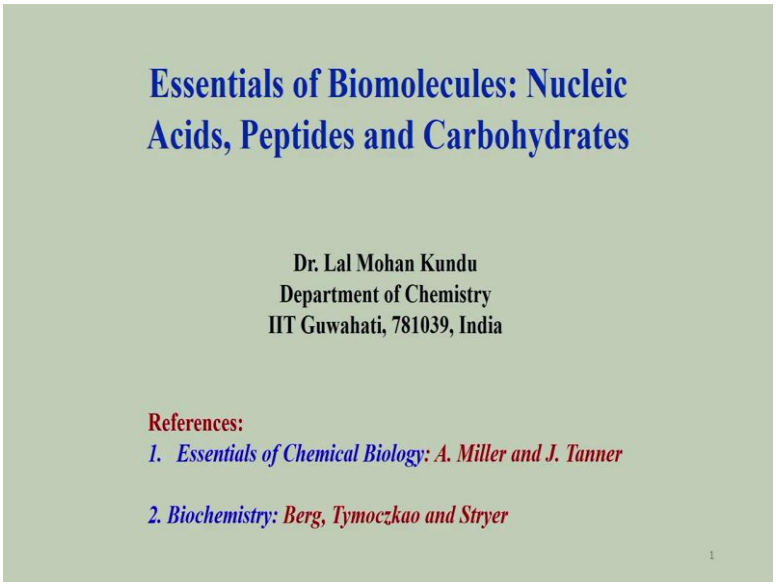
Essentials of Biomolecules:
Nucleic Acids, Peptides and Carbohydrates
Dr. Lal Mohan Kundu
Department of Chemistry
Indian Institute of Technology dash Guwahati

Lecture 01
Importance of Biomolecules

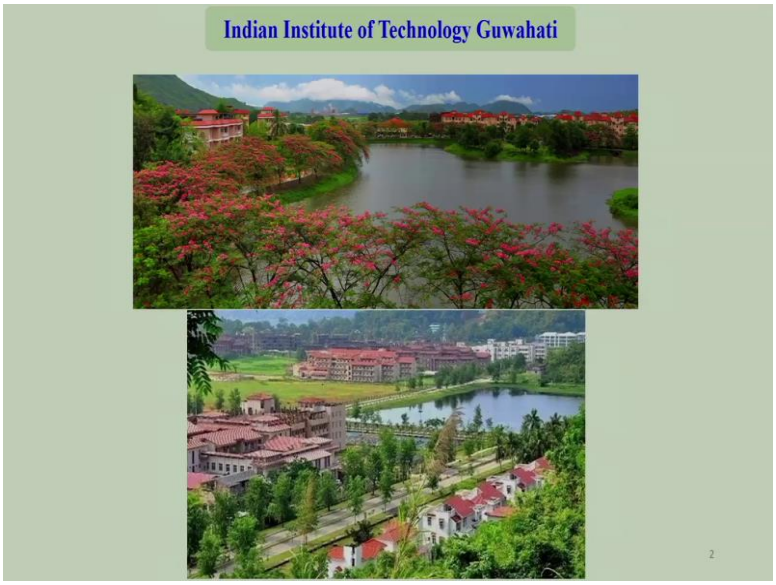
Hello everybody today we will start the first lecture of my course the course title is essential of biomolecules nucleic acids peptides and carbohydrates. As I have talked in the introductory video that in this course will cover the importance of the biomolecules. How the molecules present in our body they are involved in many biological processes. How an enormous amount of chemistry is involved in those biological behind those biological processes and what are their structures and functions and how could modify later to alter their activities.

(Refer Slide Time: 01:27)



So, in this course I will be covering two textbooks or some of the chapters should be picked up from these two textbooks one is these references first one is the essentials of chemical biology which is by Andrew Miller and J Tanner and then second is of course the biochemistry which is written by Berg Tymoczkao and Stryer.

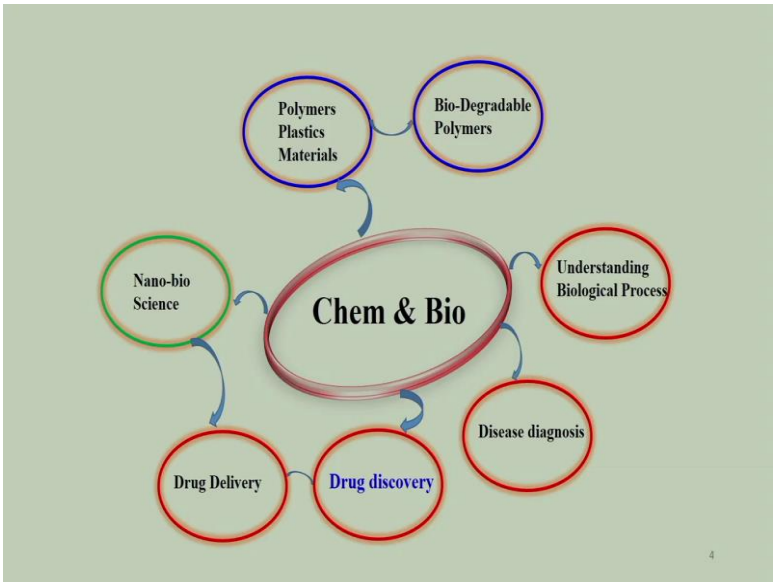
(Refer Slide Time: 01:41)



Before starting the lecture I would this is how our campus looks like I belong to IIT Guwahati and this is what the campus looks like in flowering season and it is surrounded by many Hills and we have few lakes inside and this is the structure of it. I belong to chemistry department and for those who are interested I would just tell you what are the programs we run from our department now?. One is of course the four-year BTech degree and that is in chemical science and technology and if you want to come to that you have to appear for IIT J advanced.

Next is we have two years master's program MSC in chemistry through JAM and we have of course the Ph.d program which we recruit from candidates who are eligible with gate CSR and or inspire fellowship okay.

(Refer Slide Time: 02:31)



So, why this course so this course is in Interdisciplinary between the organic chemistry and biological chemistry so organic molecules why they are import in biology? First of all of course is to understand the biological processes what are the processes that and that are going on in our body. That is the curiosity prospective of curiosity that if we want to know and of course it is a long curiosity that exactly what is going on in our body or in other living cells.

So understanding the biological processes? So, in order to know that what you have to know we have to understand what are the chemical reactions that are going on inside the cells. What are the molecules involved what are the enzymes involved and how they react for that specific kind of reactions. And you can see that many of those reactions that happen in biological cells are almost impossible to produce in laboratory.

So, there are very specific reactions or they are very specific organic transformations that happen in living cells within presence of other surrounding molecule biomolecules such as proteins. So, once you know what are the reactions going on what are the processes going on in inside the living cell then you can find out the changes of those reactions that happens in diseased cells. So, you can understand our disease why a disease is formed and then you can diagonalize a disease using other chemical tools or organic chemistry tools.

