Introduction to Biomolecules
Prof. K. Subramaniam
Department of Biotechnology
Indian Institute of Technology - Madras

Lecture – 12
Carbohydrates (Part 2/2) And Lipids (Part 1/3)

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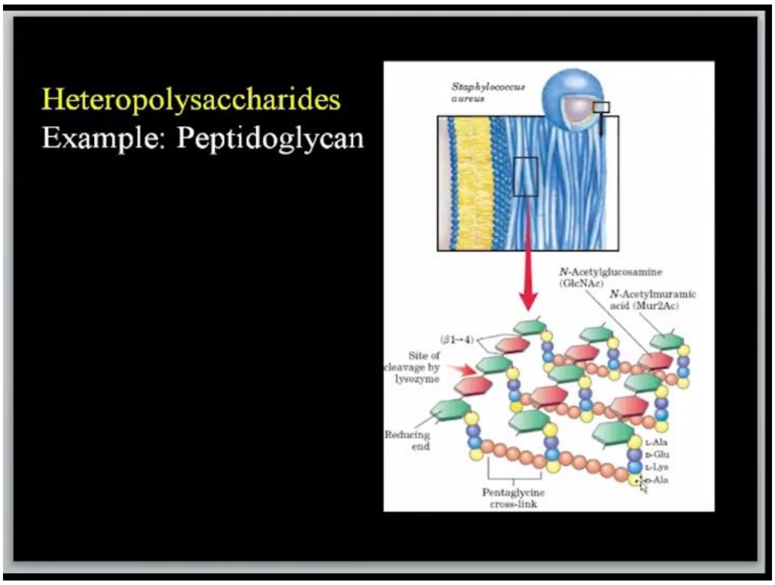

Yesterday we discussed about the homopolysaccharides. We came up to chitin. So, chitin is the polysaccharide forms the structural unit of the exoskeleton of many arthropods including the insect's protective cover for its wings. So today we will continue further. Now we will talk about heteropolysaccharides where you have mixture, it is as you can see here in this cartoon you have 3 chains of carbohydrates.

And you see that it is not one single monosaccharide that continuously repeats. For example, in starch you have glucose continuously repeating glucose after glucose. So, instead here you have a mixture of two different kinds of sugars and that is why they are called heteropolysaccharides. So here you have N-acetyl glucosamine and N-acetyl muramic acid. So, N-acetyl muramic acid yesterday we saw, you know these are the modified monosaccharides.

So, this has a lactic acid group attached to carbon 3 while the carbon 2 has the amino group that is acetylated N-acetyl muramic acid and then you have N-acetyl glucosamine. So, these two monomers alternate in these long chains and multiples of these chains are held together by these 4 amino acids attached to one of the carbons; so alanine, glutamic acid, lysine and alanine. And these chains, these 4 peptides are held together in gram-positive bacteria by this pentaglycine crosslink.

So, this sort of a structure forms the cell wall of bacteria, many bacteria like both gram negative and gram positive have these sorts of structures called peptidoglycans. So, the long chain of carbohydrates are called glycan okay. So gly is the generic term for any carbohydrate. So, if it is only glucose you will say glucan, so gly is a generic thing for any sugar. So, glycan means a long chain of monosaccharides.

So since they have peptides attached to them they are called peptidoglycan. So these peptidoglycan form the major cell wall component of a bacteria. So, in gram negative instead of pentaglycine these amino acids are directly joined like this alanine is joined either to the lysine or alanine and so on. So, this is one of the important heteropolysaccharide and it is important in studying many bacterial infections as well.

Because some of the drugs are focused on destroying these peptidoglycans. For example lysozyme which is abundant in the tear drops, the tear secreted in our eyes which protect the eye ball the outer part cornea, lens, etc. is protected by the liquid your tear and the tear is rich in an enzyme called lysozyme. And this lysozyme cleaves this glycosidic bond, this beta 1, 4 glycosidic bond of the peptidoglycan.

So as a result, the bacterial cell wall gets broken and the bacteria dies okay. So, this is how your tears your eyes from a bacterial infection.

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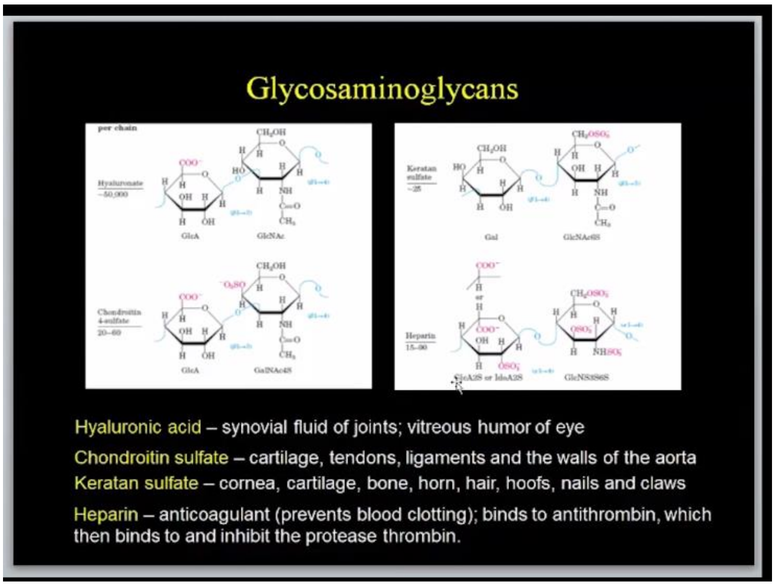

So, the next set of heteropolysaccharides we are going to see are called glycosaminoglycans. So glycosamine, so we already know glucosamine, this amino group attached to usually the second carbon and that I told you yesterday is usually acetylated, so N-acetyl glucosamine. So, we saw in chitin you have the N-acetyl glucosamine having beta 1, 4 linkage. So, this sort of structure generic when it is glucosamine you call glucosamine.

If you are referring to any other hexose or any other monosaccharide you simply got glycosamine, the focus is on this amino group. And when you have long chains of them, they are called glycosaminoglycans okay. So here we are looking at the 4 major ones and they all have very important functions and that is why we are interested in learning the structures here. The first one we are learning is called a hyaluronic acid when it is in the dissociative you call hyaluronate.

