Basics of Biology
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Module II – Origin of Life and Evolution
Lecture 7
Origin of Life (Part II)

Hello everybody, this is Doctor Vishal Trivedi from Department of Biosciences and Bioengineering, IIT Guwahati. And what we were discussing, we were discussing about the origin of life on the earth. And in this context, we have discussed about the various theories, we have also discussed, how what was the condition of the earth, so, that it was possible to have the life on the earth, we have discussed that what is the structure of the earth and so on.

So, in the previous lecture, we have emphasis most on, more on the conditions and the way in which the life was originated onto the earth. And in that contest, we have discussed many types of theories, we have discussed about the theory of spontaneous generations, we have discussed about the theory of special creations, then we have discussed about the theory of the abiogenesis and so on.

By discussing those theories, we have discussed, we have understood that these theories were mostly been based on the different types of experimental, different ideas or different types of assumptions. So, they were not based on the experiments, they were only based on the assumptions, for example, in the theory of special creations, the this is a completely a religious theory, where the people have discovered or people have believed, that God is the creator of the earth and the different types of organisms and the different religions have their own way of explaining this particular phenomenon.

And then, we have discussed about the theory of spontaneous generations where the people have said that the nonliving matter give rise to the different types of organisms and then subsequently, so, there were six major theories what we have said in the previous lecture that we are that have been proposed. Out of these six theories, the five theories were discussed in our previous lectures and all these theories were mostly being based on the assumption as well as without performing the much of the conclusive experiments.

So, now, in today's lecture, we are going to start discussing about the modern theory or the chemical theory of the origin of life. And that explains that the how the different chemical molecules give rise to the generation of the organisms. And this theory is apart from the earlier five theories, this theory was completely being dependent on or dependent on the

different types of experiment which are being performed and it is based on the scientific evidences. So, let us start discussing about the modern theory or the chemical theory of the origin of life.

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So, what we have discussed, we have discussed about the five different theories, we have discussed about the theory of special creations, we have discussed about the theory of spontaneous generations, we discussed about the theory of catastrophism, we discussed about the theory of cosmozoic and we discussed about the theory of eternity of life. Now, in today's lecture, we discuss about the modern theory. So, what is the modern theory?

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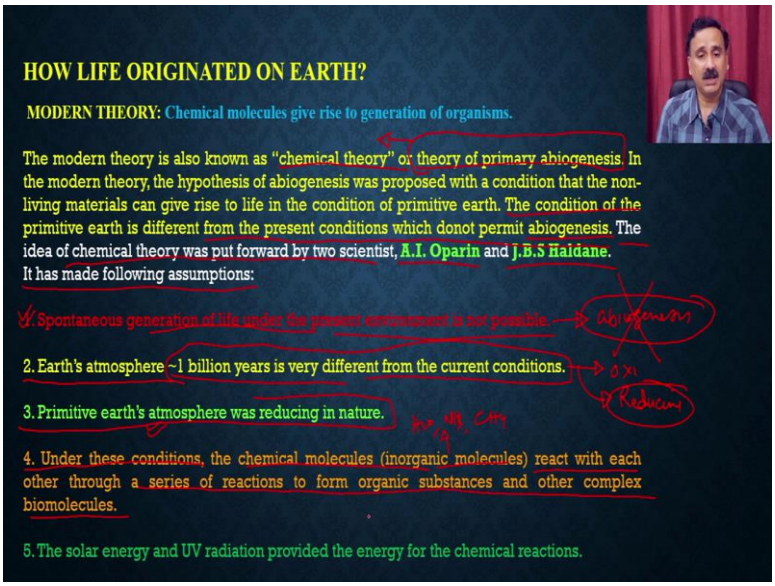

The modern theory, which is also known as the chemical theory or the theory of the primary abiogenesis. So, modern theory is very much linked to the theory of abiogenesis except with the condition that what they have said is that the, it is not possible to have the life on the earth under the current earth conditions. So, we have to create the conditions what was present on the primitive earth.

So, if you recall in the previous lecture, we discussed about what was the primitive, what was the condition on the primitive earth. The condition on the primitive earth was that it was reducing in nature because there was no molecular oxygen was present. And it was mostly the hydrogen and the hydrogen compound. Whether it is the water or the hydrogen or the methane or the ammonia, all these molecules were the hydrogen derivatives.

So, these molecules were making the environment more reducing and we have discussed in the previous lecture as well that why the reducing environment is good and what was supporting the origin of the life. Although the life cannot continue without the oxygen because it depends on the various processes, which requires the energy and that energy is being released only by the oxidation process.

But earlier in the primitive earth conditions, there was no other type of energy because energy, they were getting the energy from the solar energy, they were getting the energy through the volcanic eruptions, they were getting the energy through the lightening and all other kinds of sources they were getting the energy even from the radioactive decays and so on. So, the conditions in the primitive earth was, the condition on the primitive earth is different from the present condition and which do not permit the abiogenesis.

So, the people were trying to do the abiogenesis, if you recall the classical experiments are done by the Redi or Spallanzani or even the Louis Pasteur, they have disproved the theory of abiogenesis simply because the current condition of the earth is not supporting the life, it is not supporting the origin of the life, it is only supporting the life activities because it is supporting the generation of the energy, but it does not permit the abiogenesis.

