Physiology

Sheet Slide

number 8

Done by Sarah alda'jah

Correction Asem Hizzani

Doctor Mohammad khatatbeh

Digestion and Absorption

In the last lecture we have started talking about the digestion and absorption of carbohydrates and proteins.

So we have seen the specialization of the small intestine in the absorption process and its role in digestion due to the presence of brush border enzymes.

Now we we'll be talking about the digestion and absorption of lipids.

Lipids:

Lipids are hydrophobic, and thus are poorly soluble in the aqueous environment of the digestive tract. The digestive enzyme, **lipase**, is water soluble and can only work at the surface of fat globules. Digestion is greatly aided by emulsification, the breaking up of fat globules into much smaller emulsion droplets. Emulsification of lipids happens in the small intestine.

Emulsification is a prerequisite for digestion of lipids.

The lipids are dispersed into smaller droplets; surface tension is reduced; and surface area of droplets is increased.

**The bile salts lower surface tension , the emulsification increases the surface area of the particles for enhanced activity of enzymes.

If you calculate the surface area of the big lipid droplet and compare it to the sum of the surface areas of all the smaller droplets then you'd find that the sum of surface areas is bigger.

This process of emulsification is favoured by Bile salts (detergent action) that is a constituent of bile that is secreted by the liver.

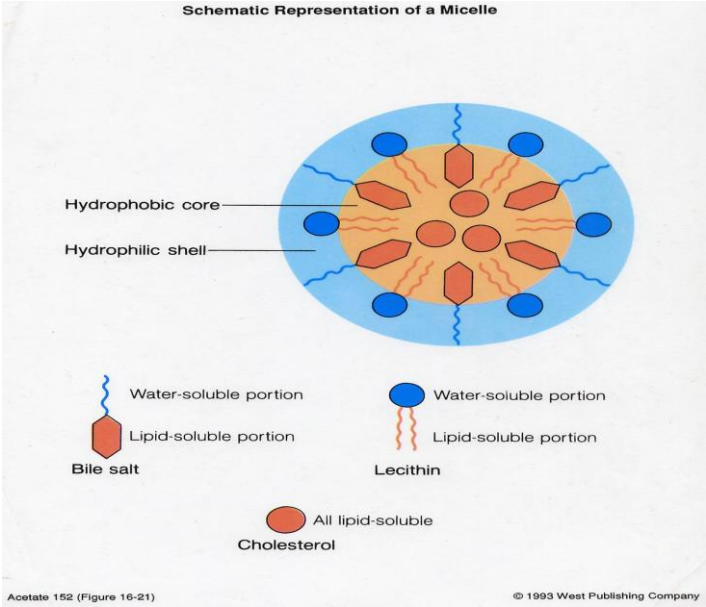
These bile salts are amphipathic molecules that have a big part which is hydrophilic and a small part which is hydrophobic.

At anytime you are ingesting lipid particles , these particles form big drops without the presence of bile salts , by adding these bile salts , these lipid particles get fragmented to much smaller droplets which are called micelles.

- The structure of micelles :

It has a hydrophobic core and a hydrophilic shell.

Because of the orientation of lipid particles , the hydrophilic part is oriented towards the outside and the hydrophobic part towards the inside .



Digestion of lipids :

Most of the lipid particles that we are ingesting are in the form of triglycerides which are composed of :

1- Glycerol[hydrophilic] .
2- (3) fatty acids[hydrophobic] .

So now we have lipids inside the core of the micelles .

Enzymes which are involved in the process of digestion(lipases) are all hydrophilic so they cant work on big drops of lipids,but they can attach on oil-water interface and digest the lipid particles. 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)forming one molecule of 2-monoacylglycerol & two molecules of fatty acid.

*note: the activity of phospholipase is smiliar to that of lipase.

So after the process of digestion now we have in these micelles free fatty acids & monoglycerides.

Once we have digested these particles they'll be absorbed.

Absorption of lipids :

The mechanism is by simple diffusion across the lumenal membrane of the intestinal epithelial cell .
At any time micelles get in close proximity with the membrane the particles start moving from the core of the micelles to the inside of the cell.