So uranic acid, remember the sixth carbon if it is oxidized to carboxylic acid you call uranic acid. If the anomeric carbon the aldehyde group is oxidized to carboxyl group we call that as aldonic acid, so yesterday I told you that. So this is a uranic acid, so the hyaluronate already suggest that it has uranic acid group and this one you have attached the glycosidic bond to N-acetyl glucosamine.

So, this glucuronate N-acetyl glucosamine keeps repeating like 50,000 of them okay. So, the disaccharide is the repeat unit because if you take this alone it does not describe the whole constituents of the polymer, but if you take both of them together then you have them repeating. So, it is a disaccharide repeating, disaccharide is the repeating unit of this polymer and it is very high molecular weight chain because it can have as many as 50,000 monosaccharides in them.

So, given all the hydroxyl groups and carboxyl group, this is highly polar and provides multiple points for interactions okay. And due to long chain nature as well as due to this charged and polar groups, they form good lubricants in our synovial fluid of the joints. If you take your knee joint that is a good example where you find plenty of synovial fluid. So, since the time you are born until you die nobody is going to open up and keep lubricating okay.

So, it is permanently lubricated, the liquid produced by the cells around there they secrete this hyaluronic acid and that gives a good lubrication. It is kind of a jelly thick liquid and that consistency comes primarily from this long chain and with multiple polar groups in them. And similarly, the vitreous humor of eye, so behind your lens the eyeball is filled with a jelly like consistent liquid and that is primarily composed of hyaluronic acid okay.

So that gives a protective and cushioning effect to the eye. So, this sort of a role is very important and this is also present in cartilage as well where it provides tensile strength. So that is the function of hyaluronic acid. And another such glycosaminoglycan are the chondroitin sulfate. So these are much shorter than hyaluronic acid as you can see here 20 to 60 and these are sulfate and so you have sulfur group attached.

And instead of N-acetyl glucosamine this is N-acetyl galactosamine having a sulfur group attached here and these are usually not present in isolation as carbohydrate, instead it is usually attached to proteins forming what are called proteoglycans. So, we will learn about it in a short while, in couple of slides we will get to proteoglycans and learn about their importance. And these molecules where the core protein is a smaller component of the whole molecule.

The major component is the carbohydrate part which is multiple chains of chondroitin sulfate. So, these are present in cartilage. For example, if you take your earlobe the outer part of your ear that has thick consistency, it is not like your skin okay, on the same time it is not like bone and that sort of consistency is provided by these proteoglycans containing chondroitin sulfate.

Tendons you know the one that joins muscles and bones, ligaments again similar structures and the walls of aorta the main artery supplying to heart. So, they all get the tensile strength primarily from the chondroitin sulfate attached to proteoglycans and having you look at this charge available here carboxylic acid, sulfuric acid moiety here, then you have plenty of polar groups, multiple hydroxyl groups.

So, all of this provide multiple points for various covalent non-covalent interactions with other molecules in these structures okay and that sort of multiple interactions enabled by this structure is what provides the tensile strength for cartilage okay. So that is chondroitin sulfate. A similar molecule is keratan sulfate. When you think of horns, hoofs, hair, nails, claws and our own cornea, they all have this keratan sulfate.

So there again you have a similar structure, here the uranic acid component is not there okay. So, these two have uranic acid and this does not have and instead it as usually galactose attached to N-acetyl glucosamine where the sixth carbon has a sulfuric acid attached okay. So, it is an ester between an alcohol hydroxyl group and then the mineral acid sulfuric acid. So, you have strong negative charge.

So, these strong negative charges ripple and as a result these molecules remain in an elongated extended structure instead of being coiled. Since it is an introductory class, I did not get into the multiple confirmations possible for cellulose, starch, etc. So, you do not need to worry about it. But here because of the repelling charges we just briefly visited structure. So here the long fiber remains in an extended form due to the charge repellent.

So, the primary aspect of this structure is that these multiple groups that can form covalent bond or electrostatic interaction or other hydrogen bond kind of non-covalent interactions. They provide multiple contact points for various molecules to interact and finally the ultimate result of such interaction is the tensile strength of these tissues. So, you look at the hair or you take a horn or take your nails that is probably the easiest.

So, the nails have a certain consistency and that is because of keratan sulfate and they also contain other fibrous proteins that is also responsible for this. Then the fourth one we are going to learn about are the heparin. So, heparin is present in our blood and that prevents blood clotting. So, when you collect blood sample from patients for any analysis usually the tube in which you collect contains little bit of heparin so that the blood does not get coagulated, does not become clot, does not become solid okay.

So normally when you have an injury when there is a cut and the exposure of the blood to the external environment that exposure like contact with the non-endogenous structure triggers a process that results in blood becoming solid like structure. So that seals the wound okay. The blood clotting is an essential phenomenon in controlling bleeding when you have a cut injury okay. So, when you do not want to have that.

Like for example the circulating blood should not become clotted and that is usually prevented by the presence of heparin. And heparin itself is a polysaccharide so 15 to 90 repeating units. It has a lot of sulfur groups attached to it, so that is the primary structural feature of heparin okay. So idose is one of the isomers, the epimers of glucose. So here you have either glucosamine the sulfated glucose or glucuronic acid.

GLcA is glucuronic acid with 2 sulfate groups or the carbon to sulfur that is what this name indicates or you might have an idose having a uranic acid like carboxyl group at the sixth carbon and the second carbon having a sulfur. So, this is an important feature primarily the sulfur attached, the sulphate groups being dominant feature of this molecule. So, these are the primary glycosaminoglycans. There are other minor ones as well.

So primarily these are long chain polysaccharides having charged acidic groups on them and they either function as lubricants or provide tensile strength to structures like cartilage, tendon and bone, horns, nails and so on. And these molecules are actually very important when you think of making extracellular matrix artificially for a tissue engineering purposes okay. So, the people who study tissue engineering, they learn a lot more details about these glycosaminoglycans and other extracellular matrix proteins.

You know extracellular matrix is the cementing material among the multiple cells okay, what is there in the space among the cells. When you have a tissue with multiple cells what is there between two cells and that part is what you call as extracellular matrix. That acts more like in a simplest crudest way is like the mortar that you use to stack up bricks in a wall. So, you are not simply stacking up the bricks to build a wall and if you push the bricks will fall.

