Animal Physiology
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Lecture – 23
Ion Transportation in Cell

Welcome back to the lecture series in Physiology. So, we finished this second lecture of the fifth week, and by this time the whole process of action potential or at least the way the streaming a positive charges are taking place is kind of clarity.

Now, today what we will do, we will assign the ions which are fluxing in and fluxing out and what sequence. So, discovery of the process of action potential dates back to the earlier part of 19 century or even the fag end of 18 century, where these observations were made by some absolutely I am patient and extraordinary league of pathologist. But in order to explain this kind of certain changes of membrane potential in specifically certain kind of cells and our real understanding or the current understanding a meson real understanding, because we keep on understanding this process is.

It took us almost 100 years, it was during 1940s 30s for the first time especially just before the second world war and kind of progress got delayed because of the war, it was the credit for first time formalizing it was known, but really to formalizing it mathematically goes to Hodgkin and Huxley they were the very first one. Who kind of developed mathematical model based on the findings of the action potentials, and I could see the action potential on a big nerves you know see slug (Refer Time: 02:30) because they have a really big axon, they could really broke the electrode they could repeat the our experiments, and they came with a mathematical model of the observations what the made and what we have already drawn in last previous two classes the exact nature of the action potential where from minus 8 milivolt all of us sudden which shoots up goes above 0.

So, it means from a polarized state a cell goes to a depolarize state, and it goes to positively polarized state because it is over shoots the 0. And it again comes back to it is polarized state, but before really merging with it is polarizer state negatively polarizer state at minus 80, it hyper polarizes negatively further and then it comes back. And we have also discussed in the previous class the slope of falling down of post positive

polarization varies from cell type to cell type, and that slope is kind of a characteristic of the dynamics or the motion of different kind of ions which are taking place. So, before I put it down in the presentation sheet, let me give you verbally what is happening what we know in last 100 years. The first thing what happens is because of some impulse which a cell receives and neuron receives.

Some of the positively charge gates; so ourselves consists of lot of gates some gates before it let me tell you the gates some gates open outside the cell, some gates open inside the cell and most of these gates behave like diodes; in other word when you talk about diodes we talked about current flowing in one direction. So, these diodes what we are bringing the analogy of diodes these gates either will allow something from inside the cell to go out or we will allow something from outside to go in. So, these gates are called could be mostly they are voltage gated or ligand gated, I have introduced two more terms. So, let me just start putting them down. So, today we are into week 5, lecture 3.

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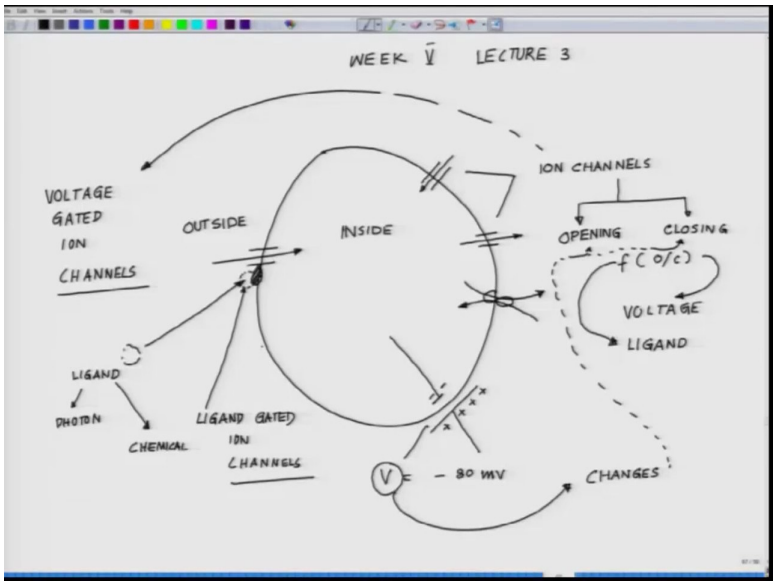

So, what I told you is if this is the cell then you have these gates or gates like this which will you allow. You have pumps sitting out there which could pump a specific kind of ion side outside and pull in another kind of ion ions inside, and most of these gates are called ion channels or ionic gates you can call them for your better understanding, and most of these ion channels opening and closing is not random; opening and closing is a

function of voltage across the membrane or sometimes they are governed by some ligands what does this two words means. These two word means at and specific voltage at a specific voltage. So, say for example we know with respect to inside outside is more positive.

