Bioelectricity
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Lecture – 24

Welcome back to the lecture series on Bioelectricity. So, this will be the twenty fourth lectures, what I will be delegating delivering to you. So as of now, we have talked in depth about bioelectrical phenomena in the animal world, we talked about action potentials, we talked about the stretch reflex arc, ion channels, patch clam measurements, microelectrode arrays, developing circuits. Then we talked about spinal cord injuries, special sensors like eyes, ears, nose, olfaction, gestation then we talked about memory acquisition, different diseases involved in memory acquisition process spinal cord injuries and so on and so forth.

So in animal bioelectricity, especially in the nervous system, I have left out some very few small techniques, which are not very regularly used, but it is good to know about the power of some of these techniques. So, this lecture will be those small bits and pieces of different techniques, which could be utilized. And apart from it, I will be highlighting two aspect of at the because that is a very complex network. So, there are certain aspects of inhibitory and excitatory circuits which I will be kind of highlighting in this talk, and how this kind of network behavior kind of you know regulate all those things.

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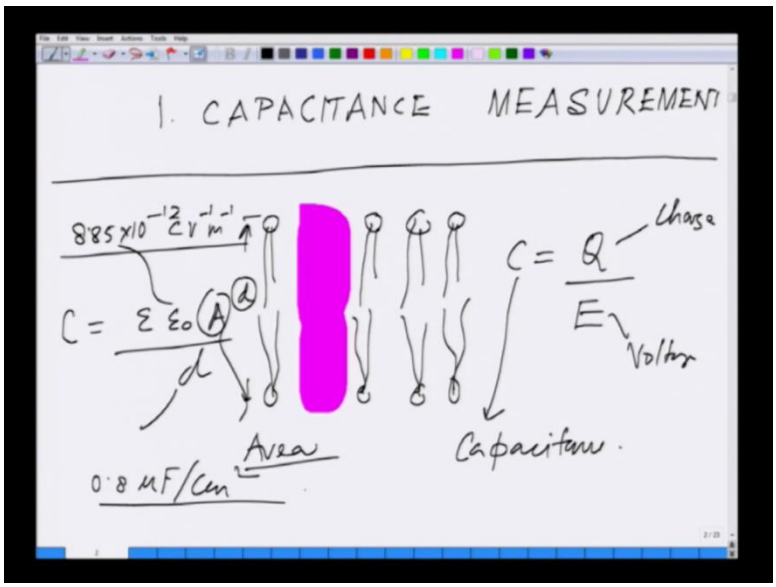

So, let us start the lecture twenty four, and let us enumerate what all I will be touching in this particular lecture. So, into lecture twenty four, and what I will be touching is first I will be talking about capacitance measurement. If you are treating cell as cell membrane as a capacitor, capacitance measurements, this is the first thing I will be dealing with. So, if you remember, while I was talking to you about the membrane it is something like a lipid bi layer it is almost like a two plate capacitor. So, here you have the proteins which are sitting out there. So, now you can treat this membrane as a capacitor membrane.

So, what happens during, so if you go back to the basics if you understand the basics, basics of capacitor is basically you see the formula C, C stands for capacitance, then Q is the charge, W is the voltage, and C is your capacitance. So, this is how we define capacitance. And further you can actually derive capacitance by E zero A by d, where d is the this is essentially is the d. And in this case, A is the area of the whole membrane, and this is the permittivity constant, permittivity of the membrane as well as… So, in the free space your epsilon zero in the free space will be 8.85 into 10 to the power minus 12. So, if it is is a parallel plate capacitor and specific capacitance will be around one micro farad, and pure bi layers slightly higher and there are pure bi layer which is approximately around is around 0.8 micro farad per centimeter square.

