Animal Physiology
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Module - 1
Lecture – 21

Welcome back to the lecture series on NPTEL on animal physiology. So, we are in section 13. So, we have done with the part 1 of the section 13 on metabolism and temperature regulation. So, now we are moving on to the part 2. So, in the part 1, we talked about how the overall flowchart or the overall scheme of things like in anabolism, catabolism, synthesis, break, breakage of another classification of lipids carbohydrates and proteins. We talked about the absorption of minerals and we talked about how the different individual components of this are through facilitated diffusion.

And diffusion co transport are being absorbed by the intestinal mucous and in transported at different parts. Then we talked about the trepcycle, we talked about the cellular metabolism, we talked about the TRICOR of silicosis cycle or trepcycle how from a single glucose molecule through the whole process of cellular metabolism we 36 molecules of ATP. So, today what we will do? We will resume from there. So, we will talk about the other route called gluconeogenesis. So, initially we talked about glycolsis; glycol means carbohydrate lysis lyses means breaking of carbohydrate.

So, when you are breaking a single molecule of carbohydrate essentially you are obtaining 36 molecules of ATP. Now, think of a situation if you had to follow a reverse route when you have to synthesize it. So, when I talked about gluconeo genesis. So, have to just break it down into 3 parts gluco means relevant to carbohydrate neo means new genesis means formation gluco neo genesis. So, we finish with gluco neo genesis and a flow chart of how gluco neo genesis taking place? And then we will move on to the lipid metabolisms synthesis of lipid and degradation of lipids and absorption of lipids. And then we will move on to the proteins the synthesis of amino acids, degradation of amino acids and absorption of amino acids and then of course, our tape using their temperature regulation. So, let us resume with the gluco neo genesis.

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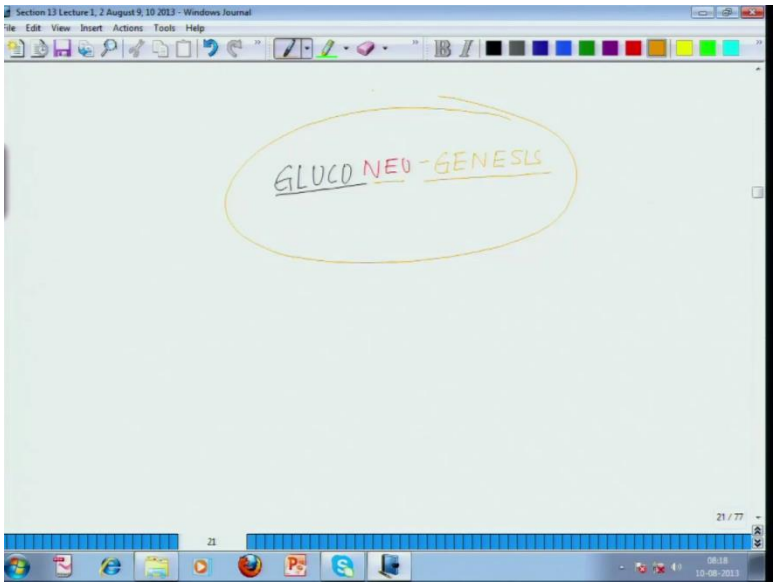

So, let us come back to the gluco neo genesis. Gluco neo genesis; so this is what essentially gluco neo genesis.

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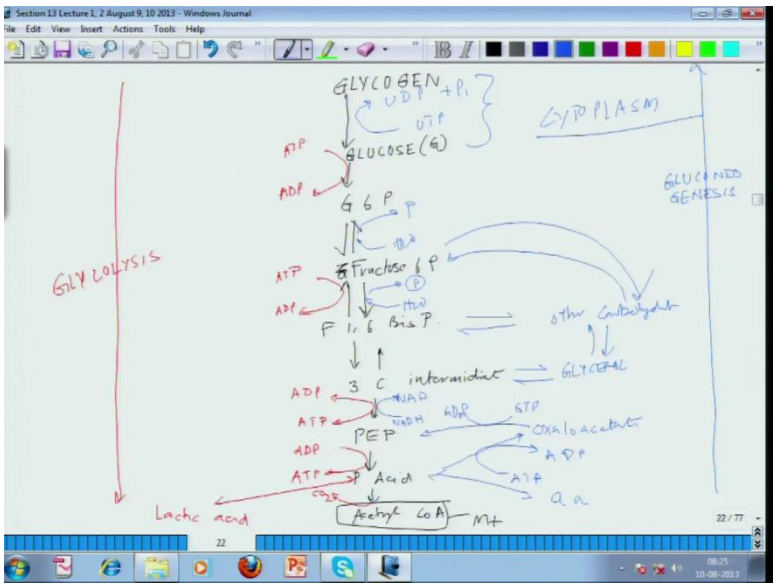

So, let us get back to the cycle what is exactly happening? So, you have the glycogen which is big carbohydrate molecules. This glycogen is through glycolsis is broken down into glucose. From glucose representing glucose by G and then you have glucose 6 phosphate then you have sorry this is fructose 6 phosphate. Then you have fructose 16 bis phosphate then you have 3 carbon intermediate. From there you have phrospornal

pirovate PEP then you have pyruvic acid and when this ends enters to through acetyl coenzyme a inside the mitochondria. So, let us come in back to the gluco neo genesis part.

So, what I will do is that I will initially talk about again reiterate all the different steps of glycolsis. And then I will go on the reverse direction where from the single molecule single precursor how the glucose molecules are being formed. So, start with the glycolsis chart what you have done in the previous class. So, you have the glycogen forming your glucose. So, let us come back to the chart glycogen forming glucose from glucose to glucose 6 phosphates and to FRS futo fructose 6 phosphates. And during this process what is happening? Glucose to glucose 6 phosphate here basically ATP in being used up.

So, that is the phosphate which is providing sufficient energy. And then from fructose 6 phosphate to fructose 1 6 bis phosphate again an ATP is being used up to form ADP. And then from 3 carbon intermediate to phrospornal pirovate this is the zone where both thing could happen ADP ATP both direction it can run and from phrospornal pirovate to pyruvic acid this is another where from ADP to ATP is formed. And out here C o 2 is been given out and from pyruvic acid your option there is another option it can form lactic acid.

So, this is how pretty much the whole glycolsis runs. So, when we talked about the gluconeogenesis we are essentially talking about a reverse mechanism it will move like this gluconeogenesis. So, what is essentially is happening is that? Amino acid is also involved which could be transformed into carbohydrates from here it forms oxaloacatate. In that process ATP is been used up from ADP oxaloacatate forming phrospornal pirovate and in that process GTP is been used up GDP from phrospornal pirovate it follows fairly reverse route it can follow. So, here basically the reverse reaction will be n ADH to NAD.

