Neural Science for Engineers
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Lecture - 34
Human Vision System

Hi, we are in Human Vision and the approach so far has been in contrasting between machine vision, computer vision and human vision and how both of them are different from each other, very significant areas where I thought I should highlight the differences I have tried to highlight.

I have tried to highlight those differences because those are places where the work needs to be done one or those are sort of ideas especially for the ML community. Because you know when I look at all kinds of ML literature, they look at very small aspects of the human vision system and they have got a lot out of that small part.

But these things which are unknowns in biology may have an answer or may have an application in the engineering side, the neural network side, machine learning side and that is the reason I focused on those particular specific areas. Rather than you know the cellular structure, the functions, how things happen and happen.

I reiterate here that this is one of those chapters where I would want people who are interested in this field to go back to the textbook, not only read the textbook, many of these articles which are shown as photographs over here have been published much earlier.

So, some of the articles I was surprised were 1985 and late 90s and things like that. So, the literature supporting these facts or the literature for these facts has been there for the past 20 or 30 years, but if you look at timeline wise, if you look at when CNNs and say the modern neural networks after AlexNet sort of its only the past 10 or 15 years of course, I know 10 or 15 years and I do understand the GPU limitations and things which have been there.

But, implementing these theories in computer science applications I think is a way ahead and that is one of the reasons why I have emphasized that one the treatment of the subject which I have done so far is for that issue.

Second, I have highlighted that these are most of mostly taken from the textbook from Wikipedia etcetera as opposed to my earlier style of discussion in which it was you know I talking and writing stuff. So, the difference is because of that. And the third thing is the not only the book please do read up those references which are there in candle relevant to your areas of interest.

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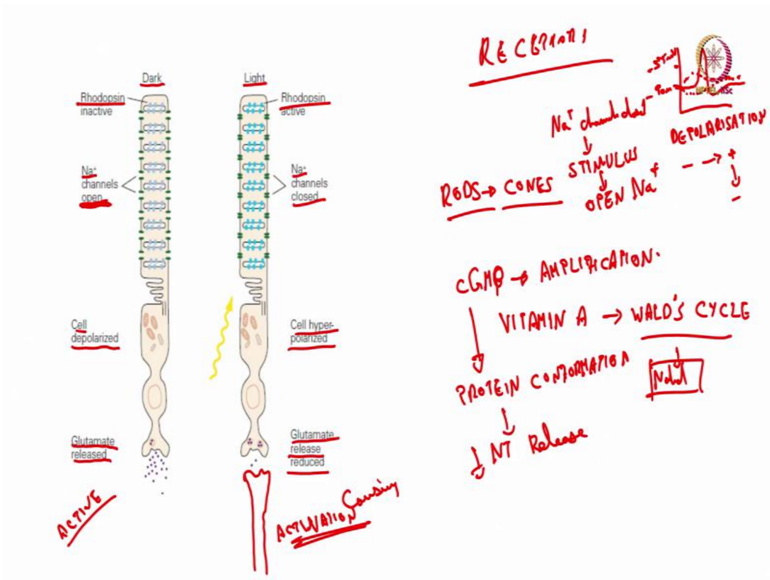

So, with that we continue a little bit into receptors, and we look at very funny things which happen in receptors. Now a brief refresher, if you remember an action potential is something like this and then I told you about EPSPs and IPSPs which are like this.

So, I also highlighted the relevance of threshold, this would be around 90 and that is how neuronal activation happens. So, you have when I say activation it is depolarisation that is negative becomes positive and becomes negative. So, that is the complete cycle of the action potential.

So, what actually happens in photoreceptors is very different and I would need you to look at to this diagram. So, in the dark state which is sort of the resting state and when there is when this when the receptors are supposed to be inactive, the sodium channels are open. Now this is opposed to the opposed to a nerve in which sodium channels are closed. So, that causes when a stimulus arrives open Na whereas, here it is open at rest. And the cell thereby is depolarized and there is continued resulting result of the neurotransmitters over here.

So, what actually happens is its in reverse. So, you have darkness in which this receptor, this cell is sort of active and you have neurotransmitters which are being released. And you should remember that this is an active process, anything which releases glutamate is the cell is depolarized so, its an active process. So, that is what is happening over here, but when there is light the channels are closed the cell becomes hyper polarized and glutamate release is reduced thereby causing activation.

So, this is how is it different from conventional nerves; conventional nerves stimulus stimulates the cell here stimulate sort of suppresses the cell. So, it is the inverse of inverse of the inverse of the physiology we have so far talked about. So, that is a key difference. So, that is one of the key differences. So, second key difference or the key point which I would like to highlight here is please do recollect tone.

Now, tone is a feature in skeletal muscles, and you have a resting state of activation. Now the resting state to refresh thoughts is the dynamics between the muscle spindle, the muscle cell and the gamma neurons. And so, there is a, there is a loop which ensures that there is a basal level of activation of a muscle cell, which can be changed when there is you know actuation physical thought process which produce muscle activation.

A similar kind of mechanism is there in which, the cell is already at a state of excitation. So, it's at a higher level so, it's at a higher energy state exempt you know taking absorbing energy and when light falls the energy level comes down and that causes the downward cascade in the in the subsequent this one.

So, it's a funny system because it is almost directly opposite to what we have learnt so far in in a either skeletal muscle and nerve physiology and the mechanism is the inverse of that. So, the that is the key reason why I thought I should show this picture.

Now, generally these discussions are on rods, and it is assumed that they work for cones and if you look at those papers, they have been they are pretty old and it's the data which we have. So, our understanding is based on these issues. Now within the cell there are lot of amplification mechanisms which CGMP pathways and that causes I have discussed this in one of the earlier classes.

So, amplification so, and there this is a lot of this is based on this entity called rhodopsin which is vitamin A based and it's called Wald's cycle for the and I recollect that this is a

Nobel. So, there are lot of Nobels in vision there are lot of Nobels in vision a lot of Nobels to be obtained in vision and this is one of those areas.

And the mechanism of vitamin is something which you can read up for those people who are interested it’s a complete biochemical process. But for all the simplicity if you look at the with the action potential.

Action potential is pretty simple it has minimal set of minimal set of actors and those actors do very you know very simple processes, but if you look at it if you look at it there is a lot of CGMP and then there is a lot of protein change conformation and then that is neurotransmitter release decrease in neurotransmitter release.

So, these are the ways in which it’s a very complicated affair to simply put. So, a complicated affair for something so fundamental as vision. So, that is the idea which I am trying to highlight here yeah

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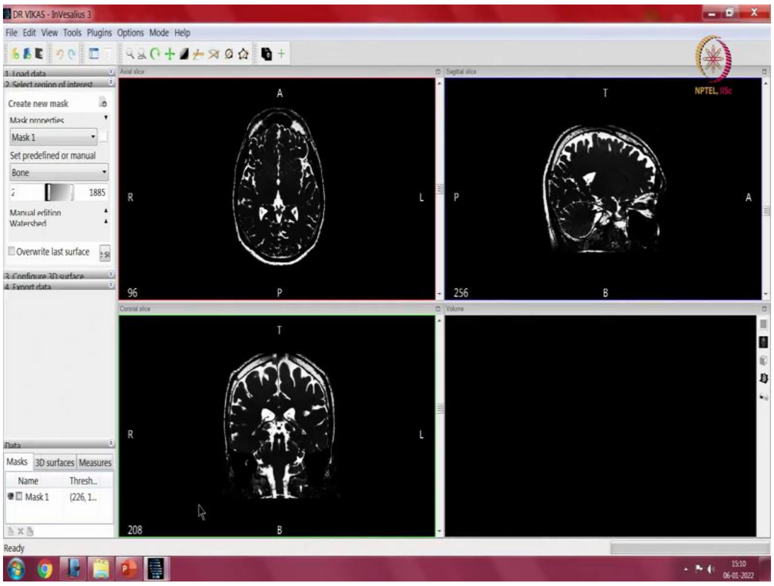

So, we now go into something else which I promised to teach you.

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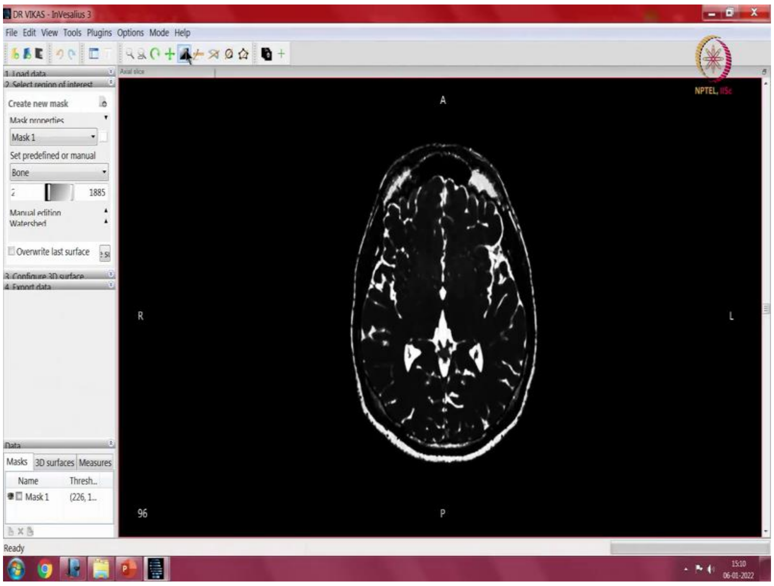

And that is given an image how do you ensure that you yeah.

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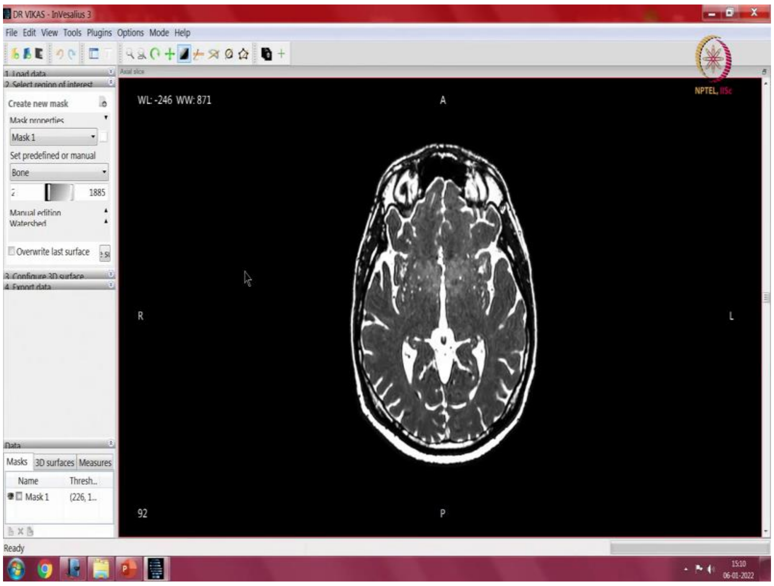

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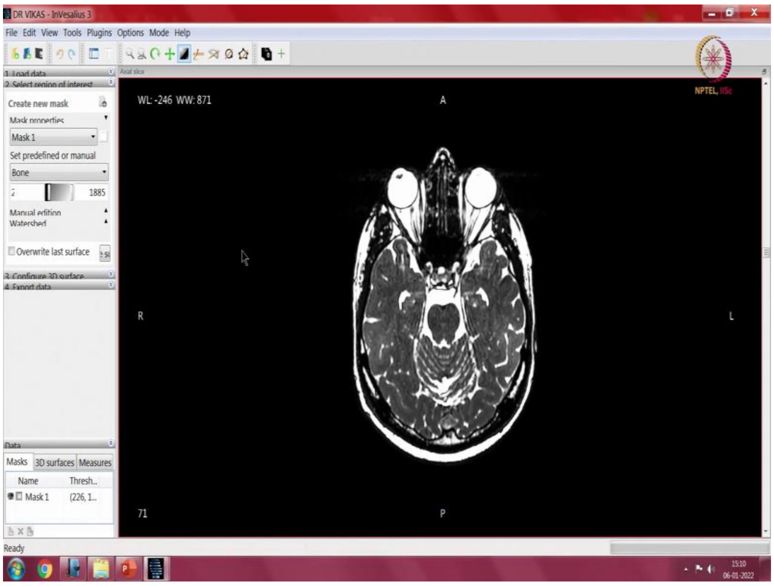

So, MR imaging you are finding out the optic apparatus in the MR imaging. So, that is what I planned to show you need to know some parts of it.

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I had highlighted the various parts in the prior discussion, and I would like you to show that these things actually exist.

