Human Physiology
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Lecture - 04

Hello everyone, welcome to another new class on human physiology. In this class, we will discuss the digestion of lipids. How the digestion and absorption of lipids happen in our body. If you remember in our last classes, we discussed digestion and absorption of carbohydrates and proteins. In this class, we will mostly try to tackle and discuss the lipid. So, let us start with that.

So, what different concepts will be covered in this class? Mostly, we will introduce you to what lipids are and what the basic role of lipids is in our body. And then we will discuss the digestion and the absorption of this lipid. So, let us see how things happen. So, what is it basically like lipid? So, lipids are like a diverse group of hydrophobic molecules.

It can be like triglycerides, phospholipids, or cholesterol. So, these are basically hydrophobic molecules where fatty acids are present. So, you can see that fatty acids are the building blocks of triglycerides or phospholipids, and they can be different types of fatty acids, as you know; either they can be saturated fatty acids or unsaturated fatty acids. So, in the case of saturated fatty acids, you can see these are mostly like a linear type of fatty acid, but in the case of unsaturated fatty acids, this is also linear; however, there can be a presence of this unsaturation, which is like a double bond C double bond C in between the linear chain, right? So, in cases of saturated fatty acids, there are no double bonds present in the overall linear chain, but in cases of unsaturated ones, there can be either one or more than one double bond. Based on the number, it can either be a monounsaturated fatty acid, which has only one double bond; this means that in oleic acid, as you can see, there is only one double bond, indicating that it is a monounsaturated fatty acid.

But in cases of linoleic acid or linolenic acid, you can see there is more than one double bond. So, it would be like a polyunsaturated fatty acid. So, basically, fatty acids are building blocks of triglycerides or phospholipids. Then what are the different types of classification, as we said, like triglycerides, which can be an important component of the diet, as they are lipids? And how are these triglycerides formed? As you can see, there is one component like this glycerol. So, this is the glycerol, and then there are three fatty acids, like three fatty acids can.

So, when there is a reaction between one glycerol and three fatty acid molecules, it forms a triglyceride, and mostly 95 percent of the lipids we consume from various parts of our diet have this triglyceride. They can be present in the case of both animal sources, for example, butter and meat, and they can also come from plant sources, including vegetable oils, nuts, seeds, and avocado. So, triglyceride is a major form of lipid that we consume from various forms of diet. Apart from that, another important factor is cholesterol, which mostly comes from animal products. So, cholesterol, as you can see, is a complex type of sterol lipid structure, and mostly, as we said, it comes from an animal diet.

So, cholesterol and triglycerides are two of the very important lipids that we generally consume from different diets. Then the third important one is the phospholipid; they are also present in a much smaller amount, similar to the triglycerides. So, you remember that in cases of triglycerides, we have one glycerol molecule and three fatty acid side chains. But in cases of phospholipids, you see we have only two fatty acid chains and the third one is actually conjugated with the phosphate. So, in cases of triglyceride, there was one glycerol and three fatty acid chains.

But in cases of phospholipids, the third triglyceride chain is not present. Instead, there is a phosphate group. And they present naturally in different types of food, for example, egg yolks, liver, soybeans, and peanuts. And the importance of this phosphate group is that it can also react with different types of other molecules, for example, choline and ethanolamine. So, this type of phosphate group can also link to various other molecules.

So, that is why it is very important, and they can also create another cascade of reactions because a vacant site is present here for the reaction. So, what are the different functions of lipids? There are different important functions, including the production of energy. So, they are a source of energy production, and as you know, like lipids, they help to produce approximately 9 kilocalories of energy per gram. So, this is like a high-energy server for our body. Apart from them, as you know, like the phospholipid cholesterol, these also participate in making our cellular membrane.

So, these are highly essential components for cell membranes. Lipids also have a very important role in preparing or serving as a component of steroid hormones. So, cholesterol is one of the starting materials or primary materials of steroid hormone synthesis, and as you know, different types of steroid hormones like estrogen, progesterone, and testosterone have a very crucial role to play in our body. We will discuss all these steroid hormones in the endocrine classes. But just remember, cell hormones are very important for our various physiological functions.

