Aspects of Biochemical Engineering
Prof. Debabrata Das
Department of Biotechnology
Indian Institute of Technology, Kharagpur

Lecture – 01
Introduction

Welcome to my course aspects of biochemical engineering. Now as you know that most of the engineering branches that usually develop from the science branches, because the science basically tell us that why it is happening and how it is happening, and engineering is the application of science. So, if you look at the chemical engineering that has been developed from the chemistry, like you know physics that we have electronics electrical engineer, then we have material science, we have development of metallurgy engineering and mechanical engineering. So, engineering is basically that is that deals with the application of kind of science.

So, I will be discussing on the different aspects of biochemical engineering, and this biochemical engineering mostly deals with the different biochemical processes. The first I try to explain what are the different biochemical processes, and then I want to give you the difference between the chemical engineering and biochemical engineering. Then also I try to tell you that what are the how this biochemical process and chemical process they differ from each other. And finally, I want to discuss the details of this course content.

So, initially that let me tell you that what is the what do you mean by biochemical process.

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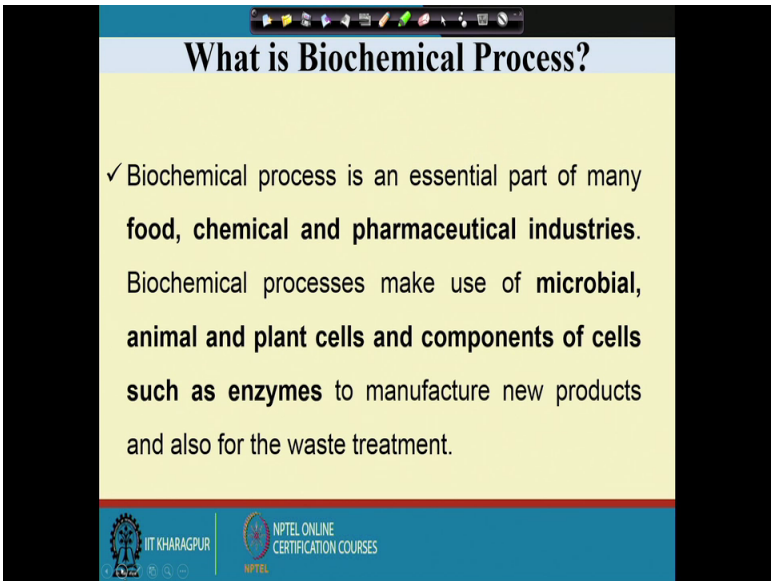

Biochemical process is a essential part of many food chemical and pharmaceutical industries. Now if you look at this is the food chemical and pharmaceutical industries.

Let me give the example. That if you look at the food industry, I we know that cheese making industry. Now cheese making industry what we are basically doing we are we produce the cheese for the preservation of milk and protein. Which is very, very good diet very, very important diet for our health. So, this is the process through we can preserve the food. And also, sauerkraut there is a another kind of product with the fermented product, through which we can preserve the vegetables in the natural color, because they the vegetables if we preserve in a longer period of time. Then either we go for drying process or use some kind of preservative.

If you go for drying process need to undergo some kind of some Brownian reaction. And due to Brownian reaction color of the vegetable will be changed that is undesirable. But if you if you in the sauerkraut, we use some kind of black lactic acid bacteria. And lactic acid acts as a preservative where the green color of the vegetable we can preserve for a longer period of time. Then I want to talk about the chemicals. Then if you look at the different biochemical industry, that we can involve for the producing different chemicals, like lactic acid, citric acid, we have bithionol the different type of chemicals can be produced through this this biochemical processes.

Now, and in the pharmaceutical industries we produce lot of antibiotics. Because in the day to day life when we are we have some health problem, we go to the doctor and doctor prescribe some kind of antibiotics for curing the disease. Now biochemical process make use of how these products are formed by using the micro microbial cells animal cells and the plant cells.

These are the different living cells, they can be used for producing this kind of products. And not only living cells some of the biomolecules which produced from the living cells, that may also use for the production of certain chemicals. As for example, I met that enzymes, which is usually secreted from this by their particular living sources that can be utilized for producing different type of products.

I can give a typical example that high fructose consider; where glucose is converted to fructose. Why glucose is converted to fructose? It has 2 advantages, one is the fructose has more sweeter than glucose so, but for diabetes patient it is mostly recommended. And another thing is that for the preparation of the medicinal tonic that if you use the glucose. As leave the medicinal tonic as you know it comprises of some amino acids and vitamins which are very much hits insensitive.