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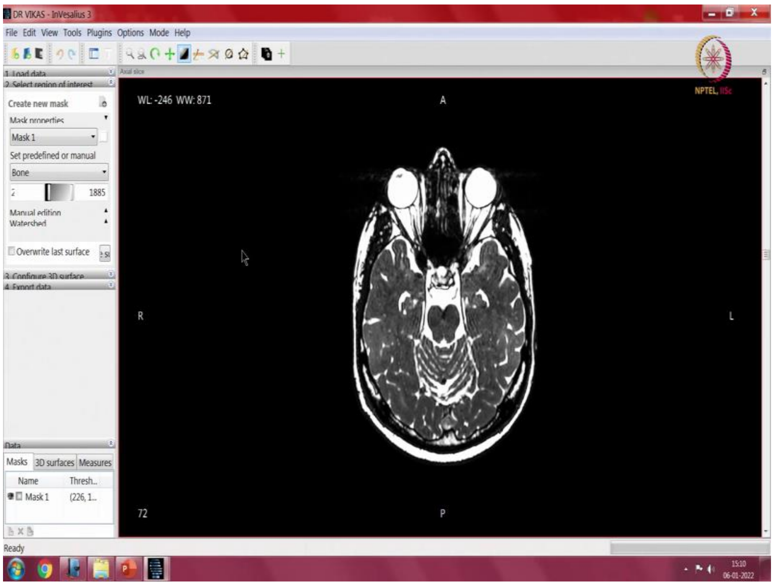

So, that is the, that is the basic idea. Second thing is as an exercise in anatomy it is necessary to you know correlate between line diagrams and how those things actually look at list in an image. I can showcase each of these in surgical videos, but I do not think that is relevant for this audience. So, we start with yeah. So, how I plan to do this is I use the pointer and then show ok.

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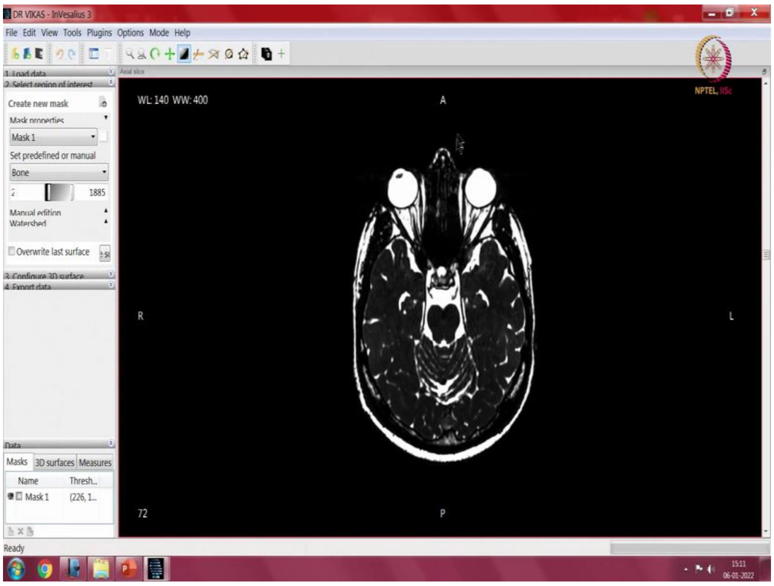

So, what is obvious over here is the eye both sides left and right and two eyes. You can see that it is the long axis is somewhere over here, and the optic nerve comes out over here. So, this is the optic nerve which is coming out of the eye that is the optic nerve.

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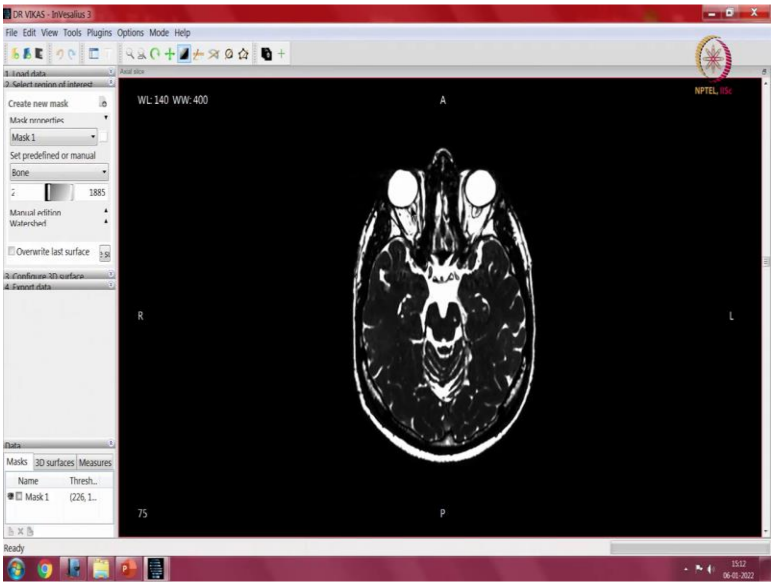

The central dark structure is the optic nerve. This whole thing is the orbit.

So, these things which are you know you can see some lines over here in 3D space you should imagine that they are, they are like cables you can see one cable over here and another cable over here, similarly there is one cable over here and that is another cable over here I think, yes.

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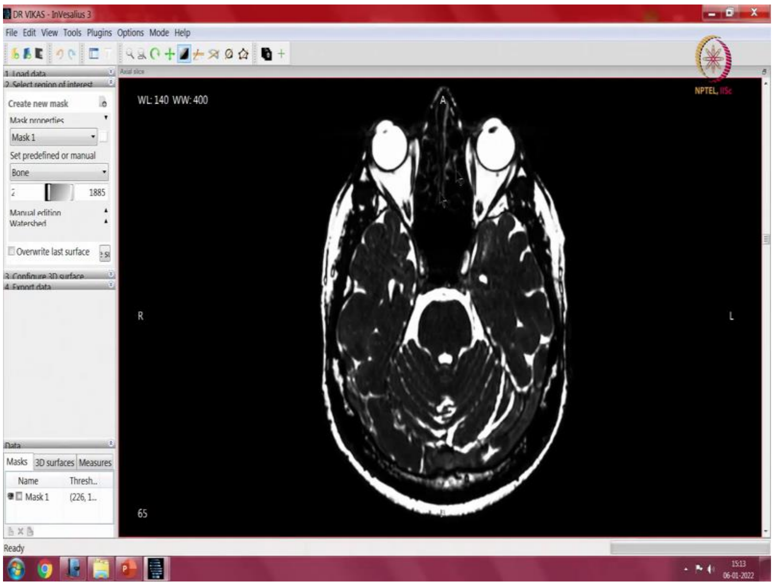

So, you can distinctly make out the cable here. So, these are the ocular muscles.

So, ocular muscles are muscles which are attached from the bone over here and then they control the movement they have four or much total of medial, lateral, superior, inferior, intorsion, extortion so, six movements. So, three degrees of say three degrees of freedom for the eye. There is also something called protrusion and some intro intrusion something like that which is I do not know how exactly it can be manipulated, meaning I cannot recollect the mechanism of manipulation three degrees of freedom.

So, the globe is here you can make out these black entities which are the which is the lens, this bulge over here is the cornea, this is the sclera. The image intensity resolution is not sufficient enough to you to understand about yeah.

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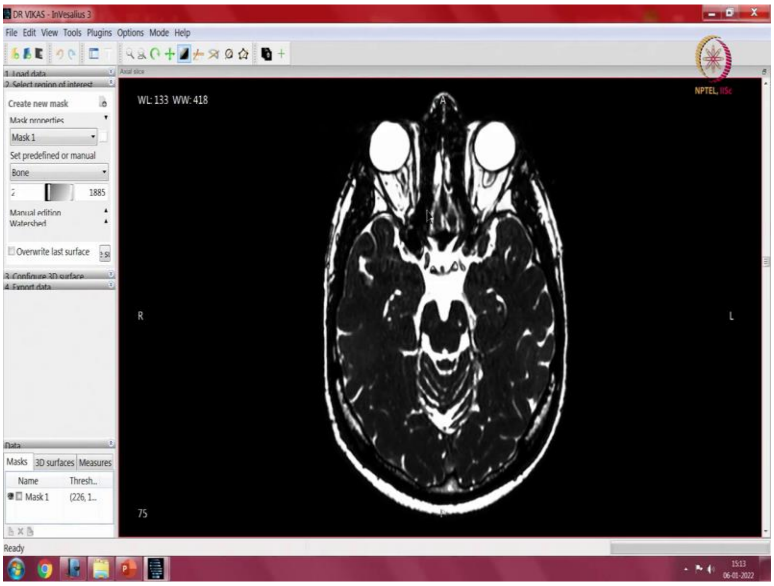

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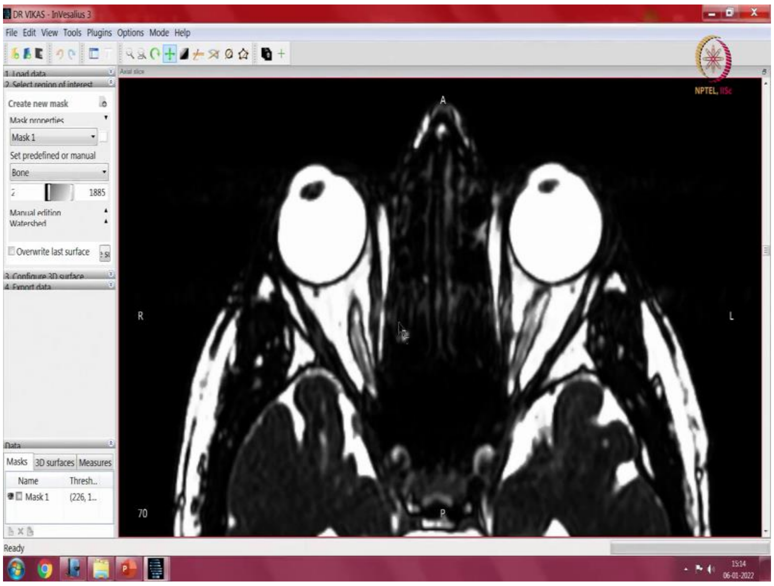

So, it’s not possible, meaning as I told you its not possible to find out where the fovea is exactly, but this is the lens, this is the midpoint of the cornea. So, central line would fall somewhere over here optic nerve is here. So, optic nerve and the optic nerve which is the optic disc, and the macula are separated by some distance.

So, the central part is the optic nerve, here optic nerve here optic nerve here. So, this central dark thing is the optic nerve. Please note again there it is redundant. So, there is some its curved here because of for allowing movement of the nerve to accommodate eyeball moments. So, this these two structures. So, there is one structure here, there is one structure here, the other structures we will see in different imaging please remember again that this is axial MR imaging from the classes on MR which I have taken earlier.

So, the optic nerve goes back out of the out of the eyeball and goes into the skull.

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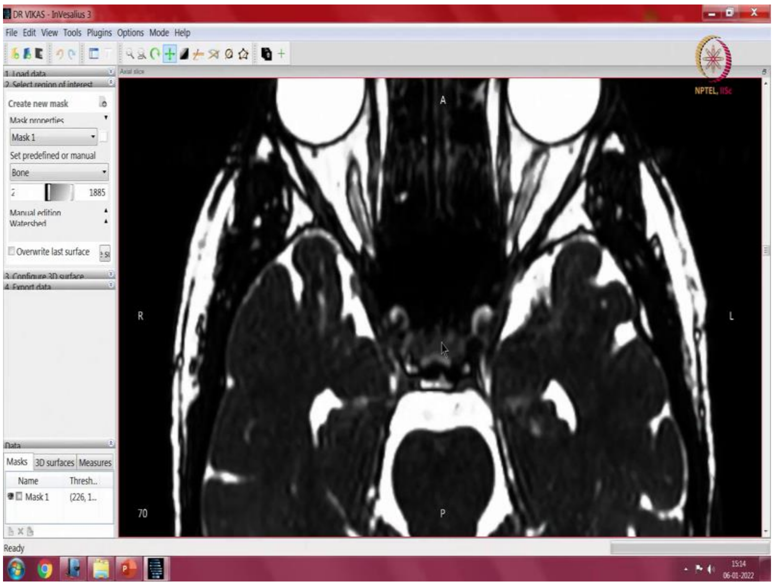

So, it to showcase that I have to change my intensity and yes.

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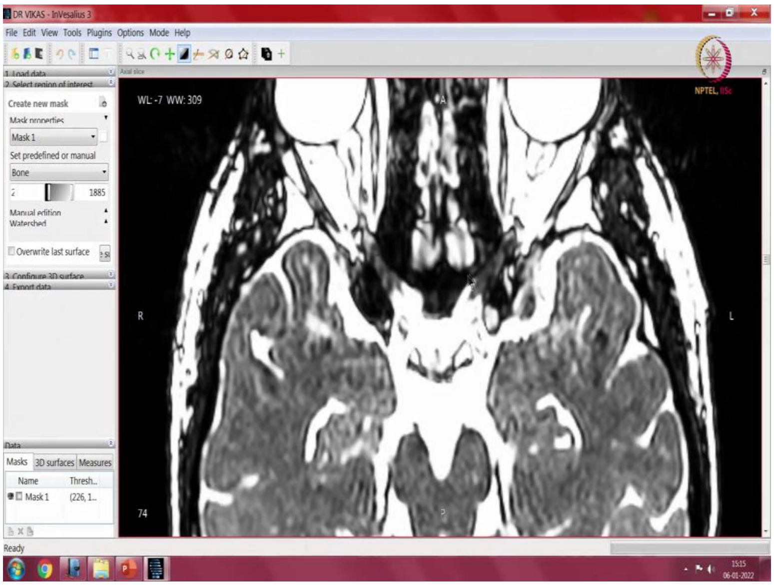

So, here note this is the optic nerve over here, optic nerve over here and its coming into the skull through this place. So, that is the optic canal, same thing seen over here optic canal. Now once the nerve comes out into this into the skull, yeah.