But you use mortar to seal the bricks so the bricks are held tight. They are stuck to each other and that sort of a function among cells if you think individual cells as bricks then extracellular matrix is like that mortar. So not only that extracellular matrix is very important for cell-cell signaling as well and in making sure the cells migrate in the right direction to take the right shape to form the different organs.

So extracellular matrix is lot more than the mortar that you encounter in the walls and to a great extent that property of extracellular matrix comes from these glycosaminoglycans. So here as we move on you are slowly seeing how we started with the few elements seemingly simple molecules and stacking them, joining them in multiple ways how we are able to build functional complexity in the living system.

So, this is the beauty I want you to appreciate and focus attention while you learn these structures okay. Do not think I have to memorize this structure which has the sulfate, which has the carboxylic acid, what is an epimer? Do not get distracted by that exam-oriented thought, instead look at the complexity coming from the simplicity in living systems.

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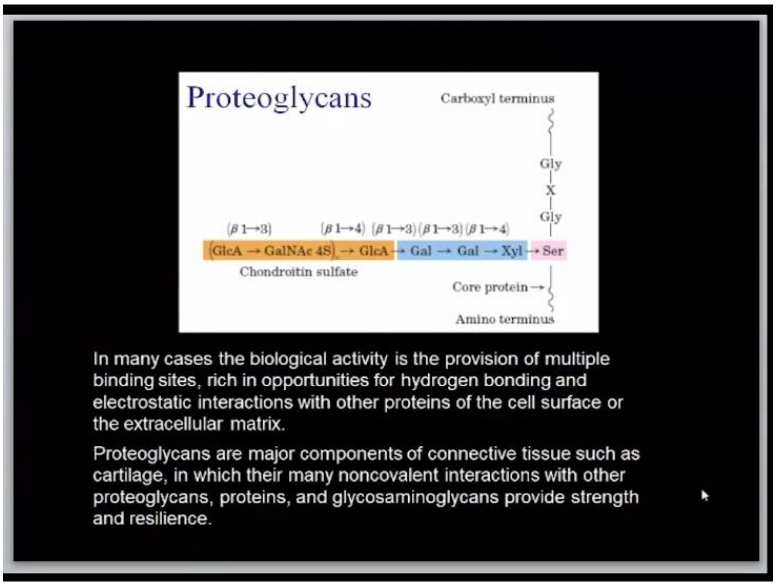

So, the next molecule you are going to learn are the proteoglycans okay. So, we are going to learn later what are called glycoproteins. So, glycoproteins where the protein is the major thing the glycol that is carbohydrate part is a minor thing. By contrast proteoglycans, glycan is the main thing, it is long polysaccharide and the protein part is the minor thing. So, let us look at its structure then we will get a good understanding.

So, I already told you proteoglycans contain chondroitin sulfate. So, usually the chondroitin sulfate polysaccharide is attached via a trisaccharide link galactose-galactose-xylose or to a serine's hydroxyl group on a protein called the core protein okay. So, proteoglycans have a protein component which we call as the core protein and to one of its serine residues or multiples of its serine residues usually in this context that serine has a glycine and any amino acid represented as x and another glycine.

Towards the carboxy terminus such a serine is potential for attaching this chondroitin sulfate via this trisaccharide link okay. So, this is the structure of a proteoglycan and again as I told you earlier in many cases the biological activity is the provision of multiple binding sites. See this is uranic acid a carboxyl group and then it has hydroxyl groups on the glucose moiety itself and similarly here you have got an amino group and acetyl group.

Therefore, another carbonyl group and fourth carbon as a sulfate and so on. So, like this you have got multiple binding sites switching opportunities for hydrogen bonding and electrostatic interactions with other proteins of the cell surface or the extracellular matrix okay. So proteoglycans are major components of the connective tissue such as cartilage. I told you a good example cartilage your outer earlobe, nose as well.

So, you touch and feel your nose how it feels in which there are many non-covalent interactions with other proteoglycans, proteins. There are proteins present in extracellular matrix the main one being collagen and then fibronectin. So, these proteins are all interconnected among themselves and to these carbohydrate molecules which are often anchored into the membrane itself.

Like for example this core protein may be an integral membrane protein where hydrophobic part of the chain interacts with the lipid by layer and therefore it is actually anchored in the membrane. So that is how the cells are cemented with the extracellular matrix. So, they provide strength and resilience to the overall structure.

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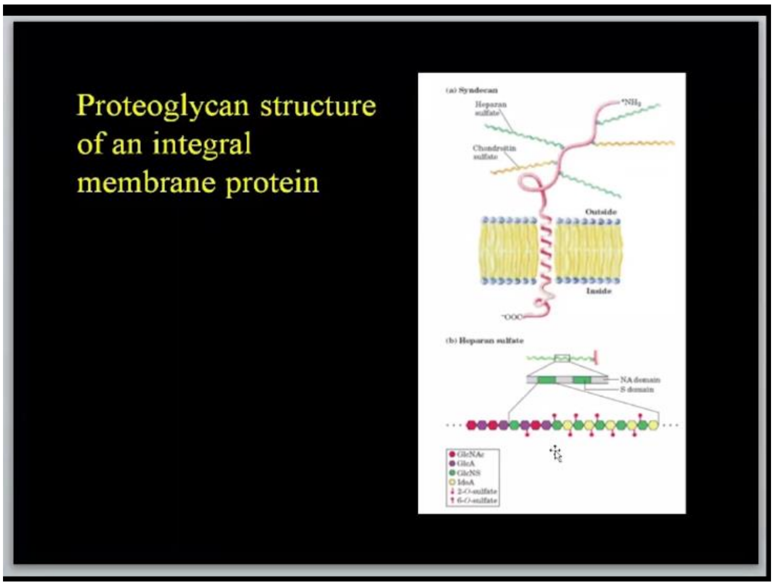

So here is an example of proteoglycan which is an integral membrane protein. So here the core protein contains hydrophobic side chains in a short sequence usually about 10 to 12 amino acids, hydrophobic amino acids or enough to get anchored in the membrane where the hydrophobic side chains here interact with the aliphatic chain so that, remember we already know phospholipid structure the glycerol part has the phosphate and therefore it is hydrophilic.

And the other two hydroxyl groups of glycerol have esterified with the long chain fatty acids, these are the yellow tails here. So these are hydrophobic. So, these hydrophobic tails of the phospholipids interact with hydrophobic amino acids on this short chain and that is how this protein is anchored in the membrane and such proteins which are integrated into the membrane are called integral membrane proteins.

