>> Anatomy Steve Langjahr: It's March 23rd, 2016. This is lecture 13 which is going to wrap up for us the central nervous system by definition the brain and the spinal cord. Both of those components you'll be looking at next week in labs so you'll get a hands on experience, but today our focus in on the spinal cord. I'm going to pass around an actual human specimen, a segment of the spinal cord. In diameter it's about as wide as your little finger and at first glance it doesn't seem that impressive, but ask anybody in a wheelchair about important this is, how life changing injury can be when the spinal cord is damaged you'll get a different impression. Twenty million axons going north and south, this is basically the highway to, the highway from the brain and injury to it permanently disabling to one degree or another. We know that technically it begins as the medulla ends, that it starts as the brain leaves the cranial cavity. So that would mean from the foramen magnum, but surprisingly the entire spinal cavity is not occupied by spinal cord. In other words, your spinal cord actually stopped elongating when you were four years old. Did your vertebral column continue to grow? Yes. So toward the distal end of the spinal cavity we don't find any solid spinal cord, but rather filaments that is nerve fibers, nerve roots which extend below that point. So technically the spina cord stops at about L2 and with that said, where would you put a spinal needle if you were interested in a lumbar puncture? You wouldn't put it above L2 where you might stab the spinal cord, but rather at or below L2. So here's a section, a transverse section a typical diagram then of a spinal cord which would be representative no matter where you slice it. In other words, this spinal cord is rather consistent although it does have cervical and lumbar enlargements, it has this basic theme throughout. We know that the spinal cord is well protected by bone and occupies what you know is called the spinal cavity or the vertebral foramen. But let's do some mapping here and before we start make sure that the posterior or dorsal aspect is noted and this out front here would be anterior or ventral. The spinal cord displays bilateral symmetry, what does that mean? Everything you see on the left you see repeated on the right, so for the sake of our discussion and diagram this will be the left side and that would be the right side. You've seen a spinal cord or you've had a chance to in lab and, in fact, this is a photograph of a cord and you've noticed and come to expect this kind of butterfly pattern which dominates the interior and actually in life this is where you'll find nerve cell bodies and dendrites and a lot of synapses, but no myelin. So for that reason, this area that has this butterfly shape is called gray matter because it's non-myelinated. Gray matter can be divisible into horns because actually this pattern, this butterfly shape does resemble a pair of moose antlers or something, so remember these are referred to as horns, this one here then would be the left posterior horn, over here would be the right posterior horn, here's the right anterior horn, over here the left anterior horn. So these are just landmarks or areas within the gray matter. The gray matter basically is gray again because it lacks myelin and is a congregation of synapses, nerve cell bodies and dendrites. Most of the nerve cell bodies which you can probably see are the multipolar type and so from lab experience you've recognized that the best place to see nerve cell bodies is here within the gray matter. So the horns of the gray matter are simply landmarks surrounding the gray matter naturally is white matter which by definition is myelinated and that's because essentially all of these areas outside the gray matter form vertical columns which are carrying signals up to or down from the brain. So the white matter represents northbound and southbound highways of information. In other words, axons, myelinated axons which form ascending and descending tracts. Ascending means what? Going up, descending means going down, so from a functional standpoint, ascending tracts would be made of what sort of axons? Ascending, sensory; descending are made of motor and before we get further obviously injury to ascending tracts would deny you sensation and damage to descending tracts would leave you weak, paralyzed or incapacitated in some way or another. But basically the white matter again is a two lane highway; ascending, descending and these are essentially axons that are myelinated. Another feature which is rather unimportant, but certainly conspicuous is this hole which is actually a tubular channel that runs right down the center of the spinal cord and for good reason it's called simply the central canal. It's not empty and it's certainly not air-filled, so what would you think, what fluid would you imagine would be found there? CSF, cerebral spinal fluid. The central canal actually extends from or originates in the fourth ventricle so naturally it contains CSF. This CSF doesn't go anywhere, that is the central canal is dead-ended, it doesn't actually open up or drain out, it's a dead-ended very narrow canal from the fourth ventricle. Now bilateral to the spinal cord and extending through the intervertebral foramen, are what we call spinal nerves. Spinal nerves pass through that gap between vertebrae which I just mentioned, right. Any two vertebrae contain notches which collectively form a circular space known as the intervertebral foramen and incidentally that space is maintained by the thickness of this fibrocartilage which you know these are called intervertebral discs. With that said, can these fibrocartilaginous discs suffer trauma? Can they collapse? Can they herniate out posteriorly? And when that happens what changes in the intervertebral foramen is that it gets narrower and what's going to be compromised or pinched is one or more of these spinal nerves. So does this produce pain, discomfort, even paralysis? Yes. So you must know somebody who has "back problems" and usually that's the result of some injury, some herniation of an intervertebral disc. There are 20, excuse me 31 pairs of these spinal nerves and so naturally