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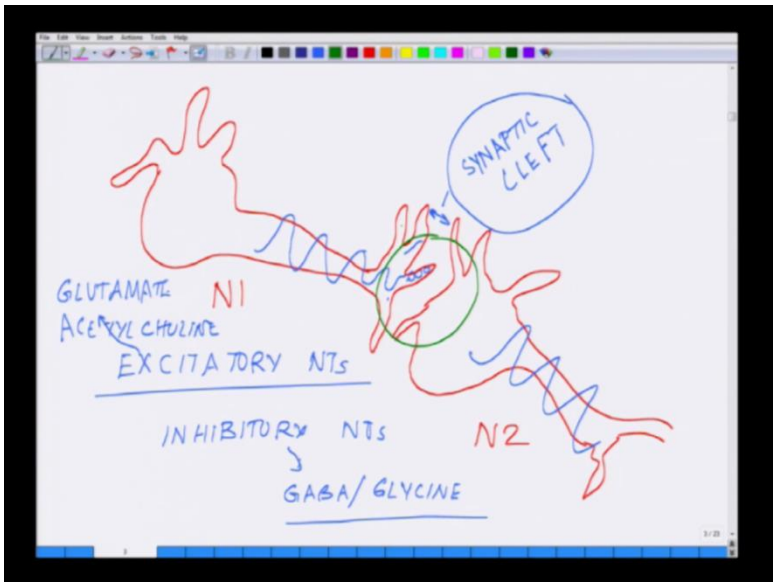

Now, what I essentially wanted you to highlight is this component area, say for example, if there are two neurons like this, and here is another neuron like this. Let me just kind of

you know these are the dendritic processes likewise, and of course, this one also will have a whole range of dendritic processes likewise and so on and so forth. So, now this one is neuron one, this one is neuron two. Now this neuron is sending an electrical impulses, and assume that this neuron is receiving the electrical impulse. So, at the zone of synapse, this is where is the synaptic cleft in the zone of synapse there are couple of things which are happening the most important thing, which is happening out here is this once this electrical signal reaches out here.

So, synapse is basically two neurons are in closest contact, but there is a small gap out there which is called the synaptic cleft which I mentioned here. So, at this level, they are at the first thing which happens is that this signal directly does not jump into this next neuron. So, from neuron one there are neurotransmitters which are secreted those neurotransmitters could be excitatory or inhibitory. Say if it is an excitatory because the next thing will be coming that is why I kind of left it out for a later excitatory n t's or neurotransmitters or inhibitory n t's among the inhibitory n t's are like something like gaba something like glycine, where as among excitatory transmitter you have glutamate acetyl choline.

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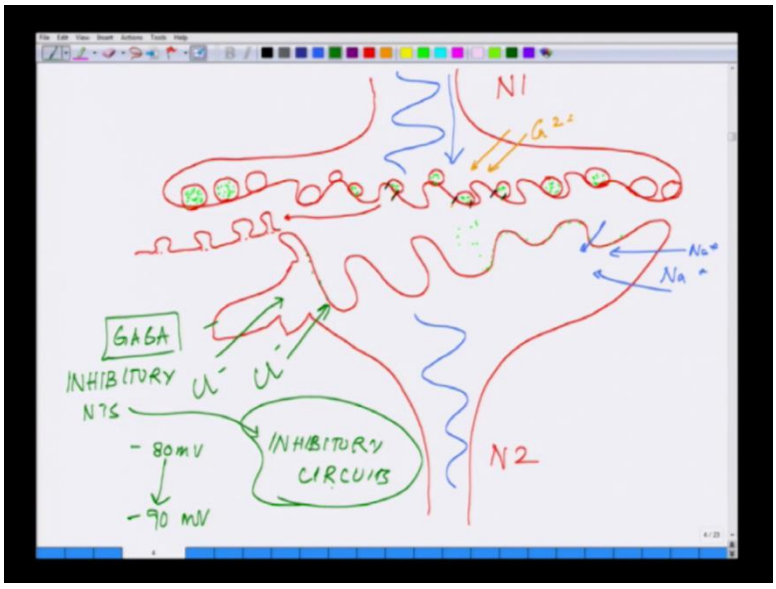

So now how this neurotransmitters are secreted. So, if I kind of blow up this zone, what essentially happens? If I blow up the whole synaptic zone synaptic zone looks like this. So, this is the pre synaptic or neuron one, and this one is the receiving neuron which is

with its dendritic processes multiple dendritic processes like this. Now, this is n one and this is your n two. So, electrical impulse reaches out here and travelling in this direction as shown by the arrow out here there are neurotransmitter vesicles in the form like this they are attached into it like this, these are membranous sacs. This circle one's what I am drawing here which are filled with neurotransmitters they are part of the membrane like this huge huge buttons of neurotransmitters sitting out here and these are all filled with. So, I am just representing it by with you know these b molecules these are the molecules of neurotransmitters what is what has filled all these things.

