Biology for Engineers and Other Non-Biologists
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Week- 02
Lecture - 09
Biomolecules: Nucleotides

Welcome to the next story in the larger story of biomolecules. I think this would be the last lecture (last) last story in the biomolecules where we tie up all the loose ends and so on so forth. We will begin the story by asking this question, how are proteins and of course enzymes, we are looking at enzymes that are proteins, made in the cell, okay?

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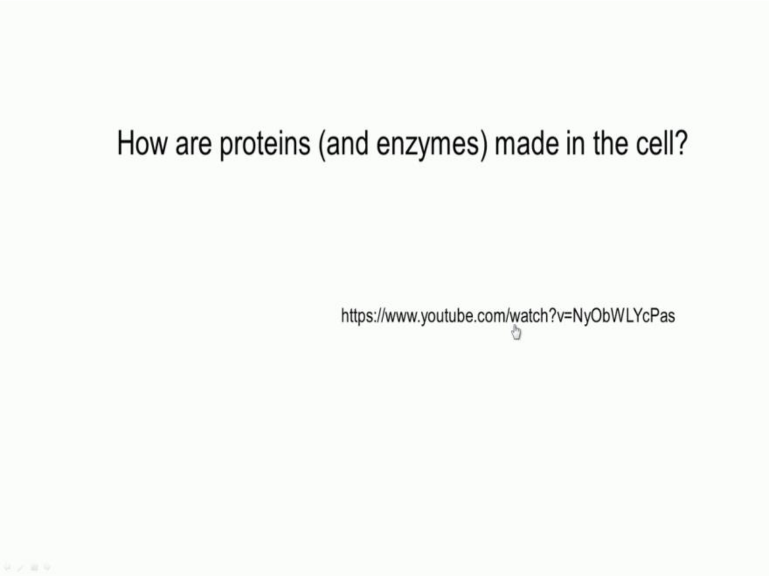

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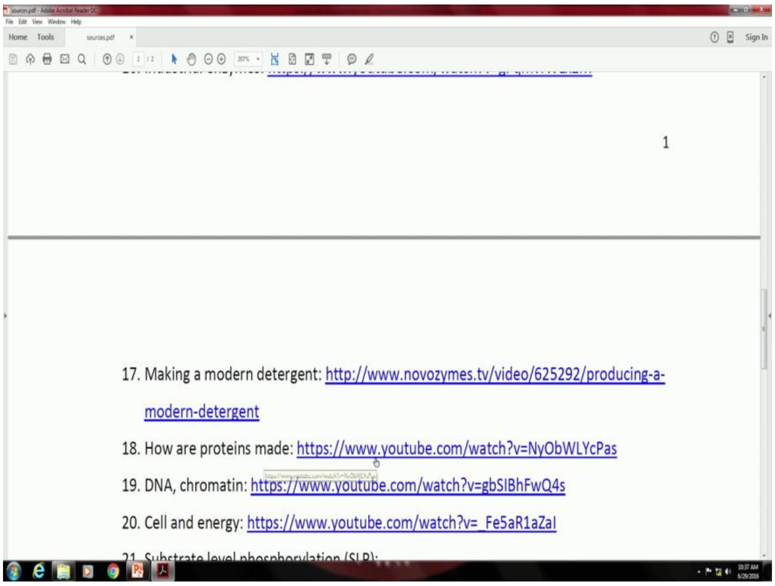

To answer this, I would point you out to required video here, I think the video in the list is number 18, it's a very interesting video and important video in terms of the principles for the course, so I would require you to see that video. Please see that video, it's only about 3and a half minutes long, okay? And it's made nicely. It was made as a part of the human genome project, but it very nicely explains how proteins are made, okay? Very briefly speaking, this video will say that the information in something called the DNA, deoxyribonucleic acid, gets converted or transcribed to the information in the messenger RNA and that gets translated to the information in the proteins.

That is the base (information) base message in this particular video. Please take a look at it, it will provide you with a nice context, it will probably clear up quite a few of those nagging questions that you may have had at several points in time and so on, okay, it's very (in) interesting aspect of life in general.

So we said that the information and what is called the DNA, deoxyribonucleic acid, gets converted to information in the mRNA, okay? What exactly is DNA, okay? All of you, I'm sure, would have heard of DNA, it's a very popular term nowadays and that's how information is stored in the cell, the information that needs to passed on from one generation to another generation, okay? In fact DNA is the code through which this information is passed down, generations. So how is, what is DNA and how (does), how does the structure of the DNA make it possible for information to be passed on, okay?

