CENTRAL NERVOUS SYSTEM

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- ★ Anatomy
- ○ Physiology
- ○ Pathology
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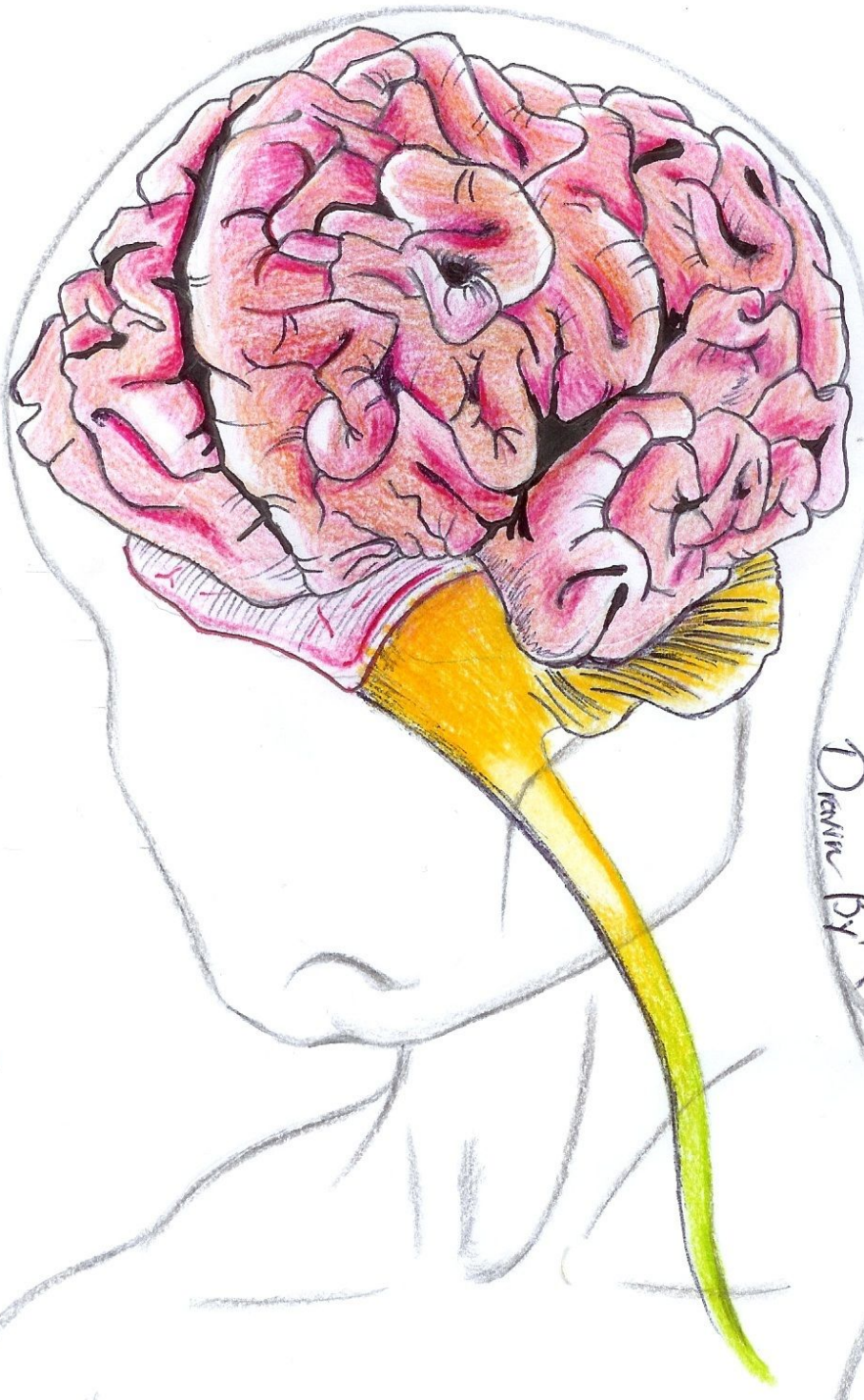

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SENSORY PATHWAYS

Classification of somatic sensation:

#Old classification:

1-Extroception: From body wall, or skin.

