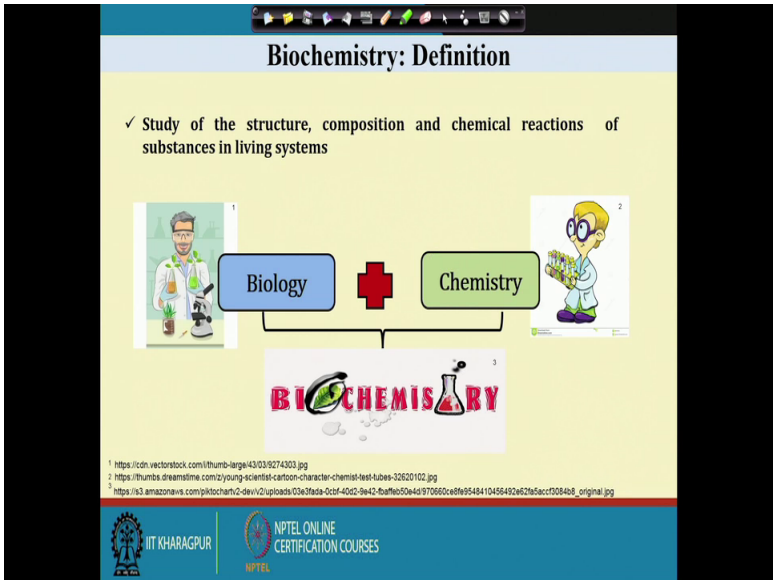
Aspects of Biochemical Engineering
Prof. Debabrata Das
Department of Biotechnology
Indian Institute of Technology, Kharagpur

Lecture – 04
Fundamentals of Biochemistry

Welcome back to my course that is, aspects of Biochemical Engineering. Now in the last couple of lectures, I try to concentrate on the Micro Biology, which is involved in the Biochemical Process and I told you that Microbiology or Microorganisms that plays very vital role; As per Biochemical processes are concerned. Now today, we will be discussing another very interesting topic what do you call Fundamentals of Biochemistry.

Now naturally, why, how the different byproducts formation take place, with the help of organism; that we can find out if we go through this Biochemistry of this problem, this is my living cells we can understand the process very nicely.

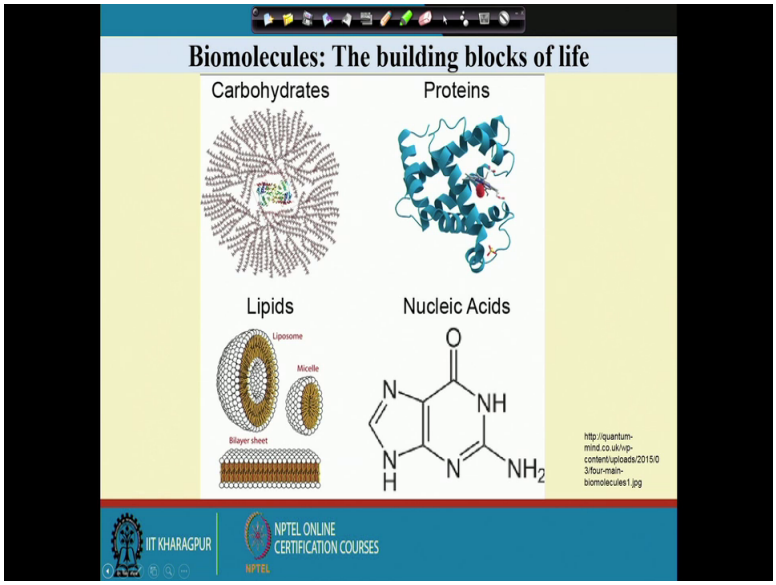
(Refer Slide Time: 01:14)



So, the first I want to tell you that, what do you mean by Biochemistry? Biochemistry is the study of the structure and composition you see, this is structure composition and chemical reaction of substances in living system; that different components present in the in the biological system. How we take part in the reactions, that that is the about is the

Biochemistry deals with. So it basically the combination of Biology and Chemistry, that is the biochemistry that we have.

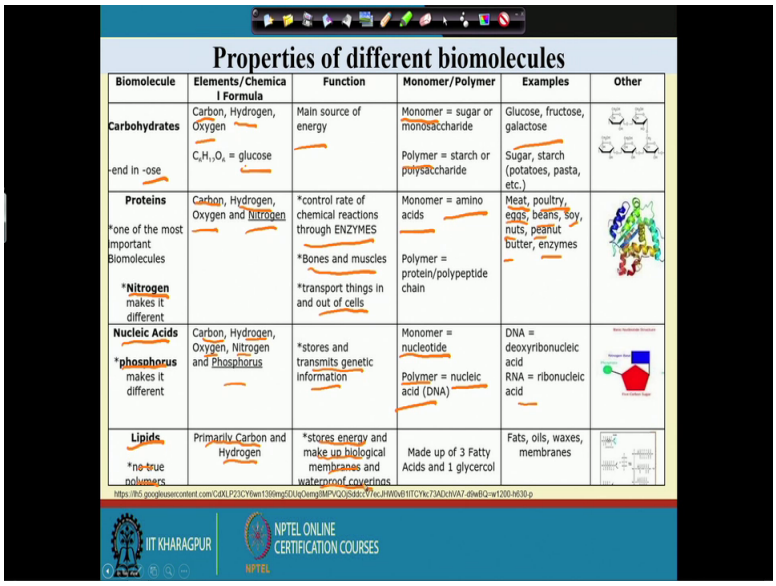
(Refer Slide Time: 01:49)



Now question comes, what are the different Biomolecules present in the, in this Biochemical process? That is very important. Because these molecules are mostly either Carbohydrate or Proteins or Lipids or Nucleic Acids. These are the different major Biochemicals that Biomolecules present in the Bio-processes. Now, what do you mean by Carbohydrate? A Carbohydrate is considered as a source of Carbon, which is I told you this is used for 3 different purposes; one is for the cell mass formation and there is the source of energy. Also it is used for the product formation, where the product is other than the cell mass.

Now, Protein is mostly used for the use for the building up of the cells and Lipids also used as a source of energy and if you look at the Nucleic Acid, this is mostly taking part for the formation of DNA and RNA, which is the genetic material of the living system.

(Refer Slide Time: 03:04)



Now, this is Carbohydrate, if you see it very minutely, you will find it is a t easily ended with ose, you know that as for example, that glucose, fructose; you know different type of with the nomenclature is usually ended by ose.

