Neural Science for Engineers
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Module - 02
Lecture - 11
Brain Anatomy Introduction

Hi, so far, we have been discussing a lot about the cellular part of the story and neurons and how neurons function and things like that we have been looking at the functions of the nervous system in general. I also gave a brief idea of how the nervous system is organized with reference to the human nervous system, I told you about top-level stuff of very gross distinct areas such as the brain and spinal cord, which are located at various different locations.

So, the next step is to understand a lot more about the anatomy. Now why am I focusing so much about anatomy, when I designed this course and thought about the syllabus my initial idea was not to incorporate too much of medical stuff into the program, but there were a couple of issues which I later thought about and I think you should be aware of that. As it stands now neurosciences is necessary and used by a lot of very diverse group of people in their work.

And as in my introductory class, I had told that the course is designed for all of those. Now, the advantage of an online course is you are not restricted to a particular syllabus, and which is the freedom I have taken so far. So, it does not follow a medical curriculum you know so, in the sense that very rigid compartmentalization of topics has not been followed.

I have taken a natural flow which basically assumes that you have something like 12th class knowledge or maybe much younger because this is class 12 of when I was doing 12th. So, people study a lot of this stuff in much earlier classes these days is what I have seen. So, the idea was to build it from there on and build it without giving a medical flavor as much as possible, even to the extent of when I have been choosing headings for topics.

I have tried to make it as non-medical as possible, but having said that it is not possible to give a complete non-medical flavor because a lot of stuff is biological medical and it

is what it is, you cannot offer an apology to that and make it more simplified than it needs to be. So, the idea here is to make it palatable, that I think is the goal of the study. So, I have titled this as build brain which you would understand in the next couple of sessions on why the title is so.

And it is a new effort from my side because I had to explain the brain to a very novice audience which I presume it to be and I also have to ensure that you have competence, now I use the word competence for a very different reason. So, I have come across students who use the brain anatomy and brain function in their studies, engineering students.

So, the most distant group is the IT group who use very nicely the terms CNNs, RNNs, LSTMs and they are the people who design these packages. We have been using core neuro neurosciences concepts. CNNs have been inspired by the visual pathway and the visual cortex. So, if you have worked with CNNs and you have appreciation for the work which a CNN does it would be nice if you could know the nervous system in greater detail.

On the other hand, there are students and faculty who are working with brain images of various kinds, it can be for image processing, it can be for finding out annotation, for various kinds of studies where brain images are used. Now what happens in such kind of work is that you know the introductory class is basically about under an hour.

So, in an under an hour neurosciences brain anatomy is difficult to be taught, it is possible but you know obviously, compress data beyond a particular resolution and at which point it becomes useless.

So, I do find students struggling because they do not have an intrinsic understanding of brain anatomy, but you are forced to work with brain images. So, it can be normal, it can be tumors, it can be several other kinds of diseases, but you know it is finally brain anatomy. So, there are instances of anatomy or disease states which you have to process.

The same thing holds for even signal processing with any kind of electrical data, that is EEG, EMG and things like that, where you know you do not start with the signal you should have an understanding of the background from where it is coming, not the where part of it but how it is coming from. Which I have dealt to some extent, but better

understanding of where it is coming from is also useful because you know it may put a lot of context into the stuff on which you are working.

Now, how do I bind an anatomy class, do I make you competent enough to go to a neurosurgical operating room and perform surgery. Well, that is not exactly an idea, but for somebody who literally works on a daily basis on the inside of the skull. So, you know it gives me a unique opportunity to share a different perspective and viewpoint.

Now, as I told you even if you look at medical curriculum neuroanatomy is a very difficult topic, you ask any first year MBBS student, you would find that neuroanatomy is not something which is very popular. You can have an intrinsic interest for that, but if you look at the section on neuroanatomy in Grey's anatomy which is the standard anatomical textbook it is very dense.

It becomes worse when you look at books like Carpenter, Carpenter's neuro anatomy which is so complex that you would feel intimidated on even holding the book and reading it, so these are two extremes. So, you have material which is very difficult to grasp, very difficult to acquire and you have material which is too less, too less in the sense that it does not become working competence. So, I had to find a bridge between these two extremes, the bridge most often may not be simple.