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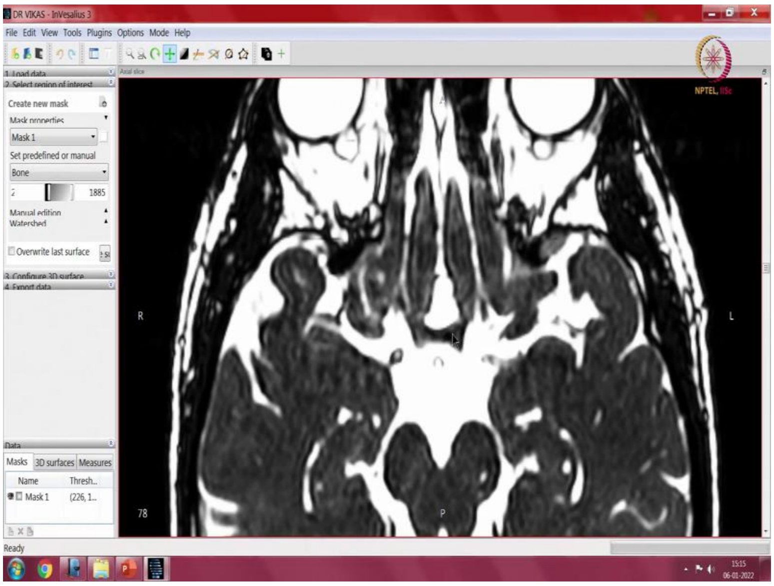

So, its joining together. So, optic nerve optic nerve coming back you can see it joining over here. So, that is the joining this part is the optic chiasm. So, these are not mythical entities that is the that is one of the messages here these are not mythical entities suitable for line diagrams, they actually exist in each one of us. And it is relevant to understand this because a lot of the subsequent discussion is based upon this understanding that there is there exists optic chiasm there exists optic nerves.

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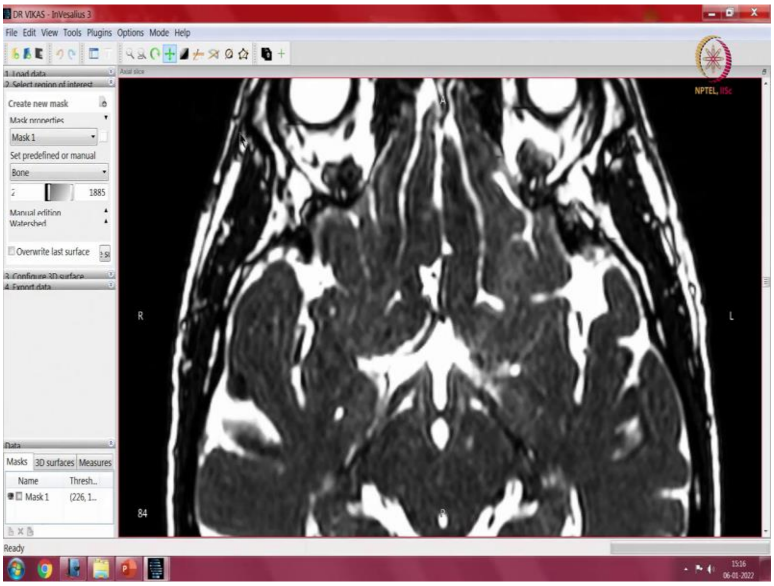

Now, this is optic nerve goes back to chiasm and then splits again. So, there are two optic tracts. So, this is one optic tract, and this is the second optic tract and you can see this is the brainstem incidentally.

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So, by the time we reach the brainstem again you please remember that this thing is the junction between the lower part of the thalamus and the midbrain. So, you can see distinctly that this is the optic tract here optic tract here and that goes around the midbrain you cannot make it out in an image and the bulge upper bulges goes back.

So, on the back you can see two bulges here one two.

So, the upper bulge would be the superior colliculus. Superior colliculus and the lateral geniculate body would be one of these things. So, operatively we can see this as distinct fairly distinct structures not very distinct structures fairly distinct structures, but on an imaging, you would not see, and I think I made an explanation I did give an explanation on MI imaging of how axial resolution versus inter slice resolutions are different.

We are giving an effective resolution of around 0.6 mm for a given machine though we are evaluating hydrogen ions in terms of physics.

The scale is different because apparently the technology does not use the amount of signals which are required to reconstruct. So, there is a, there is a lot of, there is a lot of gap between what is the potential of MRI to the and I think I discussed also why there are limits to you know there are biological limits to getting better resolutions. So. that is the, that is the LGB. Now where does the fibers go subsequently?

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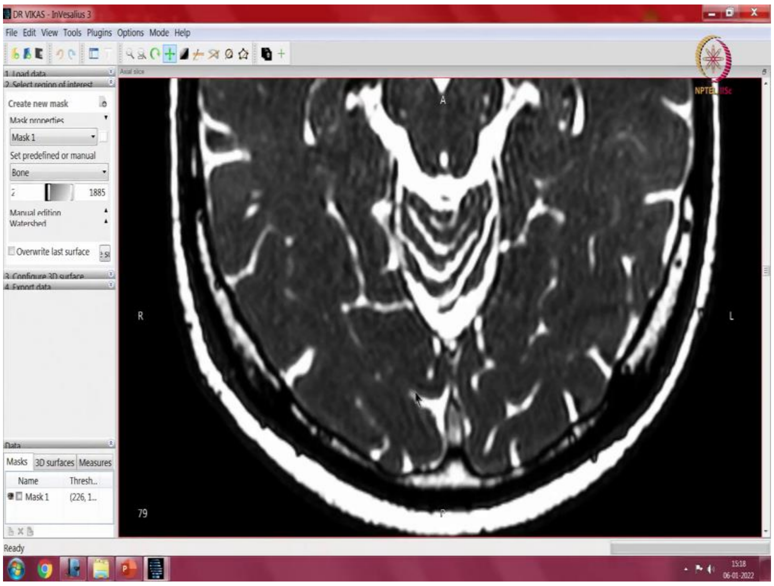

So, fibers go subsequently into the occipital cortex. So, we need to first trace out where the primary visual cortex is. So, primary visual cortex is difficult to interpret yeah. So, this is the primary visual area 18 would be area 18 yeah and this should be area eighteen we will see if we can make it better seen in the other sections.

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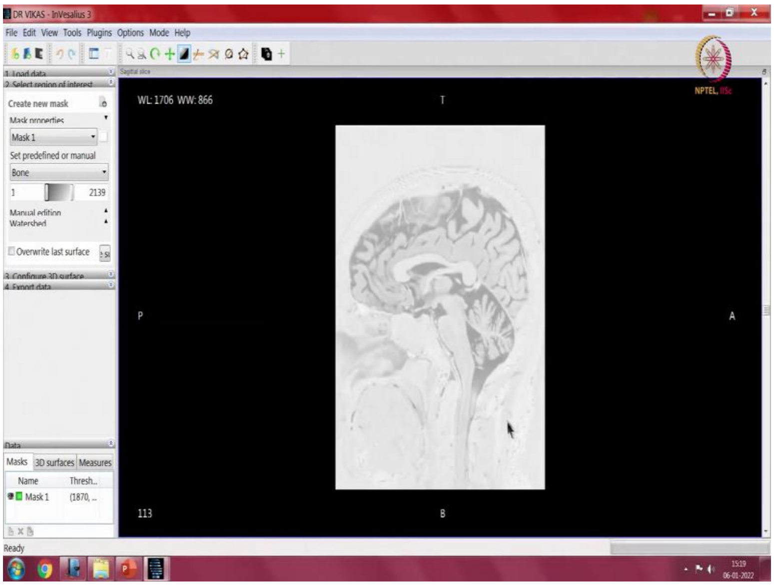

Yeah so, this would be the visual cortex area. So, the visual cortex area this is sagittal section remember.

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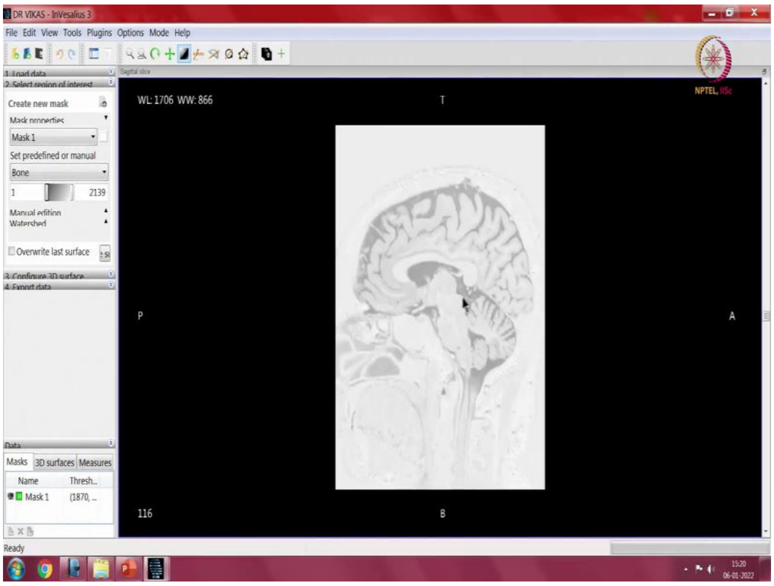

So, you can see two of the bulges here. So, this would be the superior colliculus which I was referring to in the pathway and this is midbrain. So, a little refresher on the anatomy there is a midbrain, pons and lower down this is the medulla, the spinal cord from down. So, midbrain the posterior part of the upper part of the midbrain superior colliculus, inferior colliculus is over here I would be referring to the inferior colliculus in the pathway for hearing. So, that is how its connected.

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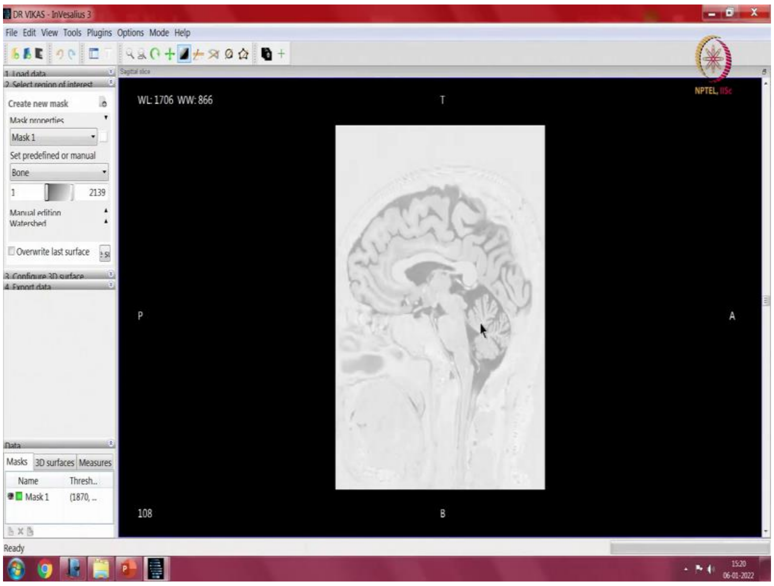

So, visual cortex.

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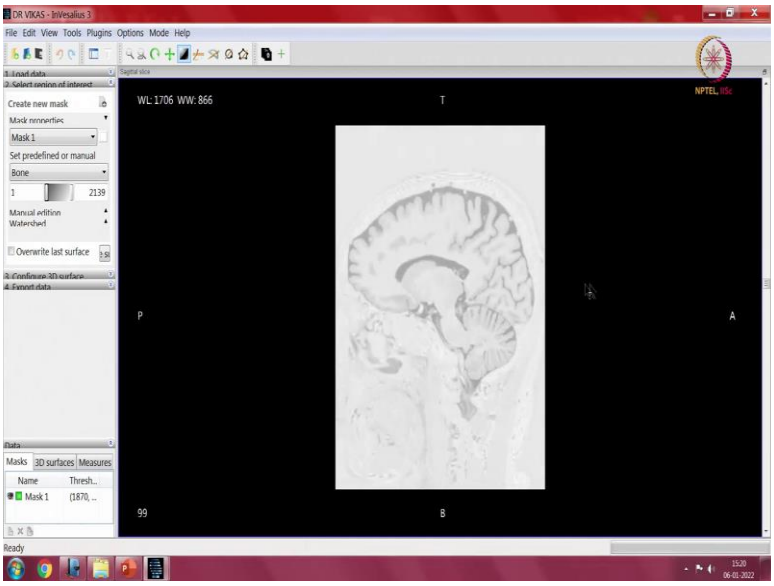

Now here also there is a lot of arrangement. So, the tip which is the largest surface area over here is the central foveal area, where there is a lot more representation of the data which comes from the eye.