The idea of the chemical theory was put forward by the two scientists AI Oparin and the JBS Haldane and it has made the following assumptions; what are these assumptions? The spontaneous generation of life under the present environment is not possible and that is why they have, that is the reason that the abiogenesis theory was disproved or which was discarded because of the classical experiments were done by the Redi and Spallanzani or the Louis Pasteur.

And the earth atmosphere approximately 1 billion year is very different from the current condition. So, the earth atmosphere what was there or proximately at the 1 billion year is very different, because current condition is more oxidizing, whereas, at the time of the 1 billion year when the earth formed, it was mostly be reducing. So, it has more of the hydrogen and the hydrogen related molecules. The primitive earth atmosphere was reducing in nature and that was very, very important.

And under these conditions, that chemical molecules like the inorganic molecules, like inorganic molecules, like the water, ammonium or the methane, they were reacting with each other and through a series of reaction to form the organic substances and other complex biomolecule. The solar energy and the UV radiation provide the energy for the chemical reactions.

Now, when these two great scientists have proposed the modern theory of the origin or the chemical theory of origin, there were also, some scientists have said okay, this is fine, but now, what can, how you say that this is be the case? So, you have to perform the conclusive experiments, you have to show me that this is be the true. And for that experiment, that for that reason, the scientists have started doing the experiment to prove or to the disprove the modern theory.

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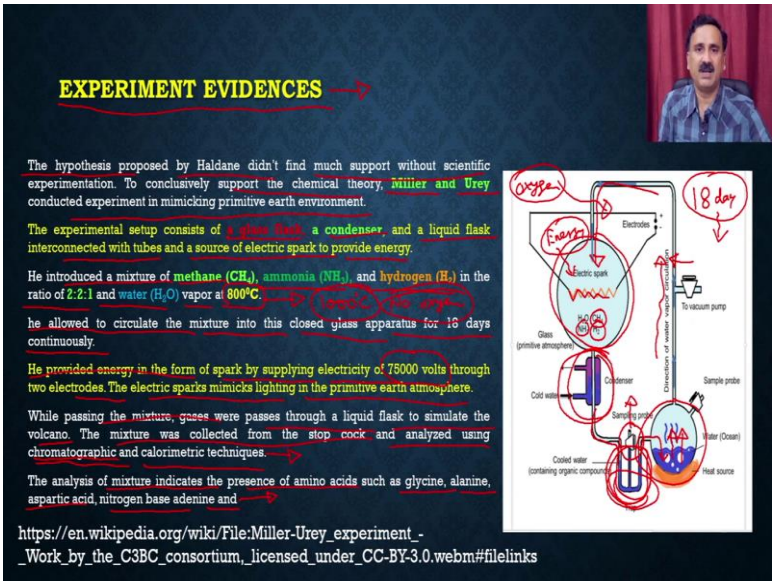

So, the first scientist who did the experimental evidences to prove the theory of modern theory that because you know, initially the hypothesis, which was proposed by the Haldane did not get much scientific attention or the support, because there was no experiment which are being done by the scientist, and then the, to conclusively support the chemical theory, the

Stanley Miller and the Urey conducted the experiment mimicking the primitive earth conditions.

So, how they have done that? They have developed a scientific experimental setup, which contains a glass flask, a condenser and a liquid flask and which are interconnected with a tube with the source of electric spark to provide energy. So, what they have done is they have taken experimental setup and where they have, having the glass flask and they were being connected to the liquid flask, this is a liquid flask, where the water can be boiled.

And then they have also have the glass flask where they are being able to produce the electric spark and that electric spark is mimicking the lightning and that is how they were being providing the energy and then they can be able to allow the entry of the different types of gases into this.

So, what they have done is they have taken the methane, ammonia and hydrogen as a gas into this chamber and then they were having the condenser, so that condenser is going to cool down these gases. So, they will be present in the liquefied form and or substances whatever is going to be formed.

So, then what they have done? They have taken this apparatus and then he introduced a mixture of methane, ammonia and hydrogen in the ratio of 2 is to 2 is to 1 and the water and water vapor at a temperature of 800 degree Celsius, if you recall, when we were discussing about the earth formation, we said that earth is been formed when the temperature was approximately around 1000 degrees Celsius.

So, they have maintained the similar kind of primitive earth conditions like 800 degrees Celsius, they have mixed the, they have made the environment reducing by introducing this hydrogen in the environment as well as ammonia and methane. So, there was no oxygen. So no oxygen in their apparatus. Then they have, what they have done, they have circulated this mixture into this apparatus. So this is a closed apparatus, there is no way you can get it can go out.

So, because outside is oxygen. So, if oxygen is will enter, it will going to destroy the chemical reaction and that is how they will not be there will be no generation of the organic molecules. Then they allowed the, to circulate the mixture into this closed glass apparatus for 18 days continuously. So, they have allowed this to be circulated. So they see the way, they have heated the water.

So water is going this way and while it is going it is also taking the different gases, different gases into this mixture, and then these gases are entering into this bulb, and once they enter into the bulb, they are putting the electric shock so because of that there will be electric spark and that mimics the lightning and that is how it is providing the heat or the energy into the system.