So, that is why this preamble to the discussion and that is what I am trying to do. So, teaching anything as one of my collaborators would call it as a performance and as in all performances there is some message to be conveyed whether the media can be different, here we have online and stuff, but even when you have a face to face audience it is important to convey a certain meaning to that and the beauty of teaching is that you are free to experiment with stuff.

So, there is a lot of experimental stuff which you are going to see which I am experimenting because I feel that you know I tell you that the optic tract is superolateral to the midbrain and goes and joins into the colliculi and from there goes to the primary visual cortex on the in the occipital lobe and from there goes on to Wernicke area.

That you know by the time I finish my first half of the sentence you lost track and it is expected too. So, what you are going to see is a very different kind of experiment, it is an

experiment from my side in trying to teach a very diverse audience such as as expected from over the course.

So, please do bear with me I am not sure whether it is going to be a success or failure because unlike in a live audience you cannot gauge from the audience reactions whether it is interesting, not interesting or whether it is possible to grasp or you know it is difficult. So, a flavor which I have maintained throughout the course so far is that I have in spite of my bad handwriting and this one I have tried very minimal photographs and things like that.

So, this is not a class in which you prepare for an exam, this is a course in which I try to make you understand things. The objective is not that you finish the course get the certificate and show the certificate, the complete objective of the course and the time which is spent over here is that the objective is that you understand the stuff you may not remember, the stuff you know, but you need to understand the stuff.

There is some difference of course, if you understand well you would; obviously, remember, but the vice versa may not be the contrary, might not be true. So, what I mean is you may remember something, but you may not understand it. So, that being the case.

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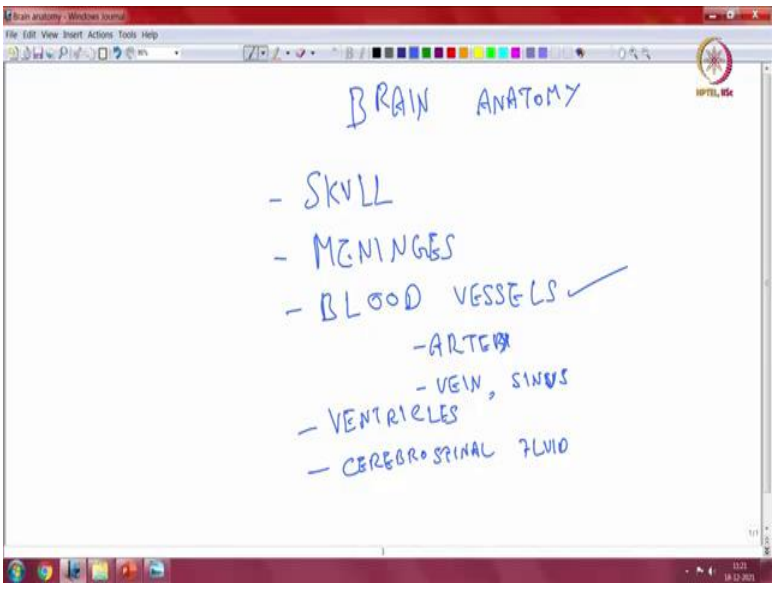

So, a little more introduction here I think I need to say because as I was telling you I had to bind my class. So, we are looking at brain anatomy.

And I already familiarized terminologies, that is what is the cerebrum? What is the cerebellum? What is the brain stem? These are core neuronal structures in the sense that these contain nervous tissue both functioning neurons and the astrocytes and oligodendrocytes and several other supporting cells, which are there within nervous system.

Now, I did not mention many other things which is you know the brain is not just about that and as neurosurgeons we need to know a lot more other stuff, but it also follows through that as an audience who is studying brain anatomy you should not, you can, but you should not take the brain anatomy in isolation because it is very difficult. Our memories to a large extent are relational, in the sense that you relate something to something else and then you remember both ideally.

So, when you are taught A for apple you remember A in the context of the apple, and you remember that the entity in your hand is named apple. So, the labeling of the topic and the topic itself from internal associations by which we remember both. So, that is the principle. So, in the context of the brain why I have to say that when you start with brain anatomy, I think I have to start with the skull then there is something called as meninges, then you have blood vessels.

Now, as I told you, it is not my intention to make you brain surgeons. So, I would limit my discussion on many of these topics, but without having this background it is a bit foolish to go deeper. So, we will start with blood vessels. So, blood vessels as you might be aware, so far from your prior education or through my discussion on gyri and sulci there are something called as artery and vein.

