Biochemical Engineering

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Module No. # 01
Lecture No. # 21
Pentose Phosphate Pathways Glycogenesis and Glycogenolysis

Good morning students. In the earlier classes we have all ready learned the glycolytic process, TCA cycle, electron transport chain and oxidative phosphorylation and which completes the cellular respiratory process. Now, during that process we have seen that how glucose is oxidized and this flow of this pathway starts and it ends with this pyruvate and then it enters to the TCA cycle and ultimately it ends with the oxidative phosphorylation process.

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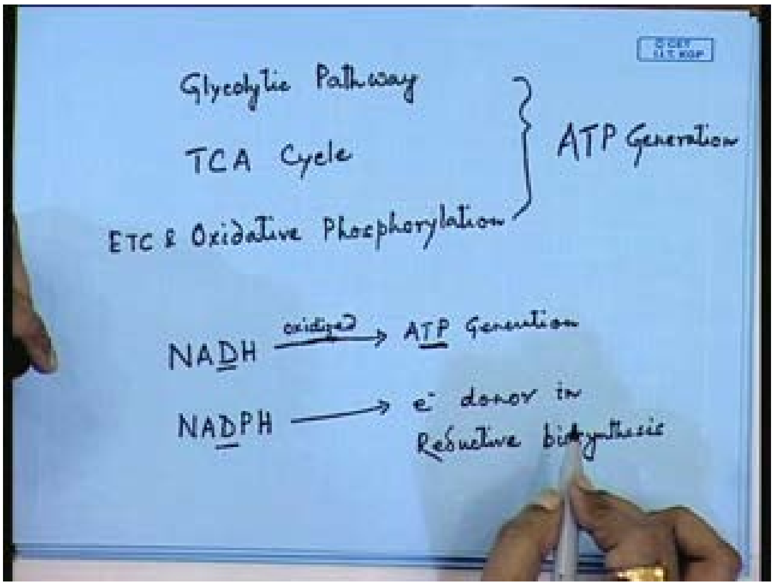

During this process we have also seen that how ATP is being generated in that process. Now, we have also seen that NADH is playing a significant role in this glycolytic to oxidative phosphorylation process. Today the topic of our discussion is pentose phosphate pathway which is little bit different from that of the earlier metabolic pathways what we have discussed.

Now, in the earlier processes I have all ready told that it is the respiratory process and this is the catabolic process. But, in this today's topic this pentose phosphate pathway, what we will be discussing here will have some product which is different from the generation of NADH. Now, the product is the NADPH. Now, we must know the difference between NADH and NADPH. Now, if we see this difference between NADH and NADPH we can find that, when NADH is getting oxidized in these earlier processes that cellular respiratory process ATP is generated. That means, the cell is getting ATP when NADH is getting oxidized. But, the today's concern is with NADPH which is acting as the electron donor and it is the product which is the which is reductive biosynthetic pathway. And it is helping in very many cellular activities going on inside the cell.

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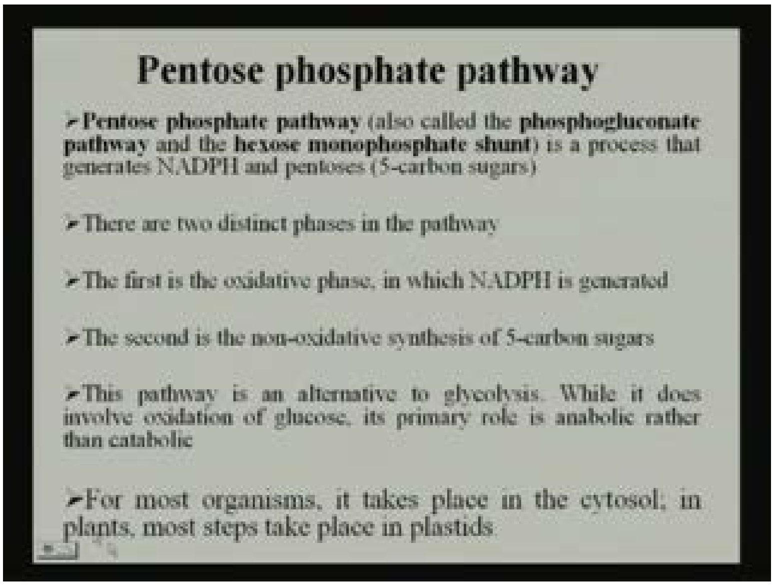

And today, I will be starting with pentose phosphate pathway and then I will be coming to the glycogenesis and glycogenolysis. Now, let let us start with the pentose phosphate pathway. Pentose phosphate pathway is otherwise known as phosphogluconate pathway or hexoes monophosphate shunt. In this process, in this biosynthetic pathway, it generates NADPH and pentose sugar that is five carbon sugar. If we see the entire pathway we can divide the entire pathway into two distinct phases; the first is the oxidative phase in which, NADPH is generated, in the second phase the non-oxidative synthesis of five carbon sugars are there. This is the pathway which is alternative to the glycolytic pathway. While it does involve oxidation of glucose, its primary role is anabolic then the catabolic process. In most of the organisms this pathway is taking place in the cytoplasmic fluid of the cell. But, in plant this particular step is taking place in plastid.

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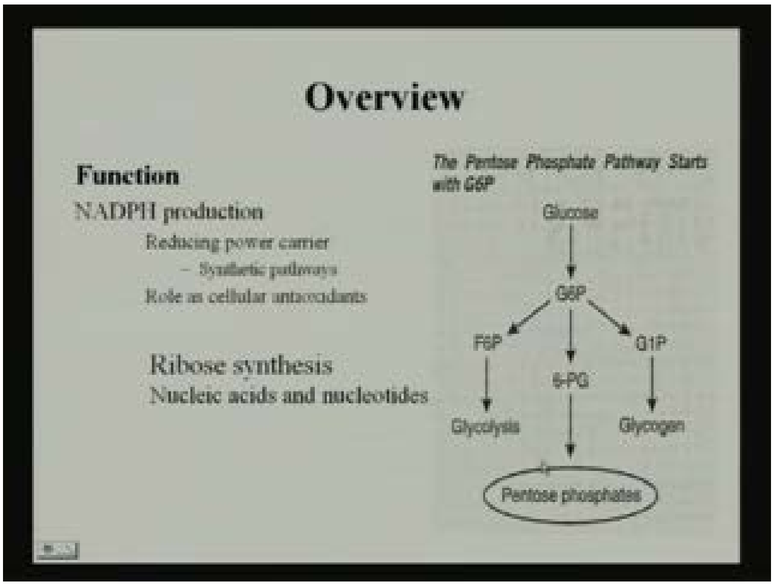

Now, as I have all ready told you that NADPH generation is there in this particular pathway, what is the important of NADPH? Now, if we see the function of NADPH then, we can find that this NADPH is acting as the reducing power carrier. That means during this metabolic process during when the activities several activities are simultaneously going on within the cell then, some molecules that we as a result of oxidative oxidation free radical generation is taking place. Now, when free radicals are formed these free radicals are harmful to the cell. What these reducing power carriers are doing? They are acting as the scavenger of those free radicals which are produced during this reaction. NADPH is acting as one of such antioxidant and it is playing a important role in cellular ant oxidation process. I have also told you that another bi product is the five carbon sugar that is the ribose sugar. And in our earlier classes we have all ready learned that, five carbon sugars are very important as for as this nucleic acid is concerned. And if we see the structure of nucleotide then we can find that in the nucleotide code structure this five carbon sugar moieties are there along with that nitrogen group and as along and another phosphate group is attached to that. This is the nucleotide and this sugar is the ribose sugar. In case of RNA it is the ribose sugar and in case of DNA it is deoxyribose sugar.

So, this ribose sugar is playing a significant role in other biochemical reactions which are going on inside the cell. So, if we see the pentose phosphate pathway it starts with glucose and when glucose is converted to glucose 6-phosphate. This glucose 6-phosphate may get diverted to different pathways. That means in a cell simultaneously different activities are going on and this glucose 6-phosphate may take part, may get converted to fructose 6-phosphate and it can enter to this glycolytic process. When glucose 6-phosphate is converted to glucose one phosphate, it enters to the synthesis of glycogen from glucose. Glucose 6-phosphate when it enters to and produce the product like 6-phosphogluconate, it enters to this pentose phosphate pathway. And today, we will learn this particular pathway where glucose 6-phosphate is producing the pentose sugar.

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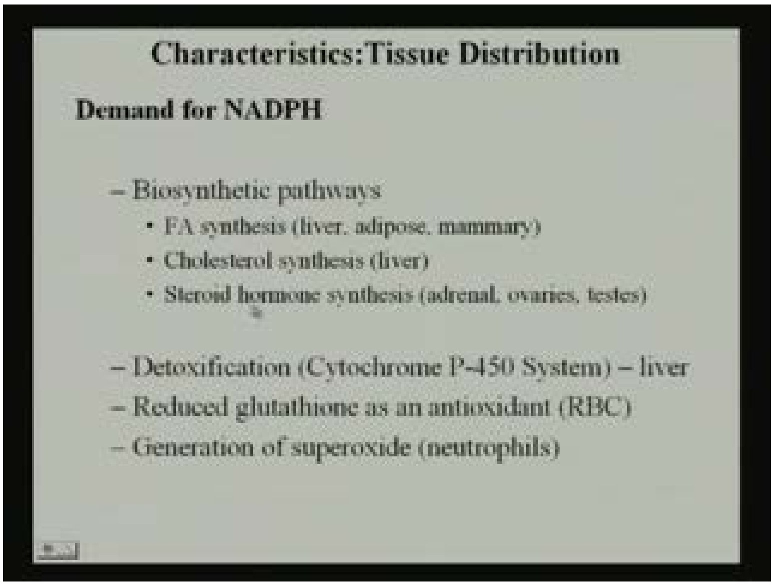

The As I have told you, that when in a cell oxidation reactions are going on simultaneously I am telling that free radical generations are taking place and there this reduced glutothiones which are there it is acting as antioxidant. Then this NADPH has got high demand for the generation of super oxide that is neutrophils in the cell. It also helps in detoxification. If we see the different biosynthetic pathway then we can find that, fatty acid biosynthesis which takes place in liver in adipose tissues and in memory gland if there NADPH has got a significant role. It has got also, it is playing this NADPH is playing also a significant role in cholesterol biosynthetic pathway which takes place in liver and steroid hormone synthesis which takes place within the cell that is in adrenal ovaries and testes. This NADPH is playing a significant role and that is the reason why today's pathway is so important to learn.

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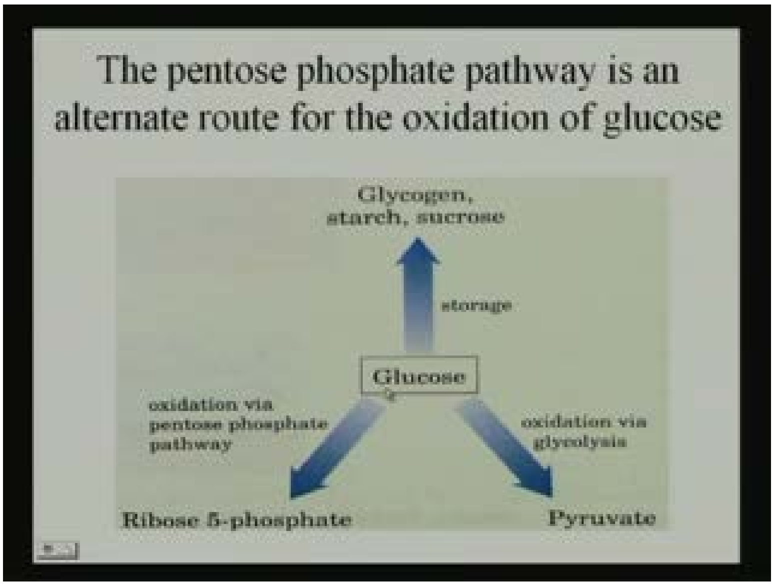

As I have told earlier this glucose may enter to different pathways for doing different metabolic activities in the cell. When glucose is glucose concentration is more in the cell it can be used it can be stored in the form of glycogene which is stored in the liver. Glucose can also oxidize and entered to this pentose phosphate pathway. Glucose can also oxidize to form this pyruvate. And today's lecture is how glucose is converted to five carbon pentose.