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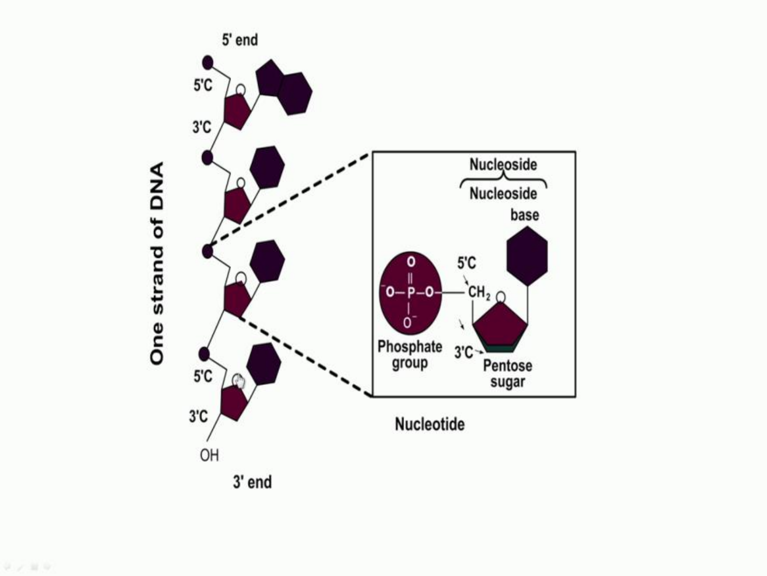

DNA is a polymer of the monomer called a nucleotide; deoxynucleotide; but let's call it nucleotide here. If you look at a nucleotide, it consists of three major parts. You have what is called a pentose sugar here, a pentose carbohydrate here. This is an oxygen, one carbon atom, two carbon atoms, three, four and the fifth carbon atoms here, okay? So this is called the three prime position, this is called the five prime position of the carbon atom and to this five carbon sugar to the first position, you have what is called as a base, a nitrogenous base that is attached to it. The combination of the base and the pentose sugar is actually called a nucleoside.

To a nucleoside if you add a phosphate group, it becomes a nucleotide, okay? And this is the base unit for DNA. Repeating; you have a pentose sugar, you have a nitrogenous base that is attached to this, and you have a phosphate group attached to this. You get the monomer of DNA which is a nucleotide. So you can see here this is the pentose sugar, the nitrogenous base and the phosphate group, okay? So this, let us start here.

The pentose sugar, right, and the nitrogenous base and the phosphate group to this is a three prime (bit) end which is free here, the five prime end of the sugar is attached with the phosphate group. The three prime and of another sugar ribose sugar of a nucleotide, get gets attached with this phosphate group and that's how the chain gets built up, the polymer gets built up, okay? So you have one three prime end that is free, the five prime end attaches to the three prime end of the next nucleotide, similarly the five prime end attaches to the next to the three prime end of the next nucleotide and so on and so forth to form the polymer of DNA.

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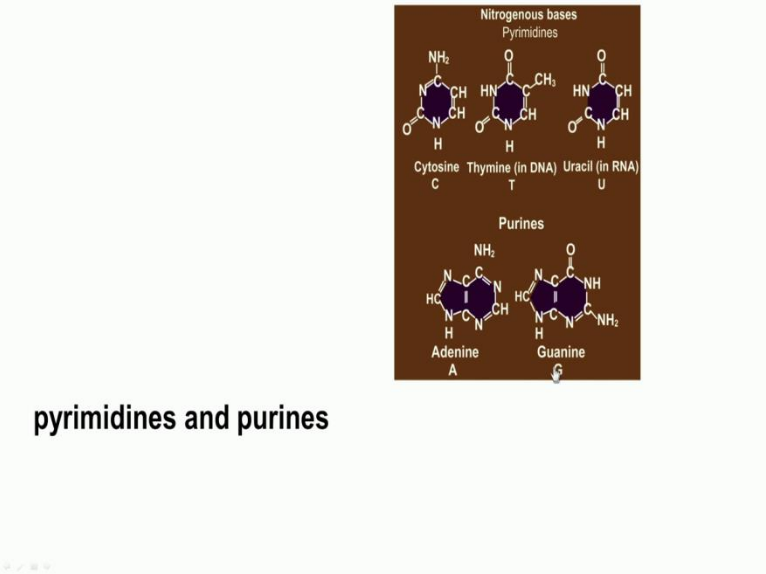

The basis, right, we said that it contains a sugar, the base and the phosphate group, the basis are of five kinds. They are, they could be cytosine, thymine and uracil or adenine and guanine, okay? Some of these terms would be familiar to you these are what they are actually. You could have pyrimidines which are these wondering nitrogenous substances and purines which are slightly bigger nitrogenous substances, okay?