Now, it comprises of 3 major components. One is Carbon; Then Hydrogen and Oxygen and as I pointed out this is considered as a major source of energy and it can be available in 2 different forms. One is called Monomer; another is Polymers. Now the Monomers when the its kind of monosaccharides. Now if you if you consider sugar, sugar is not a Monomer; it is a dimer. Actually it is a combination of Glucose and fructose. Now Polymer is a starch cellos is a polymer of Glucose. So, it is a Polymer.

So, examples is the same examples are giving here, the Glucose, fructose, galactose. A galactose also dimer, that glucose and now galactose, lactose is the dimer is a combination of Glucose and Galactose and then, we have sugar, starch for life which is available potato, pasta etcetera.

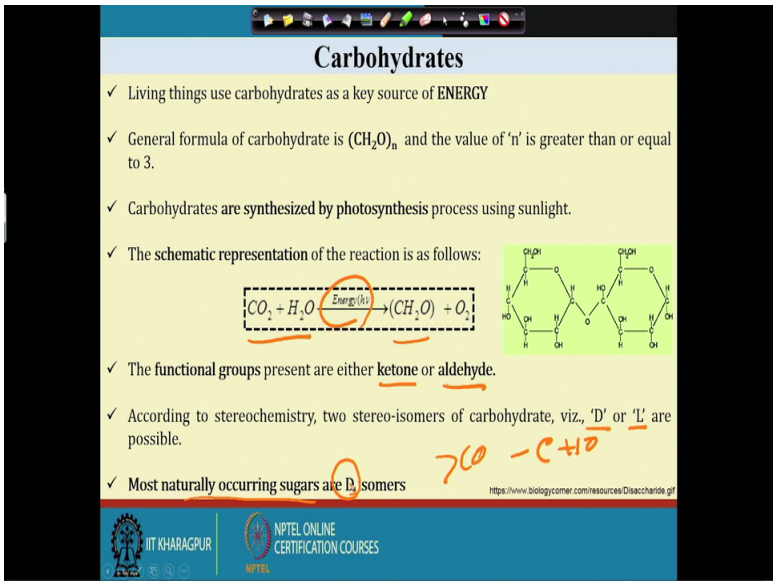
Now, if you look at the Protein Molecule, this is the most important because the use of the Nitrogen source and it is a, it comprised of Carbon, Hydrogen and Oxygen and Nitrogen. It controls the rate of chemical reaction through the ENZYMES. The ENZYMES are the basic that Biomolecules that is mostly take part in the chemical in the reaction and ENZYMES, they are consider as the Biocatalyst and catalyst role of a catalyst as we know that it take part in the reaction.

After the reaction is over, it remained non-altered. And the purpose of the catalyst is to lower the activation energy so that, your rate of reaction increases. So, this is available in Bone and muscle and transport things out of cells and then, it is, it can be Monomered; if it is Monomer, we call it amino acids. Now as you know, we have 20 different amino acids and that and this Proteins it is, basically it is a polymer of amino acids; different amino acid. So, it basically it appear available in 2 different forms; one is called Peptides and there is Protein. If the Peptides is there; it contains 2 to 50. Amino acid is more than 50, amino acids we call it Proteins. Now it is available in Meat, then, poultry eggs, beans, soy bean, nut, peanuts, butter and the enzymes.

So, these are the different sources, where these enzymes this ENZYMES Proteins are presence. Then, as I told you, Nucleic Acid, which contains special thing. It has that is the phosphorus. So, it contains Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus. Is stored and transmitted the genetic information which is very important. That you know genes as you know, it any genes that coat a particular proteins. So, and this protein that ENZYMES are basically Proteins and this is very much essential for carrying out the Biochemical activities. The Monomers is the nucleotide monomers and Polymers is the polymer of nucleic acid. As for example, you we have DNA deoxyribonucleic acid and RNA ribonucleic acid. So, this is how it looks.

And then, we have another molecules; I told you this is Lipids. It is no true Polymer and there is no true polymer here. So, we have heard this contents primarily Carbon and Hydrogen; also it contains Oxygen. It is stored as energy, I told you and makeup of biological membrane and water pool covering, waterproof covering etcetera. It is hydrophobic in nature because it has the water rippling properties. They made up of 3 fatty acids and 1 glycerol and the fats examples are fats, oils, waxes and the membranes. These are the different examples that we have.

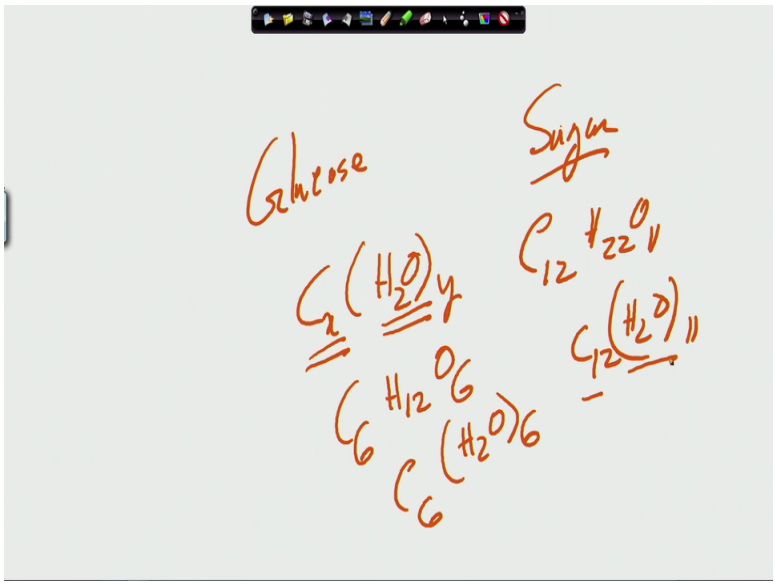
(Refer Slide Time: 07:45)



Now, next is the let us go to this Biomolecules in details. Now if you look at the carbohydrate, now as I told you that this it is a source of ENERGY.

Because the key source of ENERGY of the living organisms, as for example, that we take glucose in the day to day life and glucose we consider as a source of energy. It passed through Emden Meyerhof pathways then, TCA cycle and ultimately it convert it confident to Carbon Dioxide and Water.