2-Proprioception: from muscles and joints, sense of position.

New classification:

1-mechanoreceptor:

1-tactile sense: including (touch, pressure, vibration, tickle)

2-proprioception: include 2 types:

1. **Static:** conscious perception of the orientation of different parts of the body with respect to one another; means that when you are sitting you know where your foot is.

2. **Dynamic**: sense of movement, when you close your eyes you feel movements of any of your joints.

2-thermoreceptive sensation: hot or cold.

3-nociereceptor: pain sensations activated by any factor that induces tissue damage. Any pain receptor could be stimulated by:

1-mechanical stimuli >> Press firmly on your hand.
2-chemical stimuli >> chemical substances.
3-thermal stimuli >> high temperature or low temp.

All of these stimuli induce tissue damage. So the main stimulus and the adequate stimulus here is TISSUE DAMAGE. Keep in mind: "For each receptor there's a specific stimulus called adequate stimulus" We'll take about it later in this sheet.

#Skin receptors

Look at the Page 56B in the handout.

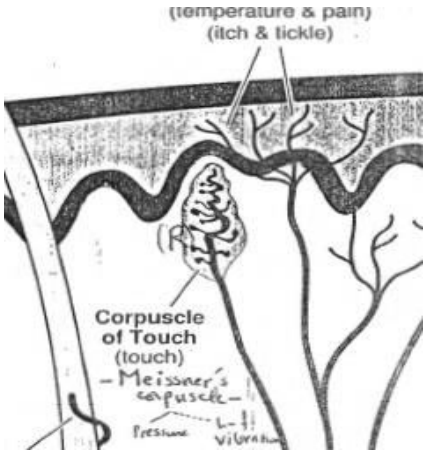
1- Touch receptor: we have corpuscle of touch “Meissner's corpuscle” it is the ending of dendrite.

> **Note**: dendrite meets the peripheral process of dorsal root ganglion.
>
> Remember dorsal root is pseudo unipolar cell and the peripheral process of it is the dendrite and the central process is the axon which enter spinal cord.
>
> The peripheral process of dorsal root goes on and on until reaching the skin.

Now, these type of receptors “touch receptor" enable you to detect site of touch anywhere in your body. e.x. when I put a cotton on the dorsum of your hand while you’re closing your eyes you should feel that by Meissner's corpuscle ((touch corpuscle)). In addition, these receptors are **rapidly adapting**.

>>Rapidly adapting:- receptor responds only at the application or removal of the stimulus. “Just when we applied the stimulus or remove it”.

>>slowly adapting:- throughout stimulation response.
“Whenever the stimulus present you will feel it”.



Corpuscle of touch is located in upper part of dermis near the epidermis; its shape is like bifurcation of dendrite.

Although it’s a touch receptor but it also responds to low frequency vibration.

2- **Root Hair Plexus:** receptors here respond to touch. It's a network of dendrite around the hair follicles whenever the air moves on the body surface, these receptors will be activated. Also, they are **rapidly adapting.**

3- Tactile Discs ((Merkel's disc, Type 1 cutaneous mechano-recptors)):

They're flattened nerve endings. This type of receptors respond to very fine touch ((very accurate touch)) or what we call discriminative Touch, also they respond to Two point Discrimination i.e. I Put 2 pins on your hand at specific distance from each other, you say "I receive 2 stimuli". This type of receptors is **slowly adapting**.

4- Type 2 cutaneous mechano-recptors "end organ of Ruffini":-

Respond to heavy touch as well as stretch of skin. They are **slowly adapting.**

*All these receptors that we have been talking about are put under the title "**Tactile Sensation"** i.e. touch and pressure.

