Textile Finishing
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Lecture - 27
Biopolishing

Welcome back to this class on textile finishing. As usual, let us see, what have we learnt till now.

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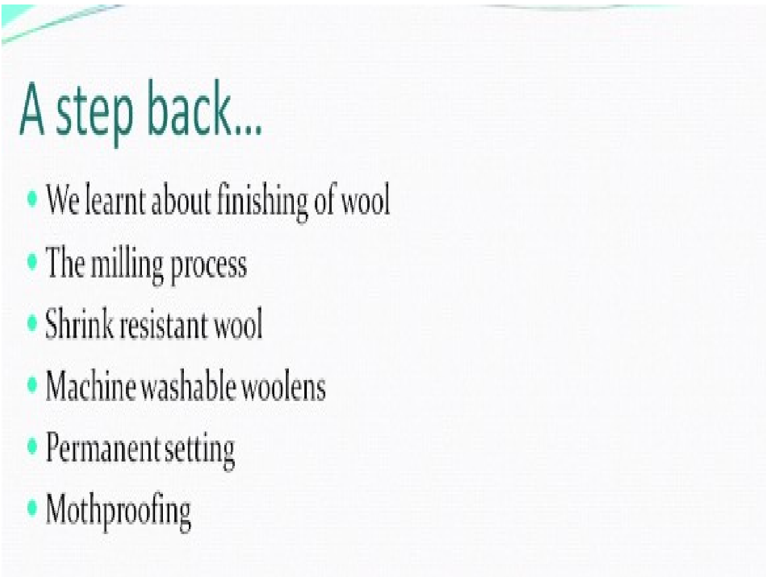

We learnt a few things about the finishing of wool. One of the processes was a milling process where you were compacting the woven or knitted fabrics can be compacted. The shrink resistant wool, where the felting shrinkage could be reduced by masking or partially destroying these scales to make the woolen garments machine washable and to make them more easy care, we talked about permanent setting of wool, and finally to protect the fabric from the damage from moth, we did talk about some mothproofing agents which can be applied on to the textile that is the wools to avoid the damage.

We pick up a different topic now, interesting enough, which is called the biopolishing you know. Polishing word which the common sense would mean whatever it means, that means you do something so that the surface become more smoother, becomes more shinier, but do it not by any other process but by using biological systems, maybe biocatalyst. You remember the process of singeing, what we do? We remove the protruding hair. How do we remove the protruding hair?

By burning, can you imagine, by burning could remove them and so the surface became more smooth and very nice, very useful process, that was a pretreatment, but after the pretreatment has been done, you have done scouring in whichever form that you have done, then did a lot of washing and after that you had probably done the dyeing, bleaching, so fabric has been handled in different ways, dried, washed, squeezed, so it is quite possible that some more hair would start getting projected on the surface of the fabric.

How do you remove them? You go back to singeing again, you can do that, but that people do not do it. One of the ways is biopolishing. If suppose the biological catalyst can do this job for you, then it will be called polishing by biological agents and that is biopolishing.

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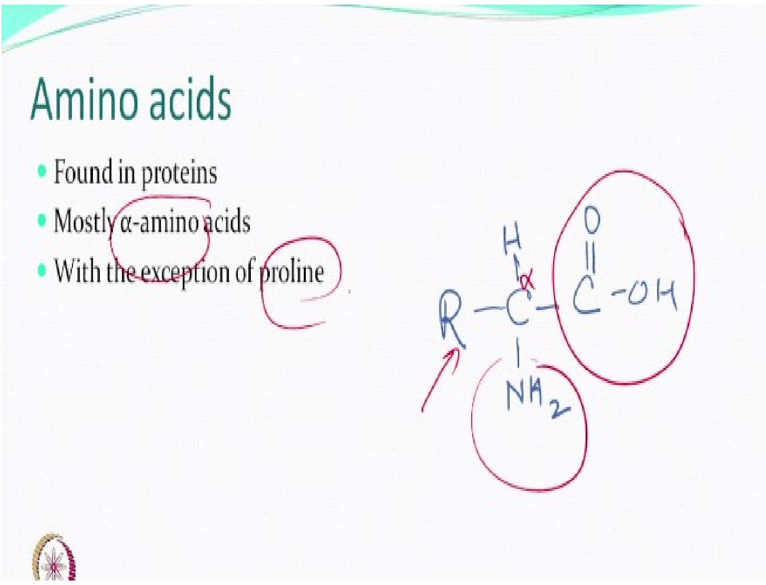

Before we go further, let us recall some things, amino acids. Where do you find them? The structure that you see is an amino acid. So, this is the acid okay and this is the amine, so you have amino acids. This R obviously is very complex branch, it could be anything, it could be H, it could be CH_3, it could be very complex phenyl group, and various things. So various types of amino acids are available, we could be interested in them, but what we are interested in are the ones which are available in the natural systems.

These amino acids which are found in protein that we are made up of, we eat proteins, a lot of things happen. So, these proteins are made up of amino acids, mostly alpha amino acids, what is an alpha amino acid, this is the example of alpha amino acid, this is the COOH group, this carbon, so this carbon is called the alpha carbon. So, this is alpha carbon, so amine is at the alpha position, therefore it is called the amino acids, and these are some of the very interesting important naturally available amino acids, which finally synthesize the protein from the genetic process with the exception of proline of course.

Proline is something with directly, not, the nitrogen is not connected to C, it is connected to a ring structure you can check it out when you look and read more about let us say wool fibre or any other protein or a silk you will remember, some of these amino acids are there, alpha amino acid generally except proline.

