Bioelectricity

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Lecture – 18

So, welcome back to the lecture series in NP-TEL on bioelectricity. So, in the previous class, we talked about that within the nervous system how the electrical impulses are translated into mechanical stimulus and that inter conversion - electrical to mechanical to electrical in the process how there ((Refer Time: 00:46)) reflect circuits are functioning, how the calcium dictates the electrical current, and how the sarcoplasmic reticulum functions. We kind of in depth and discussed all that.

So, now, what we will do, there are if you remember in the first lecture, when I was telling you the outline of it. So, there are two sections, one is the initial animal bioelectricity and the other section is a prosthesis, and they are inter linked with each other; once you understand the animal bioelectricity then you can understand the prosthesis. So, today we will talk about two special senses, two to three special senses and we will talk about the prosthesis. So, talking about the prosthesis a neuro prosthesis actually started apart from some the brain stimulation all those things. The real prosthetic devices started coming when we tried to replace our sensory systems.

So, what exactly I meant by that. So, think of a situation of a person who is blind, and the former blindness which cannot be cured with the known biomedical or biological intervention, what to do? So, talking about the visual the contact of the visual system your eyes acquire the image and this image is through the circuit is transmitted into the brains where it gets interpreted and then you understand what you are saying. So, say for example, an apple is an apple for you, orange is an orange for you, because your eyes have made image of that and it has stored in the brain this is an apple. Whenever you see an apple, the electrical impulse the structure is translated into electrical impulses, and this electrical impulses travels to the brain, and in the brain it is processed and you appreciate ok, this is an apple fine.

So, there are two levels when the problem may arise. The first level may be the image plate where he was seeing an apple is not functional, that is level one. Level 2 is the

conductive, which is carrying the message from the eyes to the brain is not functioning, or the third thing is that the area of the brain which processes the visual stimulus or visual map is not functioning and based on that we will be looking into this problem. So, let me draw it for you.

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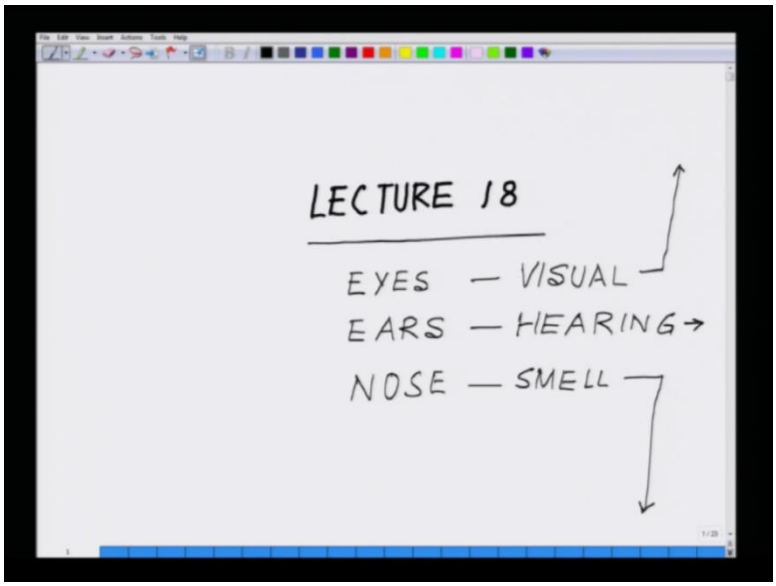

So this is lecture eighteen, and we will be talking about a special senses like eyes, ears and nose, and with its different sensing abilities, eyes for the visual, ears for the hearing and nose for the smell. And for them they are special prosthesis which are involved in it. So, let us start with the eyes, because that is much more well explored system, but to tell you very interestingly the whole prosthesis business did not start with the eyes. Actually it got started with the ears, I will come just later as I will be moving through. So, let us draw what I had just discussed with you.