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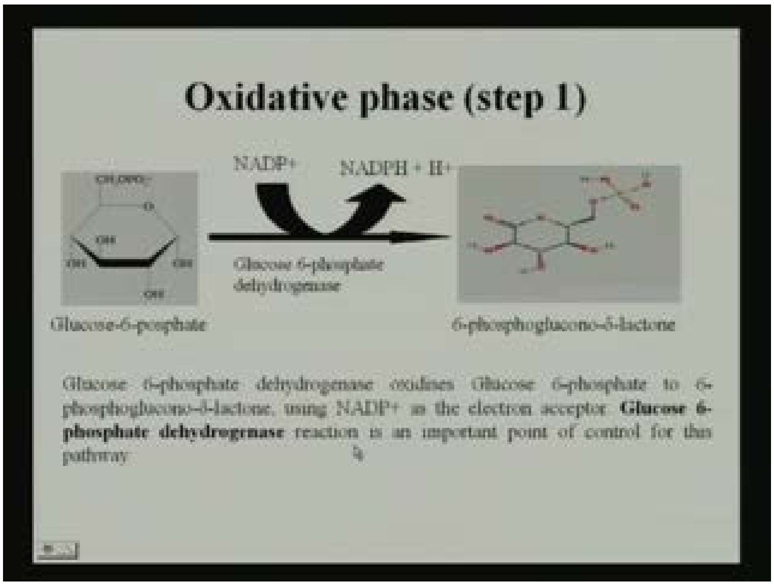

Coming to the first step of pentose phosphate pathway, now as we have all ready seen that glucose is converted to glucose 6-phosphate. So, glucose 6-phosphate when it under go some reaction like glucose 6-phosphate in the presence of the enzyme glucose 6-phosphate dehydrogenase, it produces 6-phosphoglucono delta lactones. Now, here one molecule of NADPH is produced in this reaction. This is, this particular enzyme glucose 6-phosphate dehydrogenase is playing a significant role which controls this particular pathway.

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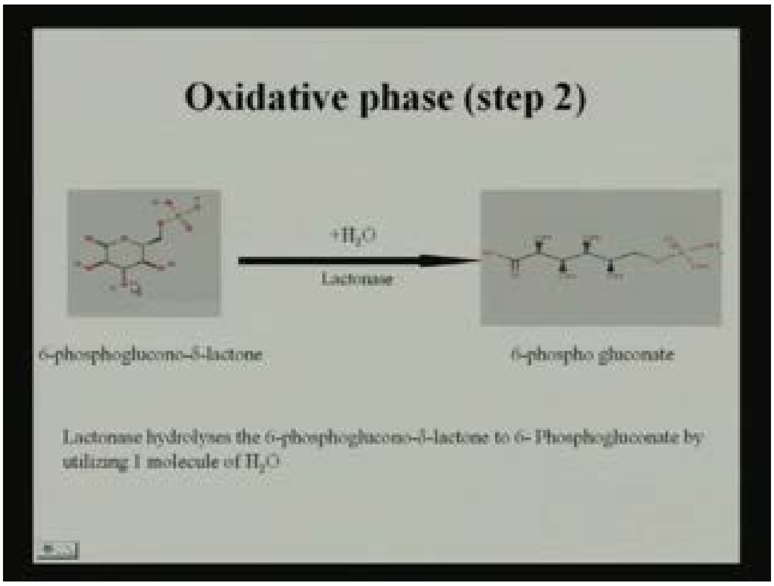

When 6-phosphoglucono d lactone is produced, it is getting converted to 6-phosphoglconate in the presence of one molecule of water and the enzyme lactonase which hydrolyses 6-phosphoglucono d lactone to 6-phosphogluconate.

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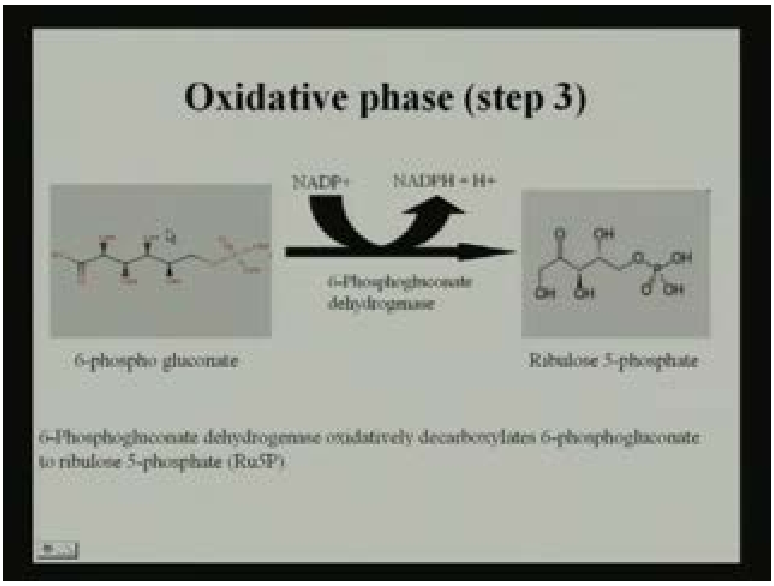

When 6-phosphogluconate undergoes oxidative reaction it produces ribulose 5-phosphate. Here another molecule of NADPH NADP is required to convert to NADPH in the presence of 6-phosphogluconate dehydrogenase enzyme.

Now here, dehydrogenation reactions are going on, simultaneously carboxylation reaction is also going on. Here see 6 carbon molecule is getting converted to 5 carbon molecule and a one molecule of carbon dioxide is being released in this particular step.

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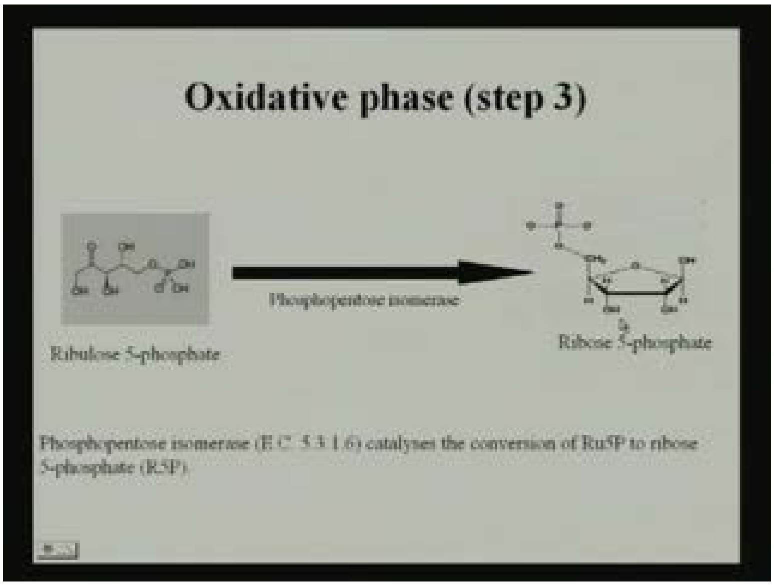

When ribulose 5-phosphate is produced, ribulose 5-phosphate in the presence of isomerase enzyme that is phosphopentose isomerase this ketopentose sugar is converted to aldopentose sugar. That means ketose sugar is converted to aldehydic sugar. That means ribose 5-phosphate and here this ribose 5-phosphate is formed.

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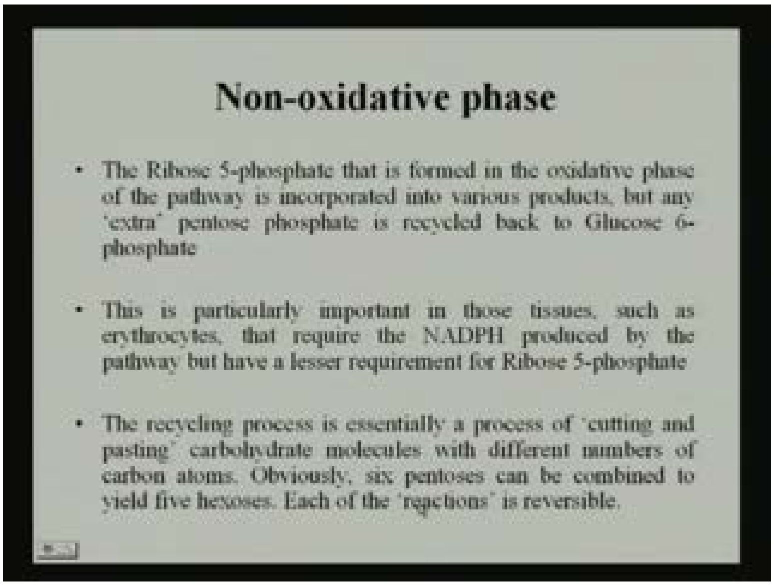

This ribose 5-phosphate is formed in this oxidative phase of this pathway is incorporate incorporated into various product products. But, any extra pentose phosphate is recycled back to glucose 6-phosphate. This is particularly important in those tissues such as erythrocyte that requires NADPH produced by this pathway. But, have a lesser requirement of a ribose 5-phosphate. The recycler process is essentially a process of cutting and pasting carbohydrate molecules with different number of carbon sugars. Obviously 6 pentoses can be combined to yield 5 hexoses. Each of the reactions is reversible in nature.

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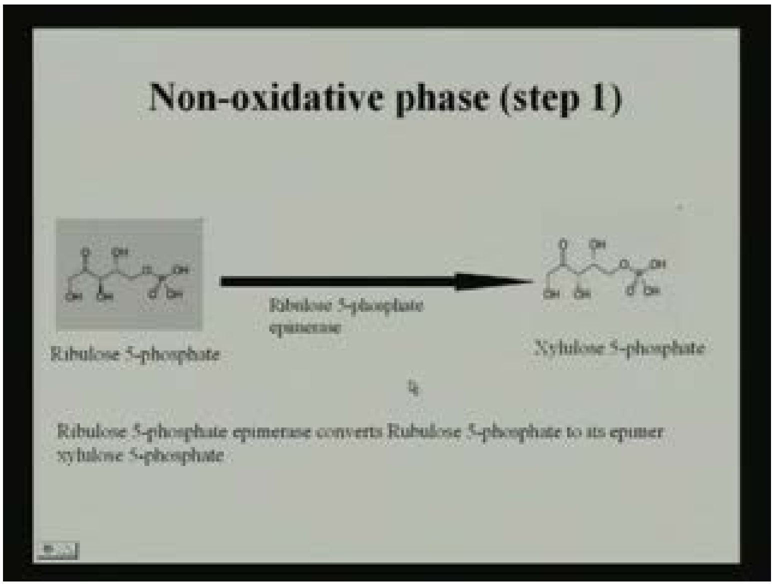

Now, when we are going to this non oxidative pathway then step one is this a ribulose 5-phosphate which is there once again in the presence of this enzyme epimerase. That is a ribulose 5-phosphate epimerase enzyme can convert this ribulose 5-phosphate to xylulose 5-phosphate. Now, this is that epimere epimera of these two sugars ribulose and xylulose. Both are pentose sugar.

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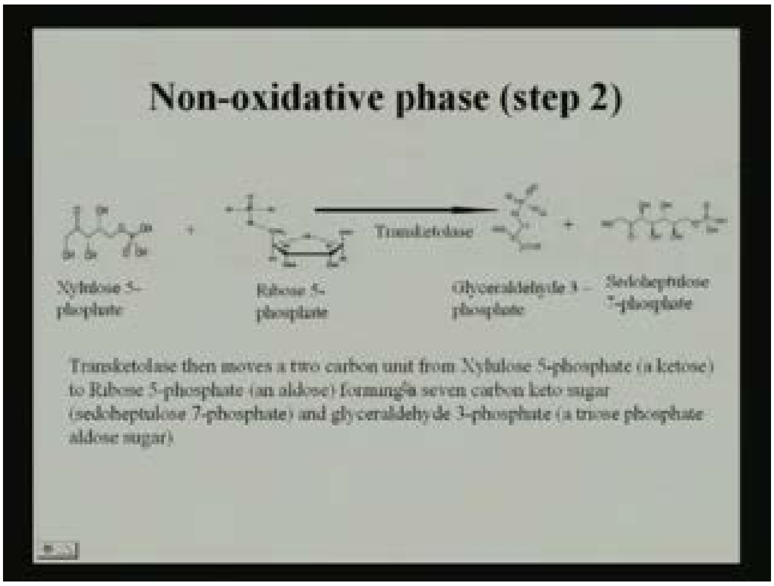

Now here when xylulose 5-phosphate and ribose 5-phosphate, this see here it is the ketopentose and here it is the aldopentose.