In modern days research we have our diagnosis techniques have been alleviated to a to a good level and we have lots of kits now available many different types to diagnose a disease. And most of those kits actually came from the chemistry chemical reactions. So, understanding the biological process and then you can find out about the disease. Now once we know about the disease then we can find out what are the ways to rectify that.

What are the ways that will rectify the anomaly in the biological reactions back to the normal way. So, that is where the drug discovery comes and of course most of drugs are the molecules that are developed in the laboratory or isolated from natural sources and many of them are organic molecules. So, in order to develop a drug compounds of course before that we have to understand all of the biological process.

And we have to understand what happens or what is the anomaly that happens in the diseased cells? Then we can find out how to stop that anomaly. So, that is a drug discovery thing, now once drugs are there once you find out a drug is active against certain disease that is not the end

of it. So, that next challenge is to take the drug inside the diseased cells that is what we call drug delivery. So, what happens in our body our cells are very well protected they do not allow the foreign particles or the foreign entities to cross the cell membranes or to get into our body.

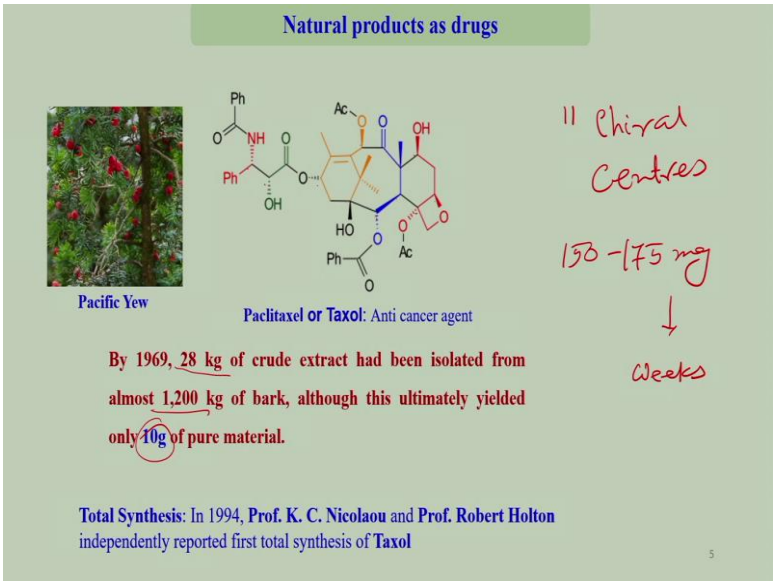
That is why the cells are very well protected otherwise every day we are exposed to so many stuffs but most of them do not penetrate our body that is how we are all still alive. So, drug have to be taken into the cells and that is what is called drug delivery. And here comes the but in modern days large part of the drug delivery comes from the nanoparticles or nanoscience. Again we can develop lot of I mean different kinds of nanomaterials where you can embed the drug inside or encapsulate the drug inside it.

And then it has a higher probability to get inside the cells because our cells although I say that are very well protected but the cells have spaces in between them they are called the pores and they are very small pores actually. When you take the nanoparticles they have a very smaller size typical for the drug delivery if you use a nanoparticles which is between 100 to 200 nanometer range then they are small enough to cross through those pores.

So, it is basically fooling the cells cells not understand that something is getting into it. So, that is how you can take the drugs into the into the cells and the foreign particles into the cells and the last one but not the least nowadays we are aware of the polymers and plastic materials we have most of our materials that we use every day and surrounding us are made of a plastics or polymers. So, now we are changing that to a biodegradable polymers.

So, you have to find out ways how can you make the polymers or how can we make the bonds which can be clipped naturally over time or by using enzymes that will degrade those molecules so that is the biodegradable polymers. So, I wanted to give you the brief idea of why in this field of organic chemistry and biology is important to understand. So, these are the ways you can you can play with alright.

(Refer Slide Time: 08:15)



So this is a molecule this is the organic molecule actually it is a large molecule can you recognize this molecule? Can you recognize this organic compound? Well this is paclitaxel or taxol a very celebrated organic compound. This is one of the most effective anti-cancer agent that is there in the market. So, if you look at the molecule this molecule is very complicated and it has around 11 Chiral centres. You see 1 2 3 4 5 6 this is not Chiral 7 8 9 10 and 11 so it has 11 Chiral centers extremely hard to find out even the structure of it.

So, this is paclitaxel which was originally isolated from a tree which is this Pacific yew it is a very large tree very old tree usually 100 years old and this molecule taxol is obtained directly taxol is obtained from the bark of this tree. It was originally isolated back in 1969 where if he was around 1200 kilogram of the bark then the crude amount of extract that you can isolate is around 28 kg and from that after processing you get only 10 gram of pure material pure Pratley taxol which is the anti tumour drug.

Now so you can understand the tedious of this process from a whole 1200 kilo gram of the bark you can get down after lots of steps of chemical processing you can get down to only 10 gram of the pure material and the dose, typical dose depending upon the type of cancer typical those of paclitaxel is around may be it varies a lot of course but 150 270 milligram per dose and that runs for weeks and weeks.

So 10 gram of pure material is enough for only few doses and obviously the necessity is that is to synthesize this molecule in the laboratory. So, that is why the natural products are coming as drugs and then of course the source of the nature is not good enough to meet the needs of the of

the patients of then the necessity comes that we have to synthesize these compounds in the laboratory that is a very tedious job of course.

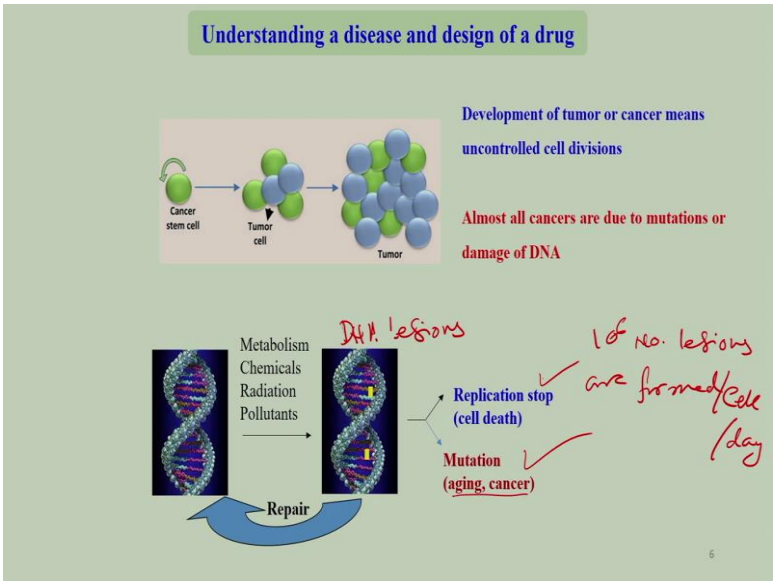
So, for this particular molecule after a lot of research hard work in 1994 professor Casey Nicholaw and professor Robert Halton they independently found out or reported the total synthesis of this whole molecule taxol. So, this is plant alkaloid which has of course 11 chiral centres and this is used in many types of different types of cancers including breast cancer, cervical cancer, ovarian cancer and so on.