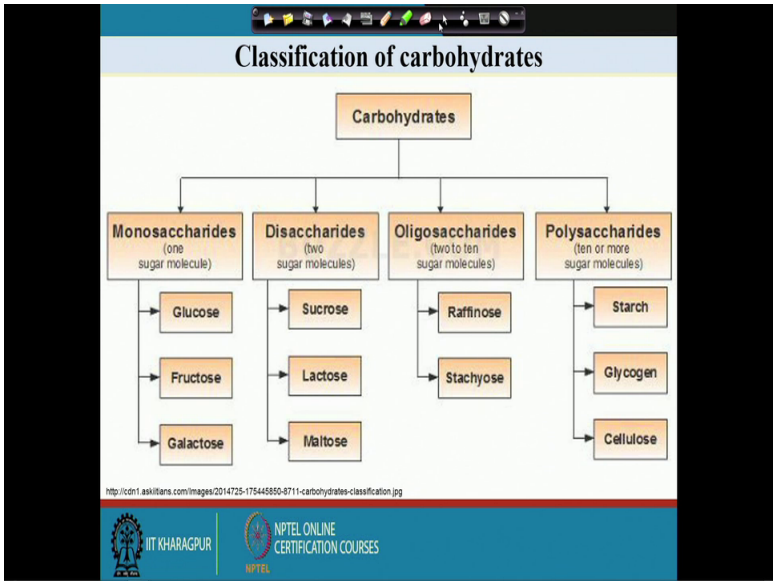
(Refer Slide Time: 08:29)



Now here I want to point out that this general formula of carbohydrate. The general formula of carbohydrate as we, I shown you this is C H2O. So, this is C x and y. So, this is called Carbo and this is called Hydro. This is how, now if I if I consider glucose C6 H12 O6. Now how you can write it C 6 H2O6. So, this is this is Carbohydrate. Now if you, if this is how about the glucose, now if you consider that you know that other molecules as for example, Sugar. Sugar, how we can write? It is C 12 H 22 O 11. So, this is C 12 and H2O. This is 11. This is how you can write. So, this is Carbo, this is Hydrate. This is how, why it calls the Carbohydrate.

Carbohydrates are synthesized by photosynthesis process using sunlight because this is the normal process, that is going on in the living system and schematic representation of the reaction is given here. You see that, Carbon di-oxide and Water in presence of light. It produces the Carbohydrate. This is an oxygen. This is how it and the words the 2 functional groups are present here; one is called ketone that this is the ketone group and another is the aldehyde groups. This is the 2 things that we had. According the stereochemistry, two stre- isomers of carbohydrates are present both d, d form and l form and usually most of the natural sugar, we have only the deforms. The D isomers are present there.

(Refer Slide Time: 10:21)

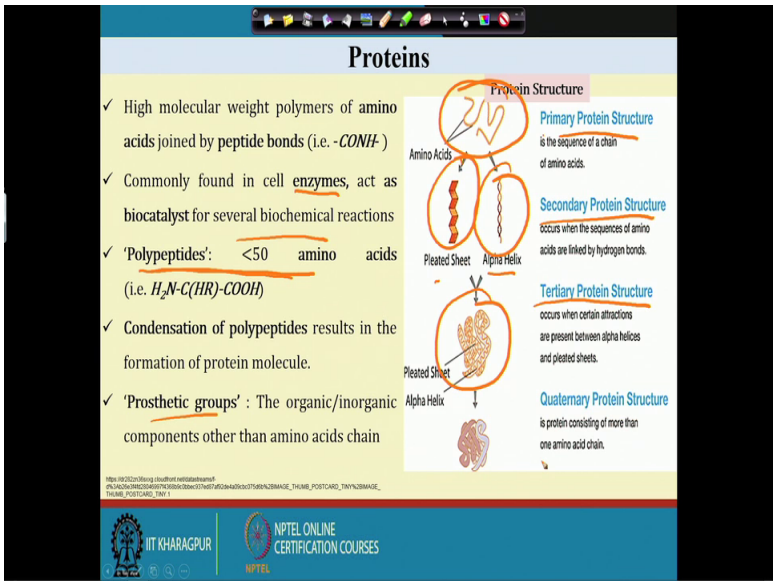


Now, Carbohydrate may be available in different forms; one is a Monosaccharide. Monosaccharide, I explained that it comprises of one one unit that is (Refer Time: 10:35)

that 1 unit you have and Fructose also same as Glucose and Galactose also this one monomer unit is there. Now if I consider Dimer, we have Sucrose, Lactose and Maltose. What is sucrose? It is a dimer of Glucose and Fructose and Lactose is a Glucose and Galactose and Maltose is a Glucose and Glucose.

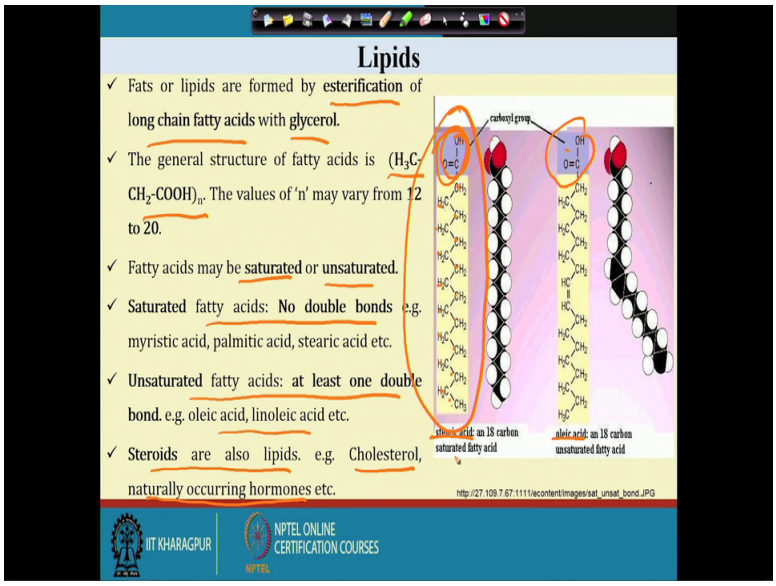
They form alpha 1 4 linkage to form the Maltose Molecule. Now Oligosaccharides is basically those are the Polymer, polymer of the 2 to 10 sugar that you know, they are together these forms if one is Raffinose; another is Stachuose and then, there is a another Polysaccharides that is, we have, which has the 10 or more sugar molecules are present. Those are present that is one is Starch; then, Glycogen and the Cellulose molecules. Now that you know that Starch, the both are polymer of, all are polymer of glucose unit and I know that we know that Cellulose is not digestible in the human system, but Starch and Glycogen, they are digestible to the human system and only the difference is that here, we have alpha 1 4 or beta 1 or alpha 1 6 linkage. Now in the Cellulose, we have beta 1 4 linkage only.

