Animal Physiology
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Lecture - 22
Excitability in Cell

Welcome back to the lecture series in animal physiology. So, we are into the fifth week and we have done with the first class where we talked about the overall idea of excitability and I told you that most of the cells in our body have a membrane potential of around minus 80 millivolt minus 70 minus 80 millivolt varying a site from cells which are sitting at minus 40 millivolt and with respect to outside the inside is more negative ok.

So, in other word there are more negatively charged species inside the cell as compared to outside and further we highlighted the fact that outside the cell if you remember the slide that what we talked or what we do?

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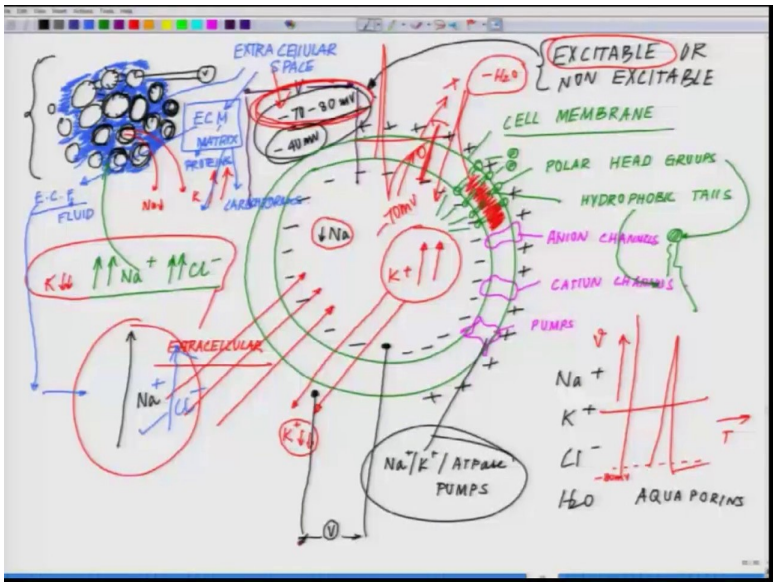

If you just let us go to the slide if you remember this slide from the last class. So, if you follow the slide this is how it looks like all those blue color spaces what you see between the cells look I am trying to again further extend that drawing. So, these circles which are here right these circles are the individual cells forming a tissue like mass and in between these a structures is that blue shades and that blue shading is nothing, but extra cellular

matrix and extra cellular fluid is accompanied in that. So, each one of these different cells are kind of you know different receptors they are cross talking with each other it is kind of a colony in between the colony you just imagine that there is a small like you know road like thing or kind of connector like thing which are filled with fluid and different other extra cellular matrix proteins.

So, this is what we call as extra cellular space containing extras I am just putting extra cellular matrix here this EC stands for extra cellular M is stand for matrix and extra cellular matrix contain extra cellular fluid ECFF is stands for fluid. So, we have extra cellular space which has extra cellular matrix which is composed of proteins and carbohydrates mostly and few other different molecules and that extra cellular matrix contains the ECF and ECF is as I have mentioned here is has a large proportion of sodium and a large proportion of chloride which is at higher concentration c l minus n a plus and few other positively charge ions.

Outside this thing if you put, if you remember we put a voltmeter across this membrane like this is one probe of the voltmeter this the other probe the voltmeter and across this we are measuring the voltage what we found out is with respect to inside to outside or with respect to outside to inside is more negative. So, now this minus signs are showing what I meant by that and with respect to outside is more positive right.

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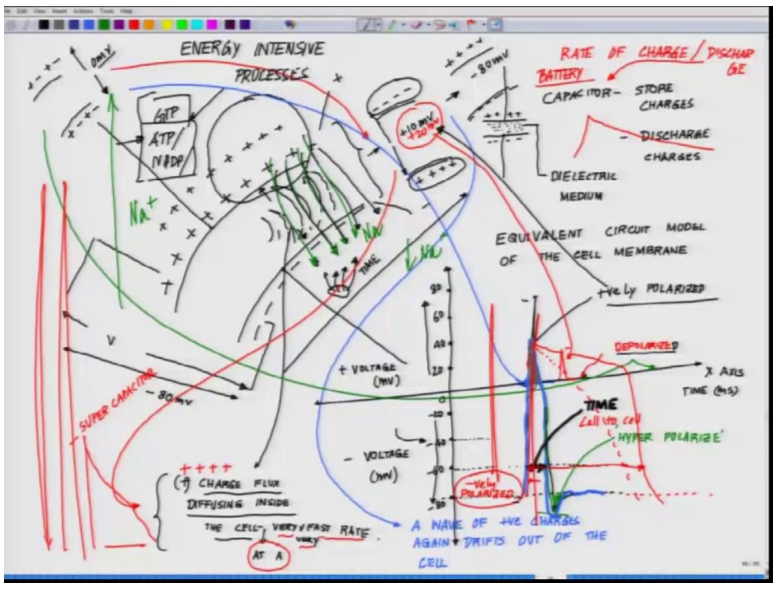

Now, if you see membrane as such than it looks like a part of the membrane will be something like this positive these are the positive charges outside and here you are having the negative charges and now if you show this picture to any person with basic knowledge of electricity and electronic devices or whatever you have studied in class 8 class 9, class 10 class 11 and 12 this structure is very similar to the component like this which is called a capacitor and capacitor is a devices which could store charges which is store charges and capacitor can store charges as well as it can discharge the charges and in between the capacitor out here the region where I am putting the dots it is filled with dielectric medium dielectric medium and it attends charges like this very similar to it. So, all membrane the closest analogy of our membrane is it is like a capacitor across its membrane it can store charges.