So for the medicinal chemist or for the natural product chemist the process is something like this most of the drugs that are available in the market many of them are actually originated from the natural sources you know. How they came into the drugs so what people do what scientists do is they first isolate and the compounds from different trees or the plants like the alkaloids terpenoids and heterocycles other molecules.

So, they isolate the molecules from the natural source and then they go for testing biological testing to see if these molecules or some of these molecules show any positive activity towards any disease cells. So, once you find out that a molecule that you have isolated is showing some response to a disease then you go for more isolation and then elucidation of the full structures that that is really a tough job and a very tedious process.

And after that then it comes to the after different stages of verification it comes to the market. So, lot of organic chemistry in involve is involved in finding out about a solution of a disease.

(Refer Slide Time: 12:46)



Next is the understanding a disease and design of a drug so if you look at the tumour or the cancer tumour is basically the development or cancer means that uncontrolled divisions of cells. If you have one cancer cell then very quickly it grows fast and it makes more cells and they are all infected tumour cells and almost all cancers I will see later on how they are formed almost all cancers are due to mutations of DNA which comes from the damage of the DNA's.

So this is a DNA so every day we are exposed to lot of external and internal agents. So, therefore our DNA also are exposed to lot of internal agents as well as external chemical agents internal chemical agents means it goes to metabolic processes and during metabolism lot of radicals are produced like peroxide radicals and all. So, they react to the DNA nuclear bases or they are exposed to chemicals were exposed to radiation for example UV radiations or pollutants.

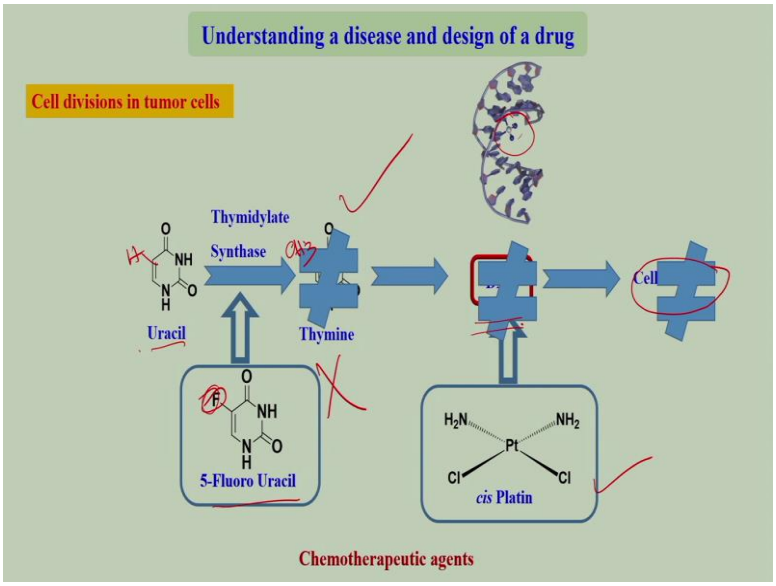
Many of them actually what they do they change the structure of the DNA I have just pointed here they change the structure of the DNA and in turn their base pairing gets changed. So, once these structures are changed now we have a very good mechanism system which actually repairs those damages these are called DNA lesions or DNA damages. DNA listens or damages so the statistics is around 10 to the power 6 number of lesions are formed in each cell per cell per day.

So around a million of DNA lesions are formed in every cell every day you can imagine how much amount of damages that happens inside our genome or in our DNA. But we have a very good mechanism to repair and those listens back to the normal. So, usually there all the lesions

are repaired back to the normal DNA. But if they are not repaired properly then there are that consequences, true consequences one is it can either stop the DNA replication process which means the cell rate or you can undergo mutations or it can induce mutation in the genome which means basically is the reason for aging or cancers.

So, once we know the chemistry behind it then only we can understand what are the mutations happen or how to alter those how to design a drug once you understand the disease.

(Refer Slide Time: 15:31)



So, here I also what is the chemical process that goes on in our normal cell as well as tumour cells. As I have said that DNA is the key material that is required for cell divisions. So, how is DNA synthesized in cell one of the ways is it starts with uracil we have uracil in our body uracil or uradine in with a deoxyribose sugar. So, uracil is transformed into thymine so in uracil you can see here there is a hydrogen H atom and in the time in this H is replaced by R methyl group.

So, this is the only addition and this is the chemical reactions a CH bond is replaced by a CCH 3 bond and this reaction is catalyzed by the enzyme time thymidlyte synthase in our body. Once the thymid is synthesized it is involved in synthesis of DNA and then DNA undergoes cell divisions. Every cell has DNA so DNA multiplies when the cell multiplies. So, that is how the cell division happens.

Now in tumour cell also same thing happens only thing is that it happens very rapidly faster much more faster than the normal cells. So, one way to block the cell divisions or to block the

number of cell tumour cells is that if you can block this reaction this transformation you Uricil to theymid in which is catalyzed by thymidlyte synthase and here come in the chemistry. So, thymidlyte synthase requires a substrate which is uracil it is very specific.

It can take only uracil now this molecule here if you see 5-fluorouracil has a floride atom here where there was a H hydrogen atom at the uracil in five floor originally you have a fluoride atom. Now hydrogen and fluoride Adams both have almost same size so what all they do not change the size of the molecule. And therefore it is expected that fiber uracil also can dock inside the active site of the thymidlyte synthase.

In other words fiber uracil can be used as a substrate for this enzyme. Now once the fiber uracil is taken or recognized by the thymidlyte synthase then the difference is the floride atom. Now if the CH bond is very difficult to break and of course the enzyme does not know how to break a CH bond in this transformation enzyme knew how to break the CH bond and make the CH 3 bond CCH 3 bond. So, once the enzyme takes up 5-Fluoro Uracil into its active pocket then it cannot do the further transformations.

Because it cannot break the CF bond and therefore the thymine cannot be synthesized. So, synthesis of thymine is blocked therefore the DNA synthesis will be blocked and therefore no cell divisions and tumour cells will be slowly dying. So, that is how this molecule was developed that you can develop a new molecule which will interfere into the biological reaction. We call them inhibitors so that is one way.

