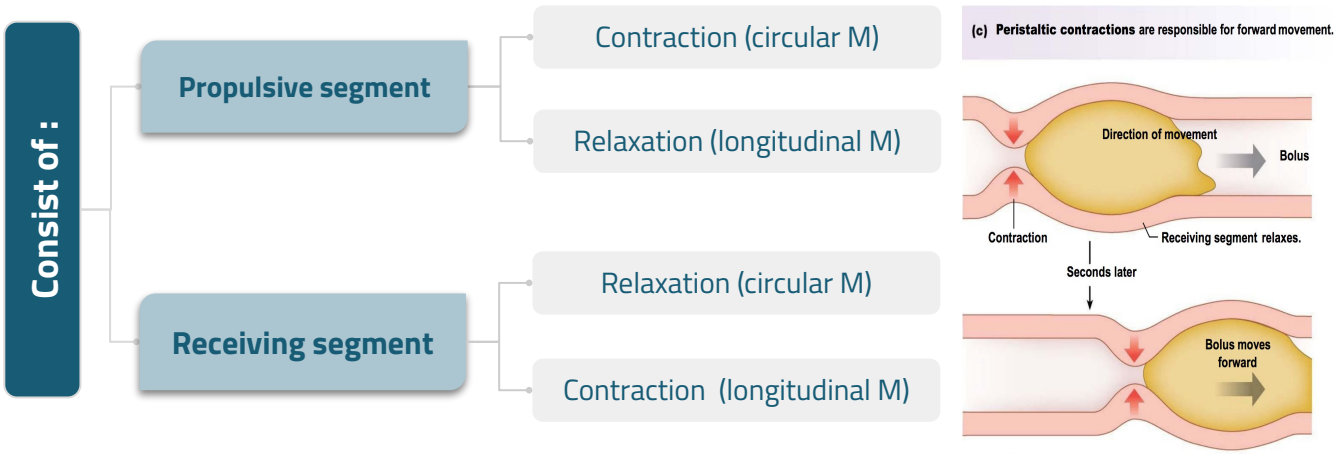
1. Propulsive Movement (Peristalsis)

-Usual stimulus is **distention** of a part of the small intestine by the chyme or food.
-Myenteric Plexus (Enteric Nervous System (ENS)) is important for these movements
-They can be blocked by **atropine**. (Parasympatholytic, which block the action of cholinergic receptors)

-Propulsive movements can occur in any part of the small intestine.
-A contraction ring appears around gut, then moves forward.
-It organizes propulsion of material over variable distances within the intestinal lumen.
-They normally are very weak after traveling only 3 to 5 centimeters, and the net movement along the small intestine normally averages only 1 cm/min.
-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)

Guyton: Other stimuli that can initiate peristalsis include chemical or physical irritation of the epithelial lining in the gut. Also, strong parasympathetic nervous signals to the gut will elicit strong peristalsis.

Contraction of the ring of circular muscles proximal to the distal part (by bolus) then it disappear after push the food, and appear in the next part. Propagate along the Length of intestine.



Motility in the Small Intestine, Cont...

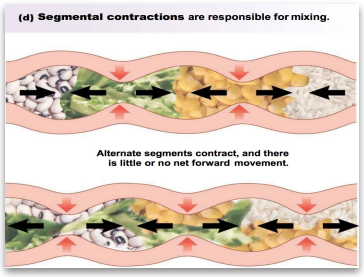
2. Mixing (Segmentation) Contractions

Division of a loop of small intestine in segments by contraction of circular muscles at certain interval at the same time (not as Propulsive, one ring and propagate)

-Usual stimulus is **distention**.
-It is activated by enteric nervous system (ENS). (Myenteric plexus)
-They can be blocked by atropine.

-When a portion of small intestine becomes **distended**, the segmentation contraction circular smooth muscle is activated by **ENS** to divide the intestine into spaced segments which last for fraction of min, and have the appearance of a chain of sausages.

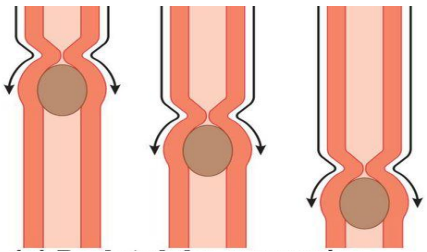
-As one set of segmentation contractions relaxes, a new set often begins at points between the previous ones. The segmentation contractions become weak when the excitatory activity of ENS is blocked by the drug atropine.



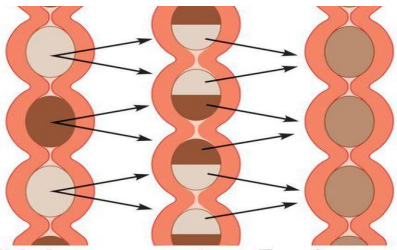
-**The significance of segmentation contractions: ****

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

Propulsive (peristalsis movement)	VS	Mixing (segmentation contractions)



Ringlike peristaltic contractions sweep food along the GI tract

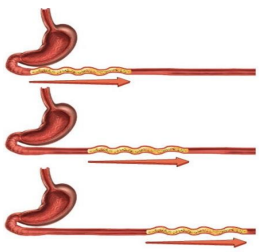


Circular muscles contract, breaking chyme into ever smaller pieces until chyme is thoroughly mixed with digestive juices

3. Migrating motor complex (MMC)

It is bursts of depolarization accompanied by peristaltic contraction that begins in empty stomach during inter-digestive period In between meal (after absorption occurs)

- Start in pylorus then Travels along whole length of small intestine to reach ileocaecal valve after 1.5-2 h, where it disappears. Then a new wave of **MMC** starts
- The function of MMC is to propel any remnants in stomach & small intestine into colon keeping the small intestine clean, during the inter-digestive period (Housekeeper)
- The activity of MMC terminates as soon as food is ingested
  End When the food is ingested, because it's in between meal.
- Regulated by autonomic nerves and by release of hormone motilin
  Recall that motilin is activated by oral glucose but it is inhibited to a stronger degree by presence of food in the stomach leading to inhibition of MMC
  Motilin is Release from MO cells



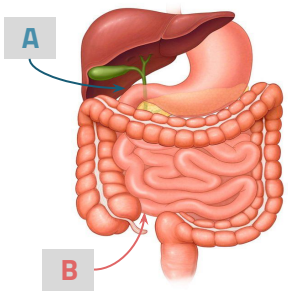
Motility in the Small Intestine, Cont...

