Enzyme Sciences and Technology
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Module - 01
Introduction
Lecture - 01
Introduction to Enzymes

Hello everyone. This is Dr. Vishal Trivedi from Department of Biosciences and Bioengineering, IIT, Guwahati. And the course Enzyme Science and Technology, we are going to discuss about the Different Properties of the Enzymes. So, in this context, in today's lecture we are first going to discuss about the basics of enzymes and then we also going to discuss about the different properties of the enzymes.

So, when we talk about the enzymes, we always think about the biological system, right, because the enzymes are also being known as the biological catalyst. So, when we talk about the biology, we are also talking about the different types of organisms. So, what you see here is that if you if any organism has to complete its life cycle, it has to go through with the different phases of the life, right.

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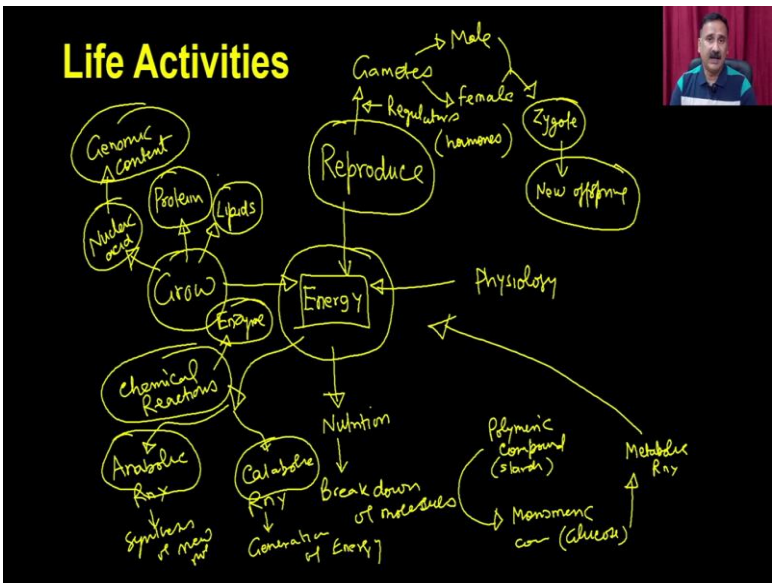

So, in this context, what are the different activities a organism is going to perform. He has to you know he has to reproduce, right, he has to grow in size, and he also has to do

all sort of running the different types of physiological processes, right. So, it has to also run the physiology. And all these processes are actually converging to a central point or the central place which are related to the production of the energy.

So, it is actually being associated with energy and you might know that if I have to if organism has to grow, it actually has to synthesize the different types of molecules like it has to synthesize the proteins, it has to synthesize the lipids, right. Because the lipids are actually going to be a part of the you know the plasma membrane, and the proteins are also being present in the different types of plasma membrane and as well as they are actually the building blocks.

Apart from that, it also has to synthesize the nucleic acid, right and that nucleic acid is required for serving the purpose of the genomic content of the cell, right. So, it is going to work as the genomic content. And because when you want to grow you also have to produce the more and more different types of cells, right. And for that purpose only you require the different types of synthesis, of the different types of molecules.

Similarly, when the organism wants to reproduce, it also has to produce, it also has to generate the gametes, right. So, it also has to produce the gametes. In higher organisms you could actually have the different types of gametes, you can have the male gametes and you can also have the female gametes. And all these male and female gametes are actually going to fuse with a complicated process and that is how they are actually going to form the zygote.

And that zygote is actually going to develop into the new offsprings. And if you see all these processes related to reproduction, you are actually going to produce the gametes that is also required the synthesis of the proteins, lipids and nucleic acids. Then, we also require the different types of you know molecules which are actually going to regulate these process. So, you also require the different types of regulators.

These regulators are commonly been known as the different types of hormones, and these hormones are either the proteinaceous in nature or they are actually going to be the lipid based. So, these hormones regulates the different phases of the development and that is how you are actually going to have the new offsprings.

Now, after the reproduction, you can also have the different types of physiological processes, that is also important for maintaining and as well as the continuing the life related activities. So, all these related activities, whether you are want to produce the new molecules or whether you want to produce the regulators, all these requires the very high quantity of energy. And all this energy is actually going to be acquired by the nutrition, right.

So, and the nutrition is related to the breakdown of the molecules, right which means you are actually going to take up the polymeric compound, right. And that polymeric compound is actually going to be converted into the monomeric compounds. For example, you can actually be able to convert the starch into the monomeric compound like the glucose.

And then the glucose, will actually going to enter into the metabolic reactions and that is how the glucose is actually going to produce the energy. The same is true for the other biomolecules like the lipids, like the nucleic acids and all those that, right. So, when we talk about the metabolic reactions, so energy you are actually going to acquire by the two different types of metabolic reactions. One is called as the anabolic reactions and the other one is called as the catabolic reactions.

