Neural Science for Engineers
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Lecture - 25
Spinal Cord Anatomy

So, far we have been discussing about the brain, the structure of the brain, parts of the brain, how to look at or understand various parts of the brain especially in the imaging context with all of these methodologies I hope you have had an understanding of what goes on within each one of our skulls. So, a continuation of the anatomy is Spinal Cord Anatomy.

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I am listing it out as a separate topic because it is not possible to proceed further without discussing the anatomy of the spinal cord to some extent. A very detailed anatomy is out of scope, is not required for the current setting and we will discuss whatever is relevant and necessary to understand for further topics in the course.

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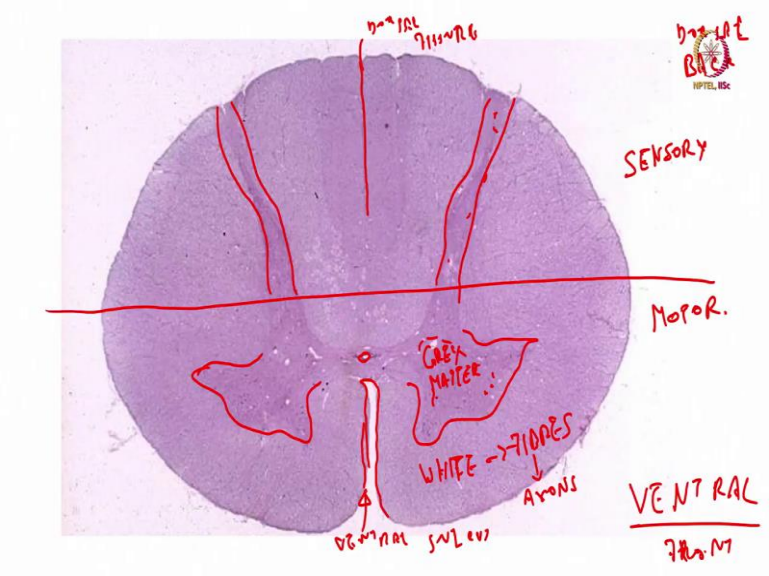

So, the spinal cord is a cylindrical structure and when I say cylindrical you should imagine it is something like this, it is a three dimensional structure and it continues from the brainstem.

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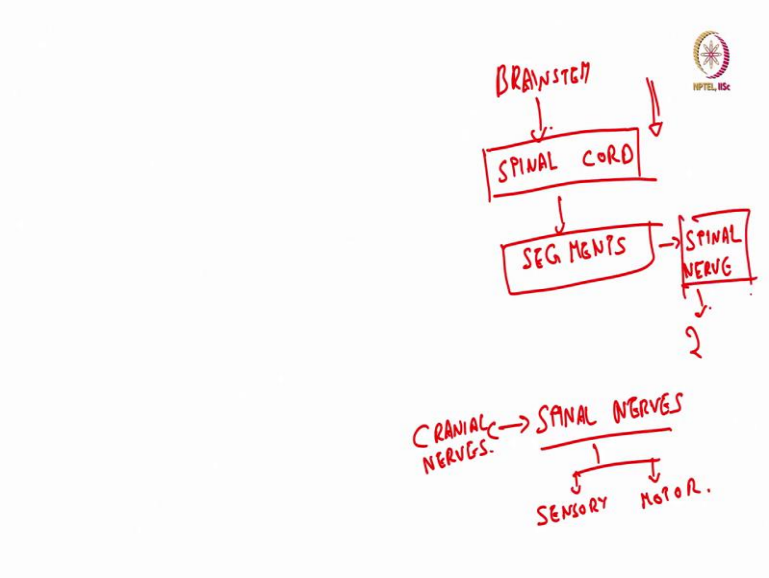

So, what I mean by continues from the brainstem is, the lower part of the medulla is almost indistinguishable from the spinal cord. There are internal structural changes which happen between the brainstem and the spinal cord.

But there is also a lot of spill over from the brainstem into the spinal cord. So, that being the case we will try to understand what the various parts of the cord are. Now, the spinal cord in turn is divided into something called as segments. So, the notion of a segment is each segment provides a spinal nerve. We are bilaterally symmetrical so, there are two spinal nerves on two sides.