(Refer Slide Time: 12:17)



So, this is the basic difference that we have. Then if you look at the Protein molecule as the High molecular weight polymer of amino acids that.

(Refer Slide Time: 12:24)



That if you look at these are the polymer of. So, anyhow that Protein is basically, it is the High molecular weight polymer of amino acids that and amino acid basically they have the polymer with that CONH this is the, so it is a combination of ammonia and the carboxylic acid. The acid that is they form this CH CONH 2, I can explain like this.

Commonly found in the, this is commonly found all the enzymes that we have and acts as a bio catalyst in the several biochemical reaction and as I pointed out that if the polypeptides come also what is the polypeptides? Where we have less than 50 amino acids are there. If more than 50 amino acid there, we considered as the Protein. So, condensation of polypeptides, if we have the combination of several peptides molecules, then, we call it Protein molecule.

We have several Proteins that we collagen protein. We have Proteins, lot of Protein molecules we have. Then another we have the prosodic groups in the organic, it may be organic inorganic component rather than the amino acids in the change, they can produce. The pictorially that protein molecule can be represented like this. It is a primary that if you look at that primary that structure is like this, that it is a polymer of amino acids.

And then it has Secondary protein structure occurs, that the linkage which they have the Hydrogen bond and Hydrogen bond is in between the Carboxylic and amino acid with the odd group, odd group of the amino acid, they form the hydrogen bond and they have

this Alpha Helix. They have related a sit like this now in in case of Tertiary structured it is the combination of both the things Alpha Helix and Pleated Sheet. Their combination they from the tertiaries and Quaternary Structure is the protein consists of more than 1 amino acid change. So, this is the gives you a brief idea, that how the protein molecule looks.

Now next come to the Lipid molecule and we as you know a Lipid is the major source of energy, if you if you look at the energy continent, the lipid is much higher as compared to the Carbohydrate molecules.

Now, lip ads or lipids are formed through the a stratification of long chain fatty acids with the glycerol. So, they form the esters. We know the fatty acid, fatty off. What is fatty acid? Fatty acid basically, this is the Organic acid. What is the Organic acid? It is comprise of Carbon, Hydrogen, Oxygen that and with the Carboxylic acid groups and then, when they combine with the alcohol they from the esters and though the fatty acid the hardener impairs or lipids are basically the ester of amino that fatty acids and the glycerol.

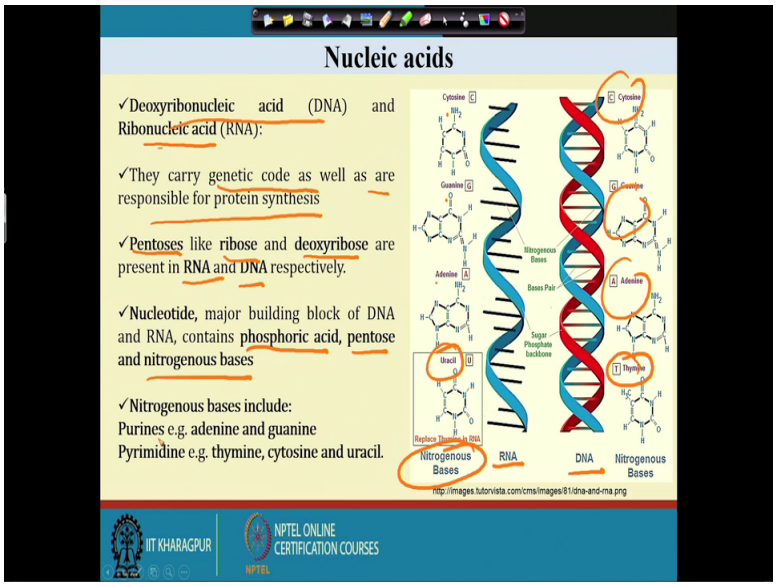
Now general structure of this is given here, this is the general structure of fatty acid is given here that CH3 CH2 C double OH n. So, you know it may be bigger. We have bigger feet of fat molecules; we have smaller fat molecules that we have now fatty acid may be 2 types.

One is structure saturated and unsaturated. What it will be saturated fatty acids? Saturated as we say it means that all the bonds are single bond. There is no double bond present in this. Now if there is any double bond present in the fats or amino this fatty acids, we call it unsaturated. Now, why we are interested particularly in this connection I want to tell you particularly Biodiesel production process, we usually preferred the unsaturated that fatty acid. Because why? By unsaturated if you are unsaturation with the fat is unsaturated, the oil should remain in the liquid phase.

Otherwise, if is saturated it will in the normal temperature it may solidify. So, it is very difficult to use as a fuel. So, here the saturated fatty acid no double bond and unsaturated at least one. Usually there should not be any double bond; maybe mostly the single bonds are present. Steroids are also lipid which examples are the Cholesterol and naturally occurring hormones. Now and this it looks like this. This how the, this is I told

you this hydrocarbon molecules, we can increase the chain, this see 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 13, 14, 15, 16, 17. So, 17 carbons and then CO n. This is the ester bonding that we have, how it formed this ester. So, now, this is sorry. This is the, this is we have the Carboxylic acid group. This is the Fatty acid and this is the, this is also fatty acid and with the help of this Alcohol, they from the esters. That this is how the organic oleic acid is the organic fatty acid and this is steric acid, also fatty acid.