Anabolic reactions are responsible for the synthesis of new molecules and the catabolic reactions are required for the generation of, catabolic reactions are actually going to have the breakdowns of the molecule and that is how they are actually going to have the generation of the energy.

Now, when we either it is whether it is the anabolic reactions or whether it is a catabolic reactions, all these reactions are actually going to be you know require the different types of chemical reactions what is going to be performed, whether it is the reduction, oxidation, condensations and all these reactions. So, all, both of these things are actually nothing but the different types of the chemical reactions.

And that is how the chemical reactions are actually going to be running of these chemical reactions is actually going to be the basis of the life on to the earth. And that is why all these chemical reactions are actually going to be run in a timely manner and that is the purpose of having a enzyme or the biological catalyst. And that is what we are actually going to discuss in this particular course.

So, these are the different phenomenas what are responsible for running a life activities into organisms. Apart from this related to this, we can also have the you know different types of requirements. So, we have seen that the requirement is about the getting the nutrition, right.

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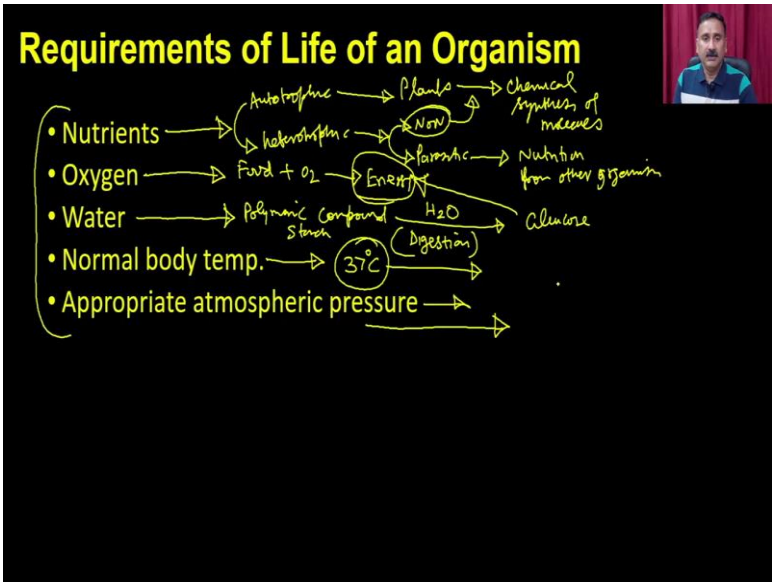

So, nutrition is one of the basic requirement of a living organisms. That we have already discussed. That, nutrition could be you know required for running the anabolic or the catabolic reactions. Then, we also require the oxygen. So, oxygen is required for running the oxidation reactions.

Then, we also require the water because the water is required for running the different types of reactions where the water is itself is going to be a substrate. Then, we also have to maintain the body temperature and we also have to maintain the pressure within the body actually.

So, as far as the nutrition is concerned the organisms have adopted the different types of mode of nutrition, so it could be either the autotrophic nutrition or the heterotrophic nutrition, right. So, and the machinery to acquire the nutrition in the autotrophic nutrition or the heterotrophic nutrition is going to be different.

So, autotrophic nutrition is the molecule the is present in the plants where they are actually going to acquire the energy or acquire the energy from the sun and that is how

they are actually going to have the chemical synthesis of molecule. Now, compared to this heterotrophic nutrition, heterotrophic nutrition can be further classified like the non-parasitic nutrition or the parasitic nutrition.

So, parasitic nutrition is actually the nutrition where the parasites are actually going to take up the nutrition from the other organisms. And whereas, in the non-parasitic nutrition they are actually going to take up the nutrition from the plants and that is how they are actually going to synthesize their own food actually.

Once you have the food it is actually going to be burned by the oxygen. So, and that is why we require the oxygen, right. So, food is actually going to be burned by the oxygen, that is how it is actually going to produce the energy. And these kind of reactions which are responsible for generating the energy from the food are actually be a part of the catabolic reactions. And all these reactions where the enzymes are participating actively into the reactions are actually we are going to discuss in detail.

Then, the water. So, when you actually have the polymeric compounds, they are called polymeric carbohydrates, for example, like starch. It has to be simplified and that is how it is actually going to give you the monomeric glucose. Because most of these catabolic reactions are actually taking up the monomeric molecule as the entry point. For example, the glycolysis, Krebs cycle and all that.

So, that is always been achieved with the help of the water because water is actually going to serve as a interesting substrate to break down the complicated polymeric compound such as starch or glycogen and other kind of polymeric substances. And this process is very actively being done in our you know our alimentary canal where in the process of digestions, the polymeric compound are actually going to be converted into monomeric compound.

And then they are actually going to absorb into the blood, and then they were actually going to be utilized into the catabolic reactions for generating the energy. Apart from that we also have to maintain a normal body temperature for example, the 37 degree Celsius. So, that is only in the in those organisms where we which are actually going to be warm blooded animals.