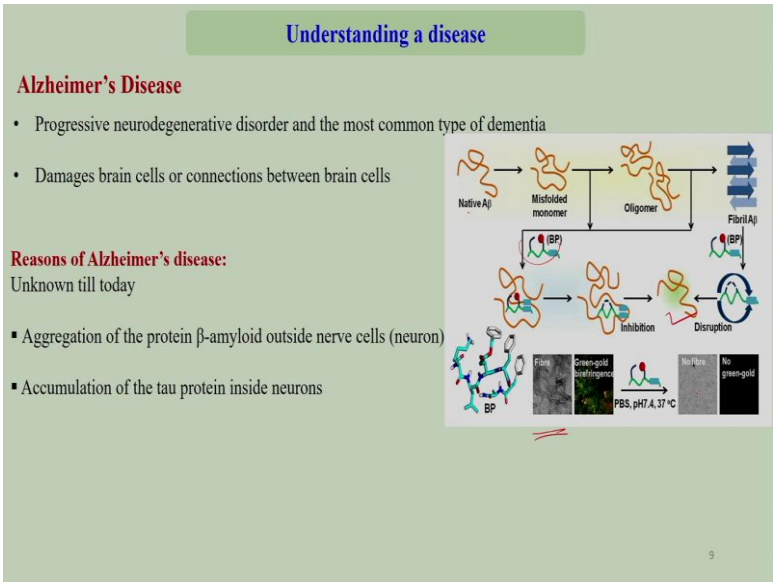
A second way is Uracil to thymine the transformation happens fine we do not do anything here. The next one is the synthesis of DNA from the thymine to the DNA synthesis. Now once this DNA is synthesized this is the structure of the DNA this double helical structure of the DNA I will explain later in detail. Now if we can block or if you can inactivate the DNA itself then it cannot do the cell division such is a molecule called cis-Platin this is an organic complex which is also a renowned anti-cancer agent.

5 Fluoro uracil is our commercial also a commercially available chemotherapeutic agent. So, is cis-Platin. So, cis-Platin what it does it binds at the core of DNA. I will show later how it exactly binds. So, it binds it forms a metal complex within the DNA and therefore that is a strong binding and therefore it cannot undergo further replication process. It is basically

blocked or it is dead. So, DNA is become stage and it cannot produce more cells therefore tumour cells will be killed.

So, once you know the reactions once you know the chemical ways once you know that a number of enzymes or what are the enzymes involved the structure of those enzymes or other molecules involved in a reaction then only you can figure out what are the changes you can make or what are the new molecules you can produce to alter those reactions. I will show you and I give you an the example of how understanding a disease is important.

(Refer Slide Time: 20:39)



So, another very notorious diseases of course is Alzheimer's disease it is a progressive neurodegenerative disorder damages the brain cells or connections between the brain cells. What is the cause of the disease? What is the reason? The full reason is not yet known even today. So one of the reasons is the aggregation of the protein or the particular type of protein amyloid peptides we call them peptide beta amyloid peptides outside the nerve cells.

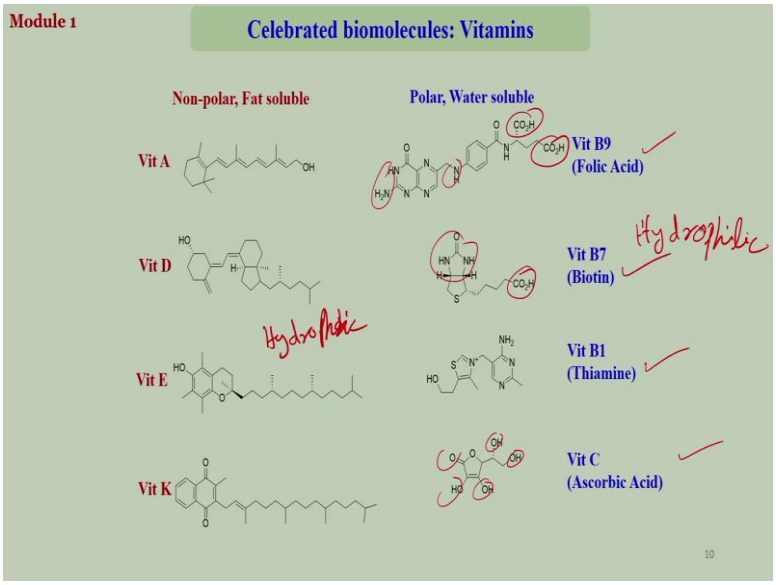
Because it is a beta structure they are actually the flat structures amyloid proteins and they get stuck on to each other forms an aggregation. And once these aggregations are formed they cannot move they cannot do the biological functions and it is like a stone formations. So, this is how the process looks like this is the native a beta peptide structures open form. Now if it is miss fold and then form say oligomer many of them come close together form oligomer and this is the fibril formations.

Because of this oligomers will be stacked on top of each other and forms a fiber basically. Here you can see in this image and the fibers are formed. So, the fibers are formed and then that is the reason for one of the key reasons for Alzheimer disease. Now once you know this process you can find out ways how to disrupt those. If we want to stop this aggregation if we want to stop the fibrous formations for example this is an example of you use a molecule which gets into the folding and then it does certain chemistry and does not allow it to aggregate.

So, here inhibition of aggregation that keeps the native structure intact, this is the native structures and here this figure you can see this is the fiber formations of the peptide of the beta-amyloid peptide and you just shortened eye to see that it shows green colour for everywhere wherever the fiber is. Now to add this molecule then the fiber is broken because the molecule gets in intercalates within insights the peptides and then it disrupts the stacking or disrupts the aggregation of the fibers or of the peptide.

There is no fiber and it is a black color no green color. So, again once you know the every step of it then only you can find out about a good solution.

(Refer Slide Time: 23:11)



So, we will see the structure of some of the important biomolecules now and then later on I will discuss them in detail as we move on. So, here these are the structures of the small molecules the vitamins that we have in our body. A left-hand side you can see some structures of the vitamins and right-hand side the other kinds of structures. All the structures in the left hand side are basically the hydrocarbons which has carbon and hydrogen mostly and they do not have

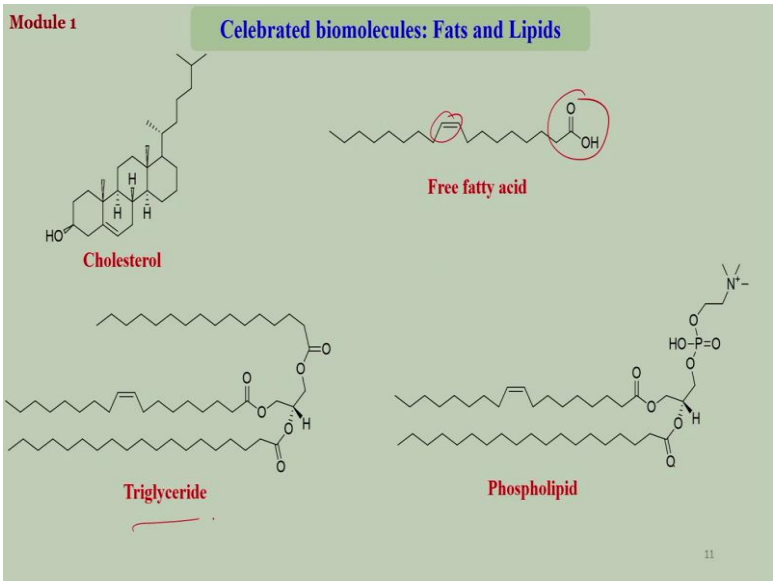
many functional groups of course it has OH but compared to the large molecule this a single functional group and no charge separations.

