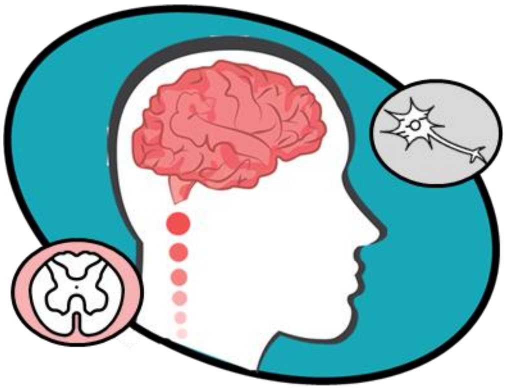

# CNS

Anatomy

Sheet ● Slide ○

## Number

-1

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Today we will start an introduction about the spinal cord

Before we start discussing the spinal cord, remember that the nervous system has 3 main basic functions and these include:

- ***Sensation:*** Monitoring changes in the environment either externally or internally. External stimuli include vision electromagnetic waves for example which are recognized by photoreceptors and then lead to excitation and formation of an action potential. Internal stimuli on the other hand include blood concentration of gases. Basically, the point behind all of these sensations whether external or internal is to inform the CNS about what is going on inside our outside the body.

- ***Integration:*** The parallel processing and interpretation of sensory information to determine the appropriate response.

- ***Reaction:*** Motor output which could be somatic for the stimulation of skeletal muscles, autonomic for smooth muscles, or even the stimulation of gland secretion.

So we basically realize that the central nervous system works like a computer, there is input, processing, followed by an output. In addition, we have two kinds of reactions that could take place, voluntary or involuntary.

## ➢ *Nervous Tissue:*

Remember that it is one of the basic tissues in the human body, accompanying muscle tissue, epithelial tissue, and connective tissue.

It is highly cellular and those cells are divided into two types:

| *Neurons* | *Neuroglia* |
|---|---|
| Functional, signal conducting cells | Support, Nourishment, and protection of neurons |
| Do not divide | Divide |
| Long Lived | Smaller cells but they outnumber neurons by 5 to 50 times |
| High Metabolic Activity | |
| Electrically Excitable | |

Remember that neuroglia are further divided into 6 types, 4 in the CNS and 2 in the PNS, and this is a recap of their names and functions:

| **CNS** | **PNS** |
|---|---|
| **Oligodendrocytes:** production of myelin sheath in the CNS | **Schwan Cell:** production of myelin sheath in the PNS, repair processes |
| **Astrocytes:** structural support, microenvironment, blood brain barrier | **Stellate Cells:** Structural Support, and maintenance of the microenvironment |
| **Ependymal Cells:** Lining the ventricles of the brain | |
| **Microglia:** Protection by phagocytosis | |

Remember than neuroglia have no role in the transmission of nerve impulses and this is purely the job of neurons. Also, neurons are very highly specialized cells, and could be as long as 1 meter.

As for the functional part of the nervous system, it is divided into:

- **Afferent neurons** which are sensory and are responsible for the input of information to the CNS.

- **Efferent neurons** which are motor and responsible for carrying the output information after processing in the CNS to produce a response either in a muscle or gland (effector organ).

If you take a coronal section of the brain, you will find two parts: white matter and grey matter.

White matter is composed of aggregations of myelinated and unmyelinated axons of many neurons while grey matter is composed of neuronal cell bodies, dendrites, unmyelinated axons, axon terminals, and neuroglia.

Now it is very important for you to differentiate between these terms:

**Neuron:** is a single nerve cell

**Nerve:** bundle of processes or axons in the PNS and it is surrounded by connective tissue. Remember that each individual axon of a single neuron is surrounded by **endoneurium**, and groups of axons (nerve fibers) are bound together forming fascicles which are surrounded by **perineurium,** and finally all the fascicles of nerves are enclosed by **epineurium.**

**Tract:** bundle of processes or axons in the CNS and DOES NOT contain any connective tissue.

**Ganglion:** collection of neuronal cell bodies outside the CNS.

**Nucleus:** collection of neuronal cell bodies within the CNS.

## ➢ *Spinal Cord:*

*Now we will be discussing the general idea for motor and sensory pathways:*

**Sensory Pathway:**

Any sensory perception that is recognized at the level of sensory receptors will be carried to the CNS for processing. However, this does not happen in one direct pathway. There are many stops on the way for processing of this information and this is what we call “synapse”. The sensation stimulus excites the receptors and then an action potential is carried to the dorsal root ganglia of the spinal cord.

