

CNS

Anatomy

📄 slides

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▶ number

Lecture #2

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Welcome :D Get prepared for this sheet as it'll be filled with things you'll hopefully enjoy! Take a deep breath, and say "Allah, ease my path, open all closed, and guide me all the way"

Quick review; Nervous system is divided to:

- 1- CNS → brain and spinal cord
- 2- PNS → 12 pairs of cranial nerves and 31 pairs of spinal nerves and their associated ganglia.

Last time we talked about:

- 1- The functional unit of the nervous system (the neuronal cell), and its structure.
- 2- The supporting cells and their types.
- 3- The interior of the CNS which is organized into gray and white matter.

The white matter → the main component are myelinated axons embedded in neuroglia "glial cells surrounding neurons".

** In histological preparation, myelin sheaths will be – as any other lipid component- lost, leaving **round empty spaces** since they're made of rapped sheaths of oligodendrocyte's cell membrane, and the cell membrane is of course lipid-rich.

The gray matter → contains abundant neuronal cell bodies; dendrites; and the initial un-myelinated portion of axons; astrocytes; and microglial cells.

The gray matter occupies the thick surface or cortex of both the cerebrum and the cerebellum, most of the white matter is found in deep regions.

** In the spinal cord white matter is peripheral and gray matter is internal.

4- Brain and its parts; forebrain, midbrain, hindbrain

5- Spinal cord; as segments:

In newborns the spinal cord is longer, filling the whole spinal canal. During development the spinal cord grows in the spinal canal in length more slowly than the vertebral column, that's why In adults, the **spinal cord occupies only 2/3 of the spinal canal** so it reaches only as far as the lower border of L1 or L2 "mostly Intervertebral disk between L1-L2".

** That's why if you opened a vertebra "you did laminectomy so you exposed the spinal canal - see anatomy glossary in last pages", you won't necessarily find the SAME spinal segment corresponding to that vertebra. This variation isn't seen much in upper segments, but as you go

down this variation increases progressively because eventually the spinal cord will have to end early at level of **IVD L1- L2**.

-to accommodate التوفيق بين to this disproportionate growth in length, the length of nerves' roots increase progressively from above downward → so the roots of the lumbar and sacral nerves below the level of the termination of the cord "IVD L1-L2" form a vertical bundle of nerve that resembles a horse's tail and is called **Cauda Equina**.

- remember as well an important concept: emergence of the spinal nerve from intervertebral foramen; general rule is that the spinal nerve emerges below corresponding vertebra, except cervical nerves "8 nerves and 7 vertebrae".

Review is done :D

In this lecture we will talk more about the spinal cord, but first we'll discuss the covering layers and spaces of it.

1. The Meninges السحايا: Connective tissue membranes

A. Dura mater "hard mother" الأم الجافية:

- Outermost** layer which is the closest to bony canal; continuous with epineurium (outermost cover of the nerve) of the spinal nerves.
- Dense irregular connective tissue (Junqueira's basic histology - A; see last page)
- Extend from the level of the foramen magnum to level of S2

B. Arachnoid mater "Like a spider's web" العنكبوتية : Thin web arrangement of delicate collagen and some elastic fibers. (Junqueira's basic histology - B)

C. Pia mater "tender mother" الأم الحانية:

- Inner most** layer which is bound tightly to surface of spinal cord.
- A thin transparent شفاف connective tissue layer that adheres to the surface of the spinal cord and brain.
- We have 2 modifications in this layer:
 - Since Pia matter is firmly attached to spinal cord, when the spinal cord ends at the level of L1-L2, the pia mater will fuse from all directions and descend to form ligament called **filum terminale** "filum; a thread-like structure, terminale; an end or relating to an end" that descends inside the canal and anchors تثبيت the spinal cord to coccyx → It has a role in the stability of the spinal cord. (See Anatomy Glossary)
 - Pia mater forms the **denticulate** "having very small tooth-like projections" (مسننة) **ligaments** that attach the spinal cord to the arachnoid mater, these ligaments extend from the pia mater to the arachnoid and inner surface of the dura mater, and they also help in stabilizing the spinal cord inside the vertebral canal.

2. Spaces: between the meningeal layers

1- Epidural “Epi; above” space: space between the dura mater and the wall of the bony vertebral canal.

- A. Some Anesthetics are injected here to relief the pain during delivery for example (to reduce labor pain ألم المخاض, epidural anesthesia is given by passing the needle from the back all the way until reaching epidural space)
- B. It's a potential space (not an empty space) → Fat-filled

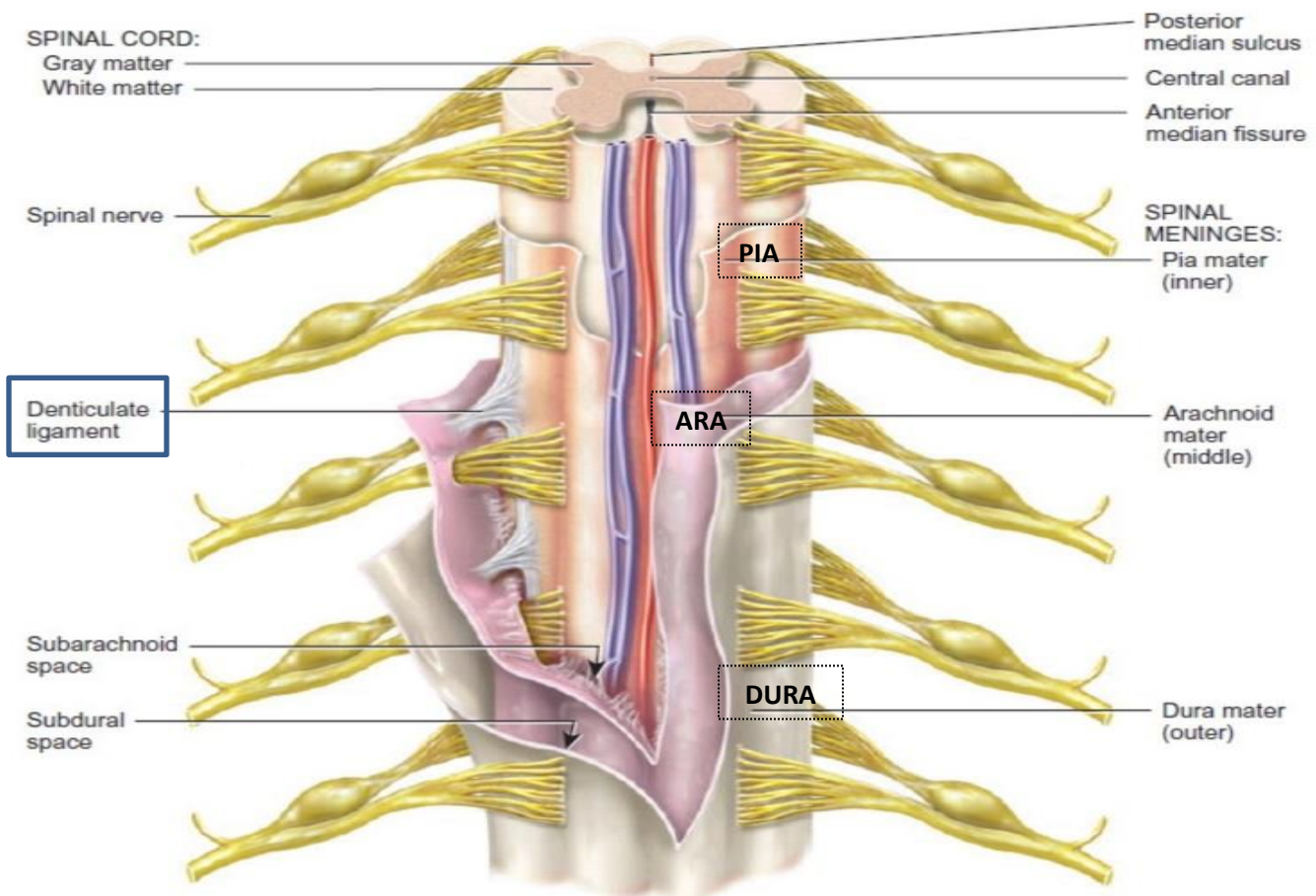
2- Subdural space “Sub; below”: Serous fluid “ fluid resembling serum” that separates the dura mater from the arachnoid.

3- Subarachnoid space: between pia and arachnoid.

- A. Filled with **CSF** which helps in cushioning and protecting the CNS from minor trauma (PHYSIOLOGIC value of CSF). This space also communicates with the ventricles of the brain where the CSF is produced from choroid plexus in the roof of these ventricles; it passes from these ventricles downward to the central canal to complete its circulation.

**** Remember:** Ventricles of the brain; 2 lateral ventricles that open into the 3rd then the 4th ventricle, this 4th ventricle has 3 apertures “aperture; a hole or opening”, a Medial aperture called foramen of Megendi; 2 lateral apertures called foramens of Luschka , these apertures open to subarachnoid space, and so in that space occurs **THE CSF CIRCULATION**.

- B. The major blood supply to the brain (big supplying arteries) runs through it.



Histology and Anatomy follow the function. (For more, see Junqueira's basic histology - C)