And then the lipids also have a very important role to play in terms of insulation and protection of the organ. Because, as you know, lipids can form a layer of fat or adipose tissue. So, they can act as an insulator of heat. Helping our body to maintain or regulate its temperature. So, this is an overall pathway of how lipid digestion happens, and I will discuss it again in the next consecutive slide, but just try to remember that one of the very important steps for lipid digestion is bile formation.

I will discuss why, but just see what the different steps are one by one. So, bile is generally produced in the liver, right? So, you know, like bile is produced in the liver and then stored in the gallbladder. And this bile has a very important role in lipid digestion. We'll see how it goes. And then you see that in the pancreas, different lipid digestive enzymes can be produced.

So, for any type of digestion, enzymes are required, as you know we discussed during our carbohydrates and protein classes, and there you also saw how the pancreas was responsible for secreting different digestive enzymes. In the same way, in the case of lipid digestion, the pancreas has a very important role to play. by secreting lipid digestive enzymes. Apart from that, the pancreas also releases bicarbonate ions, or HCO3 minus ions, and as you know, these bicarbonate ions have an important role to play in creating an acid-base balance. What happens basically with the bicarbonate ions is that our small intestines become a little bit basic in nature, and that is highly optimal in terms of lipid digestion.

Finally, the digestion of lipids occurs in our small intestine, where fat digestion, emulsification, micelle formation, and finally absorption of lipids take place. So, this is, as a whole, kind of a flowchart where you see how, step by step, lipid digestion occurs. Now, before we go to the steps of lipid digestion, we have to understand that there is a significant challenge in terms of lipid digestion. Can you think of what the challenge is? Yes, because lipids are insoluble in water or an aqueous environment, and our body mostly consists of an aqueous environment. As you know, water is one of the major components of our body, and lipids, because they are insoluble in water, do not create the compatibility needed for the easy functioning of those enzymes, as the majority of enzymes perform well in aqueous environments.

So, there is a systematic challenge because these insoluble lipid molecules in water prevent these enzymes from performing properly, and that is why there is a process called emulsification to increase the surface area of these lipid molecules. So, basically, to overcome the challenge, our body creates a system called emulsification that eventually helps to break down the large lipid molecules into smaller droplets, and eventually it increases the total surface area of the lipids, which helps the enzymatic function of this lipid enzyme. Let us see how emulsification happens. So, emulsification occurs through the production of bile, which is why I said that the liver plays a very crucial role in lipid digestion by producing bile. So, as you see in the bile, there are two components or two sites that can be like a hydrophobic site, and they have a lot of cholesterol and other components in the hydrophobic site, and there can also be a lot of hydrophilic sites in the bile salt.

Together, this bile salt, when it interacts with the lipid, creates an emulsification component. So, basically it creates a nice droplet-type structure where the core is made of lipid, and then on the shell part there is initially a hydrophobic component, and finally on the top there is a hydrophilic component. So, this creates a nice emulsified droplet, and it also improves the surface area of this lipid for the lipid digestive enzymes to function properly. So, eventually from a big droplet, you will see that multiple small droplets of lipid will form, and this will help the digestive lipid enzymes to perform properly. Now, let us see different organs and how they play an important role in terms of lipid digestion.

So, basically, in cases like lipid digestion, it happens in the small intestine with the help of the pancreas because the pancreas secretes different types of lipid digestive enzymes. So, what happens first when this acidic chyme, which contains partially digested fat or protein, enters the small intestine is that it triggers the release of a hormone called CCK. This CCK hormone, where it is secreted, is secreted in the small intestine. Okay, so what we just said is that whenever there is any acidic chyme that contains partially digested fat or lipids, it enters our small intestine, and it immediately sends that signal, starting the secretion of the CCK hormone. The CCK hormone has a very important role to play because it stimulates not only the pancreas but also the gallbladder.