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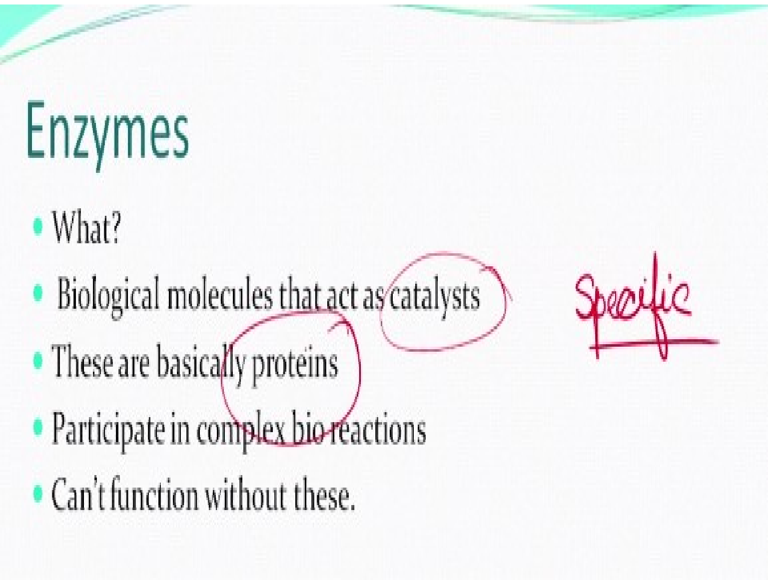

Now we are talking about enzymes. Enzymes, what are they? What are the enzymes, you know anything about them? What do you know about them? A biomolecule which acts as a catalyst. So, you know what a catalyst? What is the role of a catalyst, is to carry out reactions faster, increase the efficiency of reaction at a given condition or bring down the conditions of the reactions, that is the catalyst, but they are biological catalysts? What is so important about them?

The important part is specificity, they are very specific in their action unlike say organic or inorganic or organometallic catalyst, these are very specific. So, it is the specificity of these enzymes which makes them special. So, they will carry out the certain types of reaction and not the other type of reaction, that is how we are what we are, a lot of things are happening within us is because some such systems work and work so perfectly, therefore in a normal situation as the nature had decided that is what happens.

So, they are biocatalysts okay, interesting, did you know they are basically proteins. Proteins, so all the enzymes are proteins. The proteins are made up of amino acids, generally alpha amino acids. Now so this enzyme is a very specific thing, a biological thing which is a protein actually, so protein we are using all over getting into, breaking down into amino acids and the body gets built up, in one way or the other, we need proteins right. So, what are these enzymes and protein going to do, can we eat enzymes and enjoy life?

Enzymes are already there with us, instead of consuming them, our system uses them to break down other interesting compounds which are required for us, for everyone, for energy, for growth and so on and so forth. So, enzymes are important. So biological reactions whichever happening, they are acting as catalyst, but interesting, they are proteins. As I said, they do participate in very complex bio reactions, actually as somebody said we need them everywhere, in the whole lifecycle we need them, we cannot do without them at all.

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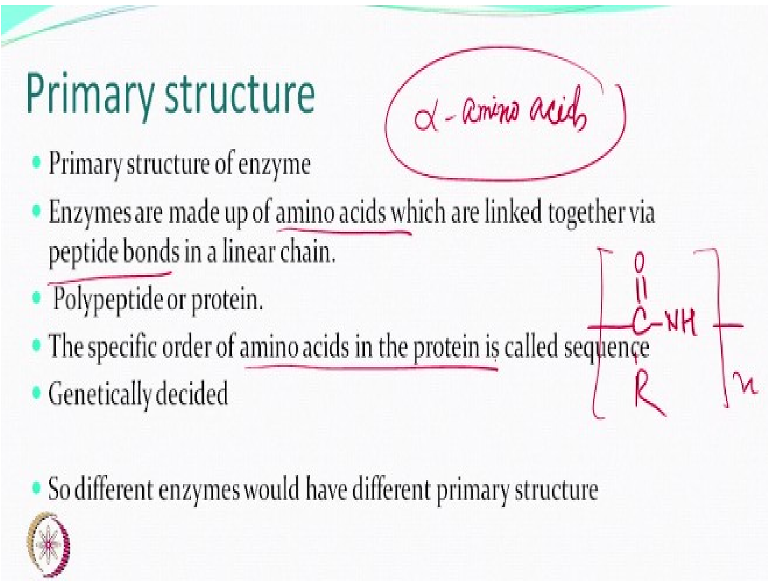

So, before we go further, **so** we learn little more about the enzyme and what is the little more, its structure. So, what is the structure? We already said that this is a protein, so we know protein, but these things whether enzyme or a protein, something is called a primary structure. A primary structure of enzyme what is it? Made up of amino acids as we talked about, generally as I said alpha amino acids, and they make peptide bonds right. Do you know the difference?

So, this an amide linkage, so why this kind of a linkage is available in polyamides like nylon 6-6, available, so why we call something as a peptide bond and other as amides, so basic linkage is CONH, which is an amide linkage. We call all such linkages as peptide or polypeptide as the final molecule if they are generally made from naturally found amino acid which are alpha amino acids except as we said proline that also is available, but when these amino acids are used where there is some R associate, then this type of structure will be called a polypeptide.

Molecule will be called protein and enzymes are also protein and this structure which we are representing here is the primary structure of protein and also therefore enzyme. So, this is what we already talked about, it could be either called a polypeptide or a protein, yeah, that is interesting thing. Different proteins are different, different enzymes are different, why? The amino acids may be same, but their sequence in which they are arranged you can have glycine, glycine, glycine, alanine, alanine, glycine, alanine, proline, which type of a sequence and what is the composition?

