Demystifying the Brain
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Lecture - 02
Understanding Brain's Shape Segment 01 - Brain size and intelligence

Hello, welcome to the 2nd lecture of the course demystifying the brain, this lecture is about understanding the brain shape.

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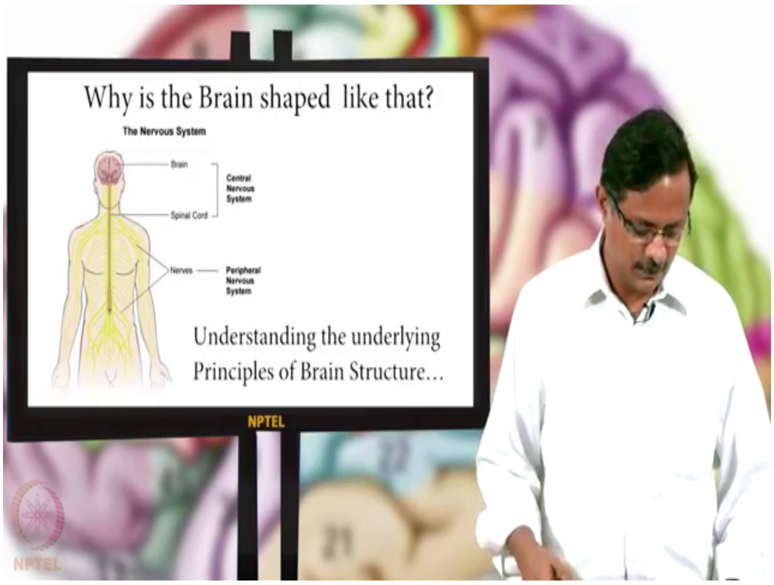

So, we all know from our high school biology that brain has 2 hemispheres and it is a little long tail like organ called a spinal cord and then you have you known Pons, medulla and cerebellum and so you learn all these anatomical features of the brain. If you are a medical student and taking a course on neuroscience you might even be learning details like which part of the brain processes vision, which part process touch and an audition and motor function and things like that and you will memorize all these parts and you know and produce reproduce them in the exams.

But, this course is not about memorizing the details of the brain; this course is about the principles of the brain, the neural information processing principles of the brain. So, particularly in this lecture we will only try to understand the structural principles of the brain. So, we will try to ask what are the revolutionary forces like that shape the brain and made it the way it is today. So, in this lecture there are 3 segments.

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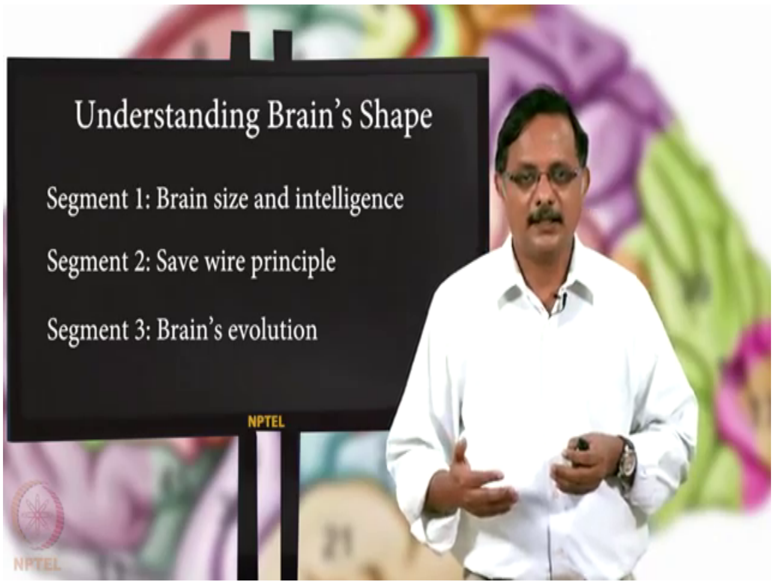

In the first lecture we will try to see if there is any correlation between brain size and intelligence is one of the things we would like to understand about brain is why is it so intelligent? What is it so special about it that makes it so intelligent? So, is there any connection with any of the structural properties of the brain? So, in segment 2 we will invoke this principle called the save wire principle. So, brain takes a lot of pains to make sure that the total wire in the brain is minimum.

So, there is a strong revolutionary pressure, how to minimize the wire length in the brain and we will also try to argue how it is related to a similar thing that we do in engineering. In engineering engineers also very often in you know especially electrical engineers so design circuits, where I try to minimize the total wire length. So, the 3rd segment will study brains evolution.

So, we look at nerve systems or very simple creatures and you know go all the way to know vertebrates, in vertebrates, mammals and then finally, humans and then see, how brain has evolved and we will try to show how this, how a very simple structural principle; the save wire principle can explain a lot of features of the brains evolution.

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So, let us start with the 1st question brain size and intelligence. So, let us start with a simple story. So, when you the moment to think of intelligence the first name that pops in to your mind is probably that of Albert Einstein.

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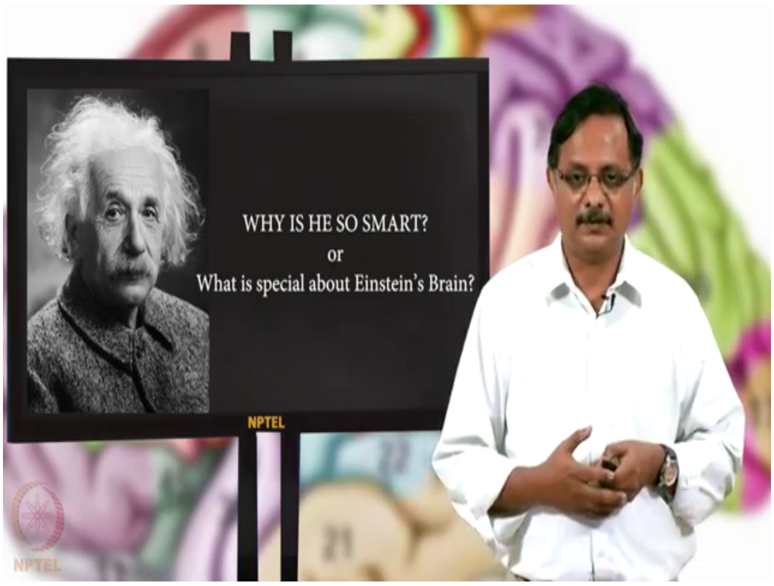

So, he is one of the greatest geniuses in of our times and so you would often wonder what makes him so intelligent? How come is able to think so differently from everybody else? So, people have even had gone to the length of asking is his brain something different, I mean what is special about Einstein's brain.

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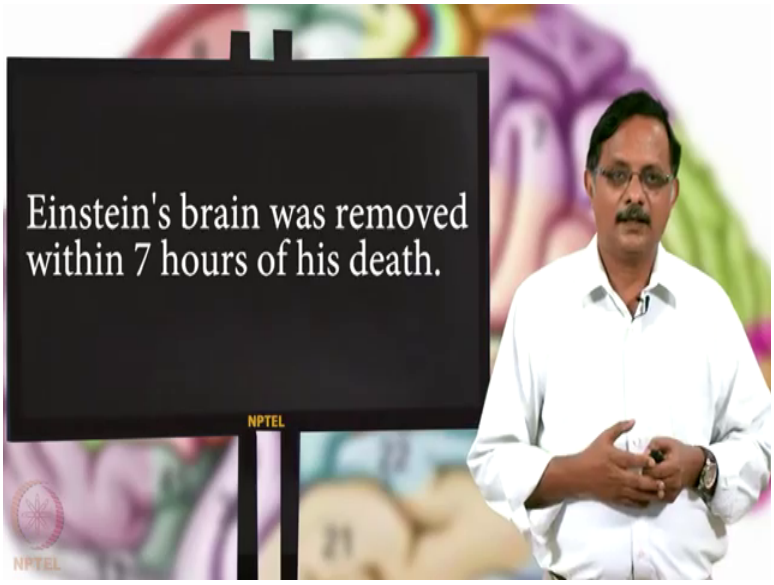

So, after Einstein's death his brain was removed, I think with his permission from his son.

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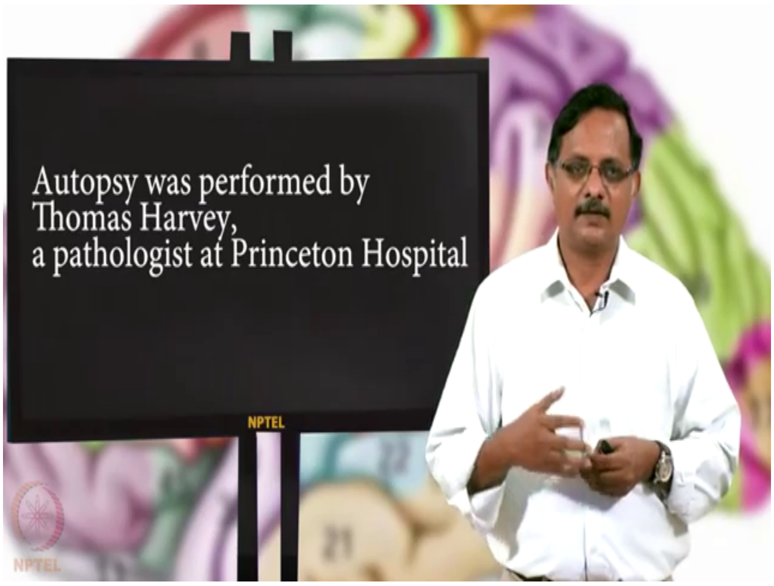

This was done by a person called Thomas Harvey, a pathologist at Princeton hospital.