Right, so if we kind of put the flowchart in the small intestine, it secretes the CCK hormone. Now, this CCK hormone stimulates both the liver and the pancreas. So, in the liver, it will stimulate bile production, and in the pancreas, it will stimulate the secretion of a lot of digestive lipid enzymes. So, different lipid digestive enzymes, for example, pancreatic lipase, phospholipase A2, and cholesterol lipase. So, these all will be eventually secreted.

But all this stimulation eventually occurs through the secretion of this very important CCK. Then let's see how these lipase molecules that are getting secreted from the pancreas eventually degrade or act in the digestion of the lipid. So, pancreatic lipase is a very important molecule for hydrolyzing triglycerides. So, you can see it is like a general triglyceride structure, and then the pancreatic lipase molecule, what it does is hydrolyze the triglyceride to diglyceride or monoglyceride. So, basically it acts either in this SN1 position or in the 3 position in the SN3 position eventually breaking the lipid bond to free of some fatty acid.

So, basically, it breaks those lipid bonds free from this fatty acid, and from triglyceride, it develops triglyceride or monoglyceride. So, basically, it hydrolyzes this ester-type bond. Then, pancreatic co-lipase is also very important. Why? Because lipase alone cannot perform the function properly, it requires other enzymes to assist. So, for example, if you remember the bile and what it creates, it creates a smaller type of lipid droplet.

And because these bile salts or the hydrophobic and hydrophilic components from the bile are tightly added to this inner lipid, the pancreatic lipase hormone or enzyme cannot tightly bind with it. So, what we are trying to say is that lipids, because of forming this emulsification condition, prevent the pancreatic lipase enzyme from properly binding with them; however, there is another enzyme, pancreatic co-lipase, that helps the pancreatic lipase to bind nicely with the lipids and initiates its function. So, co-lipase basically binds to both the lipid droplet and the pancreatic lipase, providing a cushion or platform where lipids and pancreatic lipase can bind together and initiate the digestion mechanism. So, it actually acts as an anchor. So, pancreatic co-lipase acts as an anchor.

Then there are other types of enzymes that the pancreas secretes, for example, phospholipase A2. So, as you can see, phospholipase A2 can also break this type of ester bond, and it can create free fatty acids and also form lysophospholipid. There can also be cholesterol esterase. So, they break down like cholesterol, so you can see this cholesterol esterase can hydrolyze the cholesterol ester into cholesterol and fatty acids. So, what does cholesterol esterase do? Cholesterol esterase can break down cholesterol ester into cholesterol and fatty acid.

So, this is a different way, like phospholipid, then cholesterol esterase, and then triglycerides; all this can get broken down and digested. And then let us discuss that after all these digestion steps where triglycerides and cholesterol esterase are breaking down into smaller molecules of monoglycerides and triglycerides, how the absorption happens. So, you can see that initially, this nice micelle formation happens where inside there is a lipid component and all the small fractions like the monoglycerides, diglycerides, apart from that cholesterol, ester, and phospholipid all kind of create a chain. So, eventually, this is like a mixed micelle formation. And once the degradation and digestion happen and smaller diglycerides, monoglycerides, or cholesterol form, these molecules are taken up by the intestinal cell.

In terms of short-chain fatty acids, you can see that short-chain fatty acids can be directly absorbed into our blood. So, in short-chain fatty acids, they can be directly absorbed into our blood, but in cases like monoglycerol, monoglyceric acid, diglyceric acid, and cholesterol, they are generally taken up by the cell and eventually reprocessed back to triglycerides in the smooth ER. So, what is happening here, for example, if you consider there are monoglycerides, diglycerides, or cholesterols? Initially, they were broken down components of the lipid or digestive components of the lipid. When they are taken inside the cell and reach the smooth endoplasmic reticulum, they are eventually converted back to triglycerides. So, again from the smaller component, they become or reprocess back into the triglyceride.