you'd want to know how their named. Actually they're not named as such, they're given letter and numbered designations. So what do you suppose the designation T8 left would mean? T in reference to thoracic, 8 a reference to the 8th thoracic vertebra and left meaning of course exiting on the left side. So T8 refers to the spinal nerve which exits below the 8th thoracic vertebra and so naturally this is an easy and logical way to refer to these spinal nerves. Thirty-one pairs, this then is a spinal nerve and labeling what you have in front of you this is a spinal nerve. Represented naturally on both sides, but notice as we approach the cord or as we move laterally from the cord this spinal nerve splits. One goes posterior, one goes anterior. These are called roots, because they resemble a root structure of a plant. So naturally this one back here should be labeled and you're ready to do so that should be labeled the posterior root, but we're also going to call it the dorsal root because dorsal and posterior are the same. The dorsal root is basically an entry point for afferent axons which are sensory and sensory nerves as you may know are unipolar that means the cell body is in the center of what are two basic axons. So here I'm just taking this wire and bending it, this represents the cell body and so this would be the nerve which would fill this space right there. Now curious thing about the dorsal root, is that there's a big bulge there. Do you see the bulge? And on microscopic inspection you'll find that it's basically the result of lots of these, lots of nerve cell bodies which causes the otherwise narrow root to expand at that location. The name of that then is called the dorsal root ganglion. It has no significance, but the question, the fair question is why is there a bulge there at all? It's just because here we have a bunch of nerve cell bodies which causes it to be fatter or wider at that location. The most important thing so far is to appreciate that the dorsal root is an incoming network of sensory nerves, so if you were to snip that with a pair of scissors, if you were to cut the dorsal root you would not be paralyzed but you would lose what? Sensation at that level and perhaps below. So if you've already done so this is the dorsal root and this is the dorsal root ganglion. Obviously the other root is called the ventral root and this is not incoming but outgoing and as such it's made up of motor fibers and so the question which would seem obvious is why isn't there a bulge on the ventral root? Well remember the ventral root consists of motor nerves and those cell bodies are multipolar and they're all found here in the spinal cord, specifically in the gray matter of the anterior horn. So if that's not clear, ask me why is this a bulge here in the dorsal root because we have lots of sensory nerve cell bodies; where are the cell bodies for the ventral root? They're all here in the gray matter. Here's yet another view from your text showing a spinal nerve. Here is the dorsal root including the dorsal root ganglia, notice the ventral roots don't have ganglia. A nicer view of a dorsal root, why is there a bulge here? Because we have a bunch of nerve cell bodies. If you were to ask me why it is this way, I'd say I don't know. So that's just one of those anatomical facts. It has no functional significance, but it certainly creates a characteristic difference in the two roots. Now as we look down the spinal cord, we said there are 31 pairs, 31 pairs of these spinal nerves, but many of them are coming from or converging toward a particular destination and so as we look at the bilateral arrangement of spinal nerves, in certain key locations there's a lot of tangled converging spinal nerves and these are called plexus. Plexus is Latin for a braid just like something you do with some hair. So these plexus by definition are merging networks of spinal nerves which are approaching or leaving the spinal cord that means leading to or leading from a specific bodily area. We're going to get into detail with respect to the plexus, but for today we're just going to give you the names of these and give you some rough idea of where they're affiliated, that is, their distribution in the body. The first plexus which basically comes out of the lower cervical and upper thoracic, that plexus is called the cervical plexus and not surprising it covers or is distributed to structures in the head, neck and even the upper chest and upper back. Below that is the brachial plexus which comes out of the thoracic area you would guess and it services the shoulder and the arm and then hand. Giving some meaning to that, what would you predict if someone had injury to any component of their brachial plexus? Well they're not going to be moving or feeling much in their shoulder and hand. Moving on down right here, the lumbar plexus clearly associated with lumbar vertebrae and quite naturally associated with structures in that area, lower