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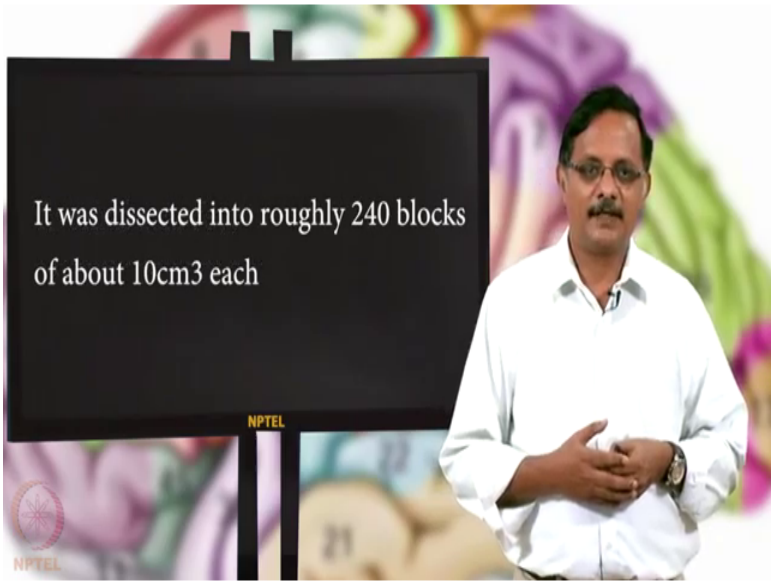

It was dissected roughly in to 240 blocks, each of about 10 cubic centimeters size.

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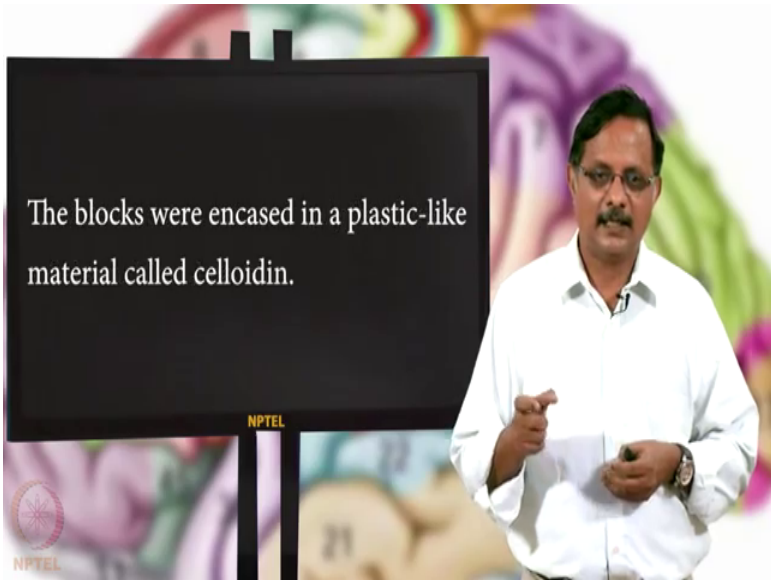

And then, it was preserved in a plastic like material called celloidin.

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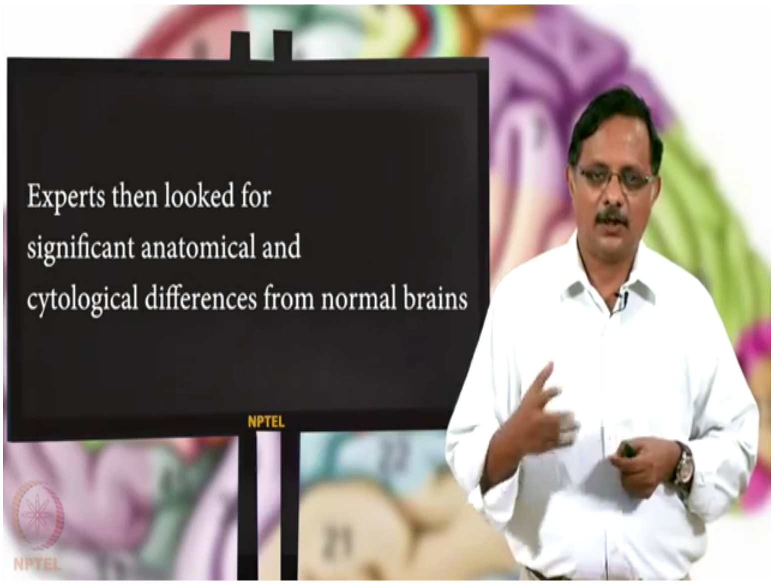

And so, a lot of structural anatomical studies were done on these blocks and there is a lot of story about how these blocks went from place to place and people have several groups have studied these blocks and so on and so forth, I would not get in to the history of what happened to Einstein's brain, but to explain the findings of these studies, I would first like to introduce a few terms to explain the features of you know brains anatomy.

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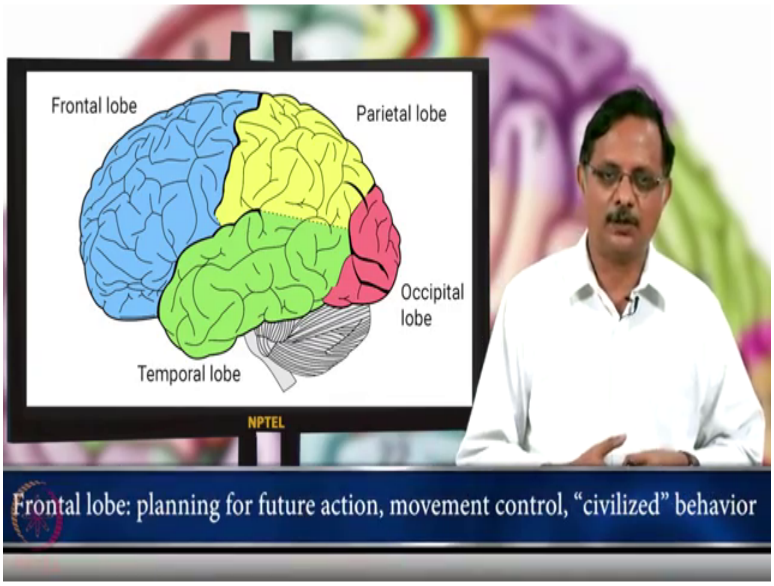

So, brain as we know a right has 2 hemispheres, this you might have learnt in your high school and each hemisphere has several loops. So, for example, the blue region that you are looking at is a frontal lobe.

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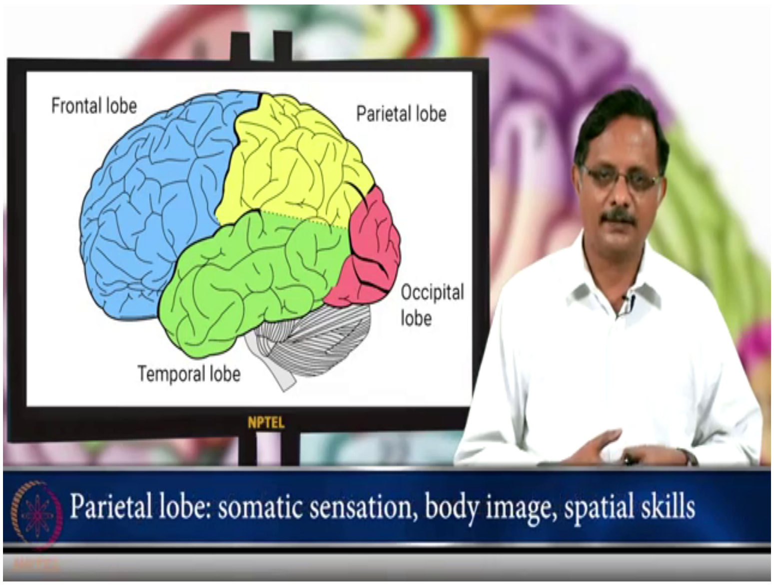

The yellow region is a parietal lobe.

