Biology for Engineers and Other Non-Biologists
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Week - 02
Lecture - 06
Biomolecules: Carbohydrates, Water

Welcome to the next lecture on "Biomolecules and the relationship to the structure and function of a cell." As we said, cell is the fundamental functional unit of life. We have seen two stories so far, the first one was about infection, what causes them and so on. And we picked up a few things that are fundamental from that story, such as microorganisms are there everywhere, the various types of microorganisms, the various types of cells, the two major types of cells and so on. And the second story was about sheer, sheer in a bioreactor and the cells being exposed to sheer and what could we do to make the cells more robust to sheer.

We said that we could do that by understanding what causes the sheer sensitivity and when we looked at that we came across a fundamental biomolecule one of the four major classes of biomolecules called lipids, defined in a vague fashion its defined lipids are biomolecules that are soluble that are insoluble in water but soluble in organic solvents, let's leave it at that that doesn't matter and we saw what lipids are fat is a lipid butter is a lipid oil is a lipid and lipids make up the cell membranes. This is what we have seen so far, this is where we left off last time. This time, let us start with another story.

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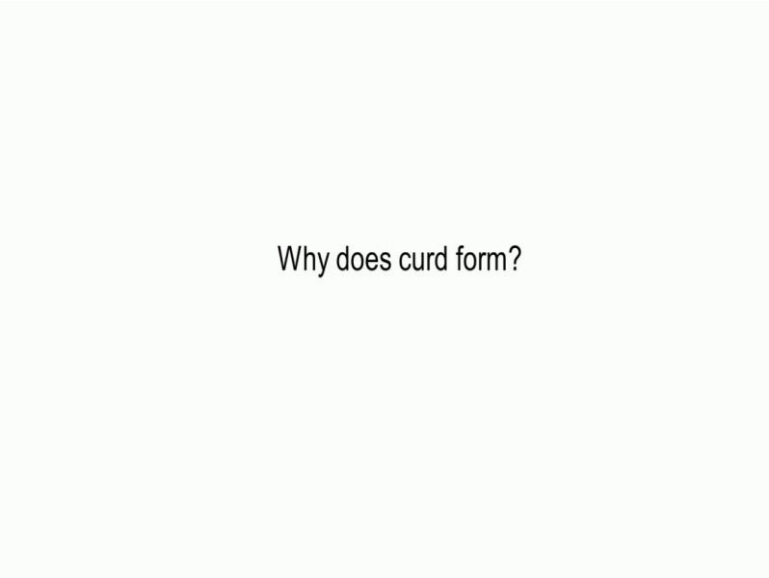

The story is rather simple in its inception but it goes on and it takes various branches, various forms, and we will probably learn some fundamental aspects from the story, various

fundamental aspects. We will keep going off-track from the story into some side stories and then come back to the main story, pretty much at the end of this module. Okay. Why does curd form, is the question that we are going to ask to begin the story. So before that how is curd made, curd or yoghurt as it is called in some countries, how is it made, it can be made at home, you take a vessel and you put some milk into it, right.

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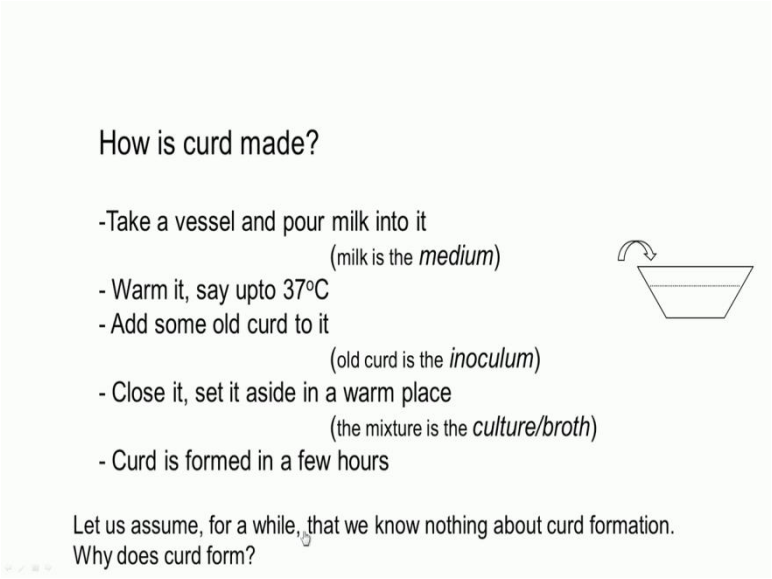