4. Antiperistalsis

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

Occurs between:

- **Stomach** and **duodenum** to allow more time for neutralization of chyme.**(A)** Because the chyme derived from the stomach is highly acidic.
- **Ileum** and **caecum** to allow time for absorption **(B)**



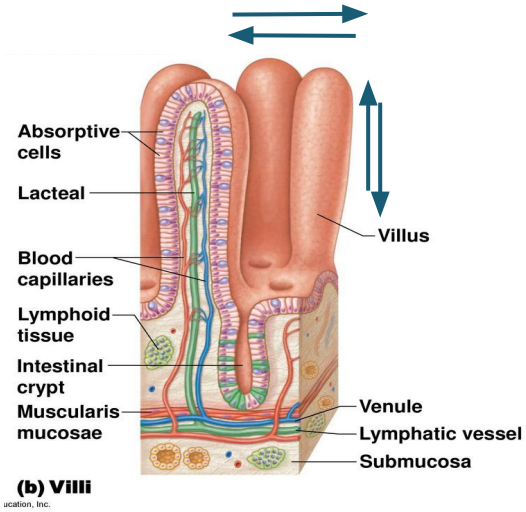
The same as the first type but occur in the opposite direction:
- Peristalsis : downward and forward. Towards the anus.
- Antiperistalsis : upward and backward. Towards the mouth.

5. Peristaltic rush

- Powerful rapid peristalsis due to **intense irritation** (chemical, mechanical or infectious) of intestinal mucosa as in **infectious diarrhea.**
  Severe irritation of intestinal mucosa by bacterial toxin or some irritant like castor oil زيت الخروع
- Initiated mainly by extrinsic nervous reflexes through the vagus nerve to brain stem and back to gut.
- Sweeps the contents of intestine into the colon and thereby relieving the small intestine of irritative chyme or excessive distension.

Movement 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. يتحرك في الجهتين وفوق وتحت
- Stimulated by **villikinin hormone** (Specific for movement of villi) released by intestinal mucosa when it comes in contact with digestive products.
- Facilitate absorption and lymph flow from central lacteals into lymphatic system.
  Because some substance are absorbed into lymph



Inside the villus there is lymph and blood vessels (arterioles and venules)

Control of intestinal motility

Neural control

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

Gastroileal reflex :

As we know in GI system (the name of the reflex) ;
First part: initiate or indicate site of stimulus.
Second part: effector organ.

- 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 (vagovagal). (parasympathetic كأنها تعمل لل)

Hormonal control

- **Gastrin, CCK, insulin and serotonin** stimulate intestinal motility.
- **Gastrin and CCK** similar to parasympathetic relax ileocecal sphincter.

  Gastrin and CCK are always mentioned together because they have the same active fragments which means they activate the same receptors
- **Motilin** secreted from duodenum stimulates intestinal motility and regulate MMC.
- **Secretin and glucagon** inhibits intestinal motility and contract ileocecal sphincter. (always mentioned together) like sympathetic system

  Secretin is released from duodenal mucosa in response to acidity of gastric juice
- **Villikinin** stimulates movement of the villi.

Digestive Enzymes in the Small Intestinal Secretion

Only in Boys Slide

Peptides

Splitting small Peptides to ⟶ amino acids by :

1-Aminopeptidases
2-Oligopeptidases
3- Intracellular Di and Tri peptidases

Disaccharides

Splitting disaccharides to ⟶ monosaccharides by :

1-Sucrase 2-Maltase
3-Isomaltase 4-Lactase

Neutral fats

Splitting neutral fats to ⟶ glycerol and fatty acids by :

Small amounts of intestinal lipase

Nucleotides

Nucleotides —Nucleotidases→ purine base, pyrimidine base, phosphoric acid, pentose sugar

Secretions of The Small Intestine

Secretion of Mucus by Brunner's Glands in the Duodenum:

- Brunner's glands are located in the wall of the first few centimeters of the duodenum

  This gland must be in the duodenum, why? Because this is the site of emptying of gastric content/ chyme which is highly acidic. So, it must be neutralized by alkaline mucus which contain bicarbonate ions.

- They secrete large amounts of alkaline mucus, which contains a large amount of bicarbonate ions, **in response to :**

  1-Irritating stimuli on the duodenal mucosa
  2-Vagal stimulation which increase any secretion
  3-Secretin hormone

- Mucus protects the mucosa
- Brunner's glands are inhibited by sympathetic stimulation

secretin
" Stimulus is highly acidic chyme "
Low pH -> Stimulate pancreatic secretions "rich in bicarb" and stimulate the Brunner's glands secretions "which rich in mucous and bicarb". Also stimulate bile secretion from liver which is alkaline.

Secretion of Intestinal Juices (succus entericus) by the Crypts of Lieberkühn

- Crypts of Lieberkühn are small pits which lie between intestinal villi.
- Volume: 1800 ml/day.
- pH: 7.5-8. It participates in the neutralization of acid chyme delivered from stomach.
  Acidic chyme needs three secretions for neutralization : pancreatic, intestinal and bile.
- Composition: 0.6 % organic, 1 % inorganic substance. As any secretion in GIT, consist of water and solutes. Solutes are organic ex. mucous, enzymes or antibodies. Inorganic: electrolytes.
- Most of the enzymes (Either intestinal or pancreatic enzymes) are found either in the brush border (the site of absorption) or in the cytoplasm of the enterocytes
- The enzymes that are actually secreted into the lumen are enteropeptidase and amylase
- 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 :
  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	Intestinal juice
Secretion is stimulated by : - Secretin - Tactile - Vagal stimulation	**Secretion is stimulated by :** - Distension, tactile , irritating stimuli and vagal stimulation. - Hormones : Gastrin , Secretin, CCK, glucagons, enterocrinin. Sympathetic system **inhibits** the intestinal secretion.

Digestion of Carbohydrates

1 In the Mouth and Stomach *Boys Slides

Where Its start?
in the mouth by Amylase digest starch into maltose.
There is no digestion in stomach "only If there is starch"

The ptyalin (an α-amylase) enzyme in saliva hydrolyzes starch into the disaccharide maltose and other small polymers of glucose.

The starch digestion **sometimes** continues in the fundus and body of the stomach for as long as 1 hour before the food becomes mixed with the stomach secretions.

