Introduction to Biomolecules
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Lecture – 2
Introduction to Biomolecules - Part – 2/2

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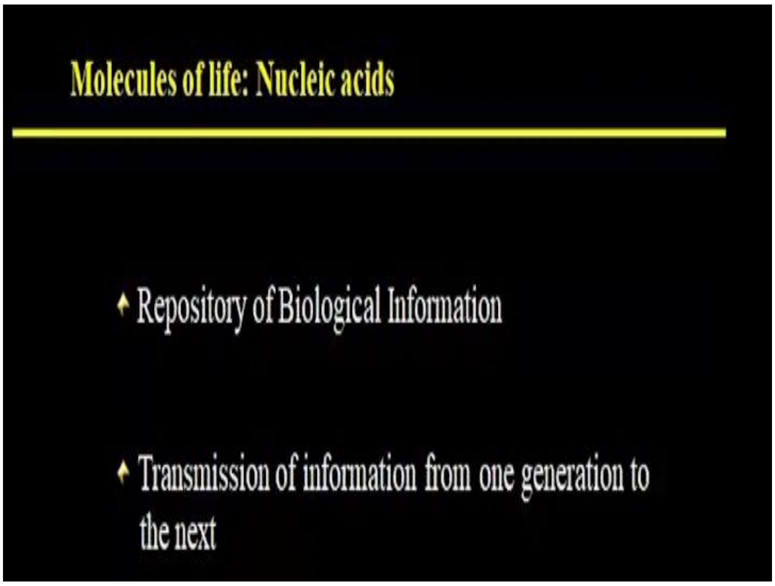

Okay alright, so let us begin. So, in the last class we learned about carbohydrates and proteins, the very basics we learned and I told you we will learn more elaborately later when we could get to those specific chapters. So today what we are going to do is we are going to continue that basic introduction to the other molecules of life. So, the next molecule in this is nucleic acids. So nucleic acids is what we are going to look at.

So nucleic acids again just like how we learn in carbohydrates and the proteins, we will first begin with the functions of nucleic acids because I always believe that once we know the importance of a molecule for life then we pay more attention to understanding its chemistry. So this one is a common knowledge anyone who knows English, I am sure already knows nucleic acids are the genetic material.

So, they are the repository of biological information. So what is biological information? The information required to make a particular biological function. For example, if you take human beings, only human beings give rise to human beings and at the same time human beings cannot produce other organisms and other organisms cannot produce anything other than their own kind. So all these tells is every species, for example homo sapiens.

We have the information in our genetic material to make another homo sapiens and that is what we call as the biological information. When I say make another homo sapiens meaning all aspects of it. The anatomy, morphology, functions, everything. So, the information to make or the blueprint to make another organism of the same kind is stored in nucleic acids and that is why nucleic acids become one of the really important molecules.

So that is their primary function. So they are not simply storage of information, they have in their structure there is the ability to copy and transmit that information to a subsequent generation as well. So that is the importance of nucleic acids, that is their main function storage and transformation of biological information.

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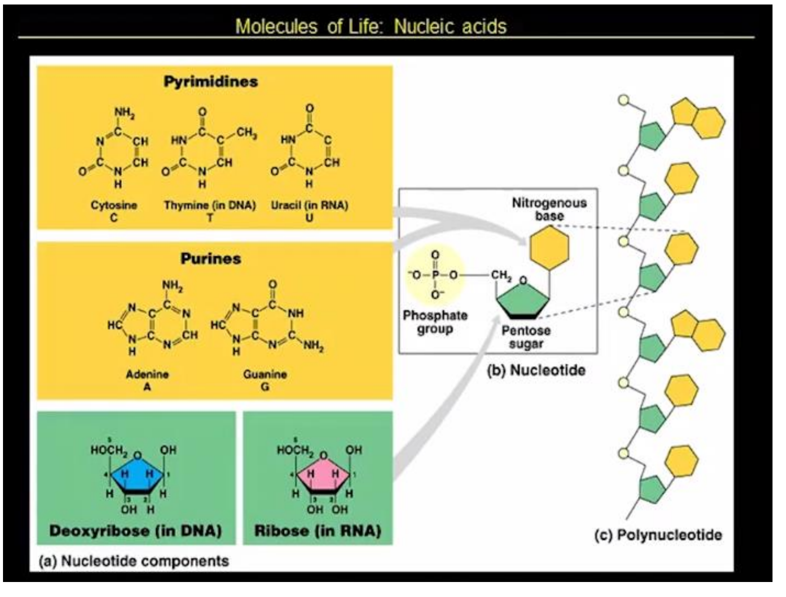

So now let us look at you know since it is a biochemistry class our focus is knowing the chemical structure and the chemical function of these molecules and then make biological sense out of them in terms of the biological function. So their structure is again like all biomolecules they look really large molecules and look really complex, but when you look into the basic principles you will realize where they are all very simple molecules.