Now, when the electrical impulse reaches here it leads to the influx of calcium out here this can calcium ions binds here and helps this particular neurotransmitter pocket to be released. So, the way it works is this this part of the membrane gets detached and this part of it is get detach. So, let me just put it make it slightly dark it is get detach and what you see and transiently what happens this membrane loses part of the membrane and they become like this.

So, a part of the membrane is lost in this process. So, when the part of the. So, let me complete I will come back to this stage. So, then these neurotransmitter comes here and goes and binds to these you know to the post synaptic membrane and then they this leads to the opening of the ion channels. And automatically there will be a huge flux of sodium out here sodium ions this sodium ions eventually carry it further, if this neurotransmitter is inhibitory then this neurotransmitter could secrete something like a gaba or glycine when these gaba and glycine binds to this particular post synaptic neuron this may lead to the opening of the say chloride. So, when the chloride is coming from minus eighty milli volt where the cell is sitting it becomes more negative it becomes minus ninety milli volt.

So, these kind of neurotransmitter does not allow the electrical signal to proceed further it could stop here. So, those kind of synapses where it leads to the opening of the chloride or which makes the cell much more negative are called inhibitory neurotransmitter or inhibitory circuits something like you know when the gaba binds here gaba leads to the entry of the chloride ions through the chloride channels, which are inhibitory n t's leading to inhibitory circuits.

But out here there is something else which is happening. So, you see part of the membrane is lost. So, now, if you go back to the previous picture out here I told you. So, it means there is a change in the area, and because if original area is a because part of the membrane is lost. So, there is a next area which is formed which is say for example, a slash which essentially is a slash will be less than a original area this change in area could help in determining the capacitance change in the capacitance and based on the change in capacitance you can actually back calculate how much current must have flown here.

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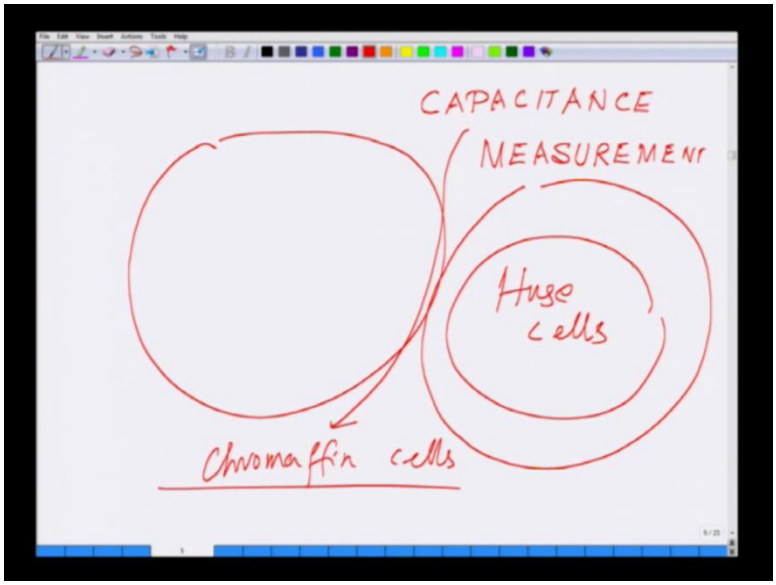

So, this is how the capacitance measurement is very comes very handy, but these kind of measurements is very huge cells where the change between two neurons is very distinct distinctly seen. So, for capacitance measurement you need a capacitance measurement a very huge cells and mostly these are done with you know something like chromaffin cell likewise there are several other cells which could do this. So, you need really huge cells for this.

So, this is one of the very potentially very powerful technique of capacitance measurement which is followed by different people who work with bovine pituitary and neuro endocrine cells. Mostly these are neuro endocrine cells which are involved in it just to give you an idea that what all different electrical techniques could be used, that is why I kind of hold it here there and I came back to this circuit. Now to tell you like you

know these kind of measurements also can be done to understand the electrical changes which are taking place. So, this is very briefly about the capacitance measurement.

