Evolution of The Earth and Life
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Origin of Life: Initial Ideas

Welcome to the course Evolution of the Earth and Life.

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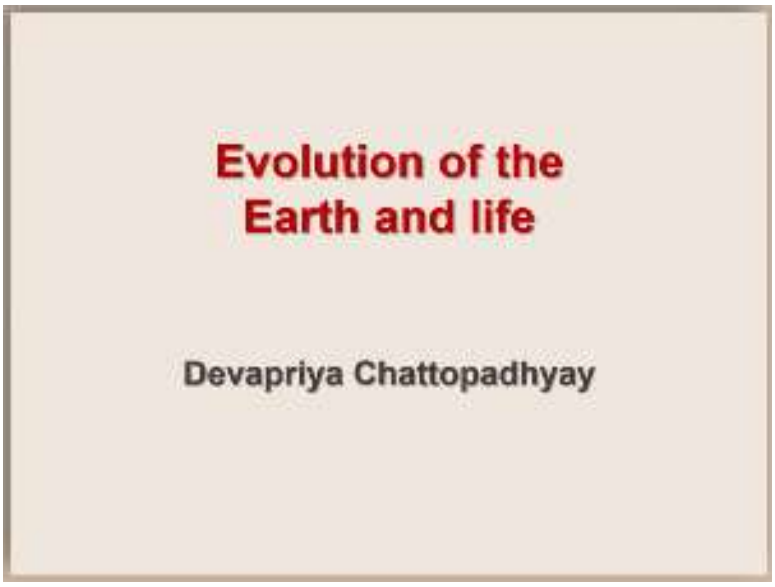

Today, we are going to talk about some very early concepts of origin of life.

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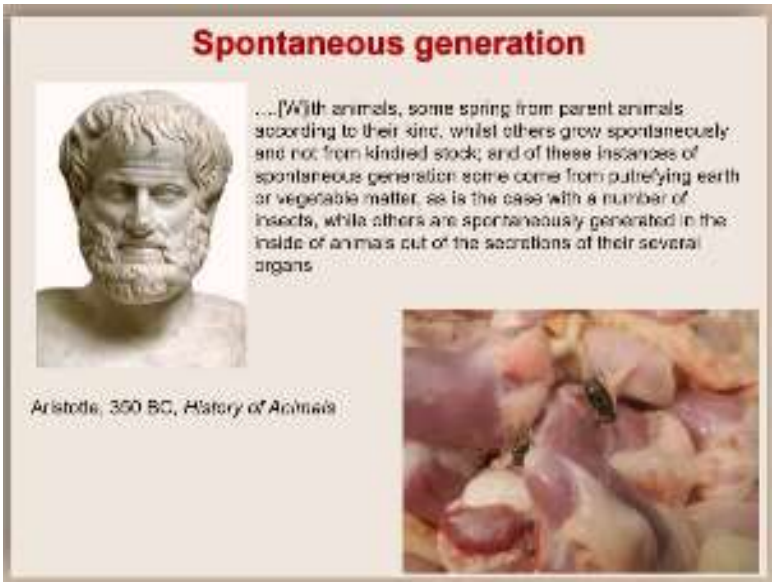

The question how life started on the planet is a very very old question. Philosophers and scientists thought about this question for a very long time. The first person to come up with a very precise statement of his views about how life came on the Earth, was Aristotle in 350

BC. In a chapter in history of animals he wrote that, the primary idea of how life evolved is from spontaneous generation.

What it means what he argued is if you look at decomposing flesh or vegetables you are going to see a lot of flies which are coming out of it and in his mind he explained it that, from those decomposing vegetables and meat these flies are generating spontaneously. And that is how life starts. And once life starts it can change and it can pass from one generation to the other generation but at the beginning that must have been the way how things started to generate.

So, in his words it says with animals some spring from parent to animals according to their kind what we see around us today, whilst others grow spontaneously and not from kindred stock. What it means again that, we see some groups which we see around us especially in his time pets such as horses and other pet animals you see that they are basically generating from their parent animals.

But, then there are other animals such as flies that he has seen he was not sure how they originated and from his observation he thought that they simply come up from the decomposing flesh. And that is why he concluded that they spontaneously generate in the inside of animals out of the secretions of their several organs. Now today it seems quite hard to believe that somebody comes up with this kind of an explanation in terms of spontaneous generation.