And one end of it the amino terminus here is extracellular and in the extracellular region it has multiple tails of these molecules, like in this particular example this molecule has two chondroitin sulfate shown in yellow and three heparin sulfate. And these now interact with collagen, fibronectin and so on and they form a tight mesh network from intracellular to the extracellular environment.

So, if we take one chain of this chondroitin sulfate and look closely what you have is a region where you have the carbohydrate moiety strongly sulfated. And then you have this gray area where you do not have sulfation, instead they are simply N-acetyl groups and therefore they are called NA domain. So, S domain because sulfate and then N-acetyl so NA domain. So, they alternate in this long chain. So, this is an example of a proteoglycan structure. So, the protein itself is called the core protein.

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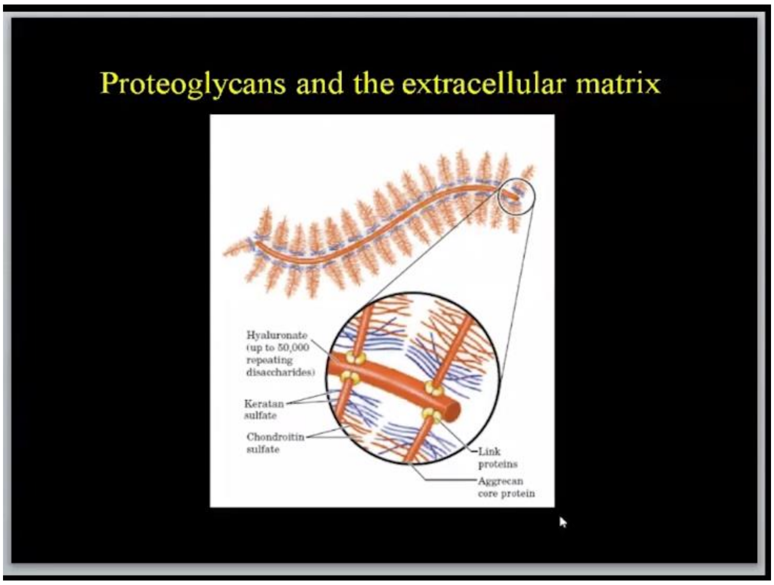

So there are certain situations where the extracellular matrix contains really a humongous molecule where you already learnt hyaluronic acid can have as many as 50,000 repeating disaccharides, meaning 100,000 monosaccharides okay, a long chain. So, these are uranic acid, remember we have seen that structure just a couple of slides ago. And to them you may have core proteins attached.

And these core proteins unlike the earlier one we saw these are smaller molecules okay, not very big molecule. Whereas this particular core protein is very large and it is called Aggrecan, written here Aggrecan. See these are long rod-shaped molecules and instead of having 2 chondroitin sulfate and 3 heparin sulphate these have several of them attached okay. And such long core aggrecan with multiple chondroitin sulfate and keratin sulfate attached are again connected to this long hyaluronic acid and held in place by link proteins.

And such long structures are a very integral component of extracellular matrix providing the structural characteristics of the extracellular matrix. So, make sure you remember this structure. So, this is how the bird's eye view big structure looks. But if you look at each one of them, they are core proteins, you have multiple proteins here in one single molecule and each protein has multiple this shorter heteropolysaccharides and all of them attach to one long hyaluronic acid.

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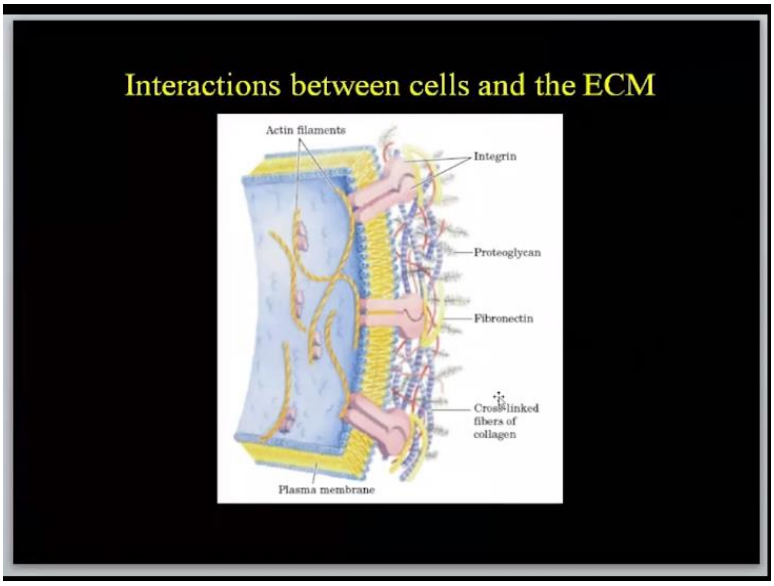

So, this gives you an overall view of the extracellular matrix environment. So, this is your lipid bilayer okay. So, this is the inner leaflet and that is the outer leaflet. So, the surface of both of them are hydrophilic because the phospholipids head group and they have this is inner side of the cell where you have the cytoskeleton made up of actin and tubulin which we have not yet learned. You will learn it in cell biology later.

So, these provide structural stability and integrity to the internal environment of the cell. They are directly connected via these protein molecules called integrins okay. The integrins are integral membrane proteins that are the main components for connecting the intracellular structural molecules like this actin filaments which is entirely made up of proteins. So here you do not have carbohydrate.

So directly it connects them to the extracellular structures like fibronectin and to proteoglycans and collagen and these are all cross-linked because you have multiple functional groups available for such interactions. So, all these multiple interactions of really large molecules make a mesh like structures and that is what is our extracellular environment is and that is very critical for the function of the cell.

And it is very important for cell migration during organism development and they are also important for cell-cell signaling. So, they have multiple roles, just do not view this as if it is analogous to the cement or mortar used for holding bricks in the wall. Okay so that is about our discussion on glycosaminoglycans.