So, naturally we shall have to preserve these in the at low temperature in the freeze. So, at low temperature when you have the sugar syrup, or you know glucose syrup, you will find some kind of crystal a crystal formation of the glucose will take place which is undesirable. Now if we have the fructose syrup, then fructosamine at low temperature it will not crystallize they remain in the in the liquid form. And another thing is they are more sweeter. So, this is the desirable characters that you have. That is how it is used mostly in the converses confectionery industry as well as pharmaceutical industries.

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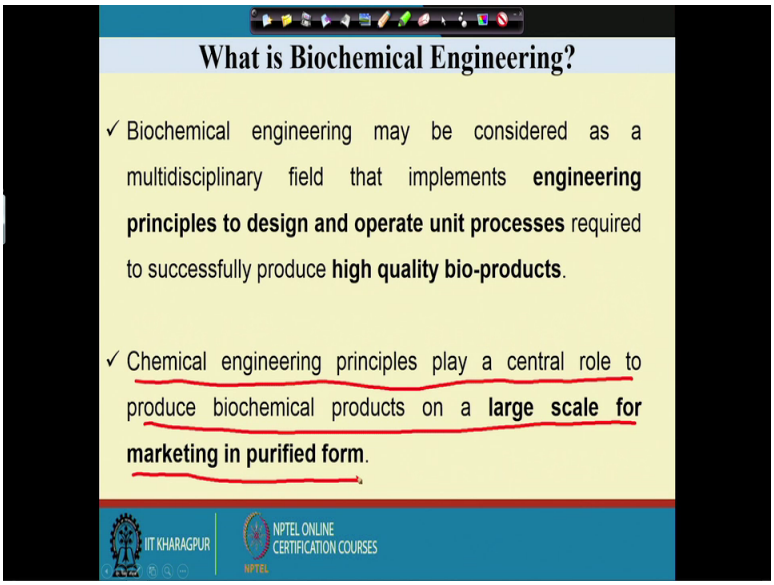

Now, next is the biochemical engineering, of what is biochemical engineering? Biochemical engineering may be considered as a multidisciplinary field, that implements the engineering principles to design and operate the unit processes required to successfully produce the high-quality byproducts. Because you know that for the operation of the process we required some unit processes.

What are the unit processes we have? As for example, bioreactor, because in the bioreactor is kind of unit process we use some kind of palms and about the sterilization some you know that there different purification also we have. So, different unit processes are involved to get the different pure products. So, this is the biochemical engineering we will deal with everything. This is this how this is the different this unit operations that can be handles. So, and another is the chemical engineering principles plays a central role you know this is this is to be highlighted that the if you if you if you look at the chemical engineering principles plays the central role to produce the biochemical products on a large scale for marketing in purified form.

So, basically, we are using the chemical engineering principles. In this process, now question come how you are applying the chemical engineering in principles. Because we know the I told you that you know chemical engineering develop from the chemist chemical reactions. And chemical reactions like this a plus b we have to give c plus d, now when it produce the product we can develop some rate equation, when you develop

the rate equation we have rate constant order of reaction from that we can do the reactor analysis.

Through the reactor analysis we can we use this erratic way that that relate equation, and then we find out the volume of the reactor. So, this is the how we can we can do and for suppose we want to produce 4 tons of citric acid, go through by using aspergillus niger. So, you know that this can be produced we can find out through this analysis that what would be the size of the reactor for getting the photons or byproducts. Both in the batch process as well as continuous process can be done. So, these are the this information that I want to we want to give you through this project. And at the end of this project you will be developing the expertise for doing this particular analysis.

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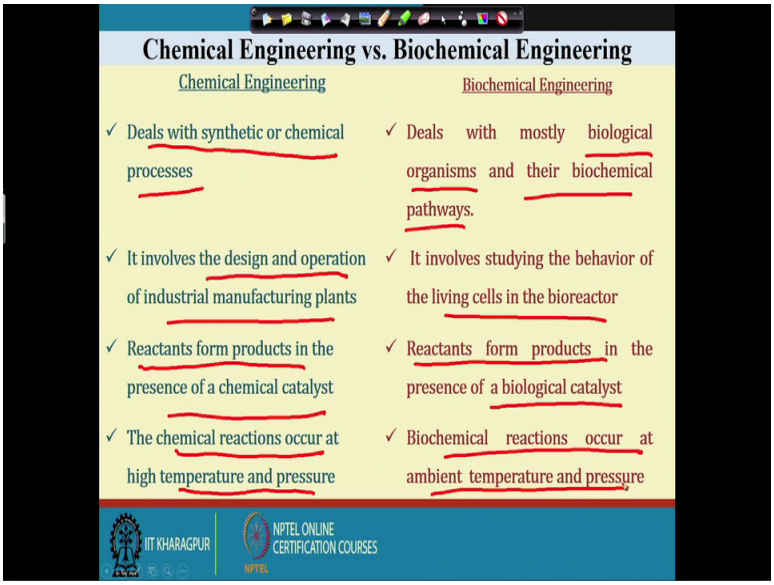