back, abdomen, pelvic structures, genitalia and the thigh especially the anterior thigh. Finally, there's the sacral plexus which innervates, that means supplies structures, muscles of the buttocks, posterior thigh and pretty much everything below the knee including the calf and the foot. So at this point, again, injury to the sacral plexus would leave you somewhat handicapped with respect to operation of these structures and sensation from these structures. So we're going to revisit this and we're going to actually give specific definition and some detail to these plexuses, but for now that's just an introduction to this arrangement. Now the interesting thing about the cord and we've already spoken of this for the brain, is that it's not in contact with the vertebrae, it's quite insulated that is protected from chaffing or rubbing against the vertebral bones themselves. In fact, you notice already if you've done some reading and certainly from our last lecture even, that the brain, the entire central nervous system is surrounded by a three-layered sheet of membranes referred to collectively as the meninges. The meninges refers to membranes and these provide protective enclosure to not just the cord, but the brain as well. So the meninges encased, enclose the entire central nervous system. So here's a cutaway through the spinal cord revealing these three membranes and let's name them and give meaning and function to each one. Starting from the outside moving inward the outer layer which is thickest and strongest is called the dura mater. Now dura is Latin for tough or durable and mater is actually a word for mother, strangely. So quite interestingly this word translates to tough mother. Now what makes it tough? What makes it so durable? If you had a piece of dura in your hand you could not tear it. It's very flexible, but it's very strong and it's white not because of myelin, but because of that protein that we mentioned again and again, the "C" word, collagen. Collagen gives this its strength and as you can see the dura mater is made of dense irregular connective tissue. Keep in mind this surrounds not just the cord but also the brain. At this point, works might make some sense to you, words you've heard before. Perhaps you've heard of an epidural block. Perhaps you've heard of a subdural hematoma, so those are clinical situations which obviously reference the dura. Essentially the dura is surrounded by fat and blood vessels and essentially also shields the delicate spinal cord from the rough surface of the vertebral bones or the cranial bones, but that really does not give full credit what it does. It's a watertight enclosure, so in that sense naturally it helps to keep in what? What fluid occupies or surrounds the spinal cavity and the brain? CSF. So one of the key functions of the dura then is to prevent leakage of CSF. Not uncommonly when people have head trauma, there may be clear fluid coming out of the ears or out of the orbits. What is that clear fluid? CSF and does that represent some considerable trauma then to the dura? So one clear function is that the dura contains and prevents leakage of CSF, but it goes beyond that. It not only keeps the CSF in, it keeps what from getting inside? Infection. And so certainly now you can correlate a term that you're quite aware of who hasn't heard of meningitis? Meningitis is an infection or inflammation of the meninges especially first the dura. So to summarize it the dura keeps out infection and keeps in the cerebral spinal fluid, as well as, having a role in minimizing friction or irritation to the spinal cord and brain. Next and deep the dura is a rather fragile, delicate web-like membrane which is called the arachnoid. If you've had biology you know that spiders belong to a group called arachnids and so arachnoid means web-like or spider-like. It's very delicate tissue made of squamous epithelium and elastic threads, elastic connective tissue. So it's not easily dissected but it is seen and I encourage you to look in the lab because just last semester we had an honor student remove the entire spinal cord of one of our cadavers and it's mounted there for you to see and admire in a long glass tube and you'll be able to see if you take the time, you'll be able to see the dura and the arachnoid. The arachnoid seen here with these web-like strands known as trabeculae basically creates a space, a space where CSF is free to circulate and the name of that space you've already know is called SAS, an acronym for? Subarachnoid space. What fills the subarachnoid space is cerebral spinal fluid, but let's be clear does the arachnoid make this fluid or just provide a space for its circulation? Just the latter. CSF actually is produced in the ventricles. Remember there's structures there referred to as the choroid plexus. Now deep to the arachnoid is the final membrane called the pia mater, so naturally you want to know what pia is right? Pia means tender, so what's the translation?