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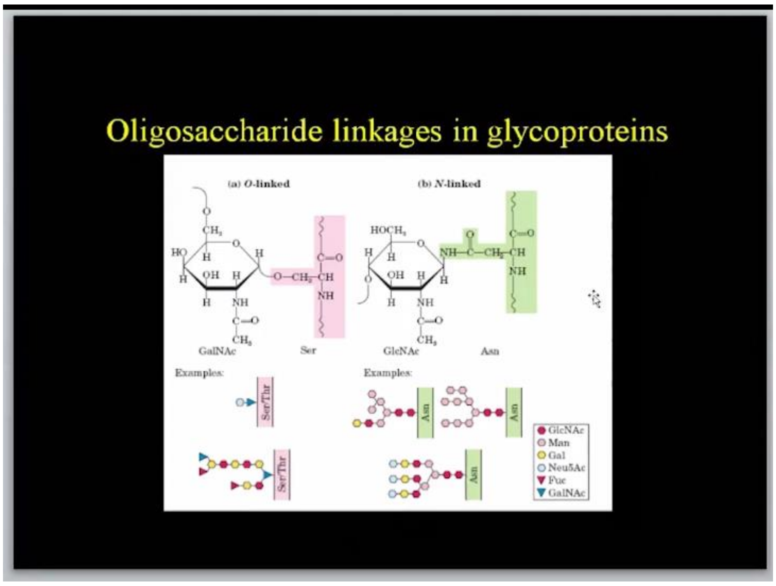

Next we are going to a set of a molecules where the carbohydrate part is a minor component, nevertheless functionally very important and the major thing being either protein in case of glycoproteins or glycolipids where it is going to be lipids having carbohydrates attached. First let us look at the glycoproteins. So here the glycol part is actually oligosaccharide, it is not long polysaccharide.

And usually there are 2 types of linkages between carbohydrate and proteins, they are either via the serine or threonine’s hydroxyl group okay. So, this is the side chain, so this is the peptide polypeptide in which you have the serine. So amino group, carboxyl group, so this is in peptide bond with another amino acid, here the carboxyl group is in peptide bond with the other one. So this is the alpha carbon.

So, you have the side chain CH 2 OH and that is in linkage with anomeric carbons hydroxyl group of N-acetyl galactosamine in this particular example. So, this sort of a linkage we call as O-linked because the atom that connects the carbohydrate to the protein is oxygen. On the other hand, N-linked ones have the amide group of the asparagine side chain, asparagine here you have CH 2 CO NH 2 and that is in linkage with the anomeric carbon here you have N-acetyl glucosamine.

So, it need not be this particular carbohydrate moiety alone, it could be any, but the point is this is an N-linkage via asparagine here it is O-linkage via serine or threonine. So, these are the kinds of linkages that we see in glycoproteins and here are some examples. So, these are specific carbohydrates attached, each one is color coded and explained here mannose, galactose, N-acetylneuraminic acid, fucose and so on.

So, you see here they all have specific sequences and these specific sequences can therefore have specific codes, each one can be like a pin code and therefore they are recognizing structures. So, if a cell surface protein has a certain carbohydrate chain attached that could be a pin code or an identity for that particular cell. So therefore, these oligosaccharides of glycoproteins confer important function in cell-cell recognition.

In terms of molecular recognition, they function as address tags okay. And that is how they are important in our blood group as well, but in blood group it is not glycoprotein, it is glycolipid, I will come to that in a minute.

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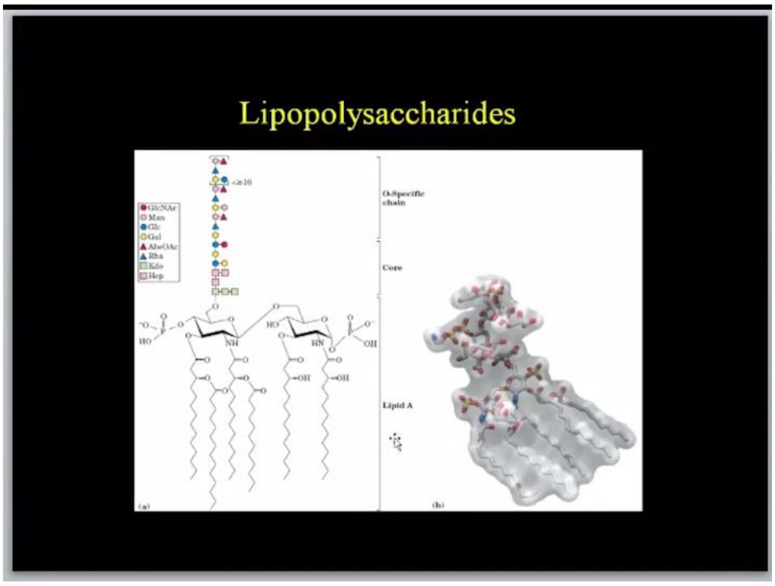

And then now we are looking at the lipid attachment. So here the structure looks complex but it is already very familiar to us. So, it is just that the Haworth formula the ring is shown in this sort of a shape because this is the way it exists, but otherwise each corner is the same on this sort of a structure okay. So, we call that as chair and boat confirmation. So, this is the char confirmation.

So, boat confirmation will be this also bent upward that would be boat confirmation, so you do not need to worry about the confirmation for an introductory course. So here you have this N-acetyl group and here instead of uranic acid, a carboxyl group or a sulfate here you have phosphoric acid attached that is all. Otherwise, it is just a regular N-acetyl glucosamine and this is another N-acetyl glucosamine and they have multiple fatty acid moieties attached.

So if you count, there are 6 of them attached to 2 N-acetyl glucosamines and one of them have a long chain of polysaccharides and this is where this name polysaccharide comes and this is what lipopolysaccharide. So, these are components just like the peptidoglycans that we saw these are components of bacterial cell bonds. So, these are primarily present in gram-negative bacteria like E. coli which is commonly used in the lab.

And certain strains of E. coli are pathogenic as well. So, they have this in that cell wall so lipopolysaccharide. This is like space filling model for the same in which the sixth one is not visible in this orientation. So, this is the structure of lipopolysaccharides.