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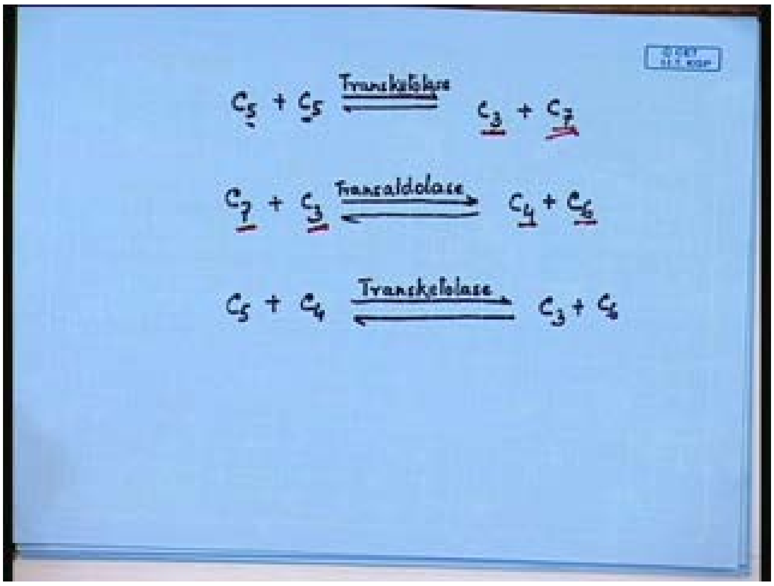

Now when 5 carbon plus 5 carbon, now 5 plus 5 ten carbon under goes reaction that is in the presence of transketolase enzyme; you see 5 plus 5 this 10 carbon sugar when under goes this reaction it produce 1 3 carbon sugar and another 7 carbon sugar. So, 5 plus 5 is getting converted to 3 plus 7, 10.

So see the carbon balance here. In the presence of the enzyme that is the transketolase so this enzyme what it does? Transketolase is then moved to carbon unit of xylulose 5-phosphate, a ketose to ribose 5-phosphate and then it becomes so when 2 carbon is coming from this sugar to this. Then it transforms its orientation from 5 sugar to 7 carbon sugar. And that is the sedoheptulose sevenm phosphate and this is and one glyceraldehyde three phosphate that is the three carbon sugar. Now, in the third step what is happening? This seven carbon sugar which is there and this three carbon sugar which is produced in this step undergo transaldolace reaction. Now when see once again, this is seven carbon, this is three carbon and here this ten carbon. Once again and it under goes reaction and it produce one C 4 sugar, another C 6 sugar. So, 6 plus 4 10, 7 plus 3 10. So, here these transaldolace reactions are going on and it produces one 4 carbon sugar and another 6 carbon sugar.

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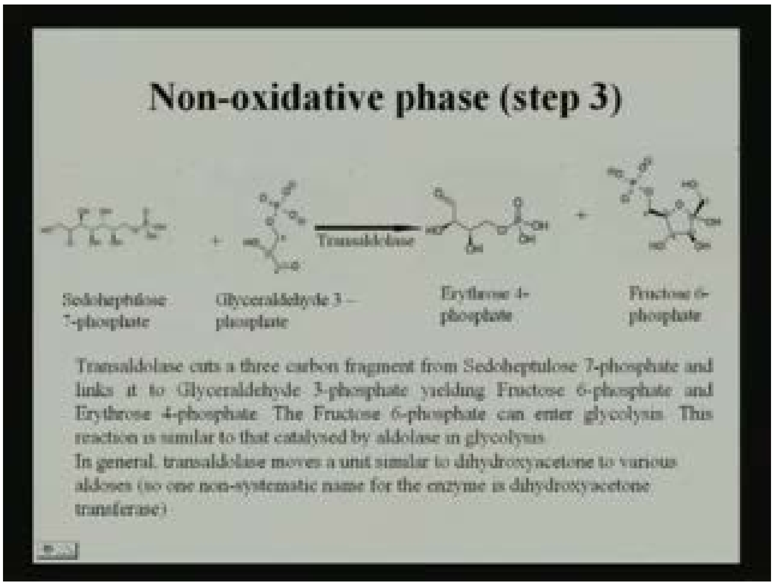

Now, here you see when this reaction is going on this transaldolace cut a three carbon fragment from sedoheptulose seven phosphate and link it to the glyceraldehyde three phosphate yielding one fructose 6-phosphate and one 4 carbon erythrose 4-phosphate. You see this is the ketos sugar, this is a aldose sugar. Here is this aldose sugar and it is the ketos sugar. Now, this fructose 6-phosphate can enter glycolytic process and this reaction is similar to that catalysis the aldolysis in glycolytic pathway. In the next step this xylose 5-phosphate and erythrose 4-phosphate.

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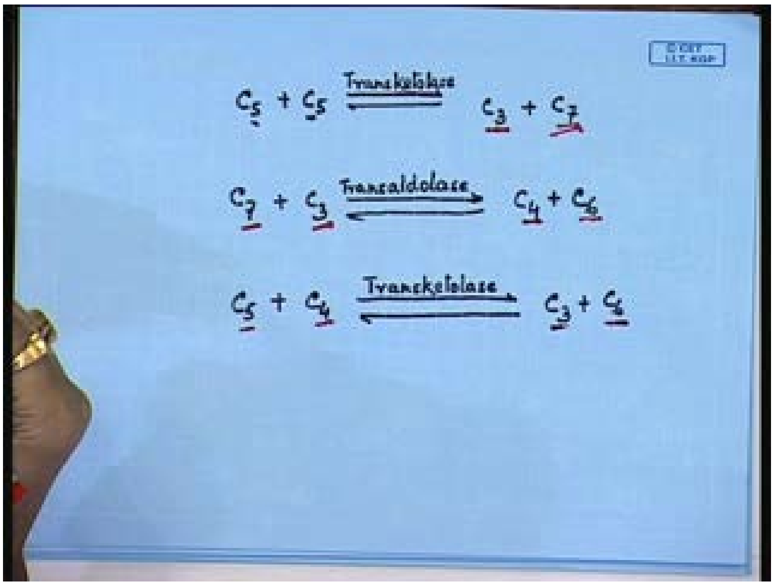

So we have seen by xylose in a step xylose 5-phosphate and erythrose four phosphate. This 5 plus 4 9 carbon sugar undergoes transketolace reaction in a presence of the enzyme transketolace. It undergoes it its biotransformation and it produce that C 6 and C 3 that 1 3 carbon sugar and another 6 carbon sugar.

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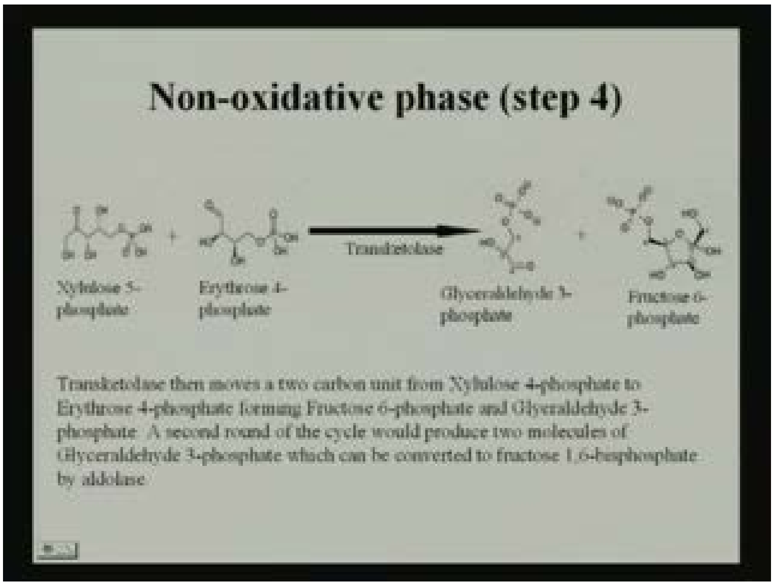

Now here you see the transketolace then moves that 2 carbon unit of xylulose four phosphate to erythrose 4-phosphate forming fructose 6-phosphate and glyceraldehyde three phosphate. Both these three carbon and 6 carbon sugars we have all ready learned are the intermediate of glycolytic pathway. A second round of the cycle would produce two molecules of glyceraldehyde three phosphate which can be converted to fructose 1 6 bisphosphate by aldolace enzyme.

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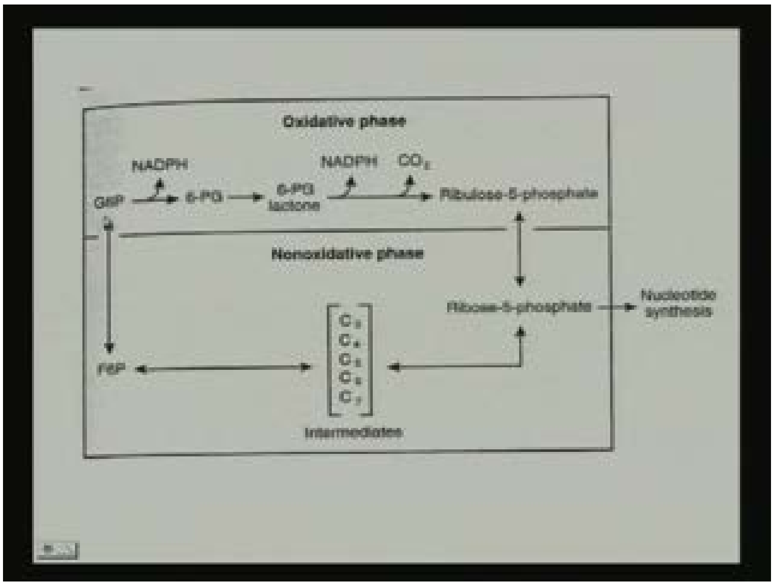

Some of the enter reactions then we can divide the entire p p p pathway into two distinct phases; once is the oxidative phase, another is the non oxidative phase. In case of oxidative phase, we have seen that glucose 6-phosphate is producing two molecules of NADPH, one molecule of carbon dioxide and 6 carbon sugar is converted to 5 carbon sugar. This 5 carbon sugar under goes this isomerize isomerization reaction and ribulose becomes ribose this aldose aldose sugar. And here with this 5 carbon 2 5 carbon sugar one aldose and ketose origin, they undergo different types of non oxidative reactions and we have see that there is a production of C 3 C 4 C 5 C 6 C 7 etc sugar. And these are the intermediate and ultimately we have seen that fructose 6-phosphate which is produced can once again rebound back to glucose 6-phosphate or fructose 6-phosphate can enter to the glycolytic pathway.

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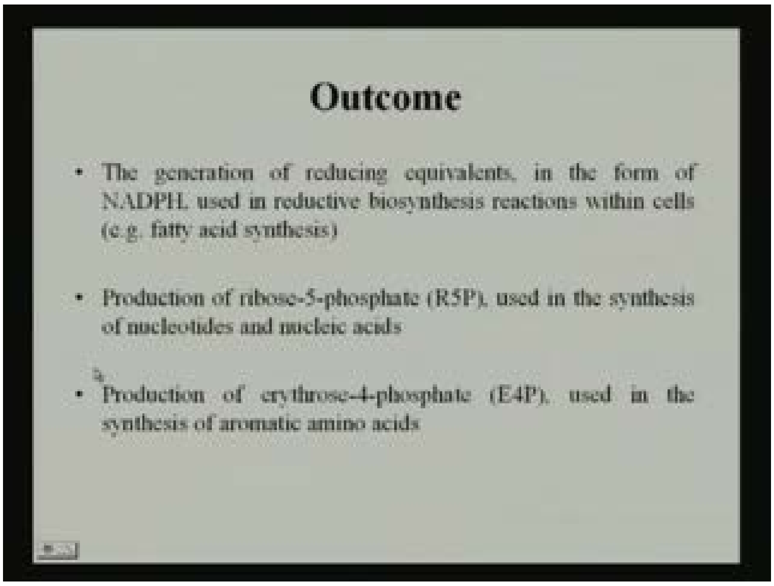

So if we sum up this what are the outcome of this p p p pathway, that is pentose phosphate pathway. The generation of reducing equivalents in the form of NADPH used in reductive biosynthesis reaction within the cell, production of ribose 5-phosphate used in the synthesis of nucleotide and nucleic acid, production of erythrose four phosphate this 4 carbon sugar which is there is acting as the (( )) for the synthesis of aromatic amino acids. So, we can see that each of the intermediates which are produced in this pathway is playing a significant role in the living system.

