PROFESSOR: OK, I hadn't talked yet about topography, and I-- even though-- I just want you to understand how the optic tract is laid out, and-- but before we do that, I'll show you midbrain of a few different species. There's one that occurred earlier in the book-- I think it was chapter 11, yes, where I compared rodent, human, and tree shrew, where you see these-- chapter 11 was the midbrain chapter.

And you can see how the size of the tectum and the size of the peduncle are what's so different in these three species. The humans are the huge peduncle, and aspera colliculus that's not so huge. Even though we're very visual, we depend a lot more on the geniculate striate system, because we depend more on learning. Whereas the tree shrew and squirrel would be very similar, and much more dependent on inmate visual reactions. And they have the huge tectum.

These are some of the questions. I asked you to describe four different anatomical methods that can be used to uncover the layers of the optic tectum. And of course, I just meat-- just stains of normal material, like fiber stains and cell stains. You could name any fiber stain, and of course, Nissl stains come in a number of varieties. But also there's histochemical stains, and I showed you some of those in the methods chapter, chapter two.

And then, of course, the Golgi. So we'll look at that just briefly today. You should also know a little bit about these species varieties, and what are the animals with the huge tectum? It's not only the non-mammalians, like the fish, and some reptiles, the visual reptiles. I'm sure that the dinosaurs had a very large tectum. And why is the term optic tectum a misleading term? Yes?

They're so loud in here, you have to-- but it could still be an optic tectum. It's optic

that's not accurate. It's just the superficial layers that get the visual input from this optic or visual sense. It gets them at a sensory and auditory input as well, and it gets cerebellar input. OK, so especially all that auditory and meta sensory input coming in there, it's a lot more than just in the tectum. So sometimes I call it a correlation center.

It brings in all these different modalities that kind of all arise from a similar part of space around the head. OK, this is a ray-finned fish, and I'm just showing the retinal projections here on the right. This animal has a fairly simple but enlarged tectum, and you see a little bit of one of the accessory optic nuclei there. This huge structure down here is actually a backward protrusion of the hypothalamus. It's the inferior lobe of the hypothalamus in this fish.

This, and animals of this group shows what that tectum is like, and how the axons from the retina come in and terminate on the superficial parts of the dendrites of the deep layer cells. There are also a few cells up in that superficial layer. And then this is true of mammals too, where the retinal input, and input from visual cortex come in superficially, and then in the layers below, in this fish it's mainly somatosensory.

In mammals it's auditory, below the visual, and then in the deepest layers somatosensory. Remember, the spinotectal pathway. Coming from spinal cord. This is meta sensory input, especially from the face, which is-- it's a trigeminal tectal pathway. But it joins those spinotectal inputs. OK, here's a teleost fish, and if you just look at the low power over here, you'll see this huge tectum, the largest single structure there.

Here's that huge lobe of the hypothalamus. This is cerebellum here. You can see the tectum's larger than the whole telencephalon. OK, and here is a teleost tectum done in a series of studies by Vanegas and his collaborators, where they-- this is a composite from a number of different studies on the cell types in the tectum.

And you can see this beautiful laminar pattern that you can just see in the way axons arborize, and the way dendrites arborize. That reminds me a lot of the retina, in fact. OK, now this is a frog. I don't think I put this one in the book. I put the iguana

next to this picture. There was a limit to how many figures I could use, and I just decided to-- you see a few more in the classroom, but this is a frog with a Nissl stain.

And this is from a study of [INAUDIBLE], who did a number of studies of the frog, especially of the tectum. And what I've done is because he identified the retinal fibers coming in in these four layers-- he used tiny little labels, so I blew up the figure and I colored those axons in. So the retinal fibers can be seen, terminating in these four distinct layers.

And that corresponded very well to the findings here at MIT of [INAUDIBLE] and his collaborators, where they were recording from these axon endings. They were recording the activity of four different classes of retina ganglion cells. But they actually recorded in the tectum. And you can see that, again, a lot of the cells are down-- you see over here on the left results from the cell stain. Cell and fiber stains.

You can see fewer cells in these superficial at the top seven layers, and then in these deeper six layers you have three major cell layers. And that's where you see these cells with axons, just like the pyramidal cells, really. Just like in the neocortex. The pyramidal cell dendrites. Cortex also go up to the pial surface, just like you see here.