I promised you that I will be talking about the field effect transistors. So, what I will be doing because that is kind slightly out of the I will be giving a handout at the end of the course you can go through it, and I will give you a very simple handout which will kind of give you an idea how field effect transistors are being used. It will be in a form of a power point or in a p d f file which would be attached to it. Along with question papers what I will be providing for the course you can go through that, and that will give you a fairly good idea.

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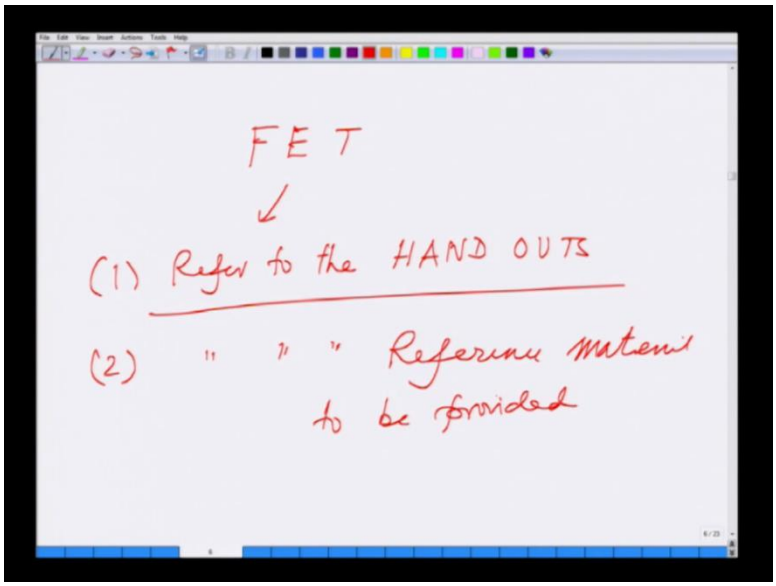

So, this is something I am just for your record let it be there. So, for the f e t refer to the handouts and at the end I will be discussing certain things about it, it is a very upcoming technology refer to the handout answer then refer to the reference material to be provided. So, this is about the f e t's Now, from here I come a little bit about the neuronal computation of excitatory and inhibitory neurotransmitters. So, this is something which I have not really discussed in depth, but back and forth we have kind of you know touched upon it, but I will specifically devote a few minutes for you to realize how the computation takes place say for example.

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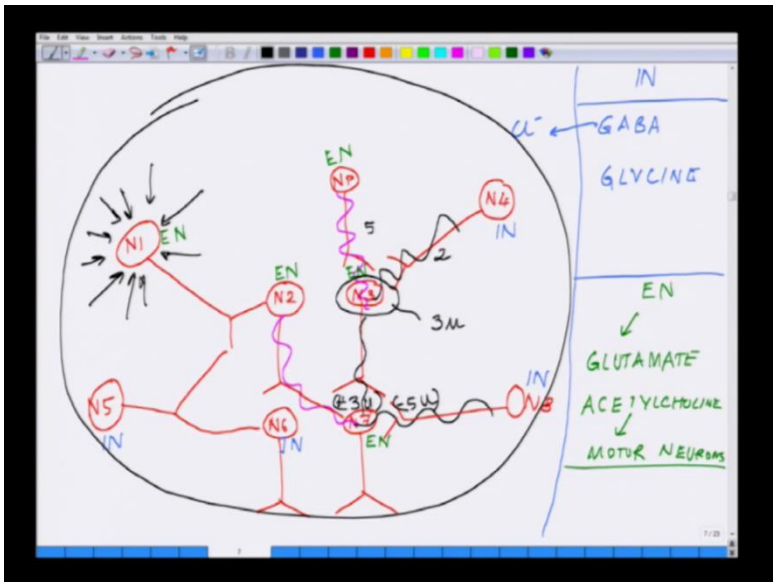

So, let us draw a simple network first to you know understand this process. So, these are the individual neurons with their cell body in circular way, and you know then let us you know draw something like this little bit more like this say for example, now let us name them n one n two n three n four these are the different name different neurons n five n six n seven n eight likewise.