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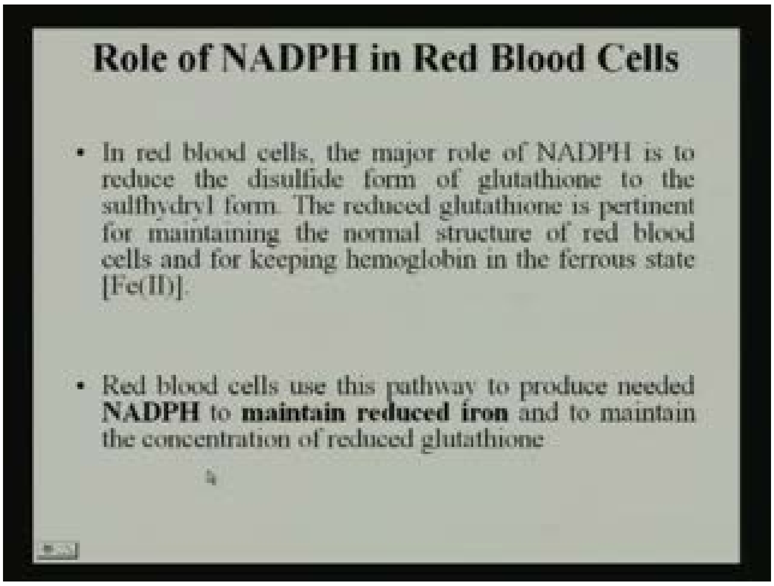

Now, if we see the role of NADPH in a red blood cell; in red blood cells the major role of NADPH is to reduce the disulfide form of glutathione to the sulfhydryl form. The reduced glutathione is pertinent for maintaining the normal structure of a red blood cell for keeping hemoglobin in the ferrous state. And red blood cells used this pathway to produce needed NADPH to maintain the reduced iron and to maintain the concentration of reduced glutathione and this is the major role of NADPH in the in blood.

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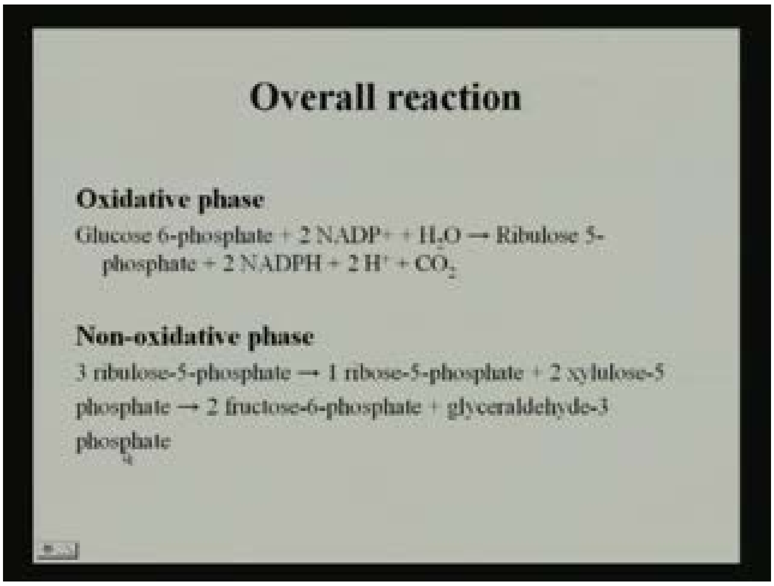

Now, overall reaction if we see glucose 6-phosphate plus two molecules of NADP and one molecule of H 2O is releasing a ribulose 5-phosphate plus 2 NADPH plus 2 hydrogen and one molecule of carbon dioxide. In non oxidative phase, three ribulose 5-phosphate is giving one ribose 5-phosphate, two xylulose 5-phosphate which under goes further reaction to yield two molecules of fructose 6-phosphate and glycerdehyde three phosphate which are the end product of this p p p pathway.

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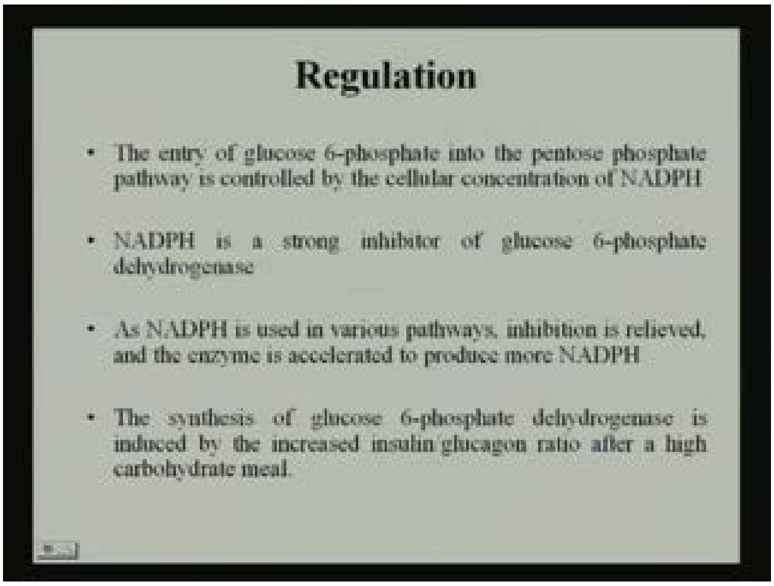

Now, if we see the regulation of this p p p pathway, we can find that the entry of glucose 6-phosphate into pentose phosphate pathway is controlled by the cellular concentration of NADPH. NAPDH is the strong inhibitor of glucose 6-phosphate dehydrogenase. That means, in this way the reaction is being controlled by the this NADPH and 6 phospo dehydrogenate. As NADPH is used in various pathway inhibition is relieved and the enzyme is accelerated to produce more and more NADPH.

The synthesis of glucose 6-phosphate dehydrogenase is induced by the increased insulin or glucagon ratio after the high carbohydrate meal. So, when high carbohydrate is being intake inside the body this insulin and glucagon, whether glucose the body needs glucose or high concentration of glucose is there, whether glucose is to be converted to glycogen, these two hormones are balancing this particular thing. And this is the regulation of p p p pathway. And as I have told you, that this particular by the bi-product of this particular cell cycle, this metabolic pathway is playing significant role in the different metabolic activities. Now, let us say that how glycogen is being synthesized when glucose is more in the body, in the cell. How glucose is getting converted and getting stored in the liver by this process? So, we will learn that how glucose is converted to glycogen.

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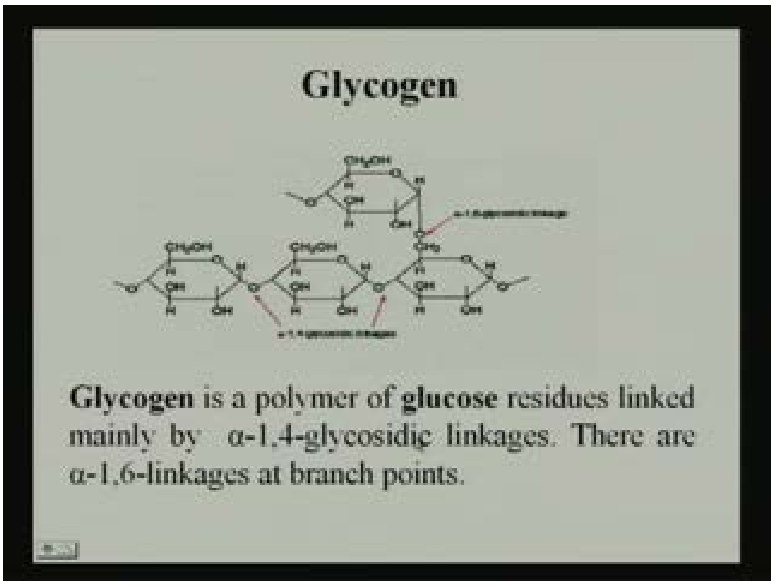

As in my earlier classes, I have told you that glycogen is the storage food material in case of animals. Now here, if we see that structure of glycogen, then we can find that glycogen is a polymer of glucose residues which are linked by alpha one four glycosidic linkages and alpha 1 6 glycosidic linkages. Now, when this branching is there, then it is alpha 1 6 glycosidic linkage.

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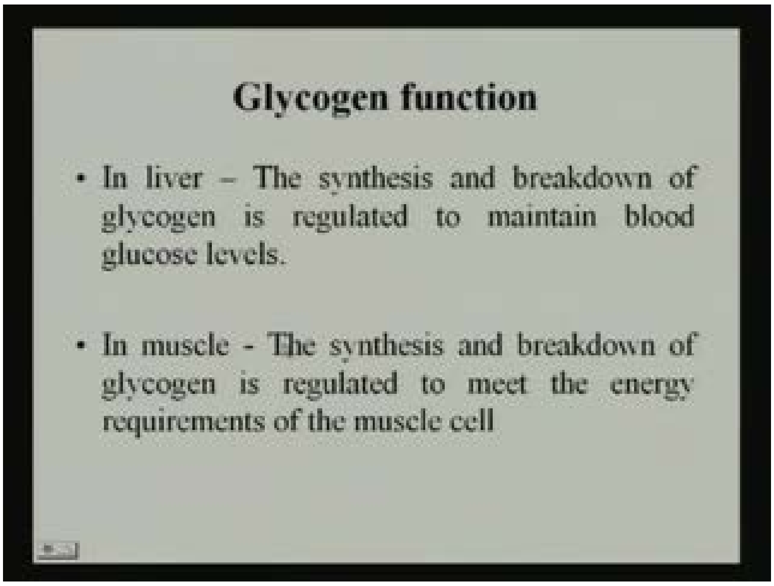

Now here, in the liver I have told you the synthesis and break down of glycogen is regulated to maintain the blood glucose level and in muscle the synthesis and break down of glycogen is regulated to meet the energy requirement of the muscle cell. That means, it is playing that the glucose or glycogen is playing a significant role to supply the glucose in different parts of the cell and glycogen is being stored. The glucose in the form of glycogen is being stored in the liver cell and then it is or muscle and it is being released and glucose is giving energy to the muscle.

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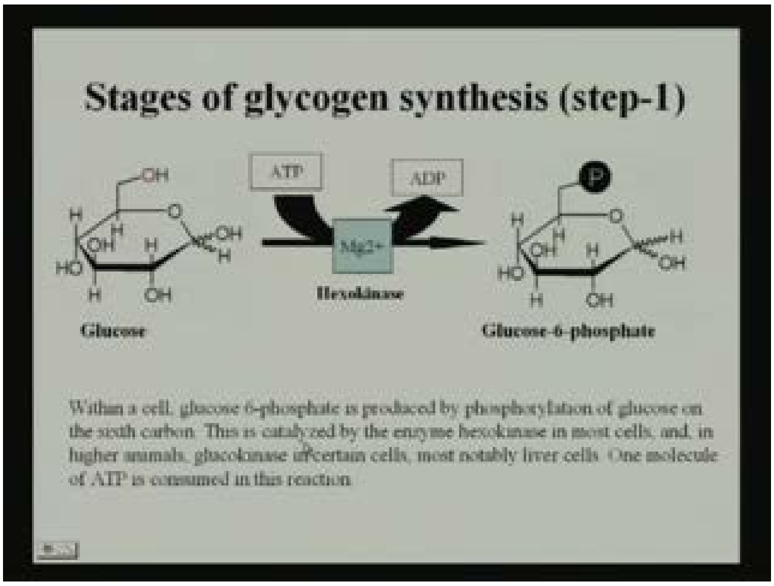

Now, when we are talking about the different stages of glycogen synthesis then we can find that glucose is getting converted to glucose 6-phosphate. This step is same to that of the glycolytic first step of glycolytic process. Here you see, hexokinase is the enzyme. One molecule of ATP is needed to carry out this reaction to first phosphorylate this glucose 6-phosphate that for phosphorylation process ATP is needed. And for higher cell glucokinase is playing a significant role for conversion of glucose to glucose 6-phosphate.