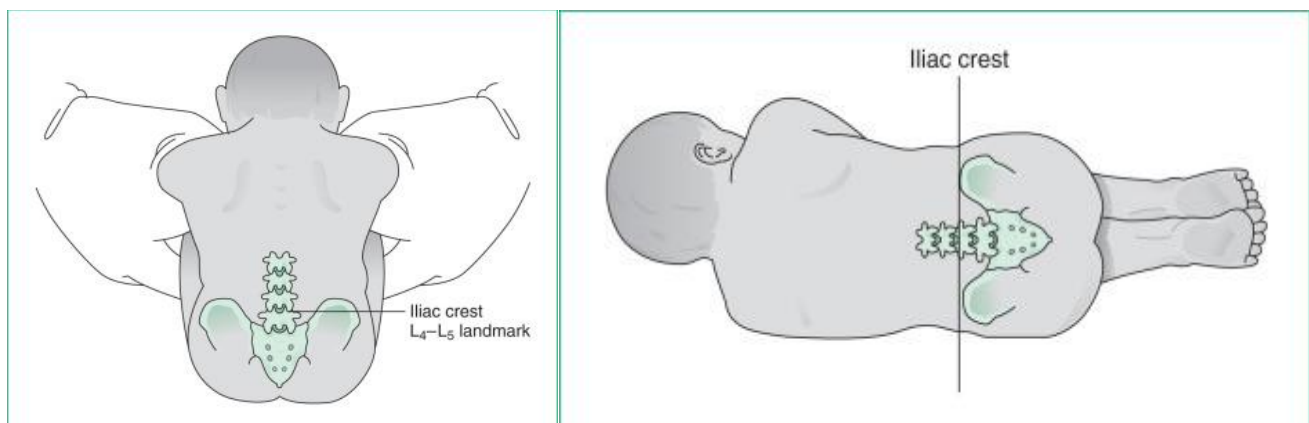
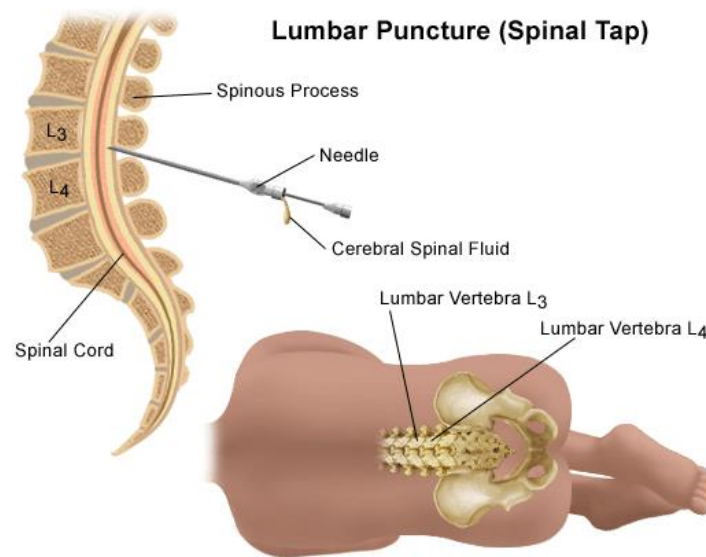
CSF also has a DIAGNOSTIC value; in some cases of hypertension and consequent aneurysm “localized dilation of blood vessel wall”, blood vessels in the subarachnoid space may rupture and cause a hemorrhage → so in this case we will find blood in the collected sample of CSF.

But from where can we take a sample???

It's done by a procedure called **Lumbar puncture** to collect and look at the fluid (cerebrospinal fluid, or CSF) surrounding the brain and **spinal** cord. During a **lumbar puncture**, a needle is carefully inserted into the **spinal** canal low in the back

The best place for a lumbar puncture is between the level of L3 –L4, in this place the spinal cord is safe from injury “it ended above us in IVD L1-L2”, thus all what we have are the roots of spinal nerves that are swimming in a fluid, so even if the needle hits one it will not be injured.

In children, we go to a **lower** level (to be in the safe side), which corresponds to the supracristal line (this line passes from the right iliac crest to the left iliac crest)



Lumbar puncture in Adults (Up) vs. Children (Down)

Herniated Disc/ ruptured disc/ slipped disc

Each vertebra is formed by a body, an arch (laminae and pedicles- see anatomy glossary in last pages), and 7 vertebral processes (1 spinous, 2 transverse, 4 articular). Between each 2 vertebrae, we have an **intervertebral fibrocartilage** “Mingling منج hyaline cartilage and dense CT” **disc** which is formed from:

- 1- Annulus fibrosus (outer layer) “annulus; a ring, fibrosus; because it’s formed by concentric fibrocartilage laminae”.
- 2- Nucleus pulposus (in the center) “nucleus; a central core, pulp; any soft, flaccid رخو, juicy tissue, especially when surrounded by harder material”.

70% of your weight is carried by your vertebral column, that’s why it’s common for disks to slip or in other words “Herniate”.

Herniation الفتق is simply the protrusion of substance or organ out of the normal place they used to be in “ through a defect in the wall of the anatomical cavity in which it lies, or into a subsidiary فرعي compartment of that cavity”.

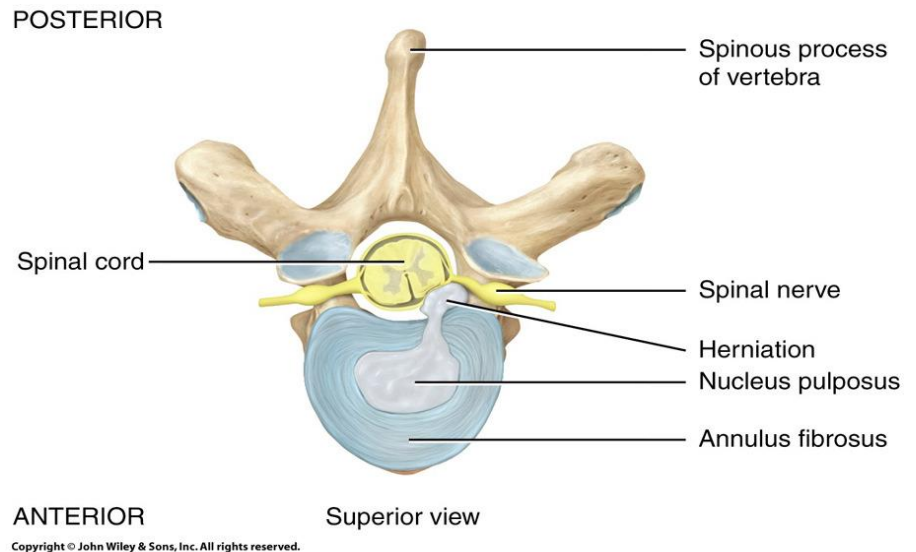
Ex. Stomach herniation in which part of stomach herniates into the thoracic cavity through the esophageal hiatus so it’s called Hiatus hernia. “scientifically it’s a part of diaphragmatic hernia where hernia of the abdominal content upwards through the diaphragm occurs”.

We can notice the **Protrusion** (leakage) of the gelatinous nucleus pulposus through the annulus fibrosus of IVD disc.

The herniation is from a **Posterolateral direction**

Why??? Because of the Thinner annulus fibrosus (it’s the weakest point)

The herniated nucleus pulposus will cause a **pressure on the spinal nerve that is emerging from the intervertebral foramen** → this will cause **symptoms**.



0.00min – 10.00min
/ slides covered 1 – 3

Note form Snell:

A sudden increase in the compression load on the vertebral column causes the semifluid nucleus pulposus to become flattened. The outward thrust دفع of the nucleus is accommodated استيعابه by the resilience مرونة of the surrounding annulus fibrosus. Sometimes the outward thrust is too great for the annulus and it ruptures, allowing the nucleus pulposus to herniate and protrude into the vertebral canal.

So what will happen in disc herniation, what kind of symptoms would we face???
As a quick teaser, it's all about the dermatome and myotome principles.

First we must talk about the spinal nerves. Each spinal nerve is connected to the spinal cord by two roots: The ventral root and the Dorsal root.

1. The Ventral root: consists of bundles of nerve fibers carrying impulses away from the CNS (efferent fibers) → those efferent fibers go to skeletal muscle and cause them to contract (motor fibers). Their cell bodies lie in the anterior gray horn of the spinal cord and they're **ALWAYS MOTOR**.

2. The Dorsal root: consists of bundles of nerve fibers that carry impulses to the CNS and are called (afferent fibers)

- These fibers are concerned with carrying information about sensations of touch, pain, temp, and vibrations, and thus they are called (sensory fibers). They're **ALWAYS SENSORY**.
- The cell bodies are situated in a swelling on the dorsal root called the posterior root ganglion (these are the ganglia mentioned in the review as part of PNS).

NOW, at each intervertebral foramen, the **VENTRAL** and **DORSAL** roots **UNITE** to form the **TRUNK OF SPINAL NERVE**. Here the **motor** and **sensory** fibers become **mixed together**.

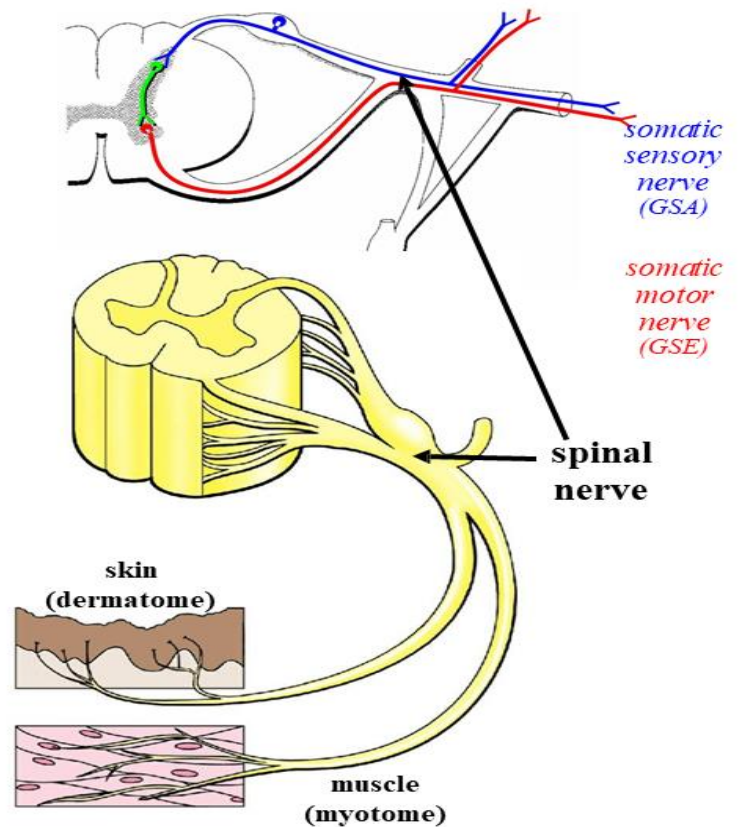
Upon emerging from the intervertebral foramen, the spinal nerve divides into many branches, some are anterior rami that are large, and some are posterior rami that are small.

(Above notes are illustrated in the figure below)

Please notice that: **Dorsal** and **Ventral** roots are pure **sensory** and pure **motor** “respectively”, but after combining to form a **single spinal nerve** that’ll emerge outside, the branches of this spinal nerve will be **MIXED** “sensory fibers coming from dermatomes and motor fibers going to myotomes”, so these rami will be noticed to spread also according to anatomical location “this is what we actually see”!!