Now, let us assume n four and we know all the cells set at a resting membrane potential of a minus seventy milli volt. And let us assume n four is a inhibitory neuron I n and n three is a excitatory neuron n two is an excitatory neuron n one is an excitatory neuron n five is an inhibitory neuron n six n eight is an inhibitory neuron n seven is an excitatory neuron n six is an inhibitory neuron. So, when I talk about inhibitory and excitatory neuron what I mean essentially is the neurotransmitter they are secreting. So, among the classification they could be when we are talking about I n's and then you have e n's e n's could be this is known as glutamate glutamatergic neuron, these are called glutamatergic neuron acetylcholine or cholinergic neuron which are essentially the major chunk of the motor neurons except drosophila. Where they are glutamatergic and in among the inhibitory neurons you have gaba gabargic neurons you have glycinergic neuron and gaba are the one's which promote the entry of the chloride glutamate are the one's which are providing the inflow of the sodium.

So, now this is how a hypothetical network looks like what I have drawn. So, now, this neuron say for example, this I n is receiving a n p and which is also excitatory neuron. So, say for example, from n p a electrical impulse is travelling all the way to all the way excitatory signal all the way out here. So, now, if there is an inhibitory signal coming from this neuron say for example, a inhibitory signal coming from this neuron. So, there will be an algebraic addition out here. So, if this sends say five units of signal and this send two unit of signal essentially in three we will have three units of signals realize. So, what it will be passing on here will be three unit I am just giving the hypothetical numbers here if you have a way to quantify it.

Now, n seven out here is receiving a input from say for example, let us make it little bit more a three unit from n three and another some x y z unit from n two. So, this one is also sending a excitatory signal to this one. So, now, three unit plus what is ever unit is coming from two, but then there is a inhibitory signal coming from this one now these three signals. So, if say for example, this is five unit. So, essentially this negative signal is coming five unit and there is a positive signal of three unit and then this signal has to be some way or other bigger then minus because there's already minus three minus five sorry plus three minus five. So, this is minus two. So, this signal which is coming should be greater than minus two in order to ensure that the signal does not end at n seven otherwise signal will end at n seven you are realizing how that this whole computation works.

So, now with this simplistic situation, if this is the most simplistic thing, I can think of now imagine there are thousands of neuron and each neuron each one of these I am just showing two connectivity each one of them are receiving input from say ten thousand different sources or they are sending signal to ten thousand different sources. At one point of time imagine the complexity of the network, it is a complexity which is fairly unfathomable by the logical or the logics of mathematics what we know, it is a very very high level of computation what is happening in the brain, because your amount of the brain area is limited.

It is within that limited area of the brain all this complete circuit has to be embedded and this. So, I mean think of it this is the total area of your brain and this is where all the neurons have to be there, if it is not there then the computation would not take place. So, within this all this connectivity has to be accommodated it is a exceptionally complex

and multi level computation which is taking place out in the brain this is absolutely an amazing feat what nature has acquired over a period of time. So, this is the reason why I wanted to highlight. So, this is a whole range of computation which is taking place and regarding the feat of these different kinds of you know gabargic glycinergic.

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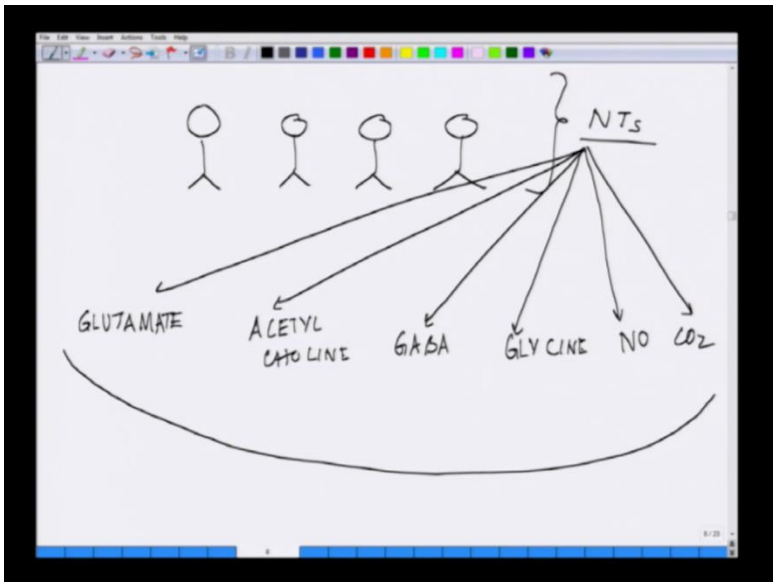