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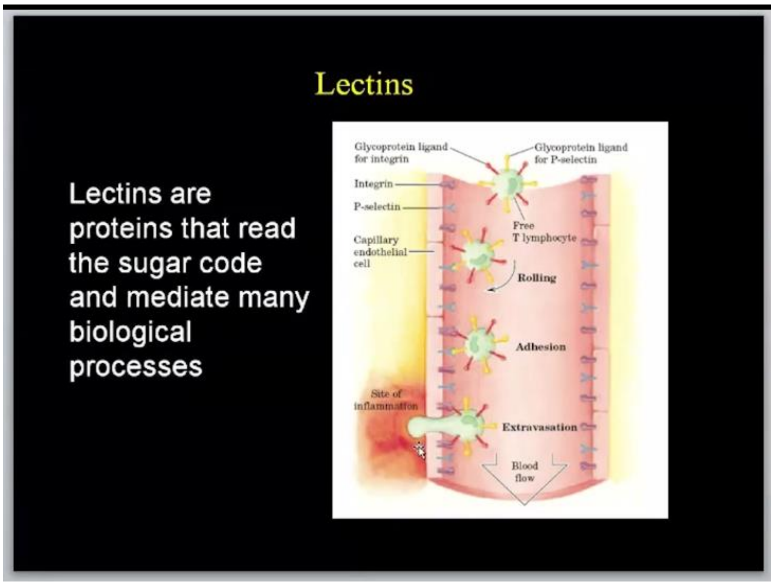

So now I told you that these carbureted moieties which are in small number oligosaccharides attached to proteins as well as lipids can provide address tags and there could be other proteins that could bind to the specific sequence of carbohydrates and therefore they could be the recognizing molecules. And such proteins that recognize specific sequence of oligosaccharides on the cell surface glycoproteins or lipids are called the lectins okay.

So, lectins are proteins that read the sugar code. So, the sugar code being that specific sequence, you have this sequence, this sequence or this kind of a sequence and so on. So it can be really there is no limit to it, you can generate variety of address pads and so you could have specific proteins each recognizing a certain sequence of sugar and that is why we call it as they read sugar code and they mediate cell-cell and many molecular recognition in biological processes.

So, shown here is an example where this is a blood vessel in which the blood is circulating and in the circulating blood you have these immune cells called the T lymphocytes going through. And when you have an injury or an infection that leads to inflammation these cells go there to take care of that. And how do they identify the place and go there? That is because as they keep going through the bloodstream, their surface molecules, this carbohydrate extension of the glycoproteins are bound by molecules.

The lectins called P selectin in this case and when they bind to P selectin then their flow is slowed down and then when they detach and move, they slowly roll along the walls and that is why it is called rolling motion. At the site of inflammation, you have many more of these interactions okay, many more integrins and beta selectins binding to different cell surface glycoproteins and they stop.

And once they stop then they migrate through the endothelium and blood cell the blood vessel wall into the tissue where you have inflammation to take care of the infection there okay. So that is how this recognition property of oligosaccharides of glycoprotein and the proteins that bind to them like in this case beta selectin or important in mediating biological process or many processes.

In this particular example, the process is immune response to an infection or a site of injury. So that gives us a really brief introduction into carbohydrates, probably in couple of classes we have finished, otherwise if you want to learn carbohydrates in detail, we can actually have a course on carbohydrate and that sort of study of carbohydrates we call as glycobiology. There are textbooks on glycobiology, there are journals on glycobiology.

So, there is a lot of things to learn about carbohydrates, but since it is an introductory biochemistry class we end our discussion on carbohydrates there. At least we know what is what in carbohydrates, what is the structure like, what is the function. So, we know if we want to learn further what we need to do, so that is all the aim of this course.

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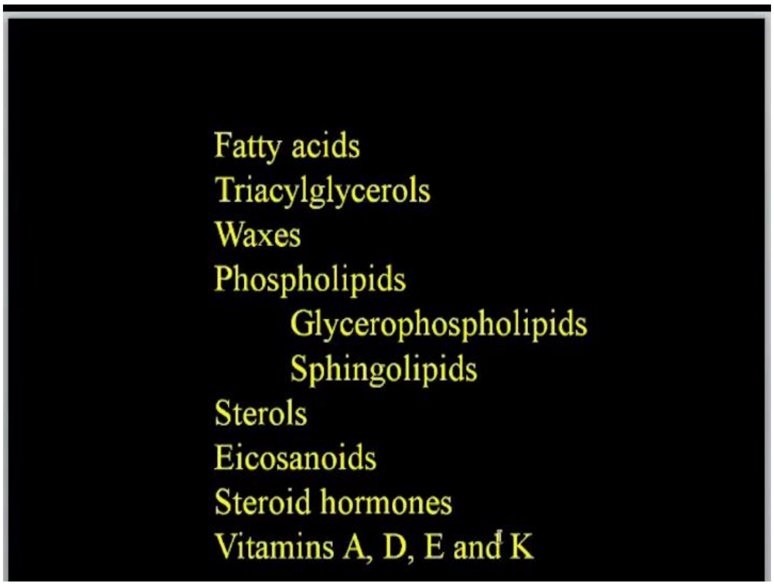

Next, we will get a brief similar introduction to lipids okay. So already I am warning you it is lipids 1, so there is going to be lipids 2 as well. So here are names, they look a lot, but when you go one by one, they are all very logical and easy to remember structures.

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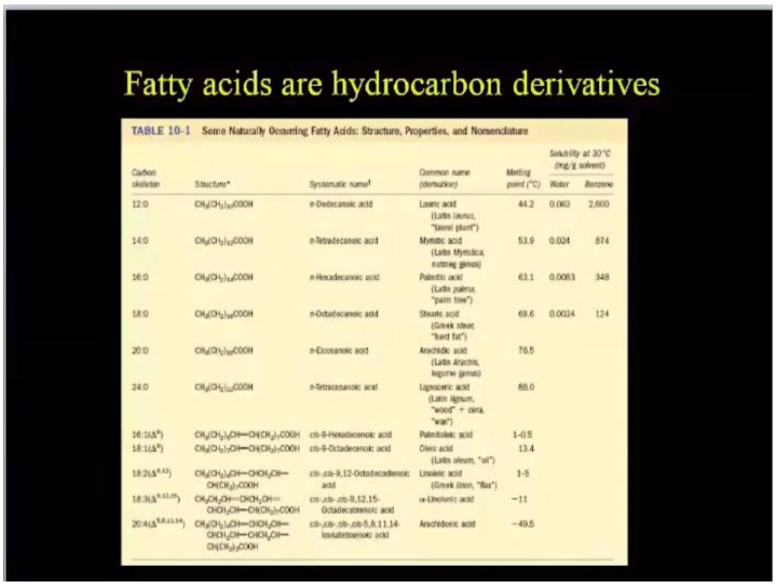

TABLE 10-1 Some Naturally Occurring Fatty Acids: Structure, Properties, and Nomenclature