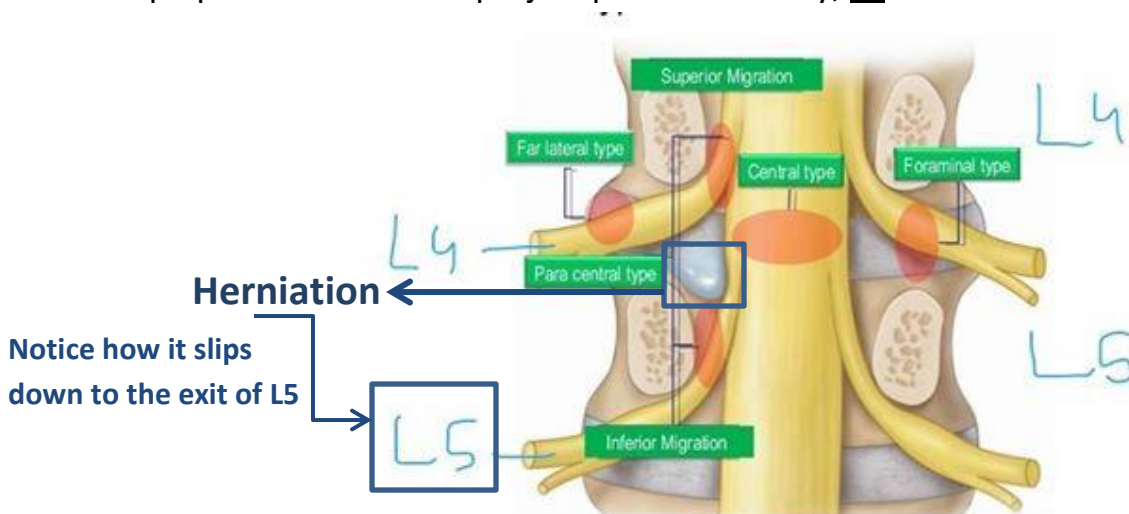
- The **posterior** ramus → passes **posteriorly** around the vertebral column to supply the muscles and the skin of the back الظهر.
- The **anterior** ramus → continues **anteriorly** to supply the muscles and skin over the anterolateral body wall.

* **In the figure:** GSA; General Somatic Afferent, GSE; General Somatic Efferent.



A question: If we have a disc herniation between L4 and L5, which spinal nerve will be more affected????

You must know that the spinal nerve leaves the intervertebral foramen from the upper part above the level of the disc (for example nerve of T5 will leave above IVD T5-T6), so when the nucleus pulposus of IVDL4-L5 project posterolaterally, **L5** will be more affected.



**** Note:** In addition to the anterior and posterior rami, spinal nerves give small **meningeal branches** that supply the meninges. We'll know later their great effect but keep them in mind for now!

All this have leaded us to concepts of:

1. Dermatome → The area of the skin supplied by a **single** spinal nerve, and therefore a single segment of the spinal cord.

**** Dermatomes distribution Map** is illustrated in the figure.

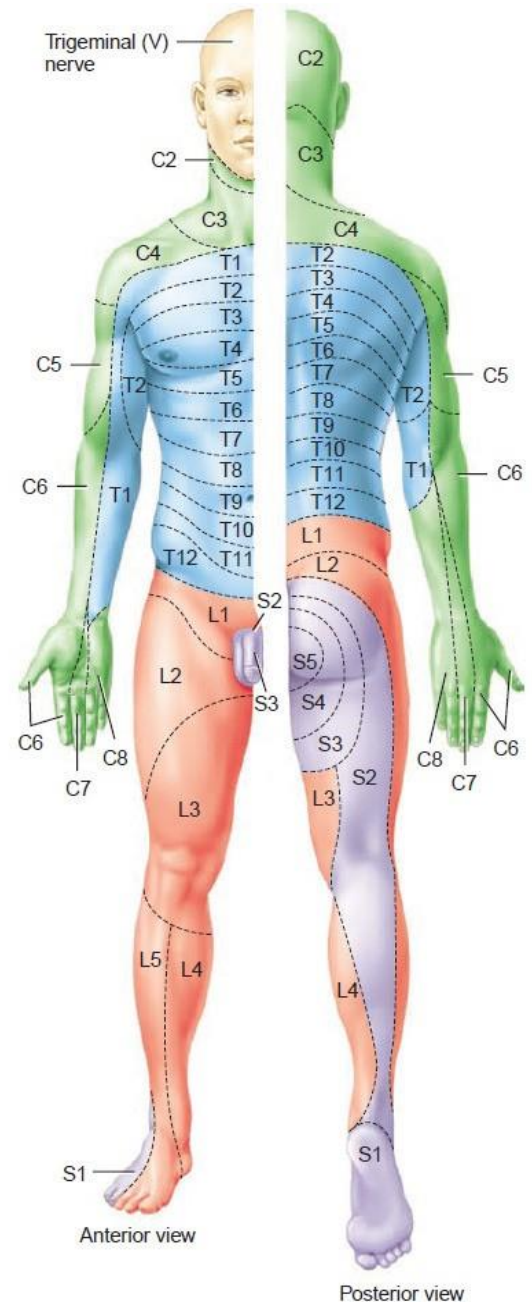
2. Myotome → The certain part of muscle receiving a **single** segment innervation. Most of the muscles are innervated by 2, 3, or 4 spinal nerves and therefore by the same number of segments of the spinal cord.

**** Example to understand:** Biceps muscle is supplied by Musculocutaneous N. "see brachial plexus in anatomy glossary; last pages", but if you traced this nerve back to the spinal cord, you'll first find that it joins the median N. to form the lateral cord; this lateral cord was formed by union of anterior divisions of superior trunk and middle trunk, segments that contribute in the formation of middle and superior trunks of the brachial plexus are C5, C6 and C7.

Now comes the Magic!

If you went all the way back to the spinal cord tracing **Musculocutaneous N. fibers that supply the Biceps muscle ONLY**, you'll find that they mainly originate from C6! So what we call **the root value** of these fibers is C6.

All these facts will help us in diagnosis of disc herniation (we will talk about "how is it done?" in a moment).



Common lumbar disc problems:

Most common place of herniation is in IVD L4-L5 or IVD L5-S1 (95%); this is so predictable, since the greatest load is on the lower vertebrae. Since they're very common to see in clinical practice, we **have to know** dermatomes and myotomes related to them.

Now we can correlate the injured spinal nerve due to the herniated disc with its symptoms.

Disc	Root	Percentage	Motor weakness (Myotome)	Sensory (Dermatome)	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 , anteriolateral leg (Common P)	Hamstring jerk
L5-S1	S1	45-50%	Foot planter flexion (Gastrocnemius)	Lateral border of foot (sural)	Ankle jerk

**** Note:** Muscles, plexuses, innervation of the lower limb are all found in Anatomy glossary; see last pages.

Let's start together with the least common for sake of understanding the principle.

1. Herniation in IVD L3-L4.

If herniation happened in this disk, can you guess which root will be affected? "Remember what we mentioned earlier".

Spinal N. will leave IV foramen through its upper part, that's why the root that'll most likely be affected in this case is L4.

a. Myotome affected: the one that is supplied by L4; Quadriceps femoris **الفخذية رباعية الرؤوس**, and that resulted in impaired knee extension.

Quick review; simple nerve supply of the lower limb: anteriorly the thigh is supplied by Femoral N.; medially it's supplied by Obturator N.; posteriorly the Sciatic N., which also supplies the leg by its branches; Tibial N. that supplies posterior aspect, and anterolateral side of the leg which is supplied by common peroneal "fibular" N.

Femoral N. “that supplies the Ant. Part of the thigh and so by default the Quadriceps muscle” has a **root value** which is L2, L3, and L4. So **L4 is involved**, and so if a hernia happened like in this case, Quadriceps will be affected, and what’s the movement that Quadri does?? **EXTENSION** of the knee.

b. Dermatome affected: sensory changes are expected to be on the anteromedial side of the leg. Why?? Sensation of Anteromedial aspect of the leg is taken by the saphenous N., which is a branch of the femoral N. that descends in the adductor “subsartorial” canal.

Some might ask why won’t I have a loss of sensation?? **Please** remember here that we didn’t cut the nerve “nerve injury” to lose transmission of sensation signals, but we pressed the nerve root, and this pressure is considered to be “neuropathy”.

** This is observed in experiments done on rats to test pain sensation; they did the following: They didn’t cut the nerve, they did laminectomy; expose dorsal root “sensory root”; ligate ربط the nerve (a procedure called Spinal Nerve Ligation SNL).

- You must know that the pressure here will not cause a loss of sensation but will cause pain → neuropathy

Returning to what is going to be observed in a rat with ligated nerve. We’ll observe a thing called **Tactile Allodynia** “Tactile; concerned with touch or sense of touch, Allodynia; refers to central pain sensitization (increased response of neurons زيادة حساسية) following normally non-painful, often repetitive, stimulation”. We see that this rat is more sensitive to pain than another normal rat.

ADD TO YOUR INFO; A research done on rats, found on Pubmed: Spinal nerve ligation-induced neuropathy in the rat: sensory disorders and correlation between histology of the peripheral nerves.

In its abstract: “We studied the effect of unilateral ligation of two spinal nerves on behavioral pain responses evoked by various types of cutaneous stimuli in the adult rat. Furthermore, we determined the effect of spinal nerve ligation on morphology of the peripheral nerves. The most consistent behavioral finding (83%) was a marked decrease in monofilament-induced hindlimb withdrawal thresholds (mechanical allodynia) ipsilateral إلى نفس الجهة to the spinal nerve ligation”

For more: <https://www.ncbi.nlm.nih.gov/pubmed/10204728>

READ ONLY :D

2. Herniation in IVD L4-L5. **IMPORTANT**

L4-L5	L5	40-45%	Big toe dorsiflexion (EHL) and TA	Big toe , anteriolateral leg (Common P)	Hamstring jerk
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Pressed root of L5 will cause symptoms mainly concerned in **Motor** part with Dorsiflexion, mainly **Extensor Hallucis longus** “Hallux; Big toe” and **Tibialis Anterior** “acting muscles are seen in Ant. Compartment of the leg – see anatomy glossary”.

Ant. Comp. of the leg is supplied by **common peroneal N.** which is the son of sciatic N. that has the root value of L4-S3.

Concerning **Sensory** part “dermatome”, the anterolateral aspect of the leg and the big toe will be affected.

3. Herniation in IVD L5-S1. **IMPORTANT**

L5-S1	S1	45-50%	Foot planter flexion (Gastrocnemius)	Lateral border of foot (sural)	Ankle jerk
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Pressed root of S1 will cause symptoms mainly concerned in **Motor** part with Plantar flexion “planta; sole of foot”, mainly **Gastrocnemius** “Gastrocnemia; calf of the leg” which is a muscle seen in Post. Compartment of the leg – see anatomy glossary.

****Gastrocnemius** is found to be larger and much strengthened in basketball players.

Post. Comp. of the leg is supplied by **Tibial N.** which is the other son of sciatic N. that has the root value of L4-S3.

Concerning **Sensory** part “dermatome”, the lateral aspect of the **foot** will be affected due to affected Sural N. which is a branch of Tibial N.

Q: How to test for herniation??