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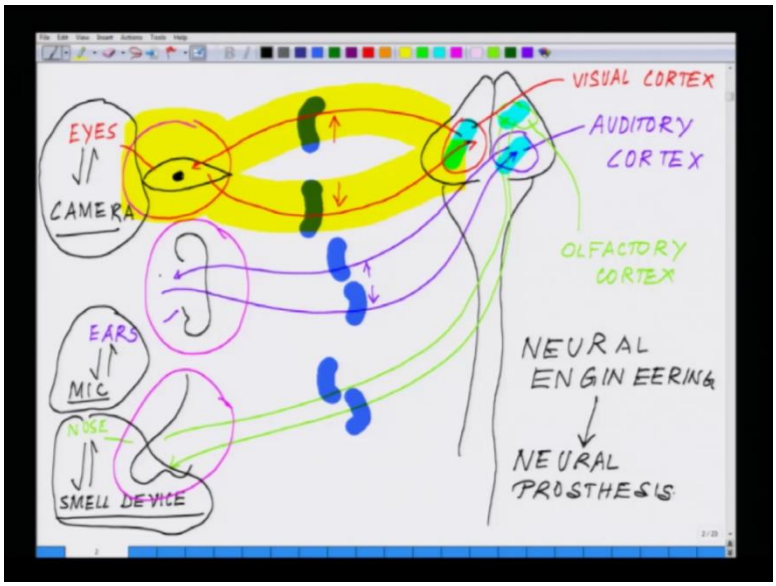

So here we have the brain, which has different areas process, visual stimulus, smell and we are talking about the three sense organs, your eyes, ears and nose correct. So, from here, a signal reaches the brain. Say for example, this area we call this as a visual cortex; and from here, a response signal comes and you realize what you are seeing. Similarly, for hearing a signal goes from here to the area which is called auditory cortex, and the transmission takes place. So, similarly these are the highways which are carrying the nerve conductive and in this case this is the visual cortex, and here are the eyes, here you have the ears, here you have the nose, and there are regions called olfactory cortex cortical region within the brain where your olfaction is being processed.

So, now possibilities are there that the damage may either take place out here, one possibility out here, other possibility are out here; either in the eyes, ears or nose. All the damages are taking place out or taking place here, here or here - the highlighted region, or the damages are taking place here, here, here, here, here, here - three levels. So, the first level what the eyes are doing? Eyes are essentially nothing but a simple camera, which capturing the image; your camera has a image plate, eye also has the image plate. Your camera has an aperture your eye also has a aperture, your camera can control the amount of light which you should enter, your eyes can control the amount of light can enter. The only difference is that one is purely purely mechanical, and other is purely purely bioorganic.

Your eyes depends on ironic current, your camera depends on the pixel by pixel and the electronic components. Your eyes depends on excitation of a specific molecules where reduction, whereas your camera depends on plates which could sense lights and eject out electrons. If you look both of that, the logic is same. So, one of the things come is there is way by which you can replace the camera in the eye. In other word, what we are talking about is could you interface your actual eyes with a camera, say for example, a person is totally blind, so essentially what we are talking about, you will have a camera in front of your eyes that will be interfaced with…

We coming back to the diagram, if you look at this diagram very carefully. So, here instead of the camera, now instead of the eyes, what I am putting in yellow is, there will be a camera, and the camera will be interfaced with this path ways, and they will be going to visual cortex, and the signal will be interpreted. Similarly, you instead of your ears, suppose your ears are not functional, you all have seen a mike, the recording devices in tape recorders or any other audio visual devices. So, you replace your ear with a mike.

Before I go this, let me show this. Your eyes what your trying to do is fitting a camera here. Similarly for a ear, you are putting a mike; and for your nose, you are trying to have some smell device which could smell. And this whole area when we try to replace biological systems or not replace exactly interface solid state electronic devices in the biological system falls under neural engineering and the specialized area for this the whole area is called neural engineering. And within neural engineering, all these falls under very specific domain called neural prosthesis. In order to appreciate neural prosthesis what we needed to understand is how these different structures are in the biological system and how we can replace them.