Now, apart from vein we have got something called sinuses, you know sinuses are there everywhere. So, there are sinuses around the nose, there are sinuses in the brain and then there is a sinus in the heart and so, that is how it is. So, we follow terminologies with the understanding that an important other entity which you would need to know is ventricles and cerebrospinal fluid ok.

So, these are the supporting actors in the story, and I would like to start out with the supporting actors actresses, for the very simple reason that you cannot see the brain in isolation, you should not see the brain in isolation and that is the point.

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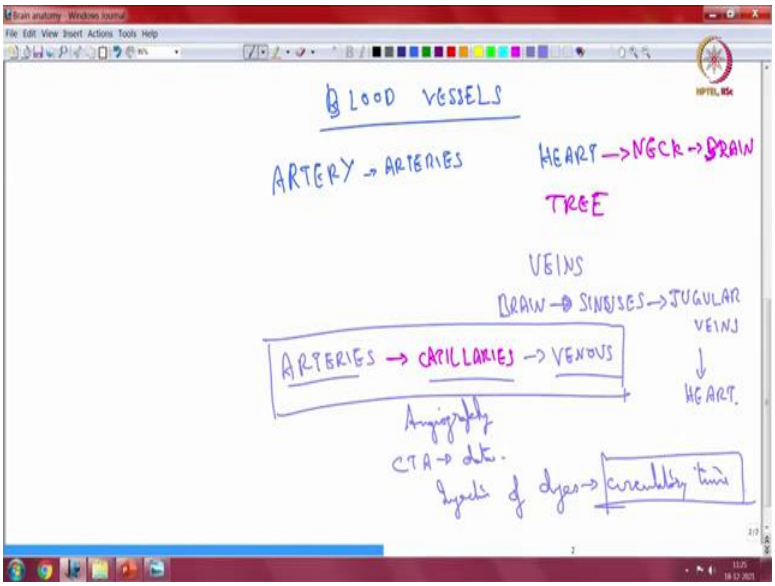

So, these are brief, I would show you a lot more details later on. So, blood vessels are also important to understand, that these have disease bearing. So, when somebody is studying on stroke you should have an idea of brain blood vessels when whether you are taking FRMI data of post stroke patients or you are looking at annotating stroke areas, early recognizing through AI packages you know all those stuff happens and there are lot of people working on each one of these things.

So, when you are doing an optimization, you should have a basic understanding of what blood vessel and what is a stroke about know. So, that is the idea of speaking about blood vessels. Now, artery which is arteries in plural, start from the heart and then that goes to the neck and that goes to the brain. So, there are, a couple of vessels which I will deal with it in greater detail. So, it is a tree basically and it splits.

So, how these blood vessels go through as I think I told earlier in one of the classes, you have the veins on your hand, these blue color things over on the back of your hand, those are the veins. So, incidentally veins go in reverse, so we name them in reverse. So, they go from the brain and there are things called sinuses and through that to jugular veins and back to the heart.

So, that is the general arrangement. So, arteries go into capillaries and then go into the venous side of the story. So, there are a lot of diseases or there are lot of stuff which incorporate this simple notation. Now, if somebody is working with angiographic

images, angiographic images would know the importance of this. So, there you have faces of these things and then you can find out. It is also important to know the circulation in say circulation time for CT angiography data.

So, where you calculate the injection, you synchronize injection of dyes to circulatory time and circulatory time is the time taken for blood to circulate from one heart cycle to the other heart cycle and that is not basically from heart back to heart, but from the heart to the brain and the various phases of the intracranial circulation. So, these are necessary for various kinds of data acquisition protocols, where if you are doing contrast injection you need to time the contrast to the time of acquisition.

And then you do various kinds of studies based on that. So, CT angiography, I am also incorporating some imaging terminologies. In my previous classes I have already introduced the underlying ideas, which are there for functional MRI. I have also introduced the concept of positron emission tomography, user part of the story not the physics or the background. And I am introducing the idea of angiography, but which is both digital subtraction angiography and CT angiography here. So, this is something about blood vessels.