So, because of this energy, these gases are going to react with each other and then they were going to be formed a new compound and that is how they will be get cooled down by a condenser. So, they will be formed the liquid and then these gases are going to the condense, the liquid is going to be condensed in this particular trap. And after that the gases will again enter into this water and once they enter into this water, they are going to come out in the form of a like a kind of volcanic eruptions or something. So, they will come out from this water and again they will travel.

So, this continued for 18 days and during these 18 days they have taken out the sample. So, they have a sample port what you see here they have sample port. So, whatever the liquid condensed here, they can be able to take out the sample and then they that sample can be tested for the synthesis of the new compound or not. So, they provided the energy in the form of spark by supplying our electricity at the 75,000 volt through the two electrode. The electric sparks mimicking the lightening what is happening in the primitive earth atmosphere.

While passing the mixture gases were passed through a liquid flask to stimulate the volcano, the mixture was collected from the stop cock and analyzed using the chromatography as well as the colorimetric technique. So chromatography is a technique or the calorimetry is a technique.

So calorimetry is going to tell you what will be the energy level or what was the free energy change of these compounds that are being formed. Whereas the chromatography is going to tell you the nature of that particular compound, whether the glucose is being formed or whether the sugars are being formed or whether the organic molecules are being formed or not.

So, chromatography is a separation technique which not only going to separate the molecule, but it also going to tell you the nature of that particular compound. The chromatography is can be also be used to purify or to characterize the molecules. The analysis of the mixture indicate that the presence of amino acids such as glycine, alanine, aspartic acid, nitrogenous base, adenine are being formed into these particular experiments. So, and so, this proves that

you can be able to by doing this experiment you can be able to synthesize the new compounds.

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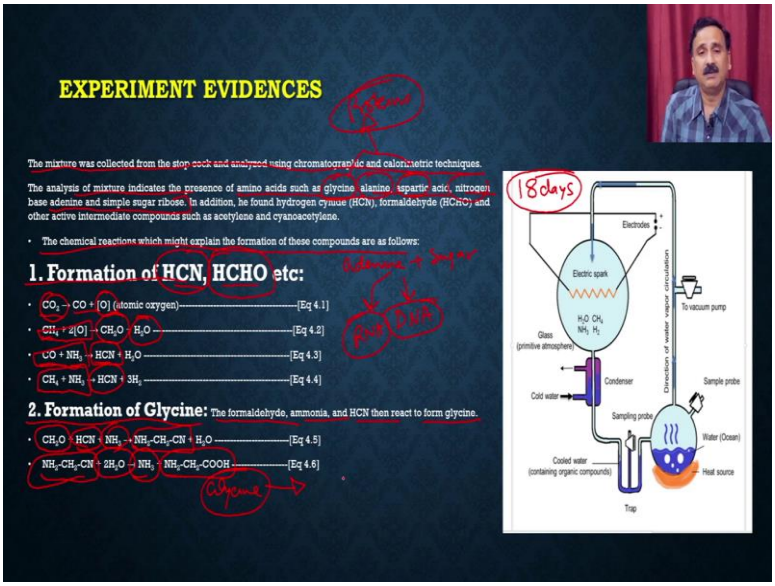

So, the mixture what they have collected from the stop cock analyzed using chromatography and colorimetric method, the mixture of these indicate the presence of amino acids such as the glycine, alanine, aspartic acid and nitrogenous base such as adenine and the simple sugar ribose. So, that the adenine and plus sugar is can give you the simple molecule which is called DNA or nucleotides.

So, these two molecules can will give it to give you the DNA as well as the RNA whereas, all these molecules like glycine, alanine, aspartic acid and are probably will be good to give you the proteins. So, that is how they have proved that by doing this simple experiment and where they have not done the experiment for a very extensive period like 18 days is a very small period, but to see that the proteins are formed or not. So, 18 days is good enough to say that by doing this method, they could, you can be able to synthesize the biomolecule.

So, once you synthesize the biomolecule they can be able to give rise to life. So, the chemical molecules, the chemical reaction which explains the synthesis of these compounds are as follows the formation of the simpler organic molecule like the formaldehyde or the HCN. So, the carbon dioxide is going to be dissociated into the carbon monoxide and molecular oxygen and then the methane is going to react with these two compound to give you the HCHO this is formaldehyde and then water is going to be released.

Similarly, the carbon monoxide which is going to be react with ammonia is going to give you the HCN. And if the methane is also going to react with the ammonia, it also can give you the HCN. Similarly, you can also explain the formation of the glycine, the formaldehyde, ammonia and HCN, then react to form the glycine. So, this is the formaldehyde, then it reacts with HCN and then it reacts with the ammonia.

And that is how it is going to give rise to the glycine and then this NH_2CH_2CN is going to be react with water and that is how you are going to have a molecule of ammonia and you are also going to have the molecule of glycine. So, this glycine, the generation of glycine and the generation of the other biomolecule proved for the first time that it is possible to have the synthesis of the biomolecule by the inorganic molecules, before that it was not possible.

So, because the condition in which the people were trying to prove the abiogenesis was not conclusive like for example, if even if you take the rotten meat, it will not give rise to the molecules. So, this classical experiment of Stanley Miller proved that modern theory of or the chemical theory is correct, and it can be able to give us the insight how the life is originated onto the earth.