But, at that point it was one of the most well accepted idea of how life originated? The major issue with that is at that point of time it was not possible to observe anything which is very small in size. Today, we know that even in decomposing flesh, there are flies which basically lay their eggs and because those eggs are microscopic, we cannot really see it. So, it may appear that the decomposing flesh is generating flies all of a sudden without any growing point.

But, it actually has these growing points because flies come to these decomposing flesh or vegetables they lay their eggs, those eggs transform to larvae and eventually grow to full-fledged flies. So, with the help of microscopy we know these stages but this again was one of the most well accepted ideas of its time and it continues to be so till at some point at 1800. But, people started questioning this idea particularly as the observation got better.

Everywhere where it was initially explained as the spontaneous generation people started looking at it more thoroughly with multiple observations and they always found that there are eggs or there are larvae and therefore it you cannot really call it a spontaneous generation. This debate went to the level where most of the scientific community were engaged in it and Paris Academy of Science decided that they have the responsibility of changing it. And therefore, they declared a prize.

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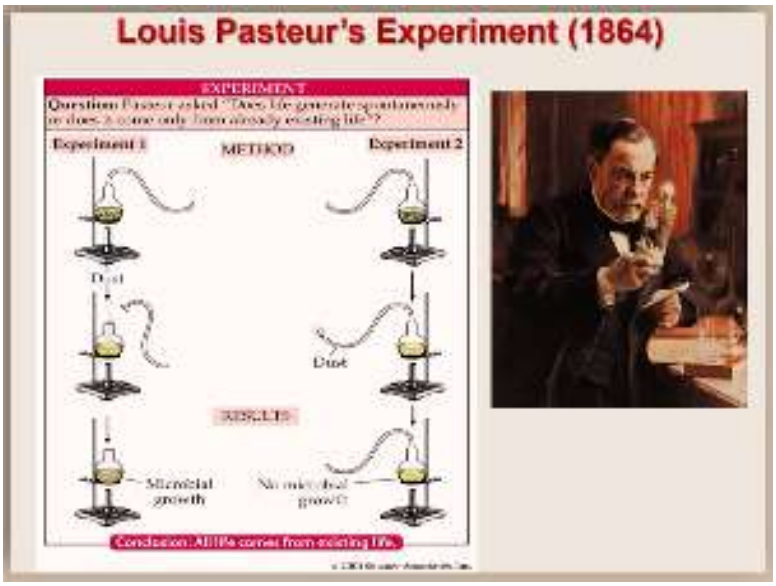

So, they said that whoever resolves this debate can get a price and it has to be through a proper experiment so that people do not doubt it. And that is when Louis Pasteur came into resolving this issue and he asked this question does life generate spontaneously or does it come only from already existing life?

So, he designed two experiments, in one experiment he took some dust and in that dust he ensured that there is air from outside and it is open and in that setup what is the final product. Then he designed another experiment where he basically put the same dust but, he did not allow the air to pass and air to infiltrate this system and then he observed what happens then.

So, because the idea was that does life generate spontaneously it means that if you are thinking about life and if it generates spontaneously it should be able to generate from things which are non-biological. And that is why the dust, so, he set up an experiment where he had these liquid where he was adding dust and eventually checking whether you can see life developing.

And what he found that between the two setup only in one he saw the development of microbial growth and by this time they were equipped with high power microscopes and they can observe things which were very small. So, you could observe microbial growth but that was happening in only the setup where air was allowed to infiltrate and interact with the system.

The other experiment where air was not allowed and only dust was passing to the system it showed no microbial growth. And therefore, he concluded that all life comes from existing life and in this case the existing life was actually coming through the air and if you stop the air to interact with this closed system then it is not going to create any life.

So, this one experiment resolved the long debate about spontaneous generation and people were convinced that it was not the explanation the spontaneous generation was not the explanation of how life first started on the Earth. But, then the question was if this is not the case and especially the conclusion that all life comes from existing life then, how does the first life appear? So, that is a more involved question.

