CNS

ANATOMY

2

Writer: Dana Alnasra

Science: Dana Oudeh

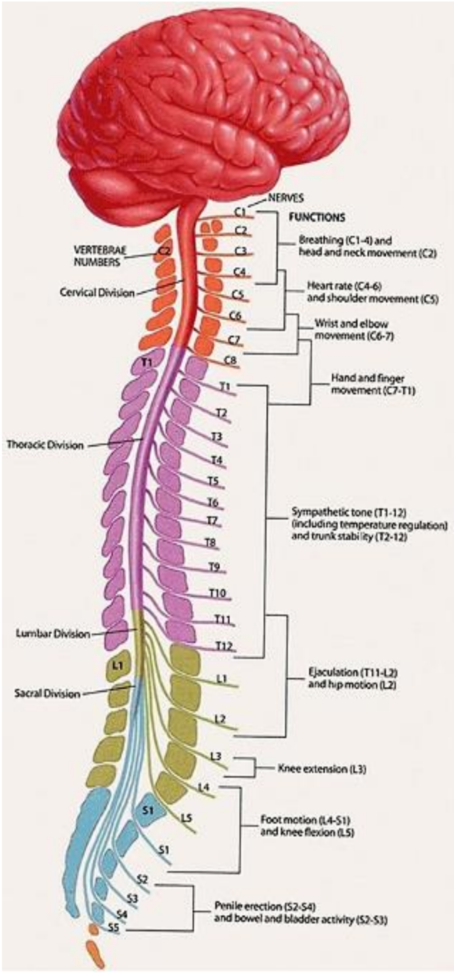
Final: Nour Awamleh

Doctor: Mohammad Al-salem

Hellooo, this lecture is mostly about the spinal cord. It's easy and simple, I'm sure you're already familiar with most of it. You only need to enjoy it and it'll be a piece of cake

Spinal cord segments

A Segment is the place where a spinal nerve emerges from, and since we have 31 pairs of spinal nerves, there must be 31 spinal segments.



In the last lecture, we mentioned that the spinal cord occupies only two thirds of the spinal canal; ending with the conus medullaris at the level of L1-L2.

But then how come we have spinal nerves below this level?

The segments of the spinal cord **<u>are not in line with the corresponding vertebrae</u>** and the difference increases as we go downward, so the nerve roots increase in length as you go downward.

Look at the picture and notice the following:

- The first 7 cervical nerves pass <u>above</u> their corresponding vertebrae.
- T1-S5 emerge from the spinal column through the intervertebral foramen <u>under</u> their corresponding vertebrae.
- C8 nerve between C7 and T1 vertebrae.

To further clarify our point, this table shows the vertebrae and the segment in line with each one:

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

You may wonder: Why the spinal cord only fills two thirds of the canal?

Embryology answers: At first, it is actually filling the whole length of the canal, but eventually bony growth will override the spinal cord growth leaving a space between them.

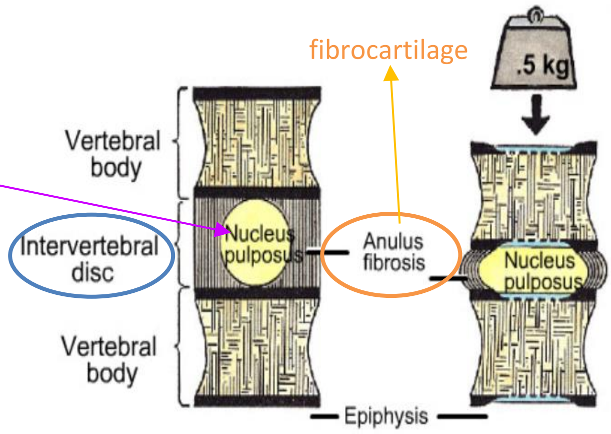
Study this case: (this is extra you can skip it if you like)

A 30-year-old female presented complaining of two months' worth of progressive low back pain and severe, radiating pain in the right lower extremity (sciatica). At the time of presentation, she reported associated numbness and weakness in her right lower extremity, particularly in her calf muscle. Her ability to ambulate and perform usual activities was severely impaired.