2 In the Small intestine *Boys Slides

Digestion by Pancreatic Amylase

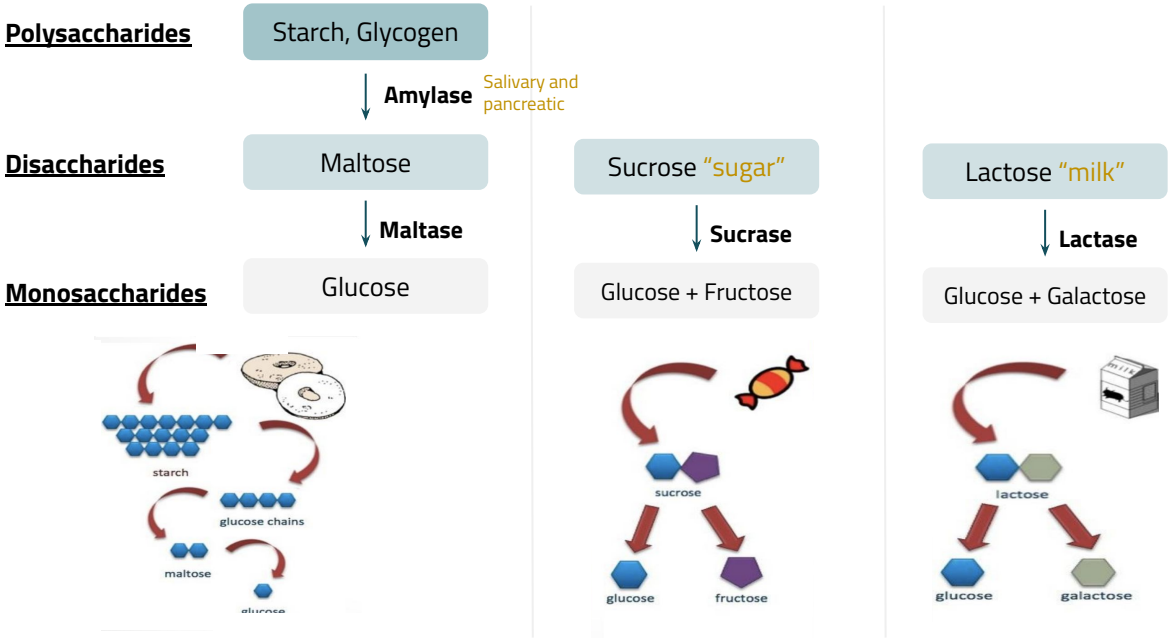
Pancreatic secretion has α-amylase that is almost identical in its function with the α-amylase of saliva but is several times as powerful. Therefore, within 15 to 30 minutes after the chyme empties from the stomach into the duodenum and mixes with pancreatic juice, virtually all the carbohydrates will have become digested.

The carbohydrates are almost totally converted into maltose and/or other very small glucose polymers before passing beyond the duodenum or upper jejunum.

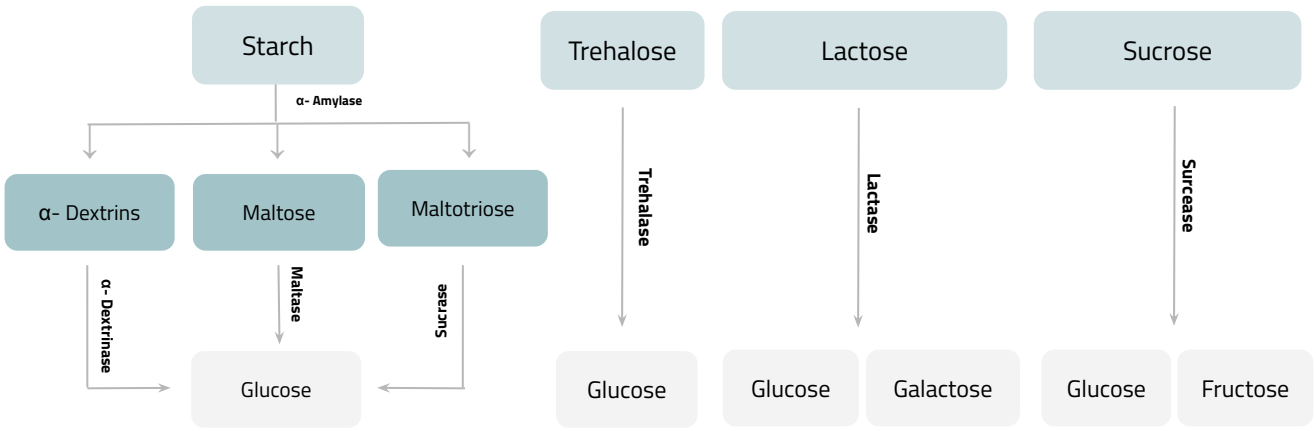
3 Hydrolysis of Disaccharides by Intestinal Enzymes

The enterocytes lining the villi of the small intestine contain four enzymes **(lactase, sucrase,maltase, 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.**



Carbohydrate Digestion



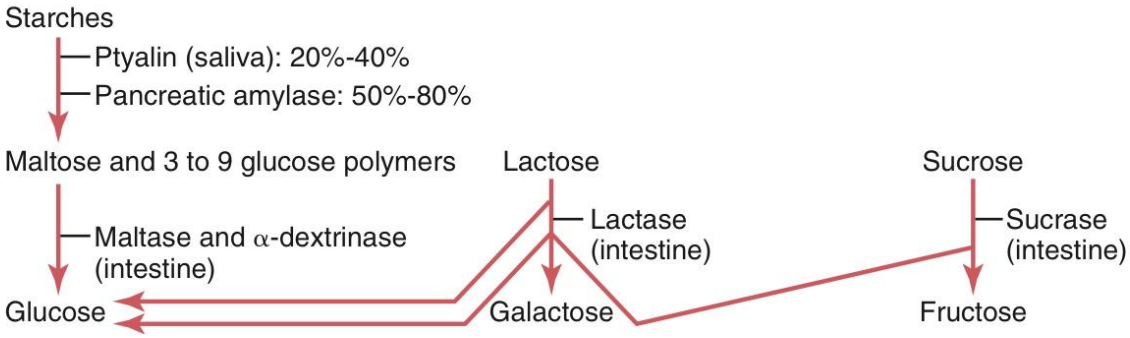
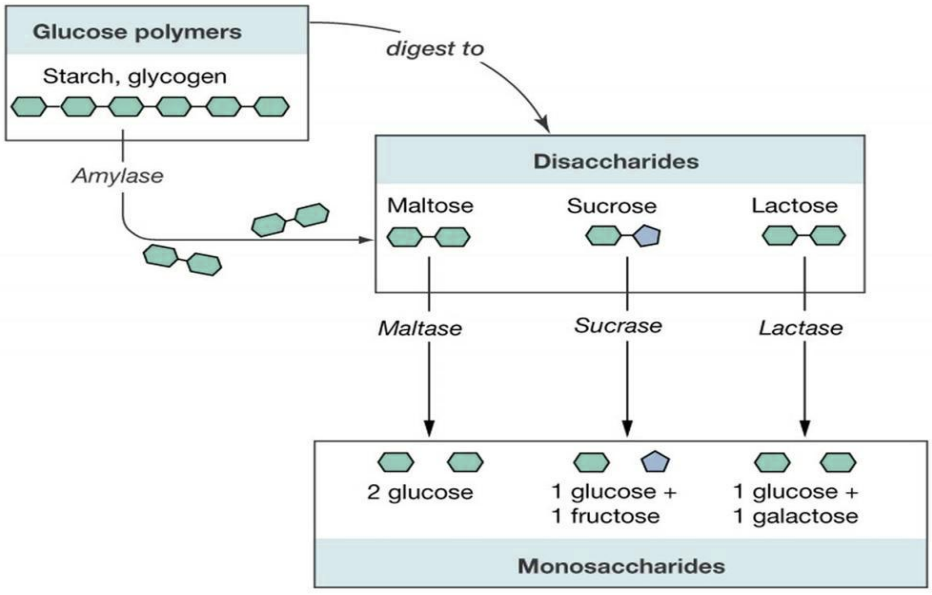