So, you can represent it as a battery right. So, this is the negative and this is how the membrane looks like. So, if you measure the voltage across it which we know is sitting and minus 80 millivolt, sometime minus 70, minus 42 minus 80 millivolt. Now if this voltage across it changes then this change across it could lead to the opening or closing of some of these ion channels, that is why we call them the word turn out to be voltage gated ion channels.

Similarly at times there are some ligands; ligands means something which comes and binds to the cell binds to on the surface of the cell, upon binding of certain things these channel gets open or close. So, say for example, suppose here we have a channel like this, which is suppose to allow the ion ionic flux to move from outside to inside and this is your outside the cell, and this is inside the cell something is suppose to say for example,. So, it has it close proximity there will be some ligand gatings.

So, say for example, this is where the ligand or something will come and bind this is that molecules. So, as soon as this molecule comes and binds to this side, this channel open and these kind of channels which are function of binding of some x y z ligands, and this ligand could be anything and everything; it could be a photon, even it could be a photon it could be some chemical.

So, these kinds of channels are called ligand gated because it is the ligand binding which leads to the opening and closing of the channel. Ligand gated ion channels and voltage gated ion channels. So, when action potential is generated what possibly happens in the beginning, ligand possibly comes I am talking in the in the sense re structures will come later into the central nerve system there will talk there a few other modifications which takes place. Certain ligand comes and binds and it opens up certain invert cation channels, what does that mean? That means, you cations which are positively charged right and ions which are negatively charged.

Now, suppose I am the imagine myself as the whole single cell, now it is a ligand comes and bind here as soon as the ligand comes and bind here it opens up certain channels

which will open or which will allow from outside something to get inside the cell and it will only allow the positive charges to get inside the cell. So, upon line ligand binding if the positively charges I will entering inside the cell what will happen? Your cell is sitting at minus 80 millevolt. So, automatically your membrane voltage is going to become slightly more positive; may be from minus 80 it may go up to say you know minus 75 or minus 70 or may be minus 60 or may be minus 30 or 40.

Now here is the catch if because of the binding of a ligand or some other means inside across the cell becomes positive up to a threshold point, and that threshold varies it is around you know minus 40 or minus 30 minus 30 if it reaches all the way up to minus 40, then that leads to the opening of all other cation channels and the biggest number of cation channels cation channels which allows let me clarified the cation channels which allows ions to move from outside to inside, and the large number of cation channels or the maximum cation channels are the sodium channels.

In other word that will allow the sodium flux to get inside the cell. So, in order to achieve this, what is happening what all I told you now?

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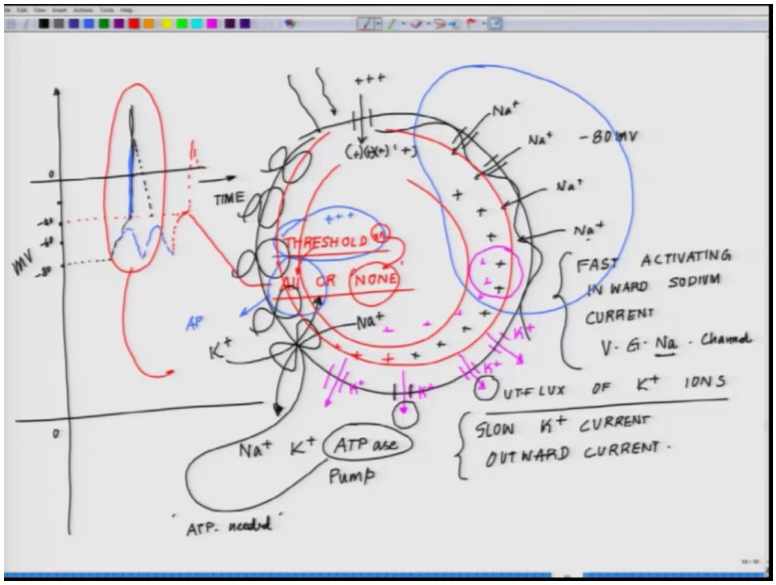

So, here is the cell sitting at minus 80 millivolt; let me this is the 0, this is the 0. So, cell is. So, here and this is telling a millivolt and this is giving at the time in millisecond. So, cell is sitting at say this is minus 20, minus 40, minus 60, minus 80, cell is sitting here. Now I impulse comes something some ligan binds or something happens which opens up

cation channels positive charges is started fluxing in. If the positive charges fluxing in, what will happen? The membrane potential will shift like this right agreeing with me because inside it is minus 80 now you are getting positive charges coming in. So, automatically this will change it but say for example, this is minus 60 minus 40.