So, these molecules on the left hand side are mostly hydrophobic molecules there are hydrophobic compounds and therefore they are not soluble in water in body they are soluble in fat in fatty acids. On the other hand in the right hand side you can see these structures for example vitamin b9 is a folic acid this has a functional group acid group is acid group all hetero atoms so many hetero atoms are there which are hydrophilic in nature.

So, this overall this molecule has a lot of charge separation it is a polar molecule and a hydrophilic. Similarly you see biotin has also carboxylic acid end with the hetero atoms there and vitamin b1 which is thaimine which has lot of functional groups and polar groups of course. So, all these on the right hand side are polar and hydrophilic in nature. So, vitamin A vitamin D vitamin E and K are called non polar fat soluble vitamins and vitamin b9 b7 b1 and vitamin C are called the water soluble vitamins.

So, folic acid and biotin are actually also in and they of course the vitamins along with that they are used as our tumour targeting agents also because they have receptor tumour cells have over expressed folic acid receptor as well as vitamin receptors. So, people use folic acid and biotin as a tagging to take the drugs or to take molecules to the targeted tumour cells.

(Refer Slide Time: 25:43)

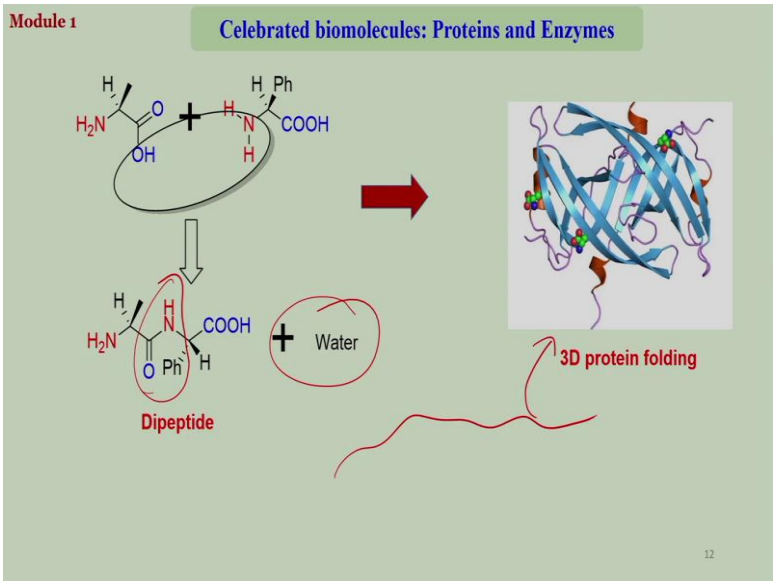


Coming to little bit larger molecule a cholesterol this is again a hydrocarbon structures which has a lot of rings cyclic structures of course and then open chain form. This is a fatty acid it is a

long carbon chain it can be saturated it can be unsaturated and terminally it has typically carboxylic acid but it is a long chain so therefore they are not soluble in water again. Triglycerides: Triglycerides I have it is a derivative of fatty acids you can say they have three long chains long carbon chains and they have a glyceride moiety.

Glyceride is basically this is glycerol CH CH OH wait CH2 OH so here there is one chain here there is one chain here there is another chain in this molecule so they are called triglycerides and phospholipid. This molecule is phospholipid where there is a phosphate group there and phospholipids are usually not naturally available there you can modify it by another charge species and then it can be made in a soluble into water also.

(Refer Slide Time: 26:57)



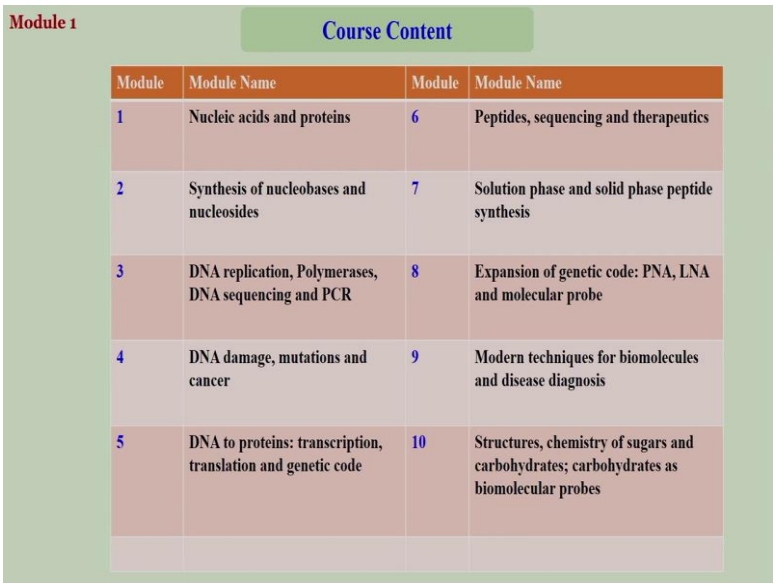
Another very important and biomolecule is of course the protein. Now these are protein DNA and carbohydrates long-chain carbohydrates. These 3 are the large biomolecules or the polymeric biomolecules that will be mostly discussing in this course. So, protein is formed out of the amino acids this is just a rough sketch that if you have amino acids if you have two amino acids in this case I have taken on alanine and one Fenealanine I mean if you have two amino acids and then under certain conditions or circumstances in the biological systems they will condense eliminate amount of water and forms a dipeptide.

A peptide this is the molecule is a dipeptide because it has two amino acids so this is the peptide bond CO and NH. This is basically an amide bond and in this case when it is formed between amino acids we call it a peptide bond. So, the new peptides are formed and the

sequence of the peptides many amino acids together will conjure ultimately a 3D structure of the protein.

So, they will fold because of its large structure long structures and they have many different functional groups hydrophilic hydrophobic both so they can they can interact in between each other they can repel so that forms a 3d folding structures of the protein that will give you the ultimately active protein which has certain biological functions.

(Refer Slide Time: 28:28)



So, this is the course content now I am coming more to the real syllabus this is how I have prepared the module there will be around 10 modules the first module we will talk about nucleic acids and proteins. Second one is the synthesis of nuclear bases and nuclear sites. So, here we will see how we can synthesize the nuclear bases or their derivatives that can have other properties other biological properties as well as other pharmaceuticals properties in laboratory.

They are basically organic synthesis protocols both the nuclear bases and the nuclear sites with the sugar. How do attach the sugar to the nuclear bases and then the third module coming back to the biology is DNA replication how the process of DNA replication happens? What chemistry is involved? Why it is particularly happens in that well? What is the difference between the two strands of DNA? What is the activity of the enzyme.