So this base here could be one of these kinds, either cytosine or a thymine or uracil or an adenine or a guanine, okay? It’s so happens that in DNA you have a only CTAG, okay (())(6:14) remember? CTAG and in in what is called RNA, you have the uracil instead of thymine. The pentose sugars are of two kinds, DNA has what is called a deoxyribose and RNA has what is called a ribose, okay? The only difference between these two sugars is the two prime position.

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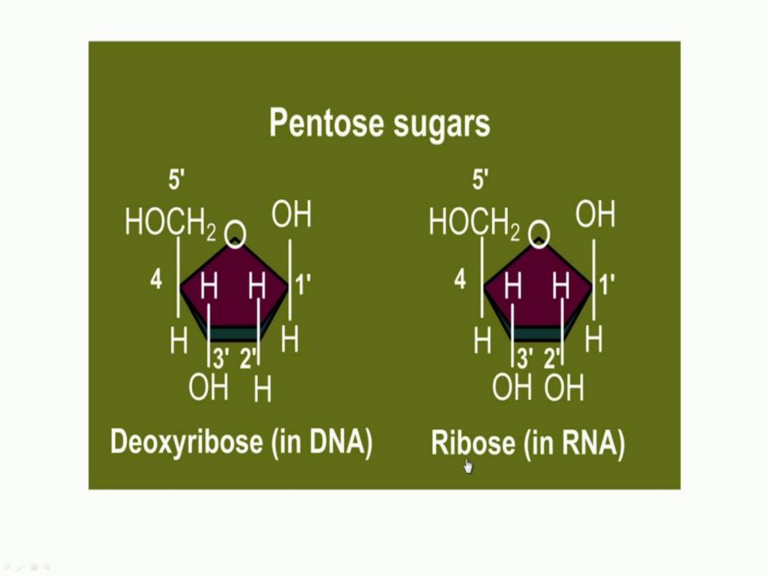

In the case of deoxyribose you have H in the two prime position, in the case of ribose you have OH in the two prime position. That's a only difference between or that's one of the major differences between DNA and RNA in terms of the sugar here, right? Okay let's go back a little bit. So you have a nucleotide which could be a (the) DNA or a RNA, you have a pentose sugar. If you have a deoxyribose sugar you have DNA, if you have a ribose sugar you have RNA.

In the case of a base you have if you have adenine, thymine, guanine, cytosine, those are the bases found in DNA, you have adenine, uracil, guanine, cytosine, then you have the bases found in the RNA, the phosphate group of course is the same. So that is what a nucleotide is all about and that is what passes on the information from (gen) one generation to another.

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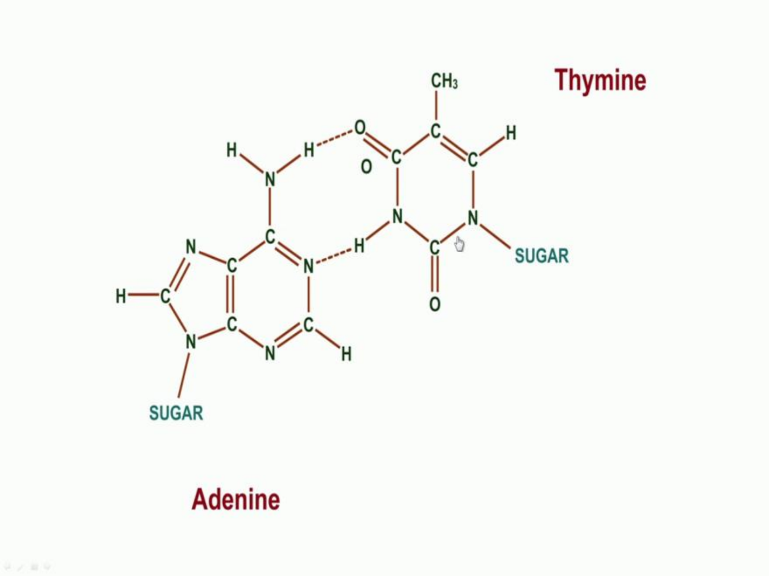

One of the reasons, (one) one of the ways by which information transfer from one generation to the other (made) is made possible, is through this. This is adenine, this is thymine, right, you have the adenine and thymine represented here in part, you have the sugar attached, then you have the nitrogenous base alone shown and then of course you have the phosphate group which is not shown.

Adenine, thymine; if you go back, adenine is here which is a purine, thymine is here which is a pyrimidine, okay? Adenine and thymine by their very nature, by the very chemical nature can form hydrogen bonds between these two, okay? There are two hydrogen bonds that are formed between adenine and thymine and this is what is called base pairing, okay, nitrogenous base, base pairing, this is a base pairing, a hydrogen bond formation between adenine and thymine. There are two hydrogen bonds that are formed between adenine and thymine.