(Refer Slide Time: 17:59)

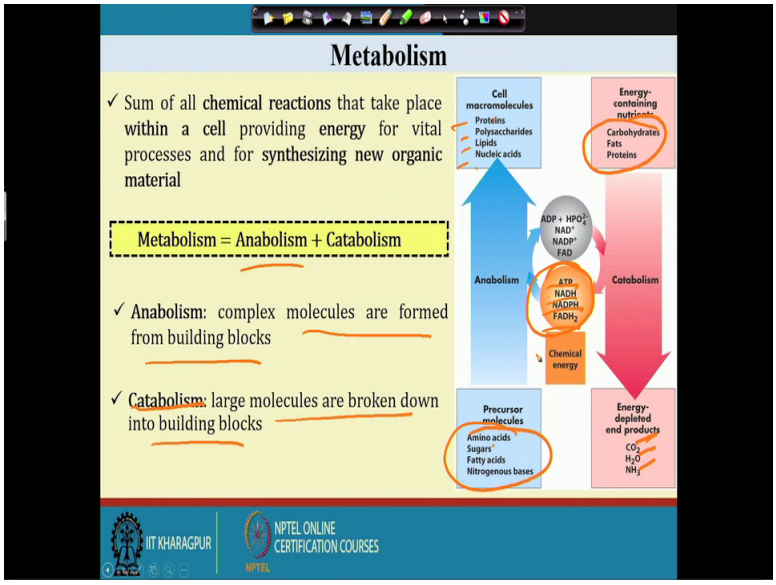


Now, Nucleic acid it is a very very very important as for living cells is concerned. Because we know that Deoxyribonucleic acid. This is largely available in the living system. This is the deoxyribonucleic acid and ribonucleic acid that we have and they carry out the genetic code as well as responsible for protein synthesis. So, this is very important and it has Pentoses the ribose and deoxyribose, they are nothing but Pentose. Pentose, this is also kind of Carbohydrate are present in the body RNA and DNA respectively. The Nucleotide is majorly build up of 3 different molecules. One is for phosphoric acid, then, pentose, then, Nitrogenous Base.

Now, what is called Nitrogenous Base? Here is the Nitrogenous Base, in case of RNA and this is the RNA. This is called DNA. Now in the RNA, you have Cytosine, Guanine and Adenine. But you heard the special Nitrogen Base is the Uracil. Or if you look at the DNA, we have Cytosine, Guanine, Adenine. But we have this, special lipids that is the Thymine. So, this is especially present this is the how the DNA, RNA. They differ from

each other. So, Nitrogenous Base includes the Adenine and Guanine, all this called as Nitrogenous Base and this is called Adenine and Guanine, we call Purines and thymine, cytosine and uracil, we call Pyrimidine.

(Refer Slide Time: 19:35)

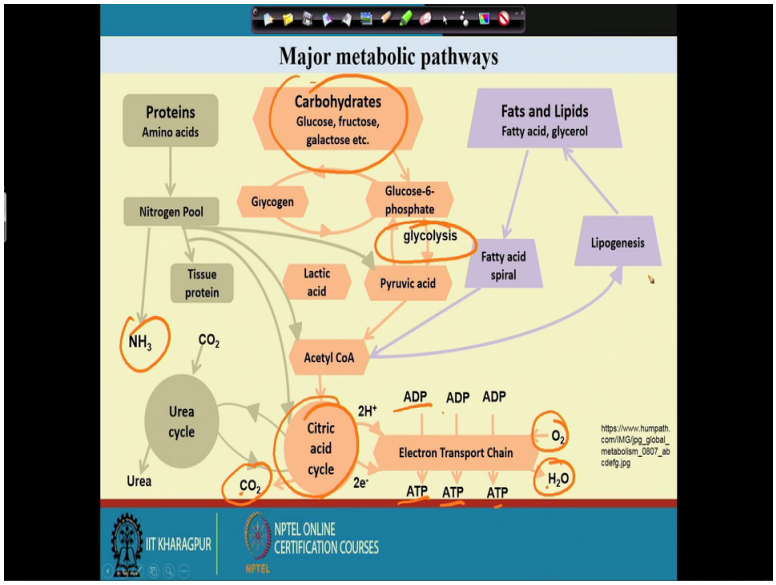


Now, let me go to the Biological system. In the biological system, 2 things simultaneously take place. One is called Anabolism; another we call Catabolism. Now what is called Anabolism? Anabolism means is a complex molecules are form for as a building blocks. Because you know, when some formation takes place, as for example, protein formation takes place or some, some molecule formation take place, that we call it Anabolism.

When degradation of the molecules take place as glucose, when we consider as the source of energy, glucose finally convert it to carbon dioxide and water we get the energy, that is called Catabolism. So, the Anabolism means formation of the body cells and Catabolism is the degradation of the organic molecules. So, that large molecules are broken down into the bonding block. Now this is Cells, we have micro-molecules, macro-molecules like Protein then, probably a Polysaccharide, then, Lipid and Nucleic acid and this, these forms from this different compound precursor amino acid sugar fatty acid and nitrogenous base. So, this when this Amino acid, Amino acid forms Protein, Protein is nothing, but Polymer of Amino acid. Then this is called Anabolism. When sugar from all the Polysaccharide; then, we call it as that the Anabolism.

But other way that if we if Carbohydrate fat and Protein molecule it degraded to that a carbon dioxide, water and ammonia, we call it Catabolism process. I hope and in process we produce some energy molecules; this energy molecules of ATP NADH NADPH and FADH 2. This is the user. The currency of energy, because as per our body requirement we use this energy for our day today recur use.

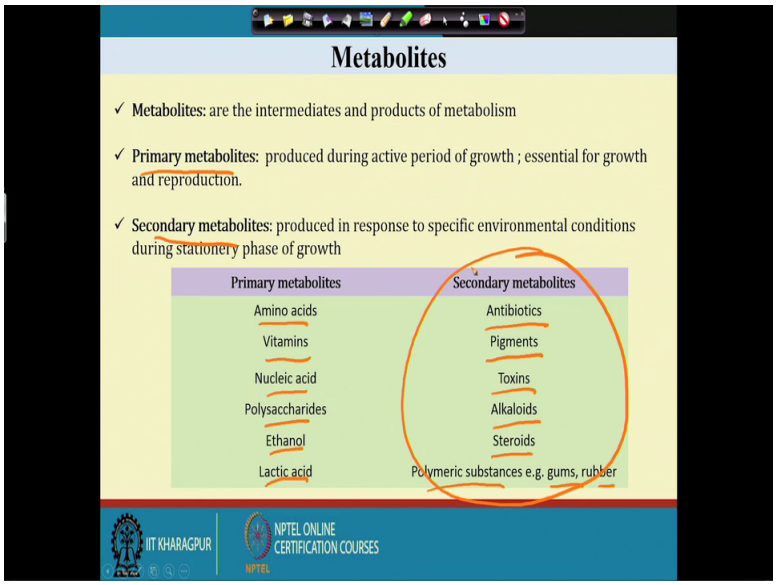
(Refer Slide Time: 21:34)



Now, a Major Metabolic Pathways are like this; that first we have Protein molecules. When a degraded Nitrogen Pool, then it from the ammonia. This is the ammonia, that we have ammonia is formed. Then in the Tissue protein, that also it forms and then, Carbohydrate. This Carbohydrate basically the Glucose, fructose and galactose; they take part Glucose-6-phosphate.