In the cold blooded animals, they are actually not going to maintain the body temperature, but they will actually going to maintain the you know temperature and that is why they will actually will not be able to be very active under the adverse temperature conditions. And then, we also have to maintain the atmospheric temperature, so that all the molecules would be under the you know adequate conditions to perform the different types of functions.

Apart from; so all these molecules are actually or all these processes are actually going to happen and that is how it is actually going to be responsible for the life of a organism. But most of these processes may actually go bad, right. So, they may actually go bad in terms of some sometime you may not have the adequate amount of oxygen, sometime you may not have the adequate amount of water for example.

So, on those conditions these processes are actually going to be disturbed. And that is why it is important that all these processes has to be tightly controlled, and that is how it is actually going to maintain the life.

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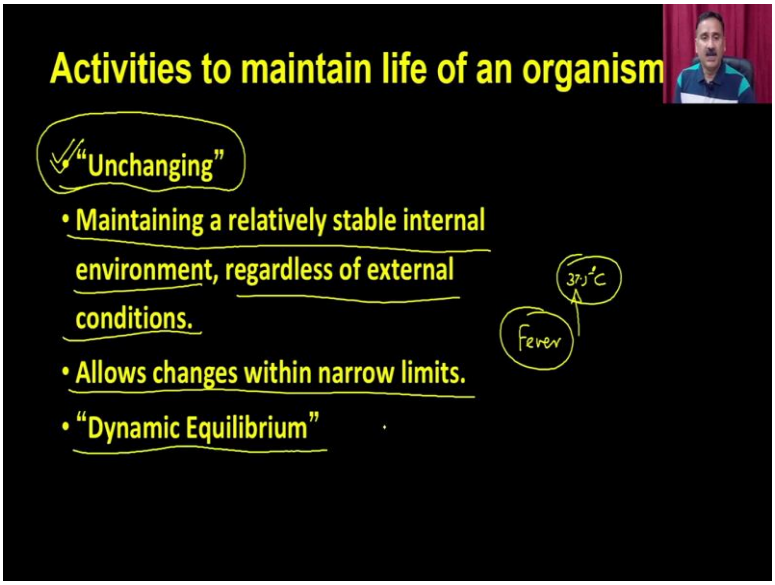

So, these are the different types of activities what are actually responsible. So, one of the major challenge is that you have to maintain the body's equilibrium under the non-changing conditions, ok. This means you have to maintain a relatively stable internal environment regardless of the external conditions.

And then you also have to allow the changes within the narrow limit, so that you can be able to accommodate the subtle changes. The for example, you can actually have the you know the fever, right. So, you can also have a fever and the temperature will go up from 37 to you know 37.5 or something like that, right. So, that is allowed. And then all these processes are under the dynamic equilibrium.

And because you do not want the changes into the body, the body has different types of physiological processes to control these processes.

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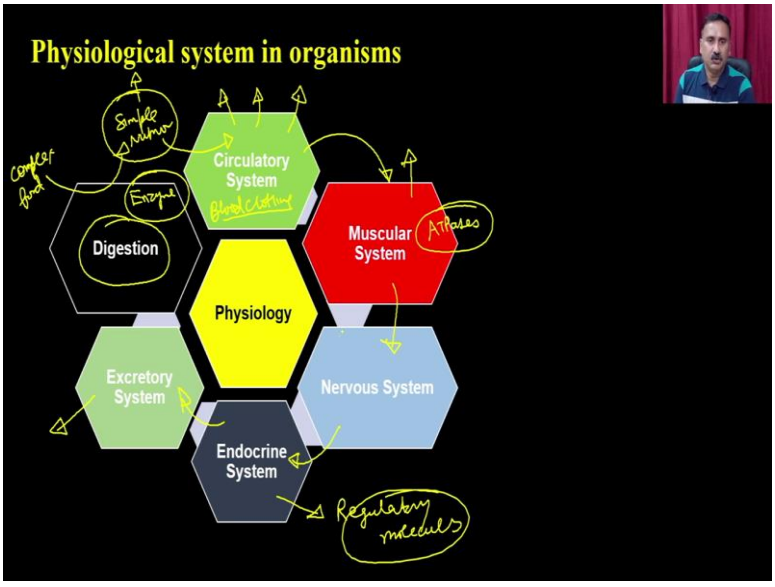

So, what are the different physiological processes? We have the digestion site. So, digestion is actually, the main purpose of digestion is that it is actually going to take up the complex food and it is actually going to convert that into the simple nutrition. And these simple nutrition is then actually going to be take up by the organism and that is how it is actually going to produce the energy.

This simple nutrition is going to be taken up by the circulatory system and that is how it is actually going to distribute the nutrition into the different parts of the body. That nutrition is also required for the musculatory system to perform the locomotion, and then would also require for you know nervous system, endocrine systems, and excretory system.