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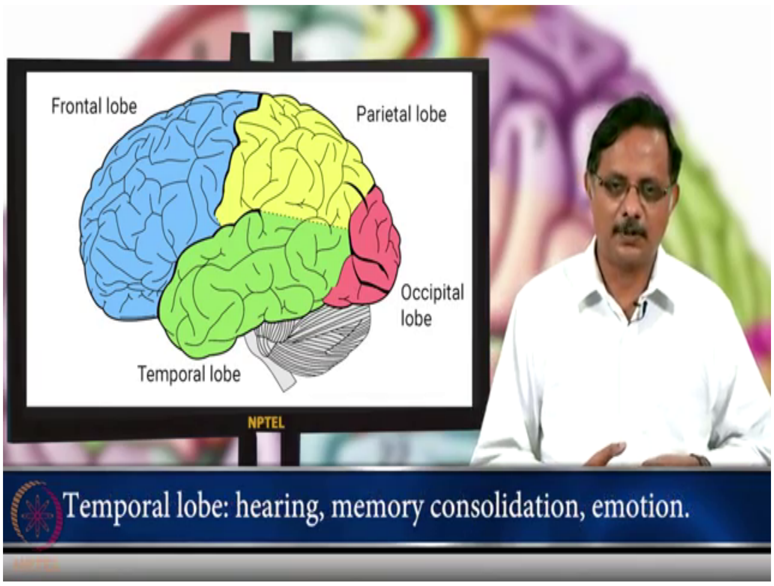

The temporal lobe is the green region.

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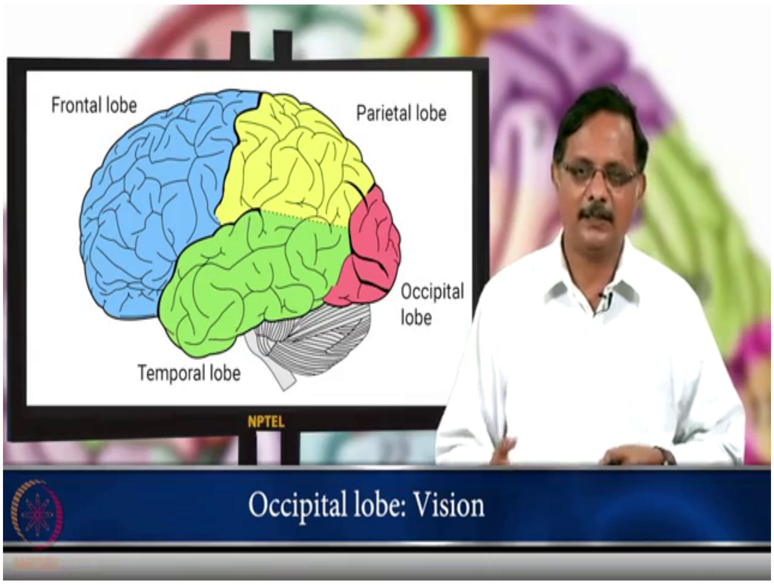

And the Pink region is the occipital lobe.

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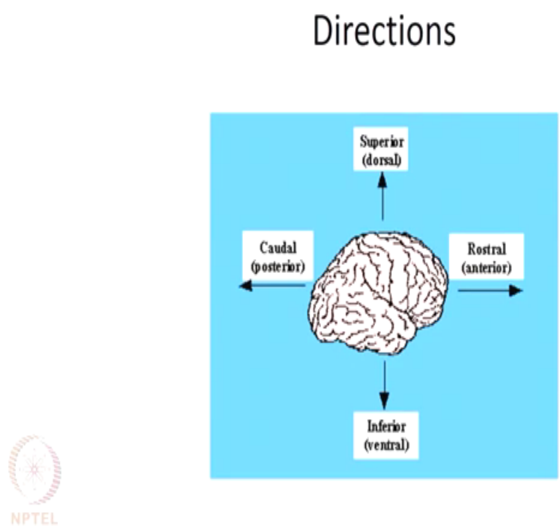

So, and then we should also mention a few directions because we use these terms again and again as you know biology is a lot to do with a jargon, although when you try to understand principles I mean jargon is not that important, but anyway just to connect with biological literature will introduce and define the jargon.

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Direction	Description
Ventral	Toward the belly (front)
Dorsal	Toward the back
Rostral	Toward the nose
Caudal	Toward the tail
Superior	Toward the top of the head/body
Lateral	Away from the middle
Medial	Toward the middle
Bilateral	On both sides
Ipsilateral	On the same side
Contralateral	On the opposite side

So, directions up means superior or dorsal and down means inferior or ventral and front means rostral; rostrum is nose. So, that is rostral is front and anterior that is also front and caudal; caudal means tails or caudal is back and so that posture is also back. So then, you have some medial is in the center or middle and later is to the side, then bilateral is on both sides, ipsilateral is on the same side as something that we are discussing and contralateral is on the opposite side.

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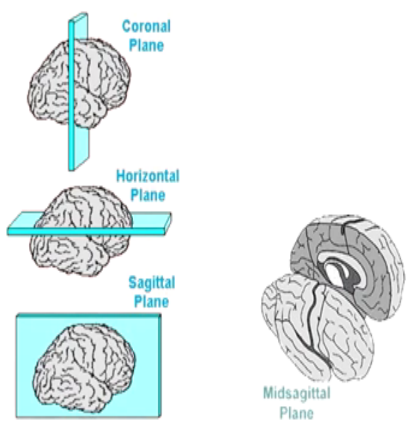
Sections



Now, the section there is a coronal plane, which cuts through the brain vertically like this, a parallel to the plane of the face and the horizontal plane cuts the brain. So, that the plane is horizontal; parallel to the horizontal and the sagittal plane is cuts the brain in the vertical plane like this and the mid sagittal plane cuts a brain exactly in the middle.

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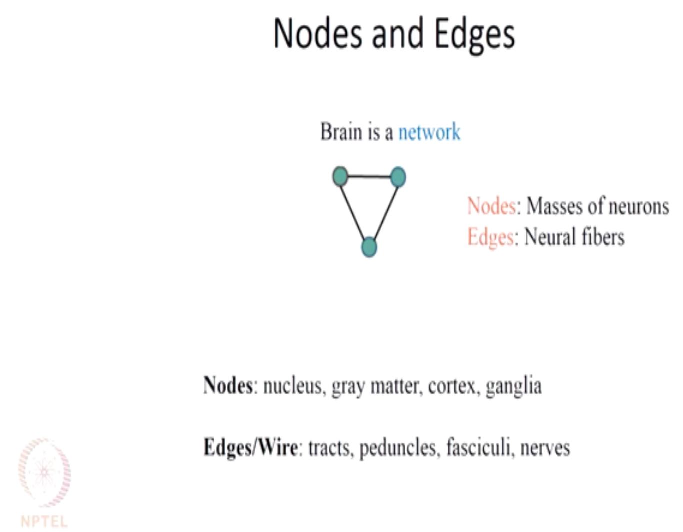

Now, brain is basically a big network, right it is a network of neurons. So, there are the nodes in the network and then there are the connections or the edges. Now, in this network of the brain the nodes are basically masses of neurons, the cell bodies of the neurons and edges are the neural fibers. Now, as it is typical in biology these same things go by many names for example, nodes are often node which are like master neurons are called nucleus.

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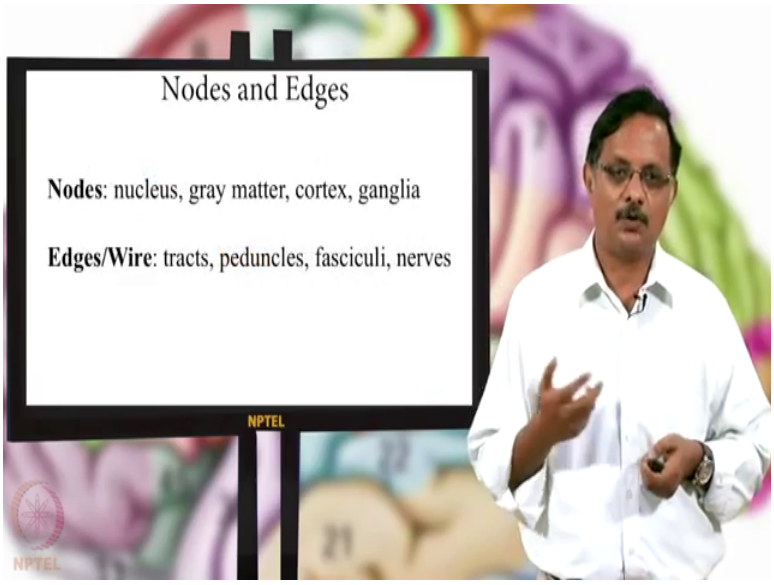

For example, if they are deep inside the brain, they also, we also call them gray matter and then the cortex which is the surface of the brain which is at 2 to 5 millimeter thick sheet of neurons, that is again that has a lot of neuron cell bodies, then there are ganglia which are an autonomous system that there is little masses of neurons and the edges or wire also go with many names, there are tracts, peduncles, fascicule, nerves and so on, so forth.

So, basically it is a brain is a network with nodes and edges, nodes are mass of neurons which go by all these names and the edges are wires which also go by many names. So, what is special about Einstein's brain? What are the main findings of these studies?