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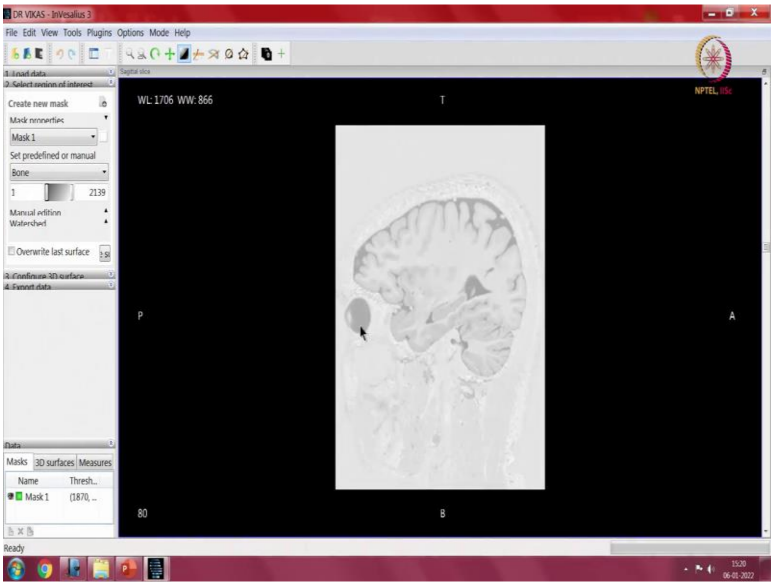

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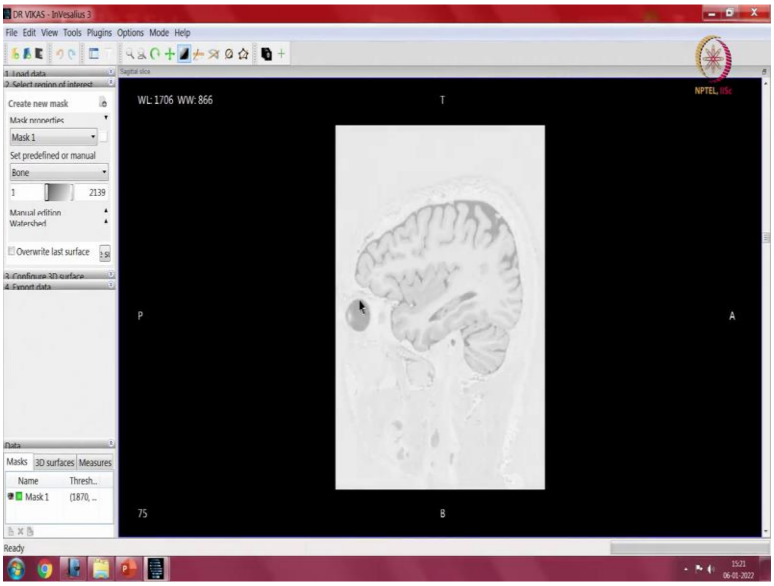

Now we reiterate the how the pathways. So, this is the eye it looks different because the imaging sequence is different, this is the inversion recovery t1 sequence, and you have the eye coming here.

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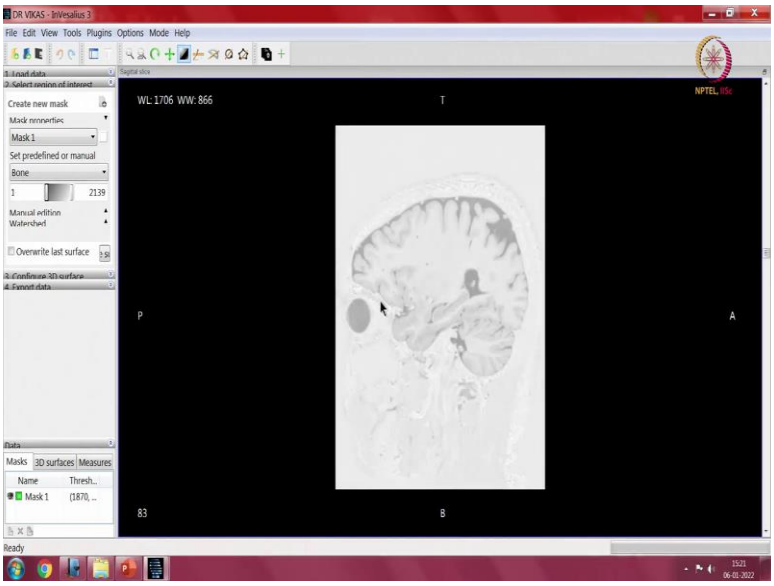

So, this is the optic nerve cannot make out the muscles over here, but yeah maybe even slight shade over here which is indicative of the muscles.

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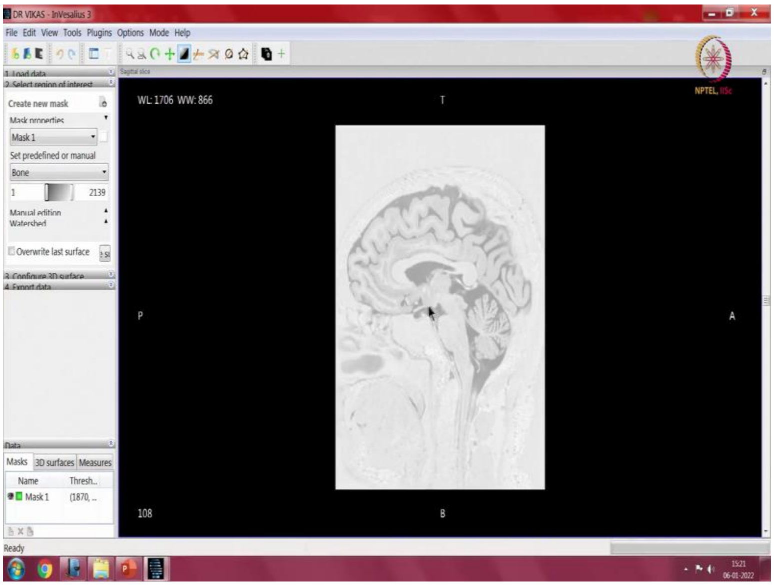

So, then it goes into the head, and this is the optic nerve white structure seen over there is the optic nerve closely related to the hypothalamus, the hypothalamus is here mammillary bodies are here. So, that is how it is.

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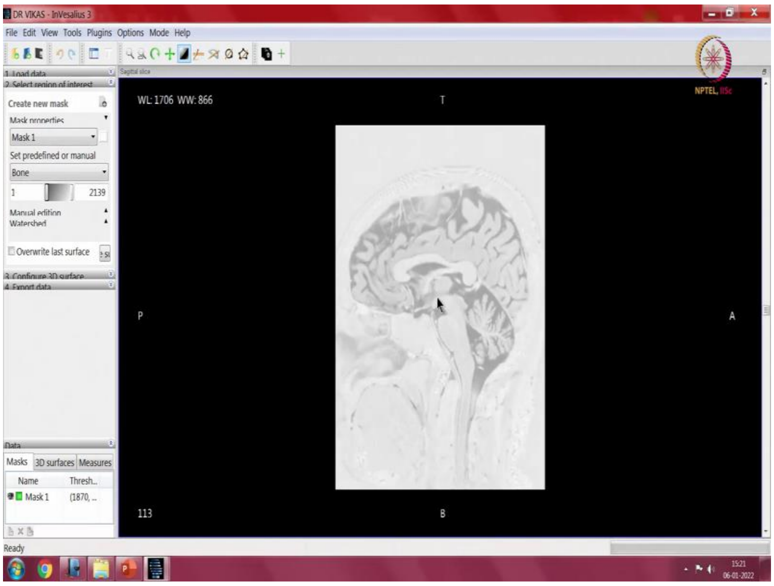

And you cannot make out the chiasm, because you are looking you are looking you are looking perpendicular to it as opposed to the other axial section in which you are looking normal meaning you can see the optic chiasm you cannot be able to make this out over here.

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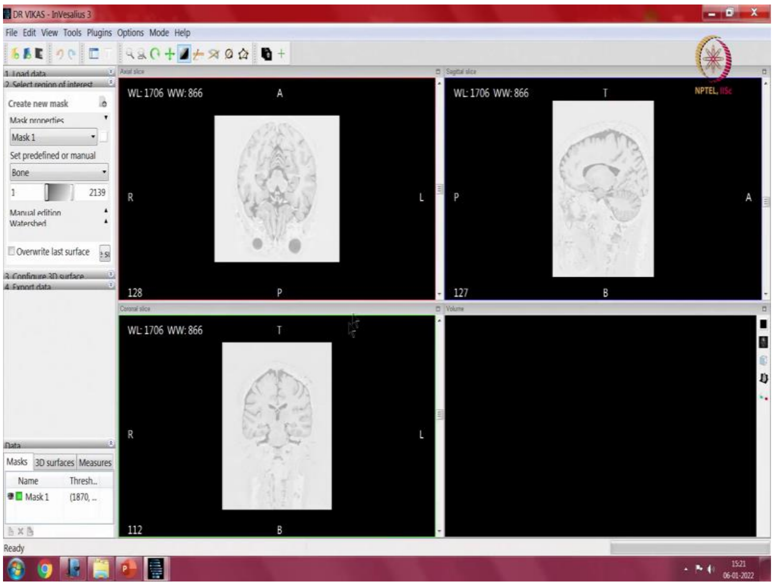

So, let me see if I can get the optic tract going around the going around the midbrain yeah.

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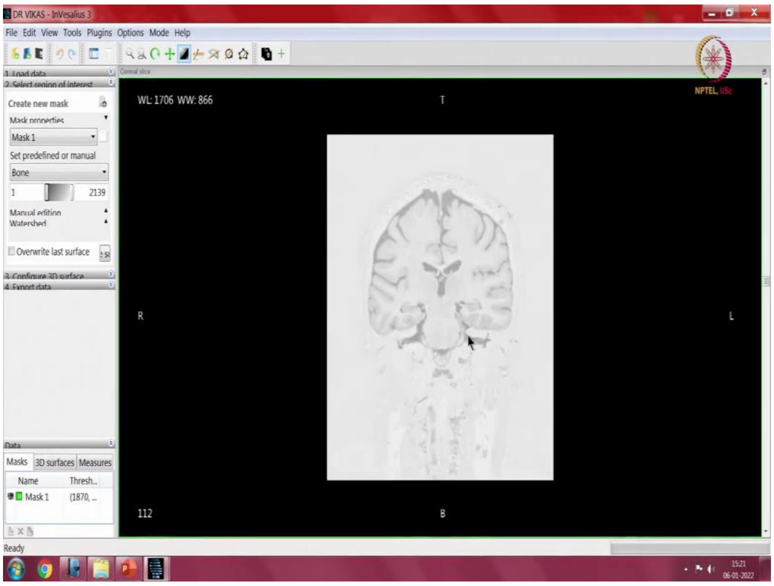

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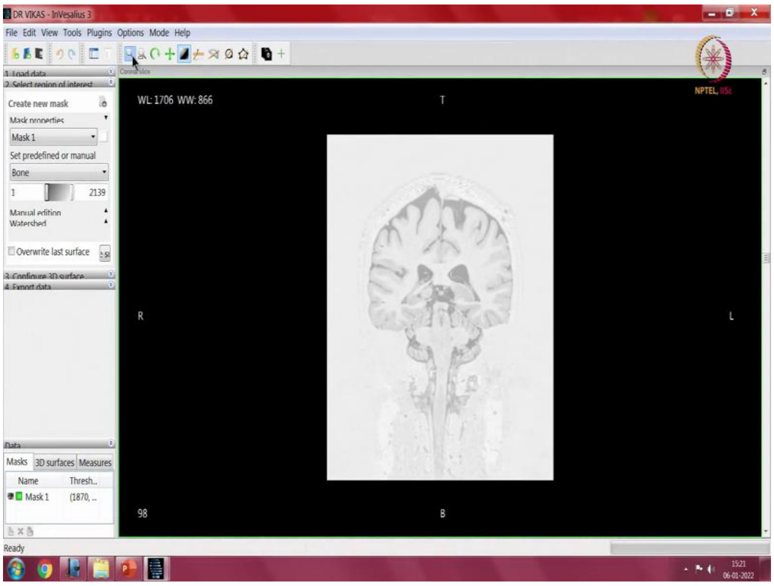

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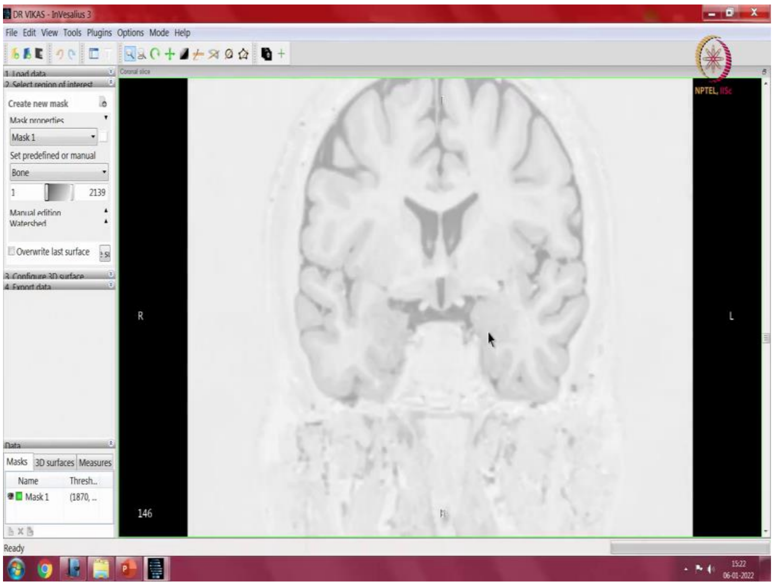

So, we will start back again from the eye easy to recognize the eye.