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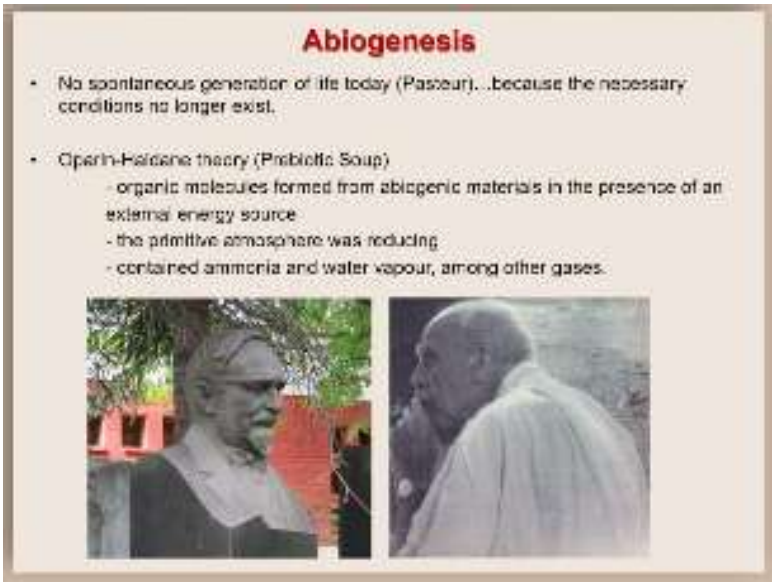

So, because Pastor actually said that no spontaneous generation of life at least today and because the necessary conditions no longer exist. And then various scientists started thinking about how the initial condition could have affected the origin of life. And, this broad idea is often called abiogenesis which basically means that development of life or biology from a biological material.

So, it is not development of life from existing life but it is development of life from non-living material. And pioneering ideas for these abiogenesis was something called Prebiotic Soup Hypothesis. So, this was proposed by two scientists who were working independently and one was Oparin was a Russian chemist and then another one an English biologist statistician Haldane.

So, now this idea is called Oparin-Haldane Theory. What they proposed that things changed or things evolved or things started in terms of life from inorganic molecules from things which are not really existing life. So, in their idea they summarize these major points number one organic molecules formed from a biological material or a biogenic material in the process of an external energy source.

And especially Oparin said that this external energy source could be ultraviolet rays or lightning something of that sort. The second condition that they thought is that the primitive atmosphere was reducing and again this is supporting some of the ideas of Pasteur that the present condition around us is not the same where life originated or where life can could come from.

And this reducing idea is important because Oparin also observed that any molecule especially the biological molecules organic molecules they have a tendency of converting or oxidizing or breaking down very easily if there is enough oxygen.

So, initially it has to be a reducing condition. The third point that he and Haldane both of them thought about was that the initial condition must have contained ammonia water vapour among other gases because these are very important when you think about the development of organic molecule.

So, in their mind it was quite clear that life even at the beginning will consist of these organic molecules certain long chained organic molecules and you have to ensure that those organic molecules are stable and they can form and for that all these conditions are necessary. So, that was their approach and their argument was that that was the initial transition from a biogenic material to organic molecules and the energy source needed for that came from ultraviolet rays or lightning.

But, again it was simply a theory and it was hard to test at that point of time. Increasingly, people also started realizing something about the conditions of the Earth at the point where probably these abiogenesis was taking place.

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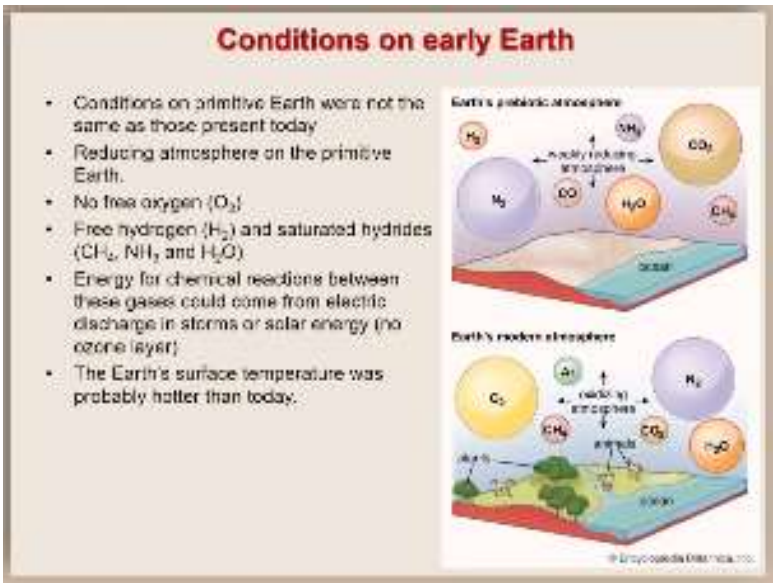

And it clearly shows that the conditions on primitive Earth were not the same as those that we see in the present day. So, one of the major changes is that the atmosphere was reducing on the primitive Earth and now we know much better about it simply because there are rock records which clearly shows us that how the atmospheric conditions were at the primitive Earth.