And through several steps it forms a 3 carbon intermediates then it has options like forming glycerol and from glycerol where as fru fructose 6 phosphate 1 6 bis phosphate and from other carbohydrates. And these are all the reversible reactions which are taking place. And from here other carbohydrate this could form fructose 6 phosphate. And this will process where basically what you happening essentially is that. So, here fructose from fructose 1 6 bis phosphate get some water molecule and it gives out a phosphate.

And similarly again it gives hydrolyze it gives it takes a water molecule and gives out phosphate.

And in the final term when from glucose to forming your glycogen you are using uridintryphosphate to u d p plus phosphate, and this basically a 3 enzymatic process and this whole thing is taking place in the cytoplasm. So, basically what I wish to highlight is catabolism and anabolism with little modification follows they are fairly close by. But some of these cycles are kept preferly conserved, but they do not follow the exactly same route by which they have you know degraded there is always kind of bypass and all those things in that whole process.

So, those of you are interested really to get in depth in to this they may refer to lubber distrier's book on biochemistry leanings; book on biochemistry; void void's book on biochemistry kananistem. There you will get much in depth study about glycolsis and gluconeogenesis and the different enzyme. But being a physiology class I would just give an overall outline of this part of metabolism which is purely I mean classes and class I mean like sections of biochemical pathways or metabolism. So, from here I will move on the lipids, we have talked about the glucose metabolism, now let us move on to the lipids.

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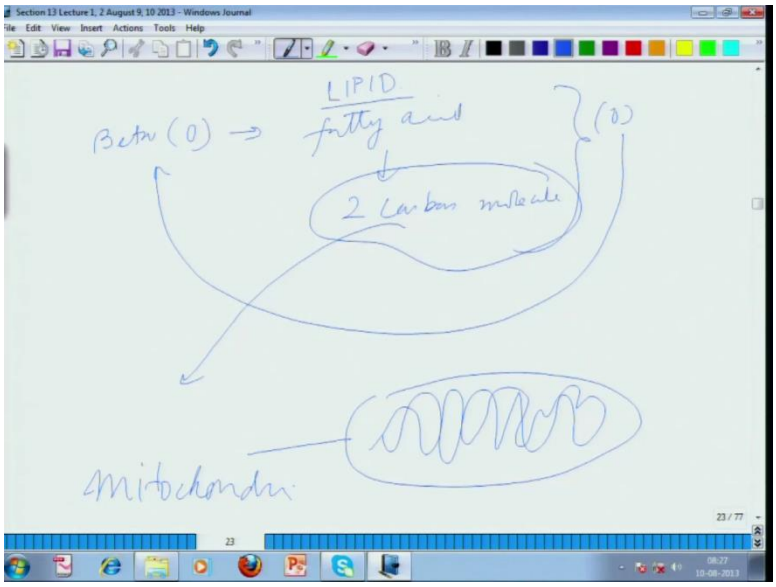

Lipid metabolism; so lipid metabolism again the site of lipid metabolism is the mitochondria. So, mitochondria as it is been very correctly says in cellular metabolism

this is the power house this is where most of the reactions are taking place, because the t c s hike and all are taking place in the myoconria. Because of and it has one of the most unique feature of electron transport chain which is functioning and the energy harvesting taking place through chemi ospotichyptesis by peter Mitchell. So, what so in mitochondria we will be talking about the lipid catabolism which follows a beta oxidation pathway.

Let us talk about that, so talk about the lipids now, so basically beta oxidation is the fatty molecule the fatty acid molecules are broken down into 2 carbon fragment in a sequence of reactions. So, basically what is happening in the fatty acid into 2 carbon molecules and this whole process oxidation is called beta oxidation. And this process occurs inside the mitochondria, so that carbon chain can enter the TCS cycle immediately. From here whatsoever this carbon is happening. So, this is all happening inside the mitochondria.

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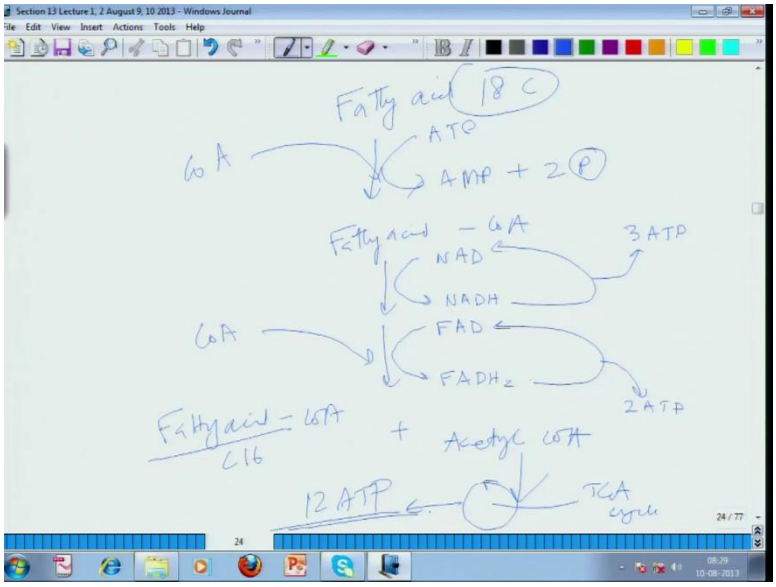

So, without much problem this 2 carbon molecule which is by product of it can move into the get incorporated into the TCS cycle. So, fatty acids say for example, 18 carbon fatty acids then this consumes ATP and forming AMP mono phosphate plus 2 phosphate it is added up with coenzyme a. And it form fatty acid coenzyme A and fatty acid coenzyme an ADN ADH and the process produce 3 ATP in the electron transport chain and then in the second step there is this FAD forming FAD H 2. And in that forming another 2 ATP molecule fatty acid there is another coenzyme a which comes into play.

So, essentially what you are having is that fatty acid Co A this fatty acid is C 16. So, you start with C 18 you end up with C 16 plus acetyl co a. And this acetyl Co A which is formed here becomes part of the TCA cycle producing 12 ATP molecules.

So, you see from 18 carbon chain it becomes 16 carbon chains. In the process 16 carbon chain it formed an acetyl coenzyme a that gets incorporated into the ((Refer Time 12:50)). So, this is how most of the fats kind of you knows breaks down from 2 molecules. So, 16 14 12 10 likewise their sizes gets chopped off slowly and you will end up with a smaller molecules. So, this is the catabolic process what lipids follows coming back to the slides. So, this where basically lipid metabolism is happening, so what about the lipid synthesis? So, we have talked about the catabolism.