The complexity comes from the way these simple molecules are arranged repetitively and joined into a polymer. So here if you look at it, on the right side of the slide you see a long chain of like hexagonal or pentagonal structures joined by a long line and that is how a polymer of nucleic acid looks. So, in carbohydrates we call that as a polysaccharide, in proteins we called polypeptide, so here it is polynucleotide.

So the repeating monomer is a nucleotide, so where my cursor you focus on that and that is a nucleotide. So the nucleotide has 3 important components. One shown in this orange color, so this is a nitrogenous base because this ring structure has nitrogen and therefore we call this as a nitrogenous base. They are of 2 kinds, the smaller one we call the purine because it is the purine ring structure or pyrimidine, so you have in a hexagon and a pentagon attached this is a pyrimidine.

So there are 2 kinds, purine the big molecule has the shorter name purine and the smaller one has the longer name pyrimidine and that is one component of this monomer called mononucleotide. Another component is a sugar. So we became familiar with glucose and fructose. So glucose is a hexose. So here what is present is a pentose, five carbon sugar called ribose and this attachment you may not find it hard.

Because we know that the sugar molecule has alcohol groups, hydroxyl groups, and with that you can easily attach the way one sugar is attached to another sugar. And similarly to another hydroxyl group on the ribose you can have another kind of link, so here it is a phosphoric acid. So it is a phosphodiester, you know it is an ester linkage, alcohol acid ester linkage and that phosphoric acid can make another ester linkage with another ribose and this phosphoric acid, this ribose sugar and this nitrogenous base.

All 3 put together as shown in this big enlarged cartoon forms a nucleotide. Nitrogenous base, pentose sugar and to that you have a phosphate group attached. So phosphate group has you know it is H3PO4 so you have 3 acid groups. The hydroxyl group here it is an inorganic acid, this is an acid moiety, it is not to be confused with the alcohol group that you will find in organic molecule.

So organic acid is carboxylic acid COOH, so here it is you know this H3PO4 these are the 3 acid groups, of the 3 acid group here one is in ester linkage with this alcohol group CH2OH and the other one is attached to the next one in a long poly nucleotide chain and there is a third one that is still free and that dissociates when dissolved in water releasing proton and therefore this long polymer is actually an acid.

Because every one of this phosphate group in this long chain has one acid group free and that dissociates giving proton in solution. So therefore, this polynucleotide is actually an acid that is why we call it as nucleic acids. So now let us get into little bit more detail. I told you nitrogenous base 2 types that is visible in this cartoon like you have pyrimidine and purine. So now let us look at what are the different purines and what are the different pyrimidines.

So here are the 3 pyrimidines shown in the top left orange box, so cytosine, thymine. So these two are present in the nucleic acid where the information is stored and whose replication helps in transmitting to next generation and that is DNA. So in DNA you have cytosine, thymine. So these are the two pyrimidines. In another kind of RNA called ribonucleic acid or RNA instead of thymine you have uracil.

So in RNA you find cytosine and uracil instead of thymine and purine in both the kind of nucleic acids they are the same two kinds, one is adenine and another one is guanine. So here you have the structures. So you see the nitrogen atoms present in these molecules, so that is why these are called nitrogenous bases. So now I introduced this new term RNA and then I first mentioned DNA. So what is the difference between the two?

The difference is quite simple. If you focus your attention on this second carbon, so we already learnt in carbohydrate class this is 1, 2, 3, 4 and there it was hexose and therefore there was one more and this was 6. So this is pentose, so this is 5. So the second carbon if it has a hydrogen instead of hydroxyl group, so therefore ending up having two hydrogens it is deoxyribose because ribose normally has a hydroxyl group here.

And if it does not have the hydroxyl group it is called deoxyribose and if that is the kind of ribose present in a long chain then that is deoxyribonucleic acid and shortly DNA and instead if a normal ribose is present with its hydroxyl group in this second carbon then we call this as ribonucleic acid or RNA. So one other important information to learn here is we do not call this carbon numbering as 1, 2, 3, 4, 5 instead we call them 1 prime, 2 prime, 3 prime, 4 prime, 5 prime.