Then they move ahead and they have given the detail what are the different steps could have happened by synthesis of these biomolecules and then how these biomolecules could have given rise to the primitive cell and that primitive cell could have been evolved into more and more complex organisms.

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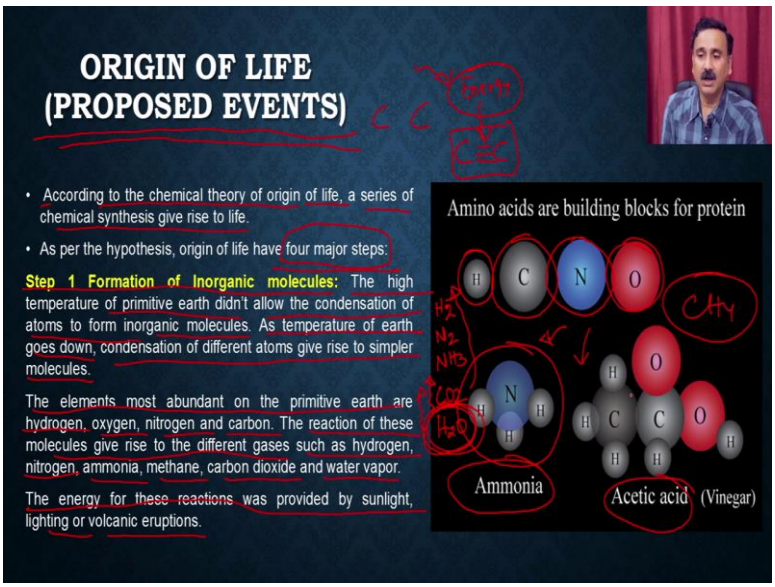

So, according to the chemical theory, so, the what is the proposed events. So, nobody knows how the whole life is originated onto earth. So, but these scientists based on these experiments, they have proposed the multiple events. So, what you have is, you have the four major steps what we to have proposed. So, according to the chemical theory of origin of life, a series of chemical synthesis give rise to the life.

You have seen how the carbon dioxide and ammonia and the methane is reacting to give rise to the formaldehyde and then formaldehyde is reacting with these molecules to give rise to the glycine. So synthesis of glycine, glycine is a simplest amino acid, but then once the glycine is formed, you can also have the multiple different combination and that is how you can be able to have the synthesis of the even complex biomolecules.

So, considering these, these scientists have proposed the events, which probably could have happened in the primitive earth environment, and that is how they have said that it is a 4 major step process. What is the step 1? Step 1 is the formation of inorganic molecule; the high temperature of the primitive earth did not allow the condensation of the atom to form the inorganic molecule.

As the temperature of earth goes down, the condensation of the different atom molecule give rise to the simpler molecule. For example, in the primitive work, you have the hydrogen, you were having the carbon, you have nitrogen and oxygen, but when the temperature goes down, these molecules were coming together and that is how they have synthesized the simpler inorganic molecule like ammonia or the acetic acid.

So, you can see that the oxygen which was molecular oxygen, which was associated with this molecule, and that is how it has given the two simpler molecules which are ammonia and acetic acid. Apart from that, you can also have the methane and the elements, the most abundant element on the earth the hydrogen, oxygen, nitrogen and carbon. The reaction of these molecules give rise to the different gases such as hydrogen, nitrogen, ammonia, methane, carbon dioxide and water vapor.

So, you will, because these elements were present, you can have the different types of gases you can have the nitrogen, you can have hydrogen, you can have nitrogen, you can have the ammonia, you can have the ammonia, you can have the carbon dioxide and you can have the water and water because the temperature is high, it is always going to be present in the form of vapor. So, water is going to react with, will be a medium through which these different gases are going to react with each other.

The energy of these reactions was proved or was provided by the sunlight, lightening or the volcanic eruption, because if you want to do a chemical synthesis, you have to form the bond, for example, you have two carbon molecules, then if they will not form the bond, they will compound they are supposed to form a bond, they are supposed to form a bond like whether it is a single bond, double bond or triple bond, this bond formation is a requires the energy.

So, that energy is going to be supplied externally and that is being supplied by the sunlight, lightning or the volcanic eruptions. So, in step 1 you are going to have the formation of inorganic molecules like inorganic molecule, whether they are the gases or the liquids.

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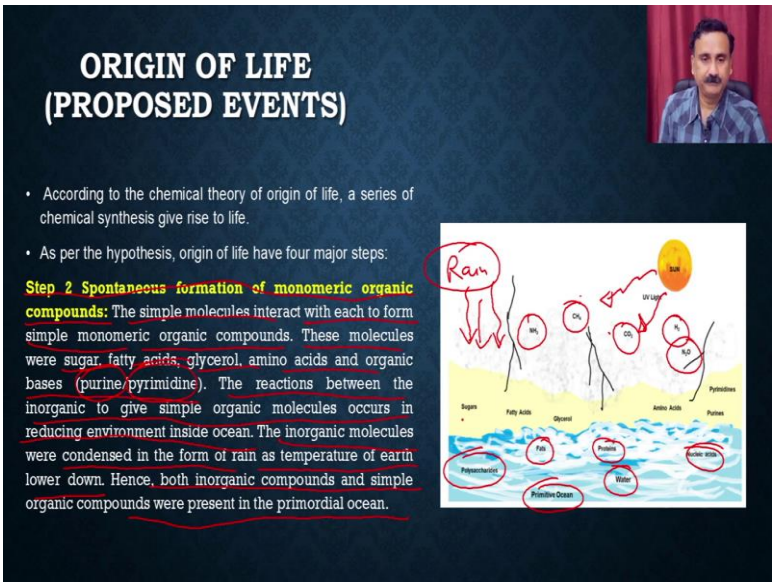