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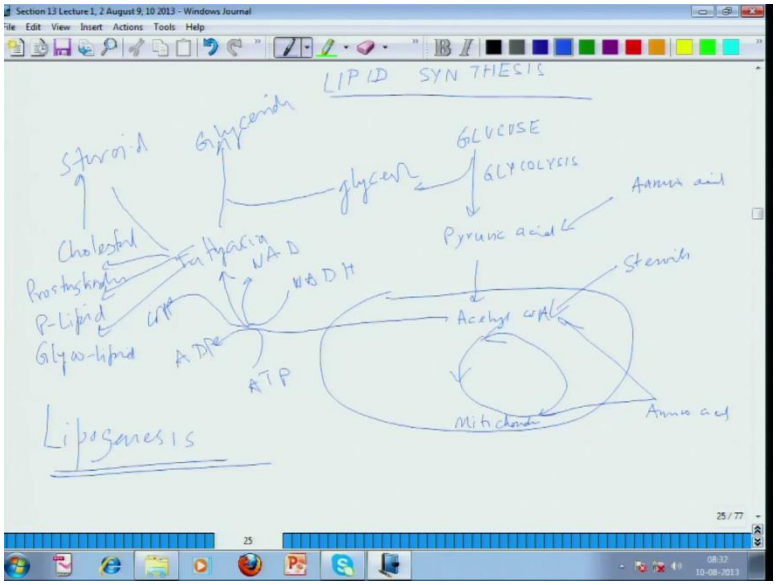

Lipid synthesis; lipid synthesis is essentially is happening in several ways, so let us start with the glucose as a starting point. Glucose throws glycolsis making pyruvic acid this pyruvic acid forming into acetyl coenzyme a. So, this is pyruvic acid with along with other amino acids and you know this is all happening inside the mitochondria this is all out side is all cytoplasm. So, acetyl coenzyme a and the steroids amino acids these are all different ways by which all this different molecules are getting incorporated into the cycle this acetyl coenzyme a which is sorry formed here is the one. So, you have this glycerol this glycerol comes here and this acetyl coenzyme a utilizing n ADH forming NAD.

And in the process here a ATP is been consumed to make ADP and secrets coenzyme a leads to the formation of fatty acid. Fatty acid when it is makes with the glycerol from glycoride and these fatty acid involved in formation of several intermediate which includes glycolipid phospholipids. I am just putting p phospholipids prostaglandin cholesterol in the memory and if you remember all this things were being add present and this whole process is called lipogenesis. So, this is the whole process overall geometry of the lipogenesis and from here what we will do? We will talk about the lipid transports and distributions. So, you if you look around if you see the cycle as long as your concept about the TCA cycle is clear.

And you can correlate the different molecules how they are fitting in the form after forming coenzyme a. Rest is all kind of you know you can develop from there, but you have to at least understand one cycle from a where glucose 2 pyruvic acid and then getting into coenzyme a getting into tricorboxcylic acid site. That concept has to be clarified first once that is cleared clear then the rest will fit in there. I mean acids can fit in there your lipids can fit in there everything can fit in, but you have to first of all understand one basic pathway. So, from here we will talk about the transport of lipids and the different forms of lipids by which there are being absorbed in the body. Coming back to slides, so the following what we basically essentially starting off with this now, is the lipid transport and distribution.

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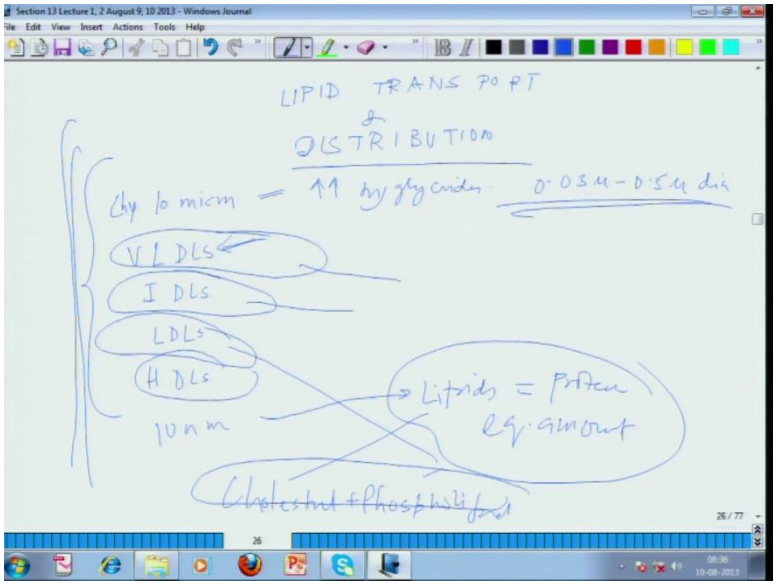

So, if you look at the distributions of the lipid they are in different forms. And this you come across on second chylo micron very low density lipoprotein. Then you have intermediate density low proteins, low density lipoproteins, high density lipoproteins. At least there are 5 different forms of lipids which are like 5 major groups of lipoproteins which are recognized. Chylo micron which is roughly is the 95 percent of the weight of chylo micron consist of triglycerides very huge concentration of triglycerides which are present here.

And chylo microns are the largest lipoprotein ranging basically their diameter may vary from 0.03 micron to 0.5 micron. So, this is the dia of chylo microns very low density lipoproteins contain triglyceride manufactured by the lever plus small amount of phospholipids and cholesterol. This is what the very low density liquid proteins we are talking about intermediate density lipoproteins are pretty much intermediate in size with respect to very low density lipoprotein. And low density lipoproteins and they contain a smaller amount of triglyceride than very low density lipoproteins and eligibly more phospholipids and cholesterol than low density lipoproteins.

This is pretty much we are talking about very low density lipoprotein and intermediate density lipoproteins. Then we are talking about these one's which are low density lipoproteins they contain cholesterol and lesser amount of phospholipids and then we have the high density lipoproteins. High density lipoproteins are about 10 nanometer in diameter and they have roughly equal amount of lipids and proteins which are present they are largely cholesterol and phospholipids cholesterol plus phospholipids. And their

primary function of low high density lipoprotein in is transporting excess cholesterol peripheral issue back to the lever storage. So, these are the different forms of the lipoproteins which are present. So, the lever controls the distribution of the other lipoproteins.

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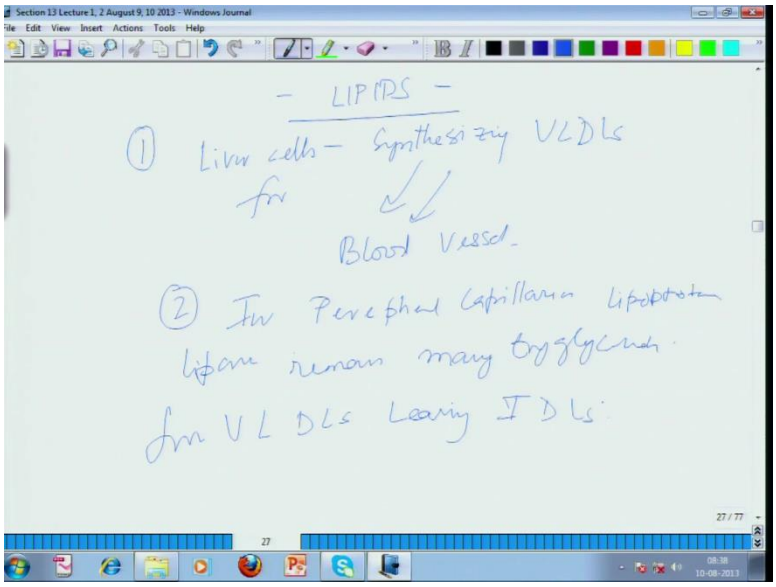

So, some of the methods what lipids follows in this whole scheme of things. So, basically what is happening is that liver cells are synthesizing very low density lipo proteins for discharging them into the blood vessel that is what liver cells do. And in peripheral capillaries, lipoprotein lipase remains many triglycerides from very low density lipoproteins and leaving the intermediate density lipoprotein. So, in that process if have to put it in diagrammatic fashion, so it will be something like this.