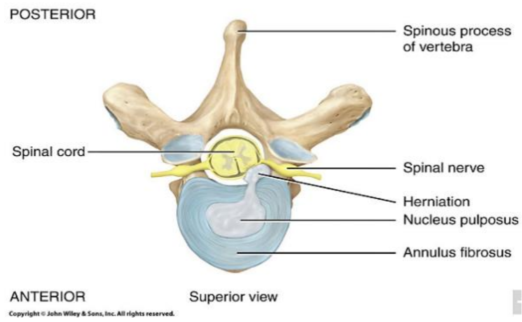
On examination, she was found to have reduced range of motion of her lumbar spine, positive sciatic nerve stretch testing, and measurable weakness in her calf muscle on the right side. Her gait was impaired, and she walked with a limp.

Herniated Disc/ ruptured disc/ slipped disc

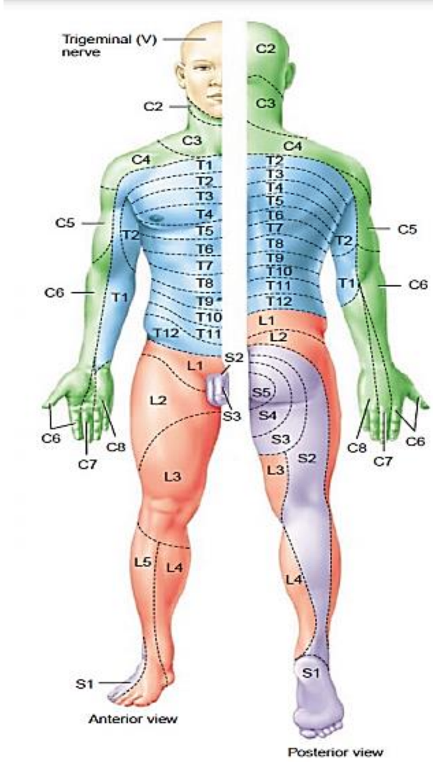
A herniated disc is a protrusion (leakage) of the gelatinous nucleus pulposus through the anulus fibrosus of an IV disc, usually as a result of heavy weight pressuring these discs.



If you look at the picture below, you'll see the hernia leaking in a **posterolateral direction**, which makes sense because it's where the annulus fibrosus is thinnest and weakest.



95% of herniated discs are the ones between L4/L5 or L5/S1.



Symptoms start when the herniated disc compresses the spinal nerve. But in order to understand the symptoms, we need to stop by the principle of dermatomes and myotomes:
A dermatome is an area of skin that is mainly supplied by a single spinal nerve.
A myotome is the group of muscles that a single spinal nerve innervates.

So, when a nerve is compressed by a herniated disc, we'll see weakness in the myotome and abnormal sensation in the dermatome supplied by this nerve, because every spinal nerve has a sensory and a motor part. See the figure above for the distribution of dermatomes and their corresponding nerves.

