Human Physiology
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Welcome to another new class on human physiology. In this class, we will discuss the digestion of proteins and also the absorption of protein. As you remember, in our last class, we discussed the digestion of carbohydrates, and we also talked about various digestive organs. So, in this class, we will only see how the digestion and absorption of protein occur. So let us stick with it. So, what would be the different concept that we will cover? So, first we will introduce the protein, what the different structures of the protein are, what the functions of protein are, and then we will see how the digestion of protein happens in the stomach.

We will also see various key enzymes for protein digestion, and finally, we will discuss the different steps of protein absorption. So, what is protein, basically? As you know, proteins are complex polymers of amino acids, right? So, an amino acid is basically like a repetitive unit of the protein, and they are linked by a peptide bond. So, as you can see in the protein, there is this carboxylic acid or COOH part, and then on the other side, you have NH2. So, once NH2 and carboxylic acid come close together by removing a molecule of water, it essentially forms a peptide bond.

So, what is a peptide bond? It is basically like CO-NH. It forms like a peptide bond or like an amide bond. So, by creating a polymeric formation of repeating units of amino acids, they basically form peptides. And as you know, there are about 20 different standard amino acids that serve as building blocks of these proteins. And each protein basically has an amino group, which is the NH2.

It also has a terminal carboxylic group, which is the COOH group. It also has one hydrogen atom, and finally, there is a variable group, which is the R. So, you can see that one is the NH2 group, and this is the NH2 group, and then you have one proton; then we have one carboxylic acid, and finally, there is the variable unit, which is the R. And this is the R group, which can vary in structure, size, and electrical charge. Determining the chemical properties of each amino acid.

So, R can vary significantly, and accordingly, it can actually play an important role in the properties of this protein. Then what are the different functions of protein? Like protein, of course, it is very important to maintain the structural functions; for example, collagen and keratin and what they do. They basically provide structural support. And then there are enzymatic activities of the protein where we can see those activities, especially the biochemical reactions in the case of digestive enzymes; we will see a lot of proteins that get involved in terms of enzymatic activities. Then, transport, for example, hemoglobin is an important protein; as you know, it binds with oxygen and transports oxygen from the heart to various parts of our body.

So, protein can also play a crucial role in terms of transporting molecules. Apart from that, we discuss various membrane transporters, for example, sodium, potassium, and ATPase transporters, right? So, this type of membrane transport protein, like aquaporin channels, is a membrane transport protein that is involved in moving molecules or ions across the cell. There can also be a hormonal role of protein; for example, insulin and growth hormone play an important role in metabolism. We will discuss their thorough roles during endocrine classes. There can be an immunological role mainly for the antibodies.

So, these are also proteins, right? And then there can be muscle proteins, for example, actins and myosins, and they have a very crucial role in muscle contraction and relaxation. Structurally, proteins are mostly like four different types: primary, secondary, tertiary, and quaternary. So, let us see them one by one. The primary structure is basically like a linear sequence of amino acids that are conjugated by the polypeptide chain. So, it can be like a linear chain of amino acids by conjugation of the polypeptide chain.

So, this is basically a linear chain, and then what is the secondary structure? In cases of secondary structure, you will observe local folding of the polypeptide chain. So, basically, it will not stay linear anymore; you may experience a local folding of the polypeptide chain, and it can form two different types of structures: one is the alpha helix, which is mostly coil and spiral-shaped, and then there can be a pleated or sheet-like structure, which is called a beta sheet. So, it can either be like a coil-like structure, which is called an alpha helix, or it can be like a pleated kind of sheet-like structure, which is called a beta sheet. And then in the case of tertiary structure, there can be the formation of a three-dimensional single polypeptide chain, and it forms mainly due to various interactions; for example, hydrogen bonds, ionic bonds, hydrophobic interactions, and even disulfide bonds. So, all these bonds contribute to the formation of a three-dimensional tertiary structure of a protein.

And lastly, the arrangement of multiple polypeptide chains in a protein complex can also lead to the formation of a quaternary structure of a protein. But you have to remember that quaternary structures are not present in the case of all proteins, and it is rare. So, as you can see, as we discussed, for the primary structure, you will mostly observe a linear chain, and then the secondary structure can either be a helical structure, which is an alpha helix, or it can be a pleated parallel structure, which is called a beta sheet. Right, and then in cases of tertiary structure, it can be like a 3D folding of a protein structure, and then multiple subunits of protein can get together and form a quaternary structure of protein. As you can see, this is like a highly coiled structure.

But this is also something you have to remember: the quaternary structures are not present for every type of protein. So, we will discuss what peptidase is and what its types are. So, basically, peptidases are the enzymes that can catalyze or hydrolyze the peptide bonds. And these are the main functional enzymes that break down and digest proteins into smaller amino acids, which can serve as energy. So, there are mainly two types of peptides: one is the exo peptides, and the second category is the endo peptides.

