Basics of Biology
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Lecture 19
Lipids

Hello everyone, this is Dr. Vishal Trivedi from Department of Biosciences and Bioengineering, IIT Guwahati. And what we were discussing? We were discussing about the biomolecule. And in this context, so far, what we have discussed, we have discussed about the nucleic acids, and we have also discussed about carbohydrates.

In our previous lecture, we were discussing about the structure as well as the function of the carbohydrates and how the carbohydrates are being utilized in the different types of metabolic pathways. So, that you can be able to utilize to produce the energy. Now, in today's lecture, we are going to discuss about another biomolecule and that biomolecule is the lipids.

So, as you can see here is that the lipid more biomolecules are required for the energy productions and lipids are, you know, been as you can see that when we were discussing about the Kreb cycle the lipids are being run through the beta oxidation and that is how they are producing the Acetyl CoA and these Acetyl CoA are entering into the Kreb cycle to produce the energy. So, the first question comes is what is lipid and what is the structure of a typical lipid? So, what is lipid?

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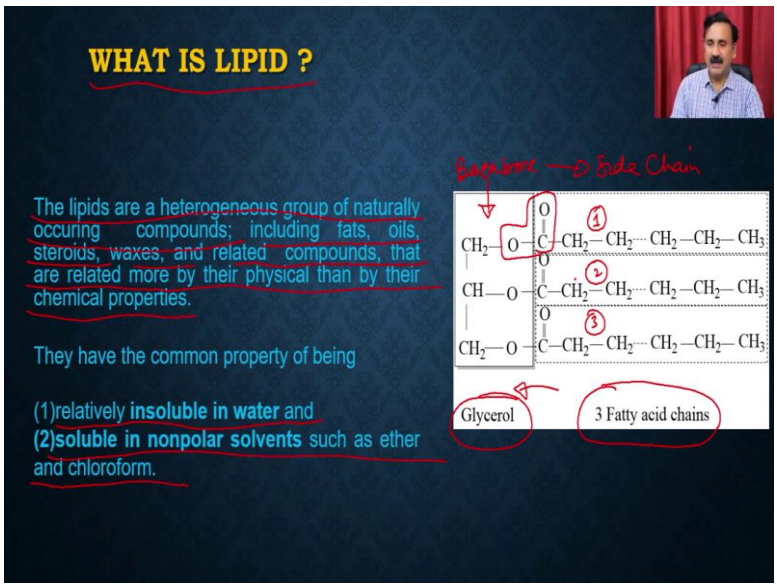

So, the first question is what is lipid and the lipids are the heterogeneous group of naturally occurring compounds, including the fat, oils, steroid, waxes and related compounds that are related more by their physical than by their chemical properties, they have the two common properties, they have their -- So, lipids are relatively insoluble in water and they are soluble in the nonpolar solvent such as ether and chloroform.

So, what you see here is that the typical lipid has two components one it is has a backbone, the backbone and then it has the side chains. So, the side chain is -- Backbone is mostly been present as the glycerol, so it has glycerol backbone or the alcohol backbone and then it also has the fatty acids. So, you can have the three chains of the fatty acids. So, this is the chain number 1, so this is number 2 and this is the number 3.

And this acid group is making a linkage with the alcohol what is present onto the glycerol and that is how it is forming a lipid molecule. So, what you see here is the three fatty acids are coupled with the three-alcohol group what is present onto the glycerol. So, let us understand this backbone and the sidechain first.

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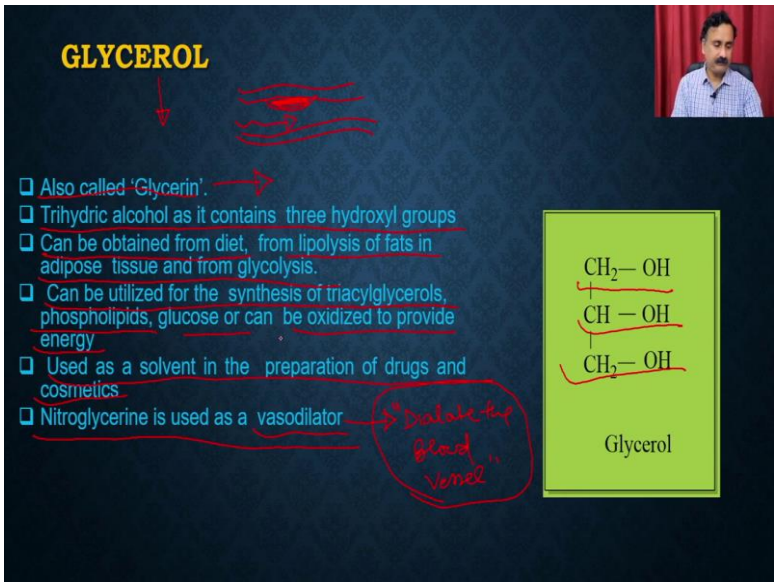

So, what is glycerol? So, glycerol which is also known as the glycerine, is a try hydroxy alcohol. So, what you see here is the chemical formula of glycerol. So, Ch2 OH, CH OH, CH2 OH. Try hydroxy alcohol as it contains the three-hydroxyl group, it can be obtained from the diet, from the lipolysis of fat in the adipose tissue and from the glycolysis. It can be utilized for the synthesis of the triacylglycerol, phospholipids, glucose or can be oxidized to produce the energy.

So, glycerol can directly be taken up into the different types of metabolic pathways and that can be utilized for the production of the triglycerides, phospholipids and even it can be converted into the glucose to produce the energy. It is used as a solvent in the preparation of the drug as well as the cosmetic industry. And the Nitro-glycerine is always been produced from the glycerol and that has been used as a vasodilator.

What is mean by the vasodilator is that it is going to dilate the blood vessels. So, you can imagine that if somebody is having a blockage, if somebody is having the heart related or cardiovascular diseases, their blood vessels are going to narrow down. So, their blood vessel is going to have the internal clots and because of that, they will get narrowed down. So, if you provide the nitro-glycerine, it is going to dilate the blood vessels and that is how the blood flow is going to be more in these blood vessels and that is going to give us some kind of relief to these patients.