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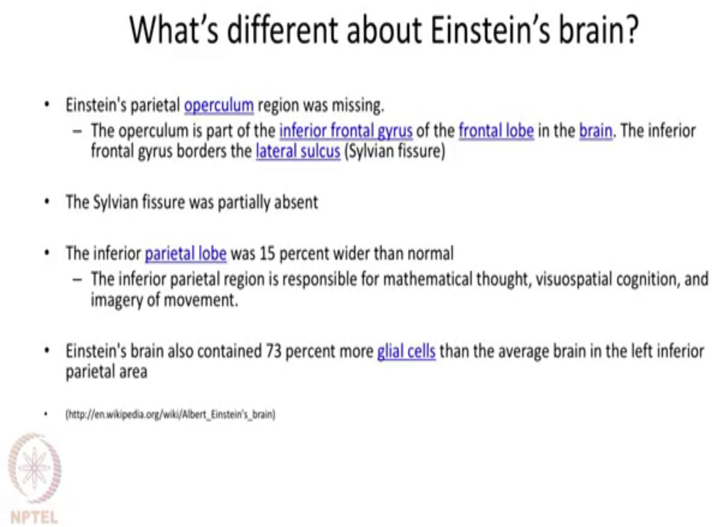

The first feature that they found is that Einstein's parietal operculum region was missing. So, what is this parietal operculum? So, operculum means late in Latin.

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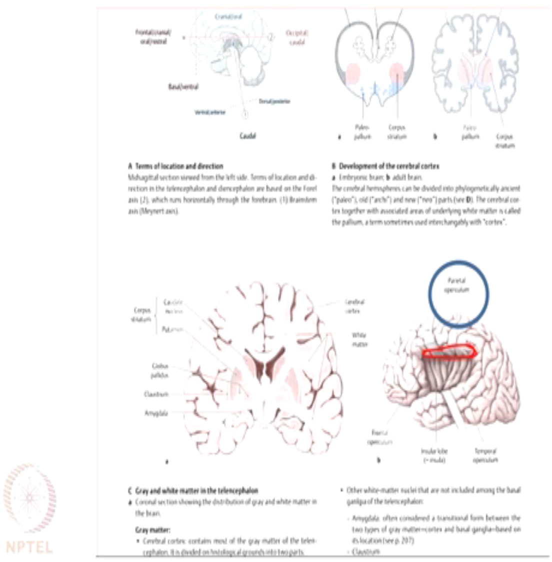

So, this particular region is called the parietal operculum, what exactly is going on here. So, if you go back to the previous slide, where we saw the lobes. So, you have this fissure between the frontal lobe and the temporal lobe, it is called a sylvian fissure and then you have another fissure which is running vertically that is called a central fissure.

So, the sylvian fissure usually goes beyond the central fissure and penetrates the parietal and the temporal areas up to a point. Now, in Einstein's brain, so the part of the sylvian fissure is actually missing and also if you open the brain right at the sylvian fissure right you will see a kind of a cave like cavity and that is what you are looking at here and this roof is the parietal operculum.

So, this parietal operculum region was missing in Einstein's brain. Secondly, the sylvian fissure was also partly absent and the third feature is that the inferior parietal lobe was 15 percent wider than normal. So, the parietal lobe again if you go back to this figure, so this is the parietal lobe and so this is the inferior part or lower part of the parietal lobe and this part is wider than normal.

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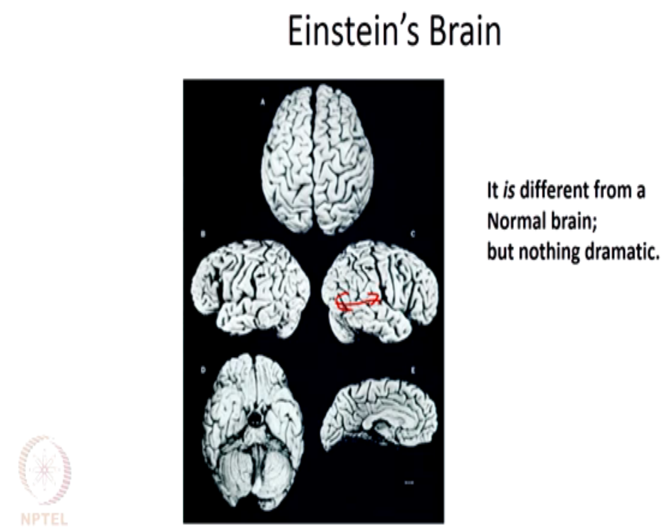

So, this is actual a figure of Einstein's brain and so you can see here that this is the inferior parietal lobe and this region is wider than normal people in Einstein's brain. The last feature is actually a cellular feature. So, in brain in addition to neurons there is a second category of cells called the glial cells and for a long time people thought that glial cells only perform some kind of a miscellaneous functions, just supporting the function of neurons, but work done over the last 2 and half decades has shown that glial cells also participate in neural information processing, they work along with neurons and perform information processing.

So, in Einstein's brain in the left inferior parietal area people have found there are 73 percent more glial cells than normal brains. So, what we can conclude is that Einstein's brain slightly different from a normal brain, but nothing dramatic; I mean so, for all the intelligence that the scientist has exhibited in his work this brain is not that different from the brain of a typical person.

So, where do we start?

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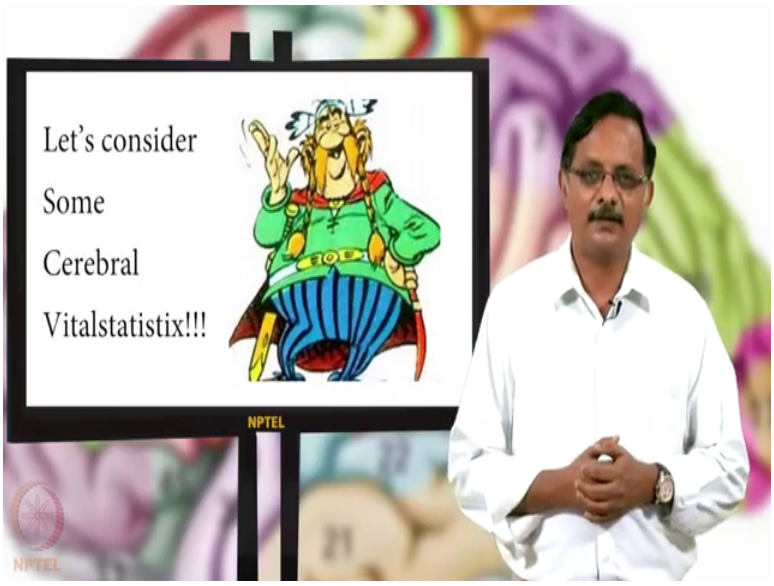

So, let us go further and let us not be too disappointed with this result and let us look at some more like you know cerebral vital statistics some more basic structural properties of the brain and see if we can find some correlation with intelligence. So, one of the first things that you can think of about brain right is the size or it is weight, right our larger brain smarter. So, let us look at the weights of various organisms, various species and see if you know the size correlates with intelligence in any sense.

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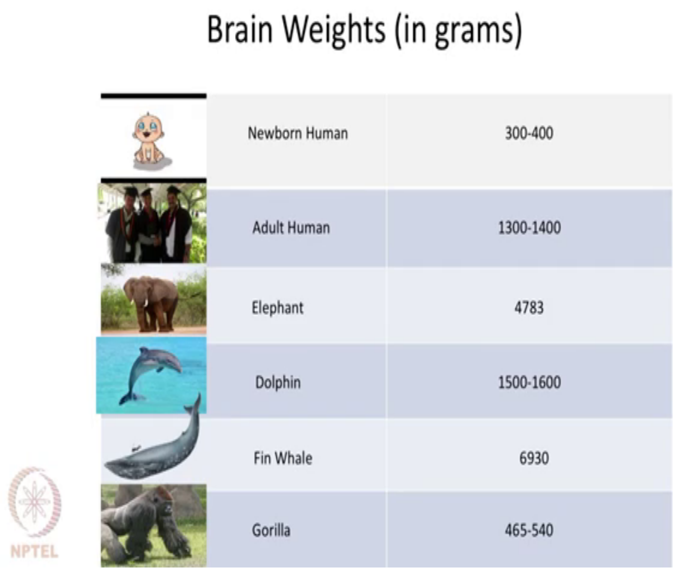
Brain Weights (in grams)

	Newborn Human	300-400
	Adult Human	1300-1400
	Elephant	4783
	Dolphin	1500-1600
	Fin Whale	6930
	Gorilla	465-540

So, the weight of a newborn human is about you know 300 grams to 400 grams, an adult human who is all educated and gone to college and in has a degree I am just kidding has a weight of about you know 1.3 to 1.4 kilos, then elephant has you known a pretty large brain that is about 4.7 kilos and a dolphin is a very smart animal that has about 1.5 to 1.6 kilos were pretty close to an in fact, slightly larger than human brain; then, the fin whales, whales generally all the whales species are very large brains. In fact, they have the largest brains in the animal world. So, that is 6.9 kilos, then gorilla has about half a kilo brain.