So, initially it is initially when like you know when the nervous system was forming probably all the neurons say say for example, it is in the formative phase all the initially all the neurons have the ability you know to synthesize all the different neurotransmitters. They could do or a multitasking, but then slowly slowly they specialize themselves. They become you know depending on the location depending on the developmental role they become either you know glutamate the major one they will be they are secreting. Then could be glutamate neurotransmitter or you know acetylcholine which it is when acetylcholine goes and binds it kind of opens up the ion channels it could be you know gaba. It could be glycine it could be n o which directly passes through the membrane it could be c o two.

So, this ability of or this plethora of different neurotransmitter adds further complexity to the nervous system, because on one hand you have these voltage gated channels then this voltage gated channels. Then you this ligand gated channels ligand gated channels are essentially the neurotransmitter driven channels. Then you have special and temporary computation something like this say for example, let us again get back to the circuit.

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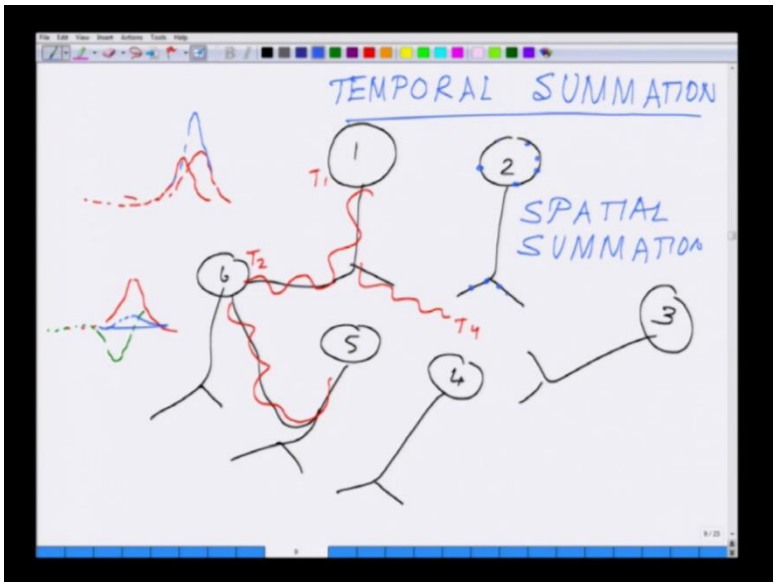

So, imagine a circuit like this ok Now, a set of signal is coming. So, these are different neurons let me just one two three four five six. Now say for example, a signal is coming from here part of this signal going say here, now at time t one this signal is started at time two it is here where as with a slight delay at t four it is here. So, simultaneously another signal maybe coming say for example, from one of these processes like this. So, maybe this signal is coming with a slight delay with respect to t two.

So, what is happening followed by t two, if another signal they will add up. So, if this is the first signal coming followed by another signal something like this. So, there will be an addition out here like this or if there is a inhibitory signal say for example, one signal is coming like this and there's another signal which is coming on the reverse like this. So, what will happen the summation will be something like this. So, what you what is essentially I am trying to tell you there's a temporal summation the keyword with respect to the time. And the signal could be inhibitory as well as excitatory, and then there is something called spatial summation spatial summation means where in space within this it could be stored here it could be stored here it could be stored here likewise there are several zones where it could be stored at different space.

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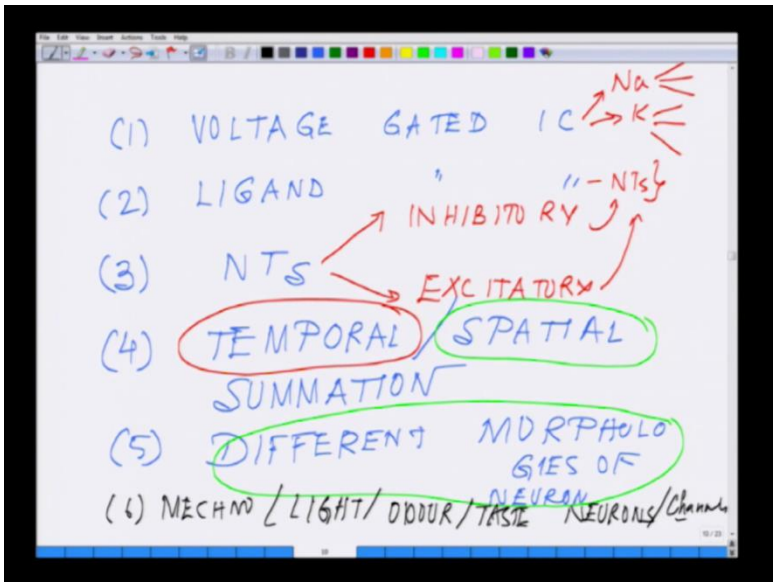