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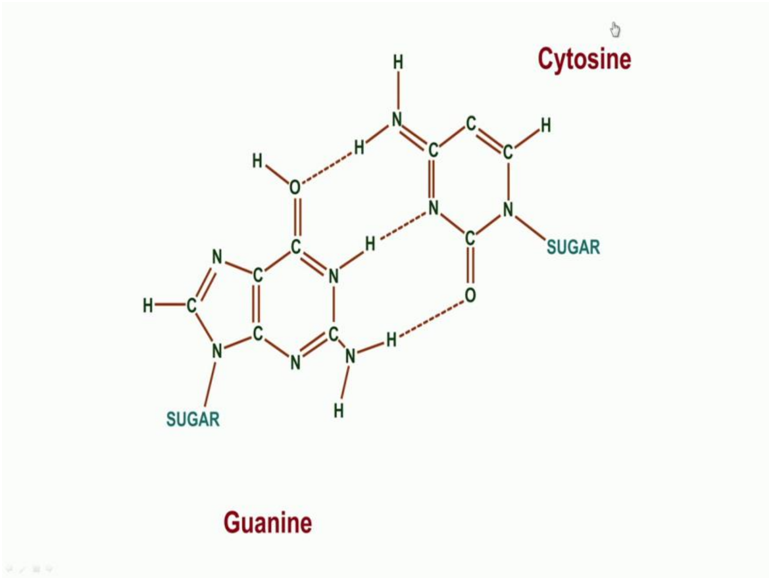

And guanine, cytosine, okay, guanine is a purine, cytosine is a pyrimidine; you (can) have the hydrogen bonds that are formed between cytosine and guanine, okay? So this hydrogen bond formation or base pairing as it is called, is what gives DNA its structure and it makes it possible to do what it does. How is that happening? Let us look at one strand of the DNA here like this, let us look at the other strand of DNA here that is like this.

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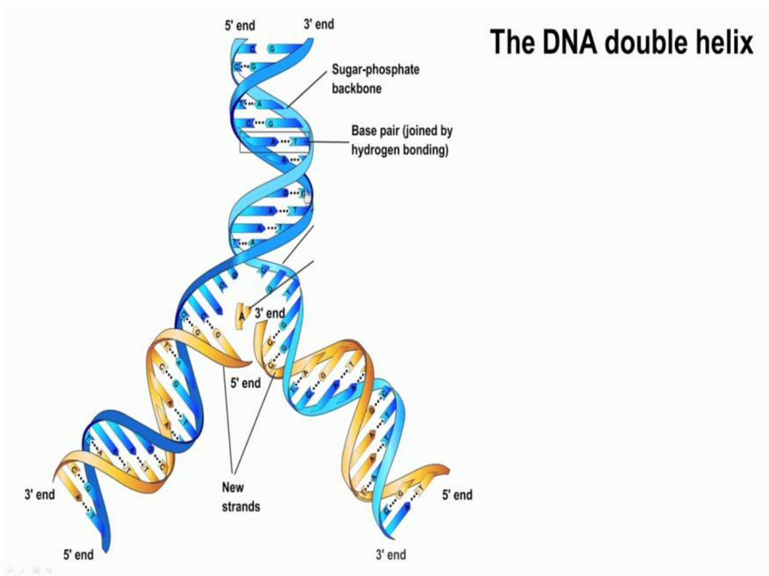

We know that adenine pairs up with thymine and guanine with cytosine, the guanine on one pair with a cytosine adenine (thymine) thymine, guanine cytosine pairing and this pairing (gives) gives the dual strands of the DNA a helical structure, okay? So this is what automatically results because of the various constraints and size and so on and so forth, the base pairing or hydrogen bonding between the bases, gives it its double helical structure and the double helical structure makes other things such as replication of DNA as well as transcription, translation and things like that possible, that we will see in later lectures, okay? So this is how the double strand is getting formed here and this double strand becomes essential for its various functions.

The DNA in a single cell, if you stretch out the DNA, can be about 2 metres long, right? The 2 metres long DNA is somehow packed into the nucleus which is sub (microscopic) sub micron sized, okay, the cell itself we saw was the (bacteria) the in eukaryotic cell that is a typical size is 10 micron, right? The nucleus is much smaller than that and in the nucleus this DNA gets packaged, right? Whatever is 2 metres long when stretched out, gets packaged there. How does that happen?