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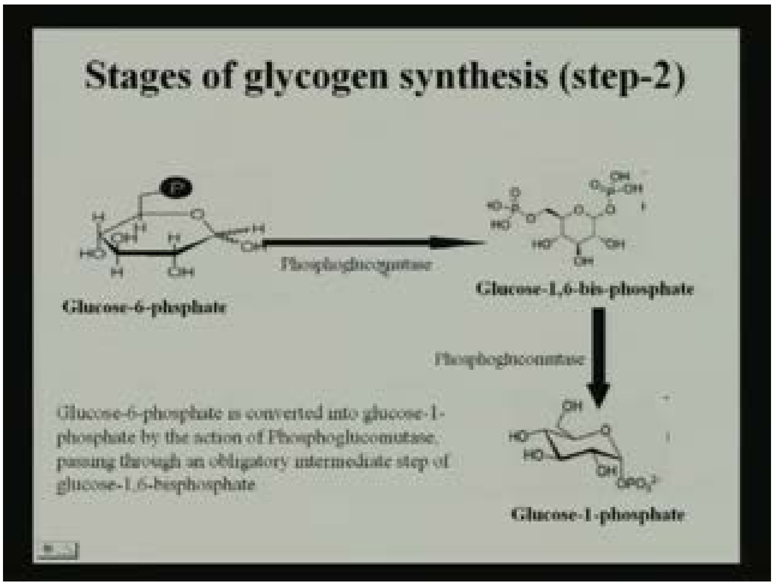

Glucose six phosphate this is a very interesting step way step for these particular pathway of glycogen synthesis. Glucose 6-phosphate in the presence of phosphoglucomutase is getting converted to glucose 1 6-bis-phosphate which is a very unstable intermediate product and ultimately it is producing glucose one phosphate.

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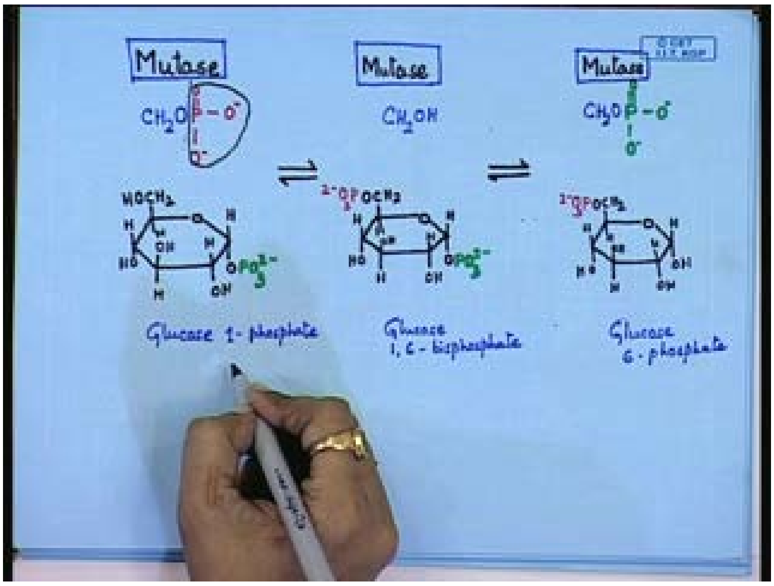

Now see, this is the structure this is the mutase enzyme which has got one phosphate group within this structure of this enzyme. This mutase enzyme has got its phosphate group within it. Now, glucose one phosphate is there. So, glucose 6-phosphate is getting with the donation of this phosphate group from this particular mutase enzyme. It is becoming glucose 1 6-bis-phosphate. That means, one position and six positions are phosphorylated. This product is a very unstable product and this enzyme once again taking back of this phosphate from the 6th position of this phosphate, is being taken up by this enzyme and it produces glucose one phosphate in this particular step.

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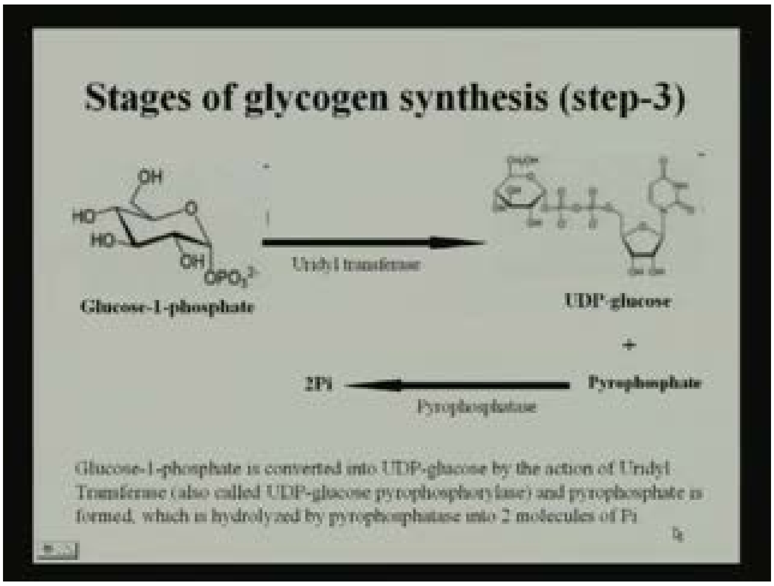

Now, when glucose one phosphate is produced one phosphate in the presence of uridyl transferace enzyme is producing UDP glucose. That means uridyl diphosphate. This uridyl diphosphate in the presence of pyrophosphate, it is releasing two inorganic phosphate. Now here, in this step once this UDP glucose is produced the synthesis of glycogen is taking place.

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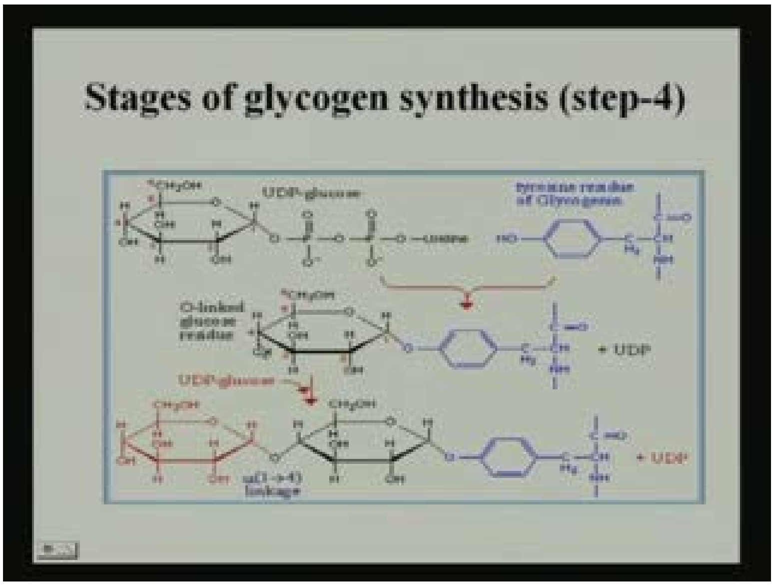

Now say, for glycogen synthesis, glycogenin protein is playing a significant role. Glycogenin protein if we see the structure, we will find that this protein moieties has got one tyrosinase residue. And in this tyrosinase residue we know that one aromatic ring and one hydroxyl group is there with this tyrosin. And this tyrosin when it comes with this UDP glucose which is produced in the earlier step, this UDP glucose and this protein glycogenin protein undergoes this reaction and here this hydroxyl group is getting binded with a first carbon of these glucose moieties and UDP molecules are getting released. And these core moieties this glycogenin protein is getting attached with this glucose moieties of this UDP glucose. Now, it becomes UDP and glucose is getting attached with this glycogenin protein. Now this way UDP glucose is going on supplying, this particular reaction to go forward.

Now every time this UDP glucose is coming in contact with this particular bonding and this fourth carbon you see it is free. And in this way this new, new residues are coming and getting attached.

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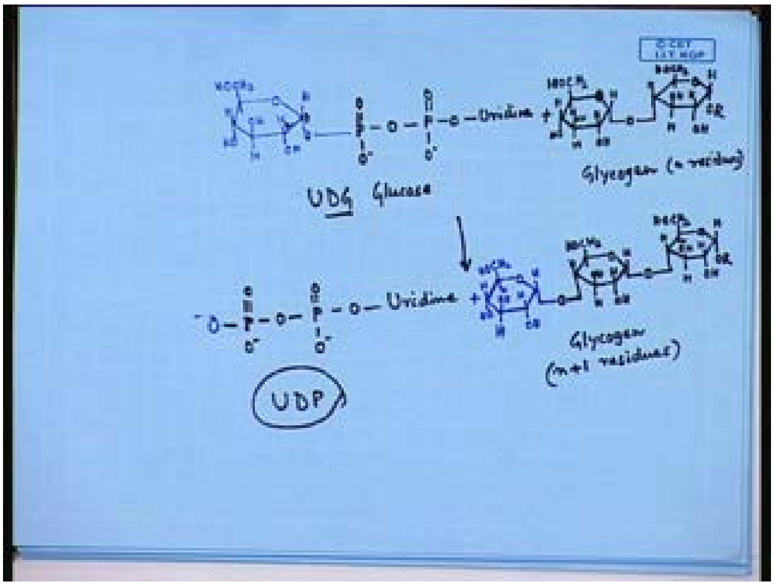

See UDP glucose is here and it is supplying this glucose to this chain and this UDP this glucose is getting attached to this and UDP is being released out of this particular reaction. That means UDP glucose is acting as the glucose donor to this and in this way the chain length of this glycogenin and one end is attached to the glycogenin protein and this way the chain length is getting increased. And it is getting attached with the this alpha one four glycosidic linkages. Now, if we see the glycogen synthesis now this way the synthesis is taking place within the cell.

Now a glycosidic bond is formed between the anomeric C 1 carbon atom moieties derived from UDP glucose and the hydroxyl thriosine side chain of glycogenin UDP is released as a product. So, see this particular reaction here which is there you see this here this first carbon, this is the first carbon, this is the second carbon. So, first carbon is getting linked with the tyrosinase this is the hydroxyl group and it is getting linked with the first carbon. The fourth carbon is getting free and when another residue is coming then it is getting linked with the first carbon of another glucose moieties. And in this way alpha one four glycosidic linkages is formed with this particular reaction.

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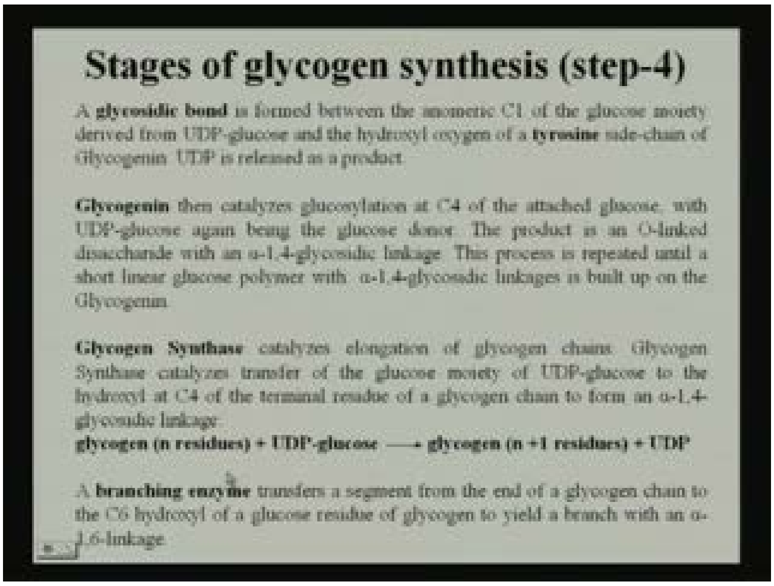

Glycogenin is then catalyzes that glycosylation at C 4 of the attached glucose with UDP glucose again being the glucose donor. The product is and O linked disaccharide with an alpha one four glycosidic linkage. This process is repeated until a short chain of glucose polymer is produced and alpha one four glycosidic linkages is build up. Glycogen synthase is the enzyme which catalyzes the elongation of the glycogen chain. That means, how been this chain length will be. Glycogen synthase catalyzes the transfer of glucose moieties. That means in presence of this glycogen synthase enzyme, the supply of UDP glucose is continuing and chain length is being determined to the hydroxyl C 4 of the terminal residue of the glycogen chain to form alpha one four glycosidic linkages. The branching enzyme transfers a segment from the end of the glycogen chain to the 6 hydroxyl group of the glucose residue.