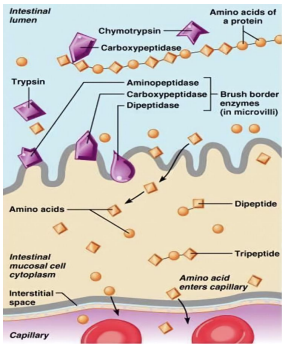
Figure 66-1. Digestion of carbohydrates.



Digestion of Proteins

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

aminopeptidases And oligopeptidases digest proteins into amino acid and dipeptides and tripeptides, which then enter cells and digested intracellularly by di and tripeptidases. .



1 In the Stomach *Boys Slides

- Pepsin is the important peptic enzyme of the stomach (active at a pH=2.0 - 3.0 and is inactive at a pH above about 5.0).
- The pH of the stomach averages around 2.0 - 3.0.
- One of the important features of pepsin digestion is its ability to digest the protein collagen.
- Collagen is a major constituent of the intercellular connective tissue of meats; therefore, for the digestive enzymes of the digestive tract to penetrate meats and digest the other meat proteins, it is first necessary that the collagen fibers be digested.
- Pepsin initiates the process of protein digestion, usually providing 10 to 20 % of the total protein digestion.

2 By Pancreatic secretions *Boys Slides

- Most protein digestion occurs in the duodenum and jejunum.
- Both **trypsin and chymotrypsin split protein molecules into small polypeptides; carboxypolypeptidase then cleaves individual AA from the carboxyl ends of the polypeptides.**
- Proelastase is converted into elastase, which then digests elastin fibers that partially hold meats together.
- Only a small percentage of the proteins are digested all the way to their constituent AA by the pancreatic juices.
- Most remain as dipeptides and tripeptides to be digested by **Peptidases in the Enterocytes** mainly in the duodenum and jejunum.

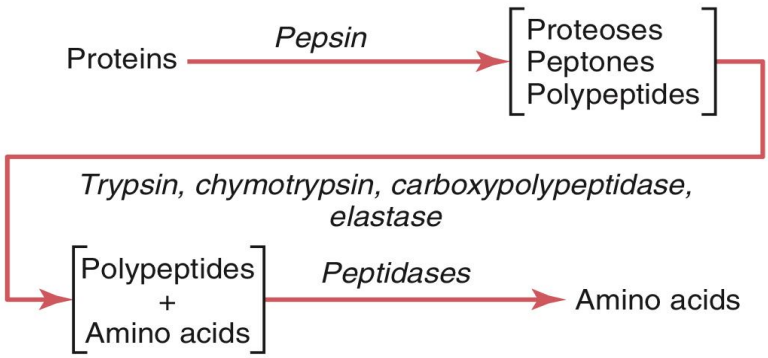


Figure 66-2. Digestion of proteins.

Protein Digestion

(A) Stomach

Protein

↓ **pepsin (Lumen)**

Amino Acids
Oligopeptides

(B) Small intestine

Protein

This route is rare in normal diets

trypsin, chymotrypsin, elastase, carboxypeptidase A, carboxypeptidase B (Lumen)

Amino Acids | Dipeptides | Tripeptides

Oligopeptides

↓ **Peptidase (brush border)**

Amino Acids | Dipeptides | Tripeptides

Figure 8–29 Digestion of proteins in the stomach (A) and small intestine (B).

Precursor | Active enzyme

Activation of Gastrointestinal Proteases

(A) Stomach

Pepsinogen

↓ **Low PH**

Pepsin

(B) Small intestine

Trypsinogen

↓ **enterokinase (brush border)**

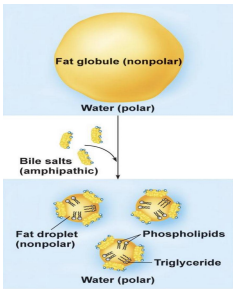
Trypsin

Enterokinase deficiency prevents activation of pancreatic enzymes and stops digestion of proteins**(M)importtttant**

Trypsinogen	Chymotryposinogen	Proelastase	Procarboxypeptidase A	Procarboxypeptidase B
↓ **trypsin**	↓ **trypsin**	↓ **trypsin**	↓ **trypsin**	↓ **trypsin**
Trypsin	Chymotrypsin	Elastase	Carboxypeptidase A	Carboxypeptidase B

Figure 8–28 **Activation of proteases in the stomach (A) and small intestine (B).** Trypsin auto-catalyzes its own activation and the activation of the other proenzymes.