And the inputs are terminating mainly on those dendrites. This is the iguana, where the lamination is particularly clear. This is from Bill Hall down at Duke University. This is a hamster in the Nissl stain, where I've not removed the cortex. But you see the evidence and lamination, and remember this structure? The central gray area, and that's the aqueduct of Sylvius there.

And this is also the hamster, but now we're looking at a myelin stain. When you see it compared to the cell stain, the myelin is even clearer, about these layers. You see not so many myelinated axons in the superficial layer, where the retinal axons are terminating, and also axons from visual cortex. And then these are-- right below it is a layer of longitudinal fibers. So we've cut across it.

These are including all the retinal fibers and privates from visual cortex. They come in, into that layer. Before they get to the tectum, they're traveling mostly on the surface of the brain, not in the tectum. And then there's another layer of fibers like that that come from cortex, and from auditory and somatosensory inputs. They're these fibers.

And then you have the layer-- it's called the layer transverse fibers in [INAUDIBLE], because they're traveling in the transverse plane. Two kinds of fibers there. Fibers of the [INAUDIBLE], of the superior colliculus, but fibers from big cells in these deeper layers. I don't know if we can-- yes, you see some of the big cells here. The axons of those cells join these transverse fibers, and then go down across the midline, become the tectospinal tract.

You see some of those big cells here in the rat. That's the rat superior colliculus. And topography-- let's just talk again about the major methods for doing topography. This illustrates the electrophysiological methods where they're recording. In a systematic way, here's a dorsal view of the goldfish tectum. And you see how they insert the electrodes in a grid.

Sometimes to avoid blood vessels, they don't get the entire tectum. But they could get it if they nudged those vessels aside. But it's dangerous, and they lose a lot of animals that way. But anyway, you can see as they move the electrode from one position to the other, the center of the receptive fields move. And so this is a map of the visual field of the fish. And you can see the results of it.

They've connected the rostral caudal rows of penetration sites, showing the orderly topography of the projection. And then this one we talked about before. This is one from work of me and my students and the hamster, where the initial method was anatomically making lesions in the retina, and tracing degeneration to the tectum. Now it would be more likely done with injection methods.

I've done that also, where you can get a more limited number of retina ganglion cells. When you make lesions, of course, you get all the axons traveling towards the optic disc from the more peripheral parts. But anyway, you can get a nice map. The

letters there stand for the center of the eye muscles at the temporal pole, the nasal pole of the retina, superior and inferior.

We call them the rectus muscles. Superior rectus, temporal rectus, and-- actually, for temporal retinas, we call it the lateral rectus. And similarly, for the nasal one we call it the medial rectus. But they're easily repeated landmarks from one animal to the other, so we get consistent results. And then we take-- this is the view of the embryonic hamster up here, and this is that flattened view.

And we take the flattened view here, we can show the topography-- I show the superior, inferior retinal axis just once out of here, because the axons assume that topography very early. When you get not very far beyond the chiasm. By the time they get to the geniculate bodies, you have the inferior retina fibers all at one edge, and the superior retina fibers all at the other edge.

Of course, you have to know which is-- this would be the rostral edge, and then it medial edge at the optic tract here. And this would be the caudal edge, which becomes the lateral edge in the optic tract here. And then I'm showing how the nasal temporal-- actually, those axons are all mixed together when they're in the tract here. And they stay mixed together, even when they're reaching the geniculate bodies.

But then they're forming and following the chemical cues that determine where they branch and enter the nucleus, what you see here. And here I've added the topographies. So you'll notice here that in the geniculate bodies and in the pretectum you get the same kind of topography. Nasal first, then temporal retina, and then it switches. Nasal again, and temporal.

pretectum doesn't have very precise topography, but there still is a pretendency for the nasal retina to terminate first here, and then the temporal retina. Then in the tectum, it switches. You get the Temporal retina first, and then the nasal. So these terminal areas are strung out along the optic tract like a string of beads. A very orderly arrangement of axons, and orderly terminations.

So in the dorsal geniculate, as you would expect here in the temporal part, temporal retina part representing the field right in front of the nasal field, that's where you get the bilateral projections. Projections from the two eyes in separate layers. Just the beginning here, today I really want to talk mainly about the multiple routes, major transcortical fibers. OK.

Make sure you can relate these kinds of pictures. We were looking at a real brain from the side, and we were looking at this stretched out view. First of all, let's see what the accessory optic tract is. In this kind of picture, it's these axons that leave the main tract, and in many small animals they leave them in three different place. And if you look at a reconstruction, they're leaving up here, they're leaving here, and they're leaving here.