So, all these physiological processes are required for maintaining the constant internal environment and as well as they are also going to help in terms of the in terms of running the different processes. And all these processes are totally controlled by the enzyme. So, whether you talk about the digestion which we are actually going to discuss in detail; the there are different enzymes which are actually going to make the breakdown of the complex food into the simple nutrition or whether you talk about the circulatory system.

There are so many enzymes which are actually being participating into the like blood clotting and all other kinds of processes or whether you talk about the muscular system where you have the many type of ATPases. And all these ATPases are participating into the generating the energy generating the potentials and all that.

And same is true for the nervous system also. In the nervous system also you have the so many signaling molecules which are actually participating and relaying the signal from one part of the body to another part of the body. And then, endocrine system, where these are the molecules which are actually these are the system which is actually going to produce the regulatory molecules and these regulatory molecules are you know be a part of the controlling the different types of processes.

And then, we have excretory system. In the excretory system also we have the different types of enzymes which are actually going to participate or which are going to regulate the renal activities. And that is how they also going to be you know contribute in terms of the running the physiology of the organisms. So, to make it very simple, let us take an example of the very simple nutrition, ok.

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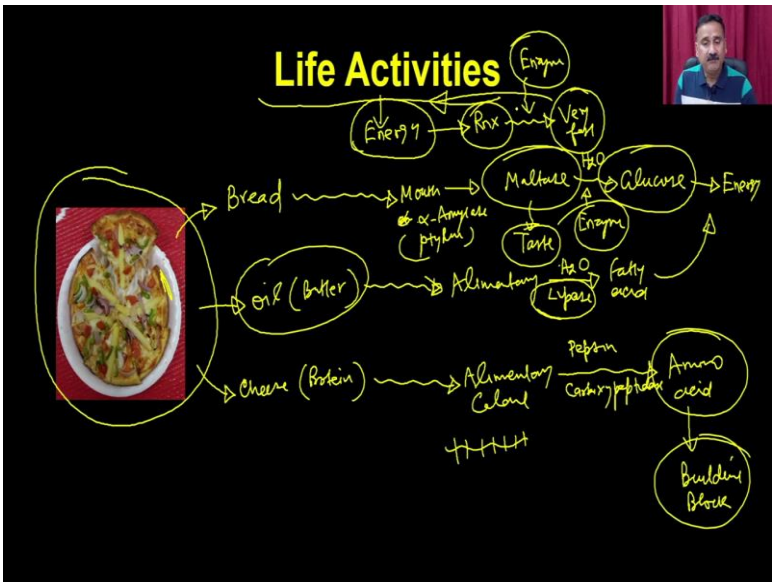

So, if we talk about the pizza, for example, if we if you take a bite of the pizza what are the things is actually going to start, so that you can be able to produce the energy and that is how you are actually going to have to maintain the life on the earth, ok. So, pizza is actually been made up of the three molecules, one is the bread, right that is the bread, right the base. It also can have the oil or the butter, right what you are actually going to use.

And it also going to have all this kind of vegetables and other kinds of cheese, right, so it also can have the cheese. So, that is actually going to be a source of proteins. And when you take the bite of the bread, right it is actually going to enter into the mouth, right. And from the mouth it actually will enter into the alimentary canal.

So, within the mouth the bread is actually going to be digested by the enzyme which is called as the alpha amylase, right, so, or ptyalin, right. So, alpha amylase or ptyalin, and that is actually going to convert that into the maltose, ok. And that maltose is actually going to give you the taste, right.

And ultimately, the bread is actually going to be get converted into the glucose after the complete digestion and that is how the glucose is actually going to you know be available for producing the energy. What you will see here is that there are so many enzymes which are actually going to participate into this process, ok. Similarly, when you have the oil, the oil is nothing but the lipids, right.

So, they are actually going to be taken up, and they will present they will go into the alimentary canal, and they will actually going to reduce the fatty acids, ok. And the fatty acid is also going to be available for producing the energy. And what you see here is there are so many enzymes which are actually going to participate. And what you see here is not only the enzyme, but it also requires the like water in both the places, it actually require lot of waters.

And then we also have the proteins, right. So, right protein will also going to enter into alimentary canal and they are also going to be get converted into amino acids and amino acids will not mostly or in general amino acids are not available for energy production, but they are also going to be part of making the building of the body which means they are also going to be a building block.

But here also you have lot of enzymes. Like, you are actually going to have the pepsin, you can also have the carboxypeptidase and all other kinds of enzymes which are actually going to break down the protein into the smaller fragments and these smaller fragments are nothing but the amino acids. So, what you see here is that a life activities depends on the energy and the energy production it depends on the different types of reaction, catalysis, right.

So, different types of reactions, but are going to be catalyzed. And all these reactions are actually going to be very fast, if we want to produce the energy at a very very fast rate, right. And that is how the place where you are actually going to utilize the enzyme, and enzyme or the biological catalyst.

But this all actually we are probably know today that the enzymes are central to catalyzing the different types of reactions. But when the people have started observing these changes, they could not be able to understand that the enzyme is actually been responsible for this.