Then in the step 2, you are going to have the spontaneous formation of the monomeric organic compound, the simple molecules interact with each other to form the simpler monomeric organic compounds these. So, you can imagine that you have the primitive ocean, primitive ocean where you have all sorts of gases like methane, ammonia, carbon dioxide, hydrogen, nitric oxide and all those kinds of molecules. So, when they will and then you have the lightning and you also have the UV light from the sun.

And all these are, when they are doing they are forming the simpler monomeric compounds like fat, proteins, nucleic acids, primitive or water and the polysaccharides. So, these molecules are like sugar, fatty acid, glycerol, amino acids and the organic basis like the organic basis which are purine or the pyrimidine. The reactions between the inorganic to give simpler organic compound occur in the reducing environment inside the ocean.

The inorganic molecules were condensed in the form of rain as a temperature of earth goes down. Hence, both inorganic compound and the simpler organic compounds were present in the primordial ocean, which means, once the temperature goes down, the water was condensing, so there was a rain. And because of the rain, all these molecules what are present in the atmosphere are condensing and getting dissolved into the molecular ocean.

And that is how they were getting a medium in which all these molecules are reacting with each other, energy they are getting from the lighting as well as the sunlight. And that is how they are forming the simpler sugars, they are forming the simple fats and simple nucleic acid molecules like the nucleotides, and all these molecules are present in the primordial oceans.

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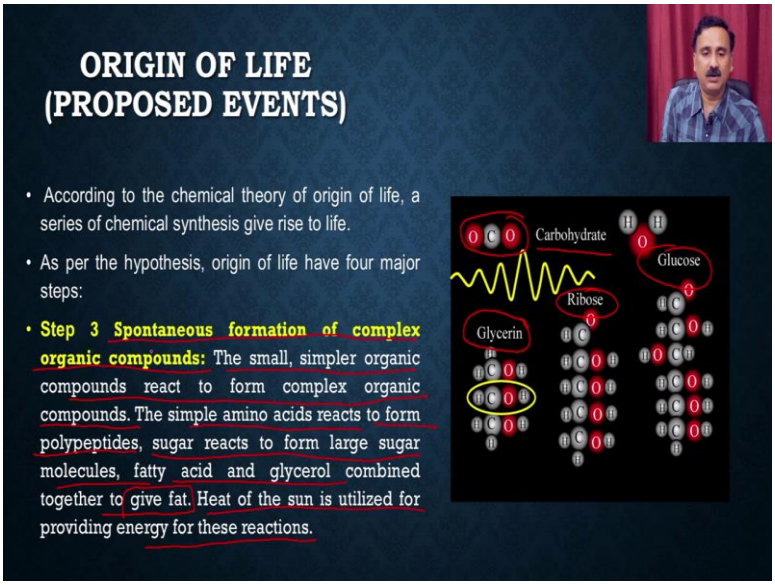

Then in the step 3, the spontaneous formation of the complex organic molecules. So since once you have generated the simpler organic molecules, these simpler organic molecules are going to react with each other. So what we have generated? We have generated the simpler carbohydrate, like simpler sugars, and these simpler sugars are then going to form the more and more complex sugars.

So, the small simpler organic compounds react to form the complex organic compound. So simpler organic, simple amino acid reacts to form the polypeptides; sugar reacts to form the large sugar molecules, fatty acids and glycerol combined together to give you the fat and the heat of the sun is utilized for providing energy for these reactions. So, you what we have is we have the simpler organic molecules, they will react with each other to give the smaller, more complex like molecules like the glycerin, ribose, glucose and on even more larger molecules.

So fat is also being developed, once we had the glycerol and the fatty acids, the glycerol and fatty acids are going to combine to give you the fat and you know that the fat is a very important component of the plasma membrane. So that is going to give rise to the plasma membrane of the primitive cell, so that we are going to discuss. So in the step three, you are going to have the synthesis of complex organic compounds.