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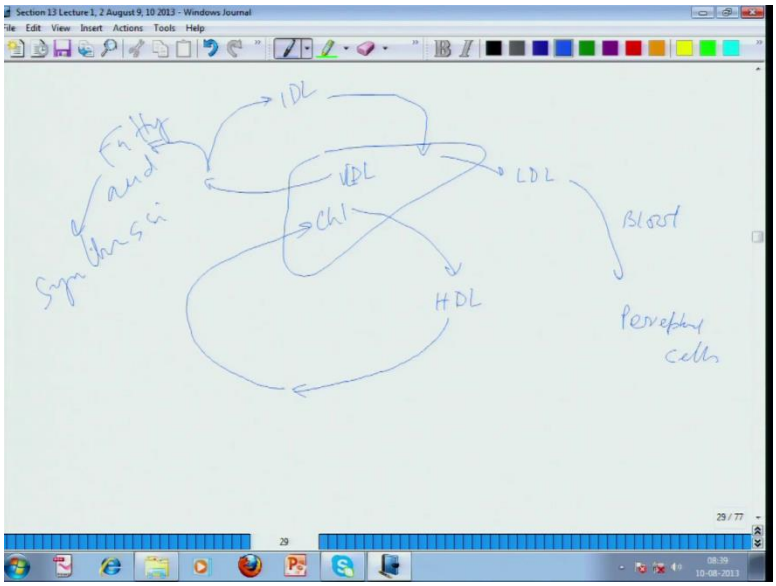

So, if you if this is the liver out here. So, from here the low density lipoproteins are being treated through the blood they are reaching to different peripheral cells. Similarly, I am just putting cholesterol as c h l cholesterol which is released from here is been taken by high density lipoproteins. And this high density lipoprotein through the blood vessels defuses out and they again come back. Whereas, some of these intermediate density lipoproteins are coming back after brokage of very low density lipoproteins. They are broking down and some of the fatty acids are being used for synthesis and where the intermediate lipoprotein comes back to the liver.

So, it is kind of a continuous turn over which is taking place across the liver in that whole process. So, this is something which I wish to highlight. So, if you look at it like what I will request you go through the liver biochemistry that will give you an overall idea how different kind of lipos molecule like how chylo microns low density, intermediate lipoprotein, high density lipoprotein, very low density lipoproteins are been transported synthesize transported. And this is critical, because whenever there is lever damage all these things are getting compromised and more and more we understand if you look at your blood report. It will say high density lipoprotein cholesterol level low density lipoprotein what is good for your heart what is not good for your heart? So, all those things, so see this is out of the preview of this course.

So, I will request please go through any Tec pick up any standard text book and in biochemistry and go through how these different lipids are been synthesis. So, I give you a kind of rough idea about it, but it I will be good if you refer to it those of you who are interested to learn more about these different lipoproteins and the chylo microns and everything. So, from here I will move on to proteins which is the tale pitch tale piece which is left. So, synthesis of amino acid catabolism and anabolism see here also I will give you certain terms which I explained to you guys. So, I will give you brief idea about them, but then I again I expect you to go through some standard text book of biology or biochemistry mostly. You know to understand in-depth about all these things especially the enzymes involved in the catabolism process and metabolism process of amino acids.

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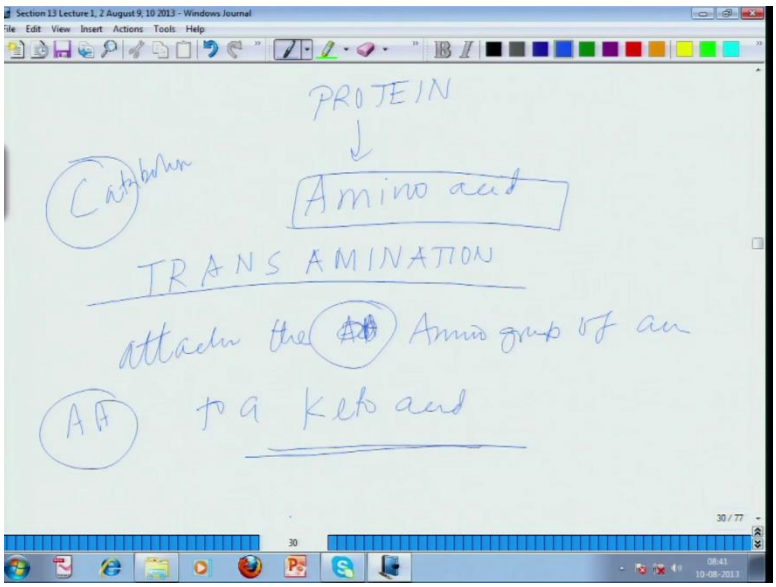

So, getting back to the slides we are into, now Protein anabolism and catabolism protein. So, essentially we are talking about amino acids now, the smaller unit of individual unit of protein. So, some of catabolic processes, so I we are into the catabolism represented by c catabolism. So, one of the processes is transamination what is transamination? Transamination is the basically attachment of the basic group of an amino acid to keto acid. So, transamination is a process where attaches the amino acid I am it is the sorry amino group of an amino acid to a keto acid that is called transamination. So, if I had to show it for little bit of your understanding.