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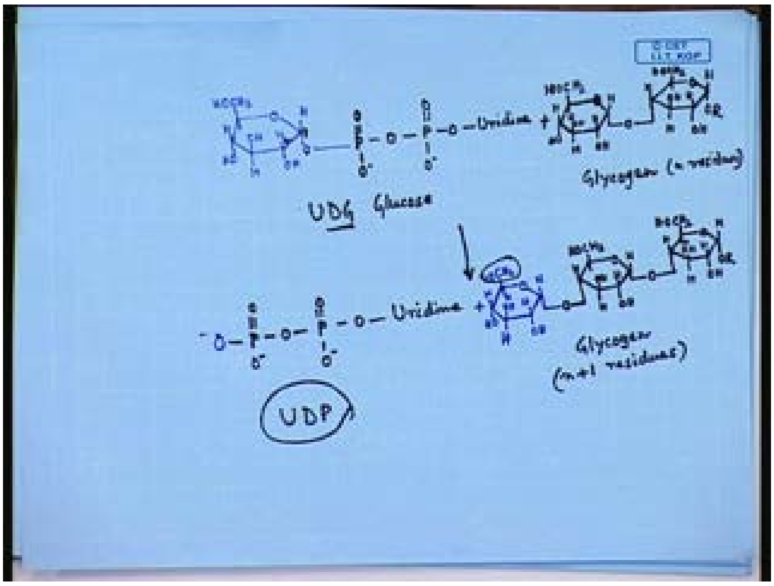

So, this 6 hydroxyl group of the glucose residue and from here the branching of alpha 1 6 linkages starts which completes the actual glycogen structure. So, one is the linear chain another is the branch chain. And here this branching is taking place and this way the glycogen is getting synthesized in the cell.

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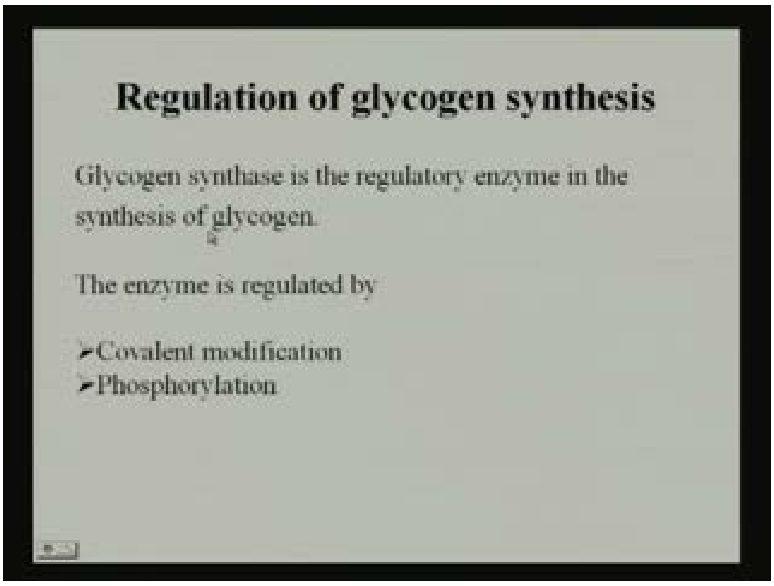

Now, glycogen synthase is the regulatory enzyme in the synthesis of glycogen. That means, in glycogens synthesis that enzyme glycogen synthase is playing a significant role. The enzyme is regulated by covalent modification and phosphorylation.

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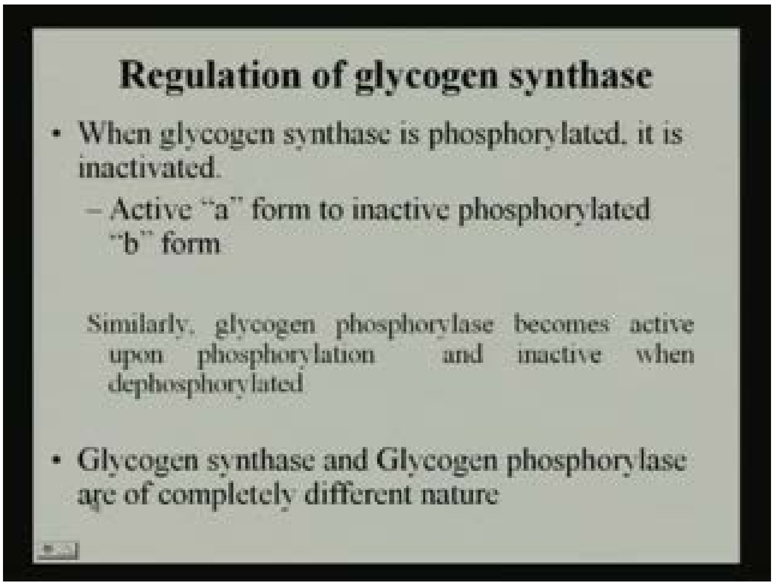

Now, if we see the regulation of glycogen glycogen synthase enzyme, we can find that when glycogen synthesis phosphorylated it is inactivated. That means in the non-phosphorylated form of glycogen synthase is the active form. And when it is getting inactive, that means it is phosphorylated. It is similar to that of glycogen phosphorylase enzyme which is active upon phosphorylation and inactive upon dephophorylation. And that thus glycogen synthase and glycogen phosphorylase are completely different in its activities. So glycogen synthase is playing a significant role in case of glycogen synthesis.

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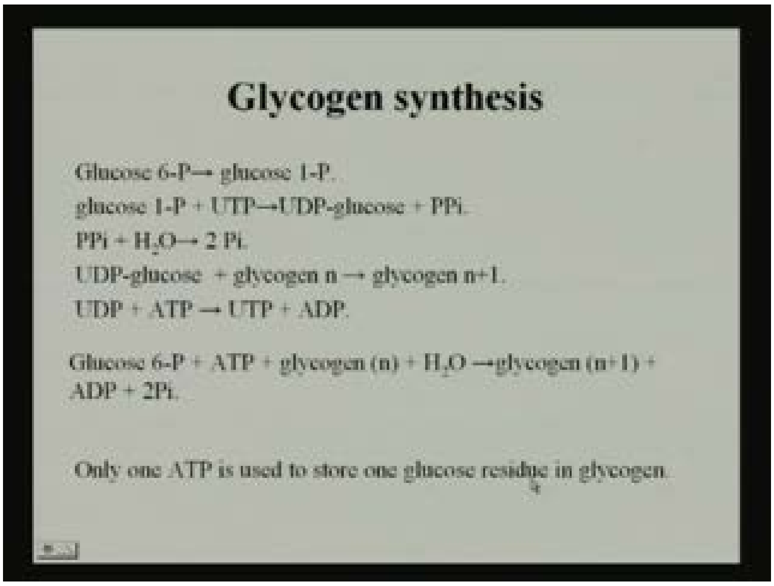

Now if we see the glycogen synthesis, we can find out this glucose 6-phosphate becomes glucose one phosphate. Glucose one phosphate in the presence of UTP produces this UDP glucose and PP i. This pyrophosphate in presence of water is giving inorganic phosphate. UDP glucose now it supplies this glucose moieties to the glycogen moieties and this glycogen become glycogen in plus one. And in this way there's number of UDP glucose is increasing the chain length of glycogen moieties. Glucose 6-phosphate plus ATP plus glycogen n molecules of glucose moieties plus water molecule gives rise to glycogen n plus 1 plus ADP plus 2 P i. The only ATP is used to store one glucose residue in glycogen.

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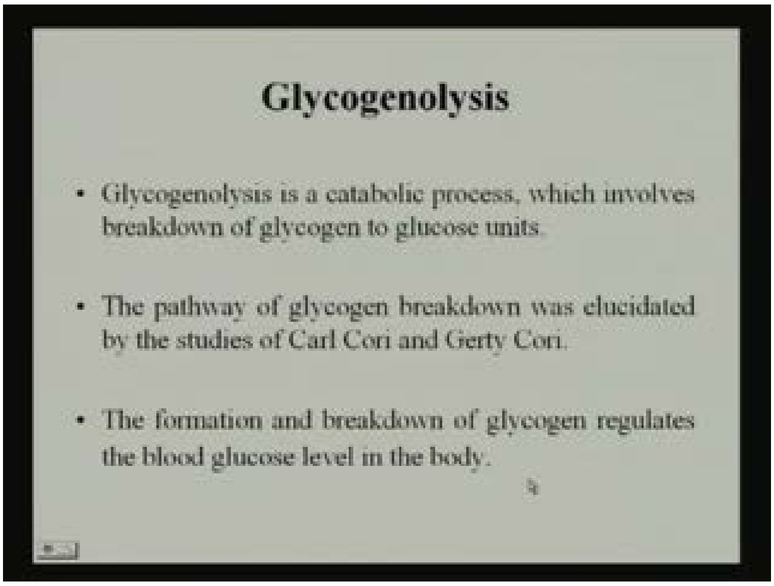

So, this is the glycogen synthesis in the cell. Now if we see the glycogen break down that means, when the cell is in need of glucose then glycogen is once again chopped down to glucose moieties. Now how it is taking place? Glycogenolysis is a catabolic process which involves the breakdown of glycogen to glucose units. a The pathway of glycogen breakdown was elucidated by the studies of cori and cori. The formation and break down of glycogen regulates the blood glucose level in the body.

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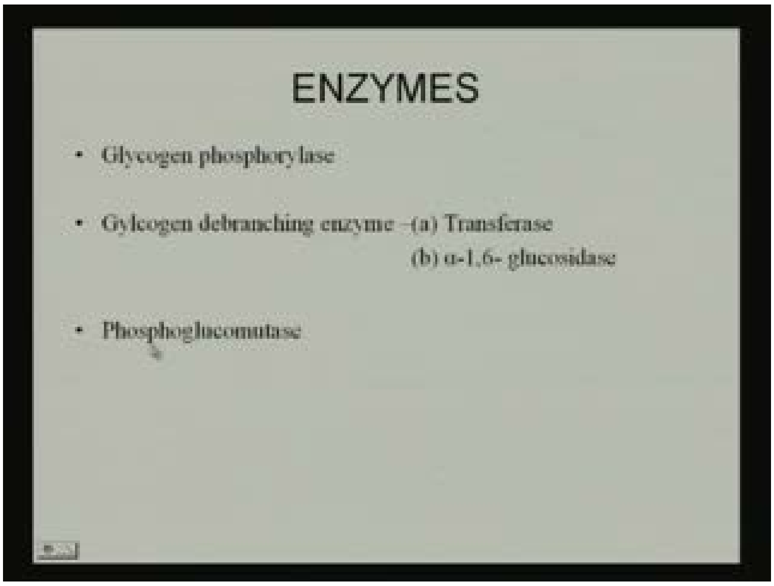

Three enzymes are playing a very important crucial role in this glycogen break down process which is the glycogen phosporylase, glycogen branching enzyme that is branching enzymes are once again divided into two; one is called the transferase, another is the alpha 1 6-glucosidase and third is the phophoglucomutase.