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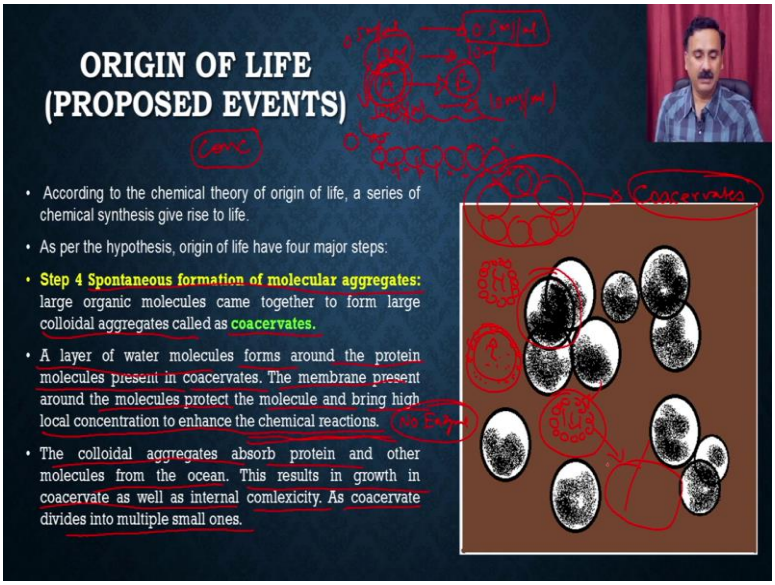

Then in the step 4, you are going to see the generation of the smaller molecular (())(26:47), see once you have generated the small molecules, they are not going to have the tendency to club together, because they can have the, but once you generated bigger biomolecules like the proteins or the nucleic acids, they will be going to react with each other and that is how they will be going to form the complex. So, they will be going to form a complex and these complexes are known as the coacervates.

So, they will be formed, they will be called as coacervates. And even see, through all these molecules where you can probably there will be a protein which is going to form outside layer. And then within this you can have the DNA or lipids and all those kinds of things. And that is how you are going to have a ball shape coacervates, where the molecules are going to come together. And they will form the colloidal aggregates which are called as the coacervates.

A layer of water molecule forms around the protein molecules presents in the coacervate. So, once the protein molecules are there, and you know that, anyway, we are going to discuss in future that protein molecules are being made up of the amino acids and amino acids are going to attract the water. So what will happen is the water molecule is going to absorb onto these

molecules? And that is how you have a coacervates and apart from the coacervates, outside of coacervates, you are going to have the layer of water.

And because of this, this small area is going to be turned into a very, concentrate. So, it will go into concentrate the reactants and that is how it is going to facilitate the chemical reaction at a faster rate, you know that the chemical reactions are dependent on the concentration of the molecules. So, if A is getting converted into B, if you have the 10 milligrams of A, it is going to be formed the 10 milligrams of B.

But if you increase the amount, if you increase the, even if you keep the 10 milligrams, and the concentration is 0.5 milligrams per ml, the reactions are going to give you the reactants in the same ratio. But if you take the 10 milligrams and make the concentration as 10 milligram per ml, then in a given time, what you are going to get, you are going to get the 10 milligrams of the B.

So rate of reaction is always been dependent on the concentration of the reactants. And you can increase the rate of reaction simply by having a protein, which is going to cover these coacervates. And along apart from the proteins, you can also have the water molecule, so that is why it is going to form a small vessel like structure and because of this lower, local concentration of the molecules are going to go up.

So the membrane which is present around the molecule, protect the molecule. So first of all it is going to protect, so it will going to be, not going to be damaged, it is not going to disintegrate. So, this is going to form the colloidal particles, which are not going to dislodged and at the same time, it is going to bring the high concentration of the reactants, so enhance the chemical reaction.

So you can see, even if we were talking about a previous lecture, it took a couple of billion years for these reactions to complete. So that you can be able to have the synthesis of these biomolecules. But if you increase the reaction concentration, the chemical reactions are going to enhance, because remember that there is no enzyme, so there is no enzyme in this. So, the chemical reaction has to facilitate spontaneously on its own.

The colloidal aggregates absorb the protein and the other biomolecule from the ocean, this results in the growth of coacervate as well as the internal complexity, as the coacervate divides into the multiple small ones. So now what happened is, these coacervates started, collecting the protein. So as an arrangement, the proteins were present outside. And inside

this structure, they were be trapping the different types of biomolecules like the nucleotides, or the DNA and RNA and outside this, you are going to have a water layer, and that is going to form a membrane like structures.

And ultimately, these coacervates started taking up the molecules from the outside and that is how they will be started growing. So they will be started growing inside and once they grow to a larger size, then these coacervates are breaking from the middle and that is how they will be dividing into the two steps into the multiple coacervates.

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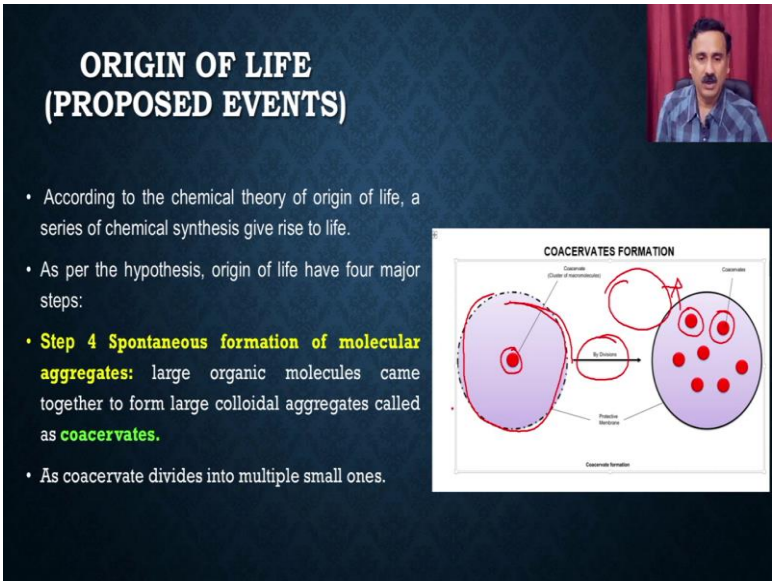

And this is what is happening. So you have a single coacervate, around this you have the, you know, the protective membrane, this protective membrane is there, and then it grows in size. So if it grows in such a big size, then it divides and gives multiple coacervates and you can imagine that all these multiple coacervate, again, will do the same, they will grow and then they will be going to divide and that is how you are going to see large number of coacervates into the primordial oceans.