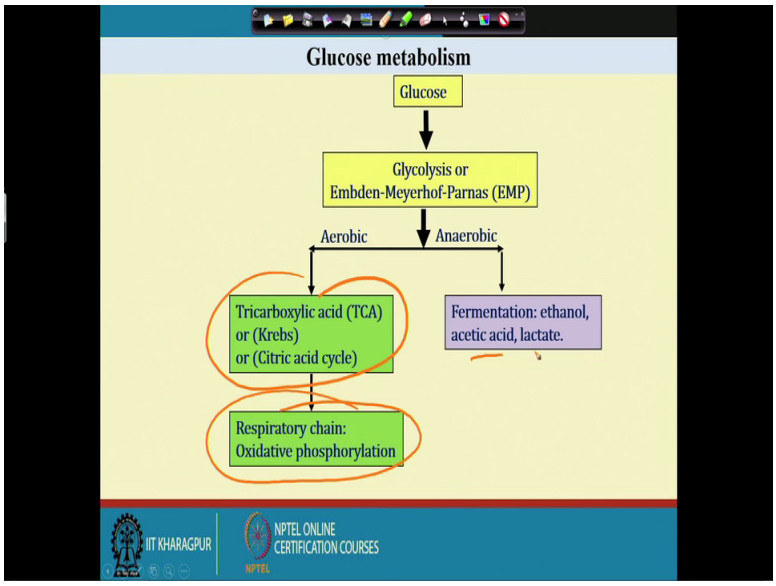
Then it ultimately through the process of glycolysis pathway, it produce the Pyruvic acid and then also this Pyruvic acid when pass through the TCA cycle or Citric acid cycle and it produces Carbon dioxide and water. Then we get lot of energy, we produce the ATP, ATP ATP ATP; different Electron Transport Chain. So, we this is carbon oxygen is required. So, 2 major products we have carbon dioxide and water, that is and then in case of Fat and Lipids, we have Fatty acids and Lipogenesis that are both is taking place in this particular system.

(Refer Slide Time: 22:43)



Now, Metabolism, metabolites are the intermediates or products of metabolism; because they know that I told you that in a chain we have several product formation take place and individual molecules, we call it metabolites. And it is broadly divided into 2 different types one is called that Primary metabolites, another we call the Secondary metabolites. Now, what is called primary metabolites? Like Amino acids Vitamins Nucleic acid Polysaccharides Ethanol and Lactic acid and Secondary metabolites are Antibiotics Pigment Toxins Alkaloids and Steroids and Polymeric substances like gums and rubber. This is the usually form, this all usually from during the stationary phase and as I told you that stationary phase, we consider as a star vision phase.

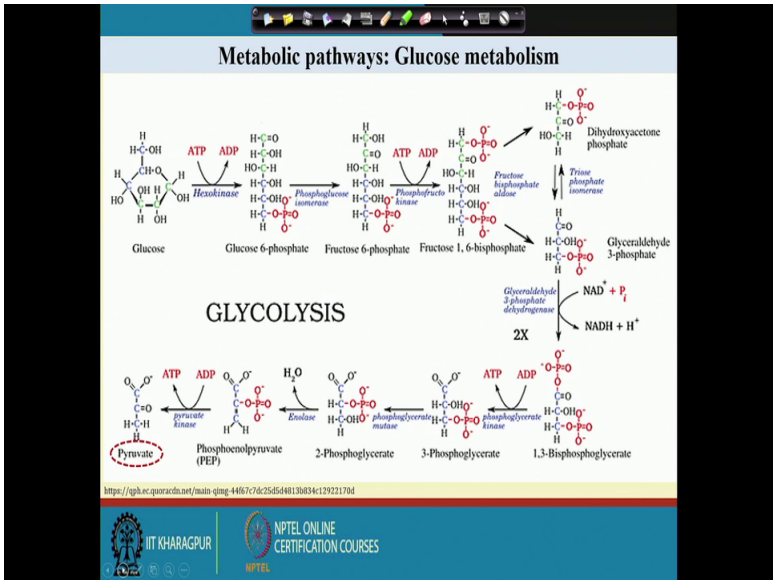
(Refer Slide Time: 23:32)



Now, common that a Glucose metabolism is like this Glucose passed through the Embden-Meyerhof-Parnas, it produced the Pyruvic acid and the through the both the Aerobic and Anaerobic, they follow this pathway and through the an aerobic it passes through the TCA cycle Krebs or Citric acid cycle, meaning is more or less it is the same that. So then, easily passes through the Respiratory chain or Oxidative phosphorylation.

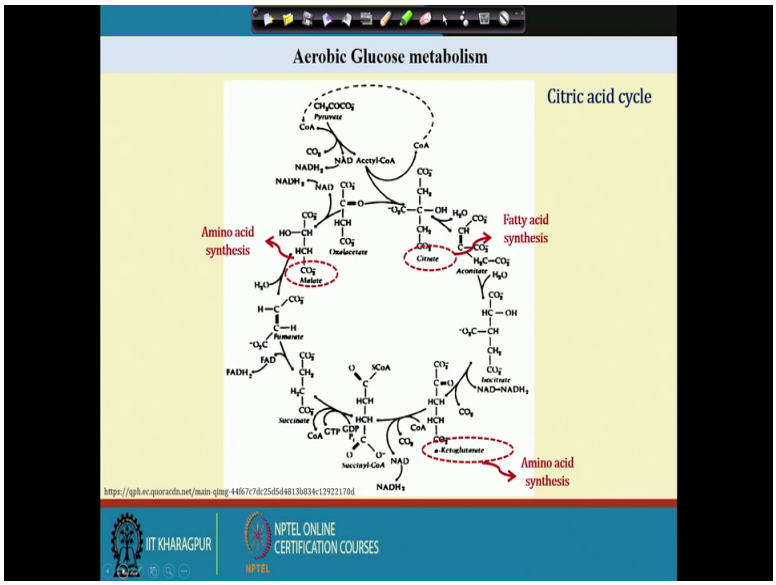
The Anaerobic system, it is a Fermentation ethanol and acetic acid and lactate acid it forms.