Key enzyme of the replication process that is polymerase there are other enzymes involved we will see. And then comes DNA sequencing once you isolate a DNA how can you find out what

is the sequence of the DNA. And then PCR is polymerase chain reaction. PCR is a technique through which you can amplify or increase the quantity of DNA that you have isolated and that is very important in laboratory research because the if you isolate a DNA from some source from a disease from other organisms and then the amount concentration of DNA would be very, very small with which you and the working in the laboratory is difficult.

So, you need to increase the amount and that is the PCR is the technique for that through which you can amplify the amount of DNA. And then fourth is the DNA damage what are the chemical changes that happen in DNA? Which is happens due to when it is exposed to in different kinds of internal or external chemical agents and those damages how are they responsible to induce mutations in the DNA.

And those mutations are ultimately the cause of cancers or other genetic diseases. Then fifth module is DNA to proteins? How proteins are synthesized taking the information from the DNA or information from the genetic code. The processes of transcription translation and the genetic code here a lot of chemistry is involved we will see all the processes there the biological process as well as the chemical chemistry behind them.

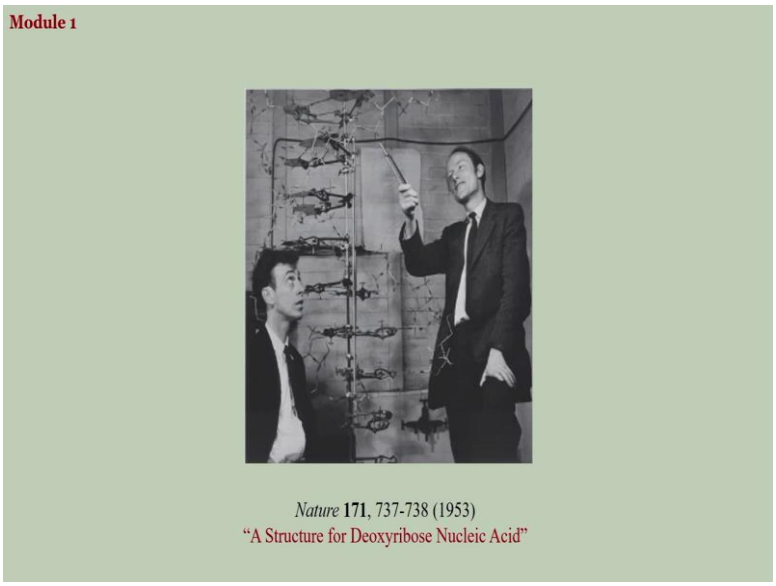
Then 6 module 6 is peptides how to characterize or how to find out the short peptides that is the constituents on the proteins. How to sequence the proteins or how to sequence the peptides you have isolated a protein sample and then of course you have to know what is the sequence of the proteins which amino acids are engaged? And what is the series of the amino acids that is the sequence of the protein. How to find out about the sequence of the proteins the chemical methods as well as the biological method and then its use in therapeutics?

Module 7 will be little bit organic chemistry that is the solution phase and solid-phase synthesis or peptide how to synthesize a peptide in laboratory. Number 8 is changing the genetic code now you can how we can develop artificial base pairs how to you can develop artificial gene genomes or we call them molecular probes that is called expansion of genetic code and there is peptide nucleic acid PNA LNA locked nucleic acid and how they act as molecular probes in diagnosis of a disease or in curing a disease sometimes even.

Module number 9 is modern techniques for biomolecules and disease diagnosis. So, nowadays we use lot of good techniques and lot of tools there can be chemical tools they can be biological

tools or they can be instrumental techniques to study the various aspects of biomolecules and to study the disease's also. So, I will cover some of the techniques important techniques that are vital for chemical biologists as well as biochemists. Number 10 is a structure chemistry of sugars and carbohydrates and how we can synthesize the carbohydrates and what are the applications of carbohydrates in biology. So, this is roughly the course content.

(Refer Slide Time: 33:04)



I will start with DNA the nucleic acids. I think many of you can recognize this picture who are these people this is James Watson and this is Francis Crick and they are showing basically the model of the DNA. So, this is the first time that people came to know how our DNA looks like the double helix structure of the DNA. And that has come out in this famous nature paper in 1953 and the title was A structure of all Deoxyribose nucleic acids.

Now if you look at the history or the story background story behind the double helix structure of the DNA then James Watson and Francis Crick they were none of them actually has done any experiments to find out the structure of the DNA James Watson was a postdoc he came from America and Francis Crick was doing still doing his PhD that time at the Cavendish laboratory. And it was their common passion and a mission to find out the structure of the DNA.

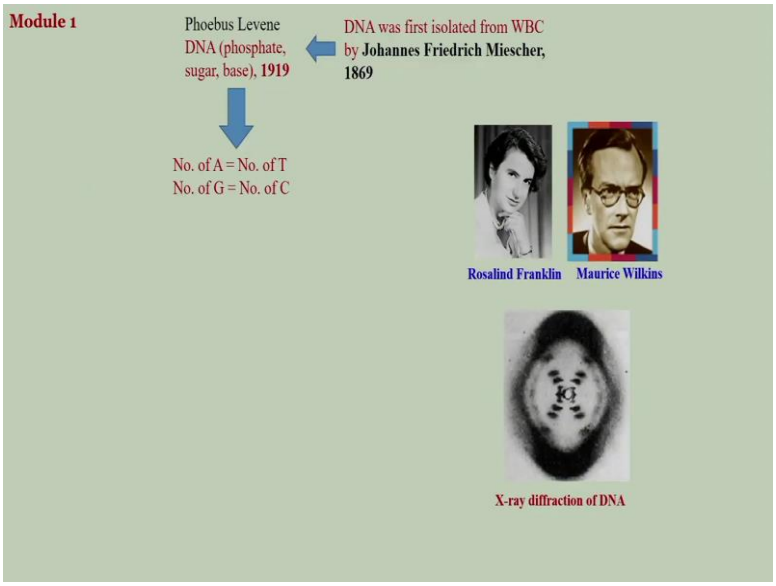
Nucleic acids and its structure was a very hot topic in that time and people were dying to know because it was known before that that the DNA is involved in storing genetic information and when cell division happens DNA is the molecule that carries all the properties or the information from one cell to the other and responsible for all cellular activities. So, the question

of us how it looks like and how it carries the genetic information from one cell to the other when cell division happens from one cell to two in new cells.

Two new cells are formed how our DNA is translating the same information in this cell as well as in this cell. So, it was very important to know the structure of the DNA and Watson and Crick they used to meet in a cafeteria and discuss try to make the models of it. Of course they are not the only people what they have done they have actually gathered the information's that that were available at that time and those are the key information there are many information's floating around of course in any science.