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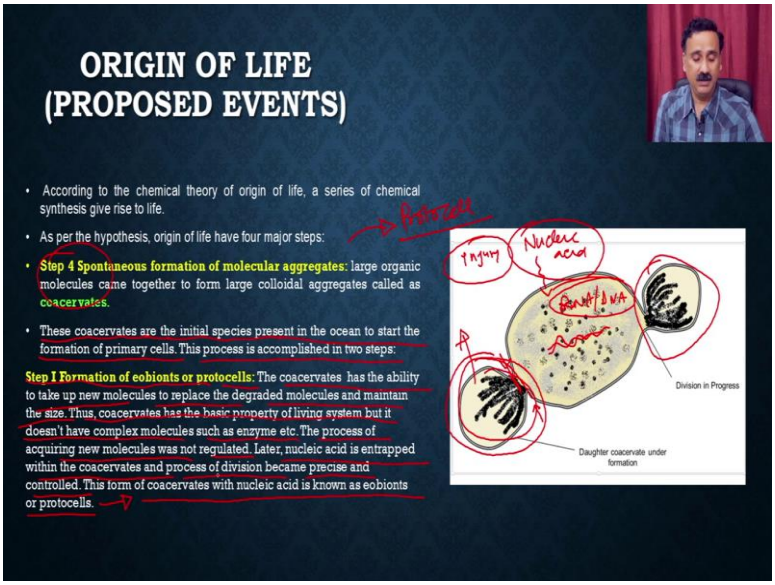

Then we have the two steps. So, step is from the coacervates, you are going to have the development of the protocell or the, so once the coacervates started taking up the biomolecule from the ocean, they have started developing the primitive cells. So, coacervates are the initial species present in the ocean to start the formation of the primary cells, this process is accomplished in the two steps.

So, step 4 further being divided into the two steps. In the step 1, you have the formation of the protocells. The coacervates have the ability to take up the new molecule to replace the degraded molecule and maintain the size. So coacervates, were the first species which are formed and they were having the ability to replace the molecule which are being degraded, and that is how they can be able to do the, you know if there is an injury, they can be able to do the repairing of that particular part.

And thus the coacervates have the basic ability of the living system, it does not have the complex molecules such as the enzyme. The process of the acquiring new molecule was not regulated, later nucleic acid is entrapped within the coacervates and the process of division become precise and controlled. This form of coacervates with nucleic acid is known as the protocells.

Later on, what happened is the coacervates have started trapping the biomolecule. So, initially, the all the reactions were very unregulated. So because they will be, they will be governed simply by the mass balance side. So wherever the mass is there, and if the mass is going beyond, I will say a size, it is getting weakened and that is how it is going to break and break into the multiple portion.

For example, this is what you see. This is the coacervate, it was very big, but at this point, it got very high size of biomolecule. So that is how this portion got constricted and that is how this portion is going to be now form the new coacervates. So, same is happening here also. So, this coacervate is not having any regulation where this could be happening, but ultimately, this coacervate have started taking up the nucleotides or the nucleic acid.

So, once they have started taking the nucleic acid, the nucleic acid has taken up the, bit of nucleic acid is a having the information. So, whether it is a nucleic acid of RNA, or the DNA that was having the information and that they have started governing the activities within the coacervates. And that is how the, these coacervates which were having the entrapped nucleotides or nucleic acids are known as the eobionts or the protocell. So, these were the first form of the living organisms.

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Later on these protocells were, form the first cell. So then, the protein molecules are and the appearance of enzyme has enhanced the synthesis of several of biomolecules which are present in the protocells, the RNA and DNA developed in these molecules and that has taken over the protein synthesis. So, initially, the protein synthesis was happening because of the spontaneous reactions between the inorganic biomolecule or the smaller biomolecules.

Because the smaller biomolecules were synthesizing the amino acids and then these amino acids were binding to each other and that is how the proteins are synthesizing, but as soon as the RNA and DNA were trapped within the coacervates, the RNA and DNA were guiding what will be the synthesis of the biomolecule. Although there are many things which are not known between in this particular process, how the RNA and DNA were governing the

synthesis of the biomolecules or the protein molecules and so on. So, that these are some of the things which we are still not clear.

The interaction of the lipid and the protein allowed the formation of the bio-membrane which has provided the selectivity in the primitive cell for intake or the exclusion. So, ultimately what will happen is the people, the lipids are forming the aggregates with the protein and that is how they have formed the plasma membrane. So now, there was a plasma membrane outside and then you have the nucleic acids in the middle and that is how it has formed the first cell.