(Refer Slide Time: 24:08)



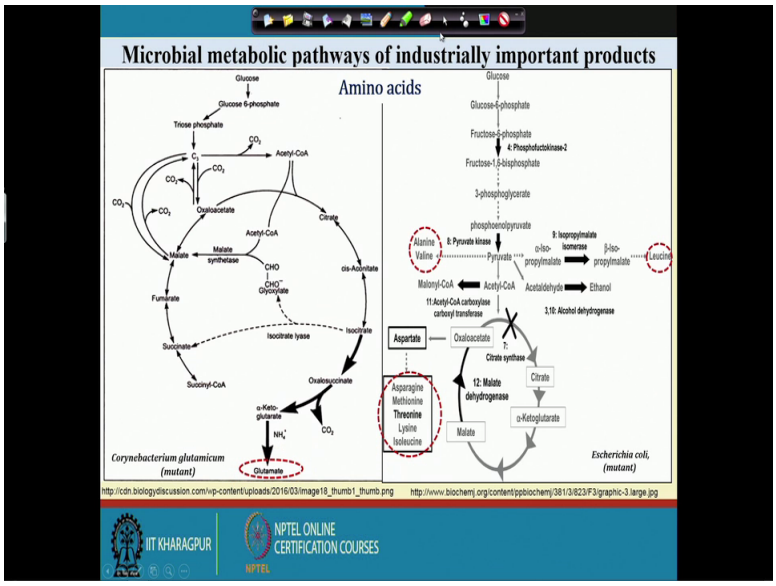
Now, this is the glycolytic pathway. How the glucose molecules is converted to Pyruvic acid. So, you know this is the, how the number of this is 1 2 3 4 5 6 7 8 9 10. So, 10 different steps are involved before it produces, 1 mole of glucose can produce 2 moles of Pyruvic acid.

(Refer Slide Time: 24:31)



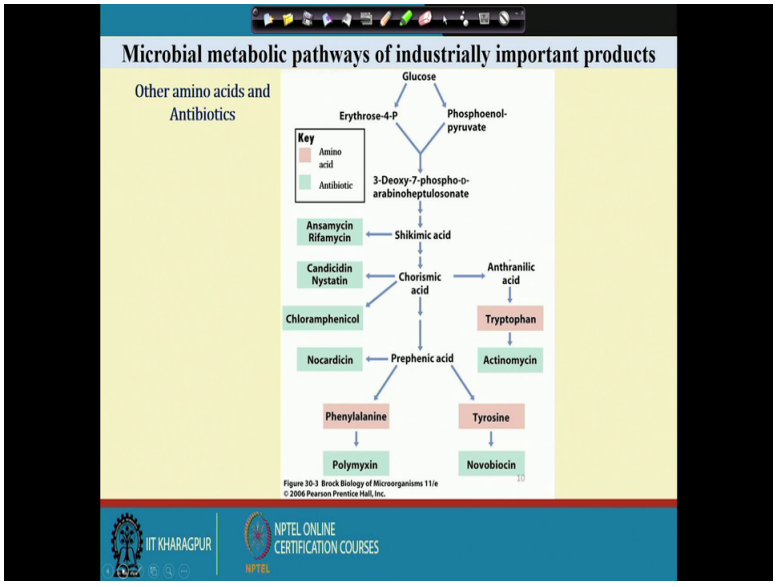
Then we have that Aerobic Glucose metabolism pathway. Then there we can produce some kind of, it passes through the TCA cycle and you can see the different molecule like Citric Acid. I thought that that kind of citric acid formation when you take. Let me try to empower innovate the subsequent steps by innovate by putting the inhibitor for a accumeter enzymes and isolated dehydrogenize we get the citric acid we do.

(Refer Slide Time: 25:04)



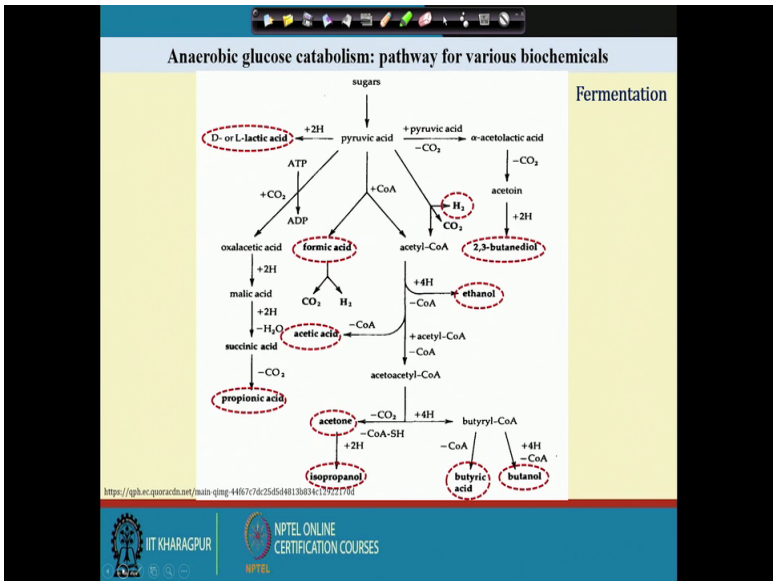
We can synthesize different Amino acids by using this process. Then we have the Microbial metabolic pathway for industrial important products, like we have Glutamate. You can see the Glutamate largely used. Then we have other different amino acids are here and that is from, how it forms do by using this metabolic pathway.

(Refer Slide Time: 25:24)



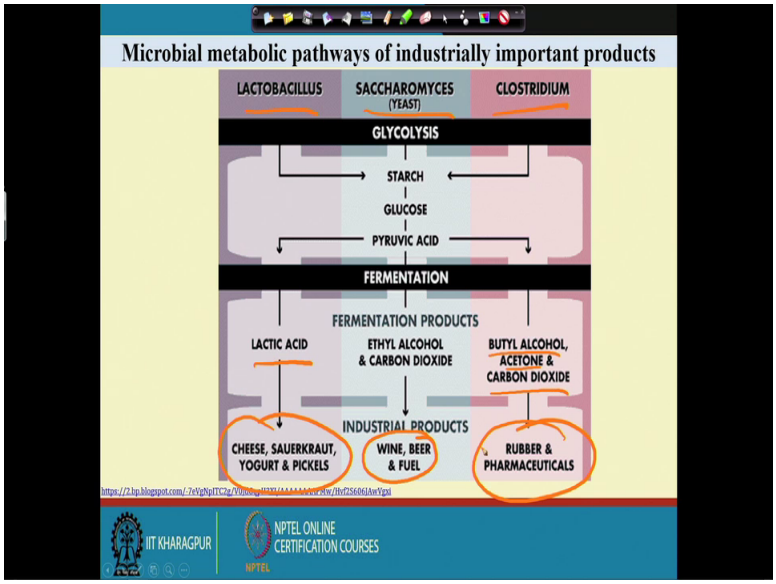
Then other industrial importance products are as for example, different type of this Antibiotics are there. One is one antibiotic is the Novobiocin, this is kind of antibiotics. Actinomycin that is the another antibiotic.