Suppose it all the way reaches something here then something amazing happens at this stage, all other channels all other sodium channels which only allows the sodium ion from outside to get inside opens up in a cascade, it is almost like a wave or a cascade which happens; and then what you see there is a overshoot at this point like this because the inside become two, two, two positive there are too many positives which comes in. So, that too many positive let us say to the overshooting inside. So, the first event what you see is what you have to mark is this line which I am now putting somewhere around here this is that threshold level if the threshold level is not reached action potential will not be shoot.

So, you could have change you could see something like this, and it will change and it will fall back it will be change it will fall back ha, but if it reaches this threshold suppose it out here it reaches this threshold then there is no stopping it will shoot up. So, this is that threshold point where there is something or all or none theory comes into play. Either it will happen all of them will open up or none of them will open up unless you reach the threshold.

So, there is a threshold for an action potential and if it reaches the threshold this leads to something called all and if it does not reaches the threshold then it is none. If it reaches and if it does not reaches if it does not reaches the threshold it is none if it reaches the threshold it will be all these positives will open. So, once all these positives will open inside it will be all positive now.

Now, there are two kind of positive charges inside; you have a huge flux of sodium and you have a huge flux of potassium inside, and now what happens there are another set of cation channels now I am representing them my pink, which allows a specific kind of cations or positively charge ions to only to move outside the cell. Those are potassium channels voltage gated potassium channels. So, what happens now there are too many positive charges inside, so there are positive positive repulsion which happens between the charges. There is a mutual repulsion there are too many positives that further this

inside that going all the way to a positive level opens up, the voltage gated potassium channels. So, based on the motion or direction of the movement based on the vector of the ionic flux there are names to this. So, the first name for the sodium channels voltage gated sodium channel is fast activating inward sodium current, which is governed by V stand for voltage gated N a for sodium channel fast activating inward.

Why it is called fast activating because if you follow this line see the rises very fast it is really really fast like zup it moves in. Contrary to it if you see the slope of it is coming down it is much more slower, and that coming part of that coming down is because of this out flux these out flux of potassium ions; this out flux of potassium ions is called slow potassium current is an outward current why it is called current; because outward because the flux of ion.

So, electricity could be defined by two ways either it will be a flux of electrons or flux of ions. So, the flux of electrons constitute the solid state electronics whereas, flux of ions constitute the ionic electronics and based on that there are whole sets of devices electrochemical cell which is an ionic device whereas, a semiconductor it is a solid state electronic device fine.

All your battery is these are all ionic devices these are all ionic phenomena, which is weight phenomena because Zeology indented medium for this ions to travel these are bulky molecule bulky structures which has to travel. So, these this is called slow activating potassium current potassium outward current governed by these potassium channels. So, now, once the potassium goes out sodium gets in now of course, the membrane can come back comes back to it is original state, but a cells homeostasis is different, it stays at a very low sodium concentration then comes into play third player into the game, and that player is a pump. A pump which is now I will introduce the pump here these pumps have a very unique way of throwing sodium from inside and pulling potassium from outside. These pumps are called sodium potassium ATPase pump.

This ATP is basically the ATP needed there where the ATP is being utilize they are energy dependent process. So, first if I had to summarize first cell has to reach it is threshold which is I am marking it in blue threshold. Once it reaches is threshold and suppose action potential is targeted what you observe is this threshold has to be because of some cation movement inside the cell, then the full family of sodium channels will

open and you will be recording a very sharp sodium current here fast activating inward sodium current governed by voltage gated sodium channels right.

After this followed by this inside their will be too many positive charges right, this too many positive charges will be colliding with each other there will be huge amount of repulsion. At that stage of membrane potential the potassium channels which are present there, which only allows ions from outside to from inside to move outside. So, they open outward. So, any potassium will be moving out they opens up and once they open up the potassium and goes out right. Potassium ion goes out now the inside the cell they have higher concentration of sodium and lower concentration of potassium.

Now the cell has to restore it is ionic homeostasis voltage homeostasis is not a problem ionic homeostasis is now is in a question. In order to restore it ionic homeostasis third set of molecules sitting on the membrane surface comes into play which is called sodium potassium ATPase pumps this sodium potassium ATPase pump their role is it is energy dependent ATP dependent pump which take sodium it will take three ions of sodium from inside and it will throw it outside. So, there are different configuration and it will take another few potassium from other side from outside and it will through it inside it is something like this a motion happen like this.