So I can show you where they're terminating the accessory optic tract nuclei, there, there, and here. This nucleus is mostly behind the peduncle and the nigra. OK? But I'm drawing this as if the brain were transparent. So this is the medial terminal nucleus, the lateral terminal nucleus, and the dorsal terminal nucleus. And the axons that get to the lateral are going like that and like that.

Here we have what we call the inferior fasciculus, which is traveling along the lateral edge of the hypothalamus. And then here you have axons going in both directions to reach those two terminal nuclei. The dorsal one is really-- it's just like a little addition to the nucleus of the optic tract, which could be considered part of the accessory optic system in the way its cells respond.

So what is the function? Do you remember? I mentioned it a few times. Discovered by one of our former students. You ever heard me talk about it? He decided he was going to solve the problem. His name was Simpson. He recorded from these groups of neurons, and found that they always responded to movement of the whole visual field across the retina. So not small objects. Everything moved in the retina.

It's the kind of thing that happens when you turn your head, when you're locomoting, or when you're tipping over. So it's a vestibular-like function that they're serving. Signaling head movement and head position. OK. Now, the multiple routes

from the retina to the endbrain. And we'll discuss the optic radiations, which refers to the major routes from the thalamus to the visual areas of the cortex.

Usually textbooks only mention two of these. But I had to mention more. For one thing, I'm dealing with evolution, and I want you to understand there's a lot more to evolution and the visual system than just those two pathways. And secondly, because at least one more of those, and maybe more than one are still very important. Just because it's neglected by neuroscientists doesn't mean it's not important. It just means they don't study it as much. OK.

First of all, let's bring up this rule about evolution. What is Deacon's rule? We summarize it by saying it means large equals well connected. It's an important rule of thumb in brain [? imaging. ?] So what does it suggest about the multiple routes to the forebrain for visual information? What is the large structure that gets retinal input? Of all those structures along the optic tract, what's the biggest one?

Probably superior colliculus in most animals. Remember, we started with the fish and saw its optic tectum is bigger than the whole endbrain. I showed you a photograph talking about midbrain of a barracuda-- a predator fish. The tectum is so huge it dwarfs the rest of the brain. And all the predatory fish that are very visual predatory fish are like that.

Some of them, like sharks, use olfaction quite a bit as well. And they also use other senses. But many predatory fish depend mainly on vision. OK, so it suggests-- if it's better connected than the others, it suggests that we should look at tectum for the source of axons that reach the endbrain. Well, it turns out the midbrain didn't connect directly to the endbrain.

OK, there might be a few exceptions, but not many. We know that those axons that determine brain state, like the norepinephrine axons and the serotonin axons, they come from midbrain and hindbrain, and they certainly project into the endbrain. But they're not the ones carrying specific information. They determine the state of the whole brain. OK, so, what are the two routes to the endbrain taken by visual information that are usually considered the major ones?

By now you should be getting that figured out. What do we talk about all the time? If someone just talks about-- he's giving a talk in our department, and say, giving a talk about the visual system, what does it usually mean? Geniculostriate system. Because it's become so dominant in the primates. OK, but what's the other big one?

It became very clear from the studies of birds that birds have something like a geniculostriate system, but in fact they have a bigger pathway common from-- remember Deacon's rule-- it comes from the tectum. From this tectum to thalamus, to a nucleus that in the bird is called nucleus rotundus. That projects to the endbrain to part of the so-called [INAUDIBLE]. I'll show you that.

In mammals, in the book I list six routes, here it's seven. They're actually all in the book, too, but I had discussed number six here, though I'm going to the amygdala, which isn't as well known as the auditory pathway to the amygdala. And I mentioned it in the first visual chapter, chapter 20. And I don't know why I didn't get it back into this list. Probably because I had written this chapter already. I didn't always write this in order.

But this is the way it probably should be, with seven major pathways. The visual information to take to the endbrain-- these are the two biggest in most animals. OK? But there's the route from the subthalamus. Recently they've even found routes from the subthalamus directly to cortex, but we don't know how many species it occurs in. It goes to the barrel fields.