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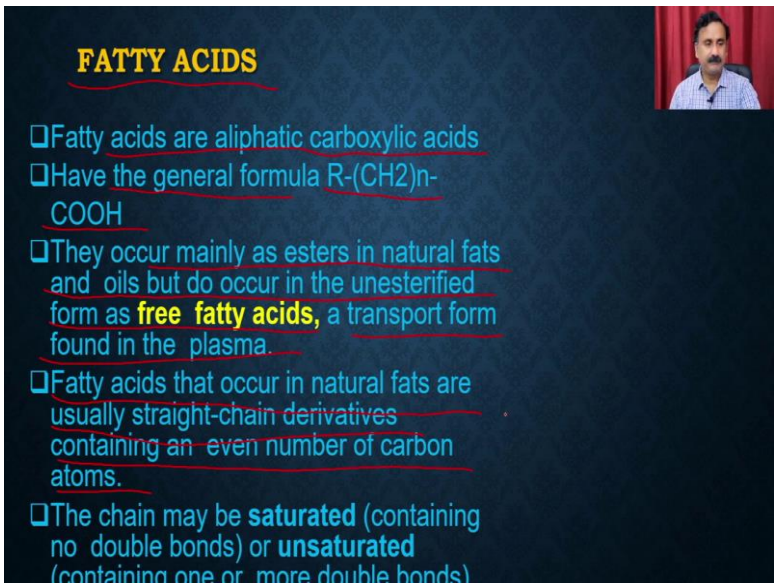

Then we talk about the fatty acids. So, fatty acids, fatty acids are the aliphatic carboxylic acids, they have the general formula as R-CH2-n-COOH. They occur mainly as an ester in the case of natural fats and oil, but do occur in the unesterified form as the free fatty acid as transported form found into the plasma. So, these fatty acids are either been presented in the unesterified form or they are also present as a free fatty acid because they are being transported that way into the plasma.

So, when we take the food, the food is a complex lipid molecule, and that complex lipid is going to be digested by the lipase, and that lipase enzyme is going to degrade the fat into

the free fatty acids and the fatty acids are then being absorbed by the elementary canal, from the elementary canal and therefore, they will transport it into the plasma.

Fatty acids that occur in the natural fats are usually the straight chain derivatives containing a even number of carbon atom, they may be saturated or the unsaturated. They may be saturated, which means they will contain no double bonds or they can be unsaturated, which may contain the two or more double bonds.

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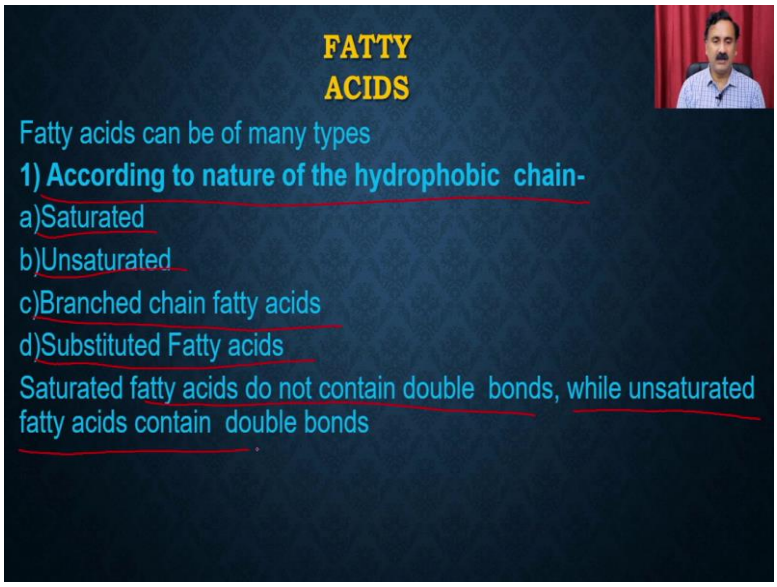

Fatty acids can be of many types according to the nature of the hydrophobic chain, it can be saturated or the unsaturated or the branched chain amino fatty acids or the substituted fatty acids. Saturated fatty acids do not contain the double bond while the unsaturated fatty acid contained the double bonds.

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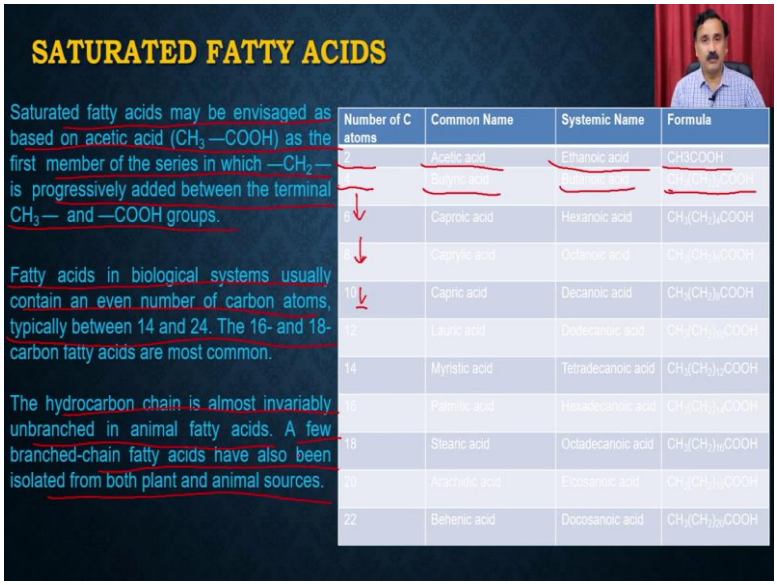

Saturated fatty acids, these are the examples of the fatty saturated fatty acids. So saturated fatty acid can be envisaged as a base on the acetic acid as the first member of the series in which the CH_2 is progressively added at the terminal CH_2 and COOH. So, you can imagine that the acetic acid is the first saturated fatty acids. So, if the number of carbon atom is 2, then it is going to be the acetic acid or the ethanoic acid formula is CH_3COOH.

Now, on this if you add another molecule of CH_2, then it is going to produce the butyric acid. So, what you see here is the 4 carbon, so 4 carbon is butyric acid or the butanoic acid and it is going to be $CH_3CH_2CH_2CH_2COOH$. So, accordingly, it could be 6 carbon, 8 carbon, 10 carbon and so.

So, fatty acids in the biological system usually contain the even number of carbon atom, which means it can be 2 4 6 8 10 and so on. And typically, 14 to carbon atoms are present into the saturated fatty acids. The hydrocarbon chain is almost invariably unbranched in the animal fat. A few branched chain fatty acids are also been found into the plants and animal sources.