Now we will talk about the vibration, we said that vibration receptors are rapidly adapting receptors. We have two types of vibration receptors:

1- **Meissenr's corpuscle** (Corpuscles of Touch): these respond to **low frequency vibration.**
2- In subcutaneous layer; in the superficial fascia "hypodermis" or in the dermis, there is another type of receptors called **"Pacinian corpuscle**": several layers of connective tissue surrounding the peripheral dendrite, these respond to pressure as well **as High frequency vibration**.

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* Now look at the epidermis we have another type of receptors called **free nerve endings** which work as receptors for pain and temperature.
* Free nerve ending means that the nerve reaches the epidermis and take off the myelin sheath; become free not covered by myelin sheath.

* the doctor revise the main point in page 56 C we talked about **tactile sensation ((1st type of sensation))** which includes touch, pressure and vibration.

** The touch receptors are:

A- Corpuscle of touch.

B- Root hair plexus.

C-Tactile discs “discrimination touch".

D- Type 2 cutaneous mechano-recptor “end organ of Ruffini”

A&B are rapidly adapting.

C&D are slowly adapting.

** Pressure & vibration receptor:

A- Pacinian corpuscle.

B - Meissenr’s corpuscle.

** Itch & Tickle receptor: same as pain receptors ----> free nerve endings

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There are other types of sensation:

1-Thermal sensation:

Free nerve endings respond to heat and Cold.

A- Warm receptors: respond to temp. above 25 C^o, If temp. reaches above 45 C^o pain receptor get activated **((Burning sensation)).**

B- Cold receptors: respond to temp. between 10 C^o - 20 C^o, below 10 C^o the pain receptor get activated **((freezing sensation))**.

3- Pain sensation: ((nociceptor))

>> Free nerve ending, non- adapting because our sense of pain is protective.

Note: each type of receptor has got specific stimulus to which it responds very quickly at the lowest threshold, we call this specific stimulus: **adequate stimulus.

Pain receptors → respond to mechanical stimuli apparently, but actually thermal, chemical or mechanical stimuli induce **tissue damage** which is considered as adequate stimulus for pain receptors.

Page 57: **Two point discrimination**:

If you put 2 pins at the same time on the tip of your finger you will feel them as 2 stimuli if the distance between them is not less than 5 mm (0.5 cm), if the distance was less than 5 mm, you would feel them as one stimulus. However, on the front of the leg to be able to recognize them as 2 stimuli the distance must be 10 cm or 8 cm, If less than that you will feel them as one stimulus.

Why these differences?

These differences reflect the **size** of receptive Field. On the tip of the finger, the receptive field is small while on the front of the leg the receptive field is large.

On the tip of the finger, the receptive field is **small**, so when the distance between the 2 pins is 0.5 cm, each pin lies in a receptive field causing 2 different stimuli (each coming from a receptive field). When the distance is decreased (less than 5 mm), the two pins will be located in the same receptive field so they'll be felt as one stimulus.

However, on the front of the leg the receptive field is **large**, when the distance between the 2 pins is 8-10 cm; each pin lies in a receptive field → the 2 pins will be felt as 2 different stimuli. When the distance is decreased (less than 8 or 10 cm), the two pins will become in the same receptive field so they'll be felt as one stimulus.

What is the receptive field??

The receptive field in the skin is an area of skin monitored by a single receptor "single nerve ending"

- The smaller the receptive field --> the more density the receptors (nerve endings) --> the greater its accuracy or discrimination ability.

- Receptive field at the tip of the finger are small; means that each sensory neuron receives information from small area of skin.

- Large receptive field at the elbow transmit sense of vibration or stretch of skin or movement of the joint.

- Each receptor in the skin interacts with the CNS ((cerebral cortex "sensory cortex"; area 3, 1, 2)) through a distinct pathway. This feature is called **labelled line.**

Labelled line: each receptor has a specific pathway.

**the result --> activation of sensory receptor produces the same sensation independent of the stimulus that activated the receptors.