I think more important for most animals is that that area in the zona incerta here, does get visual input from the ventrolateral geniculate body, and it doesn't just project to the locomotor area. The midbrain. You can control escape behavior that way. It also projects to the dorsal thalamus, the midline and ventrolateral nuclei, which affect the whole thalamus, certainly sending visual information to the endbrain, to the cortex, and the striatum.

Those structures project to both striatum and cortex. And then optic tectum and pretectum have deeper layers that are multi-modal, but it includes visual

information. They project into the lateral thalamus, and then the superficial visual layers, including optic tectum and pretectum, they both have pathways carrying specific visual information into the thalamus.

Some of it does go to the lateral geniculate part. In fact, most of it goes into the lateral thalamus near the geniculate. Goes to LP. In primates, it's usually called pulvinar. And that goes to posterior neocortex. Not primarily striate cortex. And we're going to encounter this one from the pretectum again, because it's signaling changes in head direction, which turn out to be really important in where we are, and where we're going. OK.

So I pointed out here that that first pathway is almost always-- usually ignored, in spite of its possible importance in evolution especially. The second, third, and fourth have attracted a few researchers, but they're usually not mentioned. Two, three, and four. It's this one that I think is going to attract a lot more attention in the future. I've made it a major topic in the book when we talk about hippocampus.

And the one to the amygdala, it's the auditory system that's dominated that study, but it turns out that it's a visual pathway going there, too. It might be very important in effective emotions. But the optic tectum and the LGB are the main ones. I just talk a little bit here-- this is somewhat speculative. It's about how this organization between pathways from midbrain into thalamus form.

But this is the one I want to stress here in the class, that shows those two major pathways. I used the same color code for mammals, reptiles, and birds. In the mammal we call them lateral geniculate, and LP, or pulvinar. Lateral posterior nucleus or pulvinar. And it shows that the geniculate body goes to striate, LP pulvinar primarily to exostriate.

I say primarily because it does have more widespread projections. At least some of its neurons do as well. In reptiles they get different names, but you still have separate projections. In relative terms, the one that gets direct retina input, dorsolateral optic nucleus, this optic nucleus in the thalamus of the bird, they project directly to walls through dorsolateral cortex. It's part of the dorsal cortex in the

reptile.

It's just given a different name in the bird. Wilson's bulge. And because it does in some birds, where it's well developed, like the owl, it does form a prominent bulge in the endbrain. Part of it gets directed through visual input. There's a somatosensory [? wolst ?] as well, and a motor [? wolst. ?]

And the other one in these reptiles and birds goes subcortically to this dorsal ventricular ridge here, that has been found in its connections to be like neocortex in mammals. OK? But in terms of connections, they have these same pathways, same kinds of connections. Difference is just the arrangement of the cells where they terminate. All right. This just is-- I took a picture of a turtle where I found nice studies of these different projections.

And here I've shown where the visual projections are going. In the dorsal ventricular ridge of the turtle. And you can see the cells form a nice, distinct pattern there. And this is where the more direct projection goes, from the rotundus of the turtle. Most of the are concentrated on this area, but my readings are very clear that it goes also to this thickened area out here.

All right, so those are the two pathways, shown in a little more detail for the turtle. And here is a raccoon's striate cortex. I didn't put this one in the book. I put the monkey. But you see, even in a very low power here, look how the striate cortex stands out. You see that very dense layer of granule cells next to a layer of fibers that looks wider.

And this is the calcarine fissure in the raccoon. But you can very clearly see the striate cortex, and then you see the sudden change when you get to the border of striate, and the extra striate areas. OK? This is the one I took out of the book. It comes from [INAUDIBLE] picture, where again, it's even clearer at this magnification for the monkey. You see the striate cortex. Very clear lamination.

And you see the sudden change. He's labeled that border D here, between striate area and exostriate. You see the sudden change in the cyto architecture. Very easy

to pick up. So if I showed you this picture and didn't label it for you, you should be able to label that boundary. At least there and here. And here.

So what are the visual areas of the neocortex that are the most primitive that we keep seeing? We're talking about neocortex, so we're only talking about mammals. OK? So if we look at all the mammals that have been studied, including some very primitive ones, you keep seeing primary visual cortex. What does that mean about those other pathways? Well, we see those in non-mammals as well. OK?

And they were no doubt there in the cynodonts that led to mammals. The evolution of mammals. So for mammals, you can say the striate cortex and the immediately adjacent area, what we call V2 if we're physiologists, consists, actually, of a number of different representations of the visual field, as we will see. They've been called V2, V3, V4, and so forth by the physiologists that have divided it up according to representations of the visual field. OK.