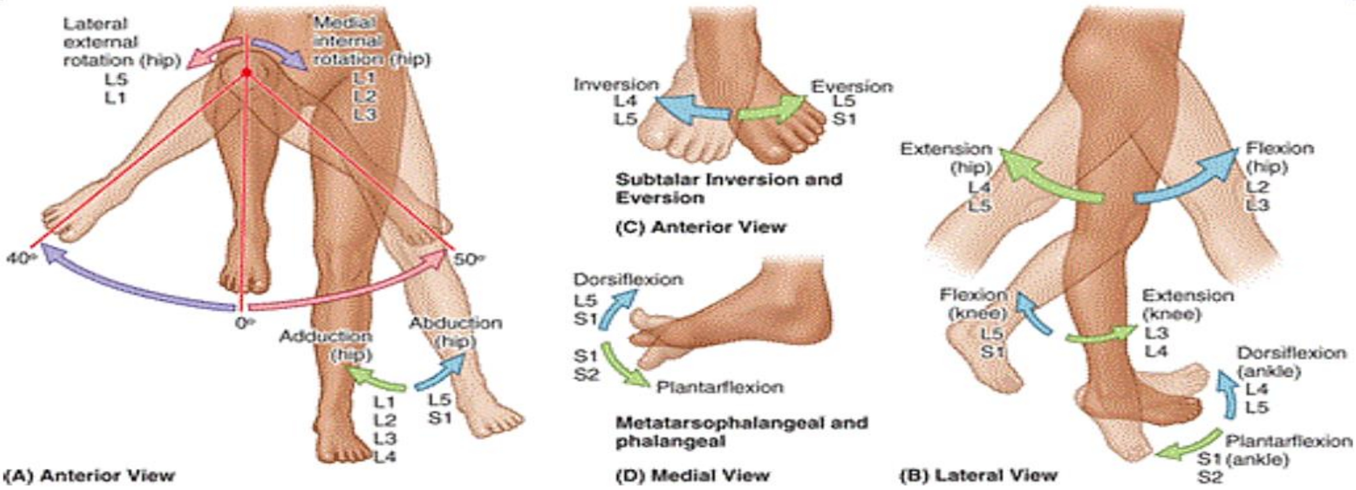
Common lumbar disc problems

Disc	Root	Percentage	Motor weakness	Sensory changes	Reflex affected
L3-L4	L4	3-10%	Knee extension (Quadriceps femoris)	Anteromedial leg (saphenous)	Knee jerk
L4-L5	L5	40-45%	Big toe dorsiflexion (EHL) and (TA)	Big toe, Anterolateral leg (CPN)	Hamstring jerk
L5-S1	S1	45-50%	Foot planter flexion (Gastrocnemius)	Lateral border of foot (sural)	Ankle jerk (Achilles tendon)

EHL: external hallucis longus, TA: tibialis anterior, CPN: common peroneal nerve

Notes on this table:

- **Motor weakness** refers to the muscle actions affected. Shown between parentheses are the names of the muscles.
- Please be aware that the root value here is not the same concept as the nerve innervating the muscle. e.g. quadriceps femoris is innervated by the femoral nerve (L2, L3, and L4), however, an injury to the L4 spinal nerve will affect the quadriceps. And the same aspect applies to the sensory changes.
- **Sensory changes** refer to skin areas affected, and the nerves are shown between parentheses.
- **Reflex affected** is a test used to indicate the location of the injury.
- This table is very important, make sure you don't skip any part of it.



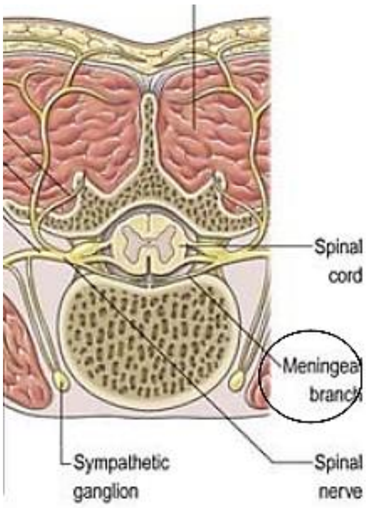
This picture shows the actions that you can test to help you figure out what nerve root is injured.

Test L5: by asking the patient to stand on his heels (dorsiflexion).

Test S1: by asking the patient to stand on his tiptoes (plantar flexion).

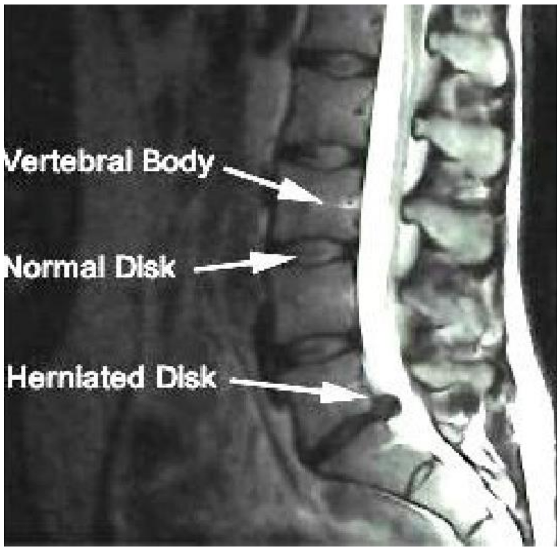
Major symptoms of disc herniation

The symptoms we discussed earlier are surely important, however, patients often only present with one major symptom which is **<u>low back pain,</u>** <u>radiating to the gluteal region, the back of the thigh and back of the leg.</u>



As you can see in this picture, spinal nerves give a meningeal branch (recurrent) that brings sensation from the dura matter, which is sensitive to stretch. When a herniated disc compresses the nerve, it'll compress the meningeal branch as well, causing diffused pain due to overlapping dermatomes.

