Animal Physiology
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Lecture - 21
Origin of Biological Cell

Welcome back to the lecture series in Animal Physiology. So, we have finished 4 weeks. So, today we will be starting our fifth week and we will be starting this week where we left on the fourth week. So, we discussed about the electrical properties and transmission of signals from the muscle cells to the nerve cells and between nerve cells and I told you in the very first week that there are two ways you can classify cells excitable cell and non excitable cells.

So, today we will talk about the genesis or the origin of excitability; how cell become excitable what we call as excitable cell and how it varies from a non excitable cell. So, in order to appreciate what is excitability of a cell or a non excitability we probably have to look at the genesis or the evolution of cell itself it is believed that life is evolved from the water bodies possibly from the ocean or sea or you know this is what that is the current paradigm in evolutionary biology is and possibly when the first cell must have formed very very first cell on earth because the earth initially was nothing, but very very early it does not have any UV; UV covering the weather was really horrendous all over the place there is parks and lightning high temperature.

To imagine it must have been a very catastrophe conditions and under that there were nothing, but inorganic elements forming compounds breaking compounds and all sorts of elemental sigma was going on probably at some point in a distant past a framework of certain inorganic atoms took place which acted as a scaffold to the generation or a self assembly of a first enclosed structure which we today call as cell this is story is mostly based on a speculation and based on life forms which evolve in extreme environments maybe in the sulphur spring or hydrothermal vents or at a very very high altitude with very low oxygen tension and very high temp very low temperature or even people try to mimic the environmental constraints of which exist in marsh they call it Martian environment or Martian Biology.

So, we really do not know how possibly the first cell has arise, but what we can conclude from looking at the present days cell is there are few features which possibly during eighteen hundred it kind of a spread around eighteen hundred the cellular theory was formulated by Rudolf Virchow and all other people where some of the theories which you must been studied in your school Omni cellula e cellula a cell rising from the pre existing cell which essentially means a cell can creates it is own replica from the pre existing one.

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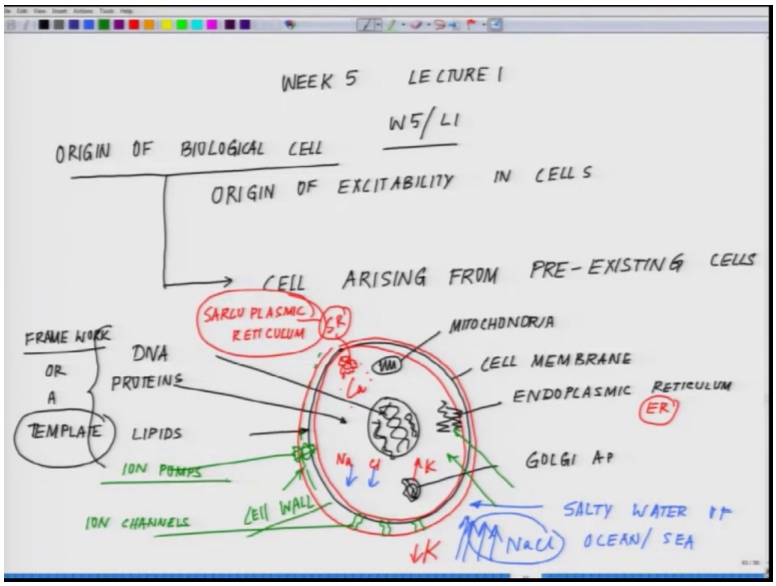

So, to start off with let us formalize whatever we are talking. So, this is we are into week 5 lecture one w 5 slash l one this is where we are. So, what we are dealing now is origin of excitability in cell and before that we are talking about prior to that origin of biological cell it could be anything from bacteria to mammalian cell to plant cell to fungus anything, but the very very first cell which decides that it is one entity which follows the thumb rule cell arising from pre existing cells.

So, I told you that the very first. So, if we wherever we draw a cell we draw it like this of course, now we have already introduced the neurones which have a different kind of you know architecture. So, so this is the mitochondria cell membrane endoplasmic reticulums then you have Golgi apparatus and like this so on and so forth it is very complex

structure. So, the very first thing which may have happened the formation of the cell membrane that hole assembly of phospholipid bilayer which made up the cell how it formed that structure is a completely unknown thing, but it is believed that the very first molecules whether it is DNA or whether it is a series of proteins or even as a matter of fact the lipids they all needed a framework to form.