Now in the spinal cord, at each segment, there are two roots for each spinal nerve, one ventral root which is purely motor, and another dorsal root which is purely sensory. There are collections of neuronal cell bodies in the dorsal root of the spinal cord and this is what we call the dorsal root ganglia.

This ganglia contains cell bodies of the 1st order sensory neurons (also called primary afferent neurons), the 1st order neurons synapse with 2nd order neurons in the dorsal horn, these 2nd order neurons will then extend to the thalamus (high center) and then synapse with 3rd order neurons which project to the cortex to the primary sensory area (3.1.2) in the postcentral gyrus of the parietal lobe. This is the general pathway.

**Motor Pathway**:

The conduction of action potentials starts in the cortex of the brain from an upper motor neuron in primary motor area 4 mainly of the precentral gyrus of the frontal lobe. It then descends and passes through the brainstem and spinal cord where it will finally synapse at the anterior horn cells then it will synapse with an interneuron present in the grey matter of the spinal cord at a specific position (later on the doctor will cover all those details), and this interneuron will synapse with the lower motor neuron where its cell body is present in the grey matter and then a ventral root will descend to supply for the skeletal muscles of the body. This means that upper motor neurons control lower motor neuron function. Keep in mind that in most cases an interneuron is present but in some minor cases an upper motor neuron can affect a lower motor neuron directly without the presence of interneurons. This orientation applies only to **spinal nerves**.

On the other hand, muscles of the head and neck like the muscles of the tongue are supplied by **cranial nerves** which have a different orientation. In this case, the upper motor neurons in the cortex extend to motor nuclei in the brain stem, and then lower motor neurons extend to the structures that they supply (for example, the facial nerve fibers that supply the facial muscles).

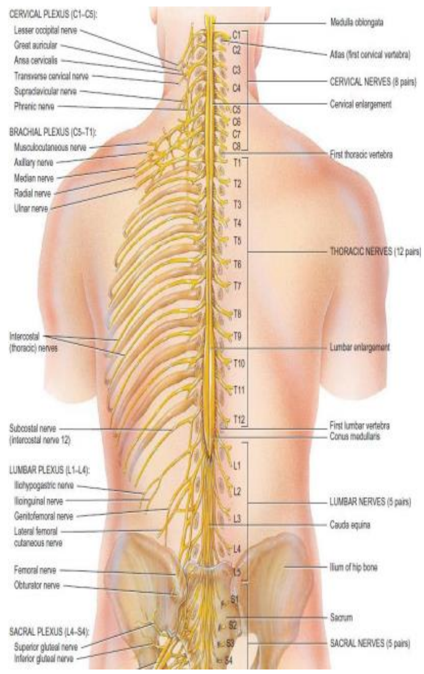
Up until this point we have only discussed somatic pathways, what about the autonomic pathways?

Remember that in this pathway we have two types of nerve fibers, preganglionic and postganglionic. The cell body of the preganglionic neuron is in the lateral horn, the autonomic motor axon leaves through the ventral horn and root to synapse in a ganglion (usually in the sympathetic chain) with a postganglionic neuron (remember that there are no synapses in the dorsal ganglia of the sensory nervous system) which extends to the effector organ which could be a gland or a smooth muscle since we are controlling involuntary actions.

However, autonomic preganglionic fibers that are carried by cranial nerves originate from nuclei in the brain stem, and usually this pathway involves parasympathetic nuclei, since cranial nerves do not have sympathetic activity. This is also known as “craniosacral outflow” since it originates mainly from sacral segments S2-S4, while in the case of sympathetic activity we have “thoracolumbar outflow”.  Again, as the name implies, it originates from T1 to L2.

You might be asking how is it that the preganglionic fibers are leaving as ventral roots while ventral roots are purely motor. This is because whether we are talking about gland secretion or skeletal muscle contraction we are still describing “motor activity”.