So, if you see the different diversity we talking about we are talking about voltage gated ion channels voltage gated I c's one then you have ligand gated I c's two. Then you have neurotransmitters three, then you have temporal and spatial summation in the network that is the fourth. Then you have different morphologies of neuron and within the neurotransmitters you have inhibitory and excitatory within the voltage electric channels your sodium potassium. And within that there are multiple sub types within the ligand gated channels you have n t neurotransmitter driven channels, which on binding then we have talked about the temporal summation over the period of time the summation is taking place then at different places within the space of the network.

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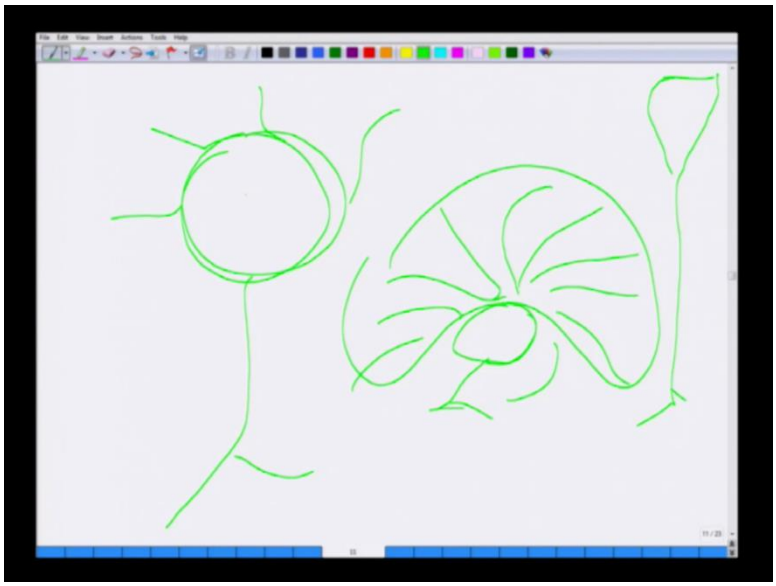

There is a summation taking place then there are different morphologies of the neuron there are morphologies something like a huge cell body of a motor neuron kind of morphology with dense network yet there are cells which has extremely high. You know dendritic tree like something like this. Then yet there are cells this is the huge dendritic tree what you observe out here this is the huge cell body what you observe here then you have the pyramidal neurons what we described yesterday in the hippocampus. Then similarly you have neurons, which has no axons only the dendritic tree which you see in the amocrine cells in the retina. Then you have hair cells and apart from it just coming back then out here adding few more complexity here voltage gated then just to add up the complexity here mechano light odor and taste neurons or channels

So, what essentially I wanted to the reason to enumerate this whole thing is to highlight the possibilities all the different possibilities the nervous system can deal with I mean it is a library of a wide variations. So, it can do several kind of permutation and combination in storing information in your in this whole circuit of the brain and whenever you explore this kind of system you have to explore it with a very open mind you cannot really afford to be kind of rigid you know like you know this is it this cannot happen or else lot of possibilities and more and more we are understanding like one of the techniques which currently is under way people are trying to develop is say for example, whenever we talk about a neuron.