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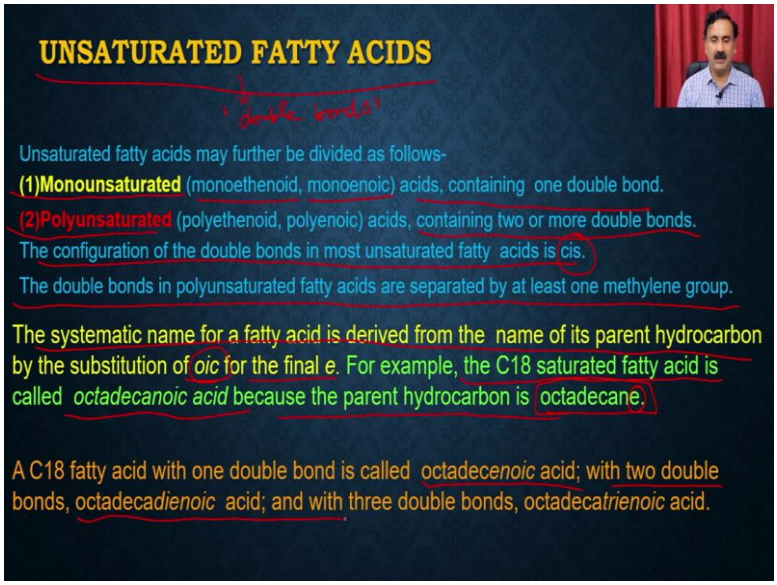

Then, we had talked about the unsaturated fatty acids. As the name suggests, the unsaturated fatty acid means it is going to have the one or more the double bonds right. And the unsaturated fatty acid could be a monosaturated fatty acid or to the polysaturated fatty acids. Monosaturated fatty acid is going to contain either only the one double bond and they are going to be called as monoethenoid or the monoenoic, whereas the polysaturated fatty acids are containing two or more double bonds.

The configuration of the double bond in most unsaturated acid is cis, so it is no transect double bonds. The double bond in polyunsaturated fatty acid is separated by at least one methylene groups. The systematic name for a fatty acid is derived from the name of its parents hydrocarbon by the substitution of oic for the final e.

For example, if you have the C18, saturated fatty acid, fatty acid it is called as the octadecanoic acid because the parent hydrocarbon is octadecane. So, in the fatty acid the last e can be just replaced with the oic. So, for example, the C18 saturated fatty acid is known as the octadecanoic acid because the parent hydrocarbon is octadecane.

Similarly, the C18 with double bond it is called as the octadecanoic acid with the two double bonds, it is called as the octadecadienoic acid and with the three gravel bonds it is going to be called as octadecatrienoic acid.

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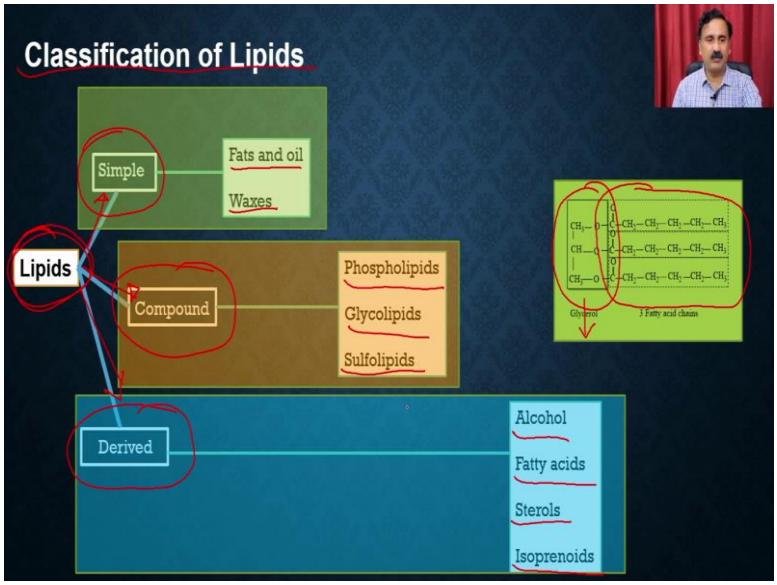

Now, was talk about the classification of the lipids. So, lipids, as I said, it is going to have the backbone, which is going to be alcohol backbone, and then it will also be going to have the different types of fatty acids. So, these lipids could be three different types, it could be the simple lipids, it could be the compound lipids, or it could be the derived lipids. In the simple lipids, you can have the examples are like fat, oil and waxes, where you are going to have the glycerol as a backbone and then you are going to have the fatty acids.

In the compound lipids, you can have the phospholipids, glycolipids, and the sulfolipids. So here, you are going to have the same kind of lipids(11:32) onto the side chain as well as or to the backbone, and therefore it is called as the compound lipids. And then you have the derived lipid, these are the special class of lipids, where you are going to have the modification in terms of the backbone as well as the side chain, so it is going to be alcohol, it is going to be a fatty acid or it can be going to be sterols or isoprenoids. So, depending on the backbone, the derived fatty lipids could be of different types. So let us first understand about the simple lipids.

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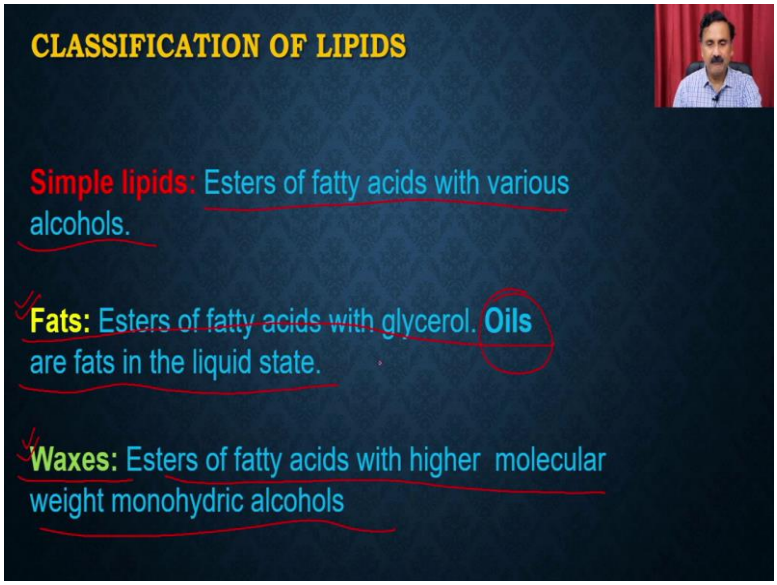

So, simple lipids are the ester of the fatty acid with the various alcohol, you have the two examples one is fat, the other one is called as waxes. The fat, the ester of the fatty acid with glycerol. Oils are fat in the liquid state. So, oil is the fat which is been present in the liquid state whereas the fat could be the solid. Then we have the waxes, the ester of the fatty acid with the high molecular weight monohydric alcohol that is called as the waxes. One of the example of the fat is triglycerides.