(Refer Slide Time: 25:48)



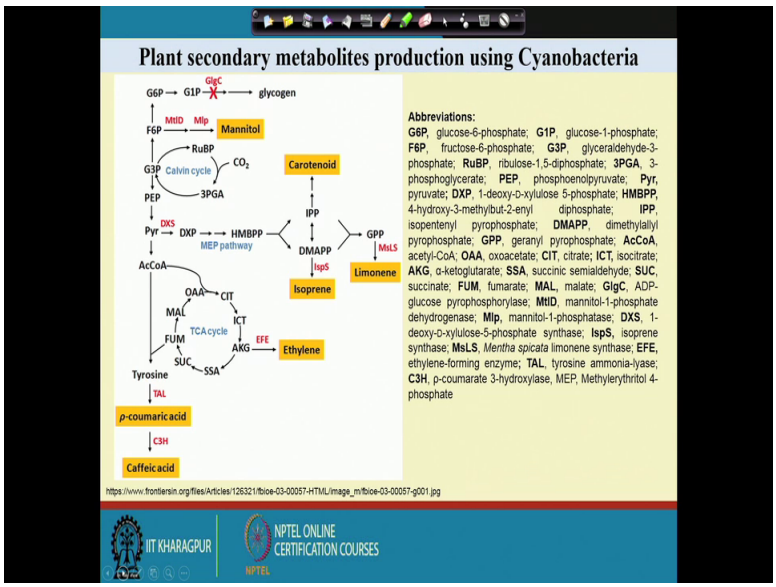
So, different type of antibiotics, how it forms it has been shown here. Then other Anaerobic fermentation process, we get different type of various chemicals we can get like Propionic acid, isopropanol, butyric acid, butanol, ethanol which now, it is plays very important role. Because as the source of energy and particularly Lactic acid is largely used for the food preservation purpose. So, it is used in the food and farm food and pharmaceutical industries and poly lactic acid is used.

(Refer Slide Time: 26:20).



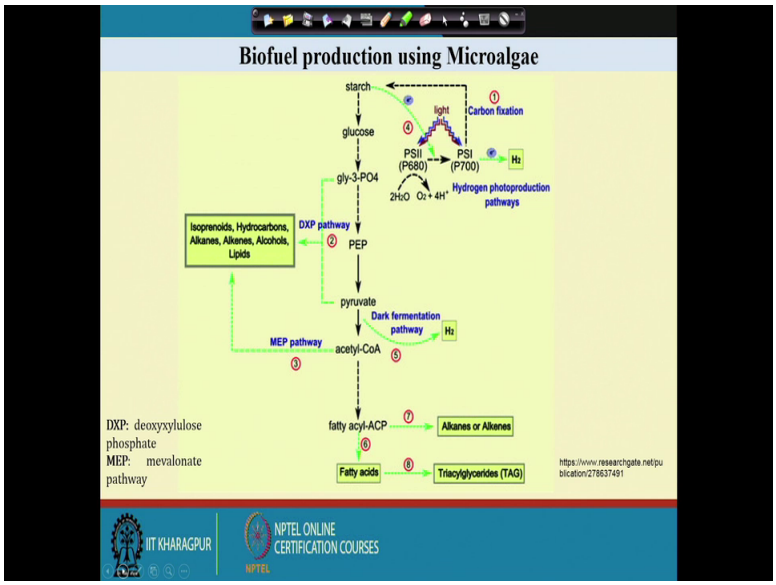
Poly lactic acid is use in the therapeutic purpose. Now this is that Microbial metabolic pathway for industrial importance, we have we have different spices. We have LACTOBACILLUS, we have SACCHAROMYCES; we have CLOSTRIDIUM. This is the very important bases we have. As for example, LACTOBACILLUS is likely that when you take part, they it reproduce the lactic acid and which is used for the CHEESE production, SAUERKRAUT production, YOGURT and PICKLES largely used. Then, SACCHAROMYCES ceremesia is used for WINE, BEER and ethanol, a ethanol acts as a substitute of Gasoline and then CLOSTRIDIUM, when we use the CLOSTRIDIUM it produced the BUTYL ALCOHOL ACETONE and CARBON DIOXIDE which is largely used in the PHARMACEUTICAL industries.

(Refer Slide Time: 27:12)



Now, Plant system also, this is the metabolic pathways, you can say it several important metabolites is produced as Caffecic acid. This is used as a stimulant; it is largely available in the in the tea or coffee. Then it produces Ethylene also; this is use in the ripening process. Then Limonium and Mannitol, that is also another products that form in the plant system.

(Refer Slide Time: 27:38)



And in the Biofuel production as I pointed out starch or glucose that it can be produced by the different type of this is different type of hydrocarbons that Alkanes or Alkenes formation is there and this is the different other products that formation. Now a days this has largely exploit particularly by using microalgae.

And Microalgae we use as a source of biodiesel. So, in conclusion I want to tell that you know Biochemistry deals with different Biomolecules like you have, we have Carbohydrate, we have Proteins, we have Lipids, we have this Nucleic Acid and that mainly the Carbohydrate and Lipid, they use as a source of energy and Protein is as a bodybuilding material, Carbon also used as a bodybuilding material.

A part of Carbon and a Nucleic acid mostly used as the genetic material, for the formation of different Proteins which is very much involved in the Metabolic pathways. There are several methodologies that we have, as for example, in Embden-Meyerhof-Pathway, where Glucose is converted to Pyruvic acid. Then pass through the TCA cycle, it produce Carbon Dioxide. Other metabolic pathway also has been discussed through which we can get the different type of products both Primary metabolites and Secondary metabolites.

Thank you very much.