Digestion of Fats

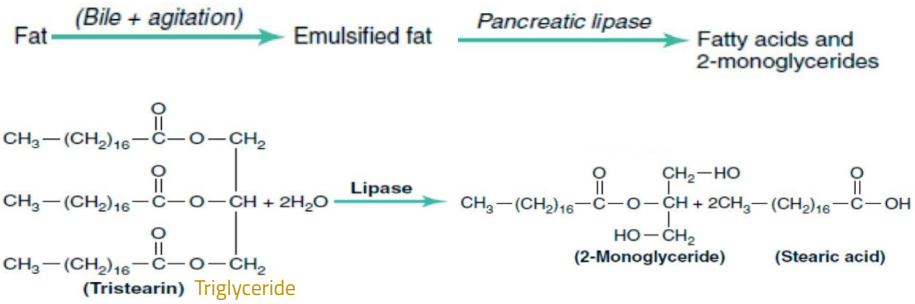


Less than 10 % of triglycerides is digested in the stomach by lingual lipase.*
All fat digestion occurs in the **small intestine**.*

Emulsification of Fat by Bile Acids:

- Break the fat globules into very small sizes under the influence of bile salts , so that the water-soluble digestive enzymes can act on the globule surfaces (emulsification of the fat).Bile salts intersperse Between the fat molecules and decrease the surface tension. Divide the fat globules into smaller particles. Increase surface area for the action of enzymes, this action is called emulsification of fat.
- The polar parts (the points where ionization occurs in water) of the bile salts and lecithin molecules are highly soluble in water. So, they are amphipathic molecules.
- The major function of the bile salts and lecithin, especially the lecithin, in the bile is to make the fat globules readily fragmentable by agitation with the water in the small bowel.
- When the fat found in the medium, the fat molecules aggregate to form fat globules, because fat molecules have high attraction force.
- Emulsification also increases the surface area of fat globules
- CCK contractes the walls of the gallbladder to help in digestion of fat

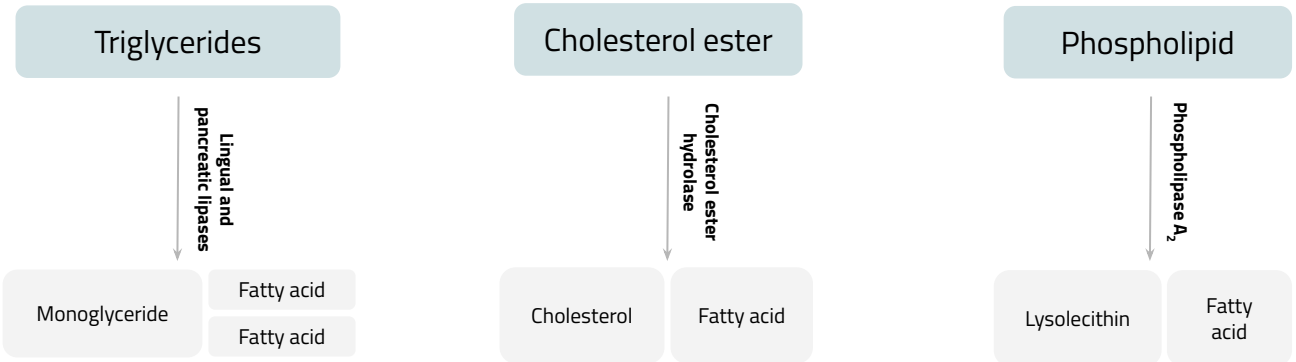
- fat digestion start in the stomach but weak by (gastric lipase).
- pancreatic lipase is the most powerful.



Digestion of Triglycerides by Pancreatic Lipase *Boys Slides

The most important enzyme for digestion of the triglycerides is *pancreatic lipase*.
Reduction in pancreatic secretion leads to Steatorrhea.

-End Products of Fat Digestion:



Basic Principles Of Gastrointestinal Absorption

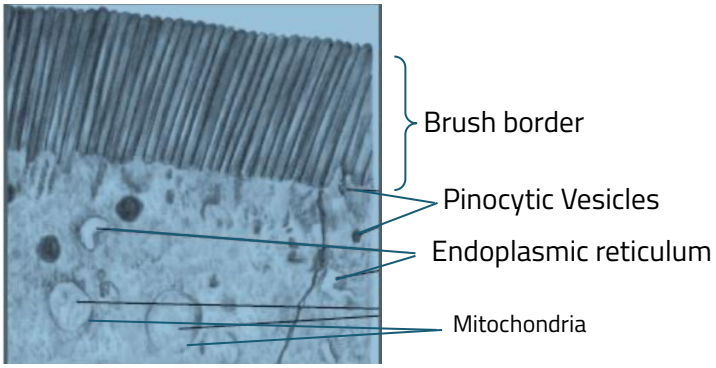
The absorptive surface of the small intestinal mucosa, showing many folds called valvulae conniventes, well developed in the duodenum and jejunum. They increase the surface area of the absorptive mucosa about **3-fold**

More than 95-97% of different type of the end prouducts of food stuffs are absorbed in small intestine, the mucosa of small intestine is adapted for absorption, there is many factors that increase the surface area.

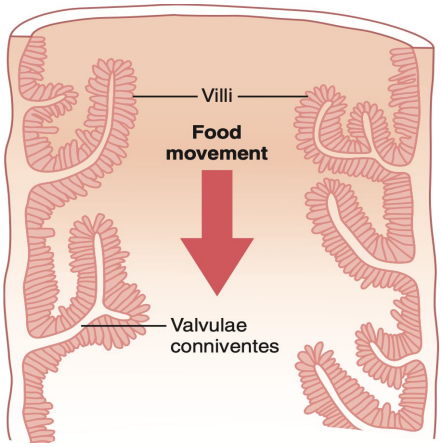
The presence of villi on the mucosal surface enhances the total absorptive area another **10-fold.**

The epithelial cell on each villus is characterized by a brush border, consisting of as many as 1000 microvilli protruding into the intestinal chyme (increases the surface area another **20-fold)**.

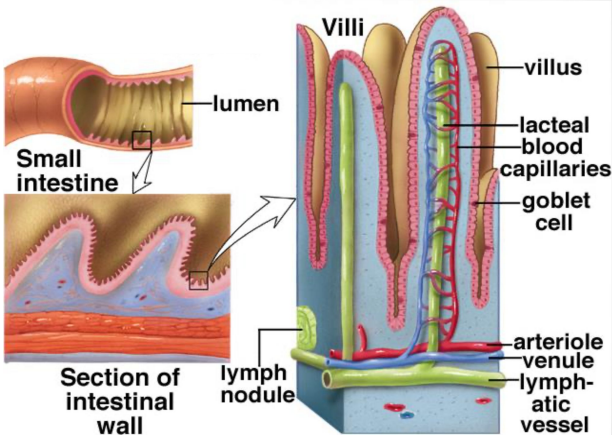
All these increase the intestinal surface **600x (250m^2)** (Provides the surface area equivalent to a tennis court)



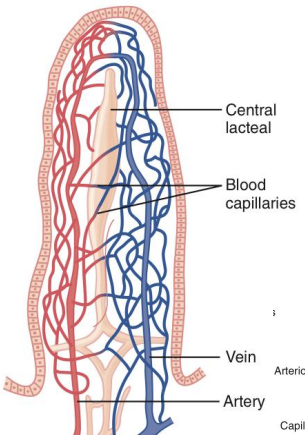
Brush border of a gastrointestinal epithelial cell



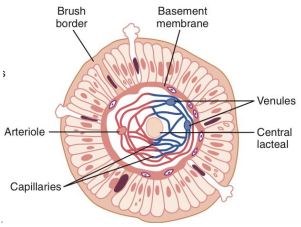
Anatomy of small intestine



Microvasculature of the villus



Inside each villus there is a lymph vessel and blood vessel (arterioles and venules). Most of the different type of the end products of digestion of carbohydrates, protein and fat are absorbed into the bloodstream (into the capillary blood, then to the portal circulation to the liver, EXCEPT the fatty acids specially long chain fatty acids.