Once these particles get inside the cell , free fatty acids and monoglycerides reform Triglycerides again. (this process need ATP and Co-A).
So 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.

After reforming triglycerides, the cells are also forming B-lipoproteins. Triglycerides (80-90%) + cholesterol (3%) + phospholipids (10%) + B-lipoprotein (5%) are combined together to form chylomicrons (60-750nm diameter).

Chylomicrons are **lipoproteins**, special particles that are designed for the transport of lipids in the circulation. Chylomicrons are released by exocytosis at the basolateral surface of the enterocytes. Because they

are particles, they are too large to enter typical capillaries. Instead they enter **central lacteals**, lymphatic capillaries that poke up into the center of each villus. Chylomicrons then flow into the circulation via lymphatic vessels.

What happens if we have no lipases or no bile salts?

No digestion or absorption in lipid happens .

Lipid Malabsorption(Steatorrhea):

Lipid malabsorption results in increased lipids including fat soluble vitamins A,D E and K in the feces. Cause may be pancreatic insufficiency, chronic diseases of pancreas or surgical removal of pancreas , it results in yellow or white discoloration of stool.

Absorption of water and electrolytes:

Water absorption is driven by Na+ absorption.

Na+ is absorbed **actively** in the small intestine by the co-transport systems and colon.

Cl- is absorbed mainly in the upper part of the small intestine (duodenum and jejunum). Cl- moves in passive diffusion when an electrical gradient is established by the absorption of Na+.

We have a lot of carriers that are Na+ dependent. So we are moving Na+ from the lumen towards the inside of the cell , at the basolateral membrane we have K-Na pump which is moving Na towards the interstitium (Diffusion is passive at the lumenal membrane and active at basolateral membrane). Now the movement of Na in this direction will create a potential across the cell which is more positive towards the interstitium , this will attract negative particles , Cl- is attracted towards the interstitium, osmolarity increases and that attracts water .

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

K+:

potassium can move across the membrane according to the electrochemical gradient .

*note :

-at the level of small intestine mainly we have absorption of potassium.

-at the level of colon we have secretion of potassium.

Ca++:

We have an encounter with regard to absorption of calcium.

The cells are forming a protein called calbindin. So at any time we have absorption of calcium, it will bind to this protein and forming a complex called Ca-calbindin complex.

Absorption of calcium is regulated and controlled by hormones (parathyroid hormones) and vitamins like vitamin D.

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. Once calcium is inside the cell it will bind to calbindin., then the calcium will be pumped out of the cell at the basolateral membrane by an active process.

Now what happens to the free Ca++ concentarion Inside the cell when expression of calbindin increase ?

The conc. decreases, so you are favoring the movement of Ca++ from the outside towards the inside to bind to calbindin.

At the lumenal membrane, the calcium is moving passively according to the concentration gradient, so by increasing the expression of calbindin we are decreasing the free concentration of Ca++ inside the cell, and that will increase the concentration gradient of Ca++, so in that way we increase the absorption Ca++.

So we are getting more absorption by increasing expression of calbindin.

Now what hormones and vitamin D do is increase the expression of calbindin to increase the absorption of Ca++.

Iron:

We are also forming a protein called apoferritin, this protein is secreted out towards the lumen , once it's outside it binds with iron forming a complex called ferritin , we have receptors for this complex at the lumenal membrane , once ferritin binds to its receptors, we are getting receptor mediated endocytosis to get iron absorbed.

Once we have absorbed the iron molecules , it remains inside the cell .

Before we talk about the fate of iron inside the cell first you need to consider some points with regard to iron reabsorption :

- iron is absorbed in the ferrous(Fe++) form rather than the ferric (Fe+++)form, because ferrous is more soluble than ferric.
- Oxalates , phosphates & phytic acids (which are found in cereals) reduce iron absorption ; it transfoms it to the ferric form.
- Vitamin C enhances the absorption of iron by increase the transformation from the ferric form to the ferrous form.

Ferritin remains folded at the level of epithelial cells , only if we have a need for this iron, we can get iron trasported actively from inside the cell towards the interstitial fluid .

Iron is not transferred freely in the body fluids , we have another molecule called transferrin that transfers iron.