Take a vessel here, pour some milk into it, milk is called the medium; this is a term that is used in (biology) biology, biological engineering and so on. It's called the medium, warm it up to, let's say, 37 degree C in this particular case, add some old curd to it, okay. Old curd is the inoculum, as it is called in other term; don't worry about it if this term seems alien, you will get used to it. Close it, set it aside in a warm place, and the mixture that has this inoculum medium initially, and then something happens with the inoculum, something happens with the medium and all that is called the culture or the broth, in fact the, the broth changes as time goes on that is set aside in a warm place and curd is formed in a few hours, okay.

The curd makers that maintain this curd at 37 degree C by plugging it into an electrical outlet you can even get curd in about an hour and a half hours, two hours; very nice curd gets formed in maybe a couple of hours, if a curd maker is used. At home it takes probably overnight or maybe a few hours if you do it in the morning and so on, okay. Let us use this as the basis for our story. Let us assume for a while that we know nothing about curd formation and ask the question, why does curd form. Let us investigate this just by using the tools that some of us might know, and some of us might be familiar with its (basic), the tool is basically

logic with some information, the scientific method, and so let us investigate curd formation using this method. Since curd is forming from milk, something in the milk must be turning into curd, right, that's very logical.

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Nutrient	Cow	Buffalo	Human
Water, g	88.0	84.0	87.5
Protein, g	3.2	3.7	1.0
Fat, g	3.4	6.9	4.4
Lactose, g	4.7	5.2	6.9
Minerals, g	0.72	0.79	0.20

http://babcock.cals.wisc.edu/downloads/de/19.en.pdf

Ans: Acid formation, and consequent protein aggregation

Where does the acid come from?

From some among the thousands of reactions that occur inside the lactic acid bacteria (*Lactococcus lactis*)

So what does milk consist of, if you look at the data in this particular case, this as the source of the data, you don't have to worry about this paper is this just additional information, if you're interested you can go and read this paper, it is not included in the list of references, but you could take it from here and read this paper.

Milk typically contains predominantly, water, protein, fat, lactose, minerals, predominantly here the cow's milk contains for every hundred grams, 88 g of water, 3.2 g of protein, 3.4 g of fat, 4.7 g of lactose and 0.72 g of minerals, okay that's cow's milk. Buffalo milk is slightly different and human milk is slightly different, okay. So this is the composition of milk. Since we are getting curd from milk, something here must be undergoing some changes to provide curd.

So what could that be? The answer is acid formation and consequent protein aggregation, is what causes curd formation, okay, this is the answer. Let me give you the answer right away, and then dig deeper. Acid formation and as a result, protein aggregation is what causes milk to turn into curd. Where does the acid come from? Okay, that's the question that we are going to ask. Where is the acid coming from? The answer is, from some among the thousands of reactions that occur inside what is called the lactic acid bacteria, in the terms of genes and species, it's called (Lactobacis lac) Lactococcus Lactis.

This lactic acid bacteria Lactococus Lactus is what was present in the inoculum, the old curd that we added to the milk and each cell has thousands of reactions that go on at any given time, and from some of those reactions, acid comes. And that acid gets out into milk and causes protein aggregation and that when done in a controlled fashion gives you milk. (Again) same thing happens when you squeeze a lemon into milk, okay you form paneer, right, you form cheese, cottage cheese. That happens quickly when you do that slowly in a controlled fashion with a lot of other flavours that get released as a part of this process then it becomes curd, that's it.