So, now if you go back to the previous diagram, so, each one of these individual cells you can treat them as capacitor membranes. So, historically what was observed at one point of time say for example, now I just treated like and when a membrane is treated as component of electrical circuit this is called a equivalent circuit model of the membranes called equivalent circuit model of the cell membrane fine.

Now there was something which was very interesting which was observed, the observation was this if across this membrane so, we told you across this membrane all the cells are sitting at with respect to inside is negative they are sitting at minus 80 millivolt. So, if your y axes on this drawing if I put the y axes like this. So, if this is your voltage negative voltage and out here is the positive voltage and here you have the origin which is 0 and most of the cells if this is 20, this is 40, 60, this is 80 and these are all plus and voltage is in millivolt 20, 40 60, 80 and the negative side minus 20 minus 40 minus 60 minus 80 these are all again millivolt fine.

Now, most of the cells have their rest in membrane potential or RMP sitting here sitting here or some of them sitting here and if there are which sits here we will talk about this these kind of cells which are sitting at minus 40 later at this point we only talk about the cells which are sitting at minus 60 or minus 80 millivolt. So, this if you across this membrane if you place a voltmeter this is what you are going to measure they are sitting at minus 80 millivolt or minus 60 millivolt, but it was observed at a certain points while recording there was something which was very very unusual in other word what they

observed was all of a sudden from sitting from minus 80 this shoots up like this and it further goes down this is just a simple recording across the membrane of a cell.

So, what people observe that all of a sudden and of course, this x axes is your time axes with respect to time it is millisecond mostly now there is the voltage of the membrane across the cell some cells all of a sudden shoots a an electrical activity which almost reaches 0 and then over shoots the 0 and comes back to its ground state, but then it further went down. So, here just before I get further. So, cells remained is called remain in a polarized state this is a word which you will come across in a neurobiological text or neurophysiology text the cells are polarized; that means, that there is a polarity across the cell and I think after looking at this diagram it is clear why it is state the cells are polarized because there is polarity across it. So, one pole is positive pole the other pole is negative pole fine that is why the cells are considered as the polar object out there.

So these polar objects all of a sudden gets depolarized this is the depolarized state where all of a sudden their polarization is being removed they became depolarized and not only that they become depolarized they further go up became positive they change their polarity for a while because going up like this means what is happening all of a sudden this membrane is behaving a part of the membrane and this membrane is behaving with respect to time here if I draw it like this with respect to time at a certain point this is becoming like this right am I right because at this state when you are measuring out here look at it out here when you are measuring you are saying with respect to in outside the inside is negative and you measure minus 80 millivolt right.

Then at same unit point you see across it when you measuring this becomes say plus 10 millivolt it means the inside with the same priority the inside becomes more positive as compared to the outside the outside transiently become negative that can only happen only can happen if for a very transient period of time for a very transient now mark my words very carefully for a very transient period of time from this c of positively charged carriers a huge population of positively charged carrier drift on this side very transiently or there is another option inside this there are some structure which stores. So, many positive charge that all of a sudden all those positive charge comes out, but there is no such structure there is one structure that is the very small structure even if it gives out all it all of it is not going to really make the whole membrane positive.

So, only other likely option in this game is this huge amount of positive charges like a wave I am drawing the wave for you guys to you know kind of remember like a wave kind of comes inside and that comes at a very. So, a positive charge flux drifting a defusing inside the cell very fast why it is very fast the reason why it is very fast is here if you follow this drawing I am shading a part like look at this one second let me look at this the period of time is this is the only period of time in which you have to half that period because it is half when it is coming down. So, in other word what does that mean let me put a dotted line? So, this is the only part when it was positive rest it is coming down.

So, there is a positive charge flux diffusing inside the cell at a very very let me add one more very fast rate as if all of a sudden lot of positive charge is zoomed inside it right all of a sudden with flux in just like the wave they came home inside it and so much. So, for a very transient period of time the inside of the membrane become over to way to positive, but the very next movement as it the cell sends that I have too all of a sudden my whole thing went like you know everywhere all of a sudden I became positive and I am not supposed to re-positive am supposed to be negative a very next movement they as if they. So, the next thing what do you see next thing if I have to draw is it comes back to this situation so, original situation of minus 80 millivolt.