Now, makes it is that I want to give you the differences between the chemical engineering and biochemical engineering. Now chemical engineering if you look at that it deals with the synthetic order of chemical processes. As for example, that why I can I can acid and alkali when they react with each other they form the salt. This is or you know if you if you I considered when the burning of coal in presence of oxygen, when coal burns it produces the carbon dioxide and water. This kind of pure chemical reactions that we have.

Or if you look at nitrogen ammonia, being presence of catalyst, it produces ammonia. And nitrogen and hydrogen when it combining produces ammonia which is largely used

in the fertilizer industry for the production of different fertilizers. Now these are the these are the purely chemical processes that we have. In the biochemical process they mostly deal with the biological organism, and their biochemical pathways. Now bile biochemical biological organism they are very sensitive. There they are very sensitive, and you know that every organism they have the metabolic pathway.

As for example, if we take glucose it goes through the metabolic pathways. What do you call (Refer Time: 09:46) pathway and include the (Refer Time: 09:47) pathway it produce the pyruvic acid. And this pyruvic acid when passed through the TCA cycle or cave cycle it produces the carbon dioxide. And this is how we get the energy in the form of ATP ADP or NADH like this the different energy molecules forms in our body. So, this is the I do not know if you look at the metabolic pathways, and you will find the different metabolize from during this.

So, we can if we manipulate this pathway. We can we can easily piece out our desired product from the this metabolic pathways. So, you know that this is this is how this bile a biological organism can be natural for the producing different kind of byproducts. Then it in the chemical process is the involve the design and operation of industrial manufacturing plants. Because how in the biggers power plant that you know it can be handled those kind of information that chemical engineering gives. And in the biochemical industry we study the behavior of the living cells.

You know that as for example, that again give you, that a living system that behavior of the living system is something different as compared to the nonliving system. Because living systems should be carefully handled. And this can be this can be handled only if we develop the feelings for the living system. I can give you a typical example, that you know if you look at the relationship between mother and the baby. And mother and the baby is with the mother from the 0 hour.

So, mother has great feelings for the baby. So, anything goes happen, it happens to the baby mother always understand what is the problem with the baby. But so, same thing when you when you handle any kind of living system, we should also develop kind of feelings for the living system, otherwise we cannot handle. We should know under what circumstances you should work in a proper manner. So, it not like nonliving systems they just you add a plus b and give the products c plus d. It is not like this.

So, you have to handle their organism, only the difference is that that intensive chemical process, suppose we want to produce any kind of product here you have to have the specific raw materials is required for product formation. But in the biochemical process is totally different because from a particular simple compound like glucose, we can produce n number of products.

The glucose can be converted cyclic acid. Glucose can be converted to acetic acid glucose can be converted to lactic acid, glucose can be converted to ethanol. So, n number of products we can produce. Only what do you do we change the organism the living organism. So, living organism that name as for example, when we produce citric acid, we use that aspergillus niger. To convert the glucose to citric acid. When we use the lactic acid, we use the lactobacillus del brookie, which convert the glucose to a lactic acid. Now when you use the suppose acetic acid.

We use the acetobacter acetic which convert the ethanol to the initially, the acetic acid ethanol is produced through the saccharomyces cerevisiae which convert glucose to ethanol. And then subsequently when you use the acetobacter acetic, then as if the ethanol is converted to acetic acid. So, what I want to highlight that basic difference between the biochemical and chemical process is that the chemical process one ramen raw materials is remaining more or less same. And only we change way by changing the organism, we can get the n number of products. In the chemical process as your product changes your raw material changes. If your products is complicated your raw materials will be complicated. I can give a very typical another example is the antibiotics formation. Like penicillin, if we want to penicillin production that we use the glucose in the fermentation broth.