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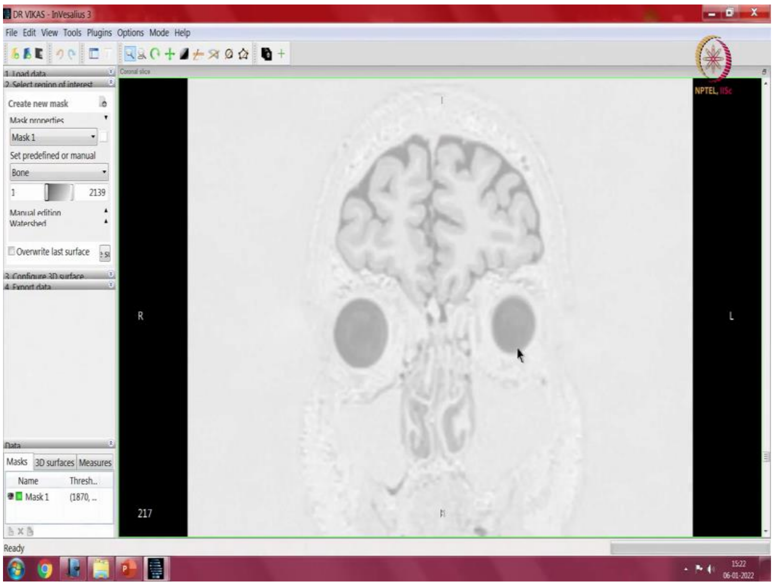

So, this is eye left right this is left side trace it back this is the optic nerve optic nerve optic nerve optic nerve optic nerve.

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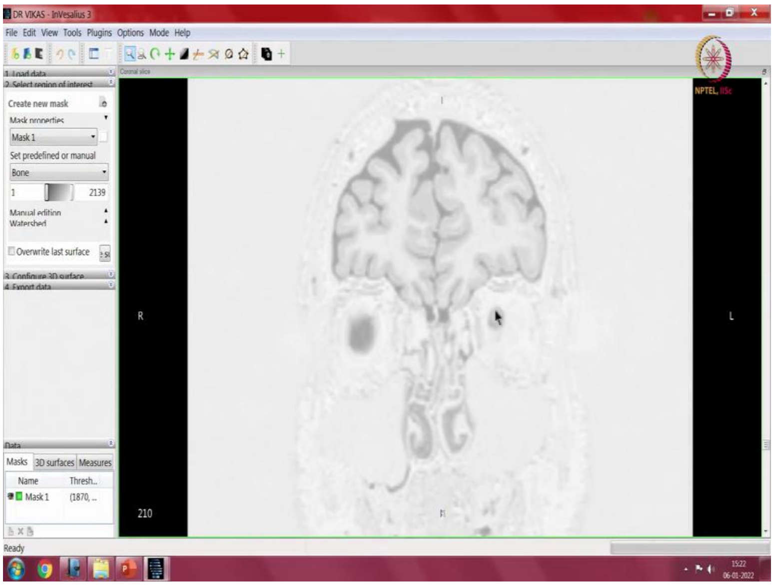

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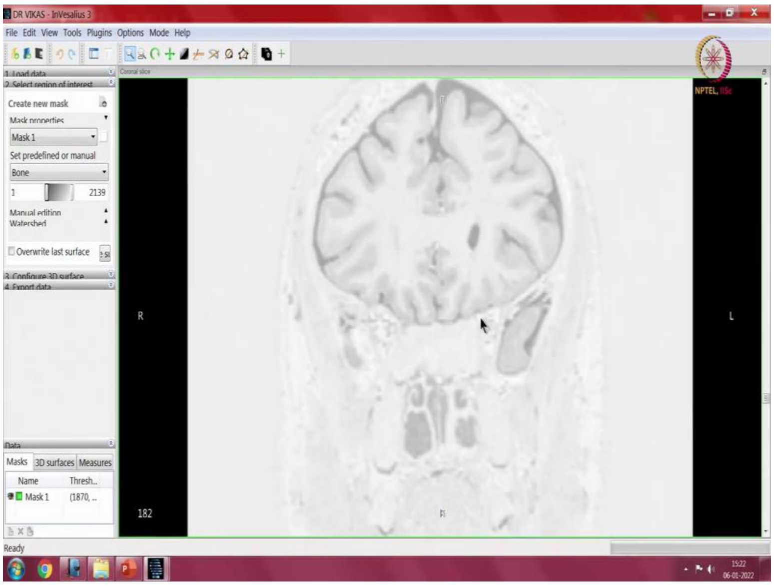

And going into the skull not very clear because this imaging sequence is different.

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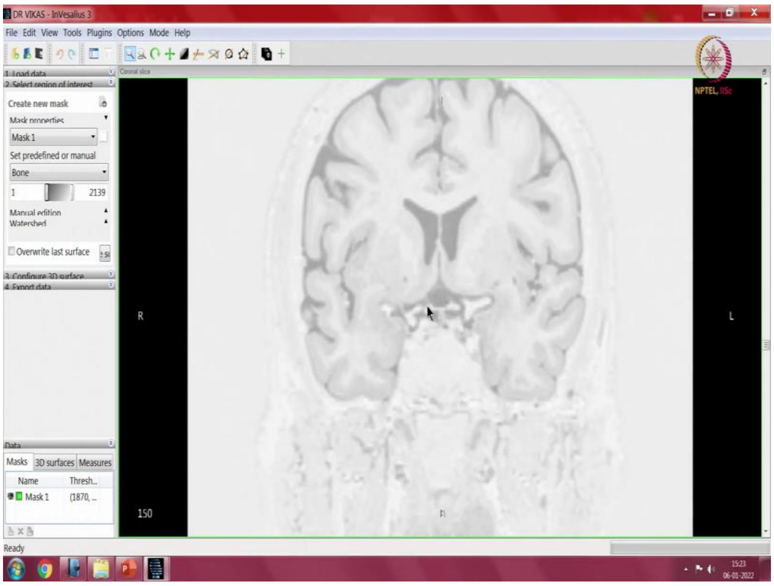

We will trace it inside. So, you can see this white structure here white structure here which is the optic nerve both coming towards each other.

So, notice this notice this. So, I go back front and then come back they converge and where they converge this is the optic chiasm. So, that is the optic chiasm and then there is a split. So, this is the optic tract we trace it back going back it goes separately you can make out this is slightly more whiter than the other structures.

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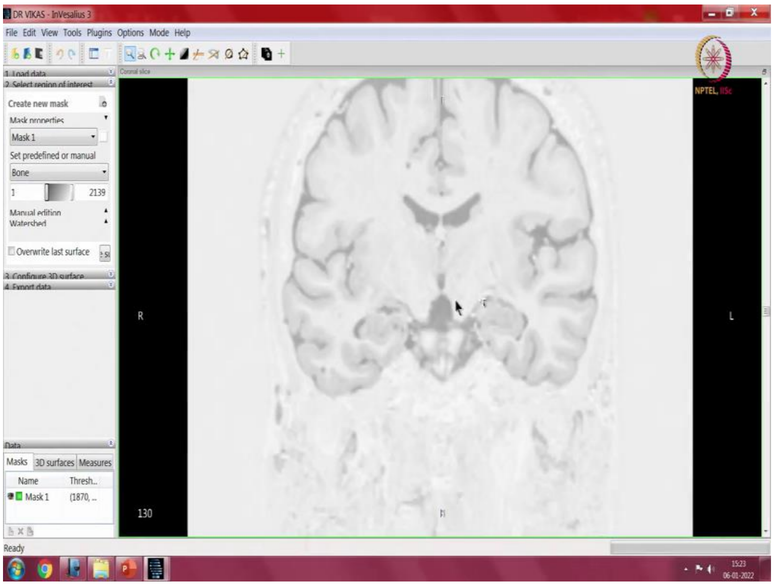

And then when it is over here and here it is converging back you lose track of it because the imaging is not able to pick it up its somewhere here and converges to the LGB.

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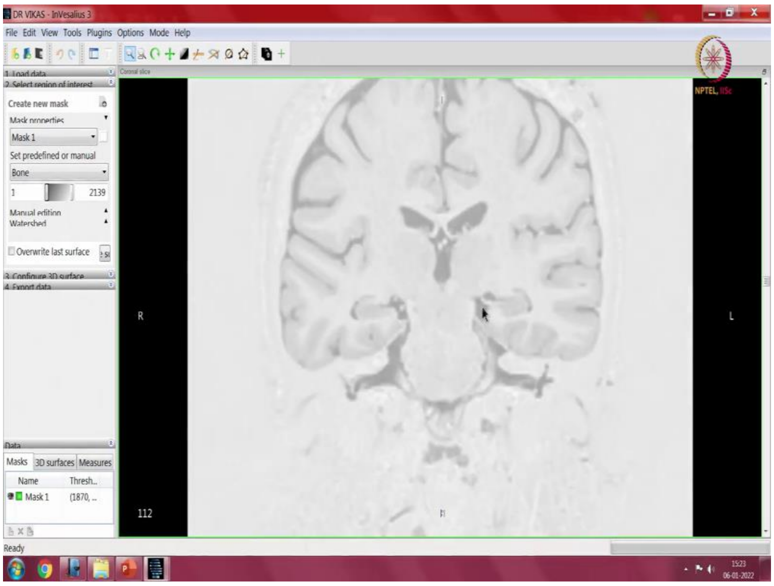

So, that is how that is how it goes there

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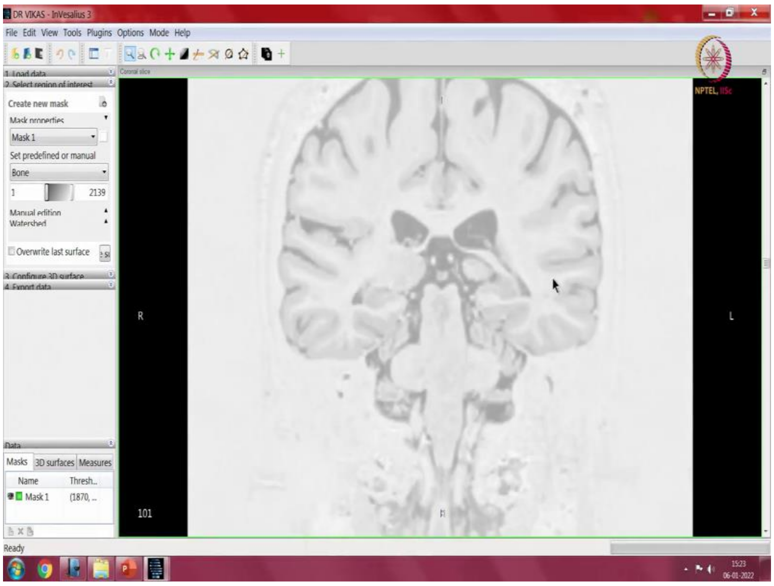

In the temporal horn. So, this is the temporal horn, temporal lobe and in the temporal lobe the optic radiation makes is situated in this region situated in this region goes all the way back into the occipital cortex, where the visual cortex is present.

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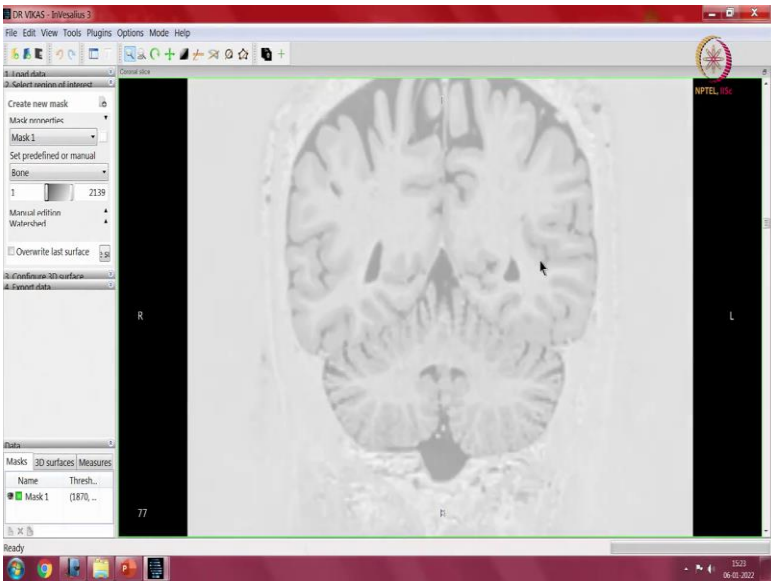

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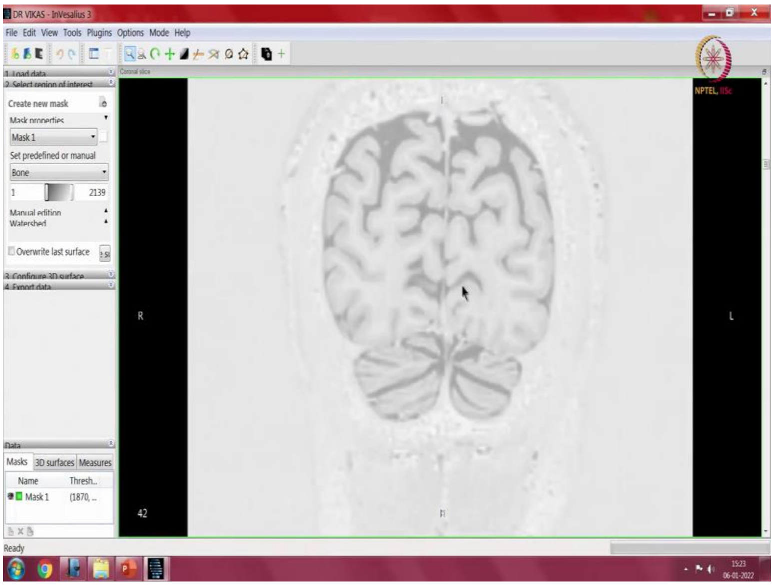

And the primary visual cortex would be here, secondary and associative visual cortex is over there.