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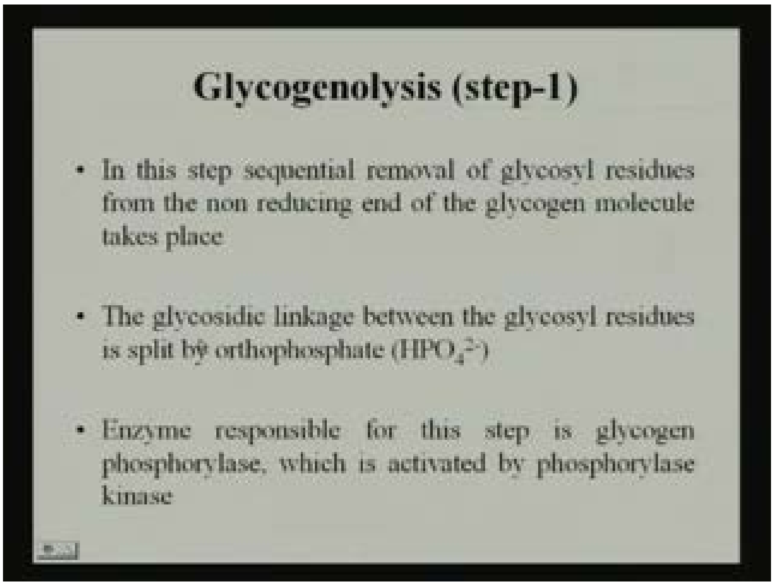

Now these three enzymes are playing a significant role in this process. Now how this glycogenolysis takes place? Now in the step one, what is happening? The sequential removal of glycosyl residues from the non-reducing end of glycogen molecules takes place. Glycosidic linkages between the glycosyl residues is split by the orthophosphor phopharic acid. That means inorganic phosphate orthophosphate is playing a significant role. Enzyme responsible for this step is glycogen phosphorylase which is activated by phosphorylase kinase. Now, this particular enzyme is very important as far as the breakdown of glycogen is concerned. In case of glycogen synthesis, glycogen synthase enzyme was playing the significant role. But, here in during this breakdown process glycogen phosphorylase in the presence of phosphorlyase kinase is playing a significant role.

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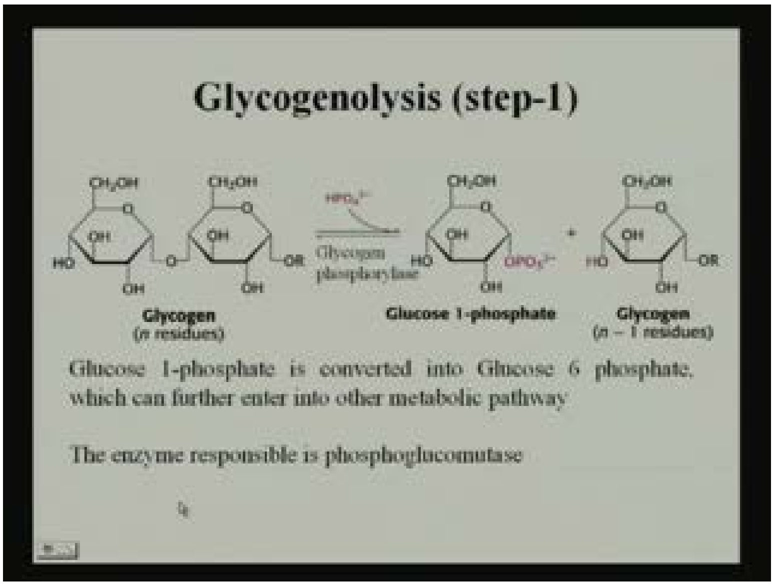

In the first step of glycogenolysis, we can see this is the one for glycosidic linkages n number of such chains are there. In presence of orthophosphate and in presence of glycogen phosphaorylase enzyme this it is getting this inorganic phosphate is occupying the first position of this glucose. Glucose one phosphate is produced and here n number of this n minus one glycogen residues are remaining. Glucose one phosphate is converted to glucose 6-phosphate which can further enter to the metabolic pathway. The enzyme responsible for this particular reaction is the phosphoglucomutase.

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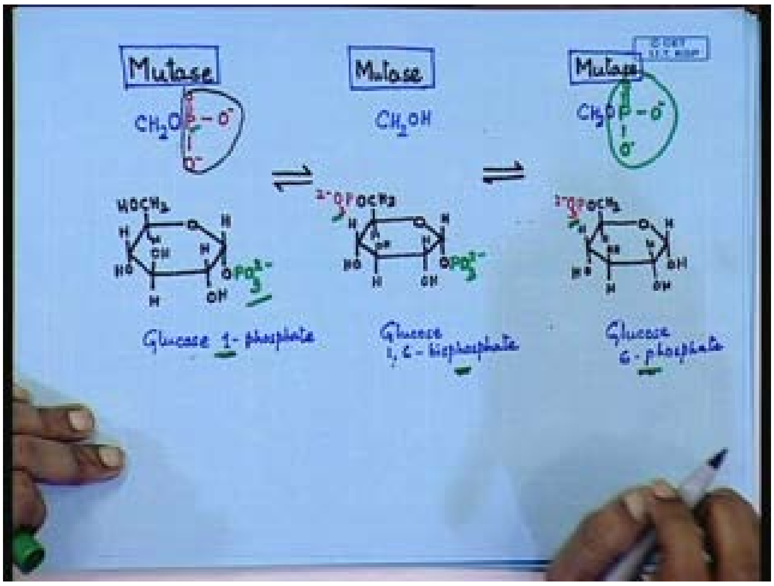

Now phosphoglucomutase is converting glucose one phosphate to glucose 1 6-bis-phosphate and ultimately it is producing glucose 6-phosphate. You see here, as I have told you that phosphoglucomutase is a very interesting enzyme. It contains some phosphate group within this and when you see glucose one phosphate has got already one phosphate in the first carbon and here this phosphate is being donated to the 6th position of this glucose and it becomes a glucose 1 6-bis-phosphate. This particular product is a very, very unstable product and immediately. What this mutase enzyme is doing? It is taking up the phosphate group from the first carbon and it go it taking back this phosphate group once again to it donating this phosphate to the 6-phosphate. And glucose one phosphate becomes glucose 6-phosphate. So this is the reaction which is going on inside the cell.

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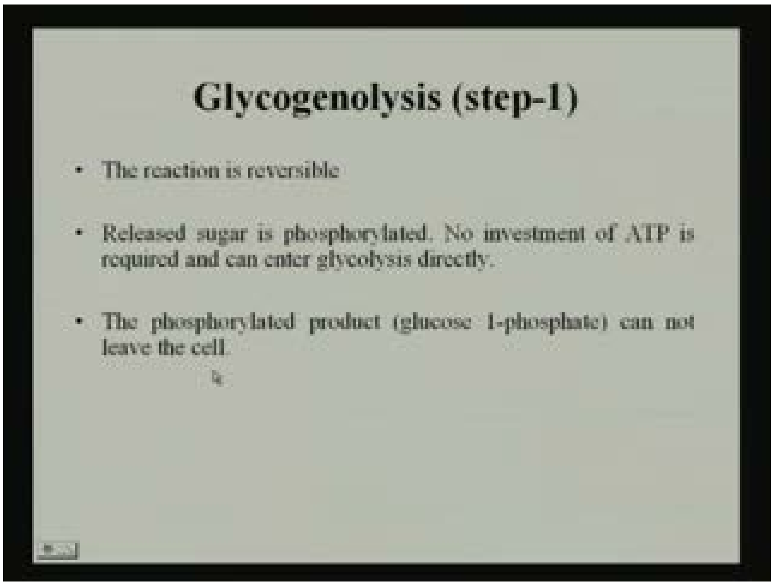

Now this reaction is a reversible in nature. Released sugar is phosphorylated. No investment of ATP is needed because inorganic phosphate orthophosphate is donating this phosphate group. No ATP is needed in this particular reaction required and can enter to the glycolysis directly. The phosphorylated product of glucose one phosphate cannot leave the cell.

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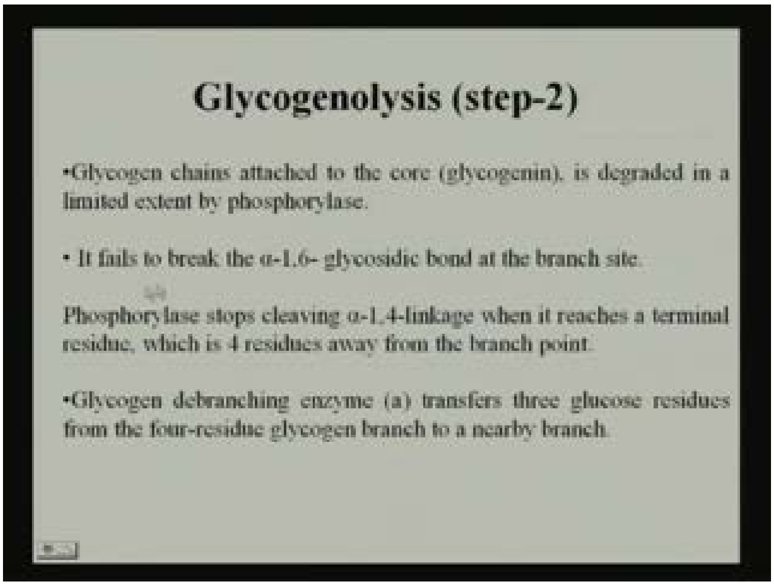

While coming to the step two; we can see that glycogen chain is attached to the core glycogenin protein is degraded into a limited extend by this phosphorylase enzyme. It fails to break the alpha 1 6-glycosidic that means, the branching chain; straight chain and brach chain it fails to break the branching chain by this alpha 1 6-glycosidic bondings are there. Phosphorylase enzymes stops the cleaving of alpha 1 4-linkages when it reaches the terminal residue which is 4 residue away from the branching point. This is very interesting mechanism.

Now, glycogen branching enzyme transfers the three glucose residue from the four residue glycogen branching to the nearby branch. Now here see 2 points; phosphorylase enzymes stop cleaving alpha 1 4-linkages till the four residues are left in this process.

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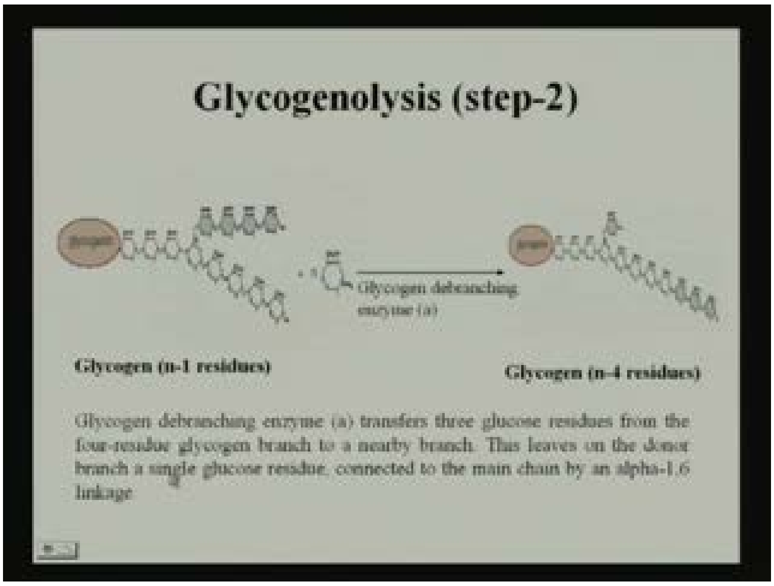

That means you see this is the alpha one four linkages. This is 1 6 and the 1 4-linkages are there and this track chain is going on and this phosphorylase enzyme is cutting down this and releasing this glucose moieties free from this branch until and unless four residues are left. As long as four residues are left. It stopped its cleaving. That means here a 1 6-linkages are there. What then it is doing now? What it is doing it is now enzyme that is that, transfer the three glucose residues from the 4 carbon chain. That means, this three carbon sugar is now getting cleaved by this enzyme and it is getting debranched and coming and getting joined to the nearby chain. So here, from the four glucose residues were there. Three glucose residues were debranched by the enzyme the transfer is and it transfered these three moieties to this linear branch remaining this one glucose with this alpha 1 6-linkages are there.

Now glycogen debranching enzyme a transfer this glucose three glucose residues to the four residues glycogen branch to the nearby branch it is getting joined. These leaves on the donor branch a single glucose residue which is attached or connected to the main chain by an alpha 1 6-linkage.