But at the same time, we use some kind of precursor like phenyl acetic acid or phenoxy acetic acid and get the product. Like this so, but in if you if you use in a chemical process they, first of all penicillin is very difficult to produce chemically, but if you use some kind of complex chemicals with your raw materials will be also complex as your raw material will be complex the other cost of the raw materials also will be very more will very, very high. Now in in the chemical process another thing that we have the reactants form products in the presence of chemical catalysts and in the biochemical engineering the product formation take place with the help of biological catalyst. Now what is the

difference between the chemical catalyst and the biological catalyst. Chemical catalyst we have platinum, palladium, nickel. They can take part n number of reaction.

Different type of reaction they can take care, but if you look at the biochemical catalyst or biological catalysts. They are very specific. As for example, if you if you look at glucose isomerize enzyme, they can act only glucose and produce a fructose. They cannot convert fructose to glucose. So, they are very specific as well substrate is concerned. Now if I like you know protease. That a that only act on the protein molecule for the degradation of protein.

It will not degrade the starchy molecules. So, they are very specific as well such as substrate is concerned. Now chemical reaction occurred and high temperature and high pressure, and since is required a high temperature and high pressure, naturally it is energy intensive. As now in in case of biochemical process is occurred at the ambient temperature and atmospheric pressure, because now this is very important because since it is the ambient temperature and as for as atmospheric pressure, that we are less energy intensive.

The energy point of view this biochemical process is very attractive. Also, a substrate point of view also very attractive substrate we required mostly the glucose sucrose type of material with largely available. I am not really largely available, that is renewables that can be who can produce the again and again through the agricultural product formation.

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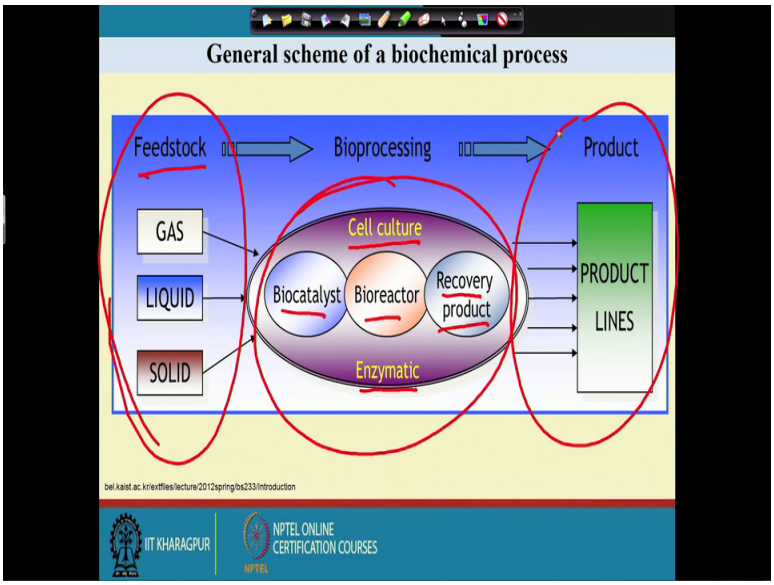

So, if you look at the biochemical process, it can be divided into 3 part. One is feed stock. Feed stock may be anything it may be gas, it may be liquid, it may be solid. Now bio processing we have bio catalyst we have bio reacted and we recover of product. So now, now here we required the cell that microbial cell, it may be plant cell, it may be my microbial cells, it may be the animal cell. Any anything can be we can use.

And then we do the product purification. So, we can broadly divide it into 3 parts. One is your this is the main part. Where the reaction take place, that where the biochemical reaction take place, and before the biochemical reaction take place. We shall have to prepared our feedstock. And this is this whole all unit we call it upstream processing. And then after the product formation, then we call the pure purification of product. So, it can be divided into 3 part one is up stream processing bio processing, then downstream processing. Up stream processing which you feed the raw materials to the process. And in the in the downstream processing, it mainly deal with the purification of products.

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Now, biochemical engineering principles can be applied in 3 different areas. As for example, food processing.

I already explained the how it is used in the food processing, I have given the example of cheese making industry and the sauerkraut. Then agricultural production. That we will largely use as for example, I can give the example of bio insecticides. Then you know because you know that usually we use the lot of pesticides in the agricultural were to increase the agricultural production.

Now pesticides is such a chemicals, if we if we if we take in our system, it accumulate in a system which has the cariogenic property. But bio insecticides that it is something different it is kind of delta protein, and which have also has that kills the pest. So, you know if you use the bio insecticides, then what is happening? Even we take in our body it is kind of protein that you know harm in our system. So, that is that is how it can be used in the agricultural sector.