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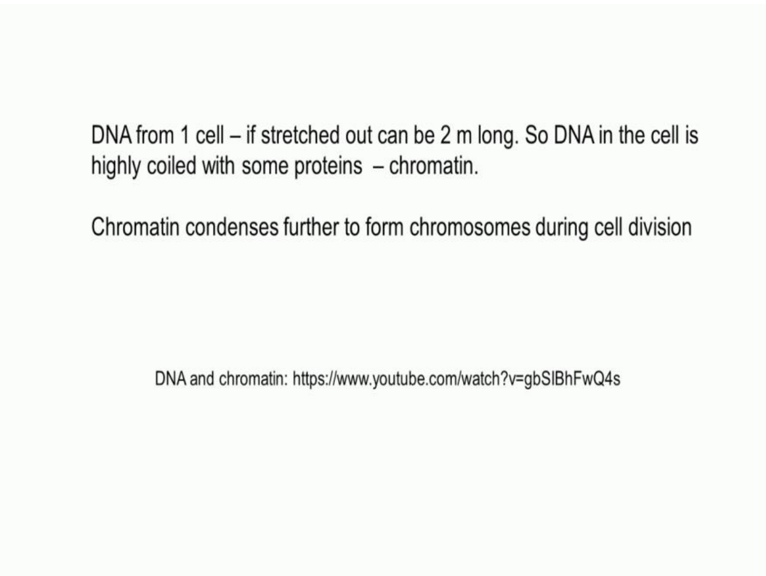

That is because the DNA is in a coiled form, okay? You (you) you can imagine this, you can take a piece string, okay, cotton string and try twisting it, there are twists and twists and twists and twists and it becomes smaller and smaller and smaller, okay? That's pretty much what happens with DNA 2 and the coiling and super coiling and super super super coiling (alo) around proteins which are called histone proteins, essentially (re) results in it being packaged into a size that can fit into the nucleus.

And, so DNA exists in what is called a chromatin form which is nothing but this coiled form, okay? Chromatin condenses even further to form visible chromosomes, the coloured substances, during cell division in other words they take up dyes during this stage and that's why they are called chromosomes, coloured bodies. During cell division chromatin condenses further to yield visible chromosomes under of course the microscope, not not to the naked eye, okay?

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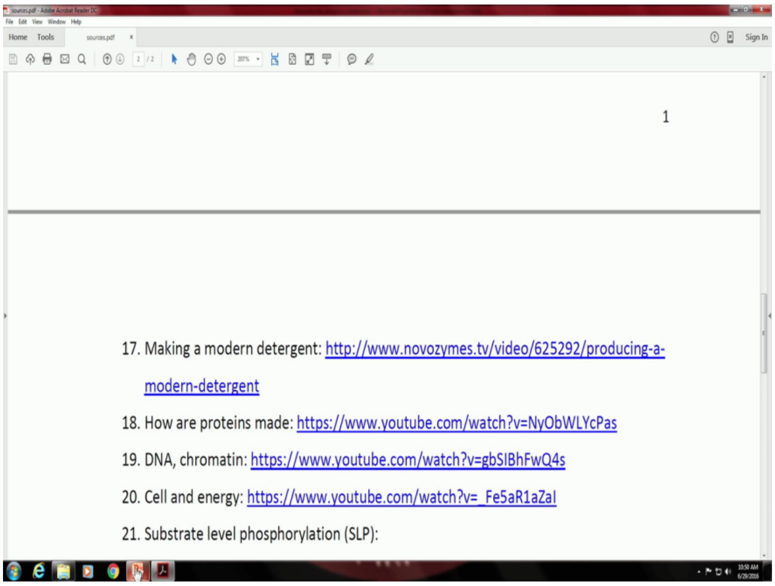

Please take a look at this video, DNA and chromatin, which gives you the details of this packaging, it is an animation which is a nice animation which shows you how the 2 meter long DNA gets packaged into a nucleus by coiling and super coiling around histones, another proteins, okay? This is (now) the video is number 19 here, please take a look at that video. Now, let us look at a slightly different aspect. We said, cell is the fundamental functional unit of life and it's a very busy place, a lot of reactions happening all the time, thousands of reactions happening all the time.

There is transport of substances into the cell out of the cell and so on and so forth. We already saw lactic acid going out of the cell and so many things happen there and any process requires energy. So how does the cell get the needed energy to do all these things and maintain life? This happens because a large amount of energy in glucose, okay, if we split glucose, or oxidise glucose, a large amount of energy gets released at one time.

The cell may not be able to use all that energy at that time. Therefore it requires energy in units that it can use directly, right? So that is what happens here, the large amount of energy (glu) glucose gets packaged into appropriate energy in what is called an Adenosine Triphosphate or ATP. ATP you would have heard, right? This (is), this stands for adenosine triphosphate, this happens to be the energy currency of the cell. And this process happens through what is called a (substrate) substrate level phosphorylation of ADP or an electron transport phosphorylation of ADP, we will look at a little bit in detail about these things. And this is how the cell gets its energy to do its various functions.