So, the composition of amino acid within the protein that is the protein structure which is the polypeptide and the sequence in which these amino acids are going to appear is going to be very specific, that is very important. Therefore, different enzymes will have different structure, but they may have similar amino acid, right. This is the most important part here as far as this primary structure is concerned, who decides how to do work around, obviously here there is no organic chemist sitting who is deciding which amino acid to come after which amino acids.

It is the genetic code which is deciding as to which amino acid would come after which, right, therefore the sequence is done genetically and that is our natural product. So, we can agree now the different enzymes would have different primary structures. Primary structure is the linear chain of polypeptide formed by different types of amino acids.

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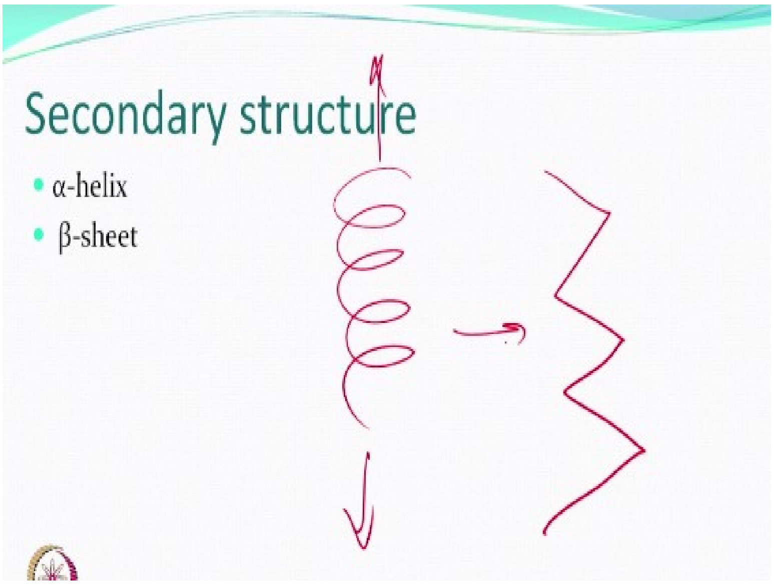

So, these protein structures and the enzyme structures also take up secondary structures. So primary is the main chain, the secondary structure and two of the important secondary structures are alpha structure which is alpha helix structure or a beta sheet structure. If you extend this, it can get converted to beta sheet, for example in the case of keratin which is in the wool, if you stretch and let us say heat or steam, you might get into beta structure, if it comes back again, it can go to the alpha structure, alpha helix structure.

So, enzymes can assume any of these structures based on their composition and based on their sequencing. So, this alpha helix means there are intramolecular hydrogen bonding, that is why these structures take place. So, this is the secondary structure.

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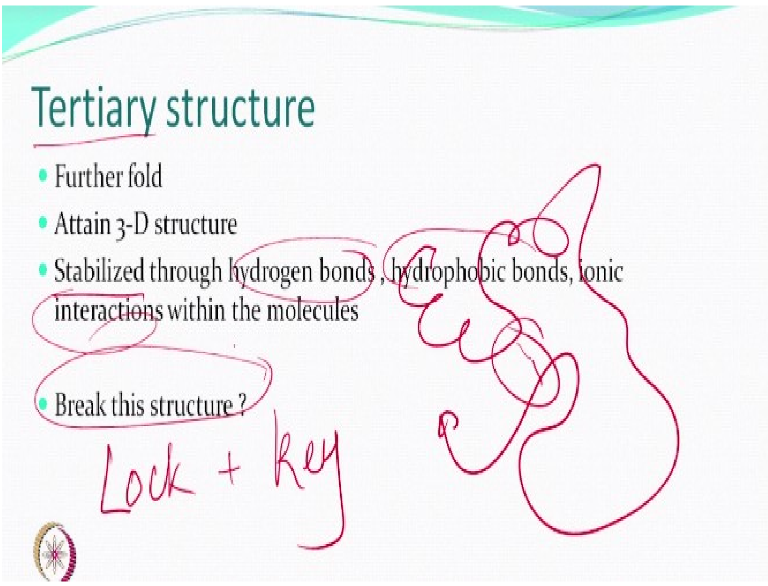

So, this is added by another thing, the same alpha helical structure may not remain like a straight helical structure, it can fold upon itself, the beta structure may not remain straight, can fold upon itself at some places depends on what is happening. So, you can create further folds of this molecule and create a 3-dimensional structure, now anyway helix is also a 3-dimensional, but the helical thing instead of roaming in a linear way could also bend somewhere, come back, and take up a shape which could be a very different shape.

For example, this type of a shape, this is 3-D structure created. Now this structure that I have just arbitrarily drawn is stabilized, through what, could be hydrogen bond, intramolecular hydrogen bonds, this could be hydrophobic bonds because of the hydrophobic things may be coming together somewhere or ionic bonds interactions which can make them come together because there are acidic amino groups, there are basic amino group, there are hydrophobic amino groups.

So, because of this nature, they would come together and randomly orient, obviously any molecule will like to randomly orient like a polymer molecule also, does not remain straight, does it? It takes up shape if you do not orient them, it will just like to make a spaghetti like structure, but in the case of enzymes, this so-called random is not so random, it is actually defined based on their sequencing, it will take a particular type of a shape and this catalyst becomes very effective if it is in this shape.

If it goes to any other shape because of my intervention, our intervention, then it will not be effective. The protein will remain same, the secondary structure may remain same, but the tertiary structure if it destroyed, destroyed means removed, taken off, then it gets deactivated, no hydrolysis, no breakdown, still it will not be very active agent and that becomes a very important way for its specificity. It works if it is in this particular thing and works on certain types of groups where it can fit like a lock and a key, actually this is lock and key mechanism people talk about right.