Framework or a you can call it a scaffold framework or a some kind of a template which is the right answer or a molecular template or an atomic template it is this initial template we have no idea how this template was formed what made the these molecules to self assemble.

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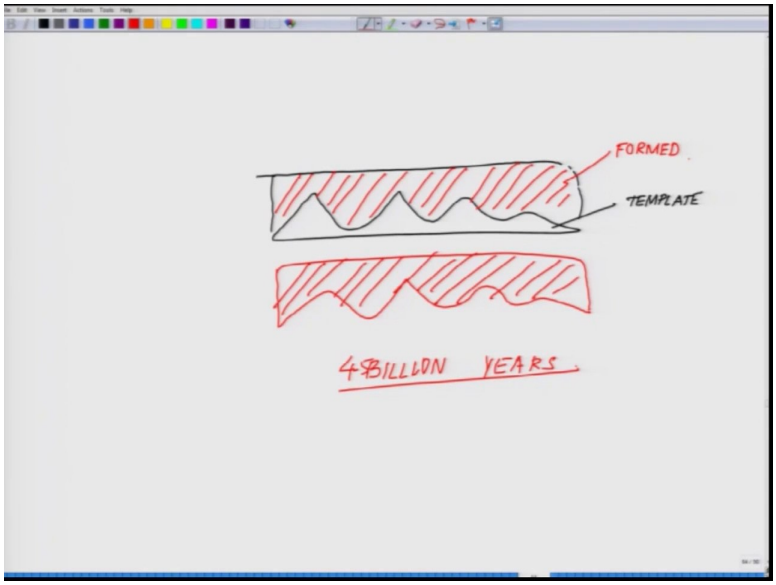

So, it is something like this what I mean to say is that say for example, you must have all of you have seen templates suppose this is a template. So, if you put some jelly like a stuff into it which is fluid then this new stuff will take a shape like this right now as soon as you remove the template. So, what you will you are going to get is something like this one second this is what you are going to get. So, your template was the black one this one was your template and on top of the template this is what has formed. So, exactly same way there must have been certain atomic templates on which these structures may have formed.

Then how in the process they develop the missionary to store this information that they can you know do this act n number of times we do not know where possibly DNA learnt that it has to store the genetic information we do not know these are unanswered question of chemical evolution because prior to the biological evolution there must have happened certain chemical evolution which led to the formation of these kind of template that part is we all are in dark we just have series of a speculation to tell what may have happened possibly these things must have happened at least this is the timeline of past we are trying to recreate 4 billion years or even maybe more it could be even 4 to 5 or 6 whatever you know we are trying to re create a history of atoms and molecules which are 4 to 5 billion years old we do not know really, but what we know now in between there is a complete dark corridor through which we have travelled for which it is really tough unless we can go back in time to figure that out, but what we know is this.

When we talk about a cell like this we realised this cell if assuming that this cell has evolved or this kind of cells and of course, if it is a plant cell then they will they will have another additional membrane which will be the cell wall though I am not getting into those finer details at this stage. So, say for example, if it has evolved in the very salty water of ocean salty water of ocean or sea where the salt concentration is very very high. So, high that you know nothing really could you know grow in that direct contact with it. So, it possibly learnt a way to create an environment around itself in a way by forming a capsule or a structured what we call as cell where this concentration of sodium and chloride out here is really low.

So, in order to do it, it had to create a boundary what in modern days term which is explain by fluid mosaic model dixon jolly followed by fluid mosaic model during nineteen sixties what we called as cell membrane where sodium inside it sodium and chloride concentration is fairly low and it has the high concentration of potassium as compared to high outside potassium one second potassium is low outside and calcium country is high, but there is no free flowing calcium because it has one organelle called s r just like e r stand for endoplasmic reticulum s r stands for sarcoplasmic reticulum sarcoplasmic reticulum SR. So, the calcium is mostly remain in an stored chelated form in the sarcoplasmic reticulum. So, the very first signature for a cell to evolve was the formation of a membrane how that membrane was formed we do not know we have no

clue about it now once this membrane possibly have was formed.