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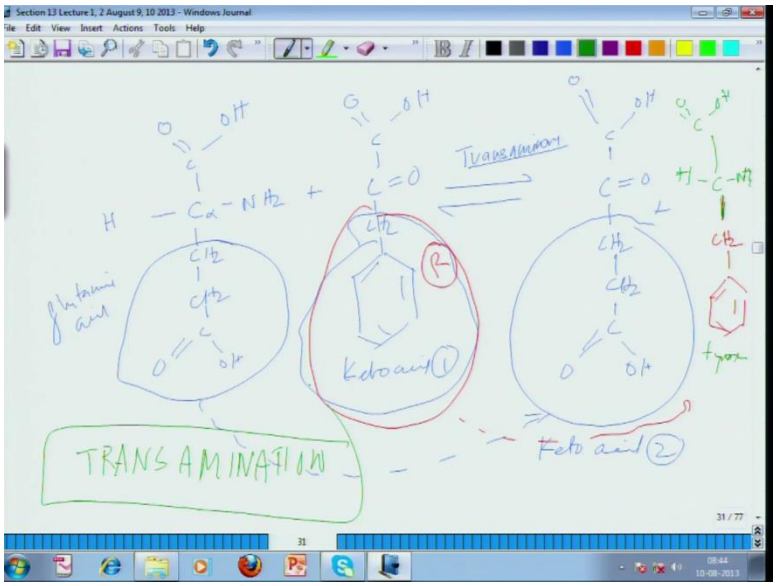

Here is the c alpha of amino acids haxolic acid sorry, one second O H here you have the hydrogen here you have the N H 2 and here you have the functional group which is r group C H 2 C H 2 and say and O H. So, this is basically example of lutamic acid plus the keto acid. So, what is the keto acid? So, here is a keto group and here you have the C H 2 attached to Benzedrine. So, here is the keto acid. So, this is the part of the keto acid. Now during reaction of transamination which is taken carried out by transaminase enzyme. So, Trans means it is transferring what you essentially get out of this is c double 1 with o and here you have C H 2 C H 2 C O H. So, this has moved here, so this becomes a keto acid 2, this is considered as keto acid 1 plus what is left.

So, this you see this functional group out here this r which is present by r group now, this r group here intact C H 2. And this r group is now, attach to 1 second and this r group is attach to amino group out here and you have the hydrogen attached here and. So, this becomes a tyrox. So, this co reaction where there is a transfer or exchange is falls under transamination. This is one of the route by which amino acids are getting degraded. There is another group which is called deamination. Deamination means you are moving the amin group, so talked about transamination where you are transferring group, now we are talking about the deamination. Let us talk about what is deamination?

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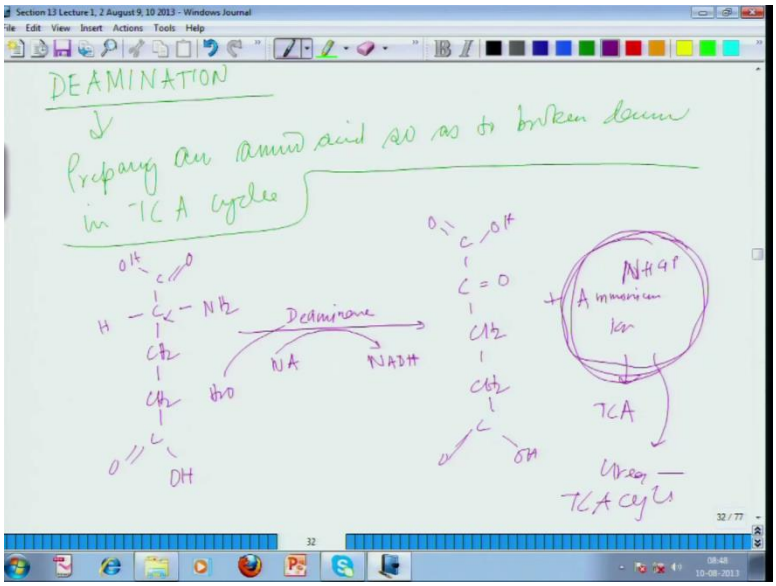

Deamination; deamination is essentially performed in preparing a amino acid from break down of TCA cycle. So, you are preparing an amino acid, so as to be broken down in TCA cycle now, what is deamination. Then, so again deamination let us take the simple example. So, you have the C H 2. So, I am writing lutamic acid recipe now and here you have the alpha carbonamino h hydrogen c o for oxicicic acid. Now, this lutamic acid in the presence of an enzyme called demitasse that is of course, is taking h 2 o and this needs NAD and NAD is getting reduced to n ADH and in that process something will get oxidized. So, what you are essentially getting this c o h and then o and C H 2 C H 2 O H plus ammonium iron which is N H 4 plus this N H 4 plus than become part of the TCA cycle. I will show you in the next slide what is happening?

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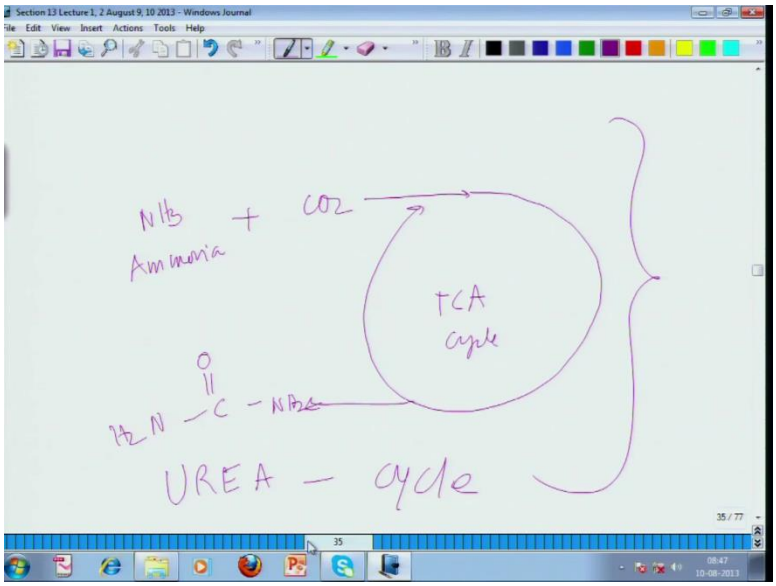

This NH 3 or ammonia plus canbodioxide which is coming from trycloroacilic acid cycle, so you are entering inside the TCA cycle now and output is this which is nothing but urea or this is a urea cycle. So, if you go back to the previous cycle just I am missing upon it. So, we talked about the transamination here we talked about the transamination we talked about the deamination here if you see the deamination. So, it is forming ammonia mine out here and this forms urea through TCA cycle. So, this is what it happens? So, this is essentially is a process by which amino acid molecules amino acids are getting degraded and becoming being removed from the body. So, if you take a very protein rich diet on all likely hoods your urine will have lot more urea as compared to or uric acid as compared to a person who take lesser amount of protein in the diet. So, these are the tools. So, next comes after this.