And each segment as such does some particular function, if you remember my earlier discussion on during the skull, I had told you the difference between spinal nerves vis a vis cranial nerves. So, cranial nerves are pretty specialized you know, when I say optic nerve it does carry only light impulses from the eye back to the head, olfactory is the same.

There are some nerves which do mixed functions of for example, the trigeminal nerve which does chewing as well as sensations from the face and from the scalp and the head. Spinal nerves that way are monotonous in the sense that they contain both the contain both the sensory and the motor components. Not only that, they go across various parts of the body.

And then take in information which is very similar say in the sense that you have pain, touch, temperature, all these sensory modalities which are taken up by every single spinal nerve to almost an equal extent. Their distributions vary, but the data which is captured by each spinal nerve is just about the same..

Motor is also the same, the motor impulses go from the part of the spinal cord as the anterior horn cell of the spinal cord and from there it goes on to individual motor cells and that is also pretty monotonous. The way in which the neurons give out these fibers the way they traverse through individual segments of the spinal cord is pretty monotonous.

So, with that background we will look at histological image of this spinal cord. So, this is ventral. So, in the earlier class I had told you what ventral means is towards the front and this is towards the back, so that will be dorsal. So, that is the way in which you interpret. If you remember again, I had discussed the architecture of white matter versus grey matter.

So, this lighter pink is the white; white basically means fibers; fibers basically mean axons and the grey stuff is the grey matter, this darker stuff is the grey matter. So, it is opposite to the cerebrum and cerebellum which I have shown both in 3 D model as well as in the imaging where you see the darker grey cortex outside and the inside of it is the white matter of course, the deep grey nuclei accepting.

So, there is also this thing called as a central canal, then there is this ventral fissure, ventral sulcus and dorsal fissure. So, this thing is the dorsal fissure, ventral sulcus. So, this thing is called as the anterior horn, this is the posterior horn. So, that is about the way in which the structures are arranged. There is another thing to be told, it is about the split in the cord approximately where this part is the sensory and this part is motor.

It is not a very hard and fast rule, you would notice that the grey matter anterior is responsible for musculature whereas, the grey matter posterior is responsible for sensations. So, various kinds of sensations from various parts of the body are there and then that has to be compiled incidentally. So, a spinal cord does compile information and then sends it across to the brainstem, to the thalamus, to the sensory cortex.

And that is how information processing happens within our bodies.

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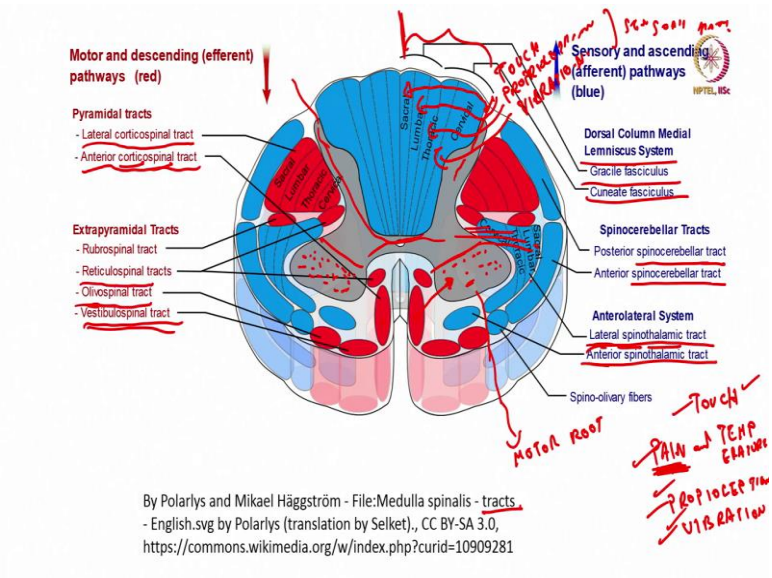

By Polarlys and Mikael Häggström - File:Medulla spinalis - tracts - English.svg by Polarlys (translation by Selket)., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=10909281

So, that being the structure we will go to the next level to have a little more understanding of what all happens within that. As I told you, the white matter is arranged

in the form of tracts. So, tracts means a single group of cables which is basically axons, these cables run in very defined manners.