>> Tender.

>> Anatomy Steve Langjahr: Tender mother. This layer is so thin that you can't just pick it up and examine it. It's very thin. It's a vascular areolar membrane which actually clings to this spinal cord and also follows the gyri and sulci of the brain. So it's virtually non-dissectible, you won't be able to see it or appreciate it in the lab. What's it do? Well the fact that's it's vascular suggests that it provides blood vessels certainly that is oxygen and nutrients to at least the superficial layers of the spinal cord and brain. Now up here I've created a very simple sketch which just summarizes these layers. The outer layer, the thick one here which is white and durable, that's called the what? Dura. Deep to that this honeycomb space which is called the space is called the subarachnoid space created by the membrane called the arachnoid and here in green even though it's not literally green, is the pia mater. So at least you'll be able to see in lab the dura and the arachnoid in the brain and spinal cord preparations that we have. So just to summarize, the dura provides a protective enclosure that is providing a watertight seal to CSF also a barrier to infection. The arachnoid provides a space for what fluid? Cerebral spinal fluid and let's not forget the function of cerebral spinal fluid it's not just, you know, to keep the brain wet, but rather to distribute nutrients, provide bouncy and to protect from shock, it absorbs energy. And finally the pia mater which is basically a vascular membrane which delivers oxygen and nutrients to at least the superficial cells of the brain and spinal cord. So study certainly some of these illustrations that are available to you online, in your textbook and remember that these membranes are not just limited to the cord, but also the brain. Here's an actual human brain and the dura has been removed but you can see a kind of glossy, translucent membrane that is adherent to the surface and that's the middle one, that's the arachnoid, the space under the arachnoid is called the subarachnoid space normally filled with cerebral spinal fluid. Alright so let's not finish up, that is spend the rest of our time with what you'll probably consider a complex mapping of the spinal cord. And what we want from you here is not the ability to diagram this because that's not what this is about, but rather understand the organization of the spinal cord and some of the specific tracts that are sensory and motor in nature. So if you have colored pencils this is a, here's an

opportunity. Here's our spinal cord without the spinal nerves and just to set the stage again, naturally this is the midline so everything over here is going to be left, everything over here is going to be right, everything back here is going to be posterior what's the other word? Dorsal and everything out here is going to be anterior a.k.a. ventral. So we just have to get that framework, basically dividing this into quadrants. So we're going to map for you and give function to what are called spinal tracts also called fasciculi a word meaning bundle. And remember these are essentially ascending versus what?

>> Descending.

