Digestive System

University of Jordan

Faculty of Medicine

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Medical Committee
The University of Jordan

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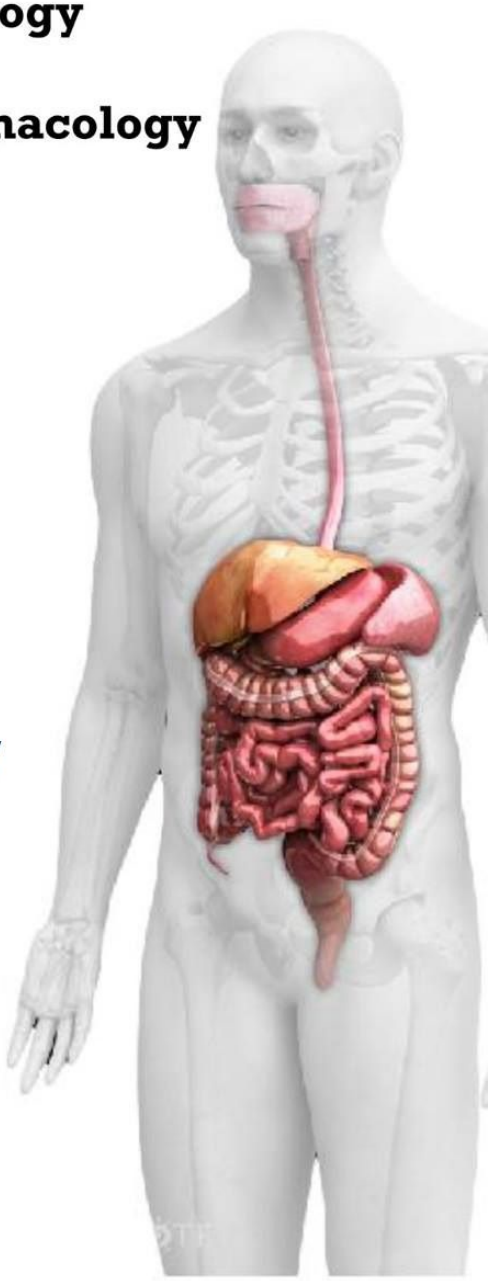

Sheet #: 8

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Digestion & Absorption 2

Last time we started talking about digestion and absorption we have seen how we are digesting carbohydrates and also absorbing them. And we have seen how we digest and absorb proteins.

So regarding digestion of proteins, we have 4 levels of digestion:

1-The lumen of the stomach.
2- The lumen of the duodenum of small intestine.
3- Brush borders.
4- Absorptive cells by intracellular peptidases.

So once we are getting everything in the form of amino acids inside the absorptive cells then these are transported toward interstitial fluids and they are taken away from there with blood. They are hydro-soluble so they can be taken away with blood.

So we said we are absorbing amino acids and small peptides, dipeptides, tripeptides, tetrapeptides... these are absorbed by secondary active co-transport mechanism, while for amino acid we can have some of them they are transported with the help of sodium dependent carriers, we also have some are transported with the help of sodium independent carriers until now at least 5 or 6 types of carriers for amino acids have been characterized (maybe 20 types of carriers).

Now What about Lipids?

- Digestion of Lipids:

There is small amount of lipases released in the stomach, but these are not significant to get full digestion of lipids.

For digestion of lipids we need bile salts"Bile".

Bile: is secreted by liver to act in the lumen of intestine.

What is the function of these bile salts?

Imagine that you have no bile salts; then lipids that you are ingesting are forming big drops of lipids but when you are adding bile salts to these drops, they become smaller and smaller droplets. We call this process "**Emulsification of lipids".**

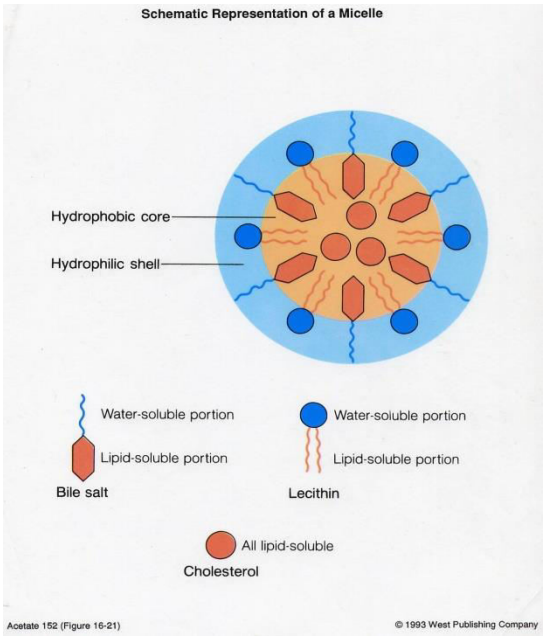
-The purpose of emulsification is **to increase the surface area** of lipid drops by forming smaller droplets with a higher sum of surface area than the single large drop. Then lipase enzymes will digest these droplets.