So, this happens when the people were started looking at a process where they were actually trying to mimic the digestion like conditions under the in-vitro conditions. And they could not be able to do it because they were not aware of the biological catalyst.

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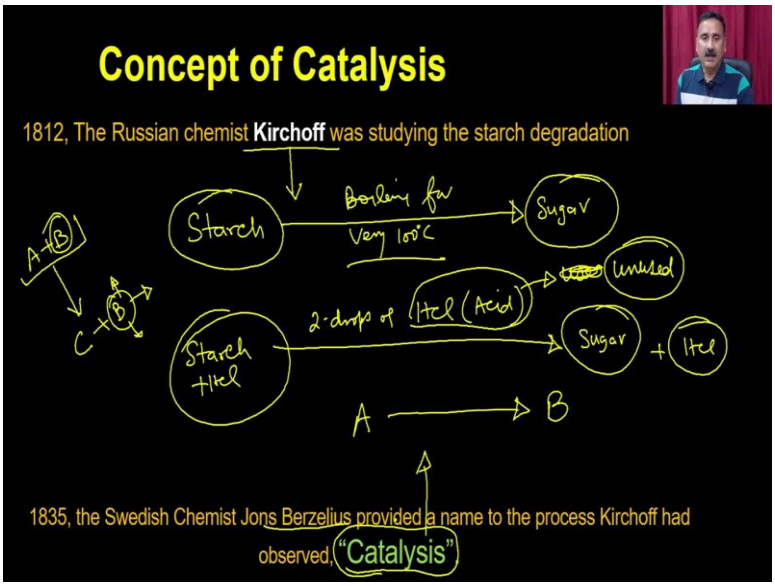

So, there was a scientist, Russian scientist Kirchoff, and what he was doing is he was actually trying to study how the starch is getting converted into the sugar, ok. So, what he was doing? He was doing different types of experiments. He was you know boiling the starch for very long time, because boiling for you know for example, at 100 degree Celsius or so.

But it he could not be able to achieve much success in terms of you know converting the starch into the sugar. So, what he did actually is that while he was doing this experiment of converting the starch into the sugar, what he did is he added a 2 drops of HCl or acid actually. So, what he found is that when he added the 2 drops of acid, he could find a large quantity of sugar and he could be able to detect.

And at the end what he found is that this HCl was unused, ok. So, he found that the HCl was unused at the end of the reaction. Which means starch plus HCl, he could found the sugar plus HCl, ok. This means HCl was actually converting the starch into the sugar, but HCl itself was not participating into the reactions.

And that is the you know that was very interesting, because before this most of the chemist were aware of that if you have the A and B are two reactants, right if you take the two reactant A and B and suppose you are generating the C, it is unlikely that the B is not going to participate into these reactions. Which means you are not going to get this

because that itself says that A is getting converted into C, but what is the role of the B, ok.

And that is how this is the guy, which was not participating into the reaction, but still it is actually doing the reaction which means when he was doing this reaction without the HCl or without the acid, he was not getting this. Which means and when he was adding this he was getting this, but at the same time the acid was not been able to participate into the reaction.

Acid could not, is was not being utilized. And that is how the this phenomena was always has been the first event which actually leads to the coining the term called Catalysis. [FL] catalysis is a term which says that it is actually a process in which the substance are actually going to be get converted into the another substance. Which means the A is actually going to be get converted into the B, but the reactants or the catalyst is actually not going to be participate into these reactions.

Well, for example, in this case the starch is getting converted into sugar, but HCl is not participating into this event. And that is how there is a new complete field of catalysis which is actually being evolved. So, people have started developing the different types of molecules and people were started developing the different types of factors, so that you can be able to do this.

Because earlier when he was boiling the you know even the starch for a very very high temperature, he could not be able to achieve much success because the if the reaction was still happening, but the amount of sugar what he was getting from this process was very very low.

So, that actually, which you know he started a new branch of science which says that you can be able to enhance the reaction without even consuming or without even consuming a molecule. And that is how that process is called as the catalysis by the Swedish Chemist Berzelius.

This actually initiated the process of discovering the different types of catalyst which can actually be able to enhance the reactions.