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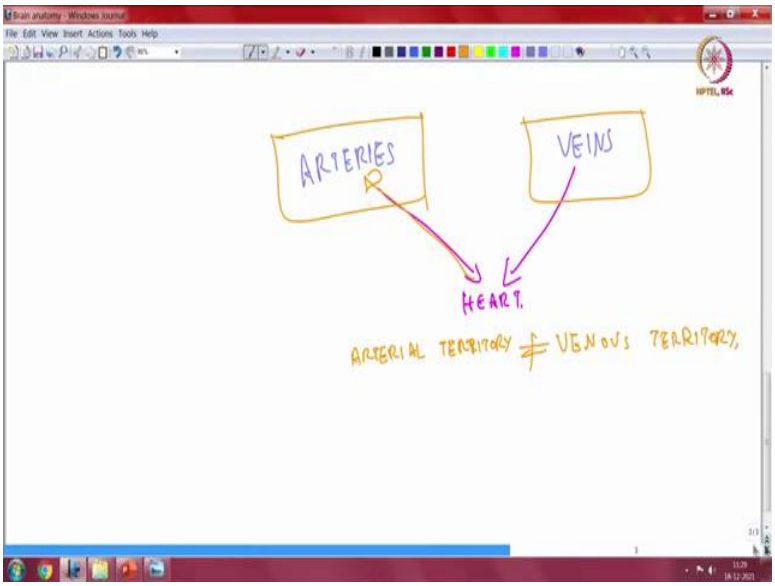

Now, interestingly as opposed to many other parts of the body, arteries and veins go separate paths. So, they only meet and in the heart. So, what that means is that in most

other parts, arteries and veins go together. So, the arterial distribution, the arterial pathways are the same and are same to the venous pathway.

So, if you look in the leg you have got the softness vein, the femoral artery, all of them together; then in the arm the brachial artery, the cubital veins. So, many of them are quite together and they have similar pathways. In the brain they are pretty well differentiated to the extent that even the gyrus, which is the anatomical atomic entity within the brain.

It has it is own different arterial path and a separate venous path, which I have discussed in the discussion on gyri and sulci. So, what happens is arterial territories are different from venous territories. So, when there is a venous damage, the amount of tissue which gets lost is very different from the tissue lost when an arterial territory is affected. So, territory is not equivalent to venous territory.

So, that is a brief introduction and something basic about the blood supply of the brain. So, the brain is very richly supplied with blood, I have spoken about the Krebs cycle, glycolysis, the power system of the brain and I have also highlighted the problem with the brain that it does not store glucose, there are no features to store glucose and it is life. So, when there is a higher requirement of glucose you increase blood flow, and it is a very tightly regulated system.

So, it also means that the amount of density of blood vessels per unit tissue is very high in the brain for ensuring the smooth functioning. So, it is very richly perfused and brain tumors as such operating on brain tumors for that reason is pretty bloody. We encounter blood losses of easily about 1 liter, 2 liters up to 5, 6 liters and things like that.

So, for the amount of tissue which is affected the amount of blood which is lost is disproportionately high, so that is what I mean. So, that is about the arteries and veins. Now we come to something called as meninges.

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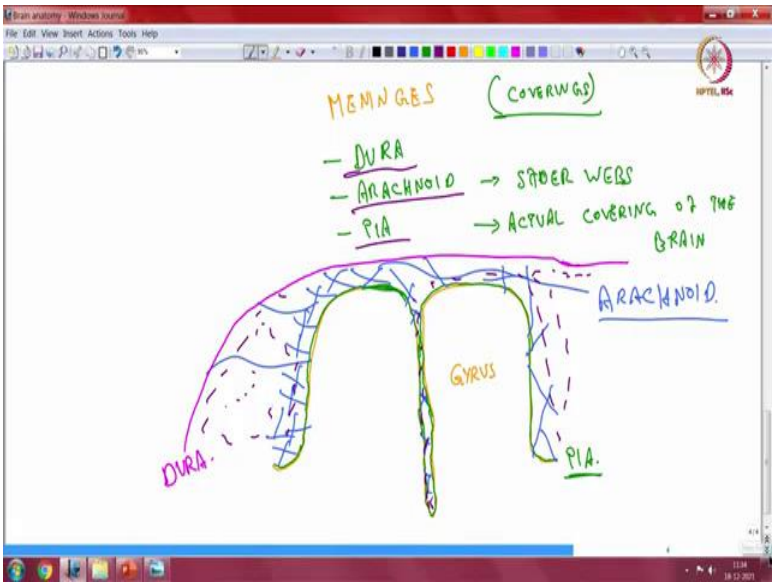

Now, for the sake of this one you need to know terminologies. So, dura, arachnoid and pia. So, these are the various kinds of meninges, basically coverings of the brain. So, you have dura, which is the outer most cover which covers both the brain and the spinal cord, there is arachnoid, which I will show in my surgical side videos, but it is something else which is there, arachnoid. Arachnida derived from looks like spiderwebs.