And eventually, this triglyceride or the complex form of those lipids gets repackaged in the Golgi body, and you can see this in the presence of this ApoE protein, ApoB protein, and ApoC protein; they form this type of chylomicron or chylomicron-type complex. And this chylomicron complex eventually, through the process of exocytosis, comes to the lymphatic vessels or the lymph. So the smaller or short-chain fatty acids, as you remember we said, can be directly absorbed into the blood, but the complex ones, which get repackaged in terms of chylomicrons, are unable to be directly absorbed into the blood; they get absorbed in our lymph. Okay, so this is very important to remember that small or short-chain fatty acids get directly absorbed into our blood, but the bigger ones, after forming chylomicrons, get absorbed into our lymph. This is a very interesting absorption state where, unlike others, you can see the initial conversion of the monoglyceride and diglyceride happen, and when those enter the cell, they eventually reprocess and convert back to the diglyceride or complex form of lipid.

It is very interesting, isn't it? So, let us see what this micelle formation is that happens. Micelles are nothing but a bilayer kind of structure where in the core we mostly have this hydrophobic type of component or lipid component, and on the surface, we mostly see the hydrophilic component. So, micelles are like a bilayer structure, right? So, bile salts are mostly amphipathic. They generally arrange themselves in a micelle-like structure. And with the hydrophobic tail pointing inwards, they interact with the hydrophobic digested lipid.

For example, like diglycerides, monoglycerides, cholesterol, and eventually the hydrophilic heads are on the outer side. Right, and eventually it nicely creates a water- or amphiphilic-like nature. So, the outside part will mostly have a water affinity, and then the inside part will have those digested lipids, which will create a hydrophobic type of characteristic. And as we said, these are like if there is a short chain or small fatty acid, they will directly get absorbed into the bloodstream. Right? So if there is a very short fatty acid, they can directly get absorbed into our bloodstream.

But in cases of long chain fatty acids, they will again be reassembled, repackaged, or reprocessed back to triglycerides. Triglycerides will eventually go to the Golgi body and get repackaged to form this type of nice complex where there are many important roles of various apoE proteins, and eventually, it forms these chylomicrons. So, as you can see, with the help of these apoproteins or apolipoproteins and what these apolipoproteins do to eventually form the chylomicrons, they provide stability to the lipophilic particles. So, this is like a lipoprotein, and this apoprotein eventually provides stability; otherwise, this will further disintegrate. So, once this repackaged chylomicron forms, as we said, through the exocytosis process, this chylomicron will be taken up by the lymph, right? So, how does chylomicron transport happen? You see, chylomicrons are packaged into secretory vesicles in our Golgi body, and these vesicles eventually fuse with the lymphatic capillaries of our intestinal villus, which are also called lacteals, by the process of exocytosis.

And the lymphatic system has larger pores than the blood capillary. So, it is much easier for this type of lipoprotein particle or the packaged lipoprotein particles to eventually get transported by the lymphatic fluid. And then the exchange further happens as this lymphatic system can eventually drain into the bloodstream via the thoracic duct. So, in this way, the larger molecules of the lipid can eventually form, like from the lymphatic duct, and can come to the bloodstream. So, in this way, the absorption of lipids happens across all parts of our body.

Hopefully, this is clear. So, do you know that infants have a special ability to absorb some whole proteins, especially antibodies, from breast milk? This is particularly important in the first few days of life before their digestive system develops. And then these antibodies also provide passive immunity to the newborn baby. This is an interesting question you can answer, and this is the activity question. Let's think of a scenario where a rare genetic mutation occurs that prevents the production of enteropeptidase. So, what happens is like the prevention of the enteropeptidase happens.

So, how would this mutation impact the ability to digest and absorb the protein? Can you answer this? And could this mutation also affect carbohydrate or liquid digestion? So, if any enteropeptidase like this gets mutated, what would happen? Try to predict if you have further questions; please interact with us during live sessions. Also, you can send your questions to our email. Hopefully, you enjoyed the class on lipids and the overall digestive system. In the next class, we will present an interesting lesson about digestive disorders, and we will examine what different types of disorders or diseases can occur in our body if the digestion process fails.

Hopefully, you enjoyed the class. Thank you again for attending another class on human physiology. Hoping to meet you very soon in the new class of human physiology with digestive disorders. Thank you again.