1. Ask your patient to perform movements related to suspected prolapsed disks

A- Want to Test L5: by asking the patient to stand or walk on his heels على الكعبين

****Note For sake of right scientific Info:** الوقوف على العقبين وليس الكعبين كما يُداول

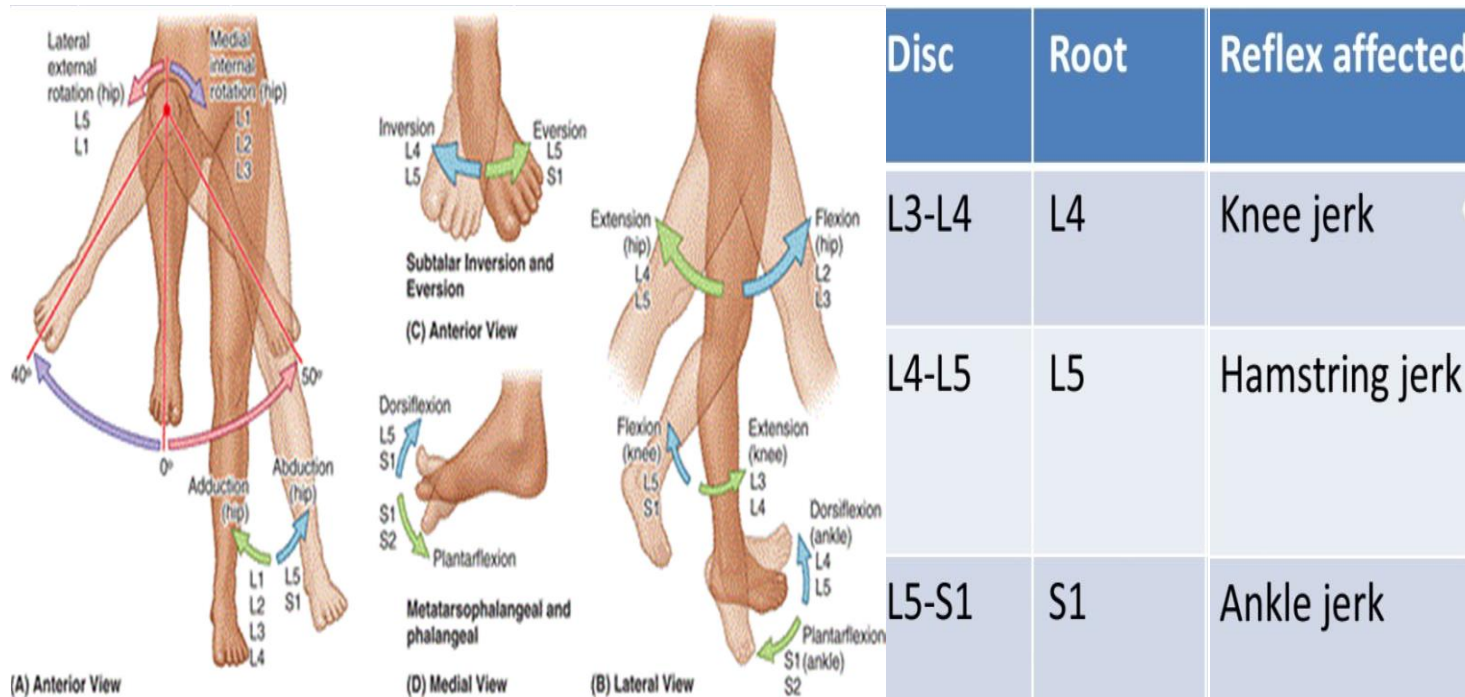
Your medial and lateral malleoli “small bones you feel on both sides are your كعبين, and they’re where water should reach in correct ablution “Wudu”

This is dorsiflexion. Now if he managed to stand or walk, the disk is fine, but if he failed to do so, this would be very suggestive for an L4-L5 disk prolapse.

B - Want to Test S1: by asking the patient to stand or walk on his tiptoes أطراف أصابع قدميه

This is plantar flexion. Now if he managed to stand or walk, the disk is fine, but if he failed to do so, this would be very suggestive for an L5-S1 disk prolapse.

2. Jerk Tests. “Jerk; muscular contraction evoked when a tendon overlying a bone is tapped نقر”



Don't be afraid of the picture on the left!! It shows you natural movements of lower limb muscles, and to which root values each movement corresponds “of course based on the root value of the muscle that does the action”

- Jerks are simply muscle reflexes upon tapping a tendon with a hammer مطرقة.

Ex.1: Upon tapping Quadriceps tendon, if everything was healthy and Quadriceps is acting, a muscle reflex should happen and so knee extension should immediately be seen. This healthy state of correct extension is not seen in case of IVD herniation.

Ex.2 “not mentioned in Lecture”: For Hamstring muscles in Post. Comp. of the thigh (Biceps femoris, semitendinosus, semimembranosus), hamstring reflex is applied to their tendons on medial and lateral side to test L5 functionality since they're supplied by Tibial N. and common peroneal N. for short head of biceps femoris.

Ex.3 “not mentioned in Lecture”: Ankle jerk is a response to →
Tapping on Gastrocnemius Tendon “Achilles tendon”.

10.00min –
20.35min / slides
covered 4, 5

- Major symptoms of disc herniation: Low back pain ألم أسفل الظهر

Low back pain is the very very important and most common symptom.

It's a Radiating pain to the gluteal region, the back of the thigh and back of the leg.

Why would we have a low back pain in disk prolapse??

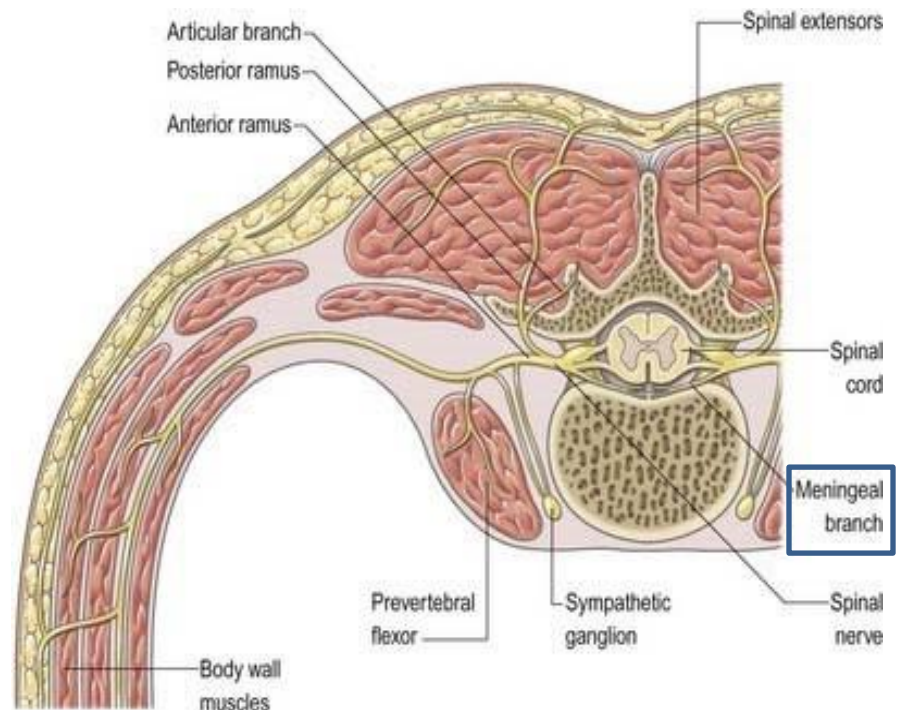
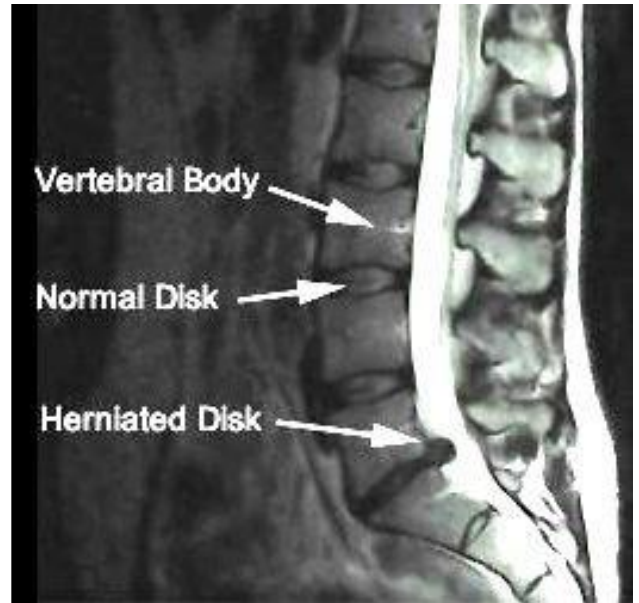
"See picture in middle of this page"

Please remember that Spinal Cord has already ended in IVD L1-L2, so this is just an illustration to show you the meningeal branch, and thus the spinal cord segment you're seeing in the picture is sure in a

higher level than L4, L5, or S1.

As we said, spinal nerve after being formed by **Dorsal** and **Ventral** roots gives a meningeal branch (or recurrent branch) that innervates dura, and bring sensation from it. Bear in mind that Dura matter is **sensitive to stretch**.

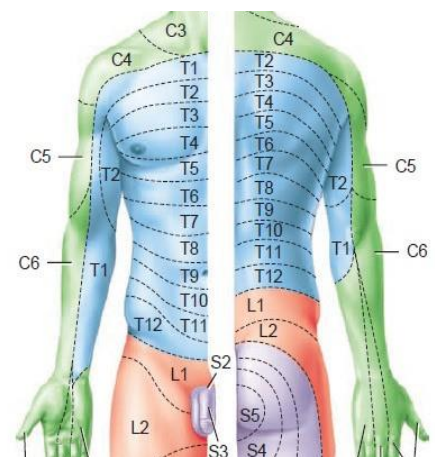
The prolapsing disc will exert a pressure on the spinal nerve and on the dura as well → **this is what will cause the pain**



** When you ask the patient **"where is the pain??"**

It's very difficult to pin-point "exactly define" the pain. He'll point at a wide area → **WHY???**

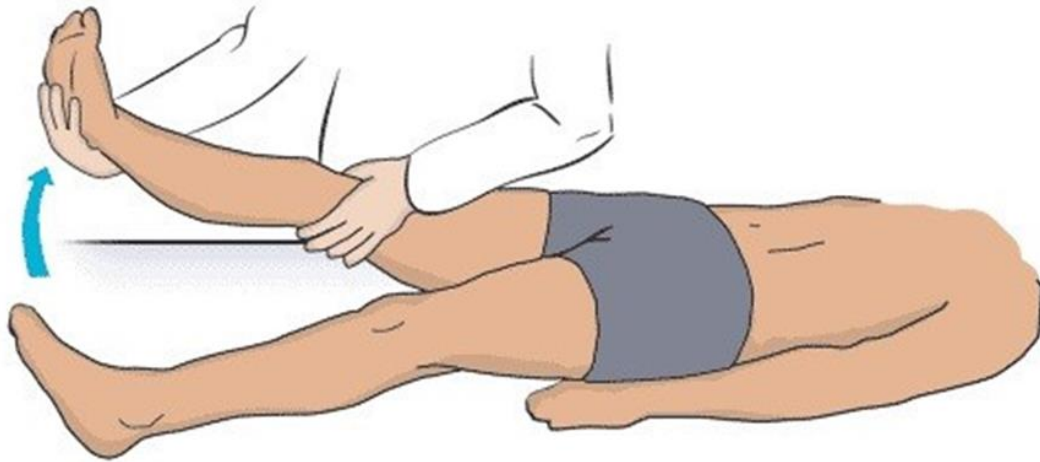
Because the pain is **diffuse** due to **overlapping** dermatomes. Dermatome linings are only for clarification, but actually dermatomes spread to neighboring sites outside their supposed linings. (The **overlapping is more in the lower part of the body**; head and neck areas which are mainly dealt with in dentistry are less overlapping).