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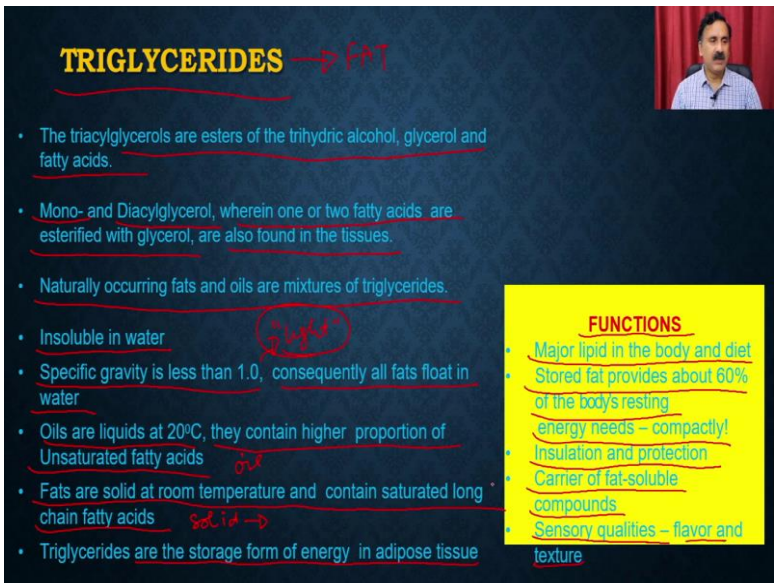

So, triglycerides, so triglyceride is one of the fat molecules. And triglycerides are the ester of the glycerol and the fatty acids. It could be the monoglycerides or the diglycerides. So, mono or di glycerol's whereas one or two fatty acids are esterified with the glycerol and

found in the tissue. They are naturally occurring fats and oils are mix of the triglycerides. They are insoluble in water. Their specific gravity is less than 1. And they are consequently all fats float into the water which means they are very light.

So, they are light and because of that they are going to be float onto the water. Oils are liquids at 20 degrees they contain the high proportion of the unsaturated fatty acids. Fats are solid at the room temperature and contain the saturated long chain fatty acids. So, if it is containing the unsaturated fatty acid, it is going to be liquid and that is going to be called as oil. If it is containing just saturated fatty acid then it is going to be solid.

So, and that solid is going to be called as the fat. The triglycerides are the storage form of the energy in adipose tissues. What is the function of the triglycerides? It is a major lipid in the body and a diet. It stored fat provide about 60 percent of the fat resting energy needs. It is produced for the insulation and the protection. And it is also be required for the carrier of the fat-soluble compounds. And it has also been a sensory quality like the flavor as well as the texture.

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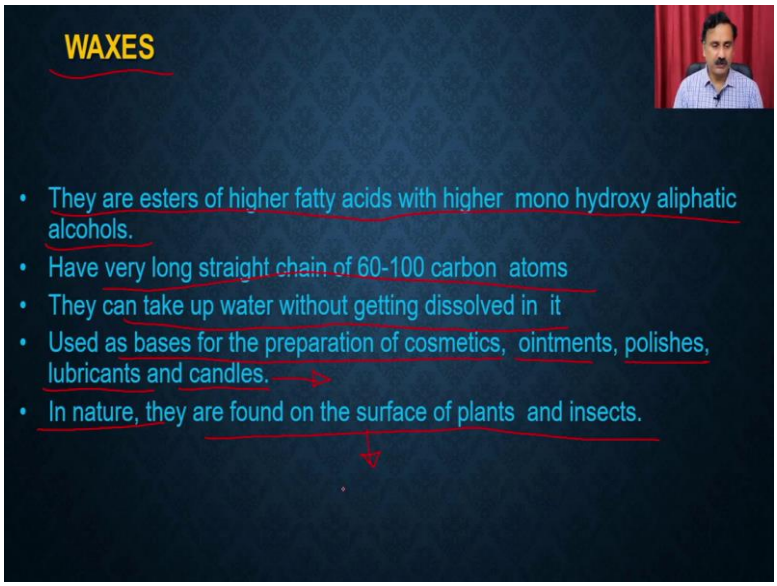

Apart from that, we can also discuss about the wax. So, they are the ester of the higher fatty acids with the higher mono hydroxy aliphatic alcohols. They are very long straight chain of the 60-100 carbon atoms. They can take up the water without getting dissolved in it. And they are used as a basis for the preparation of the cosmetics, ointments, polishes, lubricants and candles, so where you know that the wax is used for the production of the candles.

In nature, they are found on the surfaces of the plant and as well as the insects. So, wax in the plant or in the case of wax insects, they are been utilizing the waxes only to repel the water molecules.

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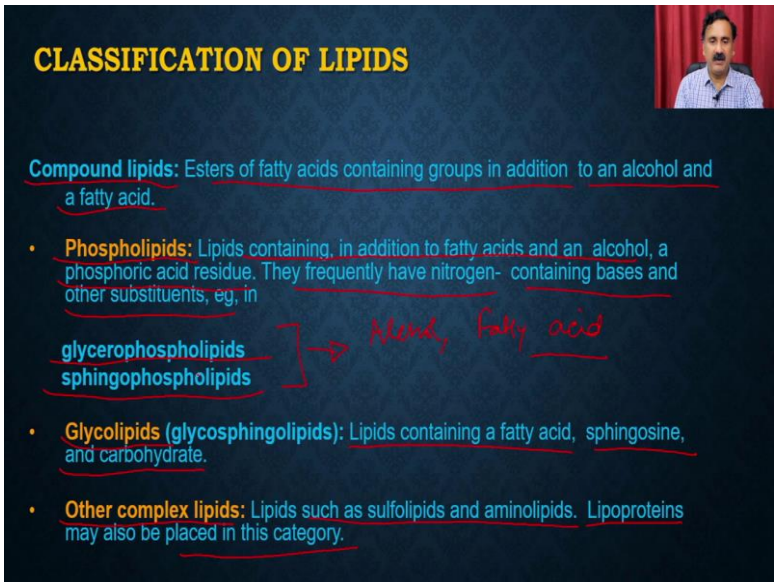

Now, let us talk about the compound lipids. So, compound lipid the ester of the fatty acid containing group in addition to the alcohol and a fatty acid. So, in this case you have the phospholipids. So, lipid containing in addition to fatty acid and alcohol of phosphoric acid residue, they frequently have the nitrogen containing basis and the other subsequent. For example, we have the glycerophospholipids or the sphingophospholipids.