Please take a look at this video to get some idea, it's a slightly longest and an old video, but I think it's a nice video which gets to all the (necess) which touches upon all the necessary aspects for an introductory kind of an exposure, please take a look at that, it's about 9 minutes long.

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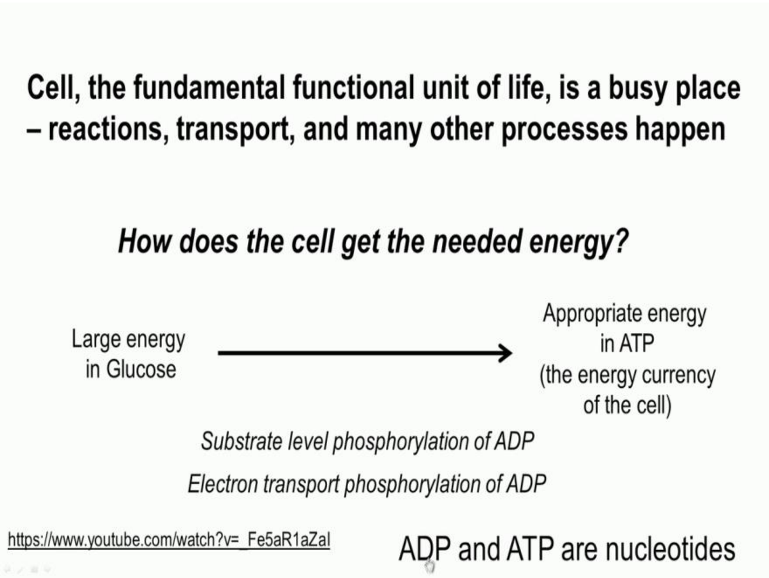

And we said ADP getting converted to ATP and so on so forth, adenosine (di) diphosphate (conv) getting converted to ATP. It so happens that ADP and ATP are nucleotides. They have the structure, sugar, a pentose sugar, a base and a phosphate group or phosphate groups attached to it.

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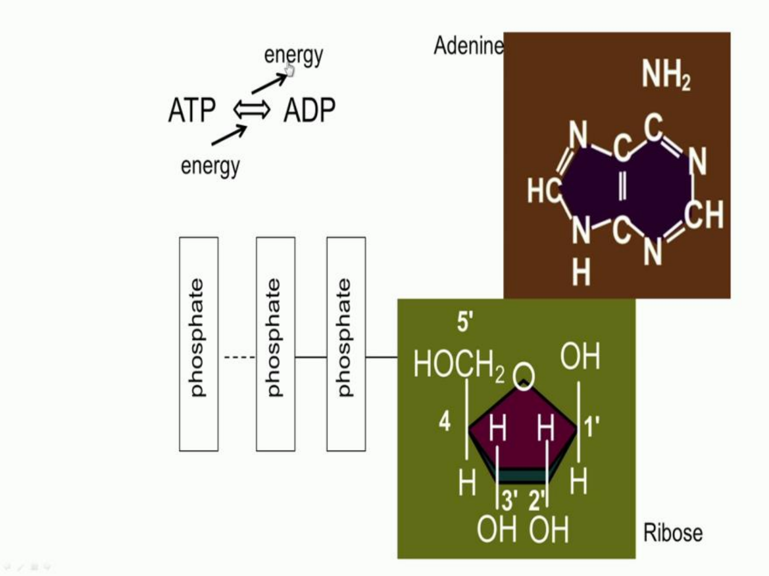

So, a ribose sugar in this case ATP, okay? So this is somewhat closer to RNA, the ribose OH in (this) in the 2 prime position. The adenine, okay, ATP, (aden) adenosine triphosphate, so the adenine, nitrogenous base it (as) is attached to the first carbon atom here and the attachment is not shown, the bond is not shown here this one needs to be removed and this one needs to go and attach to nitrogen here.

And to the 5 prime carbon, oxygen and so on, you have a phosphate groups that gets attached. If you have 2 phosphate groups then this is called adenosine diphosphate, adenosine diphosphate, okay, ADP and if you have 3 phosphate groups attached you have adenosine triphosphate. So ATP and ADP the energetically important molecules in the cell, are also nucleotides.

ATP gets converted to ADP, by the release of energy and this energy is rightly sized, right, to carry out (va) to fulfil the needs of various different cellular processes, reactions maybe and so on so forth. (So) it's about 7.3 kilocalories per mole and that's about the right size for various things. ADP gets converted to ATP and that's what we are going to, that's how ATP gets formed and that would require input of energy, okay? So ADP getting converted to ATP to kind of store up the energy currency and which is ATP 3 phosphate molecules. A breakage of this would yield energy that can the fuel or that can provide the energy for the various cellular operations.