And pia is the actual covering of the brain, you know it encompasses the brain tissue all the rest of the stuff is not exactly on the surface of the brain. So, if you look at the gyral architecture. If this is the gyrus, the pia is on the surface of the the brain and it continues both on to the gyrus, sorry it is on the brain, on the brain, on the brain and, but it is a distinct entity, it is not that it is a mythical creature.

And neurosurgically it is very important because it forms a kind of barrier for several things, and it is very important for a neurosurgical student and neurosurgeon to understand and appreciate pile boundaries whenever operating inside the brain. So, that green is pia, if you look at arachnoid it is as I told you, it is spider web like and can extend to varying extents to the sulci. So, there is pia and this is arachnoid and it continues like that.

So, you have longer fibers, longer fibers, longer fibers, shorter fibers things like that. So, that is arachnoid. Please do remember these terminologies because especially for people in the biomed side, you would need to put things in context. So, when somebody

discusses sub arachnoid hemorrhage you should be able to understand that it is something related to the arachnoid part of the whole system.

And it is very different from an intracerebral hematoma and things like that. So, that is the idea of why I need to make the terminologies vivid and why I am taking time to explain all of these things. The last layer which needs to be discussed is the dura, so dura is all encompassing. So, it covers the entire structure, so that is the dura. Now, dura is pretty thick in most places except in some areas where it is somewhat thin.

And the dura forms a very tough membrane which encompasses the entire brain. So, now, that we understand what each one of these things mean and refer to, I think the obvious question is what happens to the rest of the space. So, there is tissue inside, there is tissue outside. What happens to the rest of the space? Its cerebrospinal fluid.

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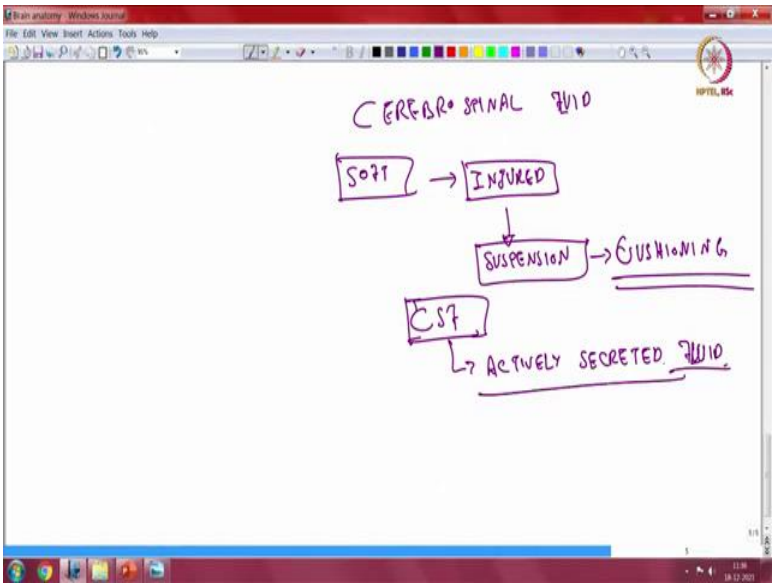

So, I would show you in the operative videos that the consistency of the brain is close to jelly like consistency. So, like you have jelly, so it is in the sense soft. So, that is the point which I have to make and anything soft has the tendency of getting injured and a mechanism of protecting, understood by any mechanical engineer out there would be that you provide suspension in engineering terms or cushioning.

So, cushioning of the brain and preventing direct contact from against the skull meninges etcetera is the function of the CSF. One of the important functions of the CSF, but the

CSF is not just anything, it is not just fluid which is there, it is a very actively secreted fluid.

So, actively secreted in the sense that now if you look at the Gibbs-Donnan equilibrium, in the first class I had told about just keeping a semi permeable membrane and putting things on either side ensures that there is an equilibrium, but like in the case of the sodium potassium pump, the CSF is generated by pumps, which ensure that the constituents of the CSF are slightly different when compared to mainstream blood.