So, in the phospholipids, instead of in addition to the alcohol base or the fatty acid, you are also going to have the phosphoric acid as the additional molecules, then we can have the glycolipids. So, glycolipids, lipids containing a fatty acid, sphingosine and the carbohydrates are called as the glycolipids.

And then we have the other complex lipid, lipids such as the sulfolipids and aminolipids. Lipoproteins are also found under this category. So, let us talk about first the phospholipids. So, in a compound lipid, I have taken an example of the phospholipids.

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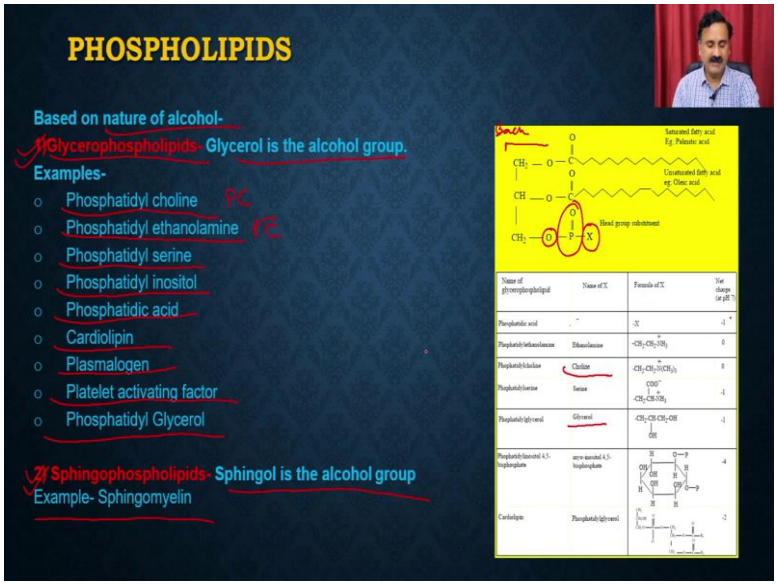

So, based on the nature of alcohol, it could be of the glycerophospholipids or the sphingophospholipids. In the glycerophospholipids, you have the glycerol as the alcohol groups, what you see here is this is the backbone what you see. And under the backbone, the first carbon as well as the second carbon is esterified with the fatty acids, whereas the third oxygen is been there is a phosphate group which is attached, onto the phosphate group you can have the different types of functional group which is going to be attached.

And depending on the functional group, you can have the different types of phospholipids, you can have the phosphatidyl choline. If the X is been replaced by the choline, then it is going to be called as phosphatidyl choline. If it is replaced by the ethanolamine, then it is going to be called as ethanolamine. So, this is called as PC, this is called as PE. Similarly, you can have the Phosphatidyl serine, you can have the Phosphatidyl inositol, phosphatidic acid, cardiolipin, plasmalogen, Platelet activating factor, as well as the phosphatidyl glycerol. Similarly, you can have the sphingophospholipids.

So, in the sphingophospholipids, the sphingol is the alcohol group for example, the sphingomyelin. So, in this case, you are changing the backbone also. So, these are the different types of lipid molecules what is present. So, you can have the different types of functional group the x what is can be, and that is how you can have the different types of phospholipids.

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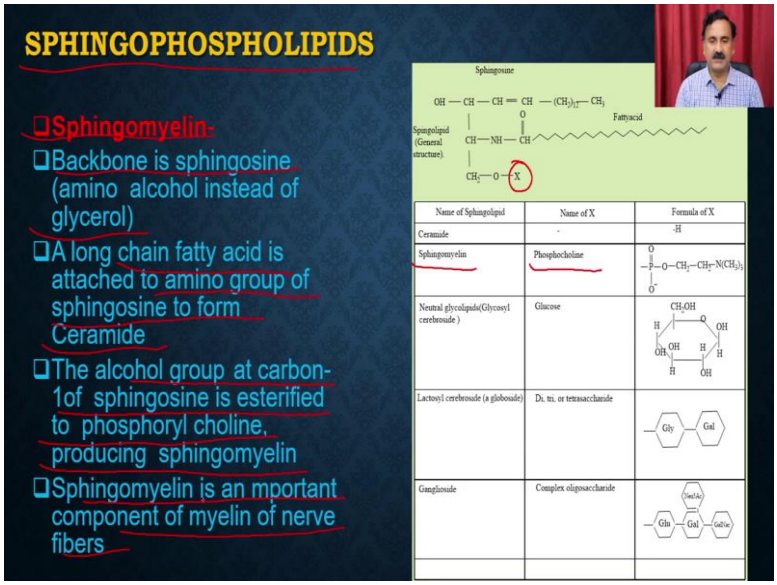

Then we have the sphingophospholipids, one of the classical example is sphingomyelin. So, sphingomyelin is where you can have the sphingosine which is being attached to the one of the carbon, first sphingo lipids. And on this you can also have the X molecule and this X based on this, X you can have different types of sphingomyelin.

So, the backbone is sphingosine instead of the glycerol in the case of sphingomyelin or sphingophospholipids. A long chain fatty acid is attached to the amino group of the sphingosine to form the ceramide. The alcohol group at the carbon one of the sphingosine is terrified to the phosphorylcholine producing the sphingomyelin. So, if you have the phosphocholine, then it is going to call as a sphingomyelin. And the sphingomyelin is an important component of the myelin of the nerve fibers.