So, you can see in the case of exo peptides here, we have given some examples; for example, you can see here, we gave examples of amino peptides that can basically cleave like amino acids at the N-terminal end of the peptide. In the case of carboxypeptides, you can see here that this can also cleave amino acids from the C terminal of this peptide bond. There are also other types of exopeptides, for example, dipeptide peptides or tripeptide peptides. These basically cleave like dipeptide and tripeptide bonds. And as we said, the second category is the endopeptides; what it does, basically, is cleave the peptides from inside the molecule.

So, when initially the peptides are long-chain complex protein molecules, endopeptides try to cleave these molecules into smaller fragments. So, these are basically the classifications of exo- and endopeptides, and once they cleave off into smaller molecules and amino acids, they will be absorbed into the body and used by the cells for energy production. Now, let us see how digestion eventually initiates. So, for example, if we consume any food that contains protein, those protein-rich molecules or the food will eventually come to the stomach through the mouth, and as they come to the stomach, the G cells of the stomach will be stimulated by the protein, and once they are activated, the G cells of the stomach will secrete a substance called gastrin. This gastrin, which will eventually be generated in our stomach, will further stimulate the parietal cells to secrete HCl.

So, let us rehearse one more time. So, as we consume the food, the protein present in this food will eventually activate the G cell of the stomach, and the stomach will eventually secrete gastrin. Gastrin enzyme will further activate the parietal cells of our stomach for the secretion of HCl, and as we all know, HCl will basically denature large protein molecules into smaller fragments. Further, HCL will convert pepsinogen to pepsin. So, what it will cause is that HCl has two different functions: one, of course, is that it will directly denature bigger molecules of peptide into smaller fractions; simultaneously, HCl also converts pepsinogen to pepsin, which is also a very important endopeptidase in our digestive system.

And once this pepsin or endopeptidase is formed, let us see what happens. So, basically, these small peptides will convert it to enteropeptidase in the intestine. So, those smaller peptides will eventually stimulate or activate different enteropeptidases in the intestine. At a similar time in the intestine, two different hormones, for example, CCK and secretin, will be secreted. So, CCK or secretin hormone will eventually be secreted into the intestine, and these hormones can activate the pancreas.

So, let us rehearse one more time. So, from the HCL activity in our stomach, eventually the big molecules will get chopped up, and it will produce smaller peptides. This peptide can activate the enteropeptidases in the intestine, and at the same time, the intestine will secrete a few hormones like CCK and secretin, and these hormones will eventually activate the pancreas. And from the pancreas, different hormones will eventually be secreted and come to the small intestine. Trypsinogen will be activated, chymotrypsinogen will be secreted, and then procarboxypeptidase will be secreted.

So, these are three different peptidases that will eventually get secreted or stimulated from the pancreas and will come to our small intestine. And as you remember, this enteropeptidase, which was initially activated by the peptides, will play a very crucial role in the conversion of trypsinogen to trypsin. So, what will this enteropeptidase do? This enteropeptidase has a very important role in the conversion of trypsinogen to trypsin. And it does not stop here. Trypsin again does like a cascade of reactions.

For example, trypsin can create the conversion of chymotrypsinogen to chymotrypsin. Trypsin can again stimulate the conversion of procarboxypeptidase to carboxypeptidase, okay. And trypsin also has a very important role in breaking those peptide chains in between. So, trypsin has a lot of several important functions; it not only breaks those peptide chains in the protein, but it can also stimulate the conversion from chymotrypsinogen to chymotrypsin and from procarboxypeptidase to carboxypeptidase. So, this is a whole different type of peptide that will be converted, and all these peptides will have significant functions to break down the protein into smaller units of amino acids.

So, now one by one we will discuss what is happening in the stomach; it has an acidic environment with a pH of about 3, which is created by the HCl from the parietal cells. We just discussed in the previous slide how the G cells, in the presence of protein, get stimulated, and these G cells secrete gastrin, which eventually stimulates the cells of the stomach, the parietal cells, and eventually the parietal cells secrete the acid for the denaturation of the protein. So, this is very important, and eventually, the pepsinogen, which is like an inactive zymogen, is secreted by the chief cells. In the presence of HCl, this pepsinogen or the inactive zymogen can be converted to pepsin or the active zymogen, and then pepsin, as you remember, has a lot of important roles in breaking down proteins, such as peptide bonds, into smaller molecules of amino acids. So, eventually from the polypeptide or complex peptide, it can form a smaller peptide or oligopeptide.

Then we thoroughly discussed the small intestine and how it happened; we will not repeat it further. Mostly, you have to remember that initially, trypsin forms from trypsinogen, and after trypsin forms, it can eventually initiate a cascade of reactions to form chymotrypsin and carboxypeptidase, right? And eventually, trypsin also has a very important role in breaking down all the polypeptides, okay. And then, as you see, chymotrypsin is also an important endopeptidase, but it preferentially leaves the peptide bonds at the carboxyl side of the aromatic amino acids. So, basically, like phenylalanine, tyrosine, or tryptophan, these are the aromatic kinds of proteins that have aromatic amino acid components. So, chymotrypsin has an important role in breaking down this peptide bond near the aromatic protein.