>> Anatomy Steve Langjahr: Ascending contain and deliver sensory information; descending are motor. So these are vertical bundles of functionally similar white matter. Again, white because of the myelination around the axons. So we're going to divide our discussion obviously into ascending tracts and descending tracts and incidentally, not all but just some of the major tracts that are important. So ascending tracts by definition are sensory pathways that are destined for and will terminate in specific areas of the brain most often postcentral structures, that is, structures behind the postcentral gyrus. So where we go. Let's talk about those that are grouped back here. Those that are grouped back here are called dorsal because they are and let's pick off a few of them. One referred to as the fasciculus gracilis which I colored light blue here for no good reason. The word gracil means narrow or slender and it is a very slender piece of pie back here, you see it. And let's not forget that there are two of these, right? So this is the one on which side? Right side. This is the one on the left. Now what sort of information is traveling along this ascending tract? It's says sensation with respect to light touch that means very gentle contact with the skin and muscle position sense where in the lower body. What does that even mean, muscle position sense? There's a better word, a more sophisticated word that you should know and you'll read about it's called proprioception. Proprioception is something we all take completely for granted, but right now you know you have a sense of where your joints, where your muscles are and even though you may not be dwelling on this and thinking of it you rely on it heavily and you can demonstrate it quite easily; close your eyes I'll do it and wave your hands around and you can still bring your fingertips together. Now how can you do that? How can you know where that is every second even though it's moving around, well you have what sense, proprioception. And you take it for granted but you need and rely on that in order to move things appropriately and successfully to bring about movements that you're trying to do especially well-developed wouldn't you say in jugglers or in athletes or dancers for that matter. So the fasciculus gracilis brings in information about our muscles, not all of them; where in the what the lower body and also light touch. Let's be clear this has nothing to do with movement. Because this is not a descending tract, it's a what a ascending tract. Now what's this remark here crosses over at medulla? We mentioned that fibers cross and it is common knowledge that your left brain, your left cerebrum controls and receives information from the right side and vice-versa. So let's use this wire just as an example and let's deal with something in the lower body, lower right side so these fibers will come in to the spinal cord from the what, the lower right side and they're going to go up the right side of the cord but what's going to happen up here at the medulla is that they will what, crossover and end up on the left side of the brain. So crossing over at the medulla means that these fibers go up the same side that they originated on but at the medulla they what, crossover. So why? Here's a question that is not unreasonable. The patient has an injury to their right fasciculus gracilis, what would be the consequence? Damage or destruction of the right-sided fasciculus gracilis. Would they be paralyzed? No. Would they lose some sensation? What sensation? And would it be on the left side or the right side? Left side. Because these haven't yet crossed over, so if we've injured the, wait a minute this is the right side, alright. How did I phrase the question? I'll have to play the tape back. We'll start over. Damage to the right-sided fasciculus gracilis would cause loss of these sensations on the right side, because these came in from the right side and haven't yet done what? Haven't yet crossed over. Got it? If not here we go, here's a little wire diagram coming in from the what, right side, going up what side, right side, eventually crossing at what level, medulla but if we damage it down here it still has a what, therefore damage here is still going to have its effects known on the same side that it came in on. Good. Sorry I confused you and me there. Next, seen here in purple the fasciculus cuneatus, essentially a companion too and carries information similar to the fasciculus gracilis light touch and muscle position but now what, upper body. That means essentially arms and shoulders and such. So in a similar way, if you had injury or damage to the right-sided fasciculus cuneatus that would lead to loss of these kinds of sensations on the same side because these have yet to crossover. Also, grouped back here kind of an orange there the spinocerebellar tracts which is a name that should make sense, indeed every name is anatomy make sense if you look for that sense, so isn't this a combination of a couple of words? Spino what? Cerebellar. So it must be going to let's guess, the cerebellum and the cerebellum gives you information that you rely on not for initiating movement, but controlling movement and therefore especially important to maintain balance, maintain posture, maintain a stance as you walk or otherwise move. So with