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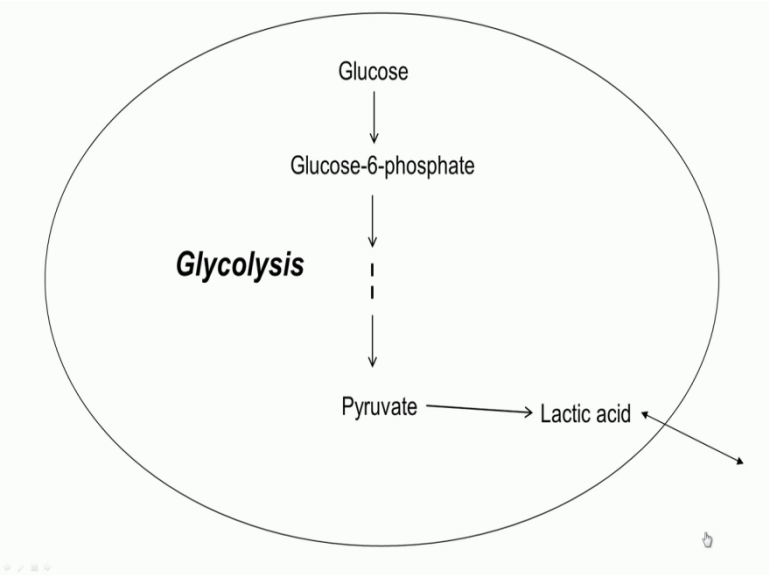

Let's dig a little deeper. So this is one set of one of the thousands of sets of reactions that occur in the cell, its typically starts with glucose, and this particular set of reaction ends with pyruvate, glucose gets converted to glucose six phosphate gets converted to fructose six phosphate and so on and so forth until it gets with pyruvate. Pyruvate gets converted to lactic acid which gets out of the cell, this is the cell that is here, you could consider this as each Lactobacillus cell. This set of reactions, glucose to pyruvate is called glycolysis and each one is catalysed by an enzyme, we will come to that a little later. So glucose to pyruvate, has ,these set of reactions has a name it's called glycolysis and as a result of this lactic acid gets formed as a result of two other reactions from pyruvate, lactic acid gets formed which causes acidification and formation and curdling of milk.

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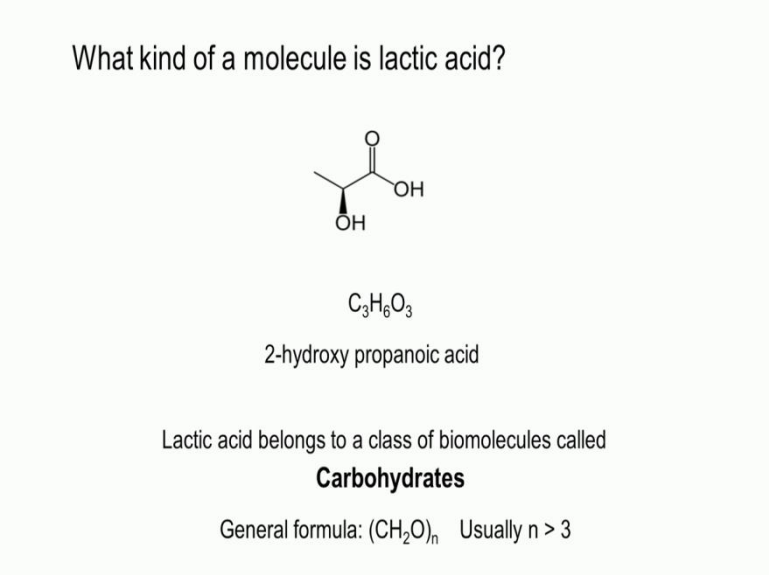

Now, what kind of molecule is lactic acid which is what is causing the curdling? That's our set question. This is how lactic acid looks like, you see here these are the carbon atoms, here there are two OHs here, this is a COOH group here and this is an OH group here, okay, there are this is a COOH and a OH group here. Therefore if you if you write down the molecular formula, it is going to be C3H6O3; one, two, three Cs and one, two, three Os and if you fill in all the hydrogen atoms then you get a C3H603 here. And from the structure you could write this is number one, number two, number three and now you need to give importance for CO its all the naming conventions that you could follow and so at the two position you have hydroxy group, therefore two hydroxyl, this is a C3, and therefore propanoic acid, okay, basic chemistry, organic chemistry. And therefore (when) this is a hydroxypropanoic acid, lactic acid belongs to a class of biomolecules called carbohydrates.