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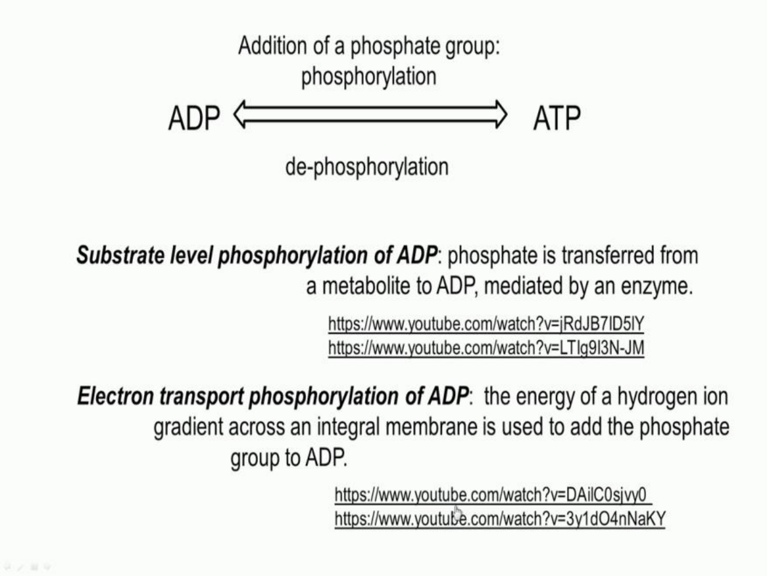

So let us look at this process in some detail, ADP getting converted to ATP. ADP getting converted to ATP we know is by addition of phosphate group, it's called phosphorylation. Phosphorylation of ADP yields ATP, and dephosphorylation of ATP yields ADP and it is this dance that provides the energy for various things and also makes the energy currency in the cell.

This phosphorylation of ADP to ATP is carried out by 2 major means; one is called substrate level phosphorylation of ADP. The phosphate group is transferred from a metabolite to ADP and is (meed) the process is mediated by an enzyme, that's what is called substrate level phosphorylation. Let's say a aphosphate molecule, can get (con) can get dephosphorylated and in that process, provide the phosphate group to ADP enzymatically to create ATP, right? And that is called substrate level phosphorylation of ADP. We are not getting into details of this, is a lot that can that one can know about this process, we are not getting into this.

However, it might be helpful to see these videos, if you're interested in knowing some details. So I would say that this is kind of optional videos. The electron transport phosphorylation of ADP, right, the energy of the hydrogen ion gradient across an integral membrane is used to add phosphate to the phosphate group to ADP to form ATP. This by itself is a very very interesting process, this was what Mitchell proposed I think in 1966 which won him the Nobel Prize, which provided the coupling between the hydrogen ion gradient and (energy) or (it it) which provided the a way by which ATP can be made which was kind of missing at that time; he proposed this as a hypothesis and (it's it) it explained a lot of things, okay, and won the Nobel Prize also. So it's that important.

And you could look at these 2 videos to get some more insights about electron transport phosphorylation, okay? These are details, I don't want to get into details in this introductory course, however if you're interested you can get into these by yourself.

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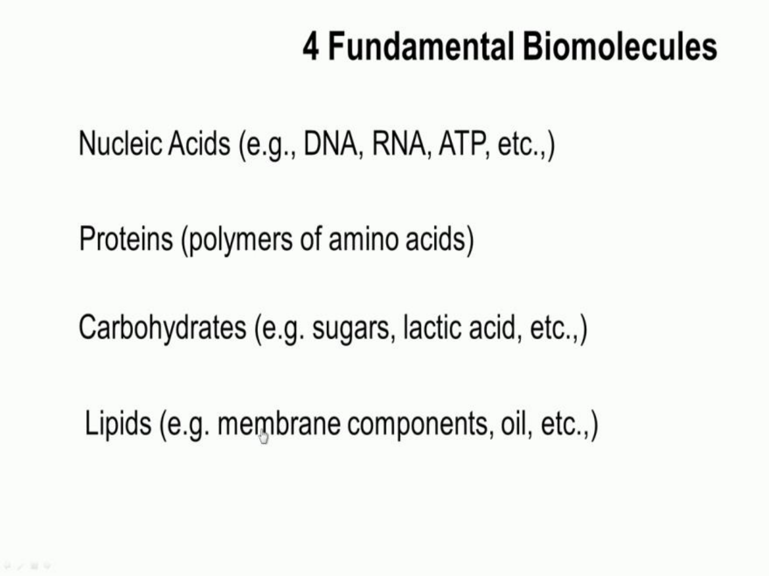

So to sum up, there are 4 fundamental biomolecules last from last to the earliest, nucleic acids, DNA, RNA, ATP and so on, proteins, polymers of amino acids, carbohydrates, sugars, lactic acid and so on that we have seen and lipids which are membrane components, oil, butter and so on, right?