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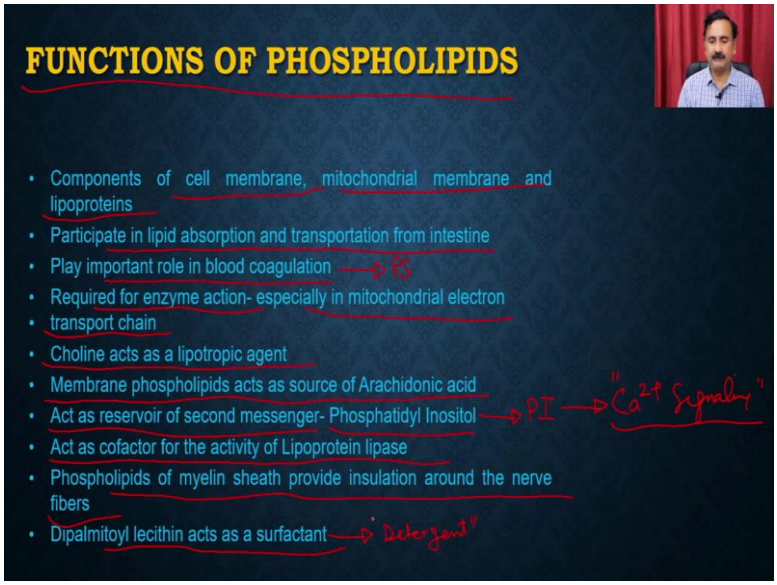

Then we have to discuss about the function of the phospholipids. So, phospholipids are the major components of the cell membrane, mitochondrial membrane as well as the lipoprotein. They participate in the lipid absorption in transportation from the intestine. They play an important role in the blood coagulation like the phosphatidyl choline.

And the required for the enzyme action especially in the mitochondrial electron transport chain. Choline act as a lipotropic agent, and then the membrane phospholipids act as a source of arachidonic acid, it acts as a reservoir of the secondary messenger such as the Phosphatidyl inositol. So, this Phosphatidyl inositol is important for the calcium signaling.

In the case of the many types of responses, there is a phosphatidylcholine which is going to be responsible for the release of calcium from the endoplasmic reticulum and that is how it is going to induce the calcium signaling. It acts as a cofactor for the activity of the lipoprotein lipase and the phospholipids of the myelin sheath provide the insulation around a nerve fiber. And the dipalmitoyl lecithin act as a surfactant, which means surfactant means it is going to function as the detergent.

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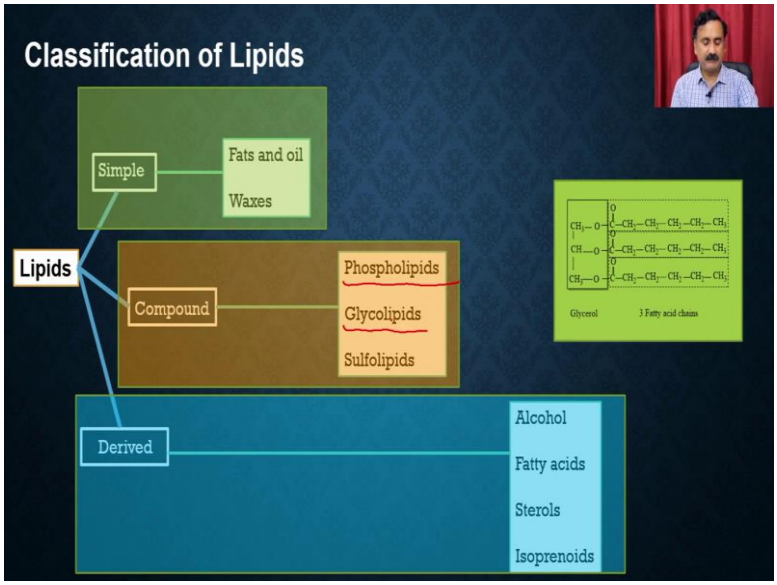

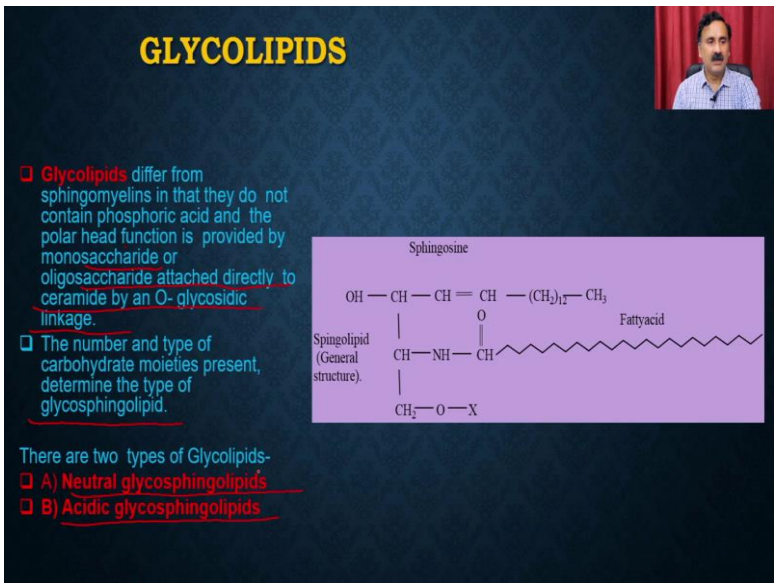

So, these are the things we have discussed about the phospholipids. Then we can also discuss about the glycolipids. Glycolipids differ from the sphingomyelin in that they do not contain the phosphoric acid and polar head function is provided by the monosaccharides or the polysaccharide attached directly to the ceramide by an o-glycosidic linkages.

And so, this is what you see. And the number and the type of carbohydrate moieties present determine the type of the glyco for a sphingolipids. There are two types of the glycolipids neutral glycosphingolipids, or the acetic glycosphingolipids.

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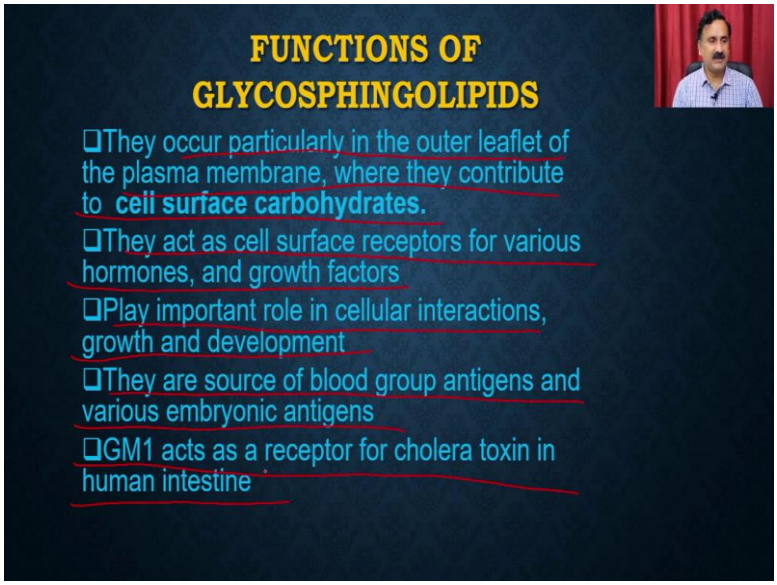

What it is a function of the glycolipids? They occur particularly in the outer leaflet of the plasma membrane where they contribute to the cell surface carbohydrates. They act as a cell surface receptor for the various types of hormones and growth factors. They play an important role in cellular interaction growth and development. And they are source of the blood group antigens and various embryonic antigens. And the GM1 act as a receptor for the cholera toxin in the human intestine.