The reason we number the carbon of sugar in nucleic acid in this manner is because these purine and pyrimidine moiety atoms also need to be numbered. So these are numbered 1, 2, 3,4, 5, 6 and as a result it would distinguish this from this, so the nitrogenous base atoms are numbered, the ring atoms are numbered 1, 2, 3 and the sugar atoms are numbered 1 prime, 2 prime, etc.

So this is the basic structure of a nucleic acid, quite simple, all we need to know is it is a polymer and the repeating monomer is a nucleotide and the nucleotide itself has 3 components, namely a nitrogenous base, a pentose sugar and a phosphate group and this phosphoric acid makes two ester bonds and therefore we call as diester bond between adjacent ribose sugar, sugars in a long chain and this is what we call as the sugar phosphate backbone.

So the polynucleotide is held together primarily by the sugar and the phosphate, sugar phosphate, sugar phosphate like this and these are attached to the sugar moiety the nitrogenous bases. So this is the basic chemistry of nucleic acids.

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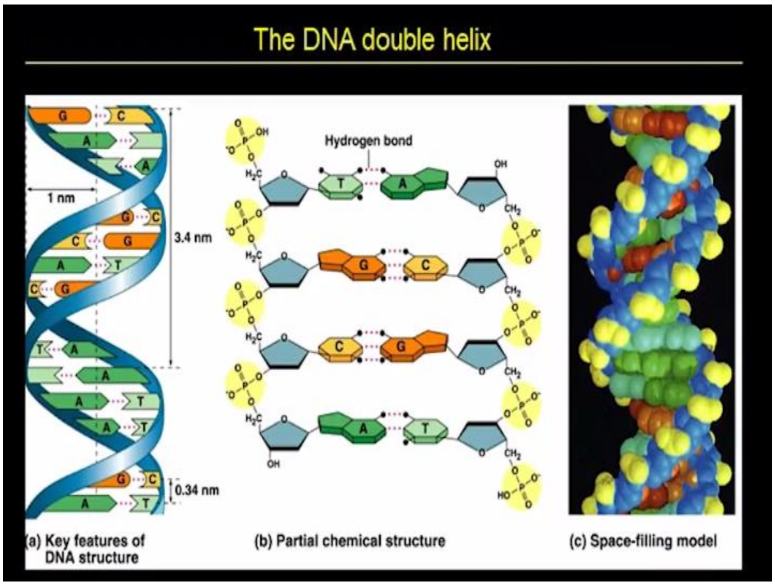

But you know from the structure an emergent property arises and emerges and that is shown in this slide. So if you have one polynucleotide chain and if you have another one adjacent, the atoms of the nitrogenous bases, the nitrogenous bases projected towards each other and the atoms of the nitrogenous bases come close enough for hydrogen bonding to happen. See here you have this strongly electronegative oxygen.

If a hydrogen comes from nearby, then you can have a hydrogen bond here and so on. So if a guanine and cytosine come adjacent to each other, there are three hydrogen bond possibilities. So in this introductory class, I am not getting into which are the three atoms here that contribute to the hydrogen bonding. Similarly, if an adenine comes adjacent in the other strand adjacent to a thymine, then two hydrogen bonds are possible.

And these hydrogen bonds individually although they are weak but together in a long chain, they are of significant force to hold two polynucleotide chains together as double stranded structures. So the DNA present in our genetic material like for example in our cell nucleus, they are present in a double stranded form, one polynucleotide adjacent to another one and the base stack up in the middle in the center of the two strands held together by hydrogen bonds.

This sort of a structure that the nitrogenous bases do not project outward like you know this this side and this this side would be outside, instead these are facing each other and this portion is called inner side and facing inside and allowing the hydrogen bonds to form was proposed by Watson and Crick and therefore these hydrogen and hydrogen bonds are often called as Watson and Crick base pairs or Watson and Crick bonds.

So this is what makes them to be in double standard form and in this stacking arrangement they do not remain like a long ribbon, instead they form a helical shape shown here. So they form a helical structure with one turn like from here to here they hold about 10 base pairs. So adjacent base pairs are of 0.34 nanometer distance and therefore one turn of this helix is about 3.4 nanometers. So this is called the major groove, this is called the minor groove.

Those details today I will ignore, when we get into the nucleic acid structure probably we will not be doing that in the biochemistry class but when you learn molecular biology where you will learn more about DNA replication, transcription, etc., there you will learn about these structures as well, but for this class all you need to know is polynucleotides contain nucleotides as the monomer and the nucleotides have three components.