Now another important product that we have the gm food. That is a genetically modified food. And as we are living in the fastly populated country that a time will come when our land will be insufficient to produce the significant amount of the desired amount of product. So, naturally we shall have to reduce the we shall have to try to use the food in a manner. So, this small amount of food will be good enough for our survival. So, this is possible if we if we enrich our food. As for example, particularly we know in case of

vegetable food, the vegetable protein the utilization efficiency is very less. Why it is less? Because the essential amino acids in the agricultural protein is less. And that to reduce the utilization efficiency. So, if we increase that whatever amino acid essential amino acid is deficiently is there. If we enrich that particular protein, the utilization efficiency of the protein will be increase drastically. This is how we can improve biochemical way. Now this biochemical processes can be used for the production of different chemicals, I have given also already the examples of ethanol citric acid, acetic acid lactic acid all this thing different type of wetaconic acid. All can be produced through the biological means.

The healthcare we have I have given the typical example of different antibiotics. Like, penicillin largely used or you know that due to invention of penicillin, it is becoming easier to cured our infection. Particularly, all the athletic, all the soldiers when they were involved with kind of interaction, they gave they have some kind of injury. And during the injury they have some fast formation due to the infection of the gram-positive bacteria. By using penicillin, it can be cured. So, this has so, lot of antibiotics now a days we use the free our health has some kind of problem, where you go to the doctor prescribe some kind of antibiotics for the rectification of that particular disease. Now energy sector that biochemical process as a greater role to play. Because the fossil fuel, resources will be exhaust very soon.

Because it has this has the limited reserve. So, different renewable energy sources are explored by energy is one of the area paying a lot of attention as per India is concerned, and as you know that particularly in the in the in the gasoline. That government recommended that 10 to 20 percent the gasoline is to be replaced by the ethanol. Now if we reduce then our gasoline consumption will be reduced significantly. Then environmental production there is another very important area, because we have a very great concern. Because particularly we can we can think about the Paris convention, where all the most of the country they agreed to safeguard the environment.

Particularly, I want to talk about this carbon dioxide content in the air. And India also signed the agreement that we should we should control the carbon dioxide in the air so that if we increase the carbon dioxide content in the air, the temperature will increase, what you call the greenhouse effect, and due to this increase of temperature there is a possibility of melting of ice in the northern spared having spared them, and that causes

the hike in the rise level. And we know some of the western country is almost as the sea level. So, if the water rate sea level increases the those country would be under this water. This is a great concern throughout the world. So, we have a lot of applications.

That we have with the biochemical engineering principles in the different areas.

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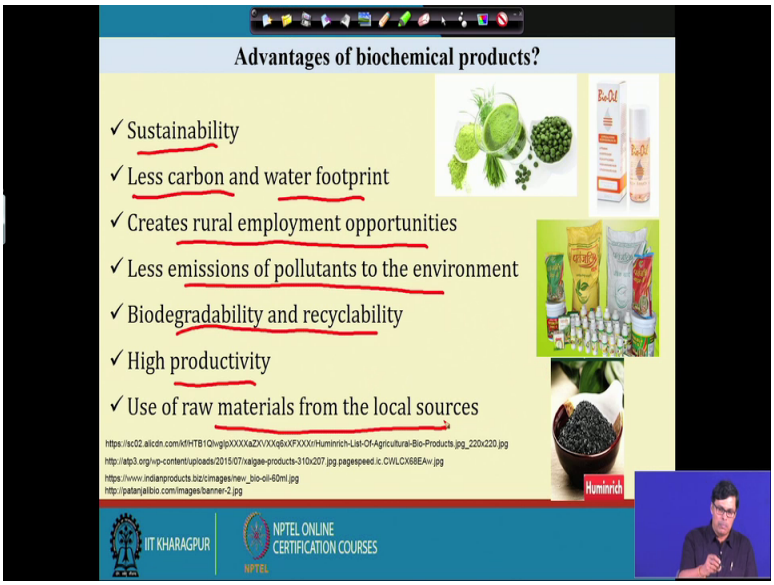

The what are the advantages of the biochemical products, that also I want to highlight; that that first important thing is that, this is sustainable means, this process we can have you know law for a longer period of time. Because the raw materials that is use that is that will be available with us, because that will not be exhausted very soon. And another very important thing is that the less carbon and water footprint. Less carbon and water footprint is very important, because water consumption because we know that as the as the time passes on, that water consumption will significantly will decreases. And this carbon and water food print plays very important role. Create the rural employment opportunity this is very important.