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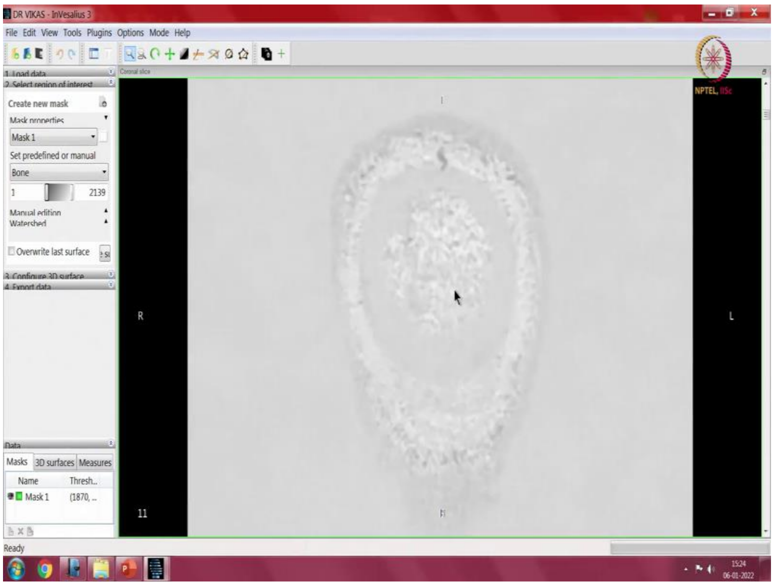

So, the tip of the occipital lobe which is what is right over here is the place where macular vision is local located both sides.

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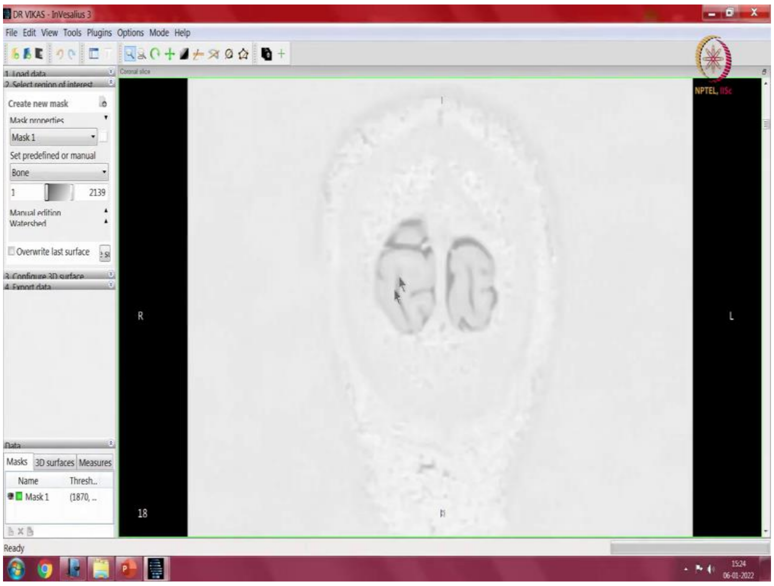

So, that is how the entire apparatus is distributed.

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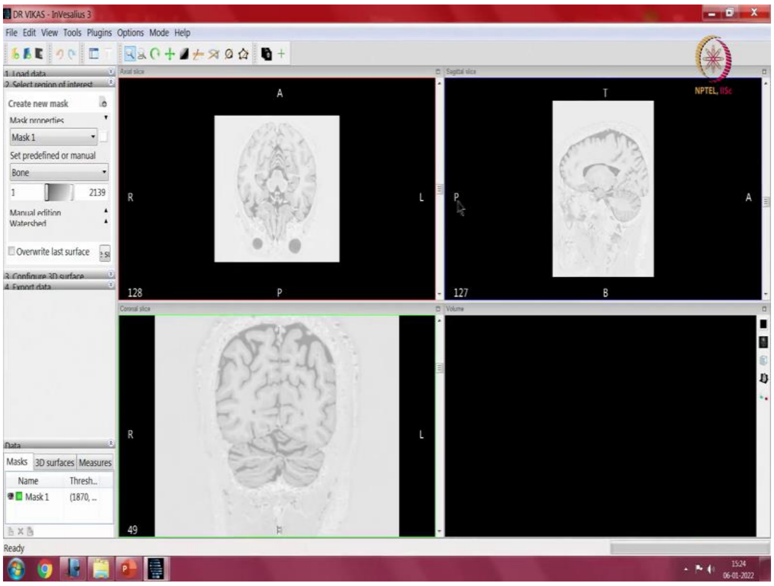

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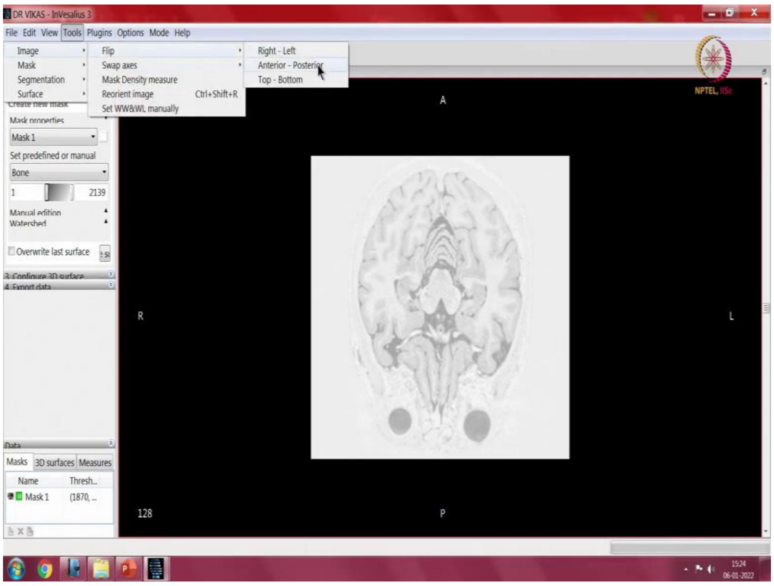

To complete the story, I would again go back to axial imaging I have to flip the image here.

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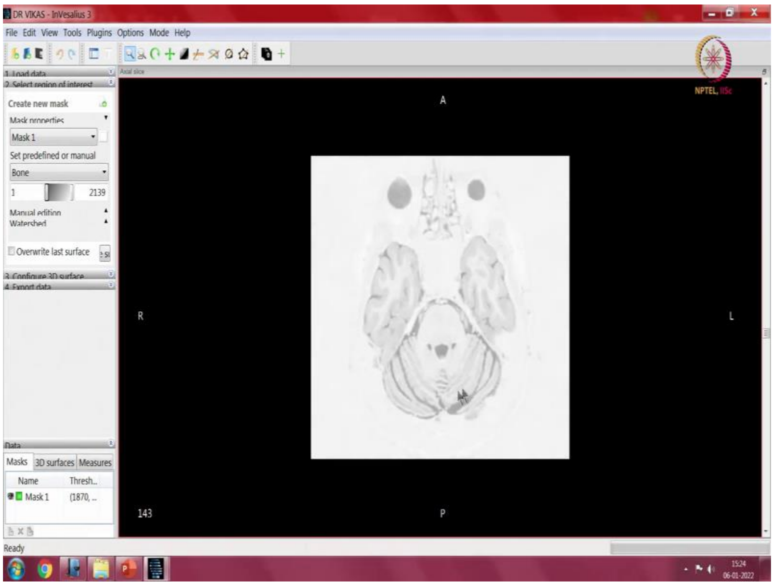

So, we will trace it back from the occipital lobe cerebellum seen.

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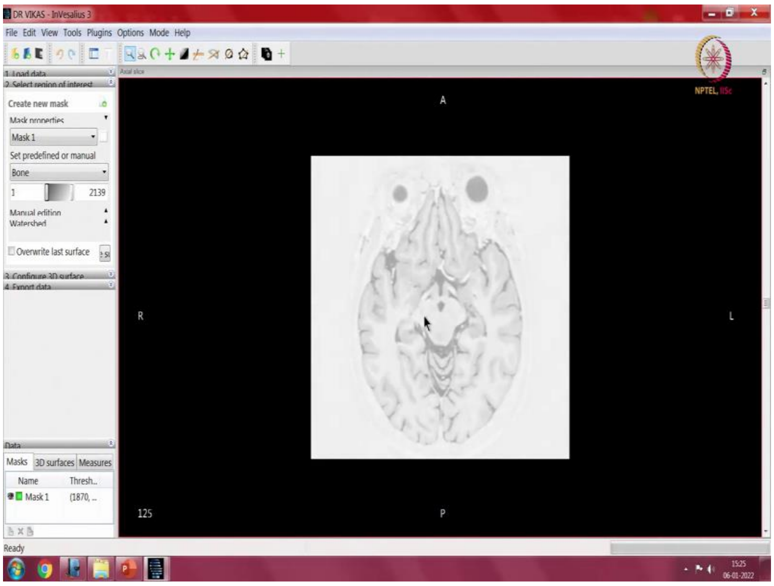

So, above the cerebellum is the occipital lobe, this is your visual apparatus.

The biggest sulcus scene should be the visual area on the banks of it is the associative visual area. So, that goes all the way over here.

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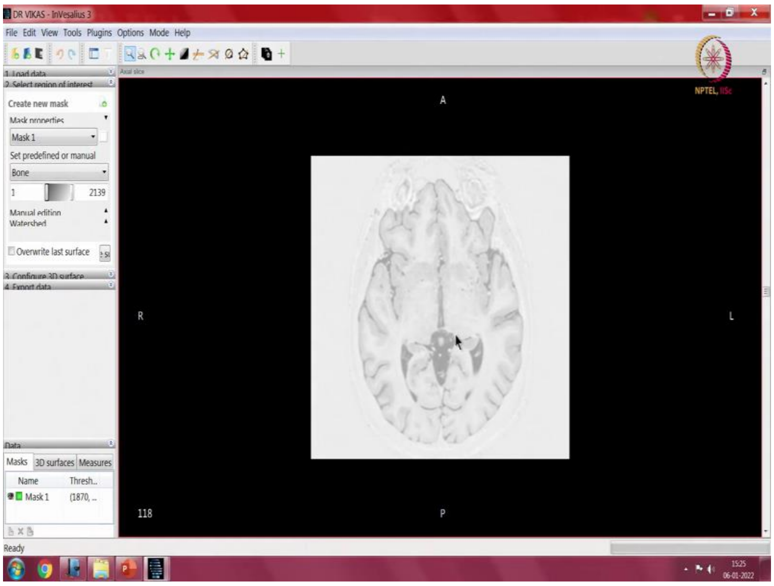

Somewhere here it would converge to the LGB which is situated in this area lateral geniculate body, and from the lateral geniculate body its going across the brainstem the first trace, which you are seeing is the optic tract optic tract here optic tract here.

Then when we trace it yeah. So, it is just seen over here, just seen over here front of the midbrain just seen. Then it comes towards each other comes towards each other forms the optic chiasm and from the optic chiasm the optic nerve start going to opposite side. So, optic nerve optic, nerve and then you can see the optical going into the eye. So, that is how you interpret the visual apparatus.

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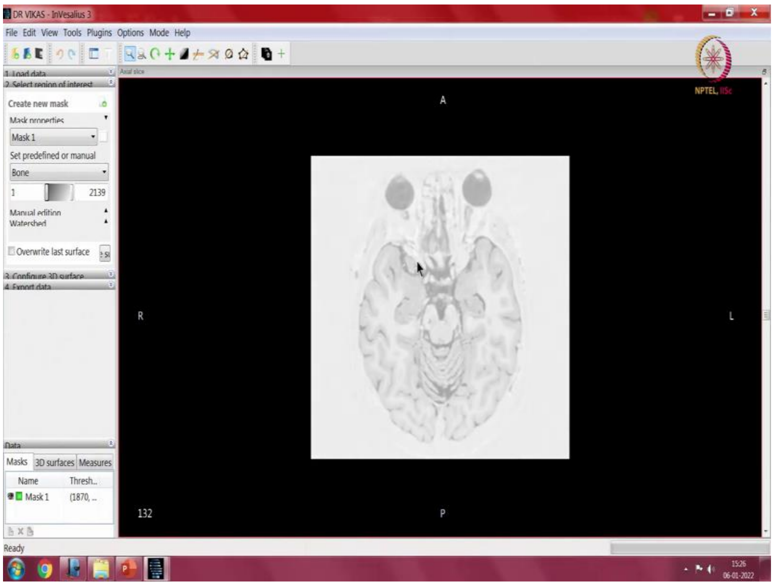

So, it's to give a sense of direction and shape to the stuff which is under discussion.