We also know a bit about it from the observation of far away planets and what would be the condition of the atmosphere if there was no life. So, far away planets or planets without life can work as a good model of how the primitive Earth would have looked like especially in terms of its atmosphere. And that clearly shows us that there could not be any free oxygen at the beginning.

There can be other things for example free hydrogen or saturated hydrides such as methane, ammonia, water vapour these would be abundant. Now, the big question is, what would lead to chemical reactions? Because, chemical reactions require energy. And in the early Earth or primitive Earth the energy for chemical reaction between these gases could come from electric discharge in storms or solar energy.

Because, today if we think about these electric discharge or solar energy solar with many of these are they are shielded by it either by a strong magnetic field of the Earth or more importantly about these electric discharge or ultraviolet rays those are being we are being shielded from those by the Ozone Layer.

Now, Ozone Layer forms only if you have enough oxygen and we at the primitive Earth because there was no free oxygen therefore the ozone layer was not present. As a result, these kind of electric discharge must have been common at that point of time.

The other thing that we know that the Earth's surface temperature was probably hotter than today couple of reasons one was that it was still cooling down the Earth which we are talking about almost 4 billion years ago. And over time Earth has cooled down so that also acts as a point that initially the temperature must have been slightly higher. We are saying slightly higher because the sun's luminosity also changed over time it has gone down.

And therefore, with the balance it must have been slightly hotter not a lot hotter from today especially when we are talking about the already formed crust which means it has cooled down but in comparison to today's crustal level today's surface it was slightly hotter. With all these conditions it makes a very different world to compare with modern day atmosphere and modern day Earth surface.

And therefore, just by looking at modern day Earth surface it is very difficult to predict whether these changes the a-biological molecules to biogenic organic molecules these conversions would take place. It requires a completely different set of experiment.

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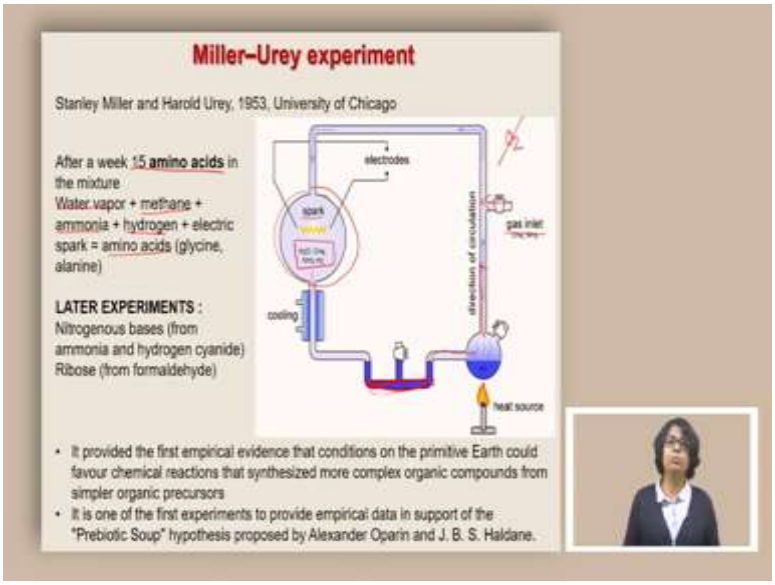

And one of the pioneering experiment came from a group in University of Chicago. From an young PhD student Stanley Miller and an established chemist Harold Urey who was also a Nobel Laureate. Now, the idea was quite simple Stanley Miller's idea was that he will create

a primitive atmosphere and he will also ensure that it gets electric discharge and then he will observe whether it actually can generate any organic molecule.

So, in this setup they started with this part of the experiment where in this particular chamber there is water, methane, ammonia and hydrogen. This is again based on the understanding at that point of time about the composition of the primitive atmosphere.

He also ensured that there are electrodes going through it creating sparks at a regular frequency again mimicking the initial condition of the Earth where it the lightings were much more common and there was no Ozone Layer and therefore this particular chamber does not have any oxygen in it. In fact, this entire system is closed up it is a closed system where there is no oxygen whatsoever and that is extremely important.

Now, what they did they basically had this chamber where there is water, methane, ammonia, hydrogen and it was sparked I mean there was a continuous spark with some regular interval. And then whatever is happening here it gets to cool down and then it passes through this tap and this trap can take some of these things that are getting produced here.

So, primarily some liquid which has water in it and anything that will get produced here will get trapped in this small region but part of it will also go back to the system where there is water and there is heating also.