Very Important: Not every patient with a lower back pain will have herniated disc; a wide variety of disease can cause lower back pain but this symptom is very suggestive for disk herniation IN CASE THIS PAIN WAS **PROLONGED**.

All in all, TO REACH A CORRECT DIAGNOSIS upon this chief “mainly complained” symptom:

1. **Take the patient's history;** identify which type of pain he has “ prolonged or not; maybe if the patient was a menstruating female then it's a menstrual pain, maybe if a smoker it's due to osteoporosis... etc.”
2. Ask the patient to do roots' tests “stand on heels, tiptoes, jerk tests” based on suspected root.
3. Perform **Straight Leg Raise Test (SLR):** in this test, the patient lie in supine position “lying on the back”, then we lift **نرفع** the patient's leg in straight manner.
The idea here is that when you lift the leg like that, tension happens to the muscles and this will stretch and pull the nerve “sciatic N.” and its roots “L4-S3”, and **will cause pain**.



Back again to the idea of pain, we mentioned the word **allodynia**; which was the result seen in rats which SNL was performed on. Simply, when a person is healthy, if you tried to poke him he might not feel pain, but in cases of inflammation or pressure for example, any poke even if small will become painful “ **areas that were not painful will become painful**” , concluding **that the threshold of pain became lower** and this is simply what allodynia is!

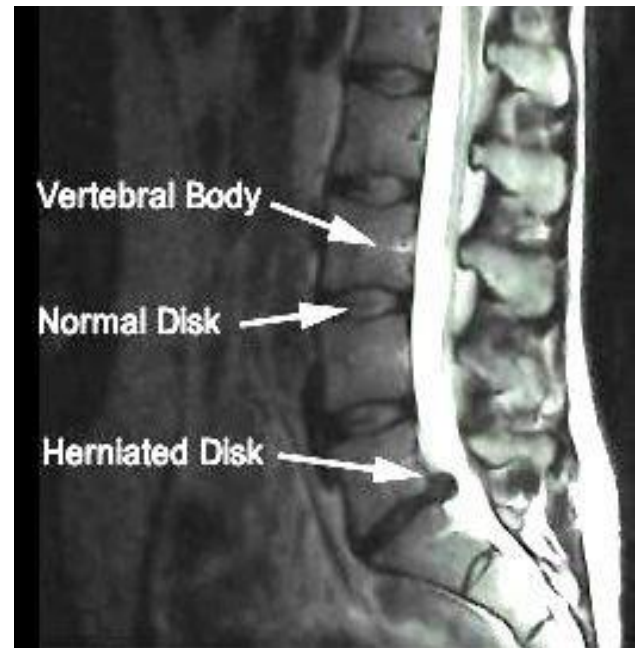
SLR is a complicated procedure, it's routinely done in neuroclinics, and it has many degrees applied according to patient's state (75, 90 ...), what we want you to understand is the principle.

4. **MRI** “Magnetic resonance imaging **التصوير بالرنين المغناطيسي**”: all above tests will not be completed without doing the **most essential test**. It is commonly used to aid in making the diagnosis of a herniated disc.

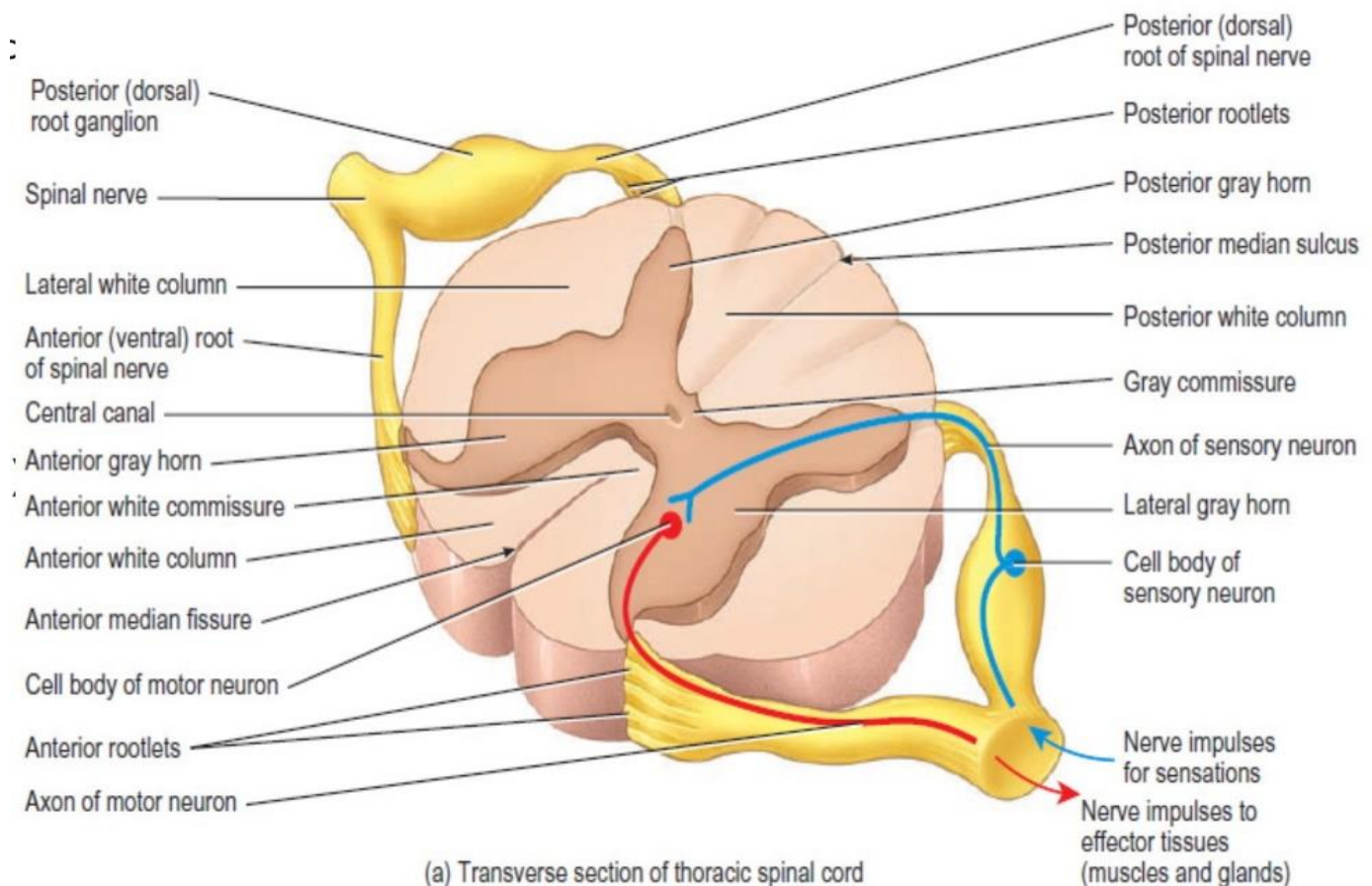
Observe the following:

1. How a normal vertebral body looks like.
2. How a normal IVD looks like.
3. How a normal IVD is different than a herniated one.
4. How a herniated disk is bulging into the spinal cord area “remember that it has ended by this level and Qauda equine is there, so we’re referring to areas where roots of spinal nerves are getting out”.

** This picture will be **CONFIRMATORY** to your diagnosis for the patient as having disk herniation



Back to the spinal cord



After carefully observing this section in the spinal cord, we can notice the following:

1. White matter outside surrounding gray matter inside
2. Some gross anatomy is noticed also:
 - A. Anterior median fissure: which is a Wide groove on the anterior aspect
 - B. Posterior median sulcus: Narrow groove on the posterior Aspect

**** Fissure and sulcus are actually kind of the same, but Fissure is deeper than Sulcus;**
Sulcus is a furrow تجعد especially of the cerebral hemispheres, Fissure is a groove أخدود or cleft which is a natural one due to in-folding during development.

- C. In the center, we have the **central canal** which:
 - (1) Represents the **Cavity** of the spinal cord
 - (2) Is a Continuation with the 4th ventricle of the brain
 - (3) Is Lined by ependymal cells and
 - (4) In it circulates the CSF.

3. We divided the gray matter into **HORNS**

- A. **Ventral** (anterior) horn → motor “ contains cell bodies of lower motor neurons”
- B. Lateral horn (in some segments) → autonomic
- C. And **Dorsal** (posterior) → sensory

The gray matter resembles a butterfly shape or letter H, with a **gray commissure** that connects the two sides of gray matter together.

ADD TO YOUR INFO: Commissure; any tissue joining two like masses of tissue or structures, usually but not always, crossing the medial sagittal plane of the body; most commonly in the CNS, where it is to be differentiated from a chiasm or decussation.