So the function of bile salts is to get emulsification of lipids.

Bile salts are amphipathic molecules which means "they have both hydrophilic and hydrophobic parts".

-The hydrophobic part will be oriented toward center (the sterol nucleus.)
-The hydrophilic part will be oriented toward outside ,(the hydroxyl groups, peptide linkage and the amino acid conjugate.)
more hydroxyl groups…more hydrophilic

The hydrophobic and hydrophilic parts form "Micelles" that have hydrophobic core inside it and a hydrophilic shell (the hydrophilic shell is because of the orientation of the water-soluble parts of both bile salts and lipids).



- ✓ We are ingesting lipids in many forms like triglycerides, cholesterol, phospholipids…etc. But most of these lipids are ingested in the form of **triglycerides**.
- ❖ The structure of triglyceride:
  1- Glycerol part: oriented toward the hydrophilic shell.
  2- 3 fatty acids: oriented toward the hydrophobic core.

The enzymes which are released from the pancreas (lipases, co-lipases, phospholipases…) are hydrophilic (proteins), so they can't go inside that big drop of lipids to digest them, so they are just attacking **the oil-water interface**. They hydrolyze the 1st and the 3rd ester linkages of triglyceride (attacking the folds between glycerol and fatty acids so at carbon position1 & carbon position3).

By the attacking of these lipases the result is :
2 fatty acids and monoglyceride (2-monoglyceride).
{2-monoglycride: the monoglyceride which has a fatty acid at carbon position2.}

So after the process of digestion now we have in these **micelles** free fatty acids, monoglycerides….etc. Cholesterol is removed from other part products with the help of cholesterol ester hydroxylase, and then we can absorb these compounds.

But how are we getting absorption of these lipids?

- Absorption of Lipids:

When the micelles are in contact with the luminal membrane, everything can diffuse across the plasma membrane by **simple diffusion** (lipids pass through lipid membranes). Inside the absorptive cells now we have fatty acids and monoglycerides so they are reforming back **triglycerides** (reformation of triglycerides inside the absorptive cells.)

- ✓ Why are we digesting them if we are forming them back?
  Because triglycerides cannot pass through the membrane, monoglycerides are small molecules they can pass in the structure of plasma membrane by flip-flop movements and reach the other side of the plasma membrane.

Now, inside the absorptive cells as we said we are forming back triglycerides but these absorptive cells are also forming **B-lipoprotein**, so we get adsorption of these lipids to these lipoproteins forming **Chylomicrons.**

❖ **Chylomicrons** are big aggregation of lipids consist of :
1) Triglycerides (80-90)%.
2) Cholesterol (3%).
3) Phospholipids (10%).
4) B-lipoproteins (5%).

✓ Now chylomicrons are inside the absorptive cells, so they are expelled out by exocytosis.

Can we take this big part of lipids directly to blood ?? Of course no.
It diffuses through the extracellular space and is removed from villus by **central lacteals** (the terminal lymphatic vessels) with the help of lymphatic circulation. Then the circulation enters the thoracic duct. And finally it lymph will be introduced slowly back to blood.

- What happens if we can't digest lipids?
  That can happen actually if there is no secretion of lipases, liver problems, blocking or low secretion of bile salts.
  So this leads to an increase in the fat content in the stool , and this will give the stool a yellow color. So when you see a yellow or white color of stool that means that we have no digestion or low digestion of lipids.
- Having mal digestion of fats results in mal absorption of that constituent of chyme.

- Absorption of Water & Electrolytes :

We have seen how we are getting absorption of sodium. We have many mechanisms of co-transport mechanisms, so with amino acid, glucose, galactose...etc, we absorb also Na^+.

Na^+ is expelled toward interstitial fluid with the help of sodium-potassium pump. So we increase concentration of sodium in interstitial fluid, this will

attract another ion from the lumen which is chloride (Cl-). By this attraction the **Osmolarity increases and this will attract water.**

So in that way we have absorption of sodium, chloride, water.

-Absorption of K+:

Potassium actually is moving across the plasma membrane to absorptive cells according to this electro-chemical gradient that gradient is favoring absorption at the level of small intestine. But at the level of the colon we have secretion of this ion.

-Absorption of Ca++:

We have special problem with regard to absorption of calcium (Ca++), to get absorption of Ca++ the cells are forming a protein which is called **Calbindin**.

Absorption of Ca++ also is under influence of some hormones like vitamin D, parathyroid's hormones...etc, so these can increase Ca+2 absorption.
If we have less amount in our body of these hormones we are getting decrease of Ca+2 absorption.

So how we get absorption of Ca++?
As we said we are forming **Calbindin** inside absorptive cells. Once Ca++ is inside, it binds to calbindin protein, by forming this complex at the basolateral membrane, Ca++ will pumped out by active process.

Vitamin D for example will increase excretion of calbindin so free Ca+2 will increase and this will favorite more absorption of Ca++.

-Absorption of Fe++:

The Fe++ absorption can be increased or decreased according to diet.
If you are taking more vitamin C, iron absorption will increase.