Carbon skeleton	Structure*	Systematic name†	Common name (derivation)	Melting point (°C)	Solubility at 30 °C (mg/g solvent) Water	Benzene
12:0	$CH_3(CH_2)_{10}COOH$	*n*-Dodecanoic acid	Lauric acid (Latin *laurus*, "laurel plant")	44.2	0.063	2,600
14:0	$CH_3(CH_2)_{12}COOH$	*n*-Tetradecanoic acid	Myristic acid (Latin *Myristica*, nutmeg genus)	53.9	0.024	874
16:0	$CH_3(CH_2)_{14}COOH$	*n*-Hexadecanoic acid	Palmitic acid (Latin *palma*, "palm tree")	63.1	0.0083	348
18:0	$CH_3(CH_2)_{16}COOH$	*n*-Octadecanoic acid	Stearic acid (Greek *stear*, "hard fat")	69.6	0.0034	124
20:0	$CH_3(CH_2)_{18}COOH$	*n*-Eicosanoic acid	Arachidic acid (Latin *Arachis*, legume genus)	76.5		
24:0	$CH_3(CH_2)_{22}COOH$	*n*-Tetracosanoic acid	Lignoceric acid (Latin *lignum*, "wood" + *cera*, "wax")	86.0		
16:1(Δ^9)	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	*cis*-9-Hexadecenoic acid	Palmitoleic acid	1–0.5		
18:1(Δ^9)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	*cis*-9-Octadecenoic acid	Oleic acid (Latin *oleum*, "oil")	13.4		
18:2($\Delta^{9,12}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-9,12-Octadecadienoic acid	Linoleic acid (Greek *linon*, "flax")	1–5		
18:3($\Delta^{9,12,15}$)	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-,*cis*-9,12,15-Octadecatrienoic acid	α-Linolenic acid	−11		
20:4($\Delta^{5,8,11,14}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$	*cis*-,*cis*-,*cis*-,*cis*-5,8,11,14-Icosatetraenoic acid	Arachidonic acid	−49.5		

So first let us take fatty acids which we are very familiar with. I am not even going to have a big cartoon of their structures because you already know them. So, they are long chain aliphatic acids. So, you have a carboxyl group and then you have a long chain of carbon where the carbon valency is satisfied with the hydrogen. So, you have CH 2 n number and then finally a methyl group so that is what is fatty acids.

So, these are hydrocarbon chains with carboxyl group at one end. And here for example I will get into nomenclature right here because it is already there, 12 means you have 12 carbons.

So, the carboxyl carbon is number 1, then you continue to number towards the methyl group. And this colon and 0 means the degree of unsaturation, how many double bonds do you have in this chain. So, in this particular molecule it is 0 okay.

On the other hand, if you look at it here you have 1 double bond, 2 double bonds, 3 double bonds and 4 double bonds and so on. So that is one thing and second where is the double bond is indicated in the brackets with this delta sign and a superscript of the carbon number where the bond is. So, for example delta 9 means delta 9 th carbon is in double bond linkage with the 10 th carbon. So here you have 1, then 7, so 8, then the 9 th carbon.

So, 9 th carbon has a double bond with the 10 th carbon that is what it means. And when you have two of them then you say 9, 12 alright. So, when you have multiple double bonds you indicate those numbers as shown here. So, the names again the IUPAC names are extremely simple names. So decanoic meaning 10, dodecanoic means 2 double that is where do comes. So dodecenoic means 12, tetradecanoic means 14, hexadecenoic means 16 and so on.

So I am not going to expect you to remember these names or the logics of it, all that you need to know is these are long chain fatty acids. The most common ones are like 16 carbon, 18 and 20**,** these are the most common ones. Like for example palmitic acid which is abundant in palm oil and that is where the name comes, so that is hexadecenoic acid. Stearic acid which comes from hard fat like the beef.

Beef has fat which is like more fatty than the butter and so that is 18 carbon steric acid. And arachidonic acid comes from this plant legume arachis that is where that name comes and so that is 20 carbon. So, these three are the main ones, particularly the unsaturated ones our body cannot make and they are important via the blood. They are usually solid at room temperature.

Their melting point depends on the chain length and the degree of unsaturation, how many double bonds, etc. So, they are usually not soluble in water because they are very hydrophobic. So, they are soluble only in hydrophobic solids like organic solvents.

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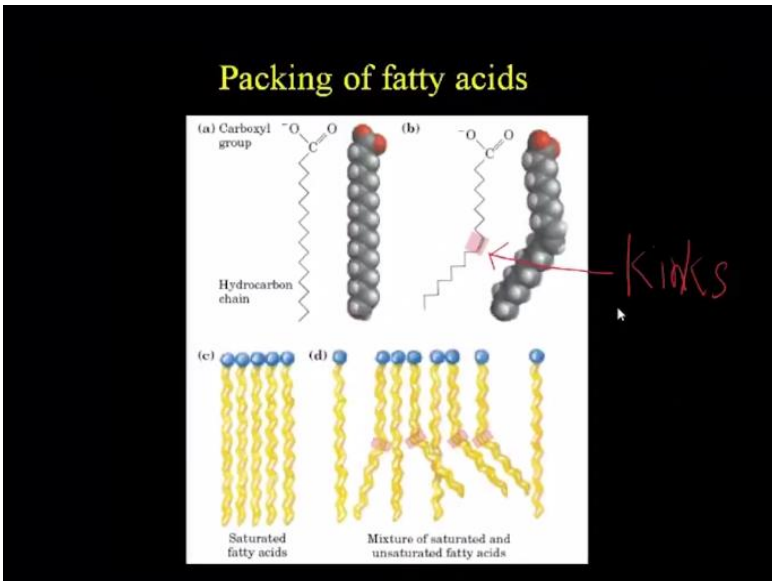

Okay so this gives you a space filling model perspective diagram and when you have a double bond, the rotation between these two carbons is restricted. As a result, you have a rigid orientation of the two sides of the chain and leading to a fixed rigid structure like this. So as a result, these molecules unlike the fully saturated ones as you can see here they can compactly pack these do not pack very well.

So as the result these molecules tend to be liquid at room temperature while these are solid. So, butter for example rich in saturated fat is solid at room temperature. Beef fat which has not only saturated fatty acids longer chain as well that is really solid hard solid at room temperature like butter is soft while beef fat is not, so only when you melt it, it becomes a liquid.