4. The white matter also is divided into **COLUMNS**

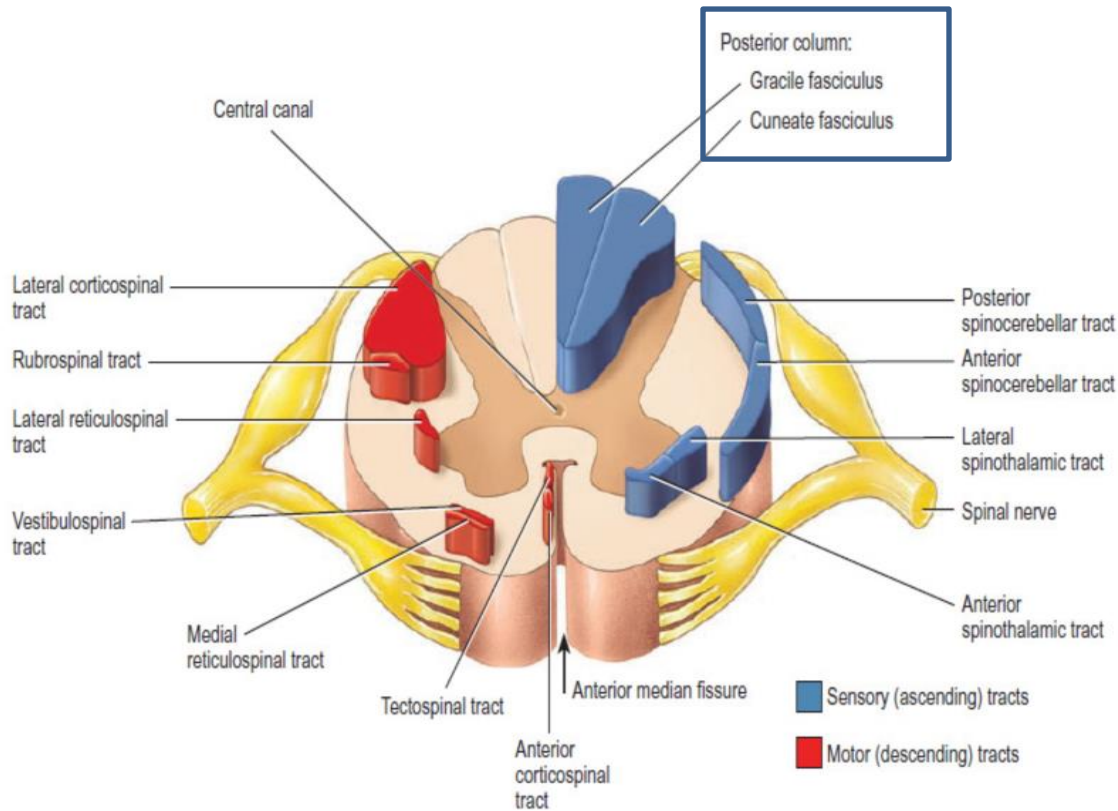
- A. Anterior white column and lateral white column (some people combine them as anterolateral system due to similarities existing between them)
- B. Posterior white column

As you know that the gray matter contains cell bodies, while white matter is occupied by myelinated axons → we call these axons **TRACTS “in the CNS”**.

*20.35min – 30.00min
/ slides covered 6, 7,
and 8*

So the white matter is divided into tracts مسارات which are either:

1. Ascending (sensory) tracts.
2. Descending (motor) tracts, since it's obvious that motor command must come from the higher centers in cortex down to the lower centers in the spinal cord.



** In the above figure we have general names for some tracts:

1) Sensory tracts:

A. Posterior column system; divided into:

- I. Gracile fasciculus. Gracile; Slight or slender نحيل, delicate, thin. Fasciculus; A bundle or collection of fibers all with the same orientation.
- II. Cuneate fasciculus. Cuneate; wedge shaped " same as cuneiform"

B. Posterior spinocerebellar tract "spinal cord to cerebellum"

C. Anterior spinocerebellar

D. Anterior spinothalamic tract "spinal cord to thalamus"

E. Lateral spinothalamic tract

2) Motor Tracts "naming flips here":

A. CORTICOSPINAL tract " from cortex to spinal cord"

B. Rubrospinal " from red nucleus to spinal cord"

C. Reticulospinal " from reticular formation to spinal cord"

Did you notice how the naming is very descriptive???

First we will start with the sensory tracts, **but first** we have to understand types of sensation and sensory signals.

- Sensory receptors are divided into:

1-Mechanoreceptors → responding to mechanicals like touch, stretch, vibration, itch حكة, and tickle دغدغة.

Also to a thing called Proprioception → informing about the position of your body.

Proprioceptors exist mainly in the muscles and muscle tendons. We will talk about it more when we discuss the motor part, but for now, it's important to know that your CNS must always know your position; which muscle is contracting and which muscle is relaxing; which joint is moved and at which angle, this will all help you to do the right motor actions in a smooth way that pleases you and your CNS!

** This is a figure representing a cross- section in the skin. Dermis “light color” and Epidermis “pale pinkish color” are seen, and between them is the wave-like interdigitations تشابكات of epidermal ridges and dermal papillae.

1- Mechanoreceptors:

A. Meissner's corpuscle:

- Respond to touch “also called touch or tactile corpuscle”, pressure and low frequency vibration (low frequency; around 50 Hz)
- They are encapsulated “an outer capsule from the perineurium”
- Rapidly adapting (تذكر توقف شعورك بالملايس بعد مدة قصيرة من ارتدائها)

B. Merkel's disc (Tactile Disc)

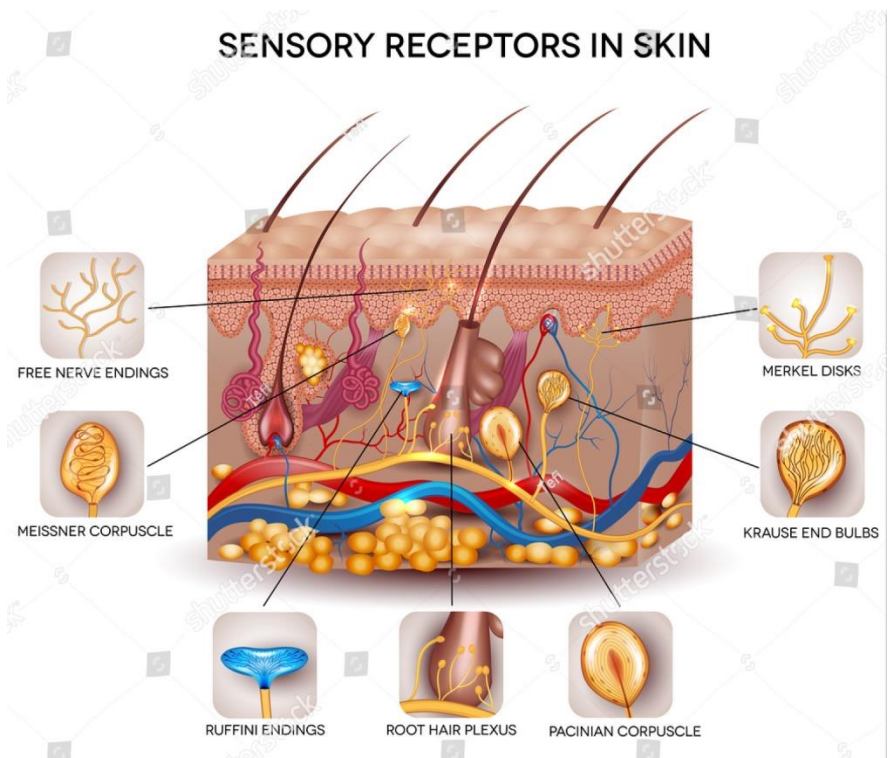
- for Discriminative touch
- Slowly adapting

C. End organ of Ruffini

- Sensitive to skin stretch
- Slowly adapting

D. Pacinian corpuscles “lamellated corpuscle”

- **Exist in deep layers** ‘found deep in reticular dermis – area of dermis below dermal papillae- and hypodermis’



- Encapsulated “concentric lamellae of flattened Schwann cells and collagen”
- Vibrations (high frequency; above 200 Hz)
- Slowly adapting

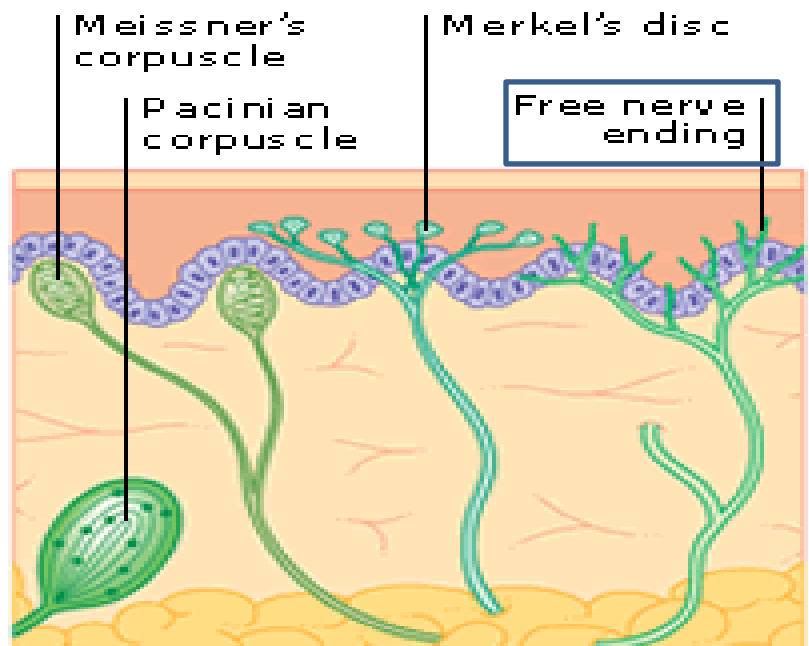
We have noticed words of slow and fast adapting, what do they mean???

1. **Rapidly adapting:** signals fade away “go away” after stimulus exposure. This is very good because not all sensations are needed to stay sensed (ex. Once you wear your clothes you feel them, but after a while of wearing them, you won’t “stay alert” the whole period of wearing them that they’re there and this is what it’s all about)!
2. **Slowly adapting:** signals are transmitted as long as the stimulus is present.

Conclusion: 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:

- Free “Bare” nerve endings
 - Detect change in temperature WHETHER WARM OR COLD.
 - TRP channels (many types TRP1, TRP2, TRP...)
 - From Wikipedia:
“TRP channels are a large group of **ion channels**, comprising six protein families, located mostly on the plasma membrane of numerous human and animal cell types, and in some fungi.”
- These channels have the ability to do a conformational change to respond to different Temp. Stimuli. So they give you a wide range of response and each channel type is activated on certain temp degree.



3-Nociceptors: Noci; damage or pain

- Free nerve endings
- Detect damage (pain receptors). They’re only activated when tissue damage occurs, so they’re considered **Multimodal** “polymodal” → characterized by several different modes of activity or occurrence.

Explain further please!!

There’s no type of sensory energy called Pain, we have sound waves or light electromagnetic waves to be sensed by their receptors, we have pressure and temp sensed by their receptors,

but there are no pain energy waves! That's why these nociceptors are activated when other sensations reach above their threshold, so when for example heat stimulus reaches a higher degree at a certain point above its threshold **"40-45 degrees; painful hot"**, this increase in heat energy is what will activate **TRP 1** thermo receptors, and in the same time will cause tissue damage that'll activate nociceptors.

**** Painful cold also activates Nociceptors.**

- Each receptor has different types of **fibers** depending on the diameter. **As the diameter increase the conducting velocity increases**. At the end, remember that these receptors exist on the 1st order neuron fibers "nerve fiber = Axon".