So, in order to really appreciate, first of all, we will be discussing about the structure of the eyes, structure of the ears, and the structure of the nose. And from there, we will try to draw a one to one correlation of what kind of current which are being sent through this conduit nerve tubes to the brain and how this could be replaced. But remember one thing, this is all about this like you know the sensory system what we are talking about to replace. But in case of visual cortex or the auditory cortex or the olfactory cortex are not functioning properly, they are damaged, we essentially do not had much hope there, we really cannot change much on that. As of now with our known technologies that is a

whole deep gamete of very challenging area then how really we represent. So, you have to philophise this whole thing.

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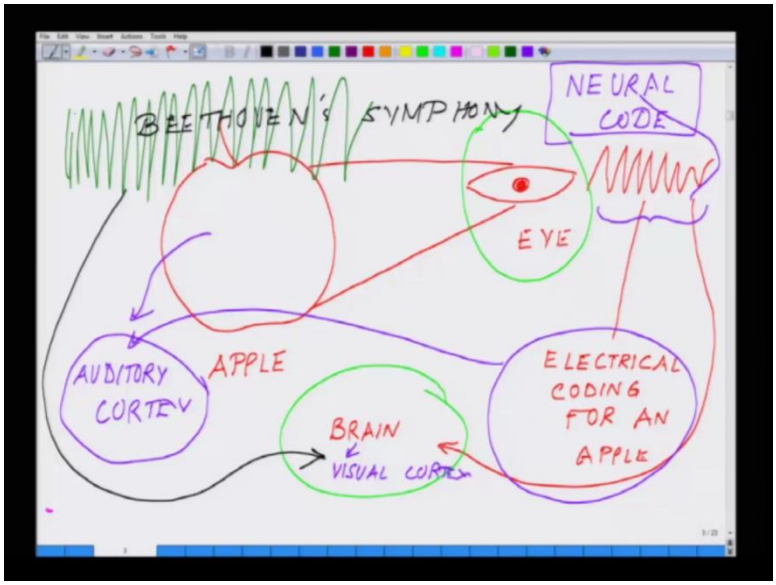

Say for example, I see an apple out here. So, this apple for my eyes, if I am looking through my eyes like this, this apple is falling in image out there, and this is being coded in form of an electrical signal. Basically here this is your apple, this your eye, and this is electrical coding for apple, and this coding electrical coding for an apple and this coding is being decoded by your brain. Now, what you can replace, we can replace this part, which we have discussed. This part of code you can replace, but this part usually do not know. And what we essentially understand as from the beginning I was trying to highlight is this part this what we call as neural code - the next challenging frontier for mankind. What is the coding, why we like certain music, why your ear like some of the symphony intervene so much, why we like certain kinds of songs, why there is a sorrow of certain kind of music beats revolves.

And in a larger extent what I wanted to say is say for example, I feed this neural code, this electrical code for an apple. To instead of coding it, putting it in the visual cortex, I feed this signal to the auditory cortex that essentially means I am trying to tell you hear an apple, I may sound very crazy. And asking you to hear an apple, because you always hear, I want to see an apple I want to see an orange, but you never hear that. Could I hear an apple, this is what exactly is trying to philophilize with this.

Of course, I will be talking about all the prosthesis, but what you have to understand that all these things back in the mind or as a race as a human race we are thinking much more in depth. It is just not that you know I replaced camera in front of the eyes; it is not that simple. Yes, I mean it is not a big deal there are people who are doing it for last hundred years, but there is a deep rooted philosophy, and which is very essential for young minds like you to understand that. This is not just putting on gadget absolutely not that it is far and beyond that how we really could think could you see an apple fine. I can see an apple, could you hear an apple now, you are bit you know shaky or say for example, I have a bit of symphony going on.

Now, I put that sympathy symphony has a say for example, a trace like this. This is a trace of a Beethoven's symphony, now I feed this trace into the visual cortex. So, this is Beethoven's symphony. So, now, I ask you a question could you see the song, you all is have here that, you know I could hear a song. This is your ear and you are listening to the song. Now I will tell you could you see the song is not that bit crazy. Yes it is, but that is exactly lies in the very core of the neural code is a simple electrical signals, which are travelling down. Could we de convolute them could you use the known techniques from the mathematical report ware to understand.