Straight Leg Raise Test (SLR): Flexing the hip joint while extending the knee causes pulling of the sciatic nerve (L4-S3) and pressure on the nerve root. This test is commonly used to check for disc herniation.



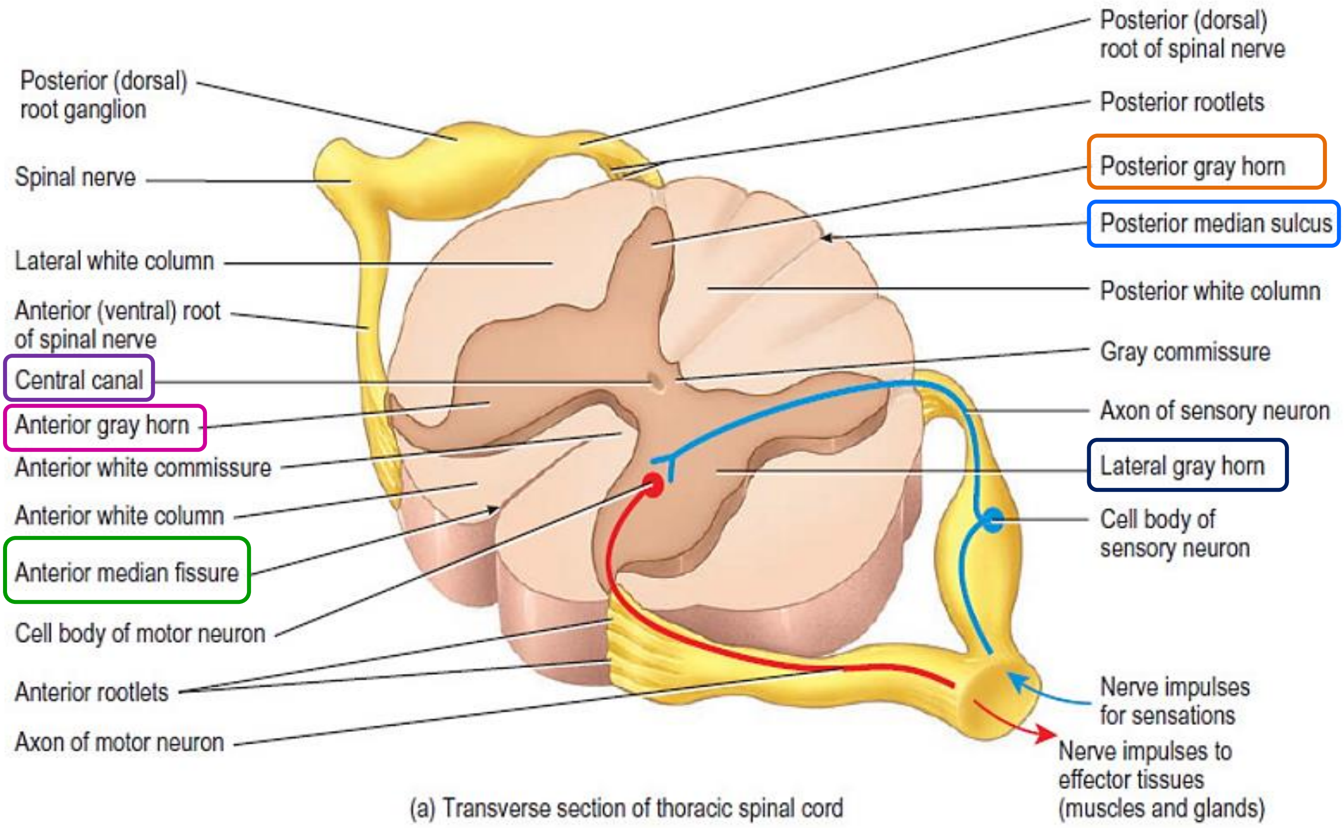
While all the maneuvers and tests above may help you diagnose disc hernia, nothing's as brilliant as a beautiful MRI to confirm the diagnosis of a herniated disc.