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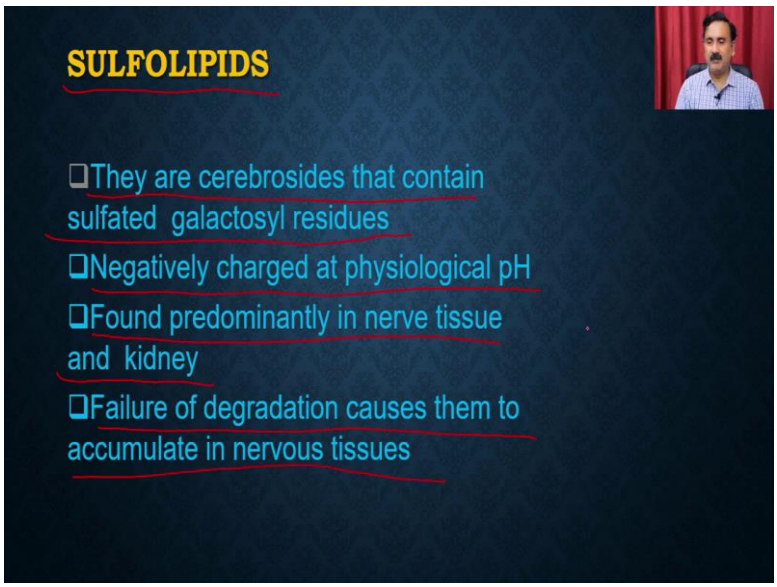

Then we will talk about the sulfolipids. Sulfolipids lipids are the other compound lipids, they are cerebrosides that contain the sulfated galactosyl residues. They are negatively charged at the physiological pH. And they are found predominantly in the nerve tissues and

the kidney. The failure of the degradation caused them to accumulate into the nerve tissues. So, lipid is being digested or been metabolized by the different types of pathways.

And if that does not happen, then the lipid is going to be stored into the different types of organs. For example, the nervous tissues, livers and all other kinds of tissues. And as a result, the lipid storage is going to be responsible for the different types of diseases because lipid has to be utilized for the energy production or other kinds of functions. If it does not happen, then the huge quantity of lipid is going to be accumulate into the cell.

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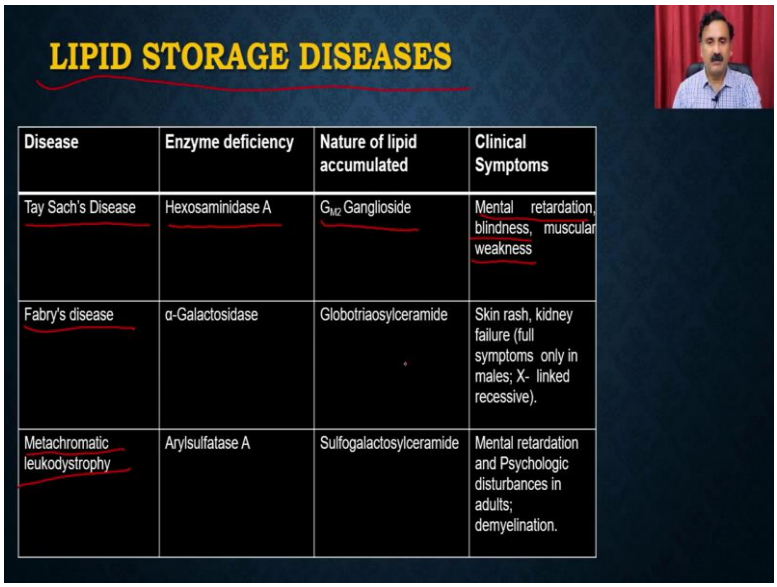

And as a result, it is going to cause the different types of diseases. For example, it can cause the Tay Sach's Disease. So, Tay Sach's Disease is happening because there is a deficiency of Hexosaminidase A enzyme and because of this, there will be an accumulation of the GM2 ganglioside and it is going to be responsible for the mental retardation, blindness and the muscular weakness. Similarly, you can have the Fabry's diseases, you can have the metachromatic leukodystropy and there are other kinds of fats what is going to be stored into the different parts of the body.

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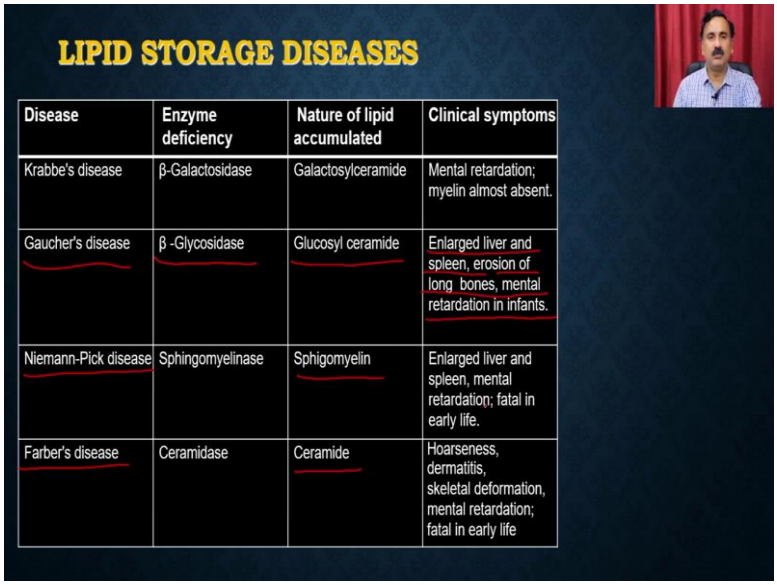

Then we have the some more like Gaucher's disease, the Gaucher's disease where you have the beta glycosidase and enzyme which is going to be absent and because of that the lipid glucosylceramide is going to be accumulated and it is responsible for the enlarged liver and the spleen and the origin of the long bones and mental retardation in the infants.