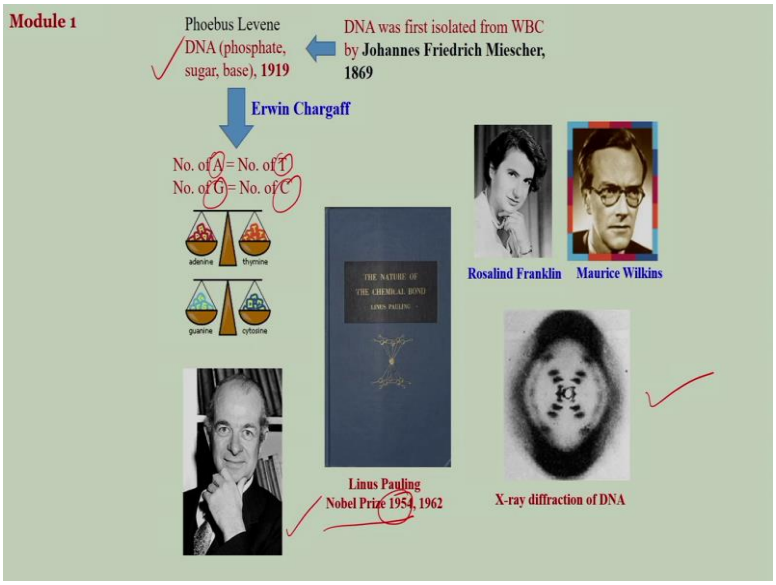
But you have to find out or you have to tune together the right kind of information's so that they have done properly.

(Refer Slide Time: 35:33)



So, the story starts with this of course and they have received a noble prize 1962 along with James Watson Francis Crick and then Maurice Wilkins this three people.

(Refer Slide Time: 35:38)



DNA was first isolated in 1869 from white blood cells WBC by Johannes Frederick's Miescher and then a key development was here in 1919 when Levin has found out the composition of the DNA. That DNA consists of it is not a single molecule it consists of phosphate it has sugar unit in it and it has a nuclear base basically a heterocyclic compound tetracycline base in it. So, it has 3 key important components in it.

So, that is that was on big discovery on DNA and then later Arwen Chargaff has found out that a very interesting fact that if you isolate DNA from multiple resources so by that time it was known that DNA consists of, of course phosphate what is the sugar it was a rival established that it has a rival sugar and it was also established that it has four nuclear bases and there they were termed as adenine thymine guanine and cytosine. So, four different compounds it heterocyclic compounds.

So, Arwen Chargaff found out that if you isolate a DNA from one sample and then analyze then the number of adenine or the number of moles of adenine that you obtain is always equal to number of moles of thymine. Similarly number of moles of guanine or number of molecules of guanine is equivalent to that of cytosine. So, that is there if you isolate DNA from sample one if you isolate the DNA from source 2 whatever the source is does not matter the DNA's all kinds of DNA all kinds of DNA has this parity in it that number of adenine and thymine are equivalent quantity guanine and cytosine are equivalent quantity.

So, that that was a very important piece of information that Watson and Crick always kept in mind. And then came the proper experiment or the most beautiful experiment done on DNA is

the x-ray crystallographic diffraction x-ray structure of a DNA that was done by Rosalind Franklin and Maurice Wilkins in Cambridge University. So, they have first found out or published the structure of the x-ray diffraction pattern of the DNA.

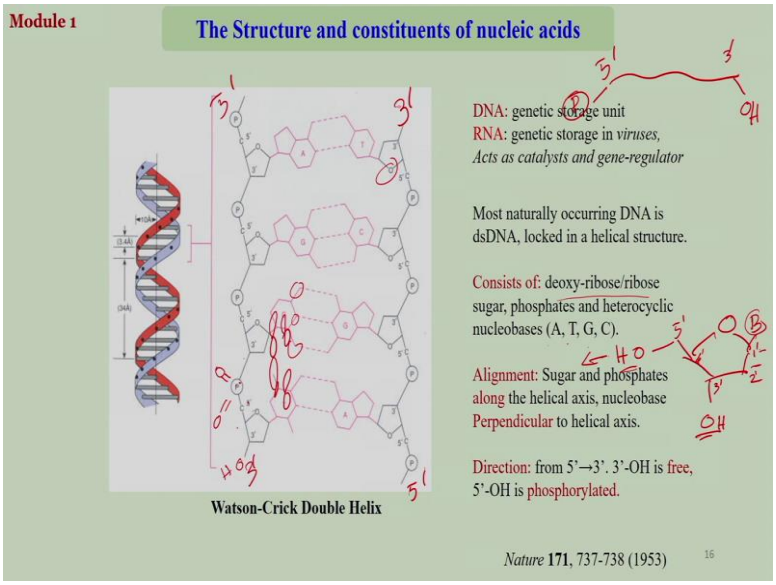
And the depression pattern get the idea that DNA has to be symmetrical geometry the molecules should have a symmetry in it, it is a symmetrical geometry. So, that is another piece of the important information but the center of this information was this book and this man Linus Pauling and his famous book the nature of the chemical bond. So, this is the book it is a center in chemistry basically. So, whatever the bond lines the single bond distance double bond distance the angle between the atoms in organic molecules.

Electronegativity scales whatever all those things are in this books and this is the Bible of for chemistry. Now all these information's that our organic chemistry is now stamped upon is due to because of this book. And Linus Pauling has received a Nobel Prize for this book and his work in 1954. So, he was already a noble laureate and he was in between he has actually he is the first one who has found out about the structure of the proteins the alpha helical structure of the protein beta sheet structure of the proteins.

So, Linus Pauling was the key person behind the three-dimensional structure of proteins. So, he was already a very celebrated scientist and he was also the one who was trying to solve the DNA puzzle. What is the structure of DNA? So, there are at least 3 key three important players one is the Linus Pouling trying to figure out the structure of DNA and he was the most likely person because he has already found out the structure of the proteins.

And then Franklin and Wilkins and then the passionate guys Watson and Creek. So, what Watson and Crick has done they have actually accumulated all the right information's that is this adenine, thymine, guanine cytosine equivalents keeping in mind that DNA should be symmetrical and they knew of course that DNA has phosphates ribose sugar and nucleus base. Now on that basis they have started making the models and when they were doing the models they have all kept very carefully the bond length the bond angles add as for given in this book.

(Refer Slide Time: 40:39)



So using this they can came up with the final structure of the DNA it is a unique structure or it is a unique molecule then only it was kind of clear the DNA is the unique molecule present in our biological body. Because no other molecule is similar looking like DNA because it is not a single molecule it has two molecules in it and they are actually connected together by hydrogen bonding and other interactions that will talk.

So, it is basically two molecules and that also explains how the genetic information's is carried over from in two different new cells. So, this is what the structure of DNA looked like and all the bonds and these things came from the book as given in the book. So, it shows that it has a ribose sugar 5 membered ring here that is connected with a phosphate the to the 5 prime end. So, this is the structure here is a nucleo base I am writing B for base deoxyribose.