And this first cell was primitive and it was still need to be develop many things like it has to develop the different types of organelles and so on. And that is how this primitive cell could be the prokaryotic in nature and this prokaryotic cell could have given up the eukaryotic cells. It allows the appearance of the membrane bound protocell and it has eventually gave rise to the first cell on the earth.

So, this is what happened, probably could happen and these are the proposed event, still there are no experimental evidences to prove these points, these are the proposed events which are being proposed by the different scientists, based on the experimental evidences, but not the direct experimental evidences through which the people are, because we all still know that if you take the protein and lipids and if you mix them or if you provide the energy into the system, they get rearranged to give you a plasma membrane.

So, these are the some of the experiment, but if nobody has so far done these steps individually and to create a protocell or to create the first cell. The mutation in the DNA and the selection of the fast-growing cell give rise to the appearance of the first primordial cell. So that ultimately there will be some mutation in the DNA and that is how the, so the first cell, cellular form was formed on the earth at approximately 2000 million years ago. So that is how the life is originated onto the earth. So, this is all about the origin of life on the earth.

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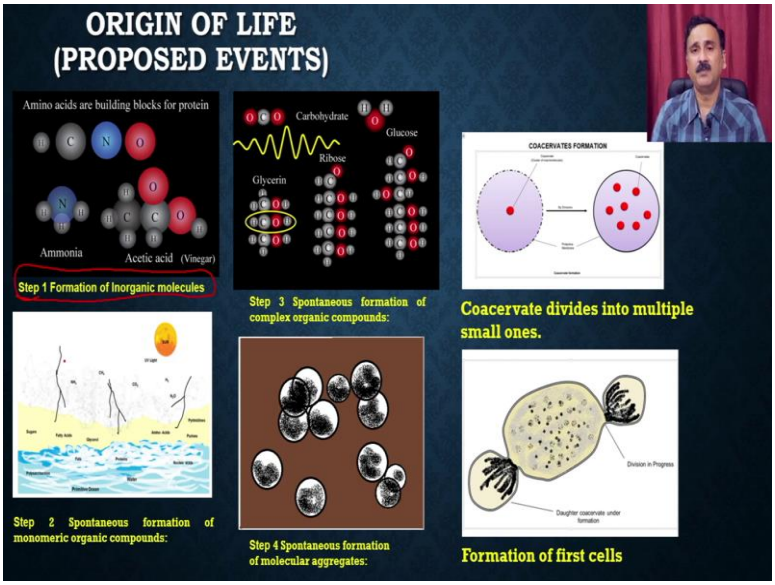

If we summarize what we have just discussed, what we have discussed? We have discussed the multiple events are required to form the life on the earth. And all these are the proposed events based on the results what people got from the Stanley Miller's and Urey's experiments. So what he says is that the proposed events are a 4 step events. In the step 1, you are going to have the formation of the inorganic molecules.

And then in the step 2, you are going to have the spontaneous formation of the simpler monomeric organic compounds. So in that you are going to form the monomeric amino acids and nucleotides, as well as the fatty acid and glycerol. And once you form the fatty acid, glycerol, they are going to form and club together. And they were going to form the complex biomolecules or complex structures, complex biomolecules in the step 3, and in this, and then these biomolecules will come together, they will aggregate and that is how they are going to form the coacervates in the step 4.

And once the step 4 the coacervates are being formed, these coacervates are going to start acquiring the biomolecule from the primordial oceans, and they will be started growing in size and that is how they will actually, and apart from that, they will also have the ability to replace the biomolecules which are being damaged. And once they grow to a certain size, then these coacervates are going to divide and they will give you the daughter coacervates.

But ultimately, these coacervates have also started develop, trapping the nucleic acids, which are also present in the primordial oceans and that is how they have formed the first protocells and these protocells once they have, having the nucleic acids, they have also directed the protein synthesis, the lipid also came into the picture and the lipid along with the protein has

formed the plasma membrane and that is how you have the plasma membrane bound first cell which is formed within the primordial oceans.

So, this is all about the origin of life and what we have discussed? We have discussed about the different theories in the previous lecture as well as in this lecture. And in this lecture, we discuss about the modern theory of origin of life and we have also discussed about the different experiments, we have discussed in detail about the Stanley Miller's experiment and how the standard Miller's experiments prove that the smaller simpler biomolecules or similar chemical molecules can give rise to the complex biomolecules.

One interesting thing, which is very important is that if people are still trying to discover the more and more molecules which Stanley Miller has formed. So, Stanley Miller has collected the different fractions and then these fractions are still being preserved in his laboratory and recently scientists have analyzed those reagent bottles or analyzed those fractions, what they could found is that because the Stanley Miller does not have the very high-end technique and that particular timeframe, he would not be able to identify some of the biomolecule.

But now, if you go and try to fractionate those molecules that people have found is that even if the, they could be able to see the different types of nucleotides and other kinds of biomolecule, which the Stanley Miller could not be able to report at that point. So, this is all about the origin of life.

In our subsequent lecture, we are going to discuss about the evolution and how the simple cells which are being formed in the primordial ocean develop into the different types of organisms. So, with this, I would like to conclude my lecture here.

Thank you.