Two adjacent strands can base pair and that base pairing is these are bases and they pair like AT and GC and that is why it is called pairing and that base pairing bond is actually hydrogen bond and this sort of a double stranded structure forms a helical twist and that is how the actual DNA structure is, so this is what we need to know. So one important additional information we should know is there is a directionality for these strands.

So let us go a little bit back and come to this again, yeah so here if you look at it say if you take this ribose let us say this is at one end of a long chain. So that means here it is no longer it is not attached to any more nucleotide towards the bottom of this slide so that means this hydroxyl group, these three prime hydroxyl groups, anyway why it is not going away, so this this hydroxyl group here would be free, this is not esterified with any other phosphate.

So this will have a free hydroxyl group at this end, this three prime carbon will be free hydroxyl group. On the other hand on the other end of this chain so you have here therefore this corner here is this 5 prime carbon, so 5 prime has an ester linkage, this one has 3 prime. So it is 5 prime, 3 prime, 5 prime, 3 prime like that it goes. At the very end of this this ribose at its 5 prime corresponding to this carbon has only one phosphate attached.

And it is not linked any further or it may not even have a phosphate in some situations and this end where the 5 prime is free we call the 5 prime end of the chain. And this end where the 3 prime hydroxyl is free we call 3 prime end of this chain. So this particular ribbon shown here runs 5 prime to 3 prime in this direction. So, if another molecule comes here exactly in the opposite orientation.

Suppose if I reverse this and have 5 prime free here and 3 prime free here it would be anti-parallel to this and that is the kind of chain with which this base pairing happens. So one chain or one strand runs anti parallel to the other one. If this is as shown here 5 prime to 3 prime, see this is 5 prime to 3 prime, 5 prime is free not linked into another nucleotide so therefore this is 5 prime end, this is not linked to another one therefore this is 3 prime end.

So this 5 prime 3 prime strand base pairs with another one that is 3 prime to like for the same direction this is 3 prime 5 prime, this is 5 prime 3 prime in this direction. So one strand essentially base pairs with another strand that is anti-parallel. So this is another thing you need to know. So when people talk about a 5 prime end 3 prime end you need to correctly understand.

Do not think that you know in the top of the slide is the 5 prime end and the bottom of the slide is the 3 prime end that is not how it is. So molecules are in solution, they have three-dimensional arrangement and they can be in any orientation. So when we say this, these are all with reference to other constituents of the molecules, not the way we are schematically writing.

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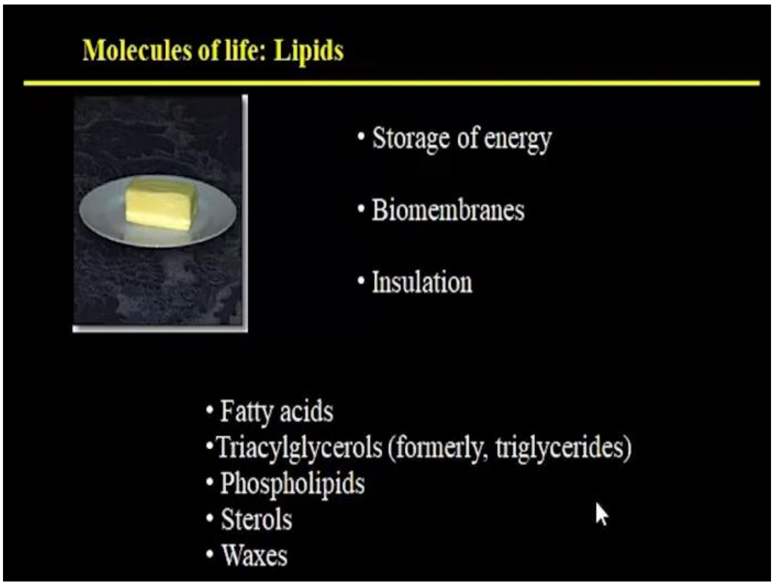

So that is all we are going to learn about RNA and DNA for this very introductory class and now we go and familiarize ourselves with the fourth large biomolecule. These are the only four we need to learn. So biochemistry is actually not that complex considering the complexity of organisms. So the last class we are going to learn are the lipids. So again, let us focus on the functions. So lipids are extremely important molecules.

Without lipids we will not be able to exist as we exist now. So, they are very important. The most obvious one easy to understand is that all our cell membranes the bio membranes are made up of lipids and lipids present just below our skin, subcutaneous fat, insulates our body internal organs from variations in the temperature in the outside environment. So they help in insulation and these are actually the most compact storage of energy.