TABLE 25.1 Summary of Primary Afferent Fibers and Their Roles

Modality	Submodality	Receptor	Fiber type	Conduction velocity (m s ⁻¹)	Role in perception
Mechanoreception	SAI	Merkel cell	A β	42-72	Pressure, form, texture
	RA	Meissner corpuscle	A β	42-72	Flutter, motion
	SAII	Ruffini corpuscle	A β	42-72	Unknown, possibly skin stretch
	PC	Pacinian corpuscle	A β	42-72	Vibration
Thermoreception	Warm	Bare nerve endings	C	0.5-1.2	Warmth
	Cold	Bare nerve endings	A δ	12-36	Cold
Nociception	Small, myelinated	Bare nerve endings	A δ	12-36	Sharp pain
	Unmyelinated	Bare nerve endings	C	0.5-1.2	Burning pain
Proprioception	Joint afferents	Ruffini-like and paciniform-like endings, bare nerve	A β	42-72	Protective function against hyperextension
	Golgi tendon organs	Golgi endings	A α	72-120	Muscle tension
	Muscle spindles	Type I	A α	72-120	Muscle length and velocity
		Type II	A β	42-72	Muscle length
	SAII	Ruffini corpuscle	A β	42-72	Joint angle?

DON'T FREAK OUT!!!! We want to understand certain concepts regarding fiber types only :D

What do you notice??

- A alpha is the fastest and thickest "high velocity"
- A beta is slower, then A delta, and C fibers are the slowest (unmyelinated; least diameter).
- For example the slow adapting mechanoreceptor has A beta fibers.

30.00min - 40.10min
/ slides covered 9-12

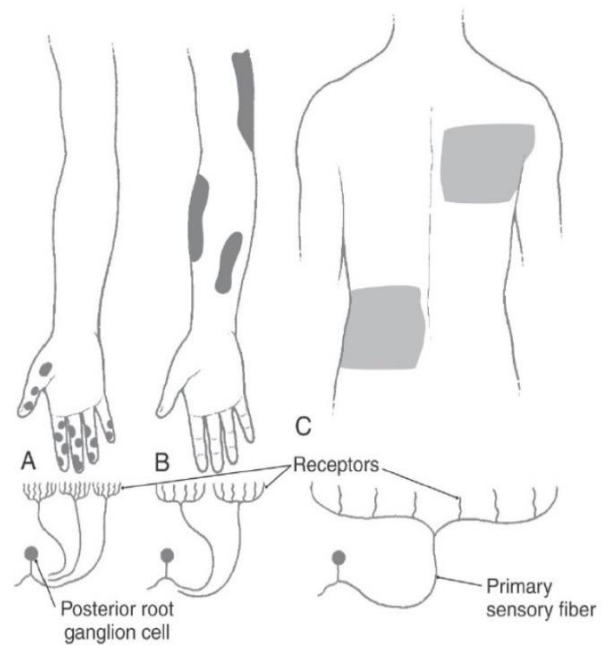
- Receptive field:

Every receptor receives sensation from a certain area of the skin; the area of the skin that gives sensation to a single receptor is called the **Receptive field**.

- Rules of receptive field:

- ✓ The greater the density of receptors, the smaller the receptive fields of individual afferent fibers.
- ✓ The smaller the receptive field the greater is the accuracy or the **(discriminative touch)**.

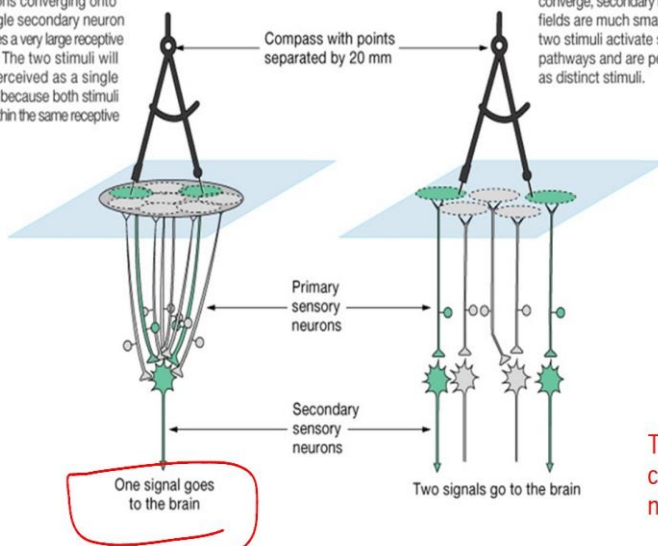
- For example the hand has very small receptive fields; in the elbow, and the shoulders the receptive field is larger; going to the back where it increases more.
- Also, the cortex “the primary somatosensory cortex; the higher center located in the parietal lobe; also called **post central gyrus**” is divided in a manner that the area representing the hand will be larger because of the huge number of receptors.



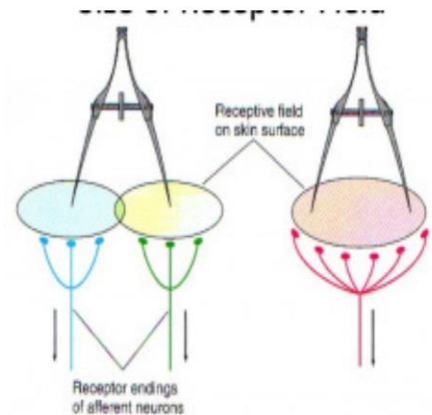
(a) Many primary sensory neurons converging onto a single secondary neuron creates a very large receptive field. The two stimuli will be perceived as a single point because both stimuli fall within the same receptive field.

Compass with points separated by 20 mm

(b) When fewer neurons converge, secondary receptive fields are much smaller. The two stimuli activate separate pathways and are perceived as distinct stimuli.



ganglion cell



The area that represent the hand in the cortex will be larger because of the huge number of receptors

If you brought a compass like above and placed its needles on the hand, you'll notice that due to receptive fields being so small, the patient will feel them as two, so you'll need to make them very close to each other to activate a single receptor and to be sensed as one; but if you placed the same 2 on the back, even if they were on greater distance, they'll be sensed as one because you typically activated a single receptor that covers a large area.

Labelled line theory:

The function of the receptors is to change certain types of energy to action potential, so how our brain distinguishes the different stimuli if **all what it receives is action potential???!!!**

Individual receptors preferentially transduce تنقل information about an **adequate stimulus**

- ✓ individual primary afferent fibers carry information from a single type of receptor
- ✓ Pathways carrying sensory information centrally are therefore also specific, forming a “labeled line” regarding a particular stimulus.

Sensation:

1. Modality → Each neuron has only one type of receptors; it's like the CNS is designing a model for each type of sensation.
2. Locality → The direction and destination in upper centers is well-located; meaning that if a site in the cortex is activated, type of sensation will be known. Also body parts are mapped in the cortex, so this will further help us in localization of sensation.
3. Intensity → the frequency= the number of the activated receptors

Conclusion: Any sensory information will have

1. A modality “type of sensation”
2. A locality “In the cortex, sensation arrives based on Somato-tropic principle, which says that fibers arrive the cortex and get aligned according to the body part they came from (hand, foot, face...)”
3. Intensity “ decided by frequency of Action potential and how many receptors were activated”

**** Note: The adequate stimulus is the amount and type of energy required to stimulate a specific sensory receptor.**

The sheet has thankfully ended, thank you for your time and we hope this was an easy-going sheet, you'll find below some references and pictures that might help you further enhance your understanding, please forgive if any mistake was found, and never hesitate to inform us with :D

May your day be blessed, and filled with joy Amazing Doc. ♥

*40.10min –
47.30min / slides
covered 13,14*

Add to your info

1. Junqueira's basic histology; 14th edition

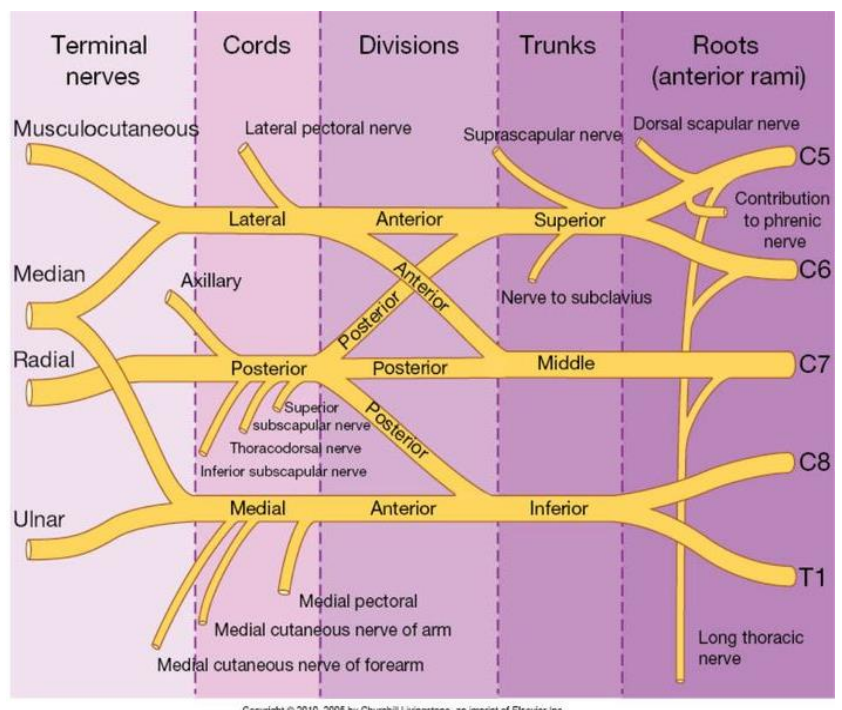
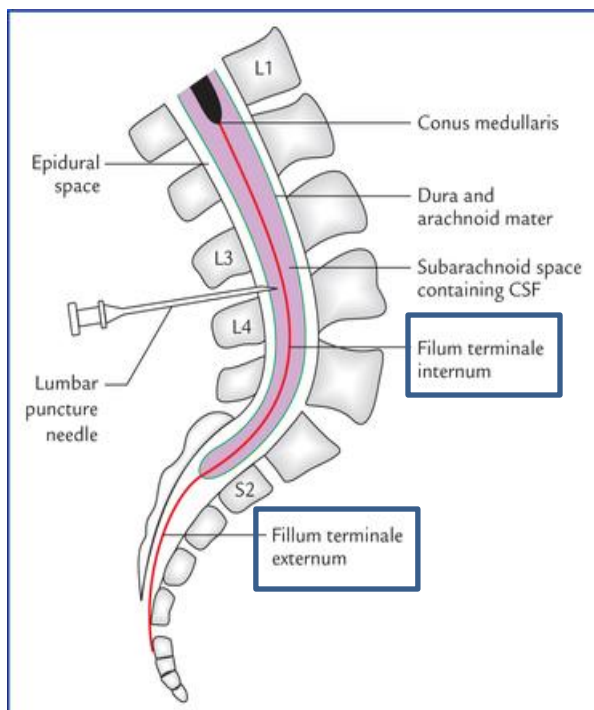
A. Page 115: "In dense irregular connective tissue, bundles of collagen fibers appear randomly interwoven محبوكه, with no definite محدد orientation. The tough three dimensional collagen network provides resistance to stress from all directions. Examples of D.I.C.T include the deep dermis layer of skin, and capsules surrounding most organs".