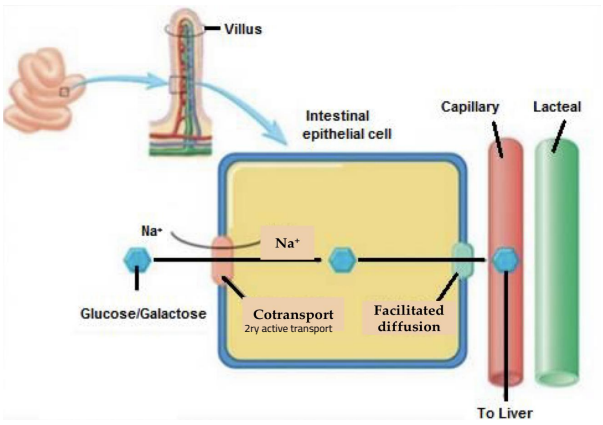
Absorption of Carbohydrates

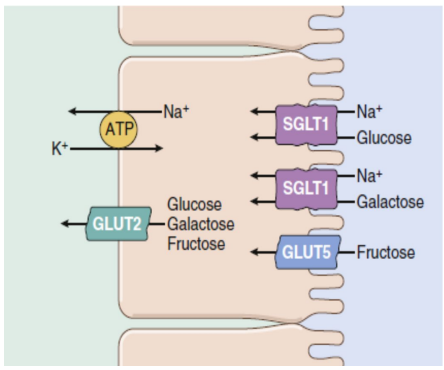
All the carbohydrates in the food are absorbed in the form of monosaccharides; only a small fraction are absorbed as disaccharides.

-Glucose and galactose absorption occurs in a cotransport mode with active transport of Na+ (2ry active transport) Na^+ dependence.

-Fructose is independent on Na+ but it transports in luminal membrane via facilitated diffusion.

-Pentose (come from DNA and RNA digestion) is transported by passive diffusion





Paracelular Space | Cells | Intestinal lumen

SGLT1: Sodium glucose transporter 1 through the brush border.

DM patients take drugs that inhibit SGLT1 receptors to prevent glucose absorption.

Absorption of Proteins

- Similar to that of glucose and galactose but with different carrier.
- They absorbed directly into the bloodstream " portal blood" and to the liver.

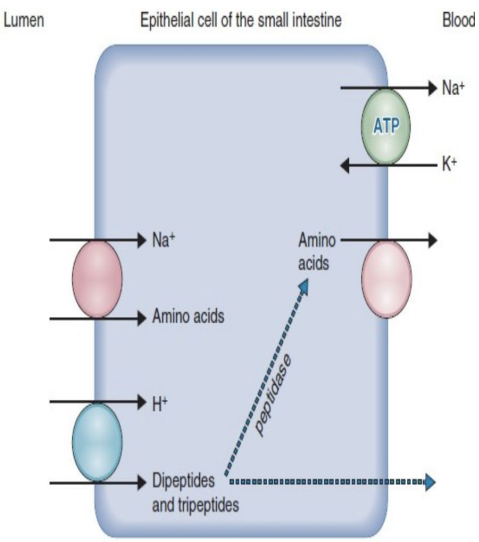
- Proteins are absorbed in the form of dipeptides, tripeptides, and a few free amino acids.
- The energy for most of this transport is supplied by Na+ co-transport mechanism (secondary active transport) .

That is, most peptide or amino acid molecules bind in the cell's microvillus membrane with a specific transport protein that requires Na+ binding before transport can occur.

After binding, Na+ then moves down its electrochemical gradient to the interior of the cell and pulls the amino acid or peptide along with it

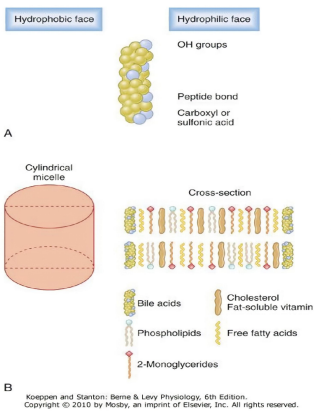
Di and tripeptides cross the brush border by active transport protein carrier. Di and tripeptides are hydrolyzed by brush border and cytoplasmic oligopeptidases.

AA leaves the cell at the basolateral membrane by facilitated transport.

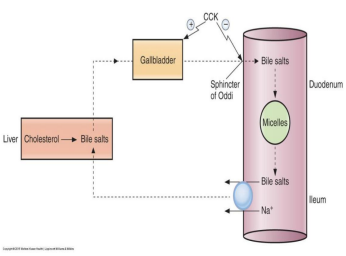


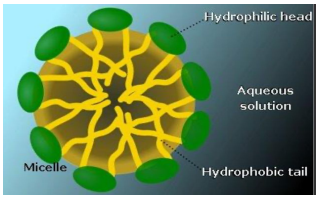
Absorption of Fats

Role of Micelles in Fats Absorption



- Bile salts have the ability to form micelles, (Bile salt are amphipathic molecules, each bile salt molecule is composed of a sterol nucleus that is fat-soluble and a polar group that is water-soluble).Hydrophilic : head polar Hydrophobic : tail non-polar
- Micelles are small spherical, cylindrical globules 3 to 6 nm in diameter composed of 20 to 40 molecules of bile salt.
- Long chain FA, MG, cholesterol and fat soluble vitamins (AKED) are incorporated into the interior of the micelle.water soluble كأنها غلفتهم وخلتهم
- The polar groups are (-) charged, they allow the entire micelle globule to dissolve in the water of the digestive fluids and to remain in stable solution. At certain conc. of the bile salts, they aggregate together. Water soluble portion: outside. Water insoluble portion : interior, This structure called micelles.
- the micelles perform a "ferrying=عبارة" function that is highly important for fat absorption. brush border المقصود بالعبارة انها تنقلهم إلى ال
- The micelles act as a transport medium to carry the monoglycerides and free fatty acids to the brush borders of the intestinal epithelial cells.
- 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.