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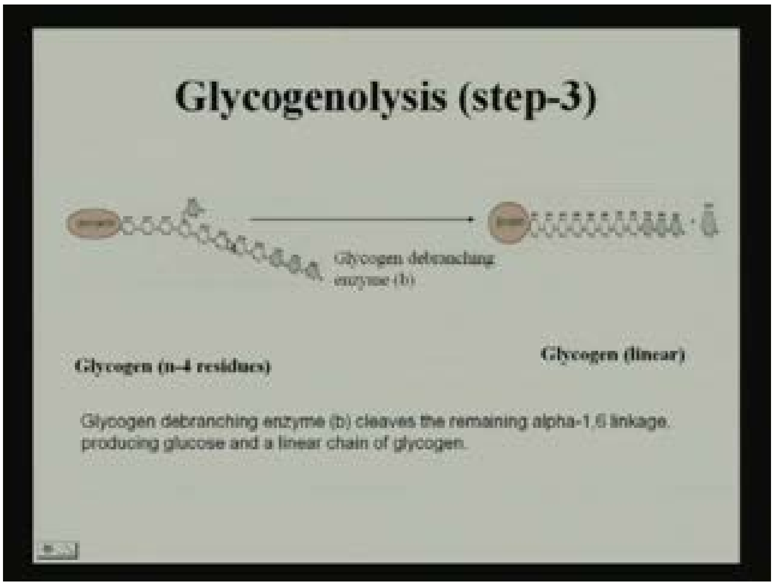

Here, this one glucose moieties which is left this glycogen branching enzyme b is now cleaving this 1 6-glycosidic linkages and making this glucose moieties free. And it becomes once again the linear chain and linear chain once again it will start breaking this particular glycosidic, this glycogen molecule and giving a continuous apply of glucose to the system.

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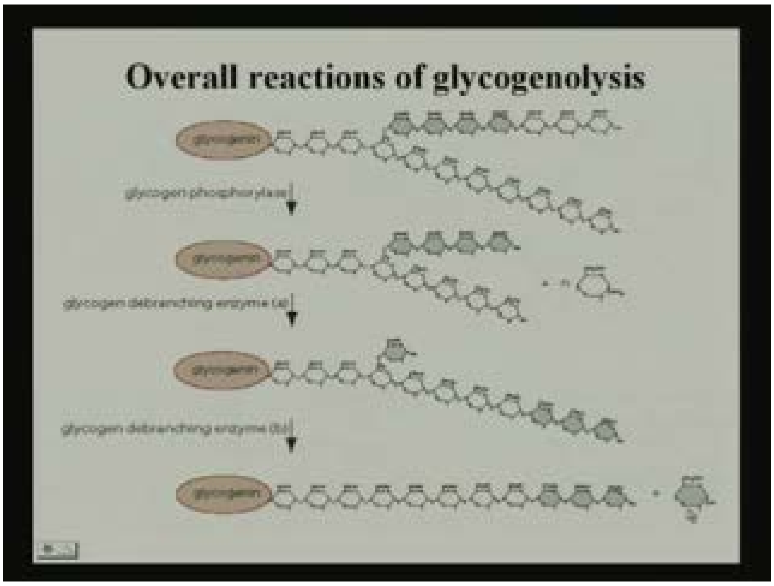

Now if we see the overall reaction, then we can find that you say this is the glycogenin protein which is attached to this glycogen and glycogen has got a one four and 1 6 linkages. So, one four linkages are the linear and it goes on chopping in a normal position. In case of 1 6, this 1 6 is the branching and there after once again this 1 4-linkages are there.

So it starts cleaving from the non reducing end of this sugar. And as soon as 4 carbon moieties are there, it stops its cleavage. When 4 carbon moieties are left, then phosphoryl this debranching this enzyme a is now active and it cleave the three carbon residue from this 4 carbon sugar moieties and it comes and getting attached to this main chain. This any straight 1 4-glycosidic linkage and here one glucose molecule is remains attached to with 1 6 glycosidic linkage. Now, when this 1 6-linkage is this sugar moieties is left then, once again glycogen debranchaning enzyme b is active and here it cleaves this 1 6 branching leaving this glucose moieties free from this branching chain and glucose moieties are getting free. And in this way this breakdown mechanism is going on inside the cell.

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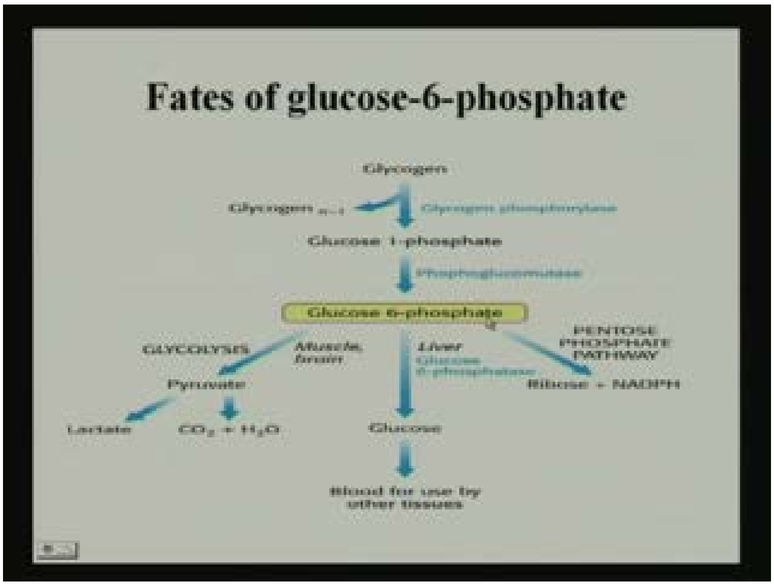

So we have learnt the glycogen synthesis, glycogen breakdown. This glycogen synthesis and breakdown is totally dependent upon the concentration and the availability of glucose within the cell. Now if we see, the fate of glucose 6-phosphate which is there, so we can see that this glucose 6-phosphate which is produced from either glycogen, this glycogen is converted to glycogen, glucose one phosphate. Glucose one phosphate is once again converted to glucose 6-phosphate and this glucose 6-phosphate under goes different reaction where in a muscle cell or in a brain cell through glycolytic process it under it is converted it is getting oxidized to (( )) pyruvate further. In under anaerobic condition pyruvate is getting converted to lacktate. Pyruvate can enter to the TCA cycle with the release of a molecule of carbon dioxide and acetyl coa is formed and TCA cycle starts that enters to the respiratory chain. Glucose 6-phosphate inside the liver, in the presence of glucose 6-phosphatase enzyme is getting dephosphorylated and it becomes this glucose. And this glucose can now come to this blood stream and it can go to the different part of the cell and it supplies the energy. Glucose 6-phosphate can also enter to this pentose phosphate pathway where glucose 6-phosphate we have learned that how it is converted to 5 carbon sugar, ribose sugar and NADPH. So, this is the overall effect of glucose 6-phosphate in the cell.

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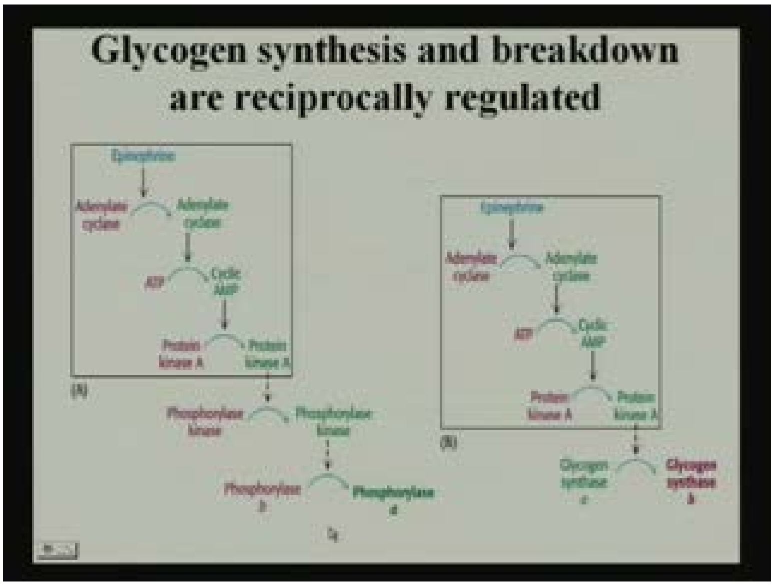

Now if we see the glycogen synthesis and breakdown; we can find that these are reciprocally regulated within the cell. Now if we see, this the hormone epinephrine it is activating adedylade cyclase enzyme which is in the active, in inactive form. With the release of this epinephrine hormone it becomes active and it is becomes adenylade cyclase. Once this enzyme is active, ATP is converted to cyclic a m p. Cyclic a m p when warmed it once again activates the inactive protein kinase a two protein active protein. Kinase a when protein kinase is active, it is regulating this phosphorylase kinase of this enzyme. And this phosphorylase kinase under goes this then it is active it is undergoing the phosphorylase v form inactive form to phosphorylase a form. And when we have seen that in the in the in the cell when phosphorylase a is active. That means glucose under starting condition when body needs glucose then this particular breakdown process is to be taken place. And in this phosphorylated form we have seen that this particular enzyme is very active. That means this when body is under starving condition this epinephrine hormone is the indicator and which is just switching on and switching off the different active and inactive form of this enzyme. And this phosphorylation and body is now getting continuous supply of glucose which is getting chopped, which is getting broken down to glucose from glycogen and this way this is controlling this particular pathway.

Similarly, the this particular when reaction starts, that means we have to also stop this glycogen synthase. Glycogen synthase we have seen that, when this glycogen synthase is there that means it is converting glucose to glycogen. But, body is in demand of this glucose. So, we cannot use this particular enzyme this enzyme to be active. So what it is doing? This adenylate cyclase it is coming this protein kinase up to protein kinase is active. Protein kinase is now inactivating the glycogen synthase which is synthesizing, which is utilizing this glycogen synthesis process and it gets stopped. So glycogen, glucose to glycogen formation is getting stopped. And here when this body is under high demand of glucose, this phosphorylase a enzyme is active. So, chopping down process and the breakdown process takes place and supply of glucose in the body is taking place.

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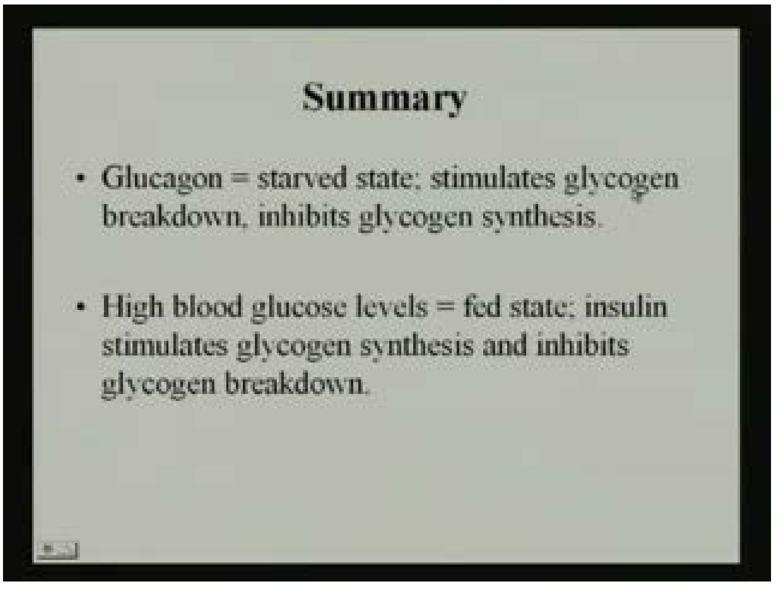

So in conclusion, what we can do, tell? That glucagon is helping when the body is under starving state it stimulates glycogen breakdown inhibits glycogen synthesis. And when high glucose body is having very high glucose, this fed state the insulin stimulate glycogen synthesis and inhibits glycogen breakdown so that further concentration of glucose in the cell is getting controlled. And in this way this pentose phosphate pathway glucose synthesis and glucose breakdown is taking place in the cell. And it is also being controlled simultaneously within the cell system. Thank you very much.