Similarly, you have the Niemann pick disease or the Farber diseases and that is there you can have the different types of fats, what is going to be stored. And mostly it is responsible for the different types of mental as well as the other abnormalities into the different types of organs.

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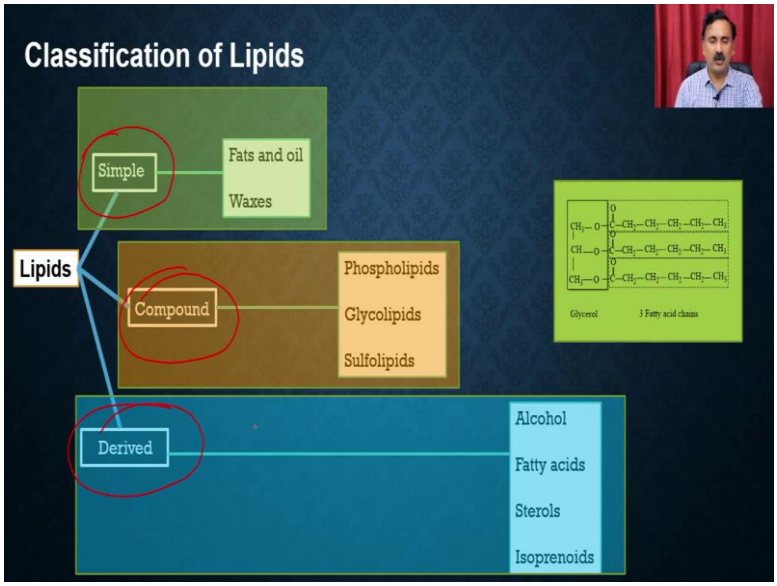

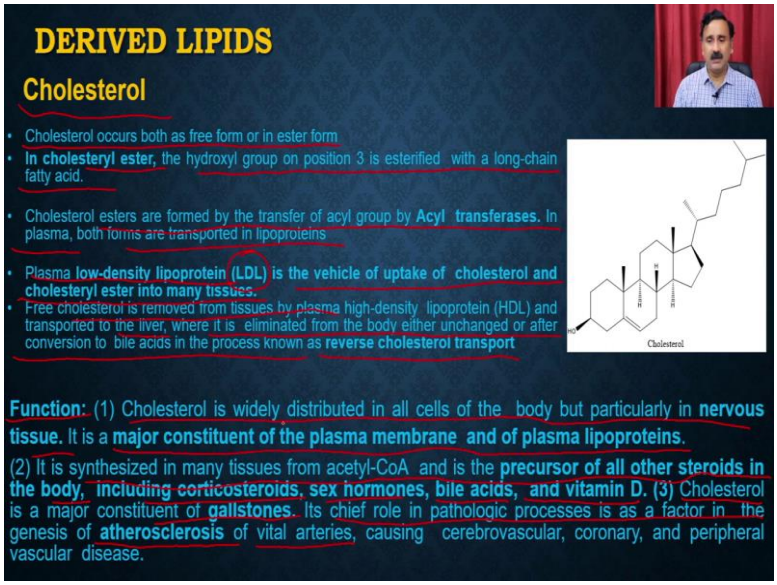

So, this is all about the simple lipids as well as the compound lipids and then talk about derived lipids. So, within the derived lipid, you have that special type of lipids. So, within the derived lipid have taken an example of only one lipids which is called as cholesterol. So, cholesterol is a different structure and the different biochemical properties and does not follow the rule where it has the backbone and then fatty acid and all that.

So, but the cholesterol occurs both in the free form as well as in the ester forms. In cholesterol ester the hydroxyl group on the position three is esterified within long chain fatty acids. The cholesterol esters are formed by the transfer of Acyl group by the Acyl transferases. In plasma, both the forms are transported in the form of the lipoproteins.

The plasma low density lipoproteins or the LDL is the vacuole of the uptake of cholesterol and the plasma cholesterol ester into the many tissues. The free cholesterol is removed from the tissue by the LDL molecules and it is transported into layer where it is eliminated from the body either unchanged or after conversion into the bile acid in the process known as the reverse cholesterol transport.

So, this is the structure of the cholesterol, what you see here it has the different types of rings and then it has this chain. What is the function of the cholesterol? So, cholesterol is widely distributed in all cells of the body but particularly in the nervous tissue. It is a major constituent of the plasma membrane and of the plasma lipoproteins. It is synthesized in many tissues from the Acetyl CoA and it is the precursor of all other steroids in the body including the corticosteroids, sex hormones, bile acid and the vitamin D.

So, major function of the cholesterol is that it is a major constituent of the lipid what is present into the plasma membrane and it is also been responsible for the biosynthetic pathway or the biosynthesis of the different types of the corticosteroids or as well as the sex hormones. It is also responsible for the biosynthesis of the bile acid and the vitamin D3. Cholesterol is a major constituent of the gallstone.

So, you know that there are stone which are being formed into different organs, whether the stones are formed into the gallstones or onto the kidney. So, the cholesterol is a major constituent of the gallstones. Its chief role in the pathogenic processes is a factor in the genesis of a disease which is called as atherosclerosis of the vital arteries, causing the cerebrovascular, coronary and peripheral vascular diseases.

So, cholesterol is an important lipid and it can be transported into the blood by the help of the LDL. And whereas, the HDL is a lipoprotein, high density lipoproteins, which can carry the cholesterol or the high amount of cholesterol into the blood, into the liver and within the liver, then it is going to be metabolized to produce the bile salts and these bile salts are being utilized to help in the lipid digestion and other kinds of things.

So, this is all about the lipids, what we have discussed so far, what we have discussed, we have discussed about the general structure of the lipids, where we have discussed about that the lipid is made up of a alcohol backbone and the fatty acids. This alcohol backbone could be of different types and depending on the alcohol group, the lipids could be of different types.

Similarly, the side chain or the fatty acids also could be or different types, the fatty acid could be saturated fatty acids or the unsaturated fatty acids. And depending on the different types of functional groups, what is present on to the alcohol backbone, the lipids could be of different types like the phospholipids or glycolipids, sulfolipids.

And then we also have this special class of lipids where we have the cholesterol and the other lipids.

So, with this, I would like to conclude my lecture here. In our subsequent lecture, we are going to discuss some more biomolecules which are important for the cellular functions. So, with this I would like to conclude my lecture here. Thank you.