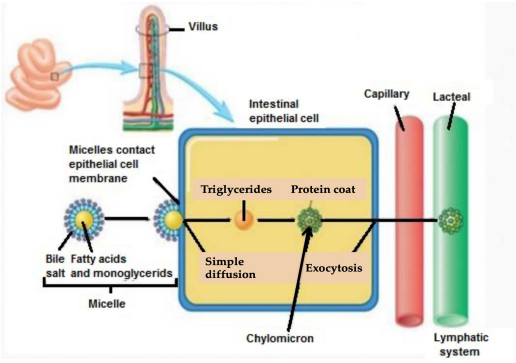




Insobule in the lumen of the intestine so they need a carrier.

Steps of fats absorption *Gilrs slides

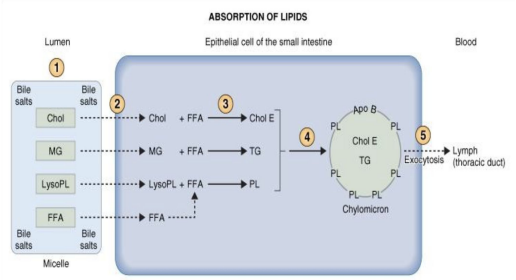
Fatty acids (FA) & monoglycerides (MG) associated with the micelles in lumen of intestine.



Vesicles fuse with the membrane, rapture of the membrane at the site of the diffusion, triglycerides ويخرج ال

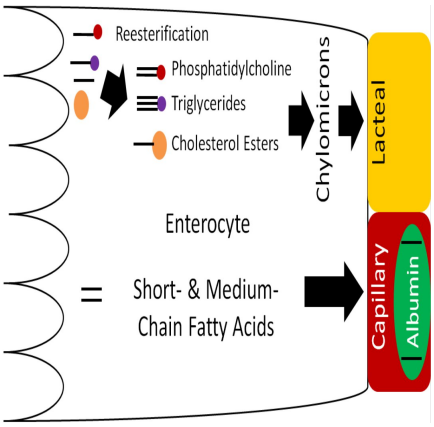
هل يعدوا لل first lymph ?

Central lacteal> thoracic duct> handling by the lymph> then pass to the bloodstream



1. FA & MG leave micelles and enter epithelial cell by **diffusion**. Passively by simple diffusion, because they are fat soluble and the membrane is bi-lipid layer.
2. FA are used to synthesis triglycerides in agranular endoplasmic reticulum. Absorbed fatty acid Reform triglycerides again.
3. Fatty globules are combined with proteins to form **chylomicrons** within Golgi apparatus. Triglycerides (from RER) partially covered by protein
4. Vesicles containing chylomicrons leave epithelial cells by **exocytosis** (Because it is bigger than the pores in cell membrane) and enter a lacteal (lymph capillary).
5. Lymph in the lacteal transport chylomicrons away from the intestine.

Absorption of small quantities of short and medium chain fatty acids *Gilrs slides

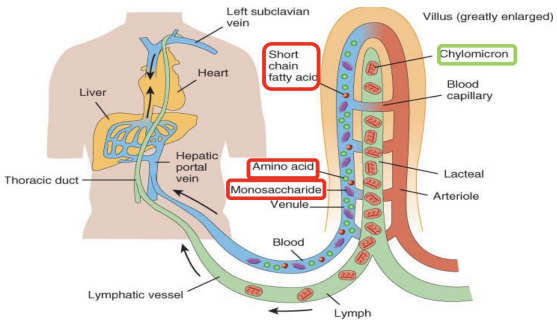


-Small quantities of short-and medium-chain fatty acids, such as those from butterfat, are absorbed directly into the capillary blood of the intestinal villi (portal blood), bound to albumin.

-The cause of this difference between short-and long-chain fatty acid absorption is that the short- chain fatty acids are more water soluble and mostly are not reconverted into triglycerides by the endoplasmic reticulum.

Small Amount of short and medium chain fatty acid are more water soluble than long chain fatty acids and not reconverted into triglycerides in RER, so can be absorbed directly into capillary and bound to Albumin to the liver

Where will the absorbed nutrients go? *Gilrs slides



Absorption of vitamins

Fat-soluble vitamins (A, D, E, & K) are incorporated into micelles and absorbed along with other lipids (As long chain fatty acid absorption need bile salts, their absorption effected by bile salt deficiency.)

Most water-soluble vitamins (C, B1, B2, B6, and folic acid) are absorbed by Na+- dependent cotransport mechanisms (Like glucose and galactose)

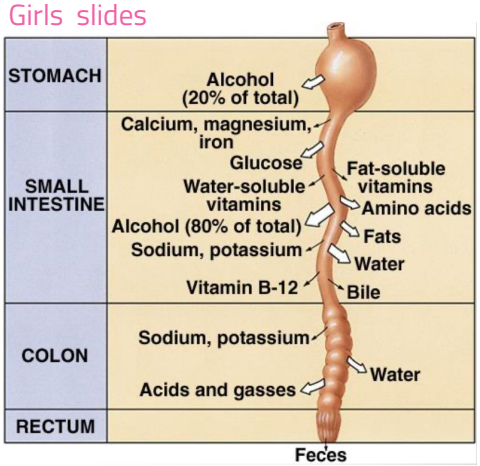
Vitamin B12 is absorbed in the terminal part of ileum and requires intrinsic factor (B_{12} synthesis of DNA of RBC, its deficiency cause anemia)

- Ileal resection can cause vitamin B12 deficiency.
- Gastrectomy results in the loss of parietal cells and loss of intrinsic factor ⟶ pernicious anemia (Affect central nervous system)

B_{12} Needs 2 thing to be absorbed
- intrinsic factor from stomach
- Intact internal ilium.