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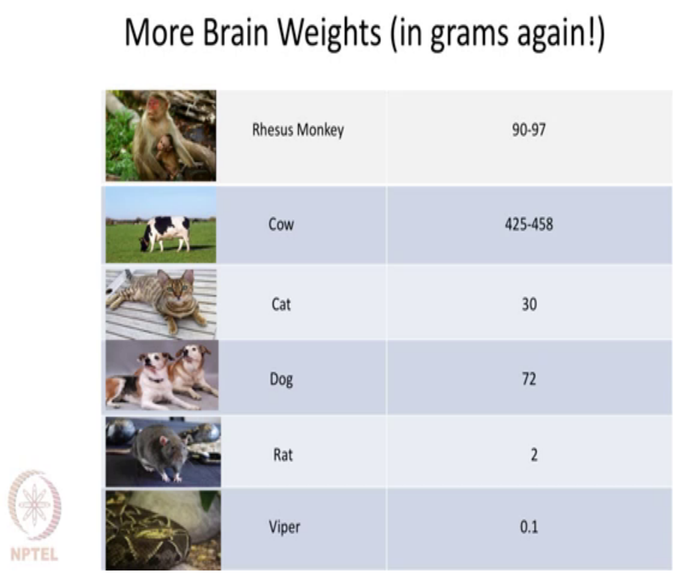
More Brain Weights (in grams again!)

	Rhesus Monkey	90-97
	Cow	425-458
	Cat	30
	Dog	72
	Rat	2
	Viper	0.1

If you look at other monkeys like this is rhesus monkey has about 100 grams brain and cow has about half a kilo, a cat is 30 grams and so if you look at a viper, it has a very tiny brain only 0.1grams.

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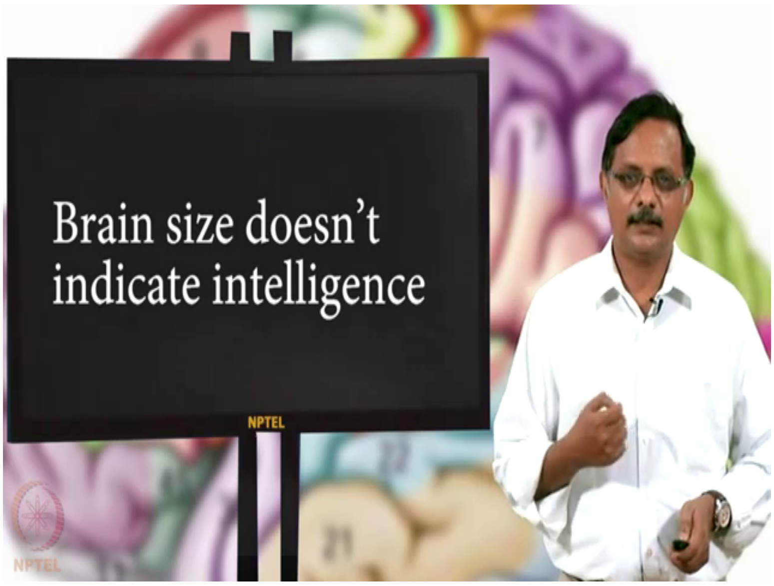

So, if you think that brains in intelligence is coated with a brains weight and it does not work very well, because the do you assume that in humans we assume that humans have most intelligence; therefore, I would expect us to have the largest brains in that, but that is not true that elephants and whales have much larger brains than us. So, therefore, brain size does not indicate intelligence; then, what do we do? So, in fact, you might complain that the situation is a lot like what you say in this cartoon.

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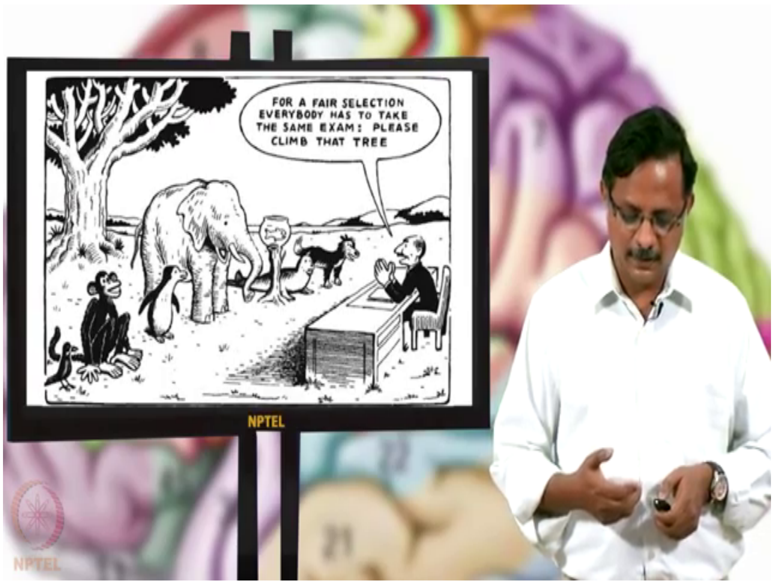

Because here all these animals are asked to perform the same task, now take the same exam. So, what this guy is saying is for a fair selection everybody has to take the same exam, please climb that tree. So, what we have done just now is probably something like that you might complain. So, that is not fair, because so thing is a large animal would need a larger brain try to control that huge body.

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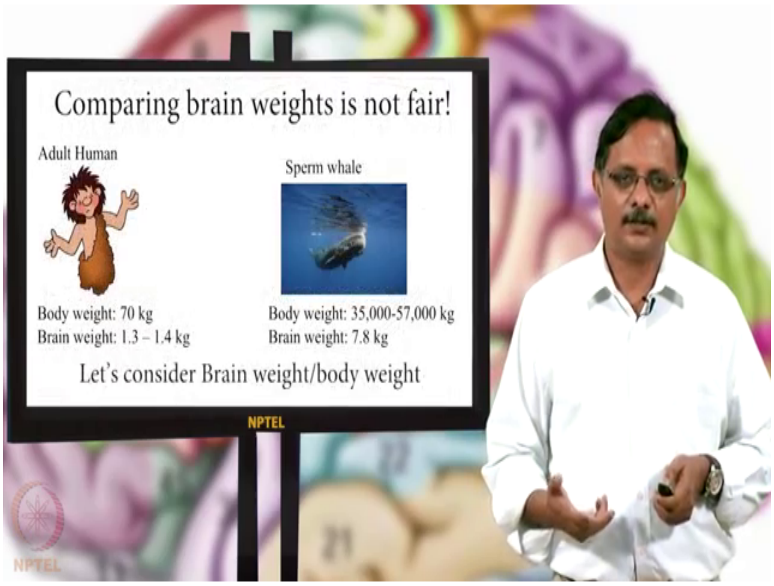

So for example, if you comparing whales brain with human brain is not fair you might say because human body weight is about 70 kilos and brain weight is 1.3 kilos, whereas a sperm whale is a is like in a huge hunk right has about 35 to 57 tons of body weight, whereas the brain weight is only 7.8 kilos. So, maybe just comparing the raw weight of the brains is not fair, you should probably compare brain by it as a ratio of some body weight. So, let us do is just that and then let us look at some data.

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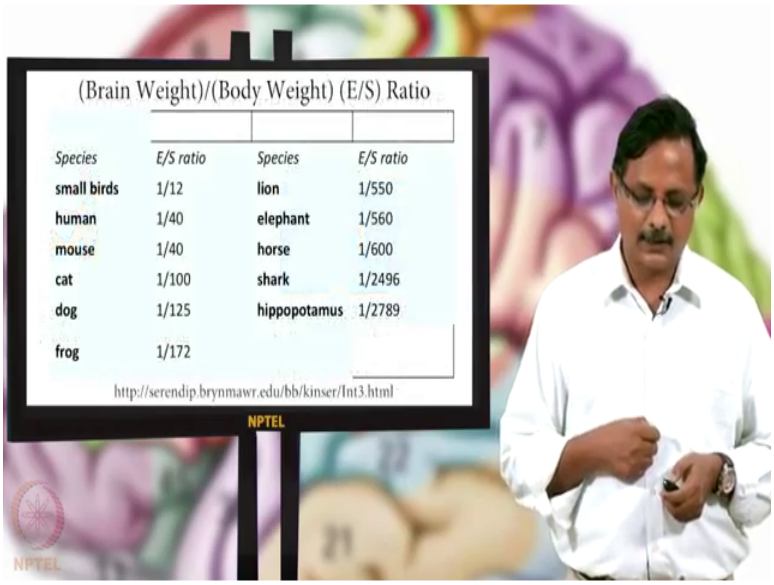

So, this quantity called brain weight by body weight is called E by S ratio, E stands for encephalon which means head of the brain and S stands for soma or the body. So, let us look at the E by S ratios of several species.

So, birds have this ratio of about 1 by 12 and humans 1 by 40, mouse is as about same way, same value as ours, so 1 by 40 and cat is 1 by 100, dogs 1 by 125 and so on, so forth, hippopotamus by virtue of it is large corporeal frame has a very small E by S ratio and so on.