So carbohydrates we learnt also store energy right. So we learned that the carbohydrates like for example starch and glycogen in our animal liver I told they store energy. So in addition to carbohydrates, lipids also store energy. Lipids actually they store more energy per mole compared to carbohydrate that is because these are highly reduced and as a result their energy content is more than that of carbohydrates.

So they nearly store double the amount of energy per unit mass compared to carbohydrate. So they are very serious storage of energy. For example, if you take all the seeds like oil seeds like groundnut, mustard and so on, they have stored the energy in the most compact form therefore the seed size need not be very big and these lipids are then used to derive energy for the seed to germinate and grow.

So since this is a very compact form of storage of energy, the seeds use them primarily for storing a large quantity of energy required for seed germination until photosynthesis can be started in the form of oil. So these are really important, therefore you know we cannot ignore lipids. So what are lipids? Like are they again polymer made up of monomers? No, so they are different, so they are large molecules but they are not polymers.

So that is one big difference between the other three groups and lipids. So lipids are actually different types of molecules, some are fatty acids. These are like acetic acid, you know acetic acid CH3COOH right, so you have one carboxyl group. Now if you keep increasing the chain, you know instead of CH3COOH you have CH3CH2COH or CH3CH2CH2 like that if you keep increasing the length of the chain what you get are fatty acids, so then we look at the structure in the next slide.

These fatty acids when you esterified with an alcohol, a sugar alcohol, you get what are called triacylglycerols and to them if you add a phosphoric acid you get phospholipids. Then there are some aromatic rings called sterols and then waxes. So these are the 5 major kinds of lipids we have. So lipids are also known as fats, so fat, they are synonymous. So we will look at each one of these how they look like and how their unique structures help the current kind of functions they perform.

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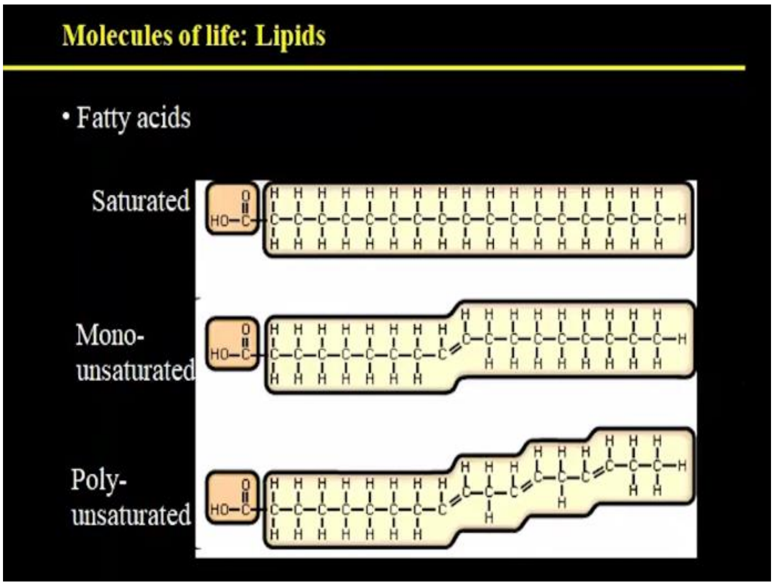

Okay so these are fatty acids. So you have a carboxylic acid, so that is why they are acids and a long chain of aliphatic group with the carbon's valency all you need to do is just fill it by adding hydrogens, the last one is CH3. So when you have a chain like this, this is called saturated fatty acid and if you have a double bond in the chain and this is a degree of unsaturation like one bond is unsaturated.

So we call this as monounsaturated fatty acid and polyunsaturated when you have multiples of them. These molecules are essential, the polyunsaturated, monounsaturated are very important and some of them cannot be made in our body. So they are usually made by microorganisms and plants and therefore they are to be present in our food and we call them as essential fatty acids, so do not worry about that for now.

So all you need to know is fatty acids can either be saturated or they may be unsaturated and depending on the degree of unsaturation we call them monounsaturated or polyunsaturated. So these are often called free fatty acids because these carboxylic groups are not linked to any other molecule, so as a result they are called FFA. So if you take any food like if you take a biscuit packet and look at the ingredients and some of them where the labeling is very professionally done they will tell you FFA, how many grams per 100 gram of that biscuit.

So FFA stands for free fatty acids and under that they would have labeled you know MFA or PUFA polyunsaturated fatty acid, they would have written that .So you can look at any food packet, any packaged food if you take and look at the composition or ingredients nutritional facts and there you will see that.