So, at one point of time it throws away more sodium as with respect to charge because it has to throw away a huge amount of sodium outside; so there as series of such pumps which comes into play like this. So, because of this the homeostasis is maintained. So, within this fraction of a moment what you see and action potential out here, a single action potential all these things are happening. So, all these things are happening in some micro seconds milliseconds domain, micro to milliseconds domain all these things are happening; that is why you considered as cell as one small machine which is doing all these things.

Now, what happens whenever such an action potential is generated, so within the cell it propagates like this. Now, you have to realize this action potential say for example, I talk about and action potential.

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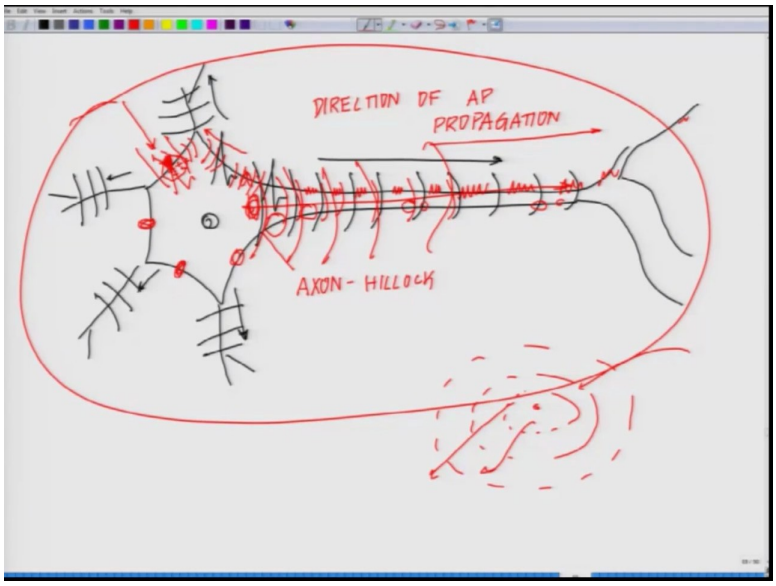

Let us take a typical neuron, now most of the action potentials are generated. I said most because there are exceptions here and there are generated here it is a local event, mark my word it is a local event these action potentials travel because this disturbances travel like this it is not the whole cell at one point becomes like this. So, they could travel like this they could even travel like this reverse direction; they could travel like this they could travel like this and they can even travel like this.

This travelling does not happen significantly they do travel certain degree on these directions towards the dendritic trees, but they are not significant. Why they are not significant because your higher concentration of sodium channels are sitting on these locations at the axon hillock, if you remember when I showed you the anatomy axon hillock.

So, that is why the predominant motion of these disturbances likes this. So, here well I am almost about to close this class let me tell you at direction of action potential is direction of action potential propagation is along the axon, but mind it does not rule out that it cannot travel in the reverse direction, but that travel is not really significant.

One more thing when I told you it is action potential, is a local phenomenon. So, what happens suppose something comes and binds here? So, this part becomes all of a sudden become positive once this become positive there is an this electrical impulse get generated then this makes this part positive then this makes this part positive then this

makes this part positive, then this makes this part positive likewise there is a way front just like suppose you through a stone in there in the pond you see a wave front spreads like this outward the precisely what happens in an action potential, then this part get activated ,but if it starts with that all or none then this will spread like this, and then something happens at this end which will come in the next class what happens there. So, remember generation of action potential is a local event, it does not happen all across the whole cell it does not happen one point of time, at particular point of time it starts at some point it could be here it could be here it could be here it could be here it could be here, but then it travels then this disturbance spread out like this just like happens when you throw a stone in the point it spreads like you see the wave fronts it is just like a wave front is spreads out and once it is spreads out.

So, say for example, if this is say for example, your axon. So, disturbances originate here this part become positive fine, then this part get restored then this part become positive, then this part become positive, then this part become positive, then this this this. So, there is a way which is moving like this right.

So, you see there is a wave, wave front moving like this and that is precisely what happens in an action potential. It is not the whole thing become positive in one short as in cell will pretty much will die out because it does not have an that much energy to with stand it is sets spot by spot it moves, and this whole thing happens in some microseconds milliseconds, this is all a millisecond process. So, at every location such thing happens.

Now, after giving you this free background about action potential, and this whole process can be mathematically explained and this change if you read through Hodgkin Huxley's work an always one more thing I want it to project Hodgkin Huxley did not know the existence of ion channels, which is protected this is a possibility of these kind of ion channels.

With this I will close and will have more stories; in the next class the story of action potential one of the most fascinating stories of last century where we come to know about lot of things about neurobiology. And we will continue with next to will be the new transmitter and little bit more about Hodgkin Huxley.

Thank you.