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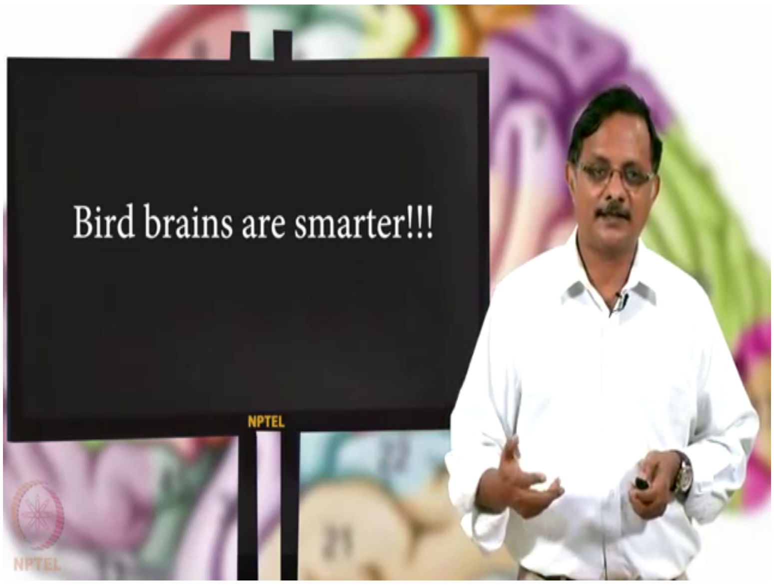

So, what we conclude from the E by S ratio data is that bird brains have smarter. Now, when you call somebody a bird brains it is you know it as an insult, but here you know by the measure of E by S ratio birds turn out to be the smartest.

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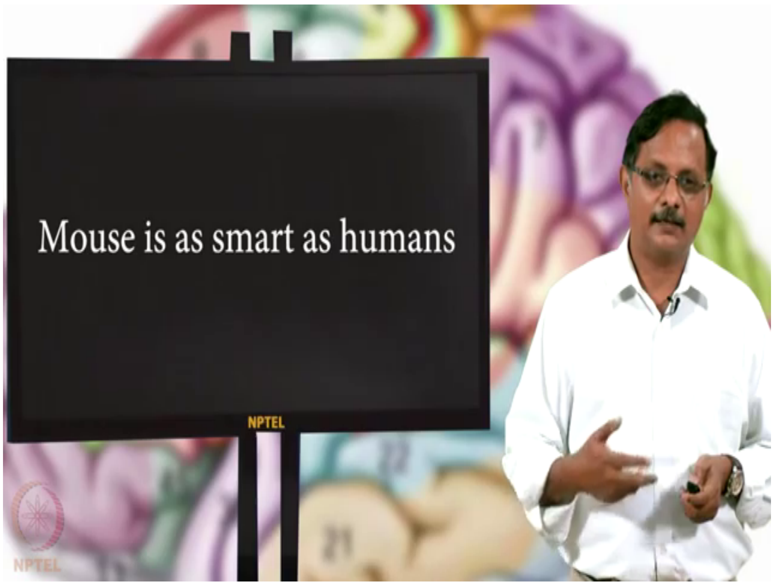

And mouse is just as smart as humans.

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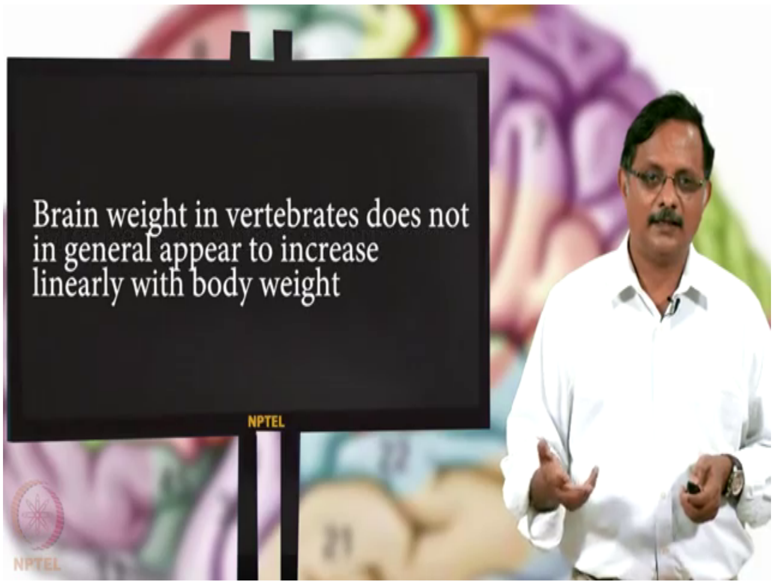

And, Brain weight in certain vertebrates does not generally appear to increase linearly with body weight.

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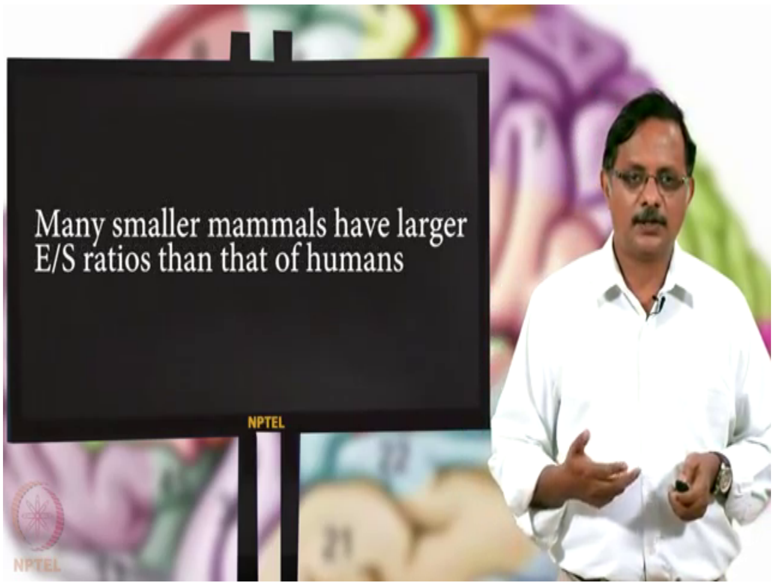

Also many small mammals have larger E by S ratios than that of humans. So, something has gone wrong again and no then let us we need to conclude that perhaps E by S ratio is not a very good index of intelligence.

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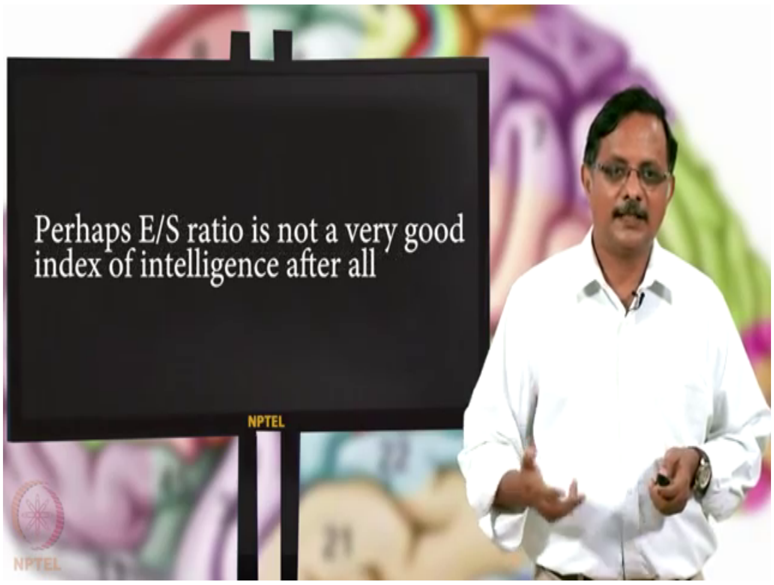

So, then can we go further, can we make a small correction to make it more sensible. So, what people have thought is maybe we should not assume that E and S are proportional, maybe there is a power law relating E and S, how did people arrive at that and that idea, the arguments go something like this.