The next criteria for this membrane was; so, now, we have enclosed say for example, the first cell which has formed it has kind of somewhere or other manage the lower sodium concentration inside it, but then there will be always diffusion right the diffusion pressure will ensure that there will be motion of sodium and which will balanced it out, but it is at that time there is another unknown story evolved it develop structures what in modern days biology we call them as ion channels and it develop something even more interesting what we call ion pumps or you can just call it pumps.

So, in other word it form a house with a pump by chance from surrounding water gaseous then it has a pump to throw away that water it is exactly the similar analogy happened here, but now here is again something unknown how this evolved who told that to evolved like that who decided the structure of the channels will be like that well we do not know these answers, but what we know today now coming to with giving you this 4.5 billion in last ten minutes what we know today is our cells have say for example, if this is the cell.

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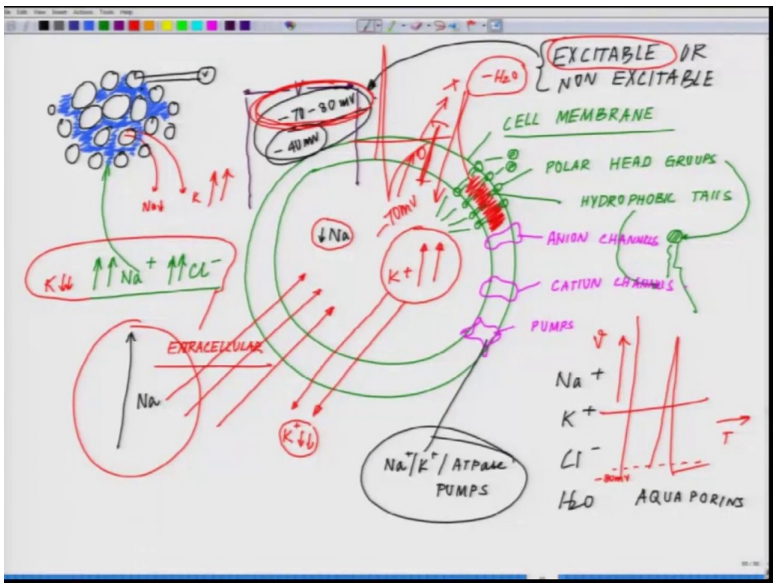

Now I am talking about the animal cells only is. So, I am not taking into account the cell wall I am just talking about the cell membrane if this is the cell membrane the first level

of self assembly forming a define definitive structure by the self assembly of the advanced organic molecules it is like this right all of you have studied that some point or other it is a lipid bi-layer having the polar head groups of lipids.

Polar head groups and hydrophobic tail; So, each lipid molecule is something like this, this is the polar head group and this is the hydrophobic tail and when the self assemble in order to minimize its surface energy all the polar head groups phases either outside or inside. So, all these are polar head groups they can interact with water out here the polar head groups the whereas, this part what you see what I am shading in red now this part is extremely water heating in other word it is a hydrophobic region now on this membrane are embedded certain unique structures like this some of them are pumps cation channels anion channels major channels which will be concerning here will be sodium channel potassium channel and as well go further while we will talk about disease like cystic fibrosis and everything we will talk about chloride channels there are water channels which are called aqua porins.

Then we have this pumps at this point will be dealing of course, as we have move to kidney and other places kidney digestive system we will talk about other kind of pumps we will be talking about sodium potassium atpase pumps. So, earlier to this I told you that inside the cell sodium is low as compared to outside has a matter of fact our whole body if we can considered our body like this these are the cells which are forming the structure between the cells there is extracellular fluid. So, the extracellular fluid is here where I am shading with blue right this region of extracellular fluid if you have a siphon or if you have some way to you know remove the extracellular fluid if you have some kind of some needle or something right and you can pull out the extracellular fluid like this then you will observe the concentration of extracellular fluid is almost similar to that of the sea water it has very high sodium very high chloride anion and the cations whereas, has compared to the sodium inside you will see sodium is low, but potassium is fairly high.