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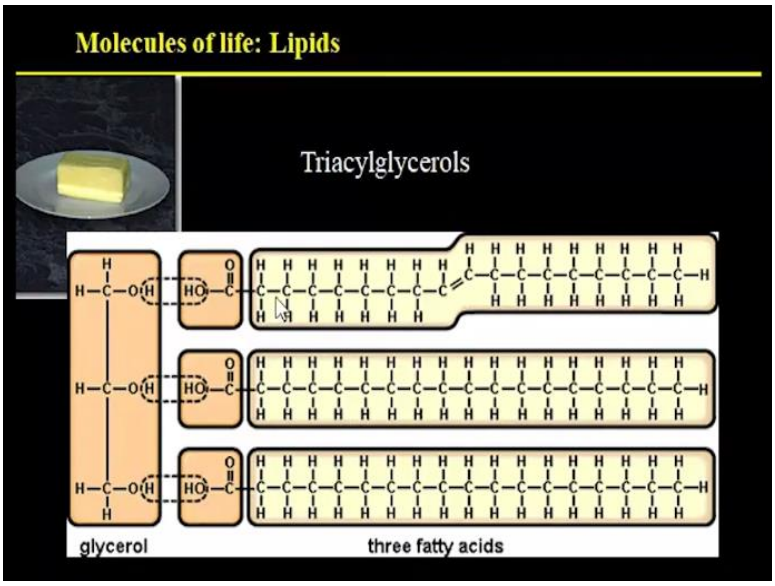

So I told you they are free fatty acids and the carboxylic acid may be linked to other molecules and one form of linking leads to what we call triacylglycerol. This is the form in which our cells store fat. So fat is stored sometimes to some limited quantity in liver as well. Some of the diabetic patients have large storage of fats in the liver are called fatty liver and the most of the normal people we have fat stored in adipose tissue.

That is a sort of tissue that is present you know lining the internal organs in the body cavity and primarily under the skin subcutaneous fat and that is primarily in this form. So here the fatty acid the acid group here is the hydroxyl group that is because it is not merely hydroxyl group it is attached to carbon here so as a result it has acid property not alcohol property. And here you see this hydroxyl group another organic molecule this is alcohol, so this is an ester linkage.

So, glycerol is actually a sugar alcohol. So it looks more like the glucose, instead of 6 carbon it is having 3 carbons. The difference is that it does not have that aldehyde group here and all of them have hydroxyl group attached. So we call this as a sugar alcohol, instead of aldehyde here you have an alcohol group, aldehyde or ketos group you have an alcohol group, so therefore it is a sugar alcohol.

So with these 3 alcohol groups of glycerol when you have 3 fatty acids linked you call that as tri acyl glycerol. This carboxylic acid moiety is called an acyl group and you have 3 acyl groups attached to glycerol. So this is glycerol derivatized with 3 acyl groups and that is why it is called triazole glycerol. So butter for example shown in this plate is primarily triacylglycerol.

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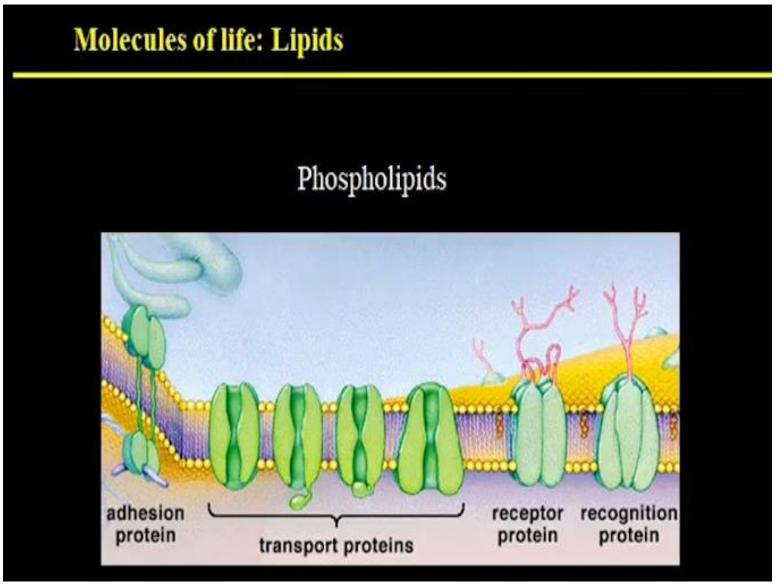

So from triacylglycerol going to phospholipid is no big deal, it is a small change in the structure and here I have shown its importance in terms of the function. You know I always get fascinated by the beauty of this molecule. So what it does is suppose if you look at this structure, so here the bulk of the molecule is essentially this aliphatic group, there are no polar groups, here it is totally hydrophobic molecule.