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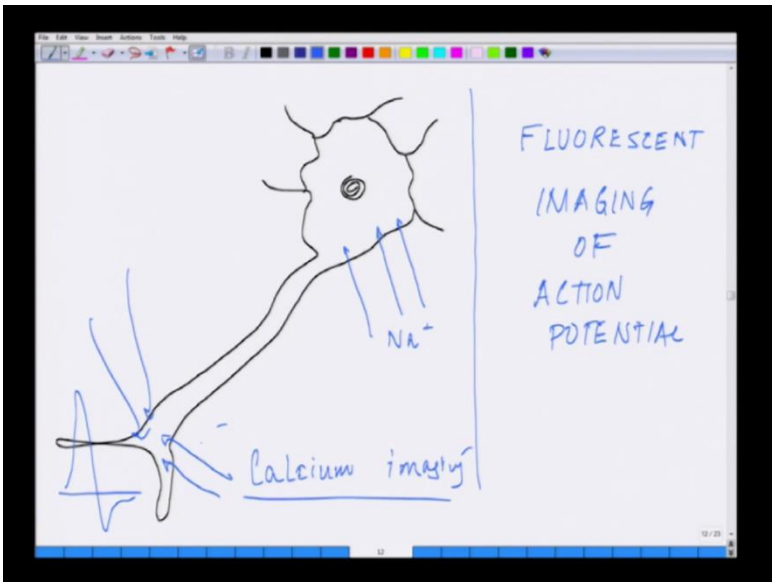

So, imagine this is a neuronal cell body you know and this is the whole process if you could. So, whenever there is an action potential getting generated or electrical pulses generated you have the sodium ions which are moving through and sodium ions eventually leads to an action potential which you have already discussed

So, essentially people are trying to you know fluorescently image the action potential fluorescent fluorescent imaging of action potential. Or there is another very powerful technique which people are trying which they are doing for a long period of time is called calcium imaging where the calcium waves, because calcium is playing a very critical role as I was telling you the calcium waves which are coming through. So, calcium imaging imaging calcium flux in order to figure out the you know electrical activity. So, there are different tools which are either very well developed or in the process of getting developed in order to decipher the electrical code within our system end of the day.

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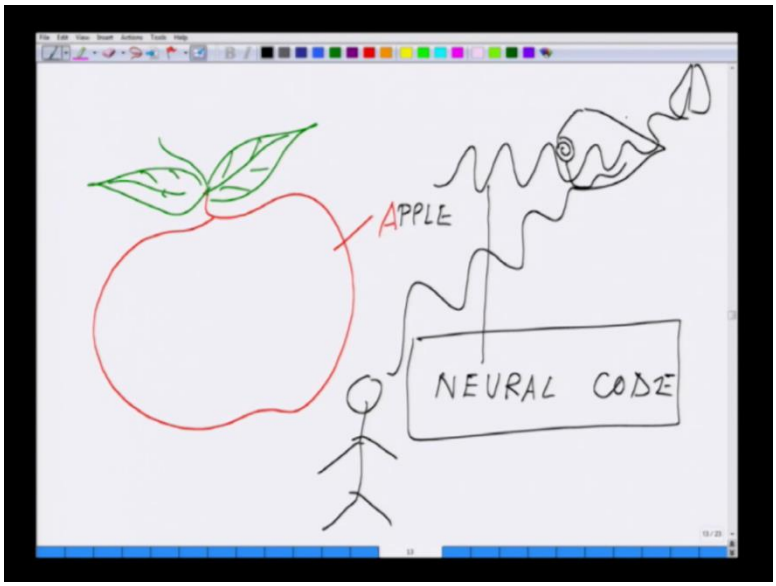

What is most important is that where I was starting the whole thing could we predict that you know that, and if this is your eye and this is your brain, what is that electrical signal which tells the eye that this is an apple, and this is where lies our neural code what makes you know that this is an apple not an orange or this is an apple not a you know human being. So, both of them have one commonality they are all driven by the electrical impulses which are sent to the brain and that is why this whole feel of bioelectricity at of the animal system is. So, very interesting at these small ionic fluxes ensures who we are and what we are. So, I mean this is a never ending story I mean this kind of go on and on forever.

So, I will close in here about the animal bioelectricity fragment this module go through it as I told you I will be giving a lot of reference material which you should go through. And there is another area of bioelectricity, what we will be dealing next after this nothing to do with the brain, but with heart the one which ensures that we are alive. So, I will close in here and next two classes or. So, we will be talking about the bioelectrical phenomena of the heart and that will pretty much well you know complete the bigger animal electricity aspects what we are supposed to deal.

Thank you.