So, there is a substrate which is any other polymer and there is this enzyme, if this can very easily go interact and fit in there, then it can start working as an enzyme, as a catalyst. If there is any change anywhere, it may not work. So, if you break this structure, this tertiary structure by any means, then this gets deactivated, right, there we are.

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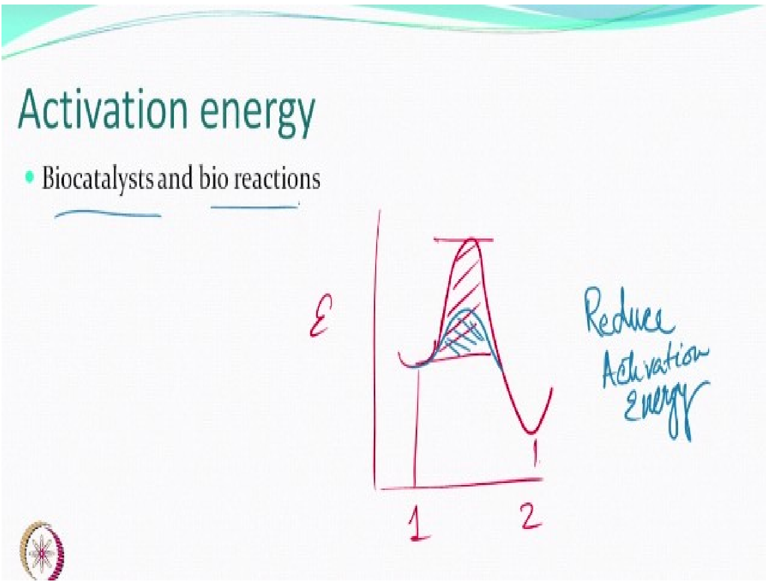

So now, this is a catalyst, so there must be something called an activation energy and how they work, normal reactions whenever they have, see so you have something which is state 1, you have to go after some reaction to state 2, so thermodynamically why would you go to state 2 because this must be the way the things are done. So, it will go somewhere there, but you have to cross a hurdle, that is the activation energy. If you are having energy being plotted here, so the amount of the energy has to be spent.

So, you got to go reach up to this point and after that, the reaction will take place automatically. These are related to what we call as the activate a system, give enough energy to activate a system. Now if you are using catalyst, like biocatalyst also, you would probably be able to reduce this activation energy and so they work like catalyst, so that is what is there, so biocatalyst and the bio reactions are going to be facilitated by enzymes.

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How do we optimize, just for all such reactions, their important optimization parameters here are pH, why pH because pH can change the ionic character? If ionic character changes, then this tertiary structure can be stabilized, may not be exactly the same thing and so it may not function. So that means, you must know for a particular enzyme, there is going to be range of a pH in which it is going to be effective, why is going to be effective because that structure is going to be there. If this structure gets disturbed, enzyme gets deactivated.

The other optimizing parameter is temperature, so how? Because temperature means what? Kinetic energy, more vibrations. If you have more vibrations, then what happens? This loosely stabilized structure will get destabilized and so it will not be effective, and you get the point? That means for effective bio reactions, we will have to optimize the pH, that means whichever enzyme is there and once you know it then you use it around that pH and at temperature which is a temperature range which is suitable for their action, this must be known.

If you work beyond their range, life will be very different, so they are just like any molecule, not broken down, but does not work.

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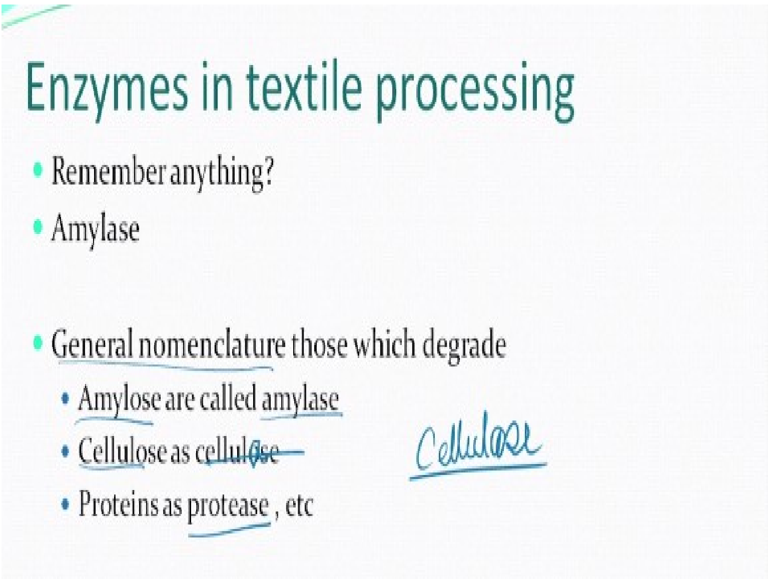

So, now let us say we have talked so much about enzymes, where do we use enzymes in textile processing. Remember anything, where do we use from your own previous recollection, remember where do we use? Yeah, you remember this name, amylase, what is it? What is amylase? Is it an enzyme or a polymer? It is an enzyme, amylase is an enzyme, used for what? amylase where do we use them, to break starch okay. Some general nomenclature, not exactly the way you like today, but it could be just to remember, amylose is available in starch remember.

So, if you break down the starch, anything that breaks down the starch, anything means the biocatalyst we are talking about, the enzyme will be in the category of amylase. Something which would break down cellulose is called cellulase alright, cellulase, so whatever breaks down cellulose is called cellulase and protein as protease and so on and so forth, but you remember amylase, where do you use? Desizing, okay.