And what is a carbohydrate? It is a general formula (CH2O)N, you could represent it as (CH2O)3, then it becomes C3H603 and so on. And usually N is taken to be greater than three for a carbohydrate. These are all usual things that happen, the normal things that happen. So, anything with a formula (CH2O)N is a carbohydrate and carbohydrates are a large class or an important class of biomolecules. Earlier we saw lipids as one major class of biomolecules, now we are seeing carbohydrates as the second major class of biomolecules. And these are all present in the various as a part of the reaction intermediates that happen in the cell.

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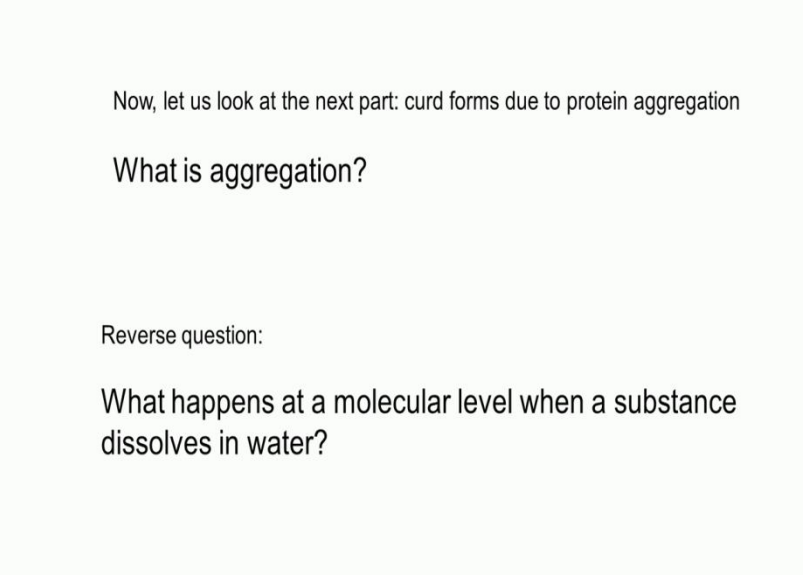

Now, let us look at the next part. We said acid formation and then protein aggregation, okay. Now what is aggregation? Okay, what do you mean by aggregation from a microscopic sense. To understand that let us ask the reverse question. What happens at a molecular level when a substance dissolves in water, okay? We said curd forms when these molecules aggregate, right, the protein molecules aggregate and get out of water. To understand that little better let us let us look at what happens at the molecular level when a substance dissolves in water.

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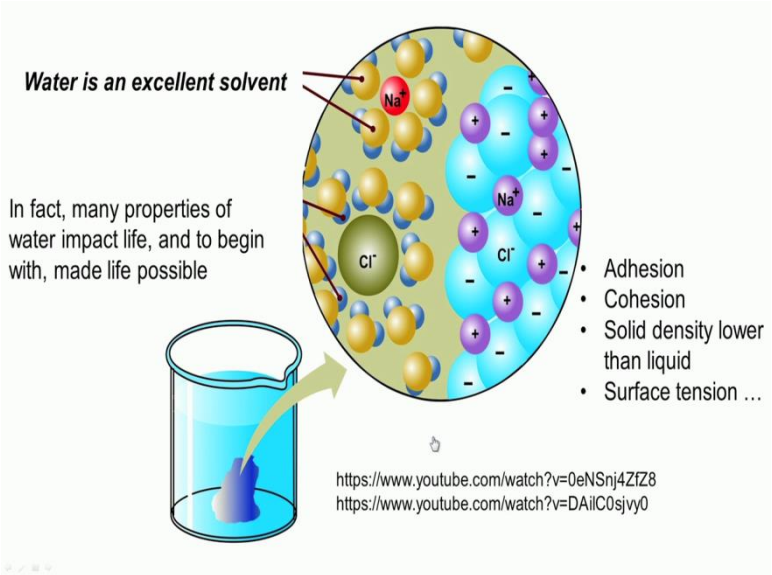