So, the blood has a different concentration of various things, sodium, potassium, proteins of different kinds whereas, the CSF has a slightly different concept. I am not boring you with details of the CSF neither would it be required, but it is important to understand that the CSF is actively secreted. It acts as a cushioning mechanism and it is situated in this space between the dura and the pia.

Now, we have covered CSF, we have covered meninges, we have covered blood vessels, the next thing to be discussed about is the ventricles.

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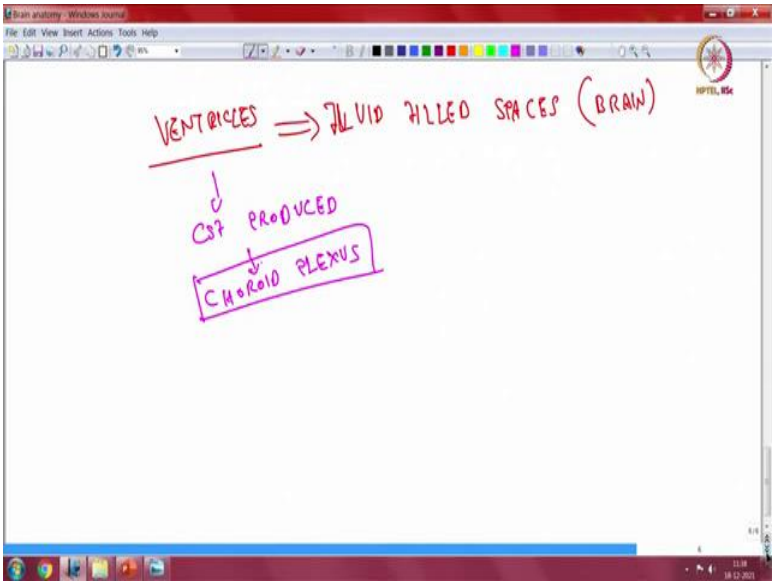

So, within the brain too there are fluid filled spaces and those are called as ventricles. Now, the terminology is a bit confusing because even cardiac heart ventricles are named similarly, and you need to actually specify which ventricle you are referring to if you are speaking to a general audience. Neuro audience would obviously understand ventricles

when referred to. In a neuro setting it refers to the ventricles which are within the brain, again anatomy would be spoken in greater detail.

But the ventricles are the place where CSF is produced by structures called choroid plexus. So, choroid plexus produces CSF. So, now, you would imagine that when I discuss earlier that the CSF, which I spoke was between meninges outside and the pia inside and it is within the arachnoid space, so how the communication happens. So, that the anatomical part of the story I would tell you later, but the circulation part of the story is like this.

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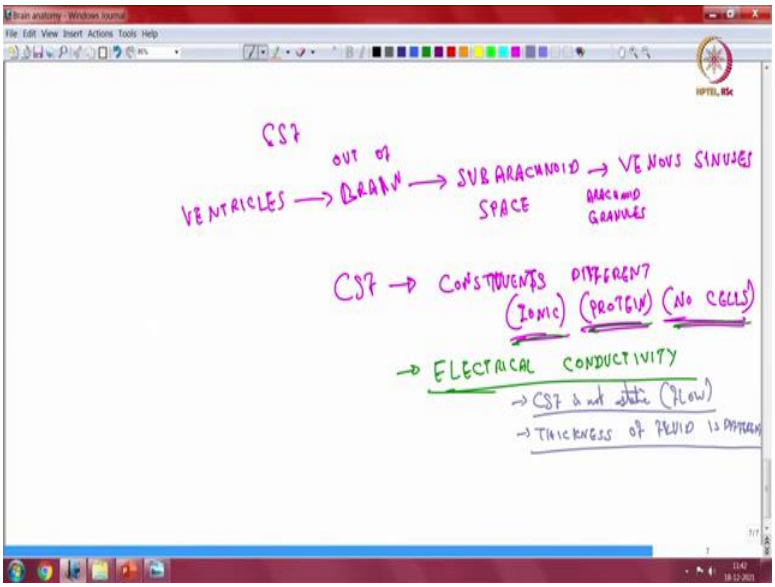

So, CSF is produced in the ventricles then it flows out of the brain, then it flows in the subarachnoid space and it gets absorbed into the venous sinuses. So, there are structures called granules, arachnoid granules. See there are controversies on many of these things. So, CSF production as such whether it is only through the choroid plexus, whether absorption is only through the arachnoid granules, there are controversies on that. I am not including any of the controversies.