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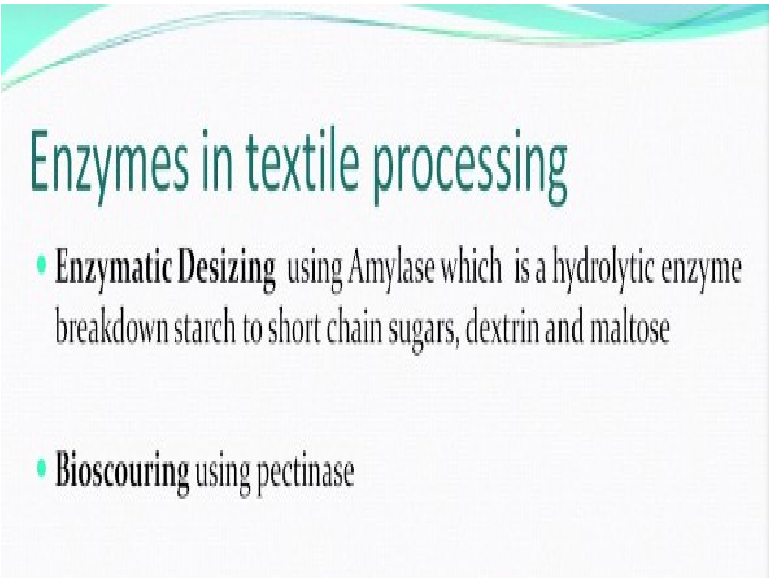

So, enzymatic desizing is where in the textile preparatory lot of amylase is going to be used for breaking down the starch into smaller products which are close to sugars, dextrin, maltose, so on and so forth. Why do you want to break down? You want to break down because it is easy to wash off, alright, but that is a preparatory. So, scouring, why do we use? Why do we use scouring, to remove fatty material? It so happens that the fatty material somehow gets associated with another compound called the pectins.

So, pectins are the ones which are responsible for their association to the cellulose through pectin and the fat, and so if you break pectin, then the fat can also come out and so the waxes, the fats can come out. So, pectinase is another enzyme which is used for bioscouring, you may have heard about it, we are not discussing.

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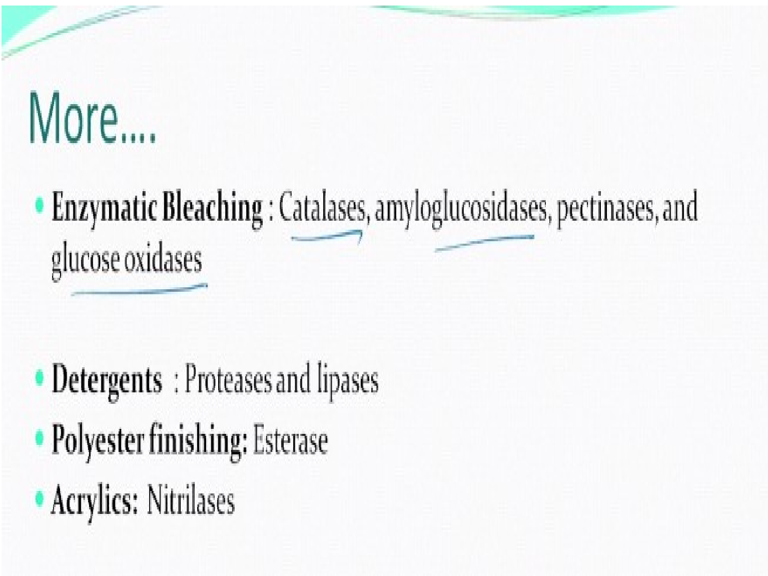

People have thought about enzymatic bleaching as well. Some of these things normally, how do we do bleaching, either we use hypochlorite or hydrogen peroxide, an oxidizing agent. So, you do have different types of enzymes which can actually lead to bleaching as well something like catalases, glucosidases, and oxidases. Nature already had done lot of homework you know, all these processes take place in our systems, and therefore some of these enzymes are already available.

How much useful they are for the textile people that textile people have to decide themselves based on the optimization so and forth. In various detergents, you may find some of the thing, like you say no stain will be removed quietly, this will happen, that will happen. So, some detergents may contain proteases because oily protein-based system like that which we people eat could be there which may have to remove, lipases which will dissolve or break down lipids, okay. So, they may be there.

Then recently people have thought that well as polyester is nonbiodegradable, slowly people found that I think there is an enzyme called esterase which is available because we do have esterase within our system, so some of them can actually work on them to do whatever they want to do, polyester finishing okay. Acrylics also people have found and beautiful system which is called the nitrilases can work on acrylics. So, there are many kinds of enzymes and systems available, they are all different, they will do different functions are available.

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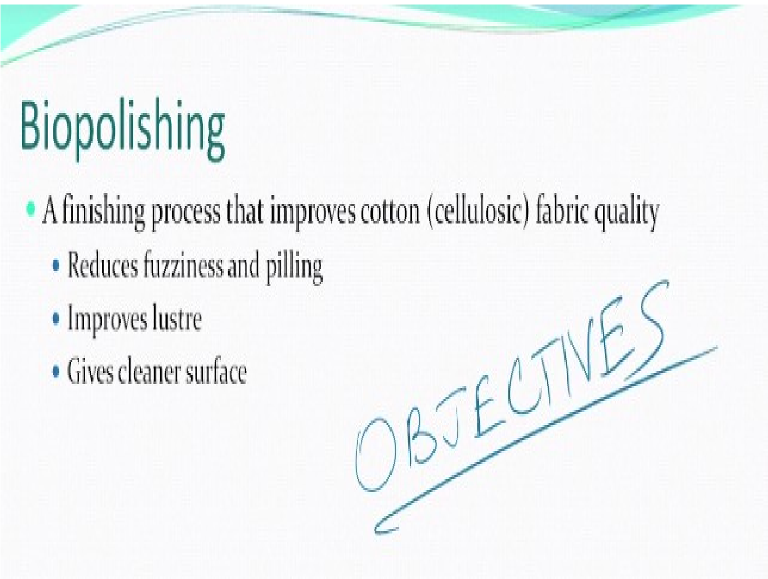

What are we talking today? We are talking about biopolishing. This is a finishing process okay. This finishing process is mainly designed as of now known only for cellulosic and within the cellulosic also, we are more keen to use this finishing process on cotton-based textiles okay. So, what it does? It would reduce the fuzziness and the pilling, now why the fuzziness, because the hairs may have come out and the pilling also is because of the hairs, some part is protruding, the other part is anchored.