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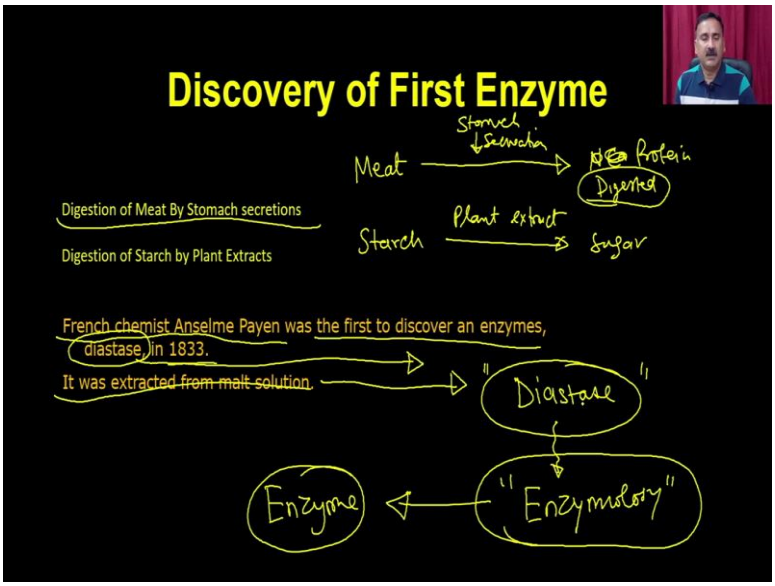

And one of the things what people have always been facilitated by the that the when you take the meat or when you take the food it is actually going to be digested. So, people have started looking at the identification of the factor which are responsible for converting the meat into the for example, the carbohydrate or meat into the protein, right. So, they started developing.

So, what they have done is they have added the meat and then they added the stomach secretions, ok. And what they could found is if we do not add meat is not going to be get converted. But when they add the meat stomach secretions the meat is actually going to be get converted into the process into the protein and it get digested.

Similarly, what they have done is they have also started you know converting the starch into the sugar with the help of the plant extracts, ok. So, because the plant extracts are also going to provide lot of catalyst and that is how they were actually going to be converted.

And that is how the French Chemist the Payen was the first to discover an enzyme which is called as the diastase in the year of 1833. And diastase is a digestive enzyme which was can be able to convert the meat or food into the simples molecules. And it was extracted from the malt sugar.

And that is how you know that today also we actually take up the diastase which are mostly being present in the most of these digestive tablets or digestive syrups and that actually helps in digestion of the food. So, that is the first enzyme. So, first enzyme which is going to be you know isolated or what is being reported is the diastase, the digestive enzymes.

And that actually started the discovery or the started the branch of the science which is called as the enzymology. So, the enzymology is the branch of science which is studying the different properties of the enzyme, ok. But the enzymology took a very very long journey through which the enzymology is being developed, and that is the enzymology what we are actually you know so developed that we could be able to do many types of experiment, we could be able to do lot of things.

So, enzymology as the name suggest is actually the field of science which study the enzymes. And the first enzyme when the people have started developed you know isolated the diastase, they started studying the different properties. But think this just did not start on the day 1, when the people started the diastase. The enzymology developed even before that also.

So, let us see what are different discoveries happened, so that you can be able to have the well developed enzymology.

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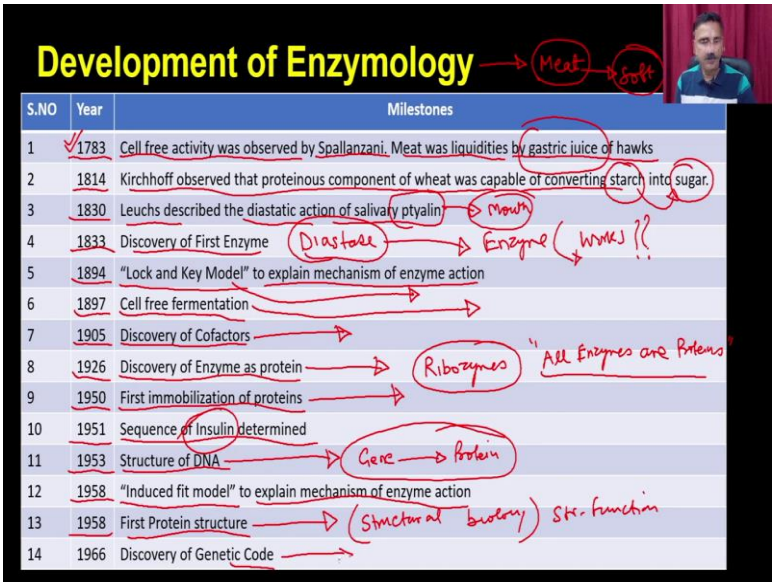

So, let us see what are the different development happens when they were developing the enzymology. So, enzymology is being developed as a field for you know for applications purpose. So, initially people were trying to see how we can actually be able to you know make their meat little soft, so that it is actually going to give the better taste.

And for that only the in the year of 1783, people have observed that meat can be little soft or tenderized if you add the gastric juices of the hawk or gastric juices of the any organisms. That actually is been you know said that there is something in this gastric juice which is actually making the meat little soft.

And that is how in the year of 1814, the Kirchhoff observed that the proteinous component of the wheat was capable of converting the starch into the sugar. So, this is another way of saying that the starch can be converted into sugar and that is how people think that there is a there is some factor which is converting this, right.