The reason is that that you know that this can be used for the smaller scale and bigger scale application. Less emission of pollution to the environment this is also very important because pollution. Pollutant which is coming out that should be as low as possible. Biodegradability is very and recyclability is very important. I can give the example of plastics is not biodegradable, but you use the bio plastics the biopolymer this can be easily biodegradable. So, it can be safe our environment and high productivity.

And raw materials from the local sources. That also very important, because if it is available from that local sources then we can use it very easily.

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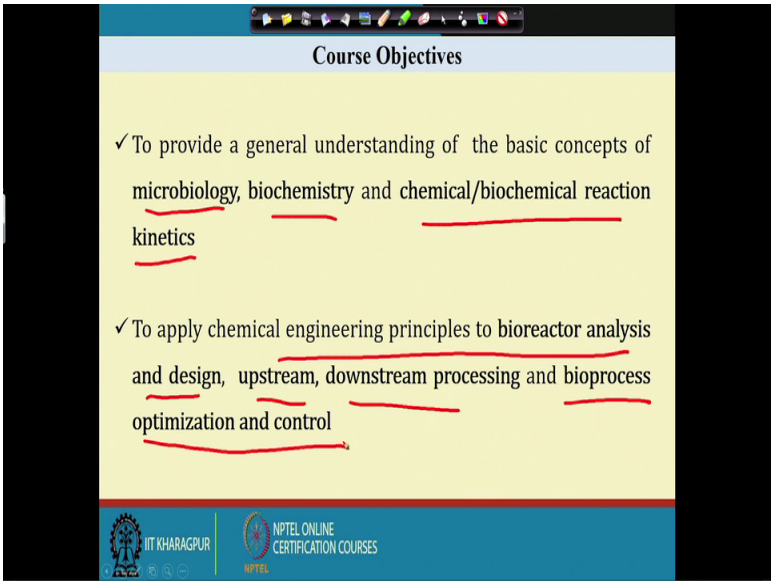

So, of course, the objective is that we want to use the basic concept of the microbiology. We use the basic concept of the microbiology bio chemistry chemical and biochemical reaction kinetics. Also, we applied so, initially we will start the course with the microbiology we will give the preliminary information of microbiology, then with the biochemistry, and chemical and biochemical reaction kinetics.

This is the different information we will give, because we will give more stresses on chemical and biochemical reaction kinetics to understand the process much in a depth. And then apply the chemical engineering principle in the bioreactor analysis and design upstream downstream processing and bio process optimization and control. So, these are the different areas we will we will cover in this particular course.

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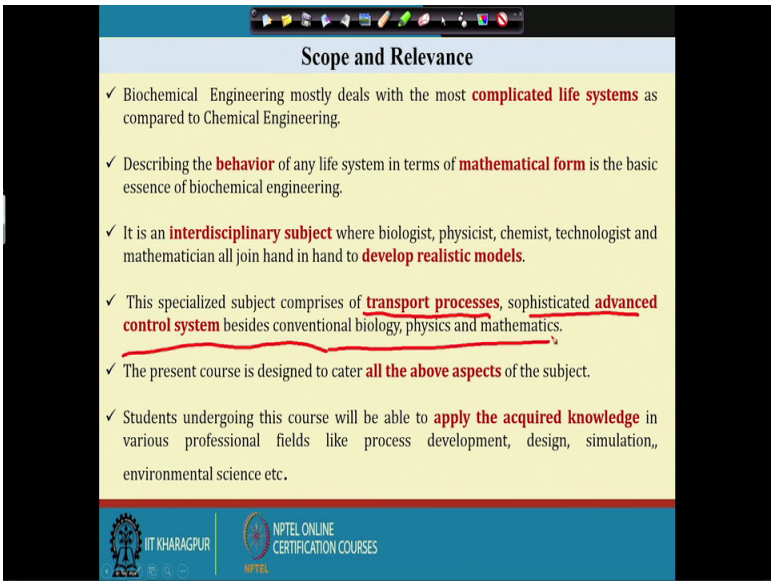

Now, scope and relevance of the course is scrabble, we have biochemical engineering mostly deals with the complicated life system. I have already explained that what do you mean by complication life.