Anything which breaks down the ball of that can get entangled with this protruding part, you will see lot of small pills on the surface the fabric, very bad looking stuff, but this can remove this because there is nothing to anchor because you are going to remove this and also improve luster because if you remove this fuzziness, so luster can improve and give you a clean surface, aright, that be our objective okay, stated objectives.

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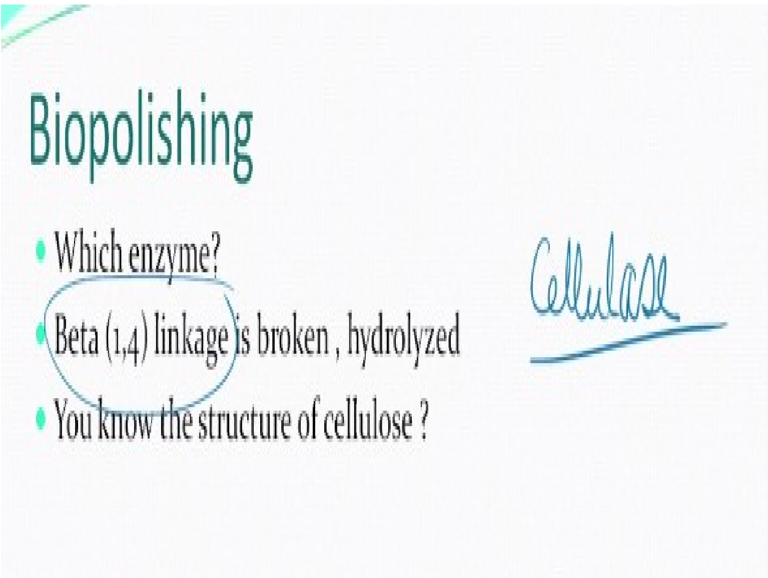

Okay which enzyme, which class of enzyme will work on biopolishing? Yeah, cellulase because we just said that we are going to be working on cellulosics okay. So, for biopolishing which is designed for cellulosic fabric, mainly cotton, you would use cellulase alright. What it does? We expect it to break this beta 1, 4 linkage, so you have cellobiose unit and you have beta 1, 4 linkage in the cellulose or no, you remember the structure, remember, if you do not remember go back, learn where is the beta 1, 4 linkage.

There are so many beta 1, 4, if you can break the beta 1, 4, well smaller molecules can come up and so this process will be used for biopolishing and what do you expect? We do not expect to damage the cotton yarn on the fabric or the fabric itself, we are only interested in doing a bit of removal only of the hairs only at the surface, not go down too much, because if you go down too much, yeah it can eat up the whole cellulose.

Then you will have nothing left, like the case of desizing you are interested in complete destruction of the amylose so that it can be washed off. Here, there is no aim, you want the cotton fabric to look good, so only the surface treatment, it is a surface treatment.

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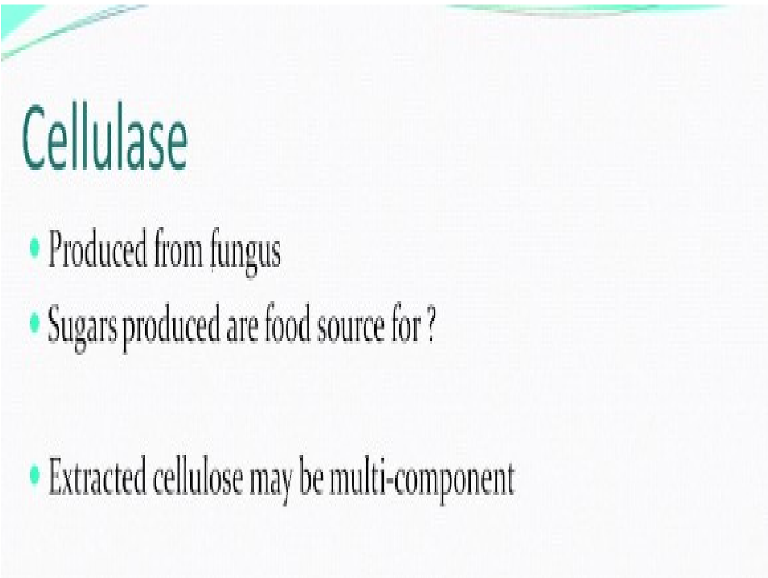

So, cellulase is enzyme which we talked about, is produced from generally industrially, now it is industrially produced because so important from various kinds of funguses. So, they have cellulase enzyme, do you remember fungus and bacteria were eating your cellulose, they had cellulase. So, what do we do? If we need them, so we extract, you cultivate the fungus now and then extract the cellulase and use it for our purpose.

So, they would produce these enzymes, the cellulase will produce sugars, these are the foods for what, foods for fungus itself, but we are not giving it back. Interestingly although in general you call it as a cellulase, but it is not just one set of enzymes which is called cellulase, so it is a group of enzymes which are in this category, so they can be multi-component. When you extract, there will be multi-component you know. Multi-component means we can isolate them in liquid chromatography and so on and so forth you can see them different.