Now, you can go back to our case earlier and apply the symptoms of the patient to what we've discussed so far. For diagnosis, treatment and more information: https://www.stiebermd.com/case-studies/lumbar-herniated-disc/

Cross Section of the Spinal Cord

The spinal cord is divided into white matter and gray matter, and the white matter is further divided to columns; lateral, posterior, and anterior, while the gray matter is divided into horns.

1. **White matter:** neuronal dendrites and axons
   a. Anterior median fissure: a wide groove on the anterior aspect (deeper than the sulcus).
   b. Posterior median sulcus: a narrow groove on the posterior aspect.

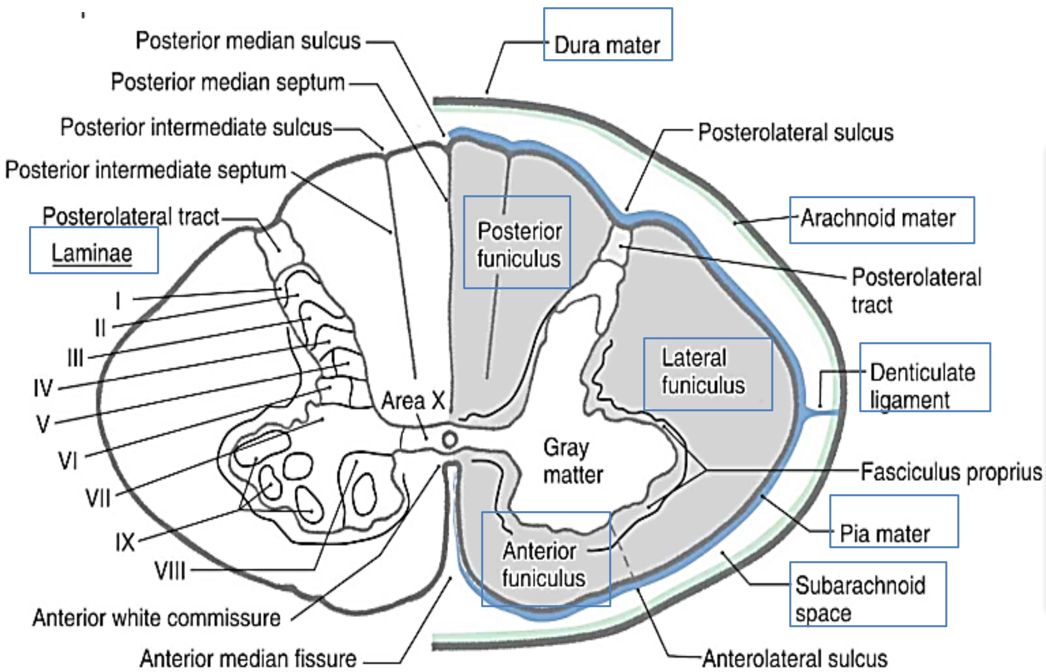


(a) Transverse section of thoracic spinal cord

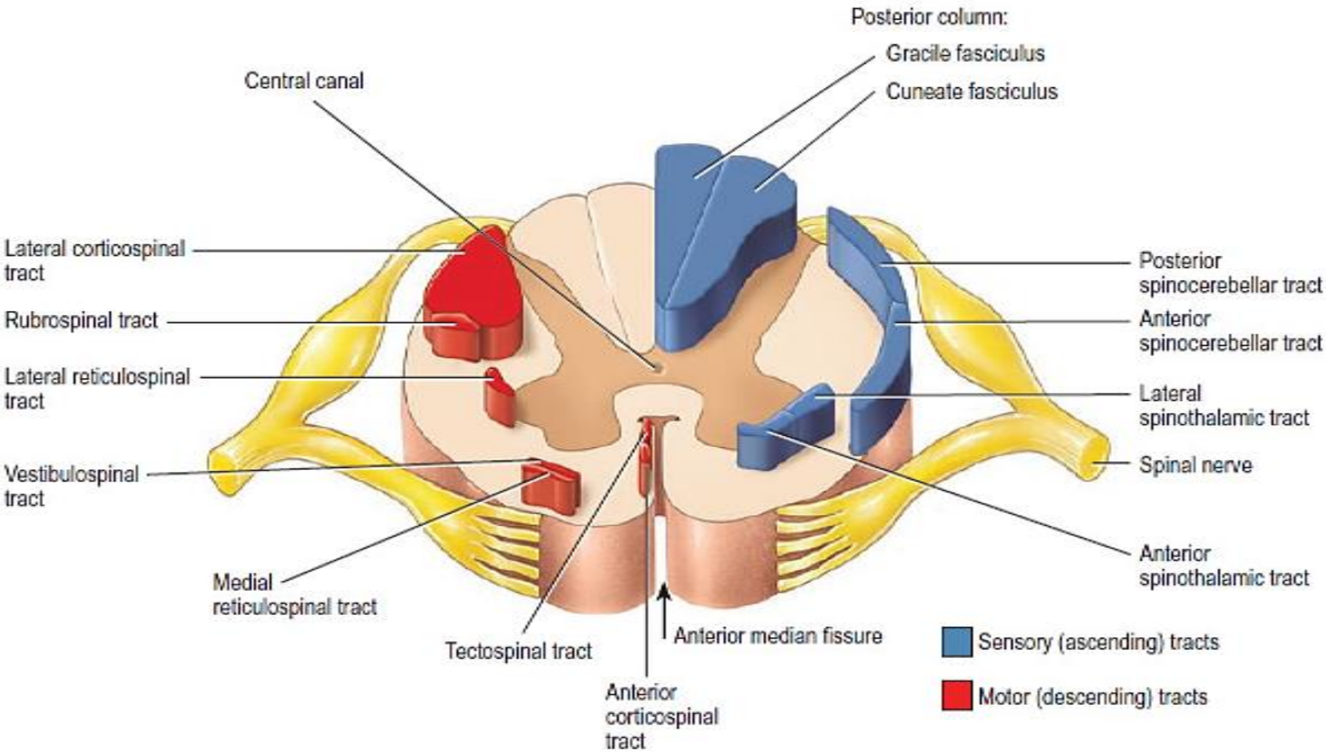
Don't confuse this with the dorsal root ganglia that has the cell bodies of sensory neurons

2. **Gray matter** (neuronal cell bodies), divided into horns:
   a. Posterior (dorsal) horn; collection of neuronal cell bodies of the sensory system.
   b. Anterior (ventral) horn; collection of motor neuronal cell bodies of skeletal muscles.
   c. Lateral horn (autonomic); collection of preganglionic motor cell bodies (to cardiac muscles, smooth muscles, and glands). However, this horn doesn't exist in all segments.

In the center of the gray horn, there is a central canal that contains the CSF and is linked to the 4th ventricle in the brain.