The straightforward pathway which you need to understand is that this is how it happens. So, the other problem with CSF where you would need to understand in two separate engineering context is one, the constituents I have told you are different, it also means ionic constituents are different. Ionic, protein and no cells. So, difference in all these

three things happen. Ions, proteins and no cells. Now it also implies changes in electrical conductivity.

Now, it does not matter much when you are looking at any kind of electrode data which is obtained from above the dura, which is the outside outer membrane, but if you are looking at anything inside you have to factor that there is one why is it important there, it is because CSF is not static. There is flow, then the thickness, sort of a fluid in different parts of the subarachnoid space is different so.

So, both of these things have to be sort of kept in your mind when you are reading data, when you write, when you design something for recording and you should also keep in mind that when you get data and then analyzing you may not get what you expect because of some things like this. These are not things which are you know routinely discussed when you process data. But these do factor in, obviously if there is a change in the CSF constituent in a particular disease state.

And then there is obvious electrical conductivity changes and there is flow. So, there is flow and so, you will have to look at degradation of electrodes, etcetera due to flow. So, that is the context of discussing about CSF. Now, so, the last part of the story is the skull. So, both the brain is protected by the skull and the spinal cord is protected by the spinal column or the spine.

So, both are bony structures and I will not be discussing in detail about the spine. We will discuss a lot more about the brain because the spine, the dynamics are different, but it is not biomechanics of course, relevant, but I do not think I am covering that over here, but the brain part of the story I am not going into the physical details of the skull, but I would need you to understand certain things in the skull for the purpose of understanding brain anatomy, it is more for understanding brain anatomy that I am teaching the skull than as an empty discussion on skull anatomy.

So, the skull which is the inner part of all of our heads.

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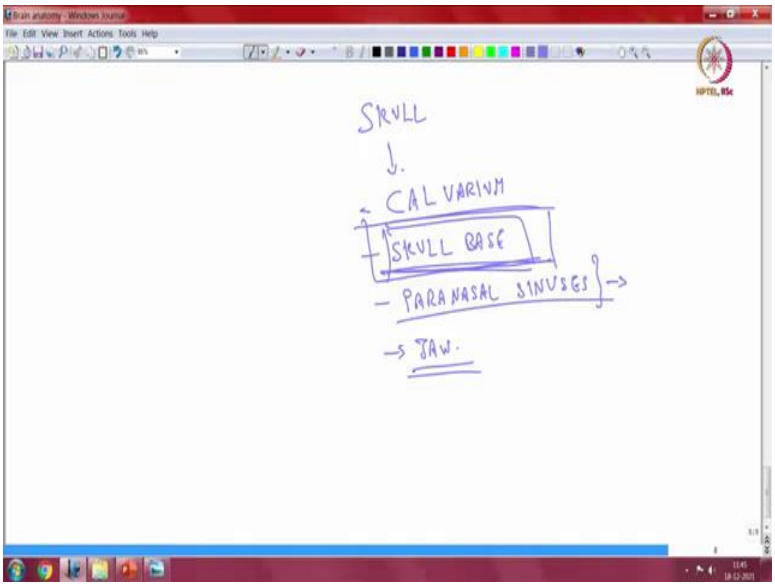

So, there can be deformities there can be diseases there can be so many things, but some things of the outer part is they call the calvarium, the down part is the skull base for us, then you have paranasal sinuses which is in the front face, etcetera this is basically for the medical side of the story.

So, not very relevant and then you have got the jaw. So, calvarium fairly is featureless, there is not much, but the skull base is one of the most complex anatomical structures in the body, there is a lot of stuff there. You would need to know something of this skull base because as I told you some anatomical entities go through various parts of it, and it is as I told you, I may also be using this skull as a basis for a lot of downstream discussions.

Paranasal sinuses I am not discussing because maybe in terms of when I discuss speech, I would highlight about the role played by paranasal sinuses in modulating voice and how sinuses help in respiration to some extent humidifying the air intake and things like that.

So, that is about it. Paranasal sinuses, jaw as such we would not be dealing as it is a medical topic, I leave it to the medical curriculum. So, most of the discussion as I told you we will focus on the skull base because there are certain ideas which you need to understand and these ideas are necessary when we discuss the brain in greater detail subsequently. I will break here and then we will take it forward from the next.