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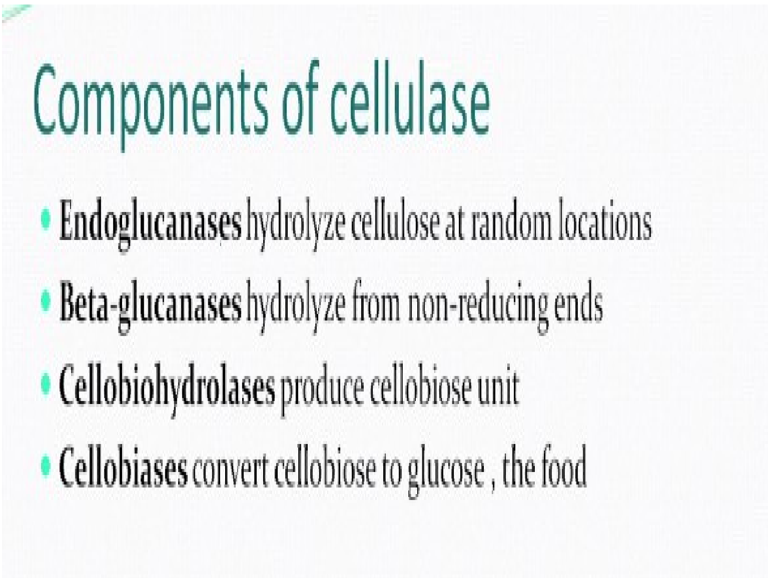

So, based on those, roughly the mechanisms using cellulase has been sort of listed like this. One type of things are called the endoglucanases. The endoglucanases hydrolyze cellulose at random locations, wherever they find something, they will just break them. Then there is a specific thing which we call as beta-glucanases which hydrolyze from the non-reducing ends, they just go to the other end and then they keep removing sugar from that end, so they work on particular end.

Then there are cellobiohydrolases, they break the big molecules of cellulose into cellobiose units, you know cellobiose units you know that, and then another one which is called the cellobiases, it converts cellobiose into glucose, which is the food from you know it. So, this is how you will break them. This is the general mechanism. This will be true for any cellulose. Now if you keep it for too long, destruction can happen, so we have to be controlled treatment with this, but it is still environmentally friendly treatment.

It is still much more slower process compared to let us say you put acid, hydrolyze or a flame, that just burns, that is too fast and different process altogether, but this is considered as one of the interesting processes which can be used.

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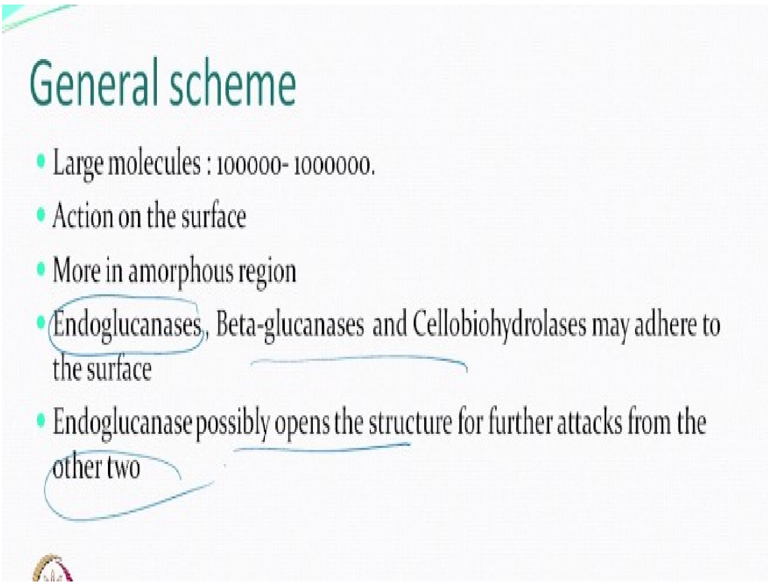

So general scheme of things is the large molecules are there. The molecular weights are very large of these proteins, so they cannot really enter too much into the fibre structure. They will generally be acting on surface and that too also if you make it compact structures, and generally they will be first acting on the surface. So, first action of these big molecules will be on surface and we are also interested in polishing, that means the surface is the one which we are cleaning.

Any fuzziness for whatever reason it is there, either protruding and balls or other kind of things attached, adhered, smaller ones, just remove them, not the main fabric structure. Attack, obviously their common-sense situation is, the first attack will be in amorphous, getting inside the crystalline region will be difficult, but once it goes, then you have smaller things and then break down. So, these things like the three endoglucanases, beta-glucanases and cellobiohydrolases may adhere to the surface and start doing their job and can further open the structure.

This will first act open the structure and the other two will then start having further attacks, so the helping is there, so this is a group of enzymes called the cellulase because together they destroy the cellulose are the ones which will be working.