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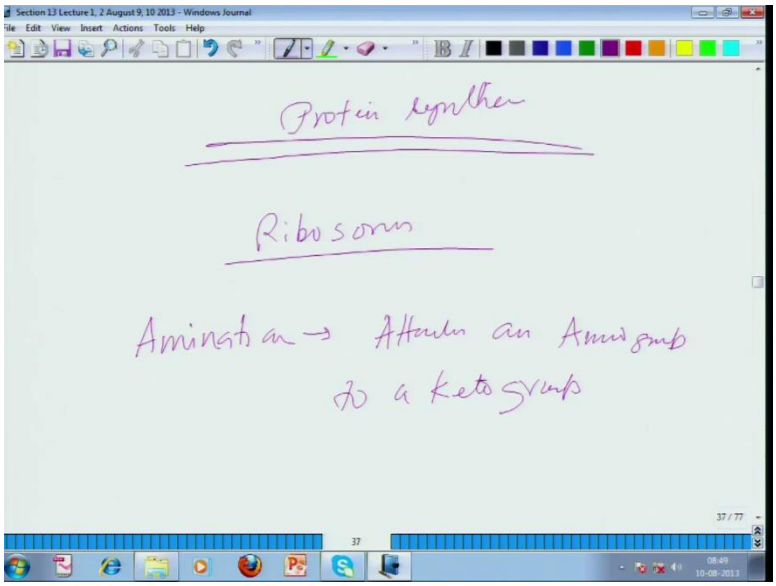

Protein synthesis; so protein synthesis basically is happening in the Ribosome's where basically all the proteins are synchronized by the body through a process of animation which attaches a amino group to a keto group just by the reverse process. So, there is other way there is basically animation technique ways where basically a animation attaches an amino group to a keto group. This is an important step in synthesis in non essential amino acids. So, if I had to give it your overall outline of this whole process.

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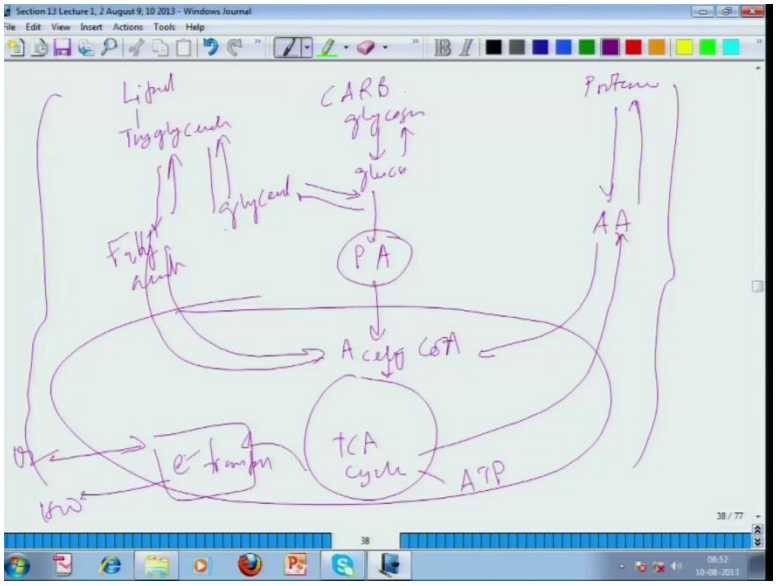

So, it is something like that. Carb proteins lipids and you have this triglyceride have this glycogen to glucose. Again these are all proteins amino acids. And all these are that whole process glucose is forming pyruvic acids am just putting into by P A and that is entering into the mitochondria for the TCA cycle. Where a acetyl coenzyme a these amino acids are also you know in both ways. And here you have the TCA cycle and from here you have the electron transport chain and here through different routes either through glycerol which is coming from at the product of glycolsis. These glycerol and here the fatty acids becoming part of acetyl forming acid coenzyme a and become part of the TCA cycle and there is this ATP synthesis which is taking place. So, this is the overall scheme of the things whenever we talk about the metabolism.

So, they all eventually feed into the mitochondria where the electron transport chains play the critical role. Where the utilization of ATP the formations of ATP s the net gain is end of the day we have high energy production which help up us to grow and survive. And all the intimidate eventually becomes part of this TCA cycle. That is very essential or otherwise the body cannot have you know think of it you know cannot have several units processing several things. The chemistry is very simple they want it to bring it down to a common intermediate. Some common intermediate through which a common cycle can run. Instead of having multiple different cycles all over the place at different organ ails which is time very cumber some. So, this is the overall idea of the of this whole lipid protein carbohydrate metabolism. Now, we briefly talk about some of the absorptive process and thermal regulation process. So, basically this is what is happening?

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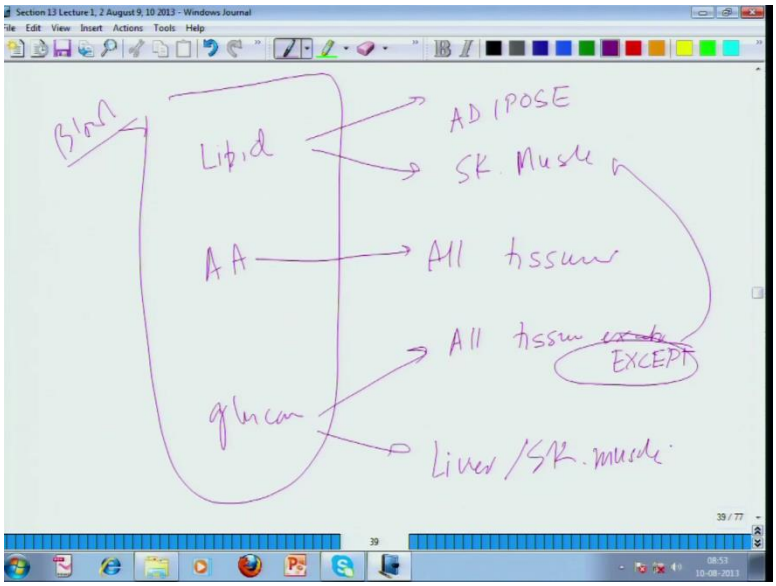

And if you look at some of the absorptive properties what is happenings? ((Refer time 35:41)) blood stream you have lipid. So, this is all in the blood, so in the lipids you have amino acids you have glucose where they are getting stored. So, lipids are getting store in adipose tissue and skeleton muscle. Whereas, amino acids in pretty much in all tissues everybody needs protein. And glucose all tissue expect skeleton muscle expect this is an exception expect skeleton muscle and other than that the liver and skeleton muscle. This is where it goes and talking about distributed in blood stream. So, how these are post absorptive phase, how these are distributed?