If you are taking more phosphates, oxalates, phytic acid and pancreatic juice, this will decrease Fe++ absorption.

- ✓ Iron is absorbed in the ferrous form (Fe++) not in the ferric form (Fe+++), because Fe++ is more soluble than Fe+3.
- ✓ Probably the process of absorption is by conversion of iron structure ferric (Fe+++) to ferrous (Fe++) or vice versa.

Now, to get absorption we have many theories some are talking about receptors for the heme structure, you know heme is having iron, and producing that heme inside the cells.
Others are saying that the absorptive cells are forming **Apoferritin** molecule. But that apoferritin first secreted into the lumen, once we are getting secretion in the lumen of the small intestine iron will bind to apoferritin, so we have a complex structure of iron and apoferretin called **ferritin**, the absorptive cells have receptors for ferritin and once ferritin binds to it, we are activating **receptor mediated endocytosis** for absorption of iron.

Iron is stored inside the absorptive cells, only when there is a need for iron in the body we are taking this iron by active transport. If there is no need for this iron it remains stored at **the level of the Mucosal cells.**
But how we know if there is a need for iron?
You know that iron is not found freely in the interstitial fluid, it is bound to **transferrin** molecules. Imagine that all the transferrin molecules are loaded with iron that means that there is no need for iron in the body.
If you find high concentration of transferrin molecules and low loaded iron that means that there was a consumption of iron so we have to transport iron to this molecules for the need of the body.

So that's how we are moving iron from intestinal epithelial cells toward interstitial fluid, otherwise iron remains at the level of small intestinal (absorptive) cells & this phenomena is called **Mucosal block;** blocking

absorption of iron at the level of mucosal cells if we don't need it. Actually it's a protective mechanism for our body but how?
Thalassemia patient have grey skin because of the high composition of iron in his tissues, so his liver, lung will be affected and his skin will have irony color. So to prevent this decomposition of iron in tissues we have this mucosal block mechanism.

-Absorption of Vitamins:

We have 2 types of vitamins:
1) Water-soluble vitamins: have many mechanism for absorption some is absorbed passively and some are absorbed actively, we don't have to know which is which but know the following:
for absorption of vitamin B12 we need the **intrinsic factor** which is released from the oxyntic cells of the stomach.
2) Lipid-soluble vitamins: vitamins (A, K, E, D), follow the same route of lipids for absorption. They form micelles first then they are absorbed by absorptive cells by simple diffusion, then form chylomicrons inside absorptive cells and are transported via lymph and introduced to blood. Any person having a mal digestion or mal absorption of lipids will have deficiency in one or more of these lipids.

This is the end of digestion and absorption.

Body Energetics

What are we doing now with these stuff? Why are we eating?
To get energy, after all processes of digestion & absorption all these nutrients are used for our body energetics.

Any meal you are eating it will eventually be amino acids, glucose, galactose, fat….etc that's the final conversion of everything you eat. We are burning these food constituents (chemical burning), to get micro energetic molecules and we are using these molecules for the body work.
what types of body works that we are performing?
We have many types; chemical work, mechanical work (as you know the muscles are moving and the heart is pumping), electrical work (your nervous system all the time has electrical activities that need pumping of ions)

We have a lot of metabolic transformation that are taking place in our body to get finally ATP molecules. And we are using ATP for our body works.
The problem is can we measure these metabolic transformations taking place in our body?
Energy can't be created nor destroyed but can be transformed from one form to another. The final form after consuming chemical energy for example is heat.
Once we are using ATP for some mechanical activities like muscles (heart for example), heart has pumped blood and blood has friction of vessels, so what is the final form of energy that we have used? Heat.

So if we measure the heat produced by the body, we can get an estimation about the metabolic transformations that are taking place in that body. So that's the idea.

- ✓ The unit used for measuring heat is **Calories**.

The direct method for measuring this heat produced if you place this body in a closed place isolated from the outside environment, and you have flow of water in and out with known temperatures, they are different because of heat produced by the body. So you know the temperature difference and the flow rate then you can measure the amount of heat produced by the body. This direct method is not convenient actually.

We can use an indirect method to measure heat produced by the body, to burn food stuff used for source of energy, what molecule we have consumed?? Oxygen.

So if we know the amount of oxygen consumed we can get estimation about the heat produced by that body and we can get an estimation about the metabolic transformation that we can have in the body.
Can we measure the oxygen consumed?
We have anaerobic energy & aerobic energy but most of the energy that we have, it is aerobic..So we are consuming oxygen to get ATP.

For each liter of oxygen consumption the body generates about 4.8 calories, this is called the energy equivalent of oxygen. So if you know the amount of oxygen consumed you can calculate the metabolic activities in the body. But as a term for metabolic activities we are measuring what we are calling the **metabolic rate**. Rate means here (per time unit) so calories per time unit (per an hour for example).

Next lecture we will talk about metabolic rate..

The End.
Good Luck ☺