So, it heats up it will go up because it gets boiled and then it goes through the system. And this process continues for quite some time. This is the gas inlet from which this methane and ammonia are introduced and again as I am saying that this is a fairly closed system so nothing is coming out or going in after the initial setup of the experiment.

So, after a week of this experiment, Stanley Miller observed some interesting things, first of all in the initial experiment where he did not have this trap it was difficult to find anything other than water and this water was constantly circulating and he did not find a major change in the water chemistry. But, then with the trap some of the water was also getting trapped inside and he started collecting materials from here and analysing it.

And what he found that after a week 15 amino acids were found in this mixture and that means that in this system we exactly know what went in and what produced and he concluded that water vapour, methane, ammonia, hydrogen in the presence of electric spark can produce amino acid, glycine, alanine. And these amino acids are very important organic molecules these are one of the most important aspects of life in all life we have these amino acids.

In later sets of experiments, he also could produce things like nitrogenous bases and ribose but, the this is one of those experiments where it clearly demonstrated that even with the primitive condition of the Earth what we know the conditions where it is possible to produce a good number of organic molecules especially the amino acids from completely inorganic or a-biological materials.

Now, what are the some of the caveats of this experiment well the composition of the primitive atmosphere at least at that point of time it was not sure it was not final whether this is the actual composition of the primitive atmosphere.

But, now we know that it is fairly good representation of the primitive atmosphere. And this particular set of experiments provided the first empirical evidence that conditions on the primitive Earth or at least what we understand about the conditions of the primitive Earth could favour chemical reactions that synthesized more complex organic compounds from simple organic precursors.

So, it does not require a completely different mechanism simple reactions that can actually produce things which are organic in nature and clearly in this entire system there is no biological intervention.

So, it is not generating life from existing life this is a closed system where there is no life inside and they have checked for it multiple times before the starting of the experiment that there is no microbial growth there is no life so you are not adding anything from outside. And this is also one of the first experiments to provide empirical data experimental data that supports the Prebiotic Soup Hypothesis proposed by Oparin and Haldane.

Oparin and Haldane’s idea was simply an idea and it is a hypothesis but this provided an experimental proof. So, finally this paper was a revolutionary paper it came out in the scientific journal called science and it was primarily Stanley Miller's paper. But, this set of experiments the future experiments do are known as Miller Euro Experiment.

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So, this showed some of the interesting ideas about how life must have originated in terms of this first conversion of a-biological materials to organic molecules. So, in summary today we learned, what were some of the very basic ideas of how life originated on the Earth about spontaneous generation and how Pasteur experimentally resolved that spontaneous generation is not possible.

We learned about ideas like abiogenesis which was proposed and finally one of the very distinct ideas of abiogenesis called Oparin Haldane Theory which talks about Prebiotic Soup and development of life from inorganic molecules or a-biological materials to complex organic molecules. We also saw how this idea was tested and eventually supported by Urey Miller experiment. These are some of the resources that I used for this particular lecture.

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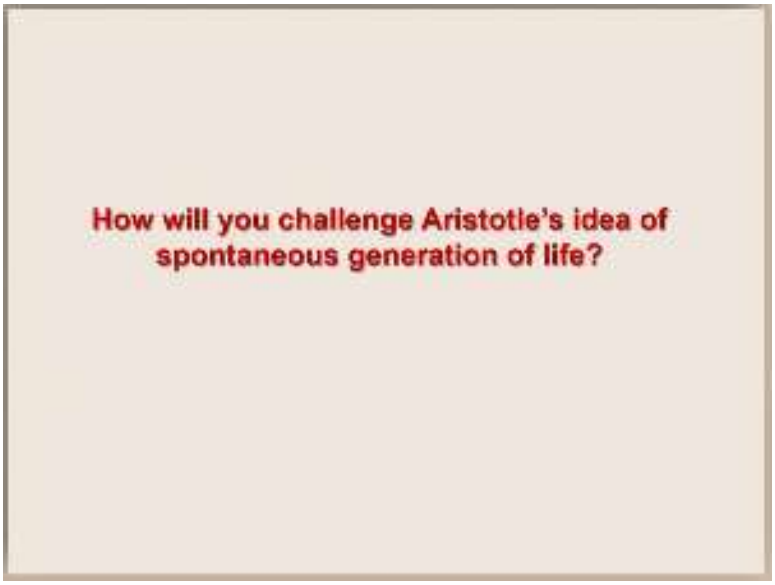

And here is a question for you to think about. Thank you.