What this bassinets code are actually carrying in them then we may be able to answer some of these crazy questions could we hear an apple or could we see the symphony you could hear the symphony and you can see the apple by your own knowledge, but could you see the symphony and hear the apple is a challenge. So, this small background about why these are so very important, all these devices and everything what we know and what we cannot do. I told you they are auditory cortex or any damage in the visual cortex or in the olfactory cortex we cannot do anything.

We really do not know those extraordinary computations which are taking place in those areas we are absolutely helpless in that program what we can do i told you we can at least replace at least last scandalous of mankind take enough to a point where we can replace some of these simple sensory system with electronic devices. So, from here i will move on to explain the structure of the eyes and after structure after that we will move on to the structure of the ear and then we will talk about the different ironic current which are involved in this process and then we will talk about the prosthesis devices.

And I will give you the references which I wish you people go through them very carefully, because that will help you to know appreciate that what all extra ordinary research which are going on all over the world to make our life much more you know much more comfortably. Especially for those people who are children's of the lesser god you know they have lost their vision or you know lost their hearing capability or loss their smelling capability and so on and so forth.

So, let us talk about the structure of the eye, so talking about the structure of the eyes. So, first of all I will draw the gross structure of the eyes which most of you have seen in high school or middle school text books. And from there, we will talk about the different forms of blindness and then we will talk about the exact image plate which is involved in it. And from there, we will talk about the different ironic current which are involved in it and and what could be done.

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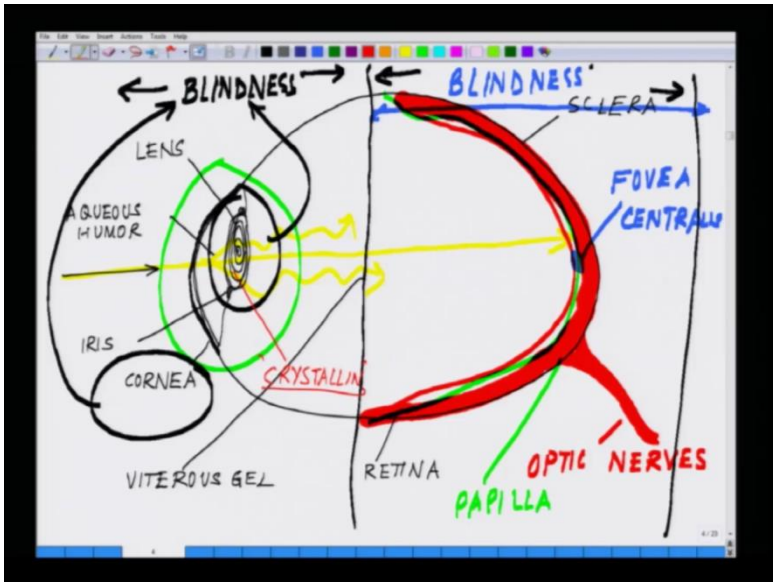

So, let us draw the complete structure of the eye. So, this is pretty much is something called lens here. So, this is somewhere the light is coming. So, the outer most layer which is called cornea, this is I am just drawing a very simplistic picture. Those of you who love complex picture, please go online, you can find several very complex and very nice dual colored pictures. Then this is the lens which is a transparent piece of tissues through the light passes without any problem then you have out here you have iris. You

have aqua simmer, this is the fluid, which is filling this aqueous humor then you have the very thin tissue here from here once again.

So, this highlighted red part what is coming is this is what we called the back of the eyes is called the retina. This zone is filled with something called vitreous gel and back of the eyes is called sclera. And out here, we have thing like this this is the conductive which is carrying this is the optic nerves here optic nerves the nerves which carrying the message to the brain and a there is a specific spot here somewhere out here which is called fovea centaurs will talk later about it then you have something called papilla here. So, this is the overall structure of the eyes to slightly spherical just a kind of drawing.

So, if you see it, so if you see from the front. So, this is the path of the light the light moves travels like this if you see the yellow arrow what I was drawing to draw. So, this all the regions were hmm one second this is the region where the amount of the light which will pass through is controlled the region what I have circled with a green highlighter and inner processing takes place out here this region. Now, what we will do now first of all, we will talk about different kind of blindness blindness could be described at at the level of eyes could be could be described to levels.