For example, pain receptors could be stimulated by thermal, chemical or mechanical stimuli → all these stimuli cause tissue damage which is a specific adequate stimulus for pain receptors. As you see, once an adequate stimulus activates the pain receptor, it will produce pain sensation, independent of the type of the stimulus (chemical, thermal, or mechanical).

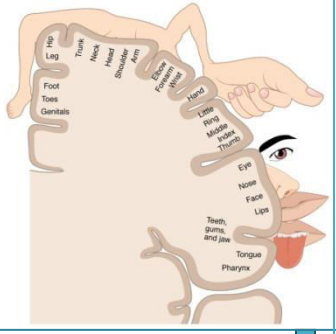
* The size of receptive field varies inversely with the density of receptors:

Large receptive field → less density of receptors.

Small receptive field → high density of receptors → more accurate sensation.

**Cortical representation: the representation in area 3, 1, 2:

The smaller the receptive field, the larger its representation in the sensory cortex.



We said in lab there is something called **sensory homunculus**:

The skin of the face, lips, thumbs, and finger have large cortical area, why?

Because all of them have something in common which is ((small receptive field)).

* Small receptive field → high density of receptors (or nerve endings) → large cortical representation.

Now, we'll start talking about somatic sensory pathways.

Page 59: **Sensory pathways:** we have 2 major sensory pathways:

1- **Anterolateral system.**
2- **Dorsal column system.**

First pathway: Anterolateral system

* Which conduct pain, touch, and temp.

* Previously it was two parts:

A- Ventral spino-thalamic tract: it was believed that it conducts non-discrimination touch (simple touch).

B- Lateral spino-thalamic tract: it was believed that it conducts pain, cold, warm, simple touch, itch & tickle, and the sexual sensation.

⇨ Now, it's believed that the nerve fibers of these two tracts are mixed together and form the anterolateral system.

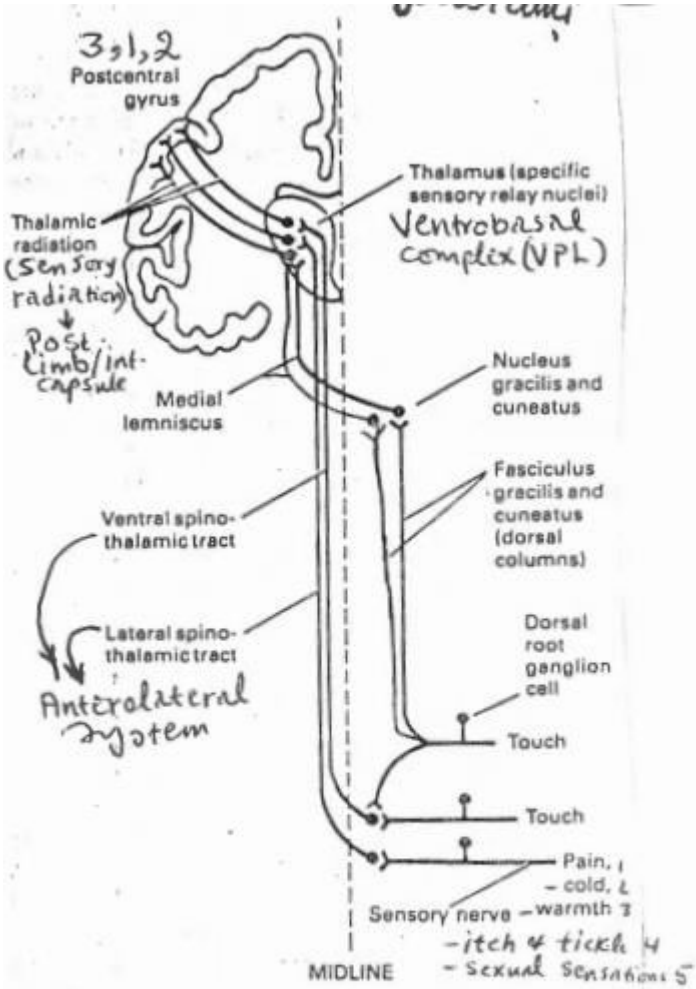


Figure 7–2. Touch, pain, and temperature pathways from the trunk and limbs. The anterolateral system (ventral and lateral spinothalamic and related ascending tracts) also projects to the mesencephalic reticular formation and the nonspecific thalamic nuclei.