*Until now, we have mainly discussed general terminology regarding the spinal cord; now let us discuss the general features of the spinal cord:*




The spinal cord runs in the vertebral canal, extending from the foramen magnum, to the second lumbar vertebra. The vertebral canal is actually a bony canal formed by the vertebral foramina.

The spinal cord does not descend uniformly. At some points, we have enlarged parts obviously called “enlargements”. We have the cervical enlargement, and the lumbosacral or lumbar enlargement.

What is the reason behind those enlargements?

Remember that the muscles of the upper limb are supplied by the nerves of the cervical plexus formed by C5-C8 and T1. At the same time we have the lumbar plexus which mainly supplies for muscles of the lower limb. This means that nerves emerging from both cervical and lumbar segments must supply a large number of muscles. Accordingly, the size of the segments of which those nerves emerge from should correspond to that and this is why they form enlargements ( later on you will understand the significance of this).

Emerging from the spinal cord, we have 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal). The exact part of which each spinal nerve emerges from in the spinal cord is called a "segment". Now you would imagine that each spinal nerve emerges from one segment so the number of spinal nerves and segments should be equal, and accordingly, each spinal nerve is named according to the segment it corresponds to. However, when you count the segments you find that we have 7 cervical segments and 3-4 fused bones forming the coccygeal segment. Accordingly, we know that we have one extra nerve emerging from the cervical segments, and only 1 nerve for the fused coccygeal segments which brings the number of spinal nerves to 31 pairs (62 in total).

Spinal nerves are **mixed** and are formed by 2 roots that we have discussed previously; the dorsal root which is **purely sensory**, and the ventral root which is **purely motor.** These two roots will then mix forming **ramii**; one ventral ramus, and one dorsal ramus. However, both of those ramii contain <u>**BOTH motor and sensory**</u> activity each.

Remember that we said that the spinal cord extends from the foramen magnum, down to the level approximately between L1 and L2. Its tip inferiorly then forms a tapered appearance (conical shape) which we call **conus medullaris.** You should also pay attention to the fact that the spinal cord ends at the **disc** between L1-L2 which is completely different than the **segment** and the reason these two positions (disc and segment) do not correspond to each other is explained by our development. In newborns, the spinal cord occupies most of the vertebral canal, but with age and development, the growth of the vertebral column will bypass the growth of the spinal cord, meaning that it is faster than the growth of the spinal cord, and this is why in adults the spinal cord only occupies the first 2/3 of the vertebral canal. Also, the lower spinal nerves descend and have longer roots than other spinal nerves forming an appearance that looks like the tail of a horse which in Latin is what we call **"Cauda Equina".**

*Now let us discuss the coverings of the spinal cord:*

Remember that the meninges are the outer coverings of both the brain and the spinal cord. It is composed of 3 layers. The outermost one is called the dura mater, the second layer called the arachnoid mater, and the innermost layer which is firmly attached to the spinal cord is the pia mater.

1. **Dura Mater:** It is composed of dense irregular connective tissue extending from the foramen magnum to S2. At its end, it forms a union which results in the formation of a fold called **filum terminale externum**

2. **Arachnoid Mater:** Thin web arrangement of delicate collagen and some elastic fibers. Adheres to the inner surface of the Dura mater.

3. **Pia Mater:** Thin transparent connective tissue layer that adheres to the surface of the spinal cord and brain. Since it surrounds the spinal cord and adheres to it, it will end at the level of L1-L2 where the spinal cord ends. It will form a fold called **filum terminale internum or simply filum terminale.** Its main function is to anchor the spinal cord to the coccyx to give it stability, and most importantly, forms other folds called denticulate ligaments that attach the spinal cord to the arachnoid mater and inner surface of the dura mater further increasing its stability.