To understand that, let us look at an example of what happens when common salt dissolves in water. As we all know common salt is NaCl, okay. And when it is dissolved in water it splits

up into its ions Na and Cl and as you can see here, Na gets surrounded by a set of water molecules, Cl gets surrounded by another set of water (molecules) I mean another set of water molecules oriented differently. Na is positively charged and therefore a certain orientation happens to the molecules of water that surrounded which is different from the orientation that happens to the molecules of Cl that surrounds it, okay.

So any substance that dissolves in water needs to have a set of water molecules that surrounded it, that's essentially what dissolution is at a molecule scale. What happens to be an excellent solvent, you know we are (to) off to one of our side tracks in the story, water is an excellent solvent. In fact many properties of water impact life and make life possible to begin with okay, without water probably there won't have been a life as we know it. Why is that?

Water has very many important properties that make life possible, okay. Water, at the molecular level, has very many important properties. Water molecules sticking together because of the hydrogen bonds between the various molecules of water they tend to stick together a lot more than probably many other substances, many other compounds, what I just described is cohesion, which is sticking together of the same kind. Adhesion iswater sticking onto other surfaces that is what adhesion is okay.

And adhesion to (cohesion) and cohesion together, determine a lot of things that happen with life okay. I will give you a video which very nicely explains how adhesion and cohesion are entirely responsible for the way the water gets distributed to various parts of tree, and what happens in various other things that of life that are relevant for water and relevant in the context of water and so on. So let me not get into this for the time being but adhesion is the interaction of water molecules, the stickiness of water molecules to other surfaces, cohesion is sticking together of water molecules themselves, okay.

This results in a high surface tension, for example, cohesion and makes even some insects to be able to walk on water, the water strider and so on. This third one is a very important aspect, this solid density; the density of ice form of water is lower than the liquid density, okay. The water has highest density at around 4 degree C that we know. And water becomes a solid ice at 0 degree C. When it becomes a solid the structure of water actually opens up because it (needs) needs to have a crystal structure with the water molecules being kept at a certain distance because of the Crystal needs, and the density actually goes down a little bit, and therefore the solid ice density is lower than the liquid density, is very rare not many

other substances in nature have this property where the solid is, solid form is less dense than the liquid form, at least at certain temperatures.

What happens because of this in cold countries, ice forms right, ice forms on lakes, rivers and so on and so forth. And when ice forms because of the lower density of ice, ice floats. It doesn't sink to the surface. Because it floats, the water below can support life that depends on water. If it solidifies probably it won't be able to support life. And so this very property that the density of the solid is less than the density of liquid is what makes water what makes life possible in all those water bodies, lakes, rivers and so on and so forth, in winter.

We talked of surface tension and so on (as a) as an outcome of cohesion, and I would like you to watch these two videos, you can take these as compulsory, which explain nicely how these properties determine life, how these properties of water determine life and why water is such an important molecule which makes life possible, okay. I think these are given in, under item 13, these two videos both are under item 13. Please go and take a look at these videos, they are very nice videos.

Okay let's continue. Now we said that if a substance dissolves in water, it means that it is surrounded by a layer of water molecules, okay. So if protein is dissolved in water as in the case of a protein in milk, then there is a layer of water molecules that surround the protein and keep the protein in solution, right.