So, it means that those huge number of positive charge is which enter there this was correlating with this diagram at here and the third in between something happen which I am showing in blue now out here what is happening a wave of positive charges again drifts out of the cell. So, first what we have observe positive charges out here positive charges flux defuse inside the cell and it happen at a very very fast rate within a very small span of time which is shown here so, much. So, is become plus 10 or plus 20 or whatever you know of course, diagram it to all the waves to up it generally does not happen it kind of shoots half of this because I did not draw it with scale. So, generally the it is shows a something like this most of the time.

So, this is the kind of shooting up we are talking about it becomes the cell all of a sudden become. So, if this is the polarized state of cell then this is your depolarized state of cell where. So, in between a situation comes before this one is arrive the situation comes where possibly while moving through which is this zone of the curve where across the

membrane positive negative positive negative positive negative positive negative. So, if you put a voltmeter across it, it becomes 0 millivolt.

So, there are equal amount of charges in between the membrane or across the membrane I am sorry across the membrane. So, for a transient period of time the whole membrane becomes depolarized and then it becomes altered it becomes positively polarized right again per transient period of time which is shown by this situation and out here what you see is the depolarized state where it reaches the 0 then the system again falls back to its ground state and it further over shoots the depolarized state out here.

If you look at it went will l u minus a t this zone is as if inside it has become way more negative more negative than normal for again for very transient period of time this zone is called hyper polarized. So, for your understanding we can put it like that initially the membrane always sets at negatively polarizes state of course, when we say negatively polarizes the state what we meant by that is inside is negative as compared to outside this just an axiom as how we explain something with respect to something we always have to have a comparison or a update of like you know a reference point a reference data. So, this is the reference. So, with this respect this is like this. So, that is how we explain it

So, you can for your understanding you can kind of visualize it as the membrane is negatively polarizes the state most all the time all our cells are at negatively polarizes state, but some cells if you remember the previous slide some cells which are called the excitable cells behave differently as compared to their counterpart which are non excitable cells non excitable cells all their life time maintained this value minus 80 where I scanter to this excitable cells very transiently changes their polarity they first became depolarized here is the depolarized followed by that they become positively polarized and then they again comeback like this and then they become hyper polarize negatively hyper polarized and then come backs to their grounds state.

Now this distance what you have observed of going up and coming down this gap this gap or this time varies between cell to cell; cell to cell there will be action potentials what will be dealing later while we will talk about the cardiac system you may see this gap even goes further like this in a other word the way it is falling will be something like this or you will be have cells where it may go even further up where you will see something like this or you will have cells where you see things down further like this.

So, almost what you see is something like this almost something like this almost. So, this going up and falling down is something which tells a story what it tells it tells the story that what is the rate? Rate of charge discharge and this word I am using rate of charge and discharge from the point of view of the capacitor if we treat it as capacitor is the rate at which this charging and discharging happens.

So, if from a leaven prospective think of it if it charges fast yet it can hold the charge for be long period of time to discharge that is something that we see in structures like battery or a cell right where it charge it and prolongs over a period of time you can use that it a triple a cell or double a cell or likewise for a prolong period of time on the country there a devices there are charge storage systems where like you know they charge very high and they discharge very fast something like this charge discharge those are something like super capacitors. So, exactly on the same way and yet there are some which pure capacitors where they charge and discharge at a certain rate. So, based on these charge discharge properties one can classify the membranes what will be their charge storage ability and that in a way tells in order to bring out such an act which is a very always remember these are exceptionally these kind of motions are exceptionally motion or flux of ion is energy intensive processes and all these energy intensive processes requires large amount of ATP molecules NEDP molecules you know these are the energy currencies you know ATP GTP and all those thing which are needed out here

One mostly off course we will be talking about ATP is Adios Tray Phosphate where every time one phosphorous group is attached from three phosphate. So, it liberates a huge amount of energy. So, all these processes are amazingly energy intensive processes and depending on the charge discharge rate one can get a fair idea about how much energy will be consumed while this particular cell type or that particular cell type is undergoing this charge discharge process. So, now, while we are at that fag end up the class it brings us to some very interesting aspects it means the first thing what we learn today is there is a huge amount of flux of positively charge ion inside when the accentual potential is happening and if you look at outside which is dominated by sodium positively charged sodium ions.

So, most likelihood most likely you did not all likely good the only element or in ion which can come inside the cell transiently will be sodium will come I mean just we are kind of developing the story in a systematic way further then what we observed is that

there is a large amount of positively charged ions which goes out are those sodium or are those something else and how a cell restore its balance over a period of time that where all the time it has very very low sodium inside as compare to very high sodium inside.

So, in the next class we will talk about what dictate this sodium flux and what is the next ion which goes out and how this whole balance is being restored in a cell. So, with this I will closing today's lecture idea is to go slowly and to give you a very clear understanding about the events which happens in the excitable cell if these fundamentals are once clear in your brain then you can develop the story I have full faith on whether you can develop the story on your own.

Thank you.