The anterolateral system is considered as broad spectrum, because it carries different types of sensation.

Second pathway: dorsal column system (posterior column system/ medial lemniscus system)

In the figure 7-2 page 59, notice that part of touch sensation is conducted through Anterolateral system and the other part is conducted through dorsal column system → this indicates that touch is very important since it's conducted through two systems. Also, notice that the fibers of the dorsal column system don't cross the midline, they ascend in the same side (the doctor here means that they don't cross in the spinal cord; crossing of the dorsal column system happens in the medulla), then reach the medulla and form the medial lemniscus (which is an important part of the dorsal column system).

>> The nerve fiber of this pathway run in **gracile and cuneate.**

1- **Fasciculus gracilis** --> from the lower limb.
2- **Fasciculus cuneate** --> from the upper limp.

The dorsal column system is considered as mechano-receptive sensation; it carries several sensations: discriminative touch "tactile localization & 2 point discrimination", vibration, sense of position "proprioception", and sterognosis "knowing objects by feeling without the help of vision" (but all these sensations are considered as mechano-receptive sensations). This is the opposite of ALS which is considered as broad spectrum carrying pain (with all of its types; slow or fast), simple touch, cold, warm, itch & tickle, and sexual sensation.

the two pathways ((anterolateral & dorsal column systems)) must go to the relay station (thalamus) before reaching the sensory cortex (post-central gyrus) ((area 3, 1, 2)) Which nucleus of thalamus? The **ventrobasal complex (VP) with its two parts.

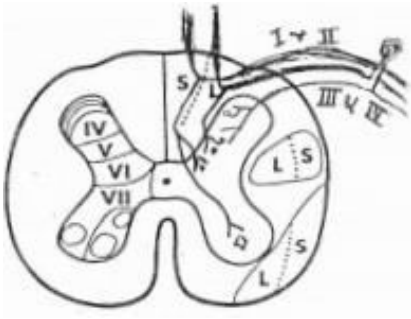
VP parts:
1- VPL --> from the body ((pain, temp., touch, proprioception))
2- VPM --> from the face.

>>any sensory pathway simply has 3 order neurons:

First order neuron: (dorsal root ganglion), the sensory cell in the dorsal root ganglion sends peripheral process (dendrite) to a receptor on the skin, and the central process enters the spinal cord.

“Cells of the Dorsal root ganglion (sensory ganglion) are pseudo-unipolar".

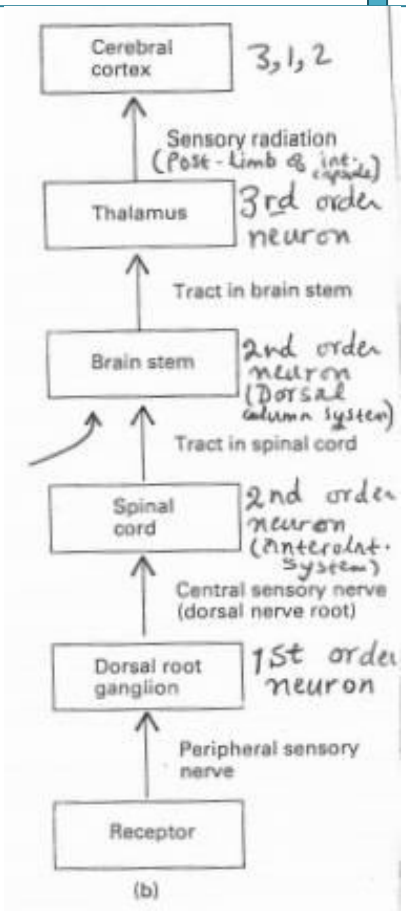
* Dorsal root entry zone: between the end of the dorsal root and the tip of the dorsal horn.