And then what do we mean by temporalization of the cerebral hemispheres? In development and evolution, it's correlated with the expansion of one group of thalamic nuclei. Which ones am I talking about? Temporalization, formation of a prominent temporal lobe. That's what temporalization is. What's happening to cause that? It's an expansion of the uni-modal and multi-modal association areas of posterior cortex. Primarily visual.

It expands so much, you know? Sorry? Oh, it's associated with the lateral thalamite nucleus, and in primates it's mostly pulvinar. See, here I show an animal like a rodent, that doesn't have a temporal lobe. And then I'm showing what happens if the posterior areas, concerned with vision and audition, expand. I mean, there's not room in the skull for it just to expand, and expand, and expand.

So it forms a whole lobe that folds in, like a grub here, and with it comes the hippocampus. I'm showing how the position of the hippocampus changes in relative position. But the topography, the topology is the same. This is all visual areas, from about here all the way down to here in the primate. And there's hippocampus nearby. So that's the process.

Well, let's look at in the optic radiations, which are the fibers coming from thalamus, you know, up to that visual cortex. We saw it in this picture that-- I think I had very early on from [? plexus ?] work, German anatomist that published a developmental study of myelinization. This is from a seven week human, where myelin is just beginning to appear to in the hemispheres. And he shows it's appearing first in this pathway to the occipital lobe.

That's the genicular striate pathway. It also appears in the primary auditory radiations, the auditory context, and it appears-- it's actually earliest here through the somatosensory cortex, in the ventral posterior thalamus. So there's a lot of myelin in the cerebellum. There's a lot of myelin in the hindbrain and other parts of the brain stem. But just starting in the hemispheres.

And it appears first there in the geniculate striate pathway. This just shows you what I did to make this picture. I had the original plexic picture, which I got from the University of Chicago. And these were German labels that he had in there. So I carefully removed them, and the artist helped in removing the lines here, and everything. And I put in the major labels we needed to understand that picture.

OK, and these are some very nice pictures of the growth of the human brain that you can see the change in relative size. These are all to the same scale from that-- 10 weeks, up to 41 weeks gestation. So this is it for-- birth is 40 or 41 weeks in that. So back here you have a brain that's about at the stage of development of a hamster at birth. Because a hamster's born and the stage that corresponds to a premature human. A prenatal human.

About a 2 and 1/2 month human. All right, and there you see the temporal lobe forming. See, it starts really early. Humans have a very large temporal lobe. Already at 12 weeks it's beginning, and then you see the progressive expansion of it. The visual areas end up being just visible only at the pole there in humans. And if you look at the medial view, very early you see the calcarine fissure folding in.

So this is all visual cortex here. In the adult it's all along the deep fissure. This just

shows you the temporal lobe at the temporal area of an animal that doesn't have a temporal lobe, but he's still got an auditory cortex here. And small areas outside the striate area, which is here, that do correspond to some of those areas outside the striate cortex in a human. But of course, in monkeys. A lot of them are simply not there in the rodent.

And then it's happening very differently in the cat. Now, we call this the pseudo Sylvian fissure, because it goes up right in the middle of auditory areas. Whereas in the primates, the monkey and the human, the auditory areas are always below that deep fissure. OK, so there's the temporalization picture. Once you understand temporalization, you can understand what Meyer's loop is. This is the figure of that I used for the cover of the book. The artist chose it and extracted it. She got it from it.

And this is the same picture from Nauta, where he's left the caudate there, caudate nucleus. And here the hippocampal formation in place, and there's the amygdala. Here he's removed those. Because what he's showing here is fibers of the internal capsule, and the caudate is always medial to the internal capsule. He's removed the containment in this section.

And here with all those structures removed, you see the-- we call it the corona radiata fibers. And these fibers here from Meyer's loop are part of the optic radiation. It's the part that represents the upper visual field. So if you get a temporal lobe injury in humans, you seem to be very far from the visual cortex, which is here. But the fibers that go to the visual cortex go through part of the temporal lobe there.

At least the ones representing the upper visual field. So you can get cortical blindness in the upper visual field from a temporal lobe injury because of that. Or a tumor in the temporal lobe can cause that. And it's easily understood once you understand the topography of the optic radiations. And these pictures are just meant to help you understand that concept.