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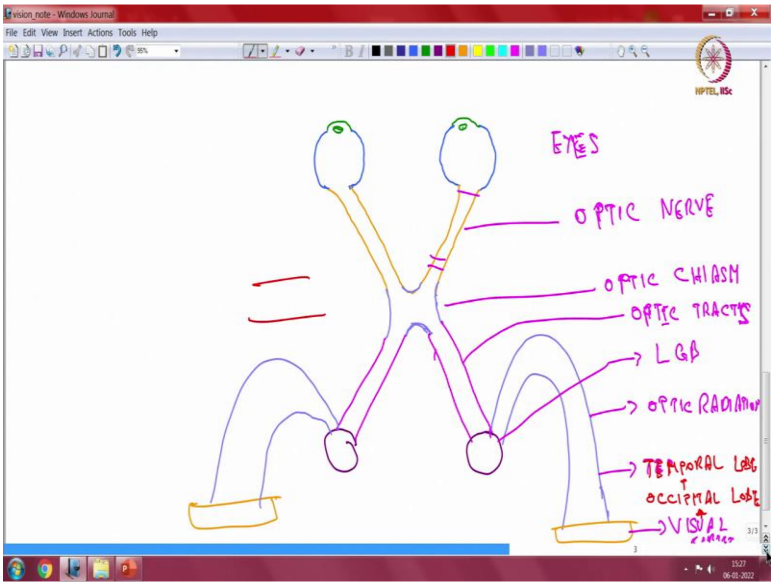

We come back to this diagram. So, what is specific and what is what becomes more and more funny with many of these things is, the people in AI would appreciate and I hope it rings a bell when you design your networks and or rather more than that use any kind of complex CNNs for various purposes that many of the designs are coming from this particular diagram and the subsequent discussion is for that purpose.

Now, splitting of fibers is not a very straightforward process. So, what happens over here is not a very not very logical for people who have not read about it.

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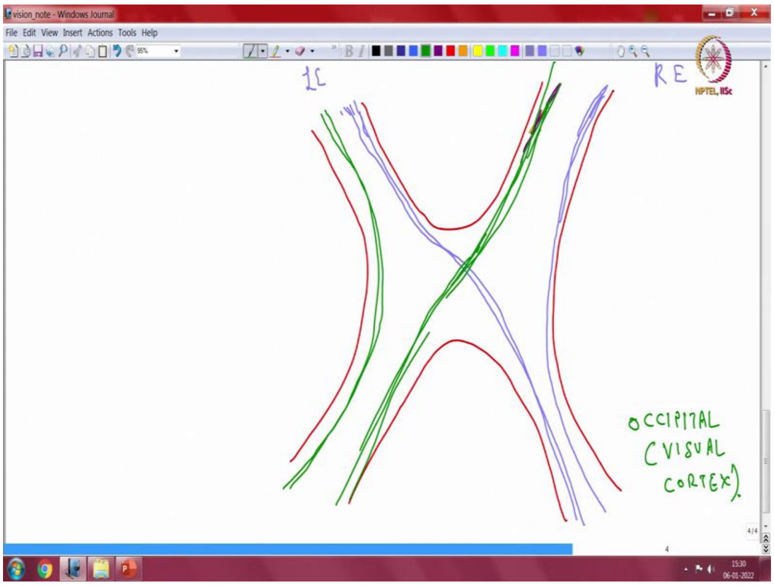

So, here I am dropping the optic the eye, but using. So, this is how the outer surface of the nerve and chiasm, and tracts would look like. They are very smooth entities they look like distinctly like somewhat very entities. Now what happens is a part half of the fibers actually half of the fibers which are coming from this would be the left eye and this is the right eye.

So, these fibers actually cross over here and then continue on the opposite side. Now for completion's sake I would draw at the same color that these fibers which are half of this now half of this now would continue in the same direction. So, that is a crossover remember crossovers have been discussed earlier crossovers happen in the medulla for the motor fibers, which come all the way from the cortex to the spinal cord and then there is a decussation in the medulla from which by which they go to the opposite side.

So, there are several kinds of this fibers which go to and fro from one side to the other side some do not go and that is a very unique feature of the nervous system, it's been very religiously practiced across various hierarchies of the nervous system and this is one of the places, where this crossing over business and uncross both its not that the entire set of fibers cross over, but part of the fibers crossover and part of the fibers don not cross over.

Now, if you look at what happens on the right eye part of the story, the right eye part of the story the the nasal part. So, this part of the fibers will converge cross over to the opposite side and continue on the opposite side. Whereas the one set of fibers which are on this side will continue on the continue on uncrossed. So, there are crossed fibers and then there are uncrossed fibers.

So, what actually happens is these fibers instead incidentally go to the occipital cortex. So, they go all the way to the visual cortex and that ishow its hardwired remember that these things are hardwired it is like you have a CNN which is given to you, and you can just put in the input and look at the output.

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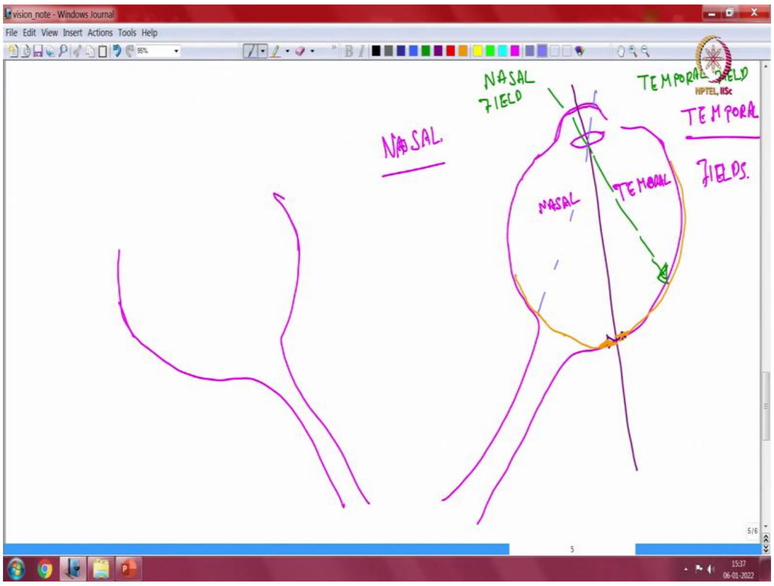

So, the optic apparatus is like this, and it is hardwired that there are yeah it is not part it is half. So, the half part of the story is the next part of the story.

So, what exactly happens within the retina is something which we can which we need to look at. Remember I spoken earlier about not judging me on my diagrams yeah. So, this is the nose. Now, some terminology. So, temporal region is this part temple is the side of your head a very precious area for us surgically because we access so many things in the head through the temporal region. So, then there is. So, temporal ok. So, nose is you know you have to you have to change it into nasal.

Now, once we done that, we realize that you can actually split the visual field. See I have drawn this line asymmetrically, this is drawn asymmetrically because the fovea is somewhere over here ok, and the fovea is there. So, the cornea would be somewhere over here, that should be the midpoint of the cornea and the lens is somewhere over here. So, that is the visual axis and. So, that is what happens is you split the optic field into a nasal field and then you have a temporal field.

Now, the field is meant in terms of the retina. So, that is a key thing key concept to be understood. So, the there is a nasal part of the retina and a temporal part of the retina. Now all of us who understand basic physics.

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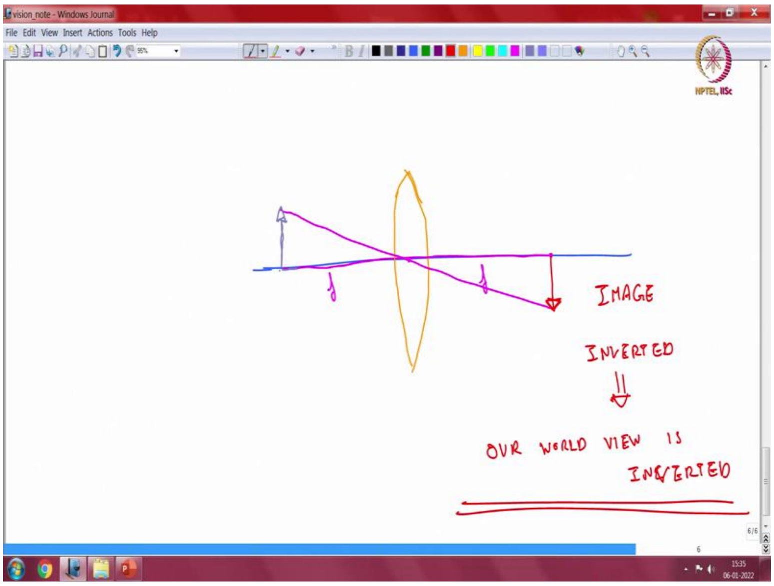

Now we need to go further a little more into physics the principles of convex lens and how images are formed. So, this is drawing back from 30 years yeah, my physics teacher should be proud of this.

So, we have an object and if you do the ray diagram for this central line goes without goes without reflection this is the focal distance and image is formed behind and you have one part which is here, and this is the center of the lens.

The second line should go all the way through the focal length I did not take a scale. So, that is wrong how do I do without a scale I do not have an option on that, but I think the idea should be clear. So, that is how an image is formed and physics remains the same whether it is the eye or whether it's a lens sorry whether it's a camera or whether its whether it's any kind of you know astronomic lens.

So, the image is inverted. So, that implies our world view is inverted those of you are philosophical can contemplate on this statement it is true and whatever we see is upside down, it is taken into the head and then you have a straight view of things. So, it's a profound statement, philosophical statement and also biological statement. So, that is the point.

Now, I needed to introduce that concept into this diagram, because we are looking at something called as fields. So, if you look at what comes to the temporal side of the vision is. So, you have nasal field, and you have temporal field. So, temporal field is this one. Remember I excluded the optic nerve. So, nasal retina and the temporal retina.

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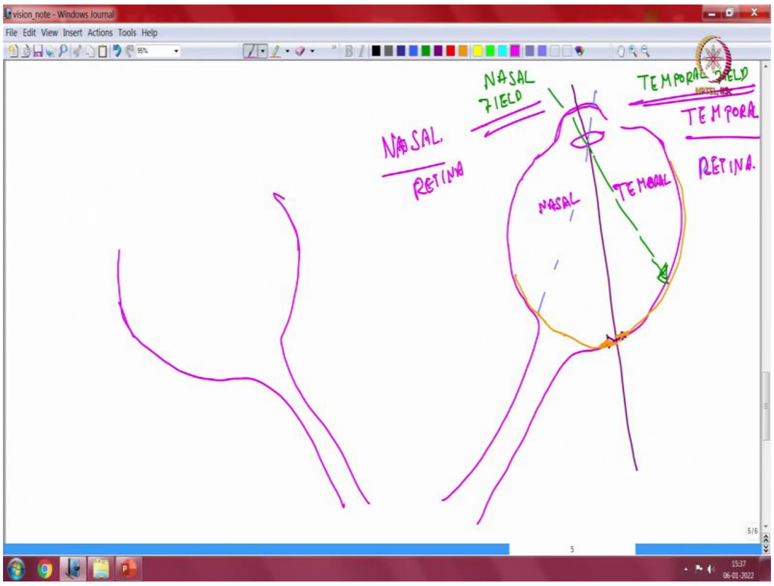

I think and a field right. So, we go to the next part of the derivation.

So, that is how that is how things are and the lens is important, because the lens is responsible for generating inverted images inversion happens not only in the upside down, but also in the right to left part of it. That is the reason you are getting nasal field and temporal field which is different from each other.

Now, we will scale back the images a bit. So, what happens when you actually look at a very distant object? So, when I mean distant object then the eyes are supposed to be parallel to each other. So, when you have a look at distant object fairly large object, because you should not have convergence.

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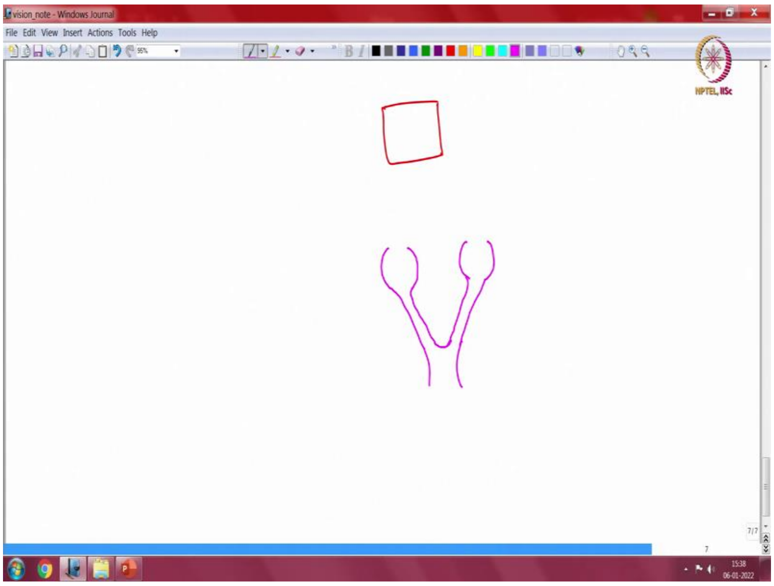

So, then what happens within the eye is this. So, better diagram because otherwise the concept would get lost yeah.