Imagine that all the transferrin molecules are loaded with iron, this means that there is no need for iron in the body. If you find high concentration of transferrin molecules which are unloaded with iron that means that there was a consumption of iron so we have to transport iron from these cells towards the interstitial fluid.

If not needed, iron is lost when cells are desquamated. This mechanism prevents excess iron from entering the blood and causing toxic effects.

This process is known as **Mucosal Block** which is a protection for your body.

Thalassemia is a disorder that causes the destruction of red blood cells , these blood cells are filled with iron , with time this iron will be propelled to tissues including liver , lung & skin , and it will affect the function of these organs.
The high deposition of iron in skin tissue results in grayish color of the skin which is the color of iron.

Absorption of vitamins:
Vitamins are two kinds ; lipid soluble and water soluble .
In regard to water soluble there are vitamin which are absorbed actively and some are absorbed passively.

water soluble vitamins are absorbed passively except Vit. C, Vit. B1, and Vit. B12.
Absorption of vit. B12 requires the ***intrinsic factor*** secreted by the oxyntic cells of the stomach. Most vitamins are absorbed in the upper part of the small intestine, but vitamin B12 is absorbed in the ileum.

Lipid soluble vitamins (Vit. A, D, E, K):
Follow the same route as lipids. They are solubilized in micelles and chylomicrons.

Body Energetics

After the chemical transformation of food into smaller food stuffs and their absorption, food stuff will undergo many processes by the cells of human body to produce energy for their activities.
After you had your meal it is digested in the form of molecules and particles and it is absorbed and entered to you metabolic pool(a reservoir of molecules upon which an enzymes can operate.)
The energy produced by these reactions is stored in highly energetic phosphate bonds in a compound known as ATP. The formed ATP then is used for body works which could be as external or internal works. These include:
Chemical works: building of cellular components, secretions, etc.
Mechanical works: muscle contractions, heart pumping, etc.

Electrical works: after nerve conduction by maintaining a concentration gradient for K+ and Na+ across membrane by the activity of Na+/K+ pumps and other pumps).

There are a lot of chemical transformations that are taking place to generate molecules of energy and consumption of these molecules, so we have metabolic activities, the question is can we measure these metabolic transformations taking place in our body?
In a matter of fact , yes you can .

The principle of energy states Energy can't be created nor destroyed but can be transformed from one form to another. The final form after consuming chemical energy in our body is heat.

Now if you measure the heat produced by your body then you can get an estimation of the metabolic activities that are taking place , so we have to measure the heat produced per time unit (metabolic rate). (Usually we use one hour as a time unit).

Now can we determine what kind of fuel the body is using ? (whether it is carbohydrates, lipids , proteins ..etc.)

Before that you should know by now that some energetic molecules are generated by aerobic pathways and some are by anaerobic pathways. If we are using aerobic pathways then that means that we are consuming oxygen (chemical burning not physical burning), and this will generate macroenergetic molecules that we are using for our body functions, and that energy will eventually transform into heat.

Now in answer to the question above :

We have differences in the volume of oxygen consumed and carbon dioxide produced between different sources of fuel.

In the case of chemical burning of **glucose**, we have the following reaction: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$

From this reaction we can calculate "Respiratory Quotient"
(RQ)= (CO_2 produced/O_2 consumed)

when glucose is used as a source of energy
In this reaction (RQ) = CO_2/O_2 = **1.0** in the case of glucose break down.

- When **fat** is used as source of energy, RQ = **0.7**.
- When **protein** is used, RQ = **0.8**.
- The RQ when **mixed** food stuff is used = **0.82**.
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From the respiratory exchange ratio by the lung over a period of time we can estimate the respiratory quotient for all body to indicate the main type of food stuffs used for metabolism in the body.

In the brain the RQ is very close to 1 and that indicates that the main source of energy for brain is glucose .
In the stomach the RQ will be negative because the stomach consumes CO_2 to produce H_2CO_3.

We can calculate the respiratory quotient for an organ by measure the difference between O_2 concentrations and CO_2 concentrations between arterial and venous blood supply of that organ.

*The RQ would be equal to 0.7(equal to fat RQ) if the body is in diabetic crisis because the main fuel source would be fats and not glucose.

The End