This in the life system you have we shall have to develop some kind of feelings for the process. Otherwise we cannot handle the process very nicely. Then then describe the behavior of any life system in terms of mathematical form. I told you that mathematical representation of a process is called mathematical modeling. We try to give them all to develop some kind of modeling on the living system. And also, you simulate the value try of the of the mathematical model comes through the simulation of the process.

Now it is an interdisciplinary subject, where the all the different discipline like biologists, physicists, chemistry all these people will all these experts will they will help each other to develop this subject. So, these are all knowledge is required to understand the process in a better way. Then we have the different transport processes. That is very important transport processes that is the involved and sophisticated and per advance control besides the conventional biology that also. We are going to explain in this. So, this this course will deal everything all these material in details.

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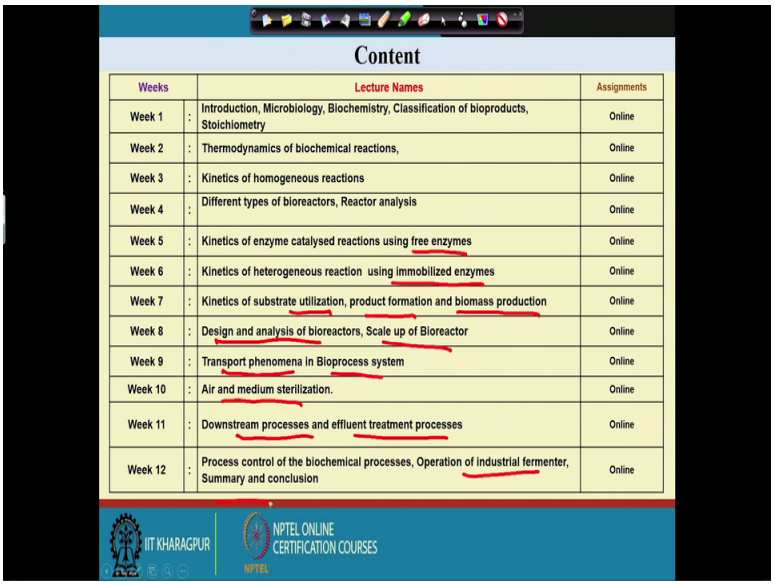

Now, let me let me give you the details of the course content. Initially, we talk about the my as I told you micro biology biochemistry classification of the byproducts. Because as for byproducts is concerned, we have different types we have low value products, high value products, medium value products, the different classification products we will talk about. Then we have we shall discuss the stoichiometry of the bio process this is also very important. Thermodynamics of the biochemical reactions, which is very important just to understand what is the nature of the reaction whether it is spontaneous, or it is unfavorable reaction.

Or also we can we can find out to what extent the reaction take place. The thermodynamics can help us to understand the process in the better way. We will we will discuss about the kinetics of the homogeneous system. And the heterogeneous system both the system will discuss in the details. Now in case of heterogeneous system. The homogeneous system easily take place when that reaction take place in one particular phase. Heterogeneous system, that one phase has to diffuse to the other phase. Then and only then the reaction take place and after the reaction is over the product has to diffuse from that first to the other phase.

So, the diffusion the phenomena is to be considered during this particular heterogeneous reaction. So, we will be kinetics of the enzyme catalyst reaction. Then we will try we will discuss about the we will we will discuss about the enzyme catalyzed reaction using

the using the free enzymes. And using the immobilized enzyme both we can discuss. And then kinetics of the substrate utilization product formation and biomass production this is very important aspects of the biochemical processes are concerned; where we use the living cells. And then design and analysis of the bio reactors. And scale up of the bio reactors that is a great concern how from the last scale we can switch and switch over to the plant scale in a bigger scale.

That we will discuss in details. Transport phenomena of the bio process that how the flow system different pro system, I want to take the momentum transfer mass transfer and a heat transfer, how take place in the system that I want to discuss in details. The heat and medium sterilization, they say I told you that in the biochemical system the one important that we want to grow our desired organism to grow the desired organism, we know in our environment comparison of different other organism.

So, if the sterility we do not maintain, then we go we cannot allow our organism to grow in that particular reactor. The stainless is very important factor as the biochemical processes is concerned. This I discussed in details. Then downstream processing and apron treatment processes, process control and biochemical process and operation of the industrial permitted. And finally, I shall as well do this our summarization of the whole course.