And you see here, I'll have some of them-- several peduncles in the pyramidal tract. And of course, many of those pyramidal tract fibers are coming from the central cortex. Motor cortex here. Sensory cortex here. So what are two methods used by

neuroscientists to map multiple visual areas in the cortex? And why do we believe the human brain contains more than the 32 areas described for those in this monkey? Yes?

Exactly. The relationship is a pretty clear one. Here's the relationships you're talking about. And we plot neocortical surface area against a number of visual areas. In either logarithmic or linear coordinates. See here on the log, log scale, you get a pretty good line. It's not totally precise, but there is a pretty good correspondence. The animals with very small cortex have fewer variates.

Some people have taken that to extremes and suggested that the tiny, tiny little shrew brains and rodent brains should only have just a few. It turns out they have more than that. So they show here, for example, mass shrews having one area. Here they have mouse, showing only two, or maybe three areas. Turns out not to be true.

So these were based on early studies, where they simply hadn't applied all these methods that I'm talking about. Now, here it was the usual method of recording, and here they're penetrating to the microbe. This is a medial view of the owl monkey, and it shows penetrations through this one area, and mapping the visual field. And they find a complete map of a retina view. OK?

So they do that, all these different areas. This was done by Allman and often working with John Kaas. They've done it together in a number of animals, and separately with other animals. Much of the work on the owl monkey was done by Allman, and I've used his pictures here. You see all these areas. How this is all visual cortex. Here we call this inferotemporal cortex. Inferior gyrus of the temporal lobe.

Of course, this is occipital, and this is posterior [INAUDIBLE]. So all of these areas have complete representation of the visual field, getting input from the thalamus. Let's answer another question right now. Each of these areas gets input from two major sources. What are they? From thalamus, and most of these we know come from geniculate body. The rest of them are coming from the lateral thalamus.

The different subnuclei of the pulvinar. OK? What's the other source of inputs? Transcortical. They get inputs from the striate here. So one of the methods used to map, then-- of course, the two methods I'm talking about are electrophysiology, which is shown here on the left side, and anatomy. And here is this picture I included in the book.

Beautiful study of the mouse. And look what they've done. They've taken three fluorescent tracer substances and put them into separate areas along the caudal part of the first visual area. Striate cortex. And they let the animal survive for a while, so you get transport of those fluorescent labels to various terminal areas. And look what they're getting. This topography is repeated there, and there, there.

You see several-- 1, 2, 3, 4, 5, 6, 7, 8, 9, and then additional areas where the topography isn't as precise, but it is still there. You see an enlargement of a [INAUDIBLE] getting sparse input here in the [INAUDIBLE] area on the medial side. But you see there still is topography. You see the rex axons, the green axons, and the yellow axons. Not as precise, but it's still there.

So they these 10 different areas in this mouse. Just to show you how the data changes, here it says two or three, we get 10. OK? And this is just a flattened view of the cortex that shows where they put those injections in. This is mouse, yes. [? Burkhalter. ?] His lab is where they did this. But he obviously had really good command of this method, and was able to get some very beautiful results.

And this is just a picture to illustrate that they keep seeing V1 and V2 in all the different mammals, including the marsupials. OK? That's all that's illustrating. Putting them on a cladogram. And this is another one where they show that most of those groups have area MT. They have a myelinated area. It's a pretty direct visual path. As does the striate cortex. But you don't find it in the marsupials.

And this is adding, besides V1 and V2, is the ancient areas. Even in the hedgehogs you see it. But you also always see an [INAUDIBLE] area. You always see two somatosensory areas, and you usually, but not always see a motor area. You don't

always see a motor area separate from the somatosensory area. In the opossum, for example. And I think we talked about that once before. The amalgam of the two areas.

Because motor cortex appears to have originated as a somatosensory area, then it became specialized for the more direct connections to the spinal cord, the motor function. OK, we've already answered this. So next time we'll start with the major transcortical connections. It won't take very long. Just read it, and where it's different from other treatments in the current literature is I'm pointing out something that was neglected by other people.

They talk about always two pathways. They were influenced by other early work that came from MIT. The two visual systems. So there's always two visual pathways. The object location, object identification. So they just neglected the third one, and Nauta had pointed it out. But he wasn't focused visual systems.

But there in his results, published results, after he died, I found these results, and I've included in my book as a medial pathway, going towards the hippocampal formation. Terminates in the parahippocampal areas. So we'll just go over that quickly next time.