So it is just not going to dissolve in water at all. So as a result it is very useful to compartmentalize aqueous environment, aqueous meaning water based. So our cytoplasm like the inner part of the cell is aqueous. So separating one cell from another cell means you need something that can partition or compartmentalize water based solution. So that means the compartment has to be something that is hydrophobic and that is served well by this you know hydrophobic nature of these fatty acid tails of triacylglycerol.

But that is in normal you know artificial human being generated world, but biology is a lot more sophisticated. So here the lipid does not serve merely as a partition, it actually can interact upon need. So that is provided by derivatizing this molecule. So instead of this group having a fatty acid attached, this alcohol group of glycerol instead of esterifying with another fatty acid it is in an ester linkage with an inorganic acid which is the same phosphoric acid that we saw in nucleic acids.

So instead of this third fatty acid you have a phosphate attached and once you have phosphate attached it is called phospholipid that is the difference between triacylglycerol and phospholipid. So phospholipids have two acyl groups in glycerol and the third one is a phosphoric acid and the other two acid groups of phosphate may be now derivatized with attaching to other polar molecules.

They are the very basic phospholipid has just the phosphoric acid and that is called a phosphatidic acid and we will learn that in detail when we go to the lipids class. So, for now all you need to worry is in triacylglycerol the last free fatty acid is replaced with a phosphoric acid to make a phospholipid. Due to this what happens is this becomes highly hydrophilic, so this molecule becomes amphipathic, it has a hydrophobic group as well as a hydrophilic group and that is what you are seeing here.

So, if you look closely on these round structures, each one of these yellow round structures, you will see 2 tails jutting out and each of those two tails like structures are nothing but these two groups and that yellow itself is this glycerol with its phosphoric acid and other hydrophilic things attached to that phosphate group and that is what we call as a head group. So we call that as head group and the two fatty acids as the tail group.

And this tail groups point towards another layer of phospholipid molecules and these hydrophobic things interact among themselves through hydrophobic interactions and these head groups being hydrophilic they can interact with the water based aqueous environment. So in this manner phospholipids help in compartmentalizing aqueous environments, but at the same time the compartmentalization comes from this the two acyl groups here.

At the same time, they are in talking terms with these aqueous environments, they can interact through this. So basically it is a wettable surface. This head group can interact with water and this head group can interact with water this side and the two layered membrane or bilayer is what is our cell membrane is. So this is the importance of the phospholipids, do not worry about these structures, we will learn about them later.

These are basically proteins embedded in the form by a lipid bilayer. So our cell membrane is nothing but these phospholipids. So each phospholipid is essentially triacylglycerol in which the third alcohol group of glycerol is esterified with the phosphoric acid and that phosphoric acid may have other polar groups attached to it and that is how phospholipids themselves are many kinds of them. So that is phospholipid.

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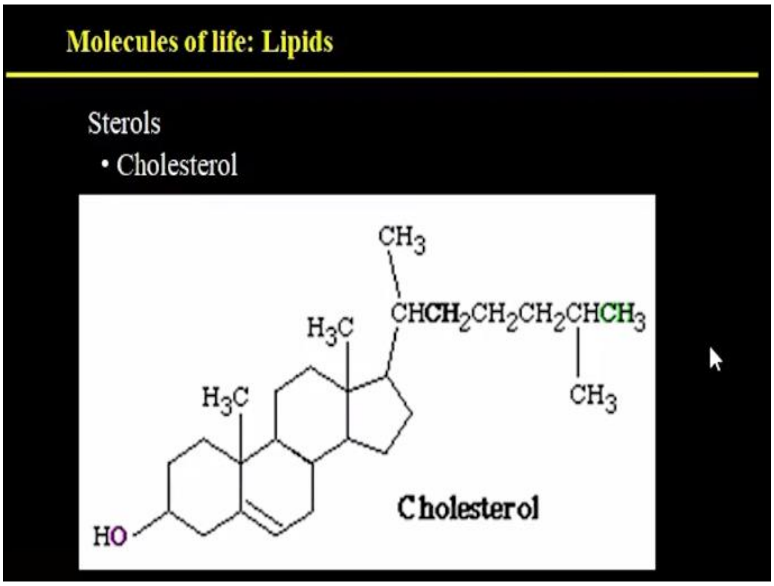

And the last class, not the last one the last but one are the sterols. So what are sterols? Sterols, the very basic kind of sterols present in living organisms is cholesterol and all sterols including cholesterol have this ring structure. So this is called cyclopentane and these three aromatic rings fused in this fashion is called a phenanthrene. So this basic ring unit is called cyclopentanophenanthrene ring.