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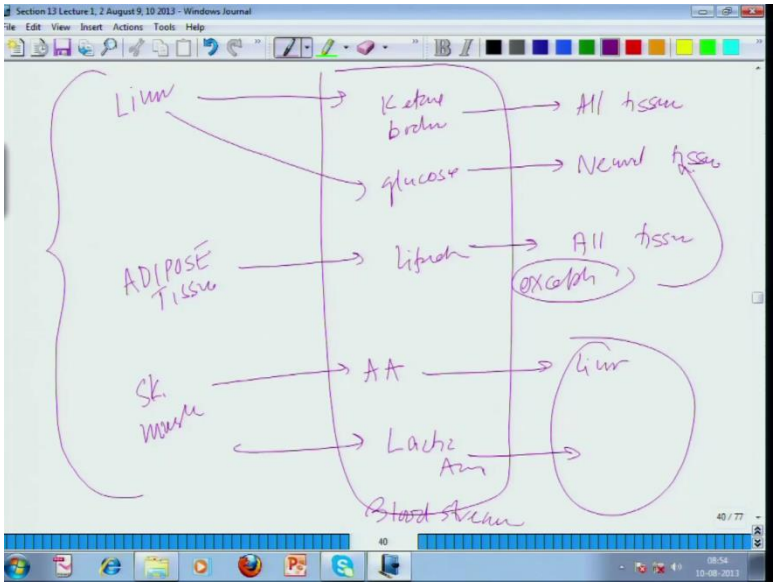

From the liver through different processes; you have ketone bodies than liver you have the glucose. And from adipose tissue you have lipids and you the skeleton muscle you have amino acids and lactic acid and they are all part of the blood stream out here. And the destinations are all tissues glucose goes to mostly to the neural tissue lipids for all tissues except the neural tissue. And you have the enzymino acids going to the liver; lactic acid also goes to the liver. So, this is pretty much is the overall distribution of the different this different kind of tissues in terms of post absorptive phase. Now, from here we will move briefly about the thermo regulation.

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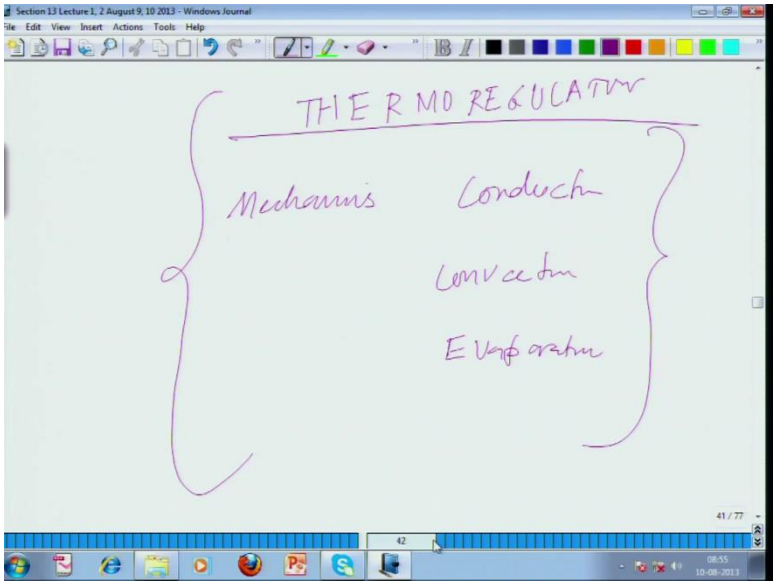

So, talking about thermo regulation, so the body has to continuously just like. It has to maintain an electro like balance body has to continuously maintain a optimal temperature for all the bio chemical processes. To take place the body has different mode by which heat is getting transfer into the body outside the body or inside the body. The basic thumb rules remain the same. Enumerate the different processes by which body is doing, so the mechanisms of heat transfer of the body. So, they are basically the very fundamental ones conduction conviction and evaporation and within the brain.

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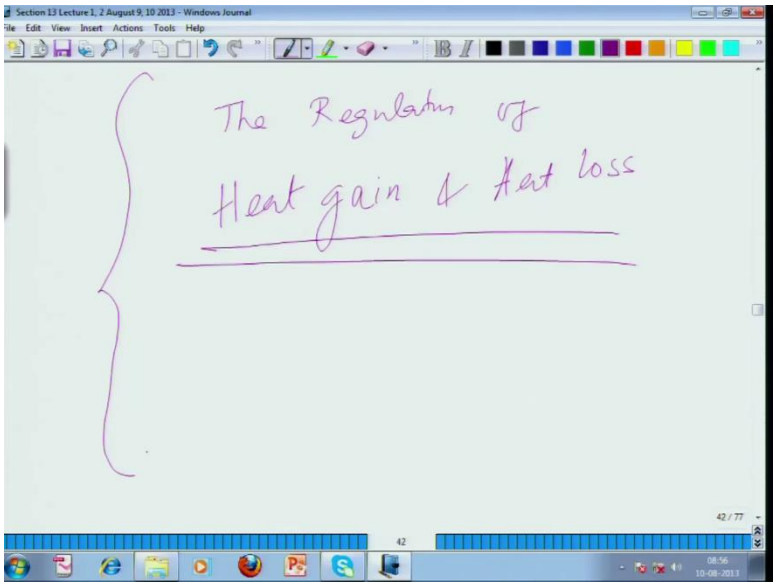

There are the different centers which are involved in it regulation of heat gain and heat loss. So, there are different heat gains and heat loss centers which functions at higher centers of the brain which regulates to body either loose heat or it can lose heat in the form of lot of perspiration. Because you are sweating a lot you are losing heat or you may you know cover yourself something conserving there are different modes ((refer time 39:46)) of the brain higher center of the brain by which all the summer relation processes are been coordinated. They are coordinated by all the higher centers of the brain. They are not coordinated they are indeed in the executed at the local level, but they are kind of control at the higher centers. So, let us talk about some of those out here. So, mechanism of increasing heat loss how you can do so one second.

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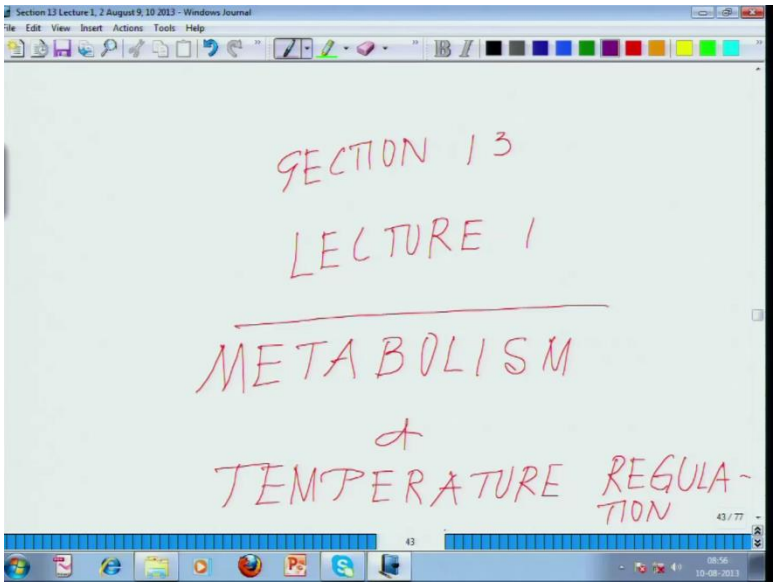