And then the in the year of 1830, the Leuchs described the diastatic action of the salivary ptyalin. So, this is another enzyme what is present in our mouth, right buckle cavity, and that is responsible for also the same activity, like converting the starch into the sugar. And then in the 1833, we discovered the first enzyme. The first enzyme is diastase, right the digestive enzymes, right. And then in the year of 1894, because once you and you discovered the enzyme, people thought that ok let us see how the enzyme works, right.

So, that also; so how the enzyme works? That is people was the first curiosity or first question people have asked, and that is how in the year of 1894, the "Lock and Key Model" was explained were was proposed to explain the mechanism of enzyme action. You do not have to worry about this because we are actually going to discuss about "Lock and Key Model" in the later lectures.

Then, the 1897 the people have started making the cell free fermentations. So, before this fermentation was a big thing, right because people were trying to convert one molecule you know the another molecule through the process of fermentations and so on. But all that was cell based where they are taking a sugar, adding the yeast and then that is that yeast is converting the sugar into the alcohol.

But, since they were aware of the enzymes, they know that there is a enzymatic activity which can convert the one biological molecule into another biological molecule, then

they have started developing the cell free fermentation also. Then, in the year of 1905, people have started developing the different types of cofactors. So, these cofactors are the molecules which are helping in the enzyme catalysis.

Then, in the year of 1926, people have discovered the enzymes, and they found that the enzymes are mostly being protein. So, in the year of 1926, people were not aware of the ribozymes. So, that is why the this is a general concept that the all enzymes are proteins, ok. So, all enzymes are proteins.

Then, in the year of 1950, the first immobilization of the protein. So, people have trying to reuse, because the enzyme is soluble in water. So, when you want to you know get the product, you are also going to get the enzymes. So, the people have started using the immobilization of enzymes, so that the enzyme will remain within the vessel and then you can be able to keep catalyzing the same reaction again and again.

Then, in the year of 1951, the people have first sequencing of the enzyme is reported which is for the insulin. And in the year of 1953, people have solved the structure of DNA because that has paved the way to actually know that ok this is the gene which is responsible for the protein and that is how you can actually be able to utilize that information to produce this protein under the recombinant DNA technology.

Then, year 1958, another model was produced to explain the enzyme activity or the mechanism of action, so that was called as the induced fit model to explain the mechanism of enzyme action. So, in the, you see that in the year of 1894, people have discovered the Lock and Key Model, but in the year of 1958 we will have developed the "Induced fit model".

Then, in the year of 1958, the first protein structure was solved and that actually started the another field which is called as the structural biology, ok. And that is responsible for understanding the structure function relationship of the different protein or even the different part of the proteins.

Then, in the year of 1966, people have discovered the genetic codes. And that is how the people started the you know knowing that this is the amino acid code by this particular gene genetic code, this amino acid is code by the this particular genetic code, and that has you know allowed them to clone that particular gene or clone that particular protein.

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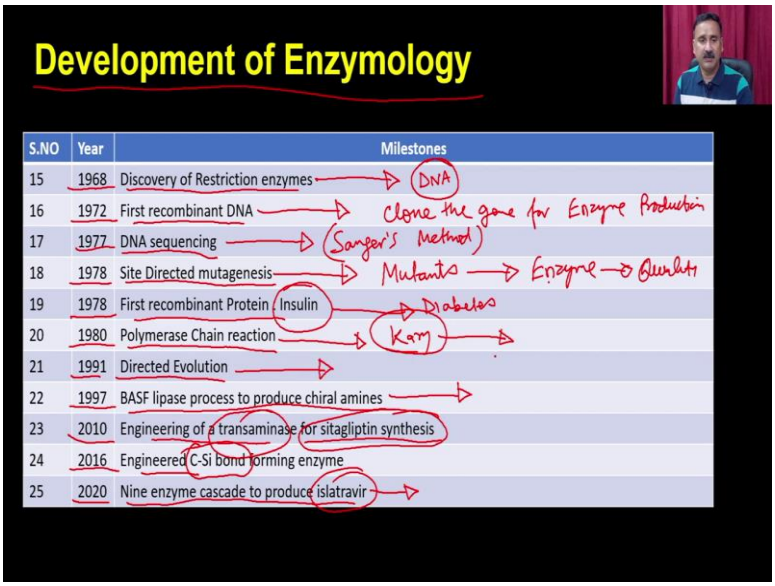

Now, in the year of 1968, people have discovered the first restriction enzyme. So, restriction enzymes are the enzymes which are actually degrading or which are you know cutting the DNA. Then, in the year of 1972, there was a first recombinant DNA which is been produced and that actually has paved the way in which you can actually be able to clone the gene for the enzyme production, right.

And then in 1977, people have developed the technique of DNA sequencing, right. You know that, the Sanger's method, right Sanger's method. Sanger's DNA sequencing method for which the Sanger actually got the Nobel Prize. And then, in the year of 1978, the site directed mutagenesis were developed. So, that actually allows the development of different types of mutants, for the enzyme and that is actually going to help in terms of improving the quality of the enzyme.