B. Page 179: " The arachnoid has 2 components: (1) a sheet of connective tissue in contact with the dura mater and (2) a system of loosely arranged trabeculae composed of collagen and fibroblasts, continuous with the underlying Pia mater. Surrounding these trabeculae is a large, spongy- like cavity, **the subarachnoid space**, filled with CSF".

C. Page 181 : " the choroid plexus consists of highly vascular tissue, elaborately بشكل متقن folded and projecting into the large ventricles of the brain. It's found in the roofs of the third and fourth ventricles and in parts of the two of the lateral ventricular walls, all regions in which the ependymal lining directly contacts the Pia mater. Each villus of the choroid plexus contains a thin layer of well-vascularized Pia mater covered by cuboidal ependymal cells. **The function of the choroid plexus is to remove water from blood and release it as the CSF**".

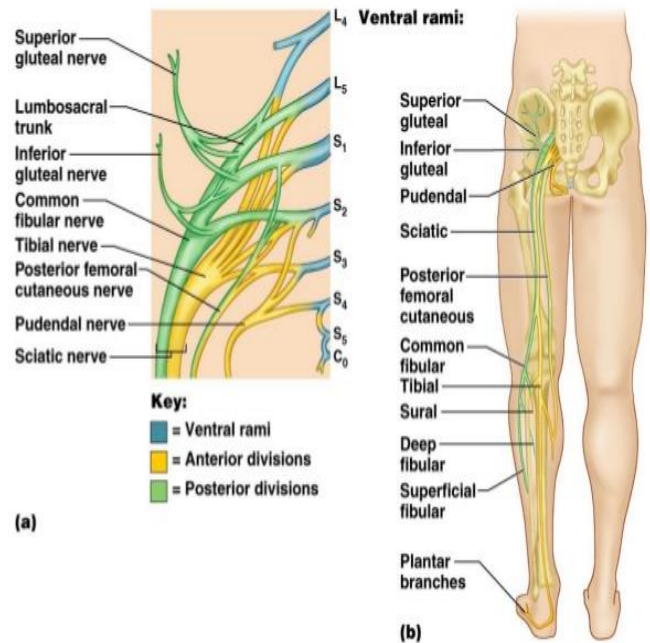
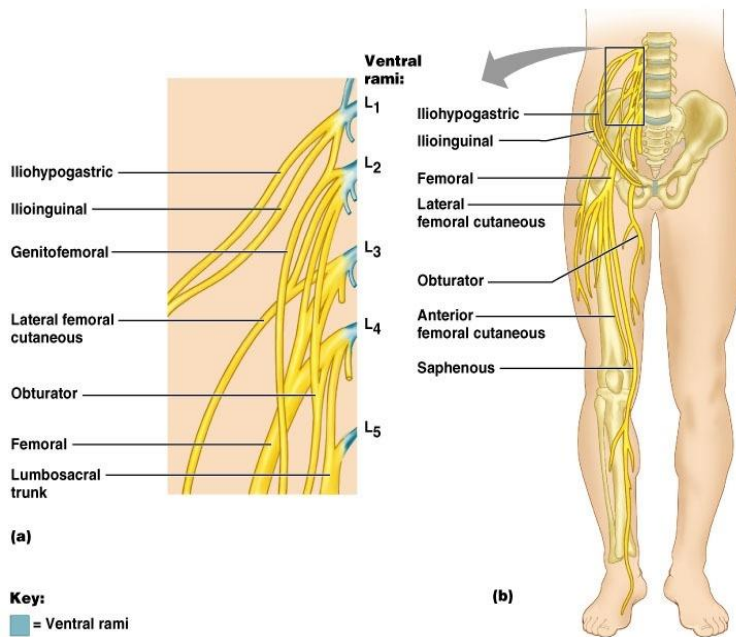
2. Anatomy Glossary

A. Filum Terminale and Brachial plexus

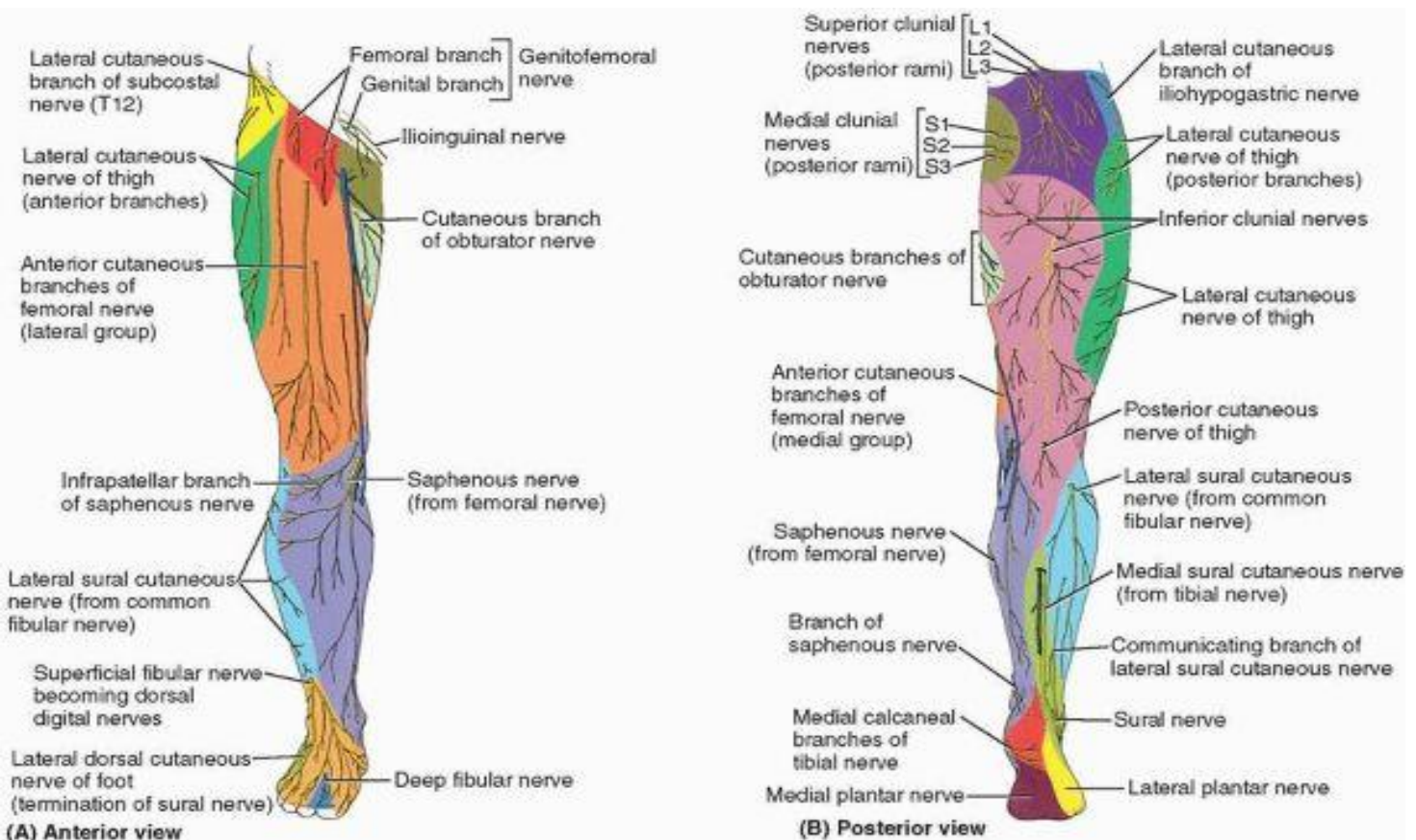


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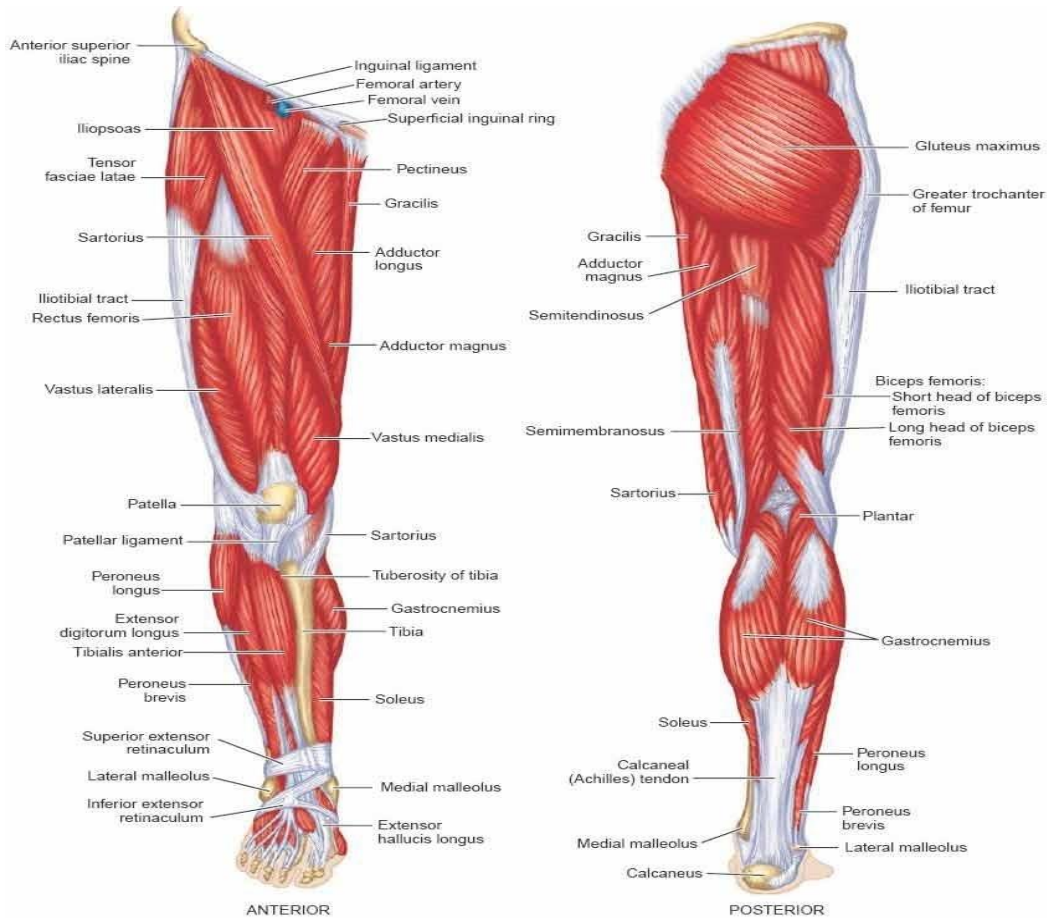
B. Lumbar plexus and Sacral plexus



C. Lower limb innervation



D. Muscles of the lower limb



E. Vertebral structure and Laminectomy