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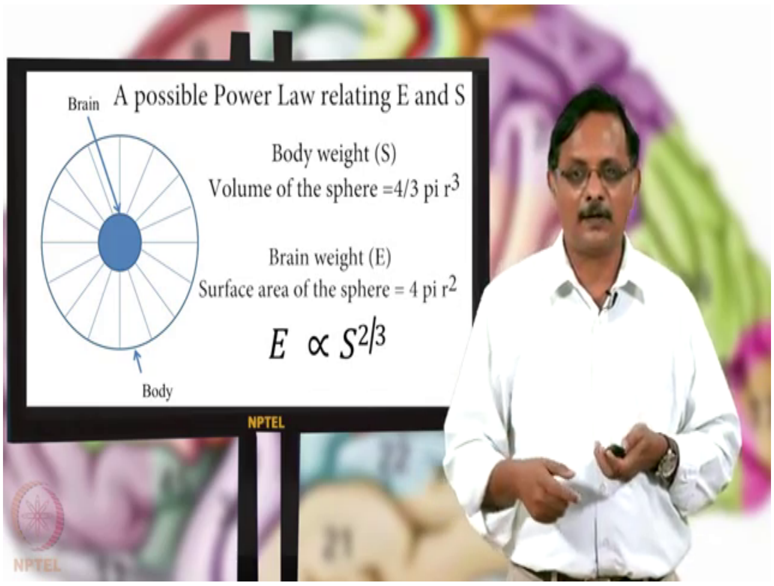

Imagine, your body is like a sphere, I mean no offense because mathematicians like to idealize things and you know compare real world objects with ideal geometric objects. So, just for sake of mathematical simplicity let us assume that the body is like a sphere and inside this large spherical body and somewhere in the center let us assume there is a small spherical brain and now which is this brain is just a mass of neurons and these neurons have signing out there their axons, their wires and to innervate the entire body and reaching all the way to the surface of the body which is the surface of the sphere.

So, the brain has to innervate the entire surface of this spherical body. The gate of the surface area the more the number of fibers that the brain has to send out to the surface and the more the number of fibers, the more the number of neurons that the brain has to have and more the numbers of neurons the greater the brain weight. So, the argument here is that body weight is proportional to the volume of the sphere which is assuming the density is constant.

So, therefore, the volume of sphere is 4 by 3 pi r cube, whereas the brain weight is since it is the number of fibers is proportional to the surface area and surface area of the sphere is 4 pi r square. So, therefore, brain weight is supposed to be proportional to 4 pi r squared. So, if you assume this, if you buy this argument then you have to accept that the brain weight E is proportional to the body weight S to the power of 2 by 3. So, you have some kind of power law relating brain weight and body weight.

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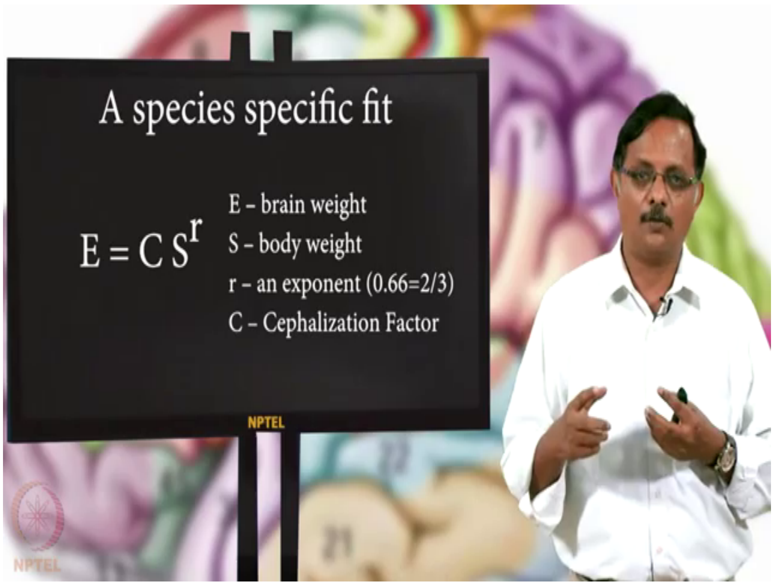

So, then people decide to fit this kind of a power law to the brain and body weights of real animals, various species. So, E is equal to some constant proportionality constant C times S to the power of r, where r is exponent which is equal 2 by 3 or 0.66 and C is a cephalization factor. Now, it tells you how much the, that animal is cephalized or rate is endowed with a brain. Now, you take, so people have fitted this kind of formula to different species they did not just take fit a common formula to all the species because that does not make sense. So, they have fitted this formula to various individual species, so for example, if we fit this formula to the average animal, you get some value of C and that is called the C average mammal.

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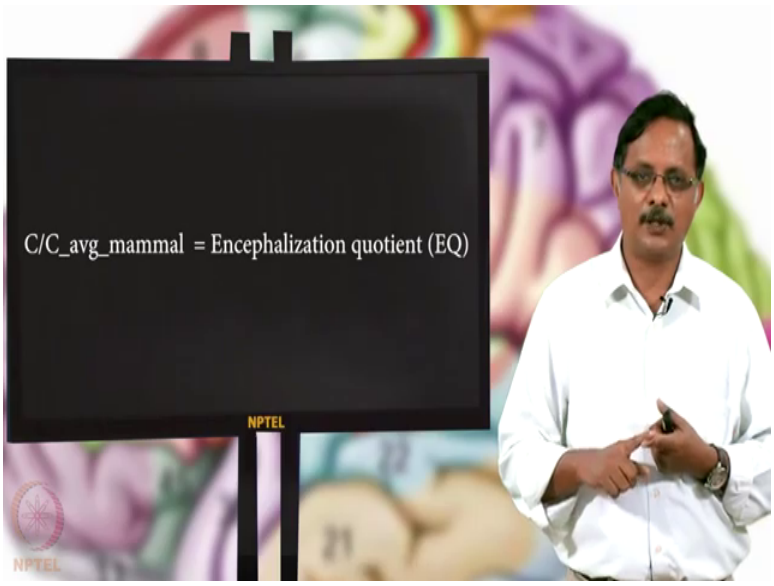

Then, fit it to some other species with which you want to compare with the average mammals them the mammals and then you get a different C. So, now, take the ratio of the C that you get from your test species and with the C of the mammals. So, you get C by C average mammal and this quantity is called the encephalization quotient or EQ of their species.

So, this abbreviation EQ is slightly misleading because you know it sounds like IQ, but actually as of now, it does not really call it with IQ, we do not know, we cannot say anything at the moment, but you know that there is a kind of application that is used. So, what does this EQ mean?

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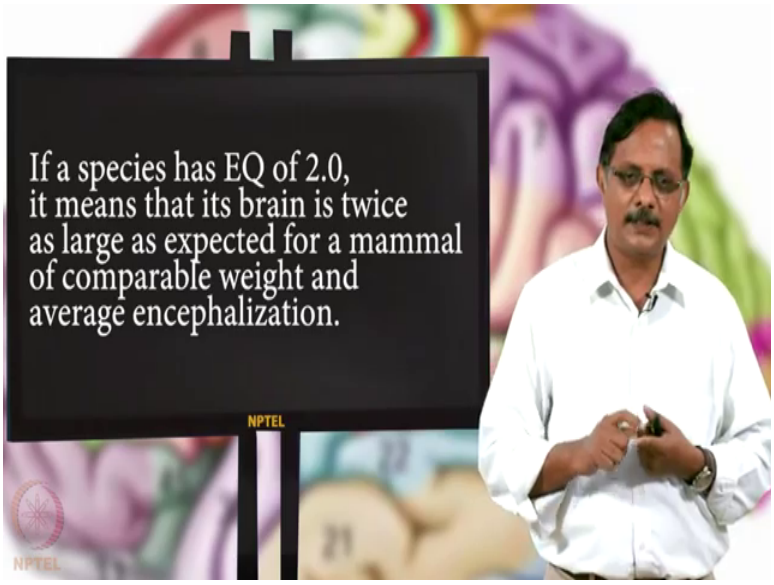

If a species has an EQ of 2.2, it means that it is brain is twice as large as expected for a mammal of comparable weight.

So, this is how this equation is measured and defined.

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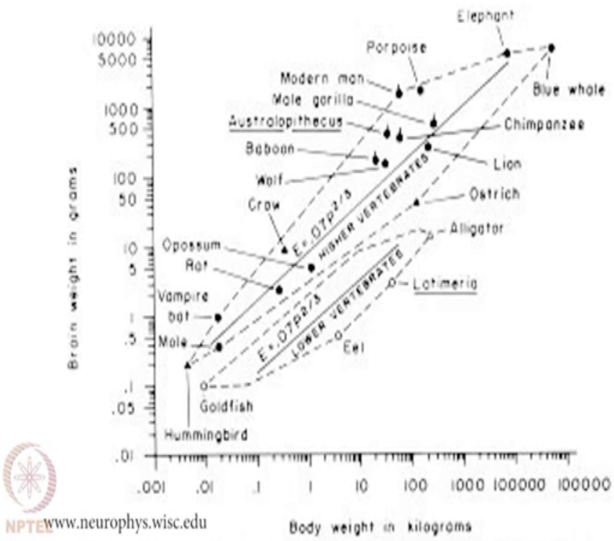

So, in this figure you have the body weight and the brain weight variation shown in the graph body weight is in kilograms and both are shown in log scale because that is when you get a since you have power law, if you access both this condition log scale you get a linear fit.

So, they fitted that and you see the kind of 2 polygons in this figure and the top polygon is for higher vertebrates and the bottom polygon is for the lower vertebrates and the C value for higher vertebrates turns out to be 0.07 and the C value for lower vertebrates turns out to be 0.007. So, you get this kind of different C values, take these quotients and then calculate EQs and let us see what you got.

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EQ is more satisfying!