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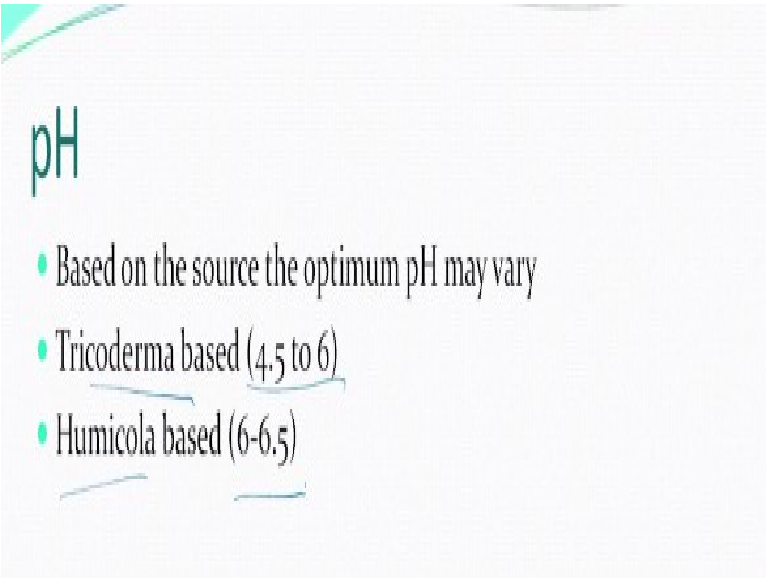

Now, the pH we said before is going to be an important thing and so we must optimize, but the optimization of a pH also depends on from which source the enzyme has come. So generally, if it is from tricoderma based fungus, then it may be around 4.5 to 6. If it is Humicola based, then it may be 6 to 6.5, that means whichever source you are getting because fungus also lot of variety is not it, which is easily available, which can grow fast, that is what people will use industrially and then get so though you optimize the pH.

Those who are generating extracting the enzyme, they will also have done some exercise and optimization will advise you accordingly.

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Temperatures based on whatever kind of enzyme between 45 degrees to 60 degrees centigrade, somewhere an optimization temperature may be there for one or the other type of enzymes. So that is optimizing of temperature, optimization of pH has to be done.

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So, like any other chemical processing system, once you have decided the pH and temperature, there will be time also, and during the time period where the optimum things can happen, you will have to keep doing the mechanical agitation. It could be jiggers, it could be tumble drying washing machines, depends on what you are doing, wherever, so you got to be doing things like this. Mechanical agitation obviously will make sure that uniform treatment takes place, this is again a common sense.

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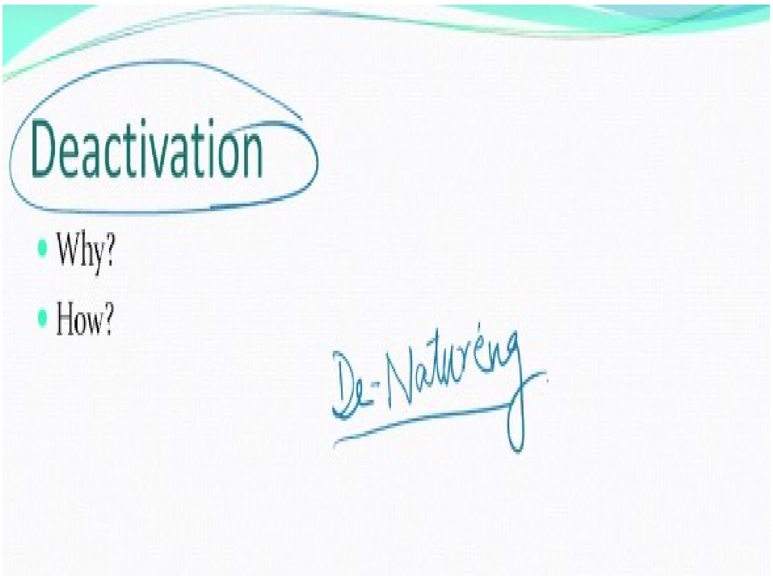

Deactivation. If we stop the process after optimization, the enzyme is still there, it will be keep degrading if you do not stop this process, then your mechanical strength of the textile can go down, the performance of the textile can go down. So, you must stop this process also, that process of stopping is called the deactivation. How do we do it? Two things, take it to more alkaline pH, things will change, take it to high temperature, let us say 80 degrees boil, the enzyme activity will stop, and this process is also from the enzyme terms called denature or denaturing.

So denaturing means naturally it appears in this particular folded structure by doing this, increasing or changing the pH range beyond the optimum, changing the temperature range above the maximum can denature the enzyme, that means deactivate.

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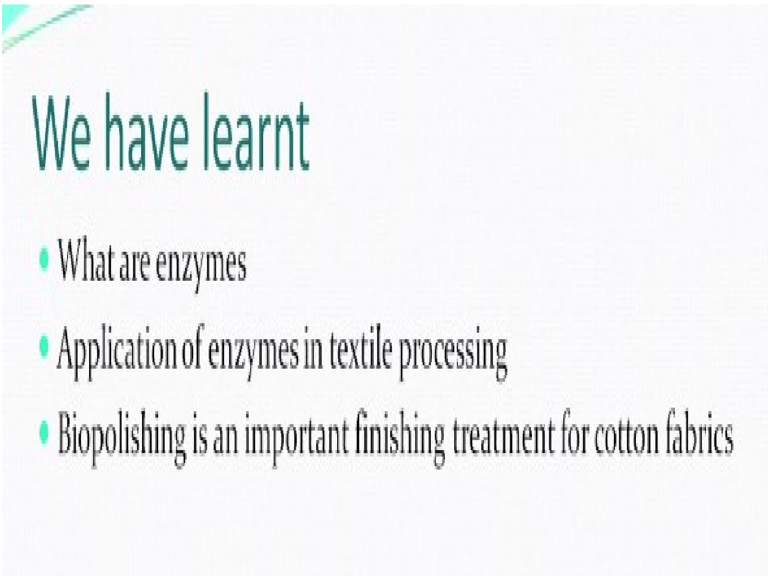

So, we have learnt today that what are enzymes, maybe it is a repeat of what you all knew, that is good. Application of enzyme in textile processing and many applications are there, but from the finishing point of view, an interesting application is biopolishing, which is done to the cotton-based fabrics. In the next class, we will talk about synthetic fibre finishing which is specific to synthetic fibres. Till then, enjoy. See you in the next class.