This is the this is what a deoxyribose sugar looks like this is number 1 number 2, 1 prime we call 2 prime 3 prime 4 prime carbon and this is a 5 prime carbon. So, you have 1 hydroxyl group at the 3 prime end another hydroxyl group at the at the 5 prime end and then at 1 prime end you have the nucleus base ATGC. So, this is the 3 prime end of it with a free hydroxyl group. And then through the 5 prime this way it is connected to a phosphate.

And then phosphate is connected to the 3 prime H of the next sugar and that is how it goes on and of course it has kept the angles at par the given angles in the book. This P means actually phosphate it has our double bond O double bond O. So, all of them so it is a sugar phosphate sugar that is the skeleton that makes the skeleton of the DNA and then you have the nucleo bases and Watson Crick found out that if you attach the nucleus to the one prime position then

you get a pattern that this is the axis of the DNA the sugar phosphate sugar this that that is the skeleton.

And then the nuclear base is a their aromatic rings so therefore planar systems they are perpendicular to almost perpendicular to the helical to the to the skeleton. So, they are like this flat this is this is the ring and this is the geometry flat. So, when the two nuclear bases are there they are present on top of each other like this one nucleus base another nucleus base so therefore they can come into the PI stacking interactions within the PI orbitals overlap.

And similarly on the other side if you think of two strands here this is the nucleus base orientation and in this case this is an incubation engine so they are coming in this way 2 nuclear bases in two strands are coming in this way that is what it is showing here, is shown here. So, they have found out that if you do that way then the two strands can come close enough proximity to form the hydrogen bonds. And hydrogen bonding of course is a key interaction that brings two molecules closer.

And it is not strong enough that you cannot detach it so that is the beauty of DNA actually. Moreover what they found out is that the second strand if you keep on the same line same direction. So, this is 3 prime directions this is 5 prime directions if you keep on the same direction then the nucleus base in this strand and nucleus in the other strength they do not come into the hydrogen bonding distance.

Once you turn it down upside down making it 3 prime on this one up and 5-prime down so one is 3 prime to 5 prime other one is 5 back 3 prime to 5 prime back here opposite orientations. Then with the sugars faces down then the nuclear bases are actually coming within proper hydrogen bond distance. Enormous amount of chemistry and knowledge in chemical structures they are present in the overall structure of DNA and functions of DNA.

So, the and parallel strand and anti parallel strand that govern the hydrogen bond distance hydrogen bonding between the nuclear bases in the opposite strands and along with that as I said that within the one strand 2 nucleus bases are on top of each other so they can they are PI orbital's can overlap that gives more stability for DNA it is called PI stacking. So, DNA is the genetic storage unit RNA is the genetic storage unit in virus and they also act RNA also act as catalysts and gene regulator.

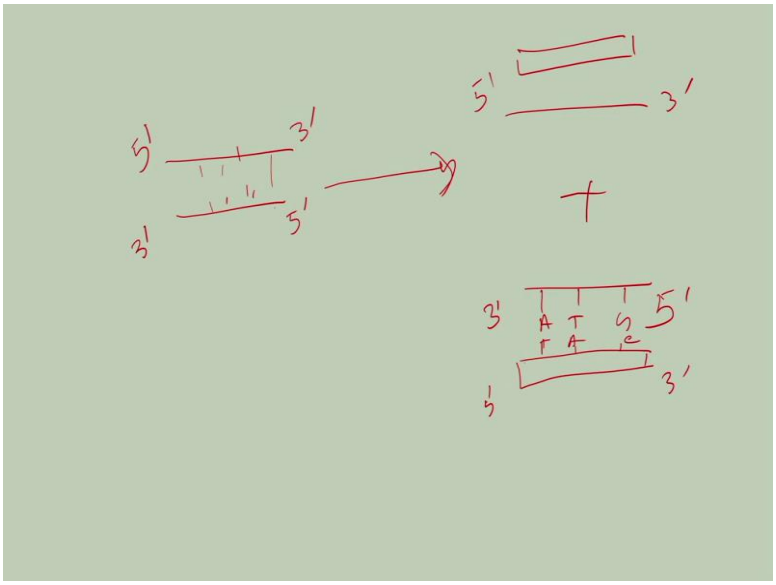
So, most naturally occurring DNA is double-stranded DNA which is the structure of which it was given by Watson and Crick locked in a helical structure and they are post consists of deoxyribose for DNA and ribose for RNA sugar 1 fourth a unit of phosphate and then heterocyclic nucleus bases for DNA it is ATGC. Alignment the sugar and the phosphates along the helical axis as I have mentioned nucleus bases are perpendicular to the helical axis.

Direction 5 prime end to 3 prime end other one is 3 prime end to 5 prime end and always 3 prime hydroxyl is free this is how a DNA is written. If you write a DNA you will always see that if this is a 5 prime if this is a 3 prime 3 prime always ends with a free hydroxyl 5 prime always starts with a free phosphate. Now the key fact now how does then the DNA transmits the genetic information from one cell to the new cells.

Now once you see that DNA is consist of two molecules now things become very easy and this also explains this hydrogen bonding between the nucleus bases also explains why the char graph has seen the number of adenine equivalent to number of thymine and number guanine equivalent to number of cytosine because adenine paired up with thymine guanine is paired up with cytosine that is the best paring the strongest hydrogen bonding interactions that you can expect if you do the model.

So, once you know the DNA has two strands parallel and anti-parallel and that has the ATGC base pairings. Now we will call then things becomes easier to explain how it stores the genetic information's.

(Refer Slide Time: 48:06)



So, I will talk in details about the DNA replication process roughly just show if you have the DNA strands this way with the hydrogen bonding here then of course hydrogen bonds are not strong enough as I have said they are not covalent bonds so they are weaker bonds with slight energy you can separate the hydrogen bonds or you can you can destroy the hydrogen bonds. Once you destroy the bonds then your DNA to DNA strands can be separated.

Now without the direction the DNA do not exist whenever you want to write a sequence or representation of a DNA we always have to mention the ins 5 prime to 3 prime 3 prime to 5 prime. So, this is 5 prime to 3 Prime and this is 3 prime to 5 prime you can change the strands and now again each strand can be acting as a template to synthesize a new strand. And of course since ATGC pair up is inevitable it will only pick up the complementary of it.

If ATGC then this will pick up this has to pick up T this has to pick up A this has to pick up C and you will synthesize a new strength. Similarly here our new strength scan will be synthesized and that is how new strands mean you have a complete DNA now here you have a complete DNA now there so two new cells will have exact sequence of the DNA which was present in the parent cell that is how the genetic information will be stored.

As explained by the modelling and the double helix model by Watson and Crick. So, it is a beautiful model one of the unique geometry of the molecule and of course the function is a unique that this is the only material that can replicate itself that can make its own copies. There is no other biomolecule no other molecule in fact which if you keep that will make its own copies.

This is the only molecule so will this I will stop today and from next class, in the next lecture I will give some more important details of the structure of DNA and then other functions other properties, thank you.