So this is basic for all the sterols in our body and one sterol varies from another sterol in the other constituents like this side chain and presence of these methyl groups, this double bond, this hydroxyl group. When you have all of these, it is cholesterol. If you have some other group, then it is some other name. Sterols are also very important, many signaling molecules in our body including the two hormones that are responsible for being male or female is sterol molecules, testosterone and estradiol.

So they are derivatives of cholesterol. So that is all we are going to learn about steroids right now. So sterols are made up of this 4 rings formed in this manner and they may have derivatives and the basic one is cholesterol and cholesterol again is a storage lipid and extremely essential important molecule. So you would have learnt about cholesterol already in the common newspaper.

And your friends and family talking about cholesterol being bad and somebody's cholesterol is high and as a result that person has diabetes or hypertension, etc., but those issues are only when the normal molecules have gone in the wrong way when they are too much or their production and degradation is not managed right that is when you have abnormality. Otherwise, these molecules are absolutely essential.

Cholesterol is embedded in this phospholipid bilayer and that is very important for our membrane function and in addition this is precursor for all the steroid derivative hormones and those hormones are important signaling molecules. So therefore, they have very important functions.

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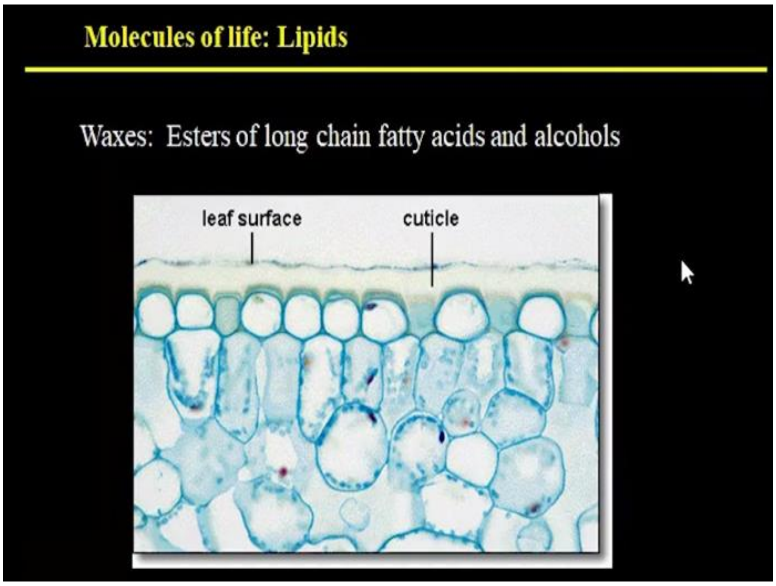

The last group of molecules we are going to learn are the waxes and waxes are extremely hydrophobic. They are simply long chain of fatty acids which we are already familiar and assume another long aliphatic chain at the end instead of having carboxylic acid suppose it has an alcohol group, they are called fatty alcohols. So when you have such a long fatty alcohol and a long chain of fatty acid linked in ester bond you call them waxes.

The waxes coat the surface of the leaves like some of the shiny leaves have that and due to that they are extremely hydrophobic and protect the leaves from transpiration, they do not readily lose moisture due to evaporation, so they give that protection. So that is why the leaf surface is shiny. The shininess comes from the coating of wax. So for us as biochemists, the information about the wax is they are esters made up of long chain fatty acids with the long chain fatty alcohols.

They are stored in marine animals like whales and they are important source for making fragrances also. So that is about waxes. So we are sort of running out of time, so I will stop here. So we have learnt today the basic biochemistry of nucleic acids and lipids and we looked at the different kinds of lipids. So in the next class, we will move on to the next topic where our goal is to understand how the arrangement or the way in which the constituents of a molecule are arranged in the three-dimensional space become very important in biology.

In chemistry it does not matter, the reactions happen through the functional group. So as long as a given functional group is there, the reaction is going to happen, but in biology simply the presence of functional group is not enough, the actual arrangement of atoms in a molecule the three-dimensional arrangement becomes important and that is what we call stereochemistry. So, we will learn that topic in the next class.