That all we are going to discuss in forthcoming lectures. Then, in the year of 1978, the first recombinant protein that is the insulin is been produced and that is been utilized for the treatment of the diabetes. Then, in the year of 1980, the PCR was discovered by the Kary Mullis, right. And that has revolutionized the way in which you can be able to perform the PCR, you can actually be being the multiple copies of the particular gene and you can be able to clone that.

And then, in the year of 1991, there will be a direct evolution concept to understand how the proteins are being evolved into the different organisms. And in the year of 1997, the

BASF lipase process to produce the chimeric amine. So, that was the first enzyme which was utilized to produce the you know the biological products. And in the year of 2010, there will be a engineering of a transaminase to for the synthesis of the chemical molecules.

Then, we also have in the 2016, there was a engineered enzymes that actually is helping to form the carbon silicon bond. And then, in the year of 2020, there are nine enzyme cascade to produce the chemical molecule islatravir. So, this is the first time that people were utilizing not only one enzyme, but a series of enzyme and then that is how they are actually producing the chemical molecules.

So, if you see how the development of enzymology is being occurred from last more than 100 years, that it has developed 3 fields actually or 3 different way in which the enzymology is being developed.

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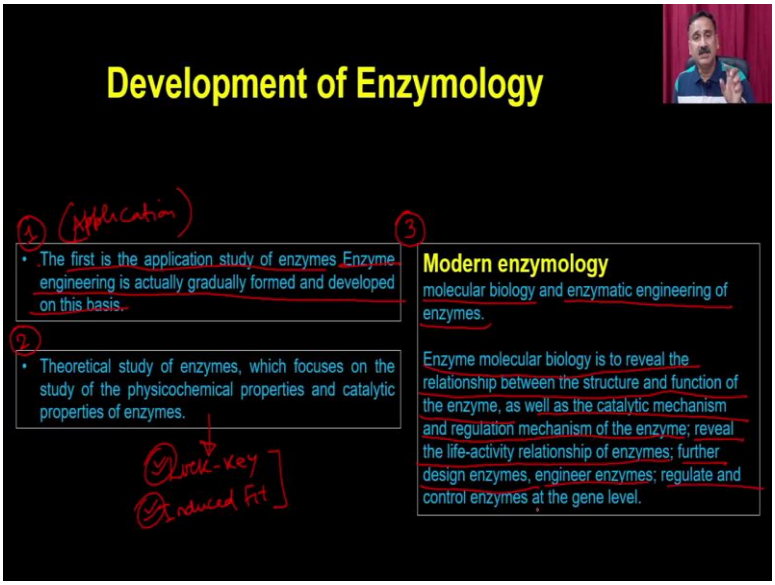

The first is that it is actually being developed as the alternative of the cell actually. So, in the first is that if you see that the initially it is being developed because there are application of the enzymes. So, it is been you know that application part is been very very strong.

So, the first is the application study of enzymes, right. So, how you can convert that meat into the soft meat or tenderization of the meat or you can actually have the replacement

of the fermentations like the cell free fermentations, how you can be able to generate the different types of chemical molecules and so on. So, initial phase was that you are they were trying to you know discover the enzymes for different types of, identifying the different types of processes.

Then, enzyme engineering is a one of the thing which gradually developed based on this particular basis because based on the requirements you can have the thermo stable lipases, you can have the lipases, you can have the enzyme which would work under the extreme conditions and so on.

Then the people have developed the theoretical understanding. So, in the second phase people have started developing the theoretical understanding of the enzymes, how the enzyme is you know interacting with the substrate, how different types of complexes are being formed and so on.

And that actually has you know evolved into the development of or proposal of the "Lock in Key Model" and as well as the "Induced fit model". Because these are the model which are actually being proposed based on the study under the theoretical study of the enzymes. And that actually helped in terms of enhancing the catalytic properties of the enzyme. So, that they can be able to process the same event even faster, right. So, you can have the more efficient enzymes.

And then the third phase is the modern enzymology. In the modern enzymology, people have started you know utilizing the molecular biology tools and the enzymatic engineering of the different types of enzymes. Which means they were trying to develop the site directed mutagenesis, they were trying to do the you know the evolutions and all those kind of parameters.

They were trying to utilize the bioinformatics, artificial intelligence, and all those kind of you know things into the modern enzymology and that is how the modern enzymology is utilizing the different tools. So, enzyme molecule molecular biology is to reveal the relationship between the structure and the function of that enzyme, as well as the catalytic mechanism and the regulation mechanism of the enzyme. It reveals the life activity relationship of the enzyme.

Further, the design the enzyme, engineer the enzyme, regulate and control the activity at the gene level, which means you can actually do the knock-outs of the enzyme, you can actually do the knock-ins, you can over express the enzymes in the different organism and so on. And that is how in the modern enzymology they were trying to do multiple things. They were trying to study the theoretical aspects, they were trying to do applications of the enzyme also.

So, with this I would like to conclude my lecture here.

Thank you.