So this is extra cellular. So, all our cells in the body are bathed. So, if you look here. So, all the cells which are forming this structure of my hand or this they are all bathed in high sodium concentration which is the reason while sometime we are given saline or

something you know we lose body fluid or something. So, all our cells are bathing in a similar condition as that of seawater, but inside the cell the story is different inside the sodium is low that brings us to a very interesting paradigm what is that paradigm. So, inside I told you the sodium is low and outside I told you sodium is high. So, automatically by the diffusion process this outside sodium should try to move inside like this and similarly inside the potassium is very high I am not giving the values I will give you in the next class purposefully, but at this point try to understand the basics by the logic this potassium which is inside should prefer to come outside because by the gradient potassium is at a much more higher gradient potential these circles tells you who is having higher concentration.

Right, but having said this brings us to another aspect of it I talked to you about the chemical potential, but there is a charge aspect to it. So, before I get to the charge aspect there is one interesting thing which I needed to point out if you take an electrode and place an electrode inside the cell and there is an electrode you left outside very close to this cell of course, and you take a voltmeter and measure the voltage across the membrane in other word you are measuring the voltage across the cell membrane.

So, inside the cell membrane versus outside the cell membrane it has been observed for all the cells of your body I told you that all your cells are bathing in extracellular fluid like this right now out here what I am asking you put an electrode here you place an electrode here and you measure the voltage across it you will observe with respect to the inside the cell with respect to inside the cell outside is more positive with respect to inside outside is more more more positive. So, it means out here that what will you observe is inside with respect to the outside the voltage is inside is around minus 70 to minus 80 millivolt there are few cells which all the ways goes up to minus 40 I will come later about those at this point just remember, but this is not absolute fact that it is minus 70 to minus 80 there are cells which are at minus 40 also, but this is what was observed all the cells irrespective of the fact whether they are excitable cells or they are non excitable cells whether they are excitable or non excitable.

All these cells maintain a cell membrane voltage across inside to outside at minus 70 to minus 80 bearing a side few cells which are called the pacemaker cells when the cardiac

system as well as some of them are sitting in other places of the nervous system with its at minus 40 millivolt irrespective of anything, but then what is this excitability non excitability now while closing on the class today I will give you one small clue excitable cells are the ones excitable cells are the ones. So, this is the one I am talking about excitable cells are the ones where this from this value all of us sudden it fluctuates like this from minus 70 to minus 80 millivolt it fluctuates to positive more than 0 and comes back very transiently as if all of a sudden there is a breakdown in the cell voltage there is a load shedding there is a breakdown all of a sudden this whole across this membrane this becomes 0 from minus 70 millivolt becomes 0 and little more than 0 even much more positive and it comes back.

So, what you see on a scale if you plot the voltage on the y axis and the time on the x axis and if the cell is sitting at minus 80 millivolt all of a sudden you see something like this and this is the classic characteristics of an excitable cell of your body. So, it means this feature is shown by the all the neurons all the muscle cell muscle tissue all the cardiac tissue all the smooth muscle tissue and the neuroendocrine cells this is the signature and that distinguishes excitable cell from the non excitable cell non excitable cell remain the status QO of maintaining minus 70 to minus 80 all throughout their existence they do not change unless otherwise you will come later into that how a non excisable cell, cell can become excitable what is the genesis how it can become and actually that is where lies some of our very fundamental questions about stem cell biology the way the field is moving especially neural; neural engineering and muscle tissue engineering and all that stuff.

But next question is that if excitable cells are the ones where all of a sudden it shoots a spike that the membrane potential what we call as minus 70 minus 80 is the membrane potential it is the membrane it the potential across the membrane if that changes. So, sharply how or what are the players not how comes next what are the players who can make that happen and under what conditions such things happen. So, I will close in here.

So, we are closing on the very first class of the fifth week. So, in the next class we will talk about how this spiking happens and that will introduce us formally to the world of action potentials because this action of coming from minus 80 going all the way to over

shoot 0 and comes back is called an action potential and that will take us to the study of Hodgkin Huxley coal and all those other people even Sherrington the discover of synapses and all that.

Thank you.