4. *Now we will talk about spaces in the meninges:*

| *Name* | *Epidural Space* | *Subdural Space* | *Subarachnoid Space* |
|---|---|---|---|
| *Location* | Space between the dura mater and the wall of the vertebral canal. | potential space between dura mater and arachnoid mater filled with seroud fluid | Space between arachnoid mater and pia mater. (L3-L4) |
| Clinical use | Anesthestics injected here and fat-fill | | Lumbar Puncture |

An additional point must be added regarding the subarachnoid space. Remember that cerebrospinal fluid (CSF) circulation starts from the lateral ventricles, then through the interventricular foramen, it travels to the third ventricle, and then through the central canal it reaches the fourth ventricle. From there, the fourth ventricle opens into the subarachnoid space through one median foramen called foramen of magendie and 2 lateral foramina called the foramina of luschka. This means that the subarachnoid space is filled with CSF and in addition to its function in protection and shock absorption, it has a diagnostic importance where you can test for things like hematoma or meningitis through CSF samples obtained through lumbar puncture. The point behind using L3-L4 as our sample obtaining location is that the spinal cord ends at the level of L2 so by that we make sure we do not injure it.

Generally, the spinal nerve leaves below the level of the corresponding vertebra, for example L1 nerve leaves below the level of L1 segment. This is the general rule. The only exception to this are cervical vertebra since we have 8 spinal nerves and only 7 segments, meaning that there must be one nerve above C1 and one below C7 to get 8 nerves. In this case nerves leave above the level of the corresponding vertebra until the 8$^{th}$ cervical nerve which passes below C7 and continues with this pattern from that point on.

| Spinous process | spinal cord segment |
|---|---|
| C7 | C8 |
| T3 | T5 |
| T9 | T12 |
| T10 | L1-2 |
| T11 | L3-4 |
| T12 | L5 |
| L1 | S1-end |

This table is not for memorization, it is just for you to notice how each spinous process corresponds to a different spinal cord segment and how as you go downwards the relationship between both becomes even more distant.

- *Disc Herniation:*

To be able to understand the concept of Herniation, look at the picture below. You realize that anteriorly we have something called in the intervertebral disc which is composed of an outer part called annulus fibrosis and an inner part called nucleus pulposus. Due to heavy weight most of the time, the intervertebral disc becomes compressed which causes the leakage of the gelatinous nucleus pulposus through the anulus fibrosus of IV disc.

It mostly happens in the posterolateral direction as you can see because this is where the thinner annulus fibrosus is present. 95% of cases happen in L4/L5 or L5/S1.

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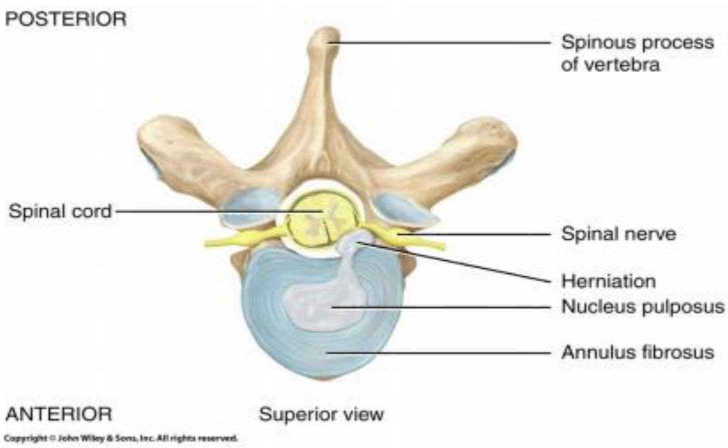


The clinical signs and symptoms are mainly based on the fact that you have compressed the nerve only and you have not cut it.

First, you should be familiar with the difference between myotome and dermatome. Dermatome is a piece of skin which is supplied by a single spinal nerve. Myotome is the same idea but with the concept of motor activity like biceps for example. This means you should know the roots of the spinal nerves that have been affected to understand the signs and symptoms.

Since spinal nerves leave below the level of the corresponding vertebra, if you have a disc herniation between L3/L4 for example, then most probably the injured nerve will be L4.

This table shows the most common nerves that could be injured and the signs and symptoms that accompany it and it is required:

| Disc | Root | Percentage | Motor weakness | Sensory changes | Reflex affected |
|---|---|---|---|---|---|
| L3-L4 | L4 | 3-10% | Knee extension (Quadriceps femoris | Anteriomedial leg (saphenous) | Knee jerk |
| L4-L5 | L5 | 40-45% | Big toe dorsifelxion (EHL) and TA | Big toe , anteriolateral leg (Common P) | Hamstring jerk |
| L5-S1 | S1 | 45-50% | Foot planter flextion (Gastrocnemius) | Lateral border of foot (sural) | Ankle jerk |