Species	*EQ*	*Species*	*EQ*
Man	7.44	**Cat**	1.00
Dolphin	5.31	**Horse**	0.86
Chimpanzee	2.49	**Sheep**	0.81
Rhesus Monkey	2.09	**Mouse**	0.50
Elephant	1.87	**Rat**	0.40
Whale	1.76	**Rabbit**	0.40
Dog	1.17		

Macphail, E. "Brain and Intelligence in Vertebrates". Oxford, England: Clarendon Press, 1982.

So, for humans or for man EQ is 7.44, for dolphins it is 5.31, for a chimpanzee which is a very smart animal it is 2.49, dolphin is also pretty smart animal, the monkey 2.09 and so, all these primates right this are considered a very smart. So, all of them have a high EQ like high EQ values with humans having the highest and an elephant 1.87 and so on, so forth, the rabbit has a 0.4 and so on and so forth.

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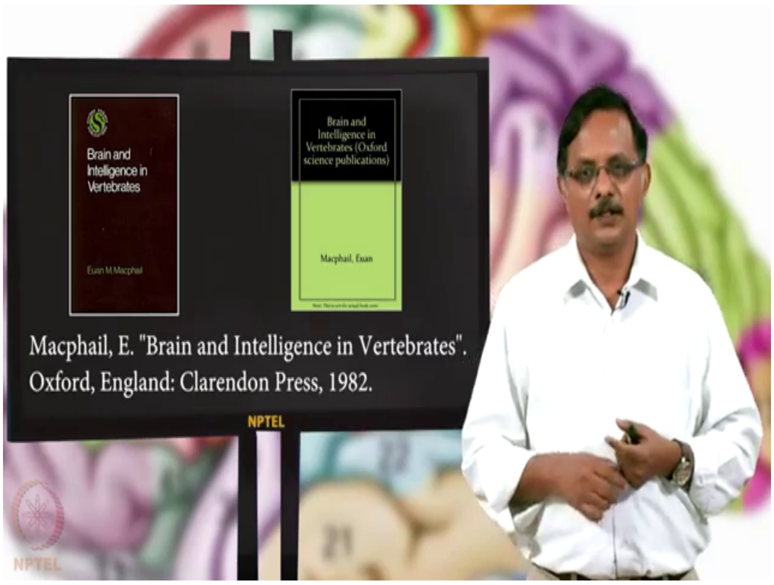

So, always, this kind of analysis are kind of taken from this book by Macphail.

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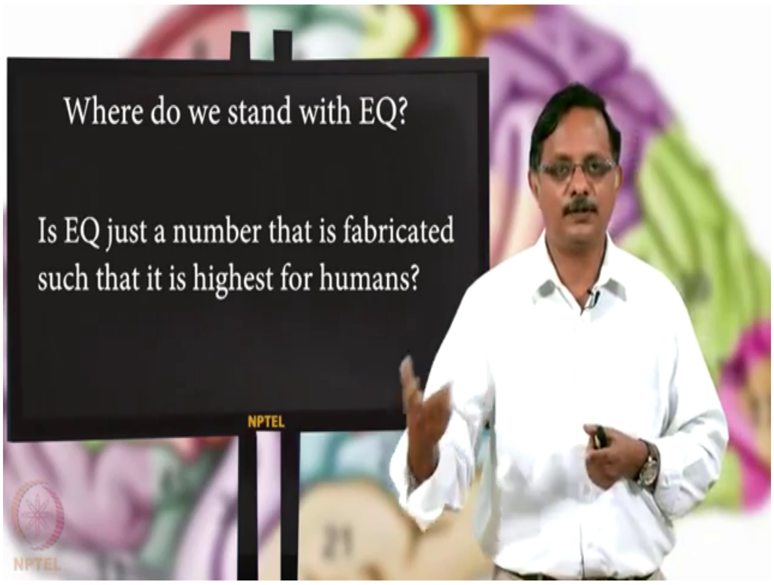

So, where do we stand? I mean so, we have looked at says we started with some simplistic measures trying to correlate brain structural properties like weight and you know weight, brain weight, body weight ratio and so on. We have tried to call it these quantities with intelligence, but it did not work out. So, then we defined this kind of a strange quantity called EQ and it worked well, it kind of it confirmed our intuitive ideas about who is most intelligent and so therefore, for humans EQs is highest.

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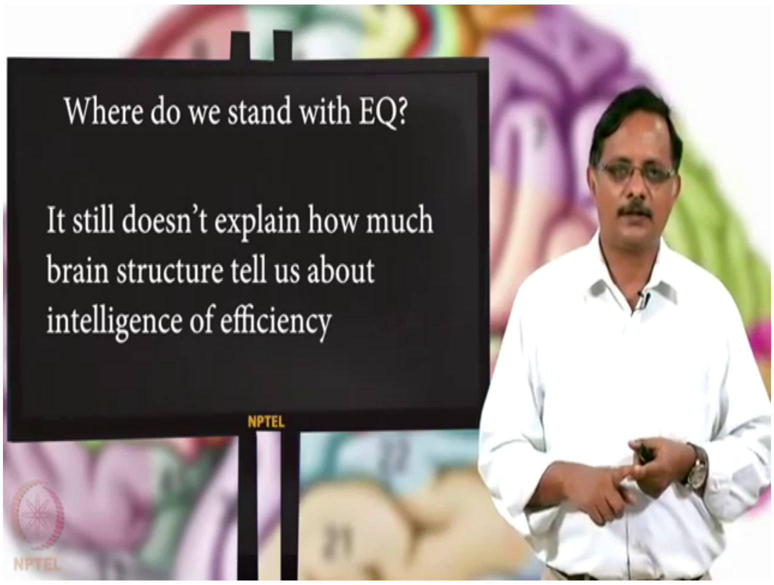

So, what is the conclusion? So, the thing is EQ does it seems does not is not very convincing because it seems like kind of a, some kind of a fit all right. So, you have already pre decided who is most intelligent and you have come up with some kind of a measure which confirms a kind of intuitive belief.

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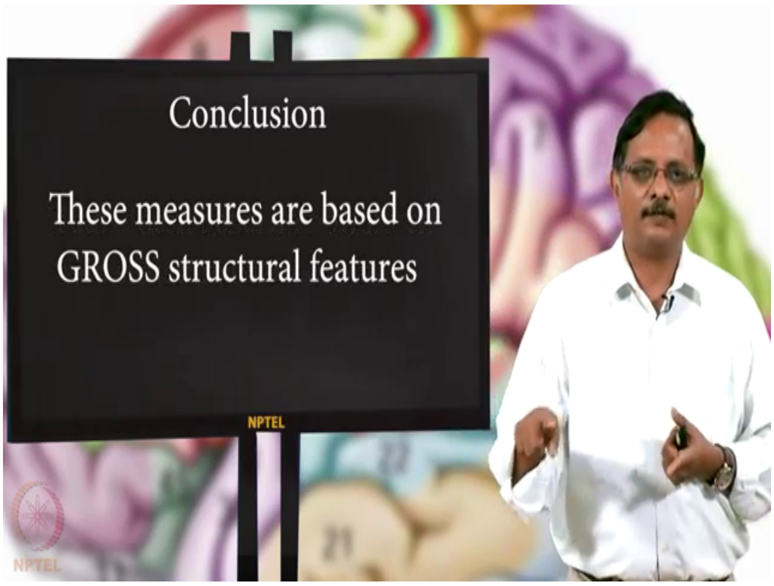

So, maybe we need to go further because these measures that we have looked at in this segment of the lecture are gross structural features.

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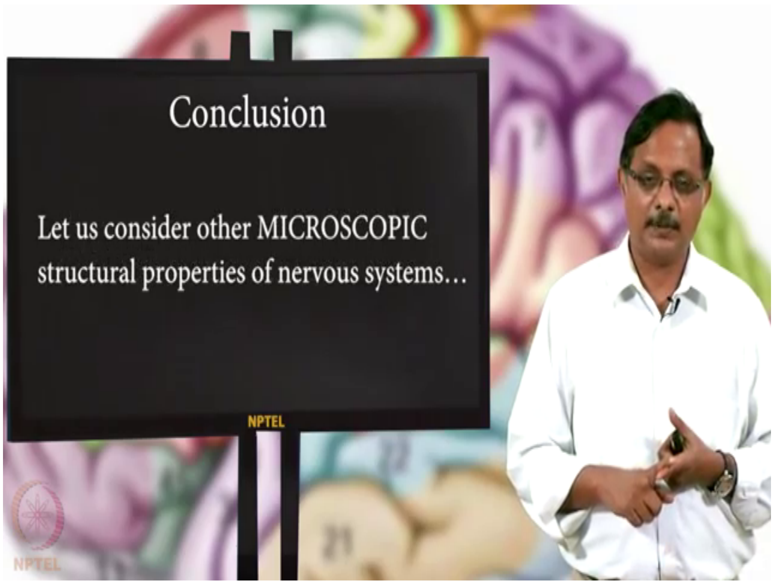

Maybe, we should look at the microscopic structural properties of nervous system, to really understand what is it, that makes a brain intelligent.

Thank you.