In this picture, please notice the meninges layers, the columns (faniculi) of the white matter, and the laminae of the gray matter. And please don't confuse the white matter and gray matter depending on this graph's colors.



The white matter, as we said before, consists of the axons and processes of the neurons, and in the CNS we call them tracts. These tracts in the spinal cord are divided according to the direction of the signal into ascending (sensory) and descending (motor). It makes sense as the sensory signal needs to ascend to the brain and motor signal will descend from the brain. And not just that, the ascending and descending tracts are also subdivided. But this will be the topic of another lecture,😁just make yourself familiar with the terms.

Receptors

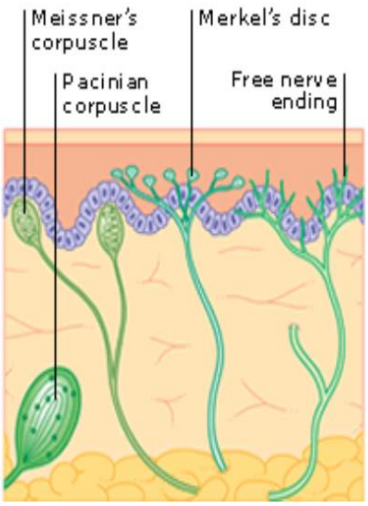
Read only

Sensation is basically converting one type of energy into a signal, and this is not possible without our dear receptors to receive this energy in the first place.

1. Mechanoreceptors

a. Meissner's corpuscle

They respond to touch, pressure, and low frequency vibration. Also, they are rapidly adapting (signals fade away after stimulus exposure).



b. Merkel's disc (Tactile Disc)

Respond to discriminative touch, and they are slowly adapting (signal is transmitted as long as the stimulus is present).

c. End organ of Ruffini

They are sensitive to skin stretch and slowly adapting.

d. Pacinian corpuscles

They respond to high frequency vibrations, and they are rapidly adapting.