So, the first level is, so let me draw it that will make things clear level one is any blindness which is happening in this side level two any blindness happening in this side what does that mean this side and that side. So, this is the side where the light is passing through the lens, light is passing through the cornea, you follow the image light is passing through the cornea. So, there is a damage in the cornea that could lead to line. Once again damage to cornea leading to blindness damage to lens leading to blindness.

So, in case of cornea the option is that replacement of the cornea by the donation of the eyes somebody donates the eyes, because cornea is a non vascular eyes tissue; that means, there is hardly any blood flow in that tissue. So, any corneal replacement would not lead to any kind of human reaction and a that is what essentially means when people say they are donating their eyes after death, essentially it is a cornea which is being removed that is it. That is the cornea which is replaced in in place of the existing cornier whose person cornea is not functional. So, that is a level one second one is the lens tissue which consists of specialize lens cells which are arranged in a circle manner that is the reason why I drew it in a spherical concentrate circle these cells.

During the process of development losses all their organ ails, and they become transparent and that whole process is being regulated by specialize enzymes which execute that process when they lose their organery skill fifty in the proxy gin is. So, these cells have specific protein called crystalline just write it down those who forget in case. So, there are special protein within those cells called crystalline and these crystalline are of course the cells are arranged in the specific way. And the crystal in protein are stack around in a particular way, but during ageing some of these crystalline protein starts mis folding individual proteins the way their experiential geometry is organized their this kind of get's disoriented s.

And what essentially that leads to is this the situation when the light passing kind of becomes like this light could not pass properly it may reach, but it will reach with staggered because the crystalline proteins are not arranged with within the cells their. Now mis-folded that is the situation what we essentially called cataract all must have heard this several people in this country. So, huge population in this country actually suffers from cataract which is major firm of form of blindness in India. So, for cataract the other or the option is that say for example, your HMM cornea is all fine.

So, for cataract your option is that you replace that transparent tissue with an artificial lens or with an artificial glass which is transparent that is the only therapy what we have that is what we essentially means cataract operation is all about with a replace it with an artificial. So, this is the second this is within the within an eye is a second level of blindness.

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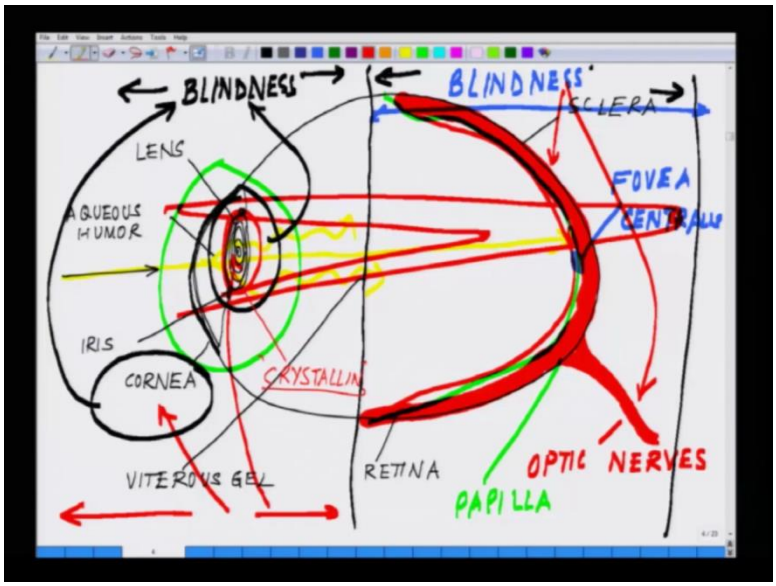

Now comes on this sight of the picture let us getting back to this side of the picture where we (( )) colors. So, this is the sight which is the very critical one what type of blindness are we talking about here. This is the blindness where this image plate of the retina is not functioning properly; it means the cellular structure of the retina is compromised. There are damages or there are mis-formation or their arrangement is not right or something x y z this is within the eye this is the second level of blindness. If I of course, categorized it or just the way in the diagram I did it on.