So, we just look we are looking at the retina. So, remember that the yeah. So, for a central object it is not very obvious I think we should shift your, we should shift the object and then it becomes obvious.

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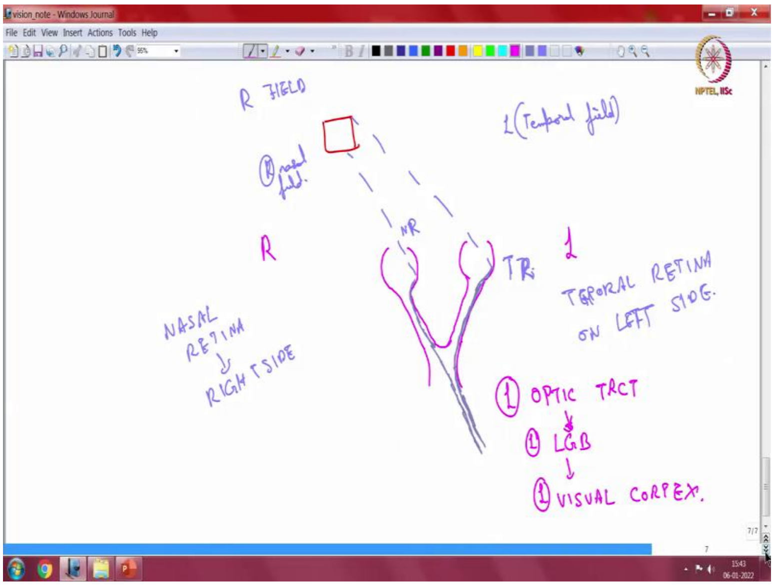

So, suppose we have object. So, this is right, and this is left its anyway please forgive the nomenclature it is not the nomenclature which is important the idea which is important. So, we have an object which is situated over here. Now this object is going to be seen like this.

So, for the right eye it would go to the nasal field and for the other eye it would go to the temporal field. So, that is the temporal field in the sense the temporal retina, temporal nasal retina nasal retina and the temporal retina. So, nasal retina on the nasal retina on the right-side temporal retina on left side ok. So, that’s what happens. So, now, if you look at in field terms. So, this is in the right field ok, and it is.

For the individual eye it would be temporal field left temporal field and right nasal field the situation of the object. So, it is to make you familiarize it is just common sense there is no hard fast physics or anything in this.

Once you understand refraction and lens and magnification it’s obvious, but for the terminologies which are used by medical people I have to, I have to make it so elaborate. So, you have got a nasal field and a temporal field.

So, in general what is outside is temporal field. So, the other what is towards the center is the nasal field one is nose related to the nose. So, both eyes have a nasal field and a temporal field, and when you are seeing an object towards one side which is what I think right side. So, right side there is an object situated over there it goes to the temporal retina on my left side nasal retina on my right side. So, that is what is pictured over here.

Now, let us look at fibers what happens to that and then I think my point is made. So, these fibers which are there which will go all the way from this side of the optic nerve and because it is on the outer side which is on the temporal side it goes continuous without crossing over.

Now nasal retina on the other hand the fibers do cross over, but I will draw it in the same color and what happens with the crossover is they still continue into the continue into the left optic tract then they go to left LGB left visual cortex. So, that is the point.

So, the left cortex looks at the opposite visual field and that is the key point which is made over here. So, what would happen to the right side is the right side would look at the left side left part of the field and the left cortex would look at the right side of the field so, that is the idea. So, the distinction is important because I am using terminologies, please remember I am using terminology of field and I am connecting it to a cortex I am not using the retinal side or the quadrant which is responsible.

So, this results in that you know if you look at visual fields of both eyes you get a diagram like that.

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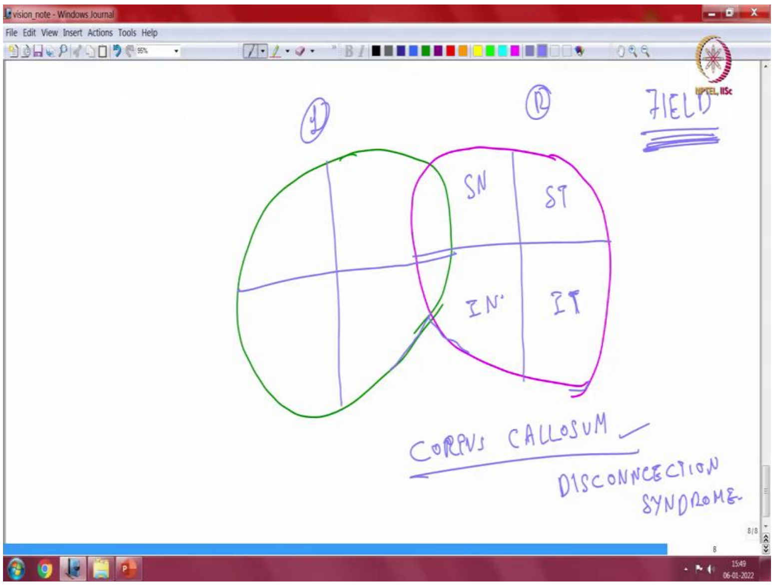

So, visual field of one side and visual field of the other side and then you draw a quadrant, quadrant, quadrant, quadrant. So, this is a depiction of a field ok. How do you explain a field? See you can imagine a field to be symmetric, but a field is not symmetric because a nose projects out. So, that is the reason for this bend over here. So, this bend which is here and this bend which is here is the nasal meaning the nose is projecting. So, that is the concept which you have to get.

So, your visual field, visual fields are asymmetric again and they do not there some amounts of overlap in the center and then there is some amount of separation in the periphery, which is also called as the temporal field so, this is this was discussions.

Now so, superior nasal, superior temporal, inferior temporal and inferior nasal. So, that is the nomenclature. So, field nomenclatures are like this please remember field nomenclatures superior nasal superior temporal inferior nasal inferior temporal.

And this would be on the right side, and this would be on the left side and there is an overlap. So, one set of one set of field data goes to the opposite occipital cortex the opposite field data goes to the contralateral cortex. So, I am confusing.

So, that is how you know the cortex perceives. So, data to the cortex is one part of what you see it’s not the whole and the whole business happens in the corpus callosum. Why do we know that as you cut the corpus callosum either due to surgery or due to injury or due to something like that, people have these things called disconnection connection syndromes? Please do read up if you have the interest time and the effort necessary.

So, disconnection in which it has been proven that data which is shown in one part of your visual field is in the world. So, field data in one side is not perceived on the other side say people who are left dominant and who have numerical ability on the left side, when presented with numerical data in the left field with a disconnection of the corpus callosum are not able to compute, because numerical data goes to the right cortex and therein lies the problem that the right side does not have numerical abilities in left dominant people. So, that is that is a long-drawn explanation.

What I imply is that it’s funny that both the eyes do not see the same stuff you know in very simple terms that is the message which is conveyed. So, both the eyes do not see the same stuff it is both the eyes see different things and then it’s taken to the opposite side of the brain, which in turn is split into two and then as a merging of this data happening at a much higher level it's not even at the level of the visual cortex see cortex as such is the highest level of processing which we have been discussing.

But field data that is something coming from the various parts of a visual field do not go there they are not you know that is not one single blend there is no blend it is going independently to two hemispheres processed independently in two hemispheres and then the relevant secondary or tertiary data gets transmitted to other parts and then you have these things.

Generally, you do not find these diseases in which corpus callosum is cut in that part of too you know have people actually doing it and please do read up the disease states if you are very interested.

But there is also one thing see these things happen in very controlled environments in which you know people are tested, there is there are hardly few things in which you perceive or interrogate visual objects in one field. You would look at a object with both eyes then there is a lot of movement happening either the object is moving you are moving and then you know the information is transmitted on both nasal and temporal and it goes to the brain.

So, what I imply here is the level we will be discussing that next is the kind of integration which happens. So, the data is hardwired you know hardwired from the retina up to the cortex and it is hardwired in this funny architecture in which you know there is a split takes data from the opposite side, and it is field data and that field data is what is compiled by one single occipital cortex.

But the data integration and the subsequent processing everything else is done both sides of the hemisphere, but through the corpus callosum. So, there is a connection which happens much higher up than what you would generally imagine for something as crucial as vision.

So, that is about visual fields and things like that I think I should show you this.

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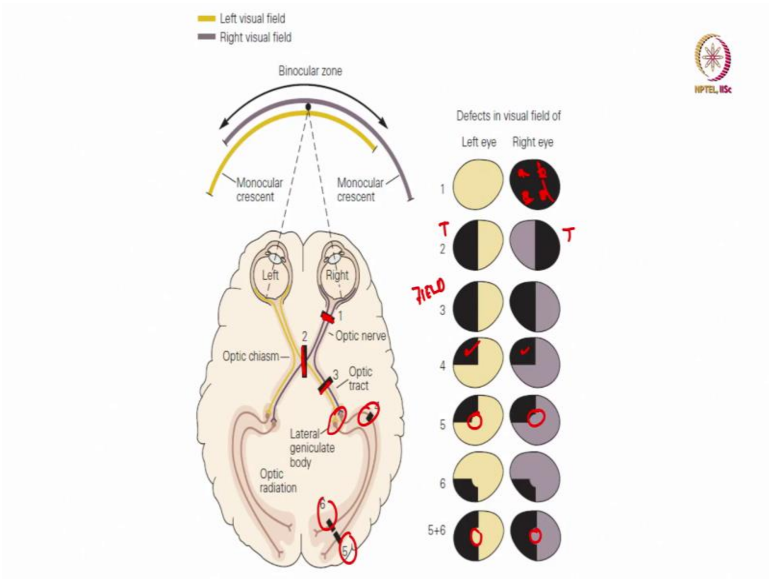

So, what actually happens what is the implication of this this thing is this you know people have diseases. So, diseases which affect different parts of the visual system you know when vision is affected it need not be that only eye diseases are responsible there are various other kinds of diseases which can result in visual loss and this picture sort of shows what happens at various level.

I will just run it through because it's interesting in the context of what I have discussed. So, when we look at one which is over here. So, right eye there is a break. So, you have a break in the entire 4 fields 1 2 3 and 4 or a b c and d. So, all four 4 in the right eye have gone left eye is normal. Now suppose you have a break here which is 2 you have problems in both temporal right. So, temporal fields in both sides.

So, incidentally people who have pituitary diseases pituitary adenomas they would notice this kind of a field defect that is a temporal hemianopia, and it is most dangerous when people are driving. So, when driving your peripheral vision is important because people vehicles people tend to come from the sides to your center. So, you lose the ability to see things coming from the periphery and that is the importance of this.

3rd is optic tract which leads to a field defect. So, one part of the field is not seen or not perceived optic radiation. So, for lateral geniculate body we will come up in the next this one it gives rise to more complex defect. So, this is a quadrant, and this is a quadrant and that is affected and that is how it is oh sorry that is in the fourth one 4th one is here. So, 4th one is in the optic radiation 5th one in the cortex.

So, what happens with cortex is the macula get spared please notice this. This is the macula which is the central part high density high fidelity not high density high yeah of course, high density cones and high-fidelity vision color vision which gets which get spared when you have a cortical insult.

So, there is a direct injury to the cortex it is spared 6 is on the other side and 5 plus 6 results in still macular sparing with field cuts corresponding to this one. So, this is this is in brief the diseases which affect the optic apparatus.

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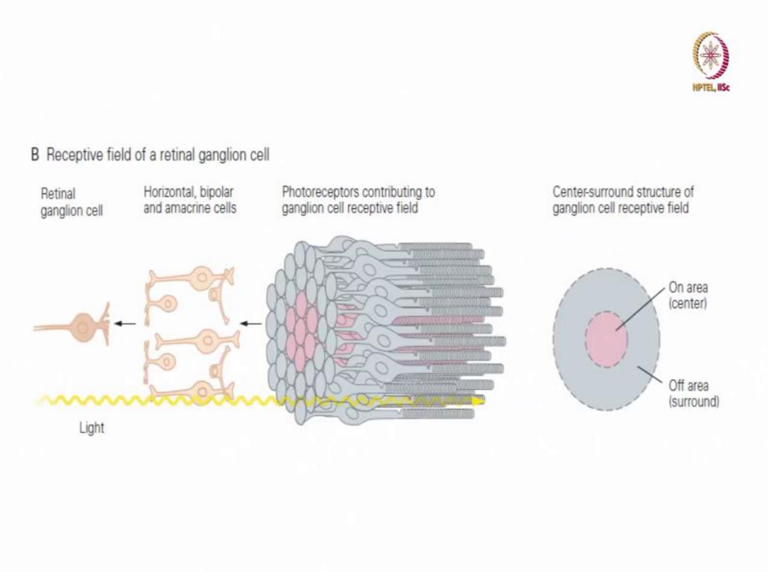

So, here we will continue in the next session.