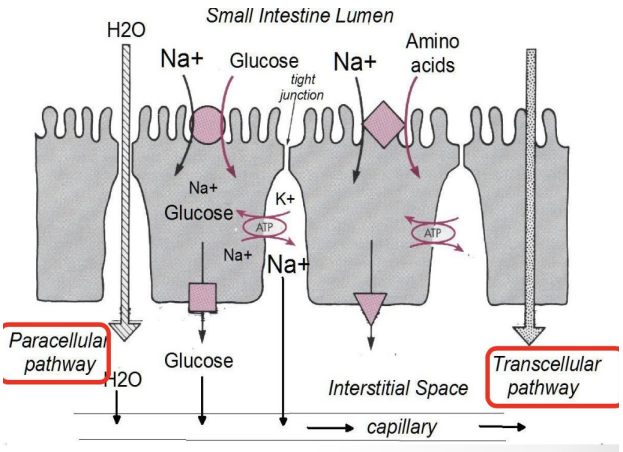
Causes of B_{12} deficiency:
- Lack of intrinsic factor due to Gastrectomy
- Damage to mucosa (parietal cells which secrete intrinsic factor)
- Resection (adhesion, inflammation, cancer) of terminal ileum and removed.

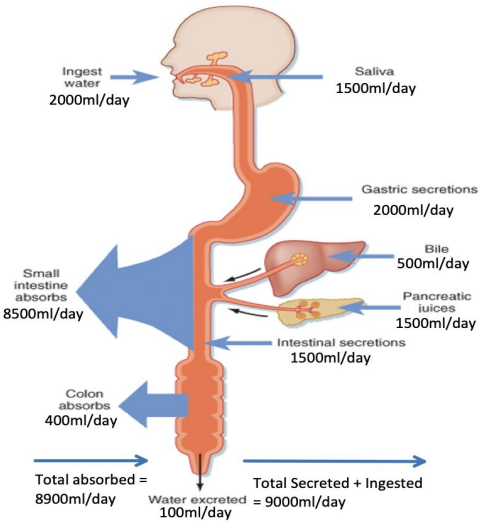
Girls slides



Absorption and secretion of electrolytes and water

- ❖ Electrolytes and H2O 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.

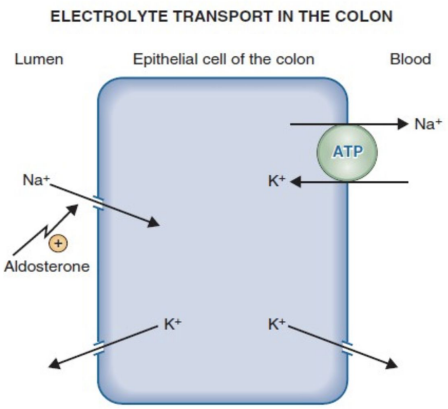
2) Na+-glucose or Na+-amino acid co- transport.

3) Na+-Cl- cotransport

4) Na-H+ exchange.

The next step is osmosis of water into the paracellular space, because a large osmotic gradient has been created by the elevated concentration of ions in the paracellular space.

▪ 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:

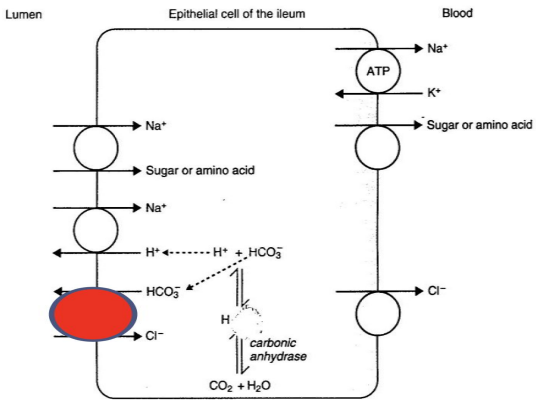
1. Passive diffusion
2. Na+-Cl- cotransport
3. Cl^- - HCO_3^- exchange

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 Bicarbonate Ions 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

1,25 dihydroxy-vitamin D_3 **stimulates synthesis of** Ca^{++} -binding protein and Ca^{++} -ATPase in enterocytes

↓ Plasma Ca^{++}

↓

↑ Parathyroid hormone

↓

In the kidney

25-hydroxy-vitamin D3 → 1,25 dihydroxy-vitamin D3

Nutrient Absorption in the Small Intestine

Girls slides

Site	Absorbed Nutrient
Duodenum and upper jejunum	Most minerals
Jejunum and upper ileum	Carbohydrates, amino acid, water-soluble vitamins
Jejunum	Lipids and fat-soluble vitamins
Terminal ileum	**Vitamin B12. (M)**

Hormonal control of Absorption and secretion Girls slides	
Glucocorticoid	= ↑ Absorption of H_2O & ions (small & large intestine)
Somatostatin	= ↑ H_2O & ions absorption (ileum & colon)
Epinephrine	= ↑ NaCl absorption (ileum)
Aldosterone	= ↑ Synthesis of Na+ channels (colon)

MCQ & SAQ:

Q1: Amino acids transported at the basolateral membrane via ...

A. Active transport protein carrier
B.Passive diffusion
C. Secondary active transport
D. Facilitated transport

Q2: Vitamin B12 absorption occurs in ...

A.Duodenum
B. All over the small intestine
C. Terminal ileum
D. Ileum & colon

Q3: Propulsive Movement and Mixing (Segmentation) Contractions they can be blocked by ?

A. Methacholine
B. pilocarpine
C. Atropine
D. Carbachol

Q4: push the food from Caudad to the Orad

A. Peristaltic rush
B. Antiperistalsis
C. Mixing (Segmentation) Contractions
D. Migrating motor complex

Q5: Gastrectomy results in the loss of parietal cells and loss of intrinsic factor that leads to which type of anemia?

A.Iron deficiency anemia
B.pernicious anemia
C.Sickle cell anemia
D.Hemolytic anemias

Q6: What is the site of absorption for lipid and fat-soluble vitamins?

A. upper ileum
B. Duodenum
C. Terminal ileum
D. Jejunum

answer key:
1: D
2: C
3: C
4: B
5: B
6: D

1- What are the mechanisms of Cl absorption?

2- in which period Migrating motor complex (MMC) appear ? and what are its function and main hormone regulate it ?

3- What is the mechanism of Ca^{++} Absorption by the enterocyte?

4- Dietary fat, after being processed, is extruded from the mucosal cells of the gastrointestinal tract into the lymphatic ducts in the form of ?

A1: 1-Passive diffusion 2-Na-Cl co-transporter 3-Cl-HCO_3 exchange

A2: during inter-digestive period
propel any remnants in stomach & small intestine into colon **keeping the small intestine clean**
regulated by **Motilin Hormone**

A3: ↓ **Plasma Ca^{++}** →→ ↑ **parathyroid hormone** →25-hydroxy-vitamin D3→→1,25 dihydroxy-vitamin D3→1,25 dihydroxy-vitamin D3 stimulates synthesis of Ca++-binding protein and Ca++-ATPase in enterocytes

A4: chylomicrons

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