Coming back to the diagram of this sight; this is one form of blindness which has two level either it will be cornea or it will be the lens. And this side of it, either it will be at this or it will be on the optic nerves. If there is a damage optic nerves your retina is all functional all, but you have damage optic nerves. And just for slightly diagnosing back little bit for a say for that is why you see people put on a specks, because when the lens is not forming the image in a right place, either it may form out here or it may form beyond it. there are lens which are being put in front of the eyes which essentially ensures that you are image actually forms on the image plate which is the retina with this brief introduction.

What I will do, I will move on to explain the cellular architecture of the eyes. that is very essential to understand because once you understand this cellular architecture of the eyes we will be able to appreciate that what is the basic difference fundamental difference

between a image plate of the camera and the image plate of the eyes there are different biochemical events which leads to bioelectrical events. So, we will be talking about the biochemical events we will be talking about the bioelectrical events and then we will move onto the what are the replacement which could be done in this.

So coming back to the structure of the retina, so the structure of the retina is a very I should say it is complex, it is very a very well organized structure of six layers of cells the layers are robs and cone layer which is called as photoreceptor layer photoreceptor. I will draw everything. So, do not worry, photo means light receptor the ones which receives the light this the most critical layer this is the layer which receives the light from x y z sources this is the layer which distinguishes colors. Rods are for light dim light and cones are for colors.

This is very easy to remember see cones for colors and we follow our r g b red green. So, we have three different kind of cones red green and blue are r g b there are fishes which is another kind of cones additional kind of cones there are four different colors they can handle there may be other species which may have other different forms of. So, we have to just understand that. So, we have the color distinction which is done by the cone cells

We have the rods which works in the dim light. So, so say for example, species of fish say for which is living deep down to the ocean. So, you will see that these fishes do not have any cones now going to wonder why it is very straight forward because light never penetrates into the see floor light hardly enters few feet's after that light does not go. So, those fishes functions only with rods because they have adapted themselves

So, again the reason why i am giving you prefer this kind of examples this biological cameras are very very well adapted to the surrounding environment depending on the needs and requirements their needs and requirement is brink modulated. So, if you do not need color sink colors interpretation of colors you do not have colors they do not care they function with you know only with the dim light. So, you have the rods and cones which is called the photoreceptor layer

Just beyond the photoreceptor layer is sitting on top of a epithelial cell layer, which is called retinal pigment epithelial cell RPE in short. It is written retinal pigment epithelial cell on top of retinal pigment epithelial cell, you have these rods and cones which are sitting on top of rods and cones. There are layer of three different layers bipolar cells and

makorine cells, horizontal cells ganglionic cells. Makorine cells horizontal cells ganglionic cells and they all converge into optic nerves what I have shown in the picture.

So, now, this different layers have different kind of function and more over they all integrate all different kind of signal the depth of the image the movement of the image say for example, the amacrine cells amacrine cells say for example, you are standing in a railway station standing in a railway station and there is a train approaching. So, you are seeing the train coming towards you.

So, within the eye you have amacrine cells, which could actually sends a moving object coming towards you. So, there is a continues real time computational computation involved because this is like video camera the video camera which is seeing the whole thing. So, it is adjusting adjusting exactly the same way or somebody's dog is running a coming towards you rushing towards you and you have to run away. So, you are continuously adjusting because the image is moving

So, by I am moving like like hands is moving towards my eyes. So, you know or I pick this is up it is moving. So, I just move my head back. So, essentially; that means, that my eyes are continuously adjusting just like a video camera you can see all the motion motion pictures. So, I am picture rising the motion. So, this is the makorine cells. So, they play a very critical role you have the horizontal cells bipolar cells gang ionic cells and and what is good about this what I told you, those three complex structure, but it is very well structure.