Read only

Adaptation of receptors occurs when a receptor is continuously stimulated. Many receptors become less sensitive with continued stimuli. Rapidly adapting receptors are best at detecting rapidly changing signals, while slowly adapting receptors are capable of detecting a long, continuous signal.

2. Thermoreceptors

A type of free nerve endings, and they detect changes in temperature. TRP channels are an example of thermoreceptors.

3. Nociceptors

A type of free nerve endings, and they detect damage (pain receptors).
They are **multimodal**; since there is no such thing as "pain" energy. Pain is considered as an exaggeration of a certain type of energy, e.g. too much heat, too much pressure.

→ After the signal is received by receptors, it is conducted through peripheral nerve fibers to reach the CNS. And here is all about these fibers:

ELECTROPHYSIOLOGIC CLASSIFICATION OF PERIPHERAL NERVES	CLASSIFICATION OF AFFERENT FIBERS ONLY (CLASS/GROUP)	FIBER DIAMETER (μm)	CONDUCTION VELOCITY (m/s)	RECEPTOR SUPPLIED
Sensory Fiber Type				
Aα	Ia and Ib	13-20	80-120	Primary muscle spindles, Golgi tendon organ
Aβ	II	6-12	35-75	Secondary muscle spindles, Skin mechanoreceptors
Aδ	III	1-5	5-30	Skin mechanoreceptors, thermal receptors, and nociceptors (fast pain)
C	IV	0.2-1.5	0.5-2	Skin mechanoreceptors, thermal receptors, and nociceptors (slow pain)
Motor Fiber Type				
Aα	N/A	12-20	72-120	Extrafusal skeletal muscle fibers
Aγ	N/A	2-8	12-48	Intrafusal muscle fibers
B	N/A	1-3	6-18	Preganglionic autonomic fibers
C	N/A	0.2-2	0.5-2	Postganglionic autonomic fibers

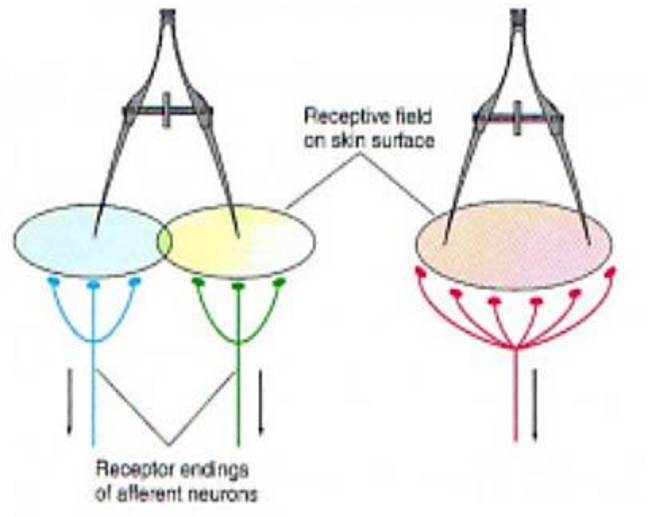
Notes about this table:

1. We are starting with the sensory part, so we are only concerned with sensory fibers here.
2. The difference between these fibers is the myelination (C aren't myelinated), and the diameter with Aα being the largest and C the smallest.
3. The greater the diameter, the greater the conduction velocity (directly proportional). (Aα > Aβ > Aδ > C) in terms of diameter as well as velocity.
4. Muscle spindles are stretch receptors that detect the length of the muscle.
5. Golgi tendon organ are receptors that detect the tension in the tendons.

Receptive field

Read only

An area of skin that receives sensation from a single nerve **fiber** (receptor).