In the same way, carboxypeptidase, or the exopeptidase, removes the amino acid from the carboxyl terminus of the peptide. So, what does carboxypeptidase do? This is basically like an exopeptidase, and it acts at the carboxyl terminus of the peptide. So, this is basically like a cascade of reactions that happens that controls a proteolysis event and eventually breaks down the big peptide into smaller units of amino acids. And also, it is important to remember that pancreatic secretions are heavily regulated by hormones such as secretin and CCK, which we already discussed. Finally, there are also brush border peptidases.

So, these brush border peptidases are located in the microvilli of the enterocytes of the small intestine, okay. And you can see they secrete a lot of enzymes, for example, aminopeptidase, right? They are basically located on the apical membrane, and their role is to remove amino acids like those from the amino acid terminus of the peptide. Then it also secretes dipeptidase and tripeptidase. As you remember, their function is basically to cleave the dipeptide or tripeptide bond. And the large surface area, because microvilli have a large surface area, can also significantly increase the efficiency of this whole process.

So, microvilli in the brush border are very important, as they are located in the small intestine. By secreting different types of amino, dipeptidase, and tripeptidase, it contributes to the digestion of protein molecules. Finally, after the digestion of the protein molecule into smaller amino acids or smaller peptides, what happens? How does the absorption basically happen? So, let us discuss the absorption of amino acids or smaller peptides, right? So, amino acids are mostly absorbed across the apical membrane of enterocytes via active transport. So, what happens, right? It happens inside the apical membrane of the enterocyte via active transport. So, first let us discuss how you remember what active transport is.

So, in cases of active transport, like 3 sodium ions going out, right? So, 3 sodium ions go out and in turn cells only accept like 2 potassium ions, right? So, in turn, cells accept only 2 potassium ions, and this is like ATP has a significant role to play because this is an active transport where energy is required. Now, let us think about what will happen as more and more sodium ions come out. Sodium concentration will build up more outside of the cell, and sodium concentration will be low inside the cell. Right, so this will create a concentration gradient, and that will basically trigger a secondary active transport, which is the sodium-amino acid secondary co-transport mechanism. As you see, once the sodium concentration builds outside from the primary active transport, this sodium will naturally come inside.

Right, and once this sodium comes inside through its concentration gradient, what happens is they act like a piggyback kind of system where they hold the amino acids when the amino acids are high outside, and this gets absorbed into the apical membrane of the enterocyte. Right, basically, amino acids then diffuse in; this is also called... Secondary active transport, specifically sodium-amino acid co-transport, is the way amino acids are taken up by the cells; eventually, they are absorbed from the stomach and then from the small intestine.

These amino acid fragments or molecules are absorbed inside the cells. And then, as you remember, the big polypeptides can also form smaller peptides, right? So, for example, if there is a peptide transporter or PEPT1 transporter, this transporter helps in the direct absorption of the peptide. And importantly, you have to remember that this PEP T1 kind of transporter has a correlation with the proton transporter. So, basically, they do not perform alone; they are basically kind of a co-transport that happens through the secondary active transport of the proton pump. So, as you see, initially there are a lot of sodium-potassium type secondary active transport processes that basically remove the hydrogen ions or protons outside, and this helps the proton concentration to build outside of the cells.

Now, as this concentration builds outside of the cells, the protons flow inside the cell through their concentration gradient. And eventually, when this proton flows inside the cell, it also helps those oligopeptides or small peptides to come inside using the PEPT1 transporter. So, this is basically like secondary active transport or like secondary active co-transport with H plus proton and the PEPT1 receptor. Okay, and you remember there are a lot of hydrogen proton-active ion pumps, right, that also kind of secrete a lot of hydrogen ions outside of the cells? So, by various ways, this type of proton concentration first builds outside of the cell, and that triggers this secondary co-transport mechanism, where smaller peptides or oligopeptides are absorbed mostly in the duodenum or the upper jejunum. So, absorptions are mostly efficient in the duodenum or the jejunum.

So, in this way, after the initial digestion of the peptide or the complex protein, the amino acids and the small peptides get absorbed in our body. Finally, the utilization of the amino acids occurs in that they are used for protein synthesis, utilized for energy production, and also play an important role in the synthesis of different nitrogenous compounds. And as you know, different nitrogenous compounds have a significant role in the development of our DNA, RNA, various neurotransmitter molecules, and different hormones. So, as a whole, amino acids have a significant role to play in various functions of our body.

So hopefully, you will enjoy the class. Do you know that infants have a special ability to absorb some whole proteins, especially antibodies, from breast milk? So, this is a special type of function that can only be seen in the case of infants. And also the activity question: imagine a scenario where an individual has a rare genetic mutation that prevents the formation of enteropeptidase. So, how would this mutation impact their ability to digest and absorb protein? Can you think about this thing and then get back to us with the right answer? So, hopefully you enjoyed today's class on the digestion and absorption of protein. So, we will come to you very soon with another lecture on human physiology. If you have any further questions, please discuss them with us during the live session.

You can also email us with your questions. Hopefully, you like the physiology class. Let us meet with another class in human physiology very soon. Thank you.