In the sense, if you take a section of the retina you can physically see of course, under the high resolution microscope, you can physically see the different layers as if they are stacked to one another like this very nicely stacked to one another. And among all the layers the most the first layer which is sensing are the only one's which has photoreceptors in them or in other word that is the layer which could translate light signal into electrical signal all other layers are divide of that they do not have any photoreceptor. So, even if the light passes through them it hardly matters for them, you know and arrangement is very interesting; this is something you people have to understand. When you go back to the picture, the arrangement is like this the photoreceptors that specially this is very clumsy, if I draw it on this.

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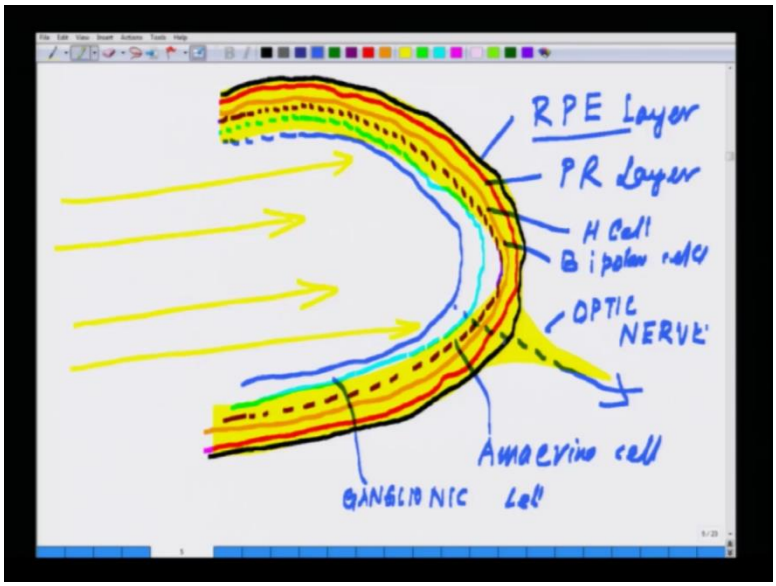

If this is the retina, which I have drawn in red in other one. So, within this the weight is arranged is. So, this is the back side. So, this is the black bordering what I am doing is the retinal pigment epithelial layer when I just for those who. So, this is optic nerves which is going out and on top of epithelial pigment layer you have this layer the second layer in the pink color what I am drawing now. This is rod cone layer and mind it light is entering like this. Light is entering like this on top of that you have the horizontal cell layer which is this is the horizontal cell layer then comes the amacrine cell layer which I am drawing in broken lines just for your understanding after amacrine cell layer you have in between the bipolar cells and the gangcronic cells.

You have the intersperse out here bipolar and the gangcronic cells. So, what I wanted to highlight here is and then all of this eventually move to the this; this is the optic nerve and this is the retinal pigment epithelial layer, this is the p r layer or photo receptor layer. Here you have the horizontal cell h c layer then you have the bipolar cells you can call this as a bipolar cell. Then you have the amacrine cell layer and very deep inside you have the ganglionic cells layer ganglionic cells layer fine let me just a cross check bipolar cell (( )).

So, these six layers might wonder, why most of these other cells are in front the reason probably being that this darker layer which is on the back on on which the r p on which the rods and cones are sitting is the one. This retinal pigment epithelial layer is the one

which is supporting neutrons to the rods and cones layer. So, if the structure is reversed retinal pigment epithelial layer is a opec layer it does not allow the light to move through. So, if it is in the front light would not pass through. So, that is why probably probably I mean this all speculations what we have probably nature have designed in such a way retinal pigment epithelial layer is in the back which is opec does not allow light to pass on top of that. You have retinal pigment epithelial layer cell, which have light sensor pigments and on top of that, you have stacked all different layers and light is coming from the front.

So, this the back. So, what we will do now is after this, we will talk about the cellular architecture of these individual layers, how their connectivity and we will pick up most important leader rods and cones layer, and we will talk about the electrical signals which are generated out there. So, I will closing here and we will review with you with the different architecture and the cellular architecture, and the electrical signals, and how these are being transmitted. And then of course, to the course to these part of it because it extremely essential that you people understand the anatomy and the physiology, the electro physiology of it before you understand or appreciate the real challenge of the processes.

Thanks a lot.