that said, what if you injured this tract? Well you would lose this subconscious sense and you might stumble or otherwise not be able to navigate without tripping and falling. Let's go over here to the lateral, the lateral group and among those that we'll single out the lateral spinothalamic tract which you see here in red. Why is called lateral, well it's on the lateral aspect of the white matter. This controls what I should say is that it delivers information about pain and temperature especially skin temperature and what have we said so far, we're grouping this under the lateral ascending tracts and this crosses over where, at the level of entry; what does that mean? Let's imagine damage to the right lateral spinothalamic tract and we'll portray that. This tract comes in to the cord but it doesn't go up the same side, it what, it crosses over to the other side before even climbing up. Therefore, this which is now on the left side of the cord actually came in from the right side of the body. Damage to this then on the right side would actually cause loss of pain and temperature sensations on what, the opposite side. You might be wondering why is it this way, my answer is I have idea. It's just the way it is, but it does have clinical significance that it's important to know. Anterior group, let's pick off this one the spinothalamic tract anteriorly here is in green and this conveys sensory information about crude touch that means rather, you know, broadly-based touch not a pinprick or anything like that and things that deform the skin, things that might be called pressure such as contact with a chair or something large. This also crosses over where? At the, level of entry. So here it is in green what if you injured that? If you injured that you would lose, crude touch and pressure and if you injured it on the right side that would be loss that is that would be actually missing on the opposite side because this tract even though it's on the right, came in from the left. Now those are some, but certainly not all of the ascending tracts. These are the ones that we want you know and to repeat, we're not going to ask you to diagram this because that would be like diagraming the freeways of Los Angeles, not terribly important. Instead we're going to create questions just like we did because we expect you to know the functions and whether this is an ascending or descending tract, whether it crosses over at entry or higher up for instance at the medulla. So let's finish off with the descending tracts. By definition, descending tracts are made up of what sort of axons? And so any injury to a descending tract is going to leave you with some degree of "P" word, paralysis. So these are motor pathways which are coming down from the cerebral cortex and/or from the cerebellum. Essentially we'll just consider two. The first group are those that are part of the pyramidal formations, the pyramidal tracts which crossover at the medulla. In lab you're going to see the medulla and on the ventral or anterior side of the medulla there are two parallel sort of mountain ranges which are called the pyramids and the reason for their extension outward is that we have fibers crossing over at this point. Hard to illustrate it with a weak little wire like this, but if you had a wire here and it's crossing over just like that and you had others that are crossing this way would there be a big rise or bulge at that location? There would be. So the pyramids are the result of crossing over and these are very easy to see along the ventral side of the medulla. The pyramidal tracts are descending and the most important in this group are corticospinal, again, two words put together what is the implications? Cortico, cerebral cortex; spinal, spinal cord. These are those that are coming from the motor strip which is just the precentral gyrus of the cerebrum and they carry information about what, fine that means delicate what, voluntary movement. So with just those three words you can predict what would occur if you injured or cut let's say the left-sided corticospinal tract. Would you have any sensory loss? No sensory loss, this is not a sensory pathway. Would you have some degree of paralysis? Yes. And if we cut it on the left side you would have motor loss on the left side because remember this has already crossed above that point where? At the medulla. So now we have to turn our imagery around, up here is the brain, this is the left side of the brain, these tracts originate but they cross over down here at the "M" word, the medulla. So by the time these are going down the spinal cord they've already what, crossed, so if they're on the right side of the cord they're going to serve muscles on the right side of the body. So damage to these would have same-sided repercussions. Now this might be at odds with what you think or previously thought, but not to be confused with brain injury. If you had injury to your left motor area of your brain, that would lead to paralysis on the right side, but we're not talking about brain injury, we're talking about spinal cord injury and by the time we're down here that crossing over has already occurred so that everything on the right side will serve right-sided muscles and vice-versa. Fine voluntary movement meaning the inability to execute actions such as writing your name with a pencil or other things that require some degree of fine muscle control. Then there's the extra pyramidal group which also cross over above the medulla meaning that by the time they're in the cord they're on the side that they're going to exit and these are not involved with voluntary movements or at least conscious voluntary movements, they tend to exert delicate influence over what we'll call coordination and balance which allows us to execute very, well amazing things like walking. So, simple question; patient has injury to his or her extrapyramidal tracts. Would they be paralyzed? Unable to move? No. Would they have difficulty with locomotion? What's that? So would they have trouble walking without stumbling? Yeah. Would they have trouble maintaining upright posture? So that's the big distinction here, the pyramidal tracts enable you to carry out dedicated, precise, intentional movement, whereas the extrapyramidal are modifying, adjusting, controlling, regulating, coordinating those activities for more successful execution and therefore enable us to do things like walking, dancing, or anything that is more than just twitching a finger or something. So what's this page that we're going to leave undone, page 55. It looks like, I don't know, some kind of doodle pad and that's really what it should be. It's there for you to practice these very ideas that we've just finished with. To understand what we mean by crossing over at the medulla, crossing over at the level of entry and therefore coming to grips with this information, because I'll tell you if you just memorize this it will be meaningless to you both now and in the future. So it's important to understand it and be able to use it to answer questions like we tried to raise here in the last 20 minutes or so. So this will all be reinforced I hope in lab, but that's not until next week so; hey next week is also the exam what a coincidence.

>> What was the cortico? You said cortico.

>> Anatomy Steve Langjahr: Cortico refers to the cortex, the cerebral cortex.

>> Cerebral cortex.

>> Anatomy Steve Langjahr: In other words, the brain or the cerebrum.

>> And then the spinal, spinus?

>> Anatomy Steve Langjahr: Spino refers to the spinal cord.

[Background Conversations]