So, there are no boundaries as such so, there are no definitive boundaries between each of these things, but there is an organizational and local topological structure to it. So, these fibers are related to each other, and they are organized in the same fashion across all the human beings, there are no variations between that. And we need to have some understanding of these things for further discussion.

So, the easiest part which I told you that is the anterior part is the motor and the posterior part is the sensory. So, what are segments? Segments I told you are regions in which there is a particular single spinal nerve which is coming out of it.

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So, how many segments would be there in the spinal cord?

So, cervical that is the neck 8, dorsal or thoracic 12; this is the chest, lumbar 5, that is the low back and sacral 5, this is back and this should be low back, coccygeal is about 1. So, these are constant in the sense that they are exactly the same across all human beings and these are bilateral. So, you have one on either side of the cord and each level at which the nerve comes out is defined to be a spinal segment.

So, the idea of a segment is that there is a lot of local processing which happens. So, each segment attends to stuff which happens at that particular segment. So, there is a

managerial role which the segment does. So, there are some things which are done within segments, some things which are done out of segment.

So, that is the idea of how segments work and why there is a functional connect to the anatomical idea. So, anatomical in the sense that is how we observe, when we open up the Dura surrounding the spinal cord we would see the spinal cord with this exit nerves. Now, another thing which I need to specify is how are these things actually of each segment.

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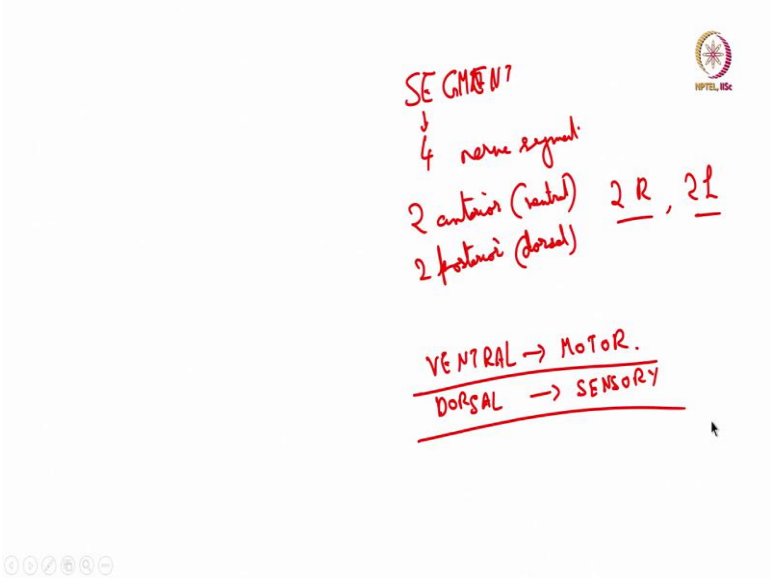

So, each segment gives out two sets of or has a total of 4 nerve bundles, you will be seeing nerve bundles which are coming out from each segment. So, there are 2 anterior, 2 posterior. Anterior is ventral, posterior is dorsal, which is also means 2 on the right and 2 on the left. Sorry total of 4, yeah 2 anterior and 2 dorsal and 2 on the right and 2 on the left.

So, it is basically right and left and the ventral ones are motor, dorsal ones sensory. So, this is also something which has to be kept in mind. So, the basis of this is what I was actually planning to discuss in this slide. So, we have already told that this part anteriorly is the motor part, where the motor neurons of the muscles are present, and these motor neurons get fibers from above.

Now, I told you that some fibers tracts are there in the medulla which crossover, but also there are some tracts in the medulla which do not cross over. So, 80 percent of the fibers cross from one side to another side, 15 percent do not cross over to either side and that is the basis of having this corticospinal tract. So, please note this anterior corticospinal tract and the lateral corticospinal tract.