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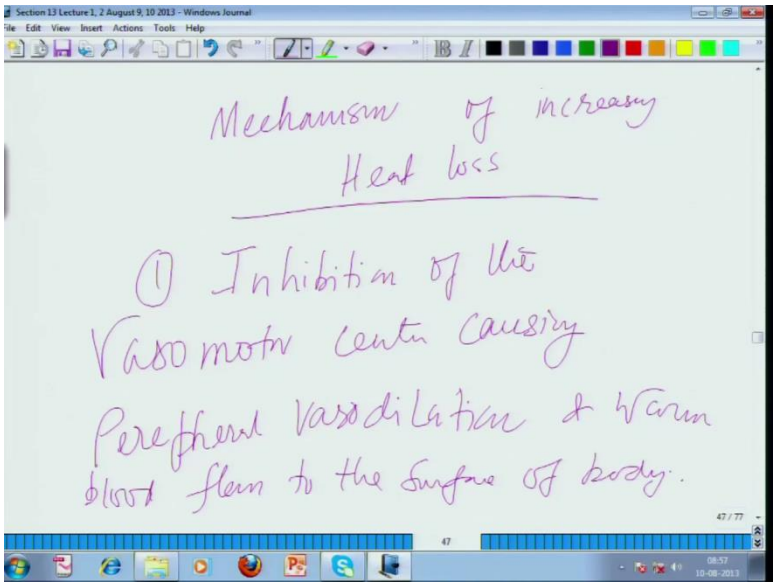

So, mechanism of say for example, you want to lose heat what all the process is there? So, the first process is that, inhibition of the vasomotor center causing by the peripheral vasodilatation and warm blood close to the surface of body. And the output of this is something like this.

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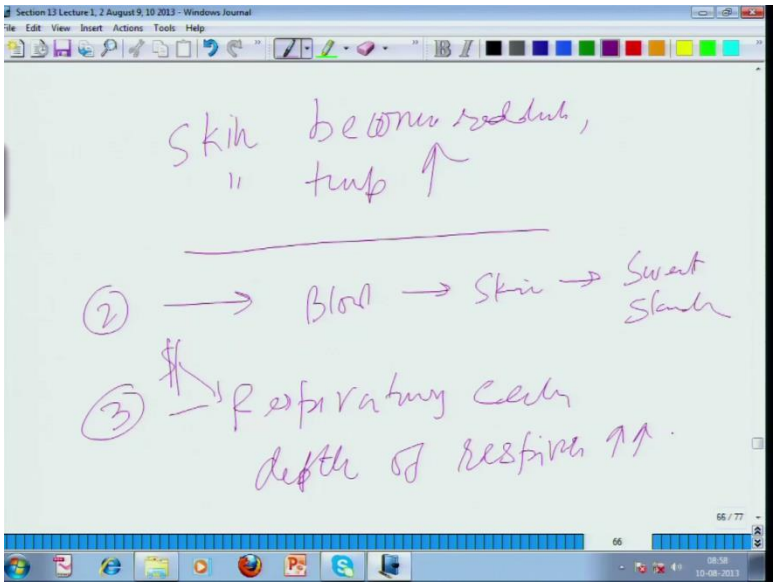

The skin becomes reddish and skin temperature rises and radiation conducted losses increases. So, what is how it losing second is that as blood flow thought the skin sun gland system is in the secretion of secretion of output blood flow to the skin and sweat gland. So, basically loosing the heat, so there is the third way here you are simulating respiratory centers of the brain you are basically simulating them. Once simulating them there is the depth of respiration increases. And what happens under such situations is that of an individual respires through open mouth rather than through and nah nasal path way.

So, basically what we are doing instead of they do start taking it from the mouth and then process you. So, if you see after you finish that kind of marathon or you know law or running you start ding like this. You are trying to loss heat, because the body is fairly heated up, because of the lot of exercise. So, this is that is the third way. So, these are very common path ways. You look at this skin red is it becomes almost red slowly start losing it or you know there are mucus land which start become hyper functional. So, this is the way how you lose it. So, now let us talk about the reverse situation how we gaining heat into the system.

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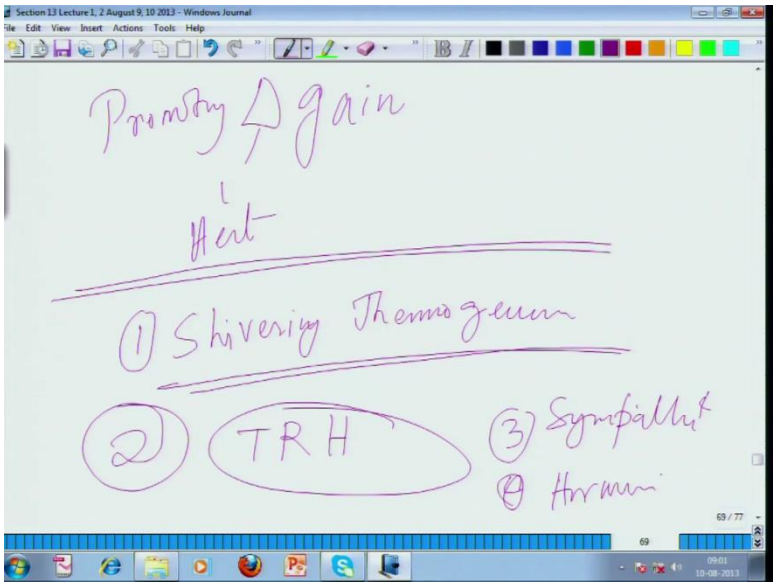

So, mechanisms of promoting heat gain. Promoting I am just putting heat as promoting heat gain in the body how we doing? So, there is something called shivering thermo genesis what is shivering? You know shivering in a cold night you are essentially what you are doing your muscles like you know moving like. So, we do like that. So, this is basically what we do you are increasing the muscle movement. In order you know you are increasing the heat shivering is the reaction by which you increase the heat of the body specially suppose it is a very chilled cold night and you are really feeling cold.

So, your body needs to generate heat in order to protect itself. This is how you protect yourself by shivering actions. This is one of the mechanism by which it is been done. So, there are other things which are called non shivering. So, non shivering thermo genesis is regulated by something like thyro trephine releasing hormone. And there are these are being regulated by sympathetic innovation. So, there are several ways by which you really can regulate all these things. There may be sympathetic innovation there are other hormonal pathways which could take care of your hormones which are taking care of your heat gain process.

So, shivering is the easiest one, but there are non shivering ways by where the body especially the thyroid hormones play a critical role. Some one feels like you know the secretion of hormone which is again regulated by the higher centers of the brain. And in that whole process of shivering non shivering or loss of heat. You are involved in all

kind of catabolic pathways end of the day it is all this catabolic and anabolic pathways who are the final molecular executor of the action. So, this is how over all the metabolism and thermo regulation is regulated in the body. So, please go through some of the standard text book on biochemistry to understand metabolism that will help you.

So, thanks a lot thank for your attention.