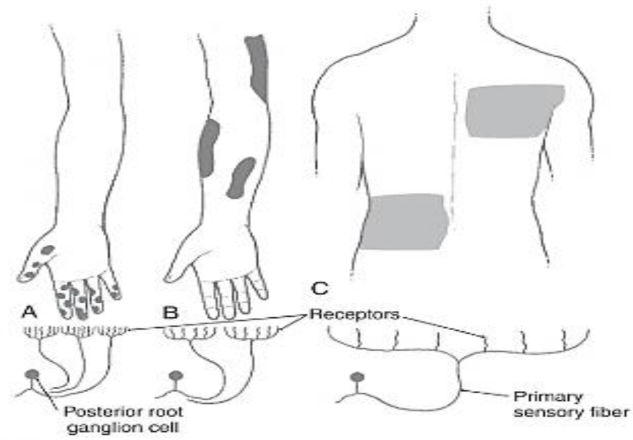


If we apply the concept of receptive fields here, we'll conclude that each circle represents a single receptive field (as each receives sensation from a single fiber). The importance of this lies in the fact that the brain can discriminate a receptive field as an individual area; no matter how big or small the area is as long as it has its own fiber.

Here, the brain can distinguish the two points of the compass as two distinct points in the case of the yellow and blue receptive fields. But it'll only feel as one point in the case of the pink one.

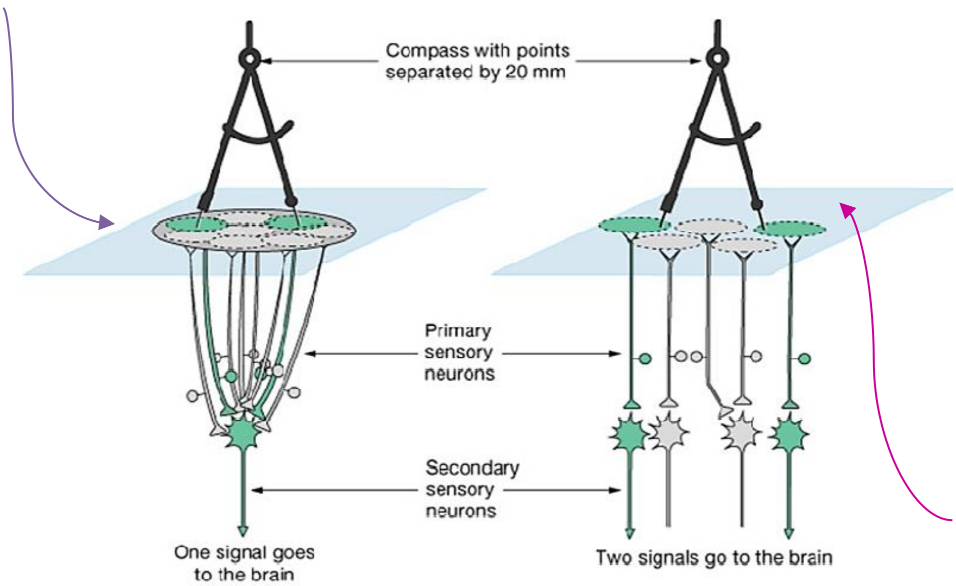
and **as a result**:

a. The greater the density of receptors (e.g. in the hand), the smaller the receptive fields of individual afferent fibers.
b. The smaller the receptive field, the greater is the acuity or the discriminative touch.



But frankly, it's not that simple. Remember when we said that in the sensory system we have 1st order neuron, 2nd, and a 3rd?

If many primary sensory neurons converge onto a single secondary neuron, this creates a very large receptive field. The two stimuli will be perceived as a single point because both stimuli fall within the same receptive field.



However, if fewer neurons converge, secondary receptive fields are much smaller, and the two stimuli activate separate pathways and are perceived as distinct stimuli.

Labelled line theory

Read only

Ever wondered how the brain distinguishes between signals, like heat, pain, pressure, or touch?

The labelled line theory is the answer. This theory says that **individual primary afferent fibers carry information from a single type of receptor.**
i.e. an afferent fiber has only one type of receptors (mechano, thermo, or nociceptors). In this way, the brain can tell the signals apart, since each fiber is "labelled" with a certain type of receptor that ONLY responds to a certain type of energy, e.g. pressure cannot stimulate thermal receptors.

Therefore, pathways carrying sensory information centrally are also specific, forming a "labelled line" regarding a particular stimulus.

Individual receptors preferentially transduce information about an adequate stimulus. An adequate stimulus is the **amount and type of energy required to stimulate a specific sensory organ. (e.g. thermoreceptors only respond to heat, and specific channels only respond to heat above a certain degree).

So, when we talk about **sensation,** there are three things to consider:

a. Modality (type)
b. Locality (remember the homunculus of the brain)
c. Intensity

Good luck