So, these are the two anterior corticospinal tracts, and the lateral corticospinal tract is not labelled properly. So, that is the undescended part, they have not gone to the opposite side is the point which I am trying to make. So, these fibers which are crossed over form majority of the majority of the output of the brain, and they carry information about how the muscle should act and when they should act and all the larger goals of the brain which have to be implemented by the spinal cord.

And from there on they go and meet these cells synapse with these cells so as to make it technical and from the anterior horn cells they come out through the anterior root and that is the motor root. So, that is how things work. The lateral semi corticospinal tract also goes into the anterior horn cells.

And from the anterior horn cells give out fibers which go into individual skeletal muscles and innovate them. Now, looking at the sensory is sensations or touch, pain and temperature, pain and temperature, then there is something called proprioception, vibration. So, proprioception and vibration, pain and temperature and touch. So, that is how the sensory system is organized.

So, there are classes of fibers which deal with these sensations not only there are specific sensors which take in a particular set of data even the pathway which carries that data into various parts of the brain is highly specialized. So, you do not mix up between pain and touch.

Touch is separate, pain is separate, pain and temperature close are actually closely associated. Proprioception which is the sense of position. So, position in the body is very important for the body to have a sense of itself and to do any further action you know maintains the coordinate system in the body in a dynamic sense.

So, at all points of time you may not be conscious of where you are sitting but there are parts of your body in your head which keep continuously you know you are aware that

you know I am sitting on the back with force being put on my chair elbow is resting on the armrest.

So, all this data is collected, it may not come into my conscious being that you know I am applying so much of force on the chair not too much force on the hand. So, that is not always there in my conscious thought process it is, but it is acquired, it is assimilated and acted upon.

So, to make you understand why it is so relevant is you must have heard of bed sores affecting people who are lying down who are not conscious. So, though the sensory systems sensors are active in such people, the you know the higher level processing which says that the pressure on a particular area is too high, it is too persistent, may be perceived but cannot be acted upon because the patient is not conscious so that is the basis of formation of bed sores.

So, each of these sensory modalities are taken up from the respective sensor systems then carried upstream. So, how the upstream part of it is what is shown over here. Now, of this touch proprioception and vibration are very important sensations for the body and they are carried through fast receptors.

Incidentally pain which is a very you know we would consider pain as the most important sensation, but it is carried through relatively slow fiber. So, how that goes through is what I am trying to showcase over here. So, the fibers which come from the leg enter into the spinal cord and then get packed up over here so, that is the sacral cords of the most medial.

The next set of fibers enter in and then go over here and then it goes over here. So, there is a laminar architecture that is the point of telling all of these things, not only laminar architecture there is also bilateral symmetry in this spinal cord. So, both the sides are separate, independent and these fibers are densely packed and then this entire area is responsible for transmitting touch and proprioception and vibration.

Now, on the contrary when we look at pain fibers, they enter the same pathway because this is the sensory root. So, sensory root is through here, motor root is through here and the sensory fibers which has touch and pain immediately go to the respective laminae,

the pain fibers on the other hand actually traverse to the opposite side. So, then they traverse to the opposite side and where do we go, they go into the spinal thalamic tracts.

So, there are two groups of fibers. So, pain comes from here, crosses over to the opposite side after some levels, it is not in the same segment, then it goes like this. So, that is why you have got sacral first, then you have got lumbar, then thoracic and then cervical so, that is the way in which the fiber. So, the first the fiber which gets into the tract gets superficial to that.

Superficial in the sense from the other direction, from the cord direction a newer fiber comes and sits closely with that. So, this is how the body sort of keeps track of what sensation is coming from what part of the body, it is not mixed, it is not that there is a relay station somewhere in the spinal cord which takes up data from various parts of the body and transfers it is not like that there is an anatomical mapping. So, the mapping starts from somewhere over here.

So, mapping is, the fibers come from various levels they undergo packing within the spinal cord in the same fashion in which the fibers are entering into the spinal cord which sort of gives a natural sense of packing. And then these fibers go up into the brainstem, maintain the same fidelity there is some rotation, there is some turning which happens in that group of tracts.