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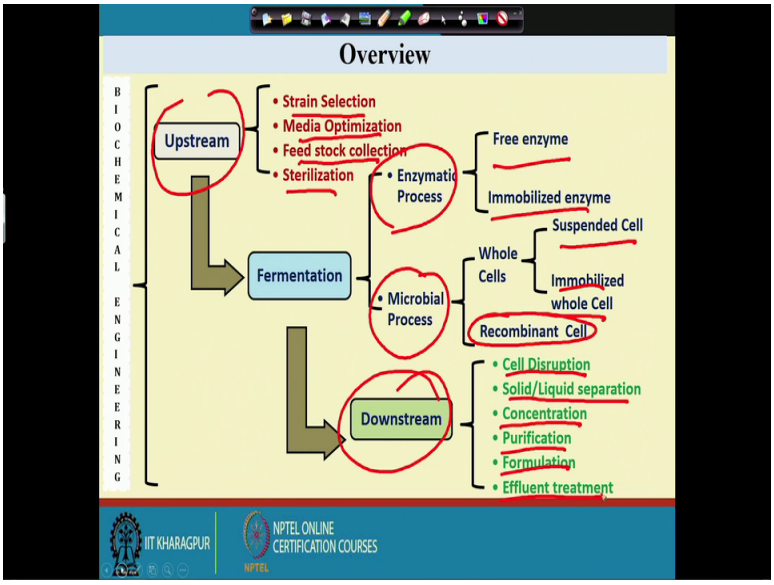

Now, the overview of the course is like this. If you look at this I told you that the upstream processing, and it deals with the strength selection. Because the my kind of microorganism that available that is in 2 different forms. One is the wild strain, and there is the industrial strain. While wild strain we cannot use for industrial fermentation process, because they are very unstable. And with the industrial strength they have the genetic stability.

So, they have reproducible characteristics. The medium optimization, there is another feedstock collection, and sterilization all these things undergo the upstream processing then in the fermentation or biochemical processes that involve the enzymatic process, and the microbial process. In the enzymatic process we have free enzyme immobilized enzyme, and microbial process we have suspended cell and the immobilized whole cell. And also, we use the recombinant cell and recombinant cells. So, you suppose we want to produce a special type of proteins.

Then we go for the recombinant I can give the example of insulin production; that is usually done with the help of recombinant cell. And in the downstream processing basically it deals with the cell disruption. Solid liquid separation concentration, purification, formulation and they effluent treatment. All these different aspects will be discussed in the downstream processing. So, this course will give you the total idea that how the biochemical process can be analyzed and desired that and over it. So, hopefully that this course will be very much useful to all of you and different references book references you I have given here.

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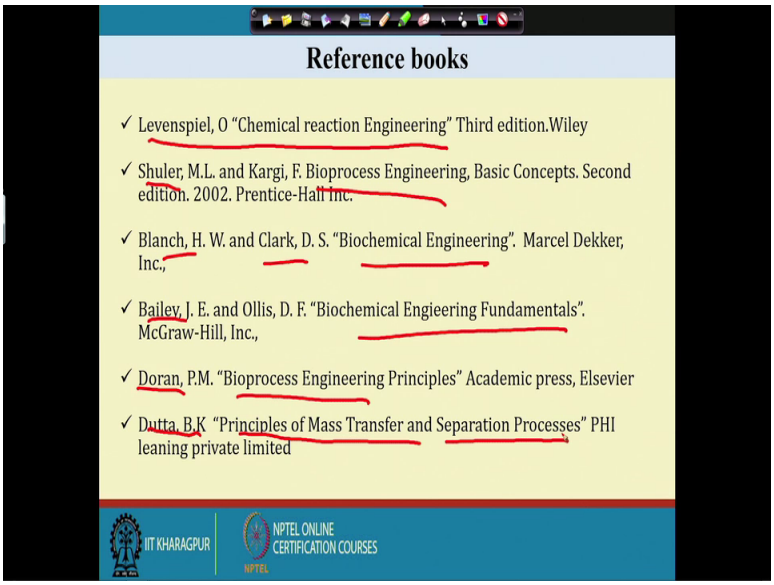

So, these books you can consider particularly Leve spiel, this is the, this is chemical reaction engineering. I shall discuss about the cave of chemical reaction kinetics, and reactor design all this thing will be available here. Then shuler and kargi, this is bio process engineering this is also very important. Then blanch and Clark that is also bio chemical engineering bailey and Ollies. Biochemical engineering fundamental Doron bio process engineering. And Dutta this is principle some mass transfer and separation processes this will be this will be used for understanding the transport phenomena.

Thank you very much.