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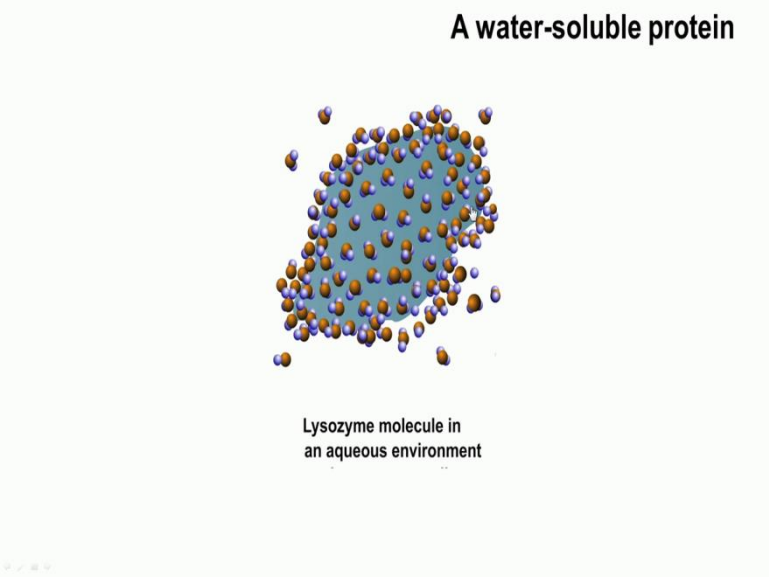

This is an example of a protein called lysozyme which is an important protein in the human body. This lysozyme is in an it aqueous environment, water environment, aqueous is water,

aqueous environment and it therefore it is a let us say, dissolved in water and which means that is surrounded by water molecules. So we looked at what happens when a substance dissolved in is gets dissolved in water, but our original story was why curd forms and we said acid formation, we saw acid formation earlier, and (from) which causes protein aggregation, so let us look at protein aggregation. Now that, now that we understand why something is in solution, aggregation happens when molecules fall out of solution, okay.

They are, they get attracted to each other because of the lack of water molecules that surround them and then they come together and fall out of solution. That's typically what happens when a substance falls out of solution. The reverse happens when the substance goes into solution, and when there is not enough water surrounding it, and they attract each other, then it falls out of solution.

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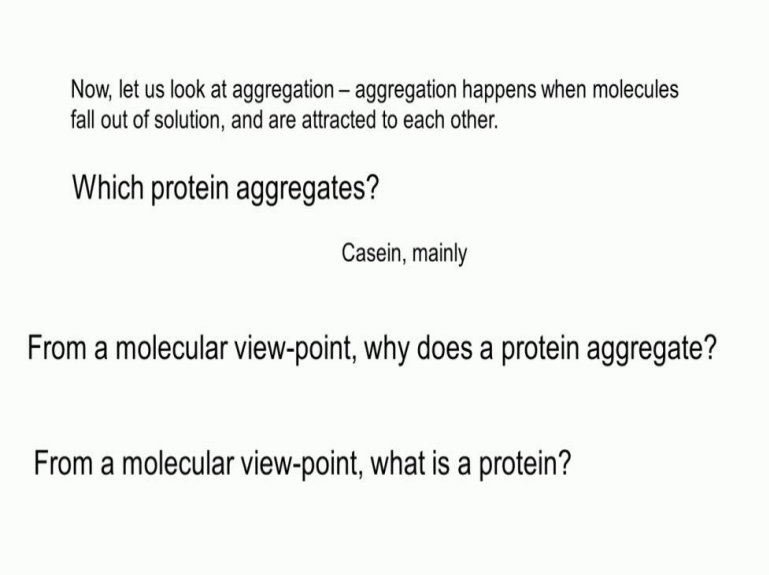

Which protein aggregates, okay, (in the) in the case of curd formation, the answer, many of you may know it, it's called casein, this is the protein that mainly aggregates when curd gets formed. From a molecular point of view, why does a protein aggregate, that's the next question that you're going to ask.

And before that, we realise we don't really know what a protein is, and therefore we are going to ask the question, from molecular point of view, what is a protein, okay. And I think we will stop here, this lecture we looked at carbohydrates and then we looked at what happens when something dissolves in water and some properties of water. I think that is good

enough information for now, fundamental information for now you munch on it, and then (we) when we meet next, we will take things forward, see you then.