So these are the 4 fundamental biomolecules, all life is made out of these biomolecules and the structure function relationship is important in these biomolecules, many of these biomolecules, and that is what determines life itself. That's why we were so (in) interested in knowing about these 4 (fun) fundamental biomolecules.

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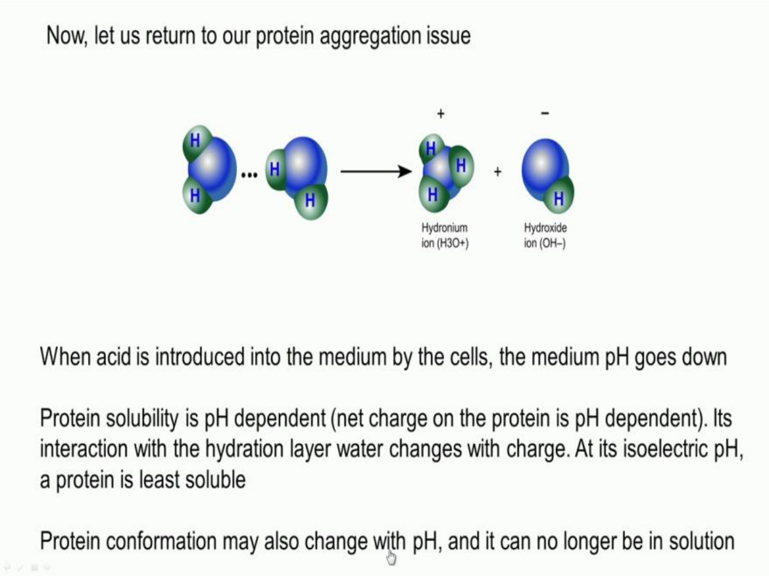

Now we are going to wrap up everything together and by (ret) by coming back to our original story which is curd formation, why does curd form. We said (la) acid formation followed by protein aggregation, protein that we are looking at (as ca) was casein. The, let us look at the protein aggregation to a certain extent, we took off on side routes and those stand out to be very enriching in terms of knowing about fundamental biology, biological molecules and so on. So let's come back to our initial story and finish up there. We have water here, you know H2O and there is hydrogen bonding between water molecules that we know now. A small part of it is ionised at any time into hydronium ions, H3O plus, and hydroxide OH minus, okay?

And a very small part, ten power minus 7, is what it is and that's why pH is 7, negative law of the hydrogen ion concentration, right? So, that gives you an idea as to the concentration of the species that is dissociated. And this happens naturally, and this is what gives water its pH. So this is what happens. When acid is introduced into the medium by the cell, the medium pH goes down further, the (hy) hydronium ion, hydroxide ion concentrations vary; H plus which forms hydronium ions and therefore this starts going up, the pH starts going down. The protein solubility is pH dependent because the net charge on the protein is pH dependent, right? (You) you know that the charges on the protein, this is (23:00 inaudible) molecule, therefore it is pH dependent and so on.

And at various different pHs (the) the net charge in the protein could be very different because of the nature of the amino acids that make up the protein. Therefore the way it interacts with the hydration layer; we said that if protein is dissolved in water there is a hydration layer around it; the interaction with that hydration layer changes with charge, changes with pH, okay? At the isoelectric pH, isoelectric pH is a pH at which there is no net charge, the interactions would be very different and at that time, the interaction between the proteins could be higher, so they fall out of solutions; there is no longer much of the hydration layer around it.

(The) therefore they fall out of solution, they aggregate because of the interactions between them. And that is essentially what happens, protein conformation may also change with pH, and it can no longer be in solution. Therefore the casein molecules, (the thepro) casein protein molecules there have different interactions with their hydration layer at one point in in pH, they came out of solution, they interacted with each other and formed they curdled and that's how curd gets formed, right?

So this is this is one of our base stories with which we started out, so let's finish up there. the take-home message is something that we saw earlier; the 4 major kinds of biomolecules, their the very nature of the biomolecules gives it a certain amount of function, the way they're put together, the structure, gives it its major function and so on, okay? And of course we started out with the fact that there are a large number of microorganisms and there are ways to organise them to make better sense of them, right? So that is the story on biomolecules, that is the module on biomolecules, and when we meet up next we will take up another aspect. See you then.