But the overall structure and overall organization of say sacral, thoracic, sacral, lumbar, thoracic, cervical remains the same. And they all go to specific areas within the thalamus and from the thalamus they go to these respective sensory cortices. So, sensory cortex I showed you one single gyrus, but the gyrus itself is has got a homunculus distribution, but it has areas in the gyrus which are specific for different kinds of sensations.

So, the highest center of integration of the sensory pathway is the sensory cortex where all these sensations are merged and then the brain somehow infers what is happening in various parts of the body. So, there is a direct mapping between a fiber which comes from the tip of the toe all the way up to the cortex. So, there are distinct pathways, defined cells which undertake this mapping.

So, that is how this so that is how various sensations are carried forward. Corticospinal; cortico is up, spinal is down so, they go from the top cortex to the spine. Spinothalamic;

so that is reverse, so spine is spinal cord and thalamus is up and that is because it is pain and temperature.

Then the dorsal column is the lemniscus system; lemniscus is a laminar arrangement of fibers so, two sets of fibers for the upper limb and lower limb.

Now, if you notice there are so many other tracts, it is a very compact, very dense and that is why spinal cord injuries are so, difficult to treat so not just difficult impossible to treat as of now. So, spinocerebellar so, these are fibers which go from the spine, and they go into the cerebellum.

Remember in the anatomy discussion that I said that the pons is connected to the cerebellum through three separate peduncles: superior, middle and inferior. These fibers, the posterior goes to the inferior and anterior goes to the superior peduncle so, that is how the organization is. There are a lot of fibers which go from the cortex back into the cerebellum also.

A cerebellum is a place where a lot of integration of signals happen and it does so, by comparing input versus output. So, input is coming from the cortex, the output information is coming from the periphery through the spinal cord into the cerebellum and the cerebellum sort of you know sets the gain. So, we will talk about it later in detail so, that is how the cerebellum functions.

And so, these pathways are important because they transfer the information from the periphery to the this one and again remember they are designated pathways, they are like rail tracks. And each rail track carries only a particular kind of train which contains a particular kind of information, and it is and it is coded, it is evolutionarily preserved and it is maintained.

So, you can think of you know more efficient pathways, but somehow evolution thought that; that is not the way to go about it. The spinal cord for all its complexity, a lot of complexity is sort of simplified by this laminar architecture in which spatial fidelity is maintained throughout the transfer of information from one part, but on the contrary different sensations do not have the same kind of fidelity.

Say for example, touch and pain, touch and vibration and proprioception go posteriorly much faster. Pain on the other hand goes first to the spinal cord does some local process over there and then goes via slower mechanism up to the thalamus from where it is passed on to various other parts of the spinal cord. So, there are other kinds, say vestibular spinal is from the vestibular apparatus. Vestibular apparatus is important because the vestibular apparatus is responsible for balance.

So, balance is not just about balance of the body, but it is also balance of the head upon the shoulders and things like that. The sensory organs for the vestibule are located in the inner ear and you should understand that; that is responsible for the balance of most part of the body. So, there is a lot of communication which has to happen between the ear canals and the rest of the body.

So, that you know when you turn your head you should not just fall off. So, there is communication which needs to happen between that part and that is in fact, taken care by the vestibular spinal tract. There are nuclei within the brainstem, the olivary nucleus is a big nucleus so, that is a fiber tract which goes through that. Reticulospinal is important because the reticular formation is the formation traditionally associated with consciousness.

There is a network extending across the central part of the brainstem we have discussed the midbrain, pons and medulla. Central part of the brainstem contains these fibers and these fibers are responsible for maintaining what we understand as consciousness. So, there are outputs from the reticulospinal tract into various parts of the body through the spinal cord they may serve as modulators you know they tune activation and decay, delay and so many other things which I would not know.

So, to summarize the spinal cord is segmental, it integrates several kinds of data, it also gives out several kinds of data. I have so far, just spoken to you about only as a conduit of the spinal cord being conduit of information from the brain to the periphery and from the periphery to the brain.

Subsequently we will start seeing the bigger role in which the spinal cord functions and see how necessary it is for our activity. But, for the time being I would want you to remember these tracts, the organization of the grey and white matter and the topological

structure, topological organization of the spinal cord and how anatomical fidelity is maintained throughout the spinal cord.