On the other hand, many of the plant oils, vegetable oils, palm oil, groundnut oil, gingerly oil, etc., they have a lot of unsaturated fat with these sorts of structures and due to that they are liquid at room temperature okay. So that is one important point to consider.

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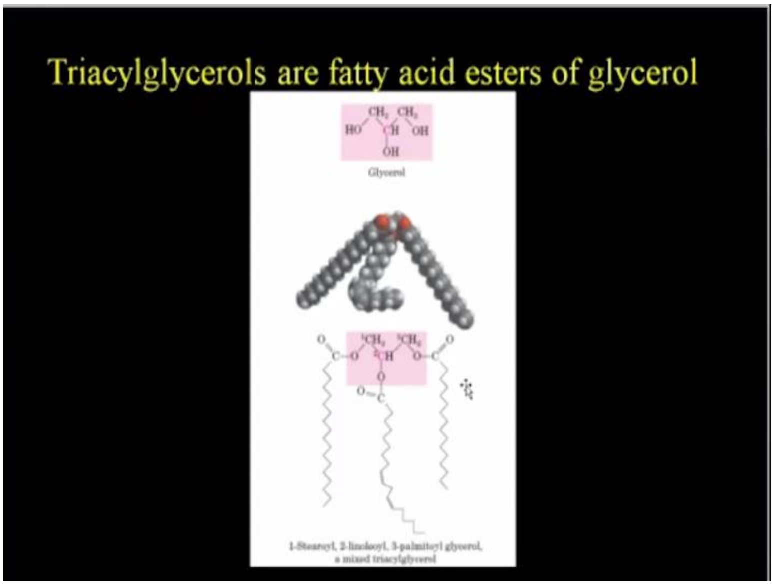

Then usually these free fatty acids they travel around in our blood bound to proteins because these themselves are not soluble in water, so they move around primarily associated with proteins. And usually they are not found in the free form, instead they are esterified with the glycerol with the three alcohol groups of glycerol. So, they form triacylglycerol as shown here. So, this is the glycerol molecule with three fatty acids.

So, one of them in this particular cartoon has two double bonds. So, we call this structure as kinks okay. Kinks, this becomes very important when we go to lipid bilayer okay. So, I will talk about lipid bilayer in a minute, but let us complete this triacylglycerol part. So, this is the form in which the free fatty acids are usually present. So, as you can see here there are no oxygens or any polar thing.

So, these are completely reduced and therefore when you oxidize them there is potential for a lot of oxidation and therefore a lot of energy liberation. So, these are very compact storage of energy, compare it with glycogen or starch where the carbon atom of these monosaccharides have hydroxyl groups they are basically poly alcohols. So, their ability to they have limiting potential for oxidation, they are not fully reduced.

So as a result, the amount of energy available per unit weight of carbohydrate is about approximately half of the energy available from this. So that is why your body tends to convert the extra calorie that you eat into triacylglycerol and stores in adipose tissue. A common place is the adipose tissue around your belly and that is why one gets pot belly-like structures or subcutaneous all over the body under the skin. So that is triacylglycerol, it is important storage molecule, energy reserve.

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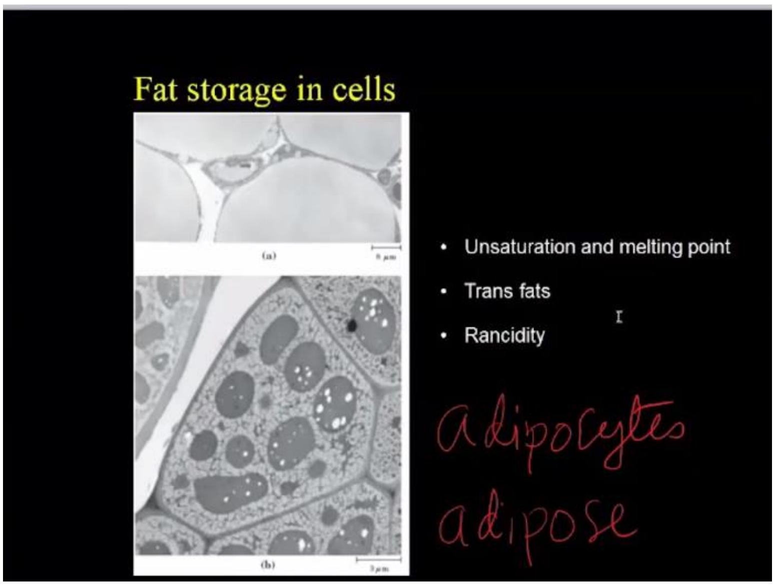

And here is an example of four major adipocytes. These adipocytes are the cells which are fat filled adipocytes okay. So, these are present in adipose tissue which is under our skin and also surrounding many internal organs okay. So, this is a cross section of 4 adjacent adipocytes. Here the cytoplasm is actually pushed to the edge. This clear area is all triacylglycerol, fat filled structures.

So here you see little bit blood capillary there, but the primary structure here is the fat. This is a cotyledon of a plant cross section. So, this is one single plant cell with its cell wall. So, these are protein storage here and this white area are all fat filled here. So, it is a compact storage of energy. When the seed germinates you can get more energy out of these lipids compared to if these were actually filled with carbohydrates. So, they are important storage of energy.

Okay, those who have class leave, but I will answer the questions that have already come and then stop. So, one question we have is lectins same as the pus that is formed? No, lectins are specific protein molecules, it is not the liquid. The pus is actually mixture of multiple things. So, lectins are protein molecules which are present in all our tissues and cells and in the blood and they are also present in plants.

They are proteins that recognize specific sequence of oligosaccharides attached to other proteins or lipids and that is how they might identify a given cell. So, we will learn more about it when we go to the blood group, so do not worry about it. They are not the pus. Did not get proteoglycans being majority in the extracellular matrix when there is clearly 50,000 disaccharides to which proteoglycans are attached, my doubt being should not its name glycoprotein extraction.

No. So when you say glycoprotein, protein is the main thing but in proteoglycans the glycan is the main thing. When you talk about 50,000 disaccharides that is whole lot of carbohydrate. The protein itself is going to be about 300 amino acids or so. So therefore, they are appropriately called proteoglycans, the glycan part is the big one. So, I will go back to that. See here, compared to the protein this is a long chain and each one of these chains these are all carbohydrates.