The fibers of the central processes (of the dorsal root) are of 4 types; divided into 2 groups:

1- medial division :
   - ✓ Type I (Aα) and type II (Aβ) → large in diameter, thickly myelinated fibers ((rapidly conducting)).
   - ✓ Carry precise sensory information, sense of position "proprioception", discriminative touch "tactile localization & 2 point discrimination", sterognosis "knowing object by feeling without the help of vision".
   - ✓ Don't enter the dorsal horn instead they ascend directly and run in the dorsal column ((forming the gracile & cuneate tracts)).
2- lateral division :
   - ✓ Smaller in diameter, less myelinated and unmyelinated; type III (A delta) which is poorly myelinated & type IV (C) which is non-myelinated → slowly conducting.
   - ✓ Enter through dorsal horn and carry simple touch, pain and temp.

Now let’s continue with the order neurons, we done with first order neuron now this 1st order neuron will enter the spinal cord and synapse with **the second order neuron** which is "the dorsal horn" (for anterolateral system), while second order neuron (for the dorsal column system) is in the medulla “gracile & cuneate nucleus". The most important feature of the second order neuron is that they cross the midline "right to left & left to right".



>>crossing of the Anterolateral system happens in the spinal cord.
>>crossing of the dorsal column system happens in the medulla

After crossing they reach to the ventrobasal complex (VP) in the thalamus (VP = VPL: somatic sensation from the body + VPM: somatic sensation from the skin & muscles of the face).

*thalamus is the **3rd order neuron.**

→ And the final station is the somatosensory cortex (area 3, 1, 2).

* The pathway between the thalamus and the cortex (area 3, 1, 2) is called **sensory radiation** "pass in the posterior limb of internal capsule"

**most cases of stroke happen in posterior limb of the internal capsule which contains the sensory radiation, pyramidal (corticospinal tract and corticobulbar tract), and extrapyramidal.

>>**IMPORTANT**: Lesion in internal capsule -->> contralateral spastic hemiplegia, contralateral temporary hemiansthesia, and contralateral weakness of lower face.

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* Dorsal root bringing sensation from the skin through Nerve fibers which have several types:
Type 2: is Aβ "transmit mechanoreceptors" touch, pressure, vibration, and itching → these sensations either ascend in the dorsal column or enter lamina 3, 4, 5, 6.

Type 3: A delta, slow conduction, also transmit mechanoreceptors " touch", nocieceptor "pain sensation ", thermoreceptors " temperature/heat" →These fibers go centrally, touch fibers go into lamina 3& 4, Pain mainly go to lamina 1&5 >> (fast type of pain).

Type 4: C fibers, non-myelinated, slowest one, conduct slow type of pain to lamina 1 & 2. ALSO, conduct thermoreceptor and some touch mechanoreceptor.

>>Gray matter of spinal cord considered as laminae and each lamina contains cells that are similar functionally and structurally and the lamina is a column in origin. When we take section in column we get a lamina.

* So lamina 1&5 are the main station to fast pain.
* Lamina 1&2 are the main station for slow pain.

⇨ Axons of lamina 1 will cross the midline and continue as spinothalamic tract.

There's interaction between laminae: suppose an impulse (pain sensation) reaches cells (neurons) in lamina 5 and activate neurons, these neurons synapse with other neurons in lamina 1&2 and some books say that the pain sensation reaches laminae 3&4 also. So we can't say only lamina 5 receives pain sensation, also other laminae receive pain sensation; dendrites of neurons in lamina 2 synapse in the main cells in lamina 5, and what reaches lamina 2 will reach eventually to lamina 5 through this interaction because the dendrites of neurons of lamina 5 extends and interact with lamina 2.

Spinothalamic tract: (Anterolateral System)

* Old classification: ventral and lateral

Ventral spinothalamic >> touch

Lateral spinothalamic >> pain, temperature, tickle…

* Now this pathway is mixed so it's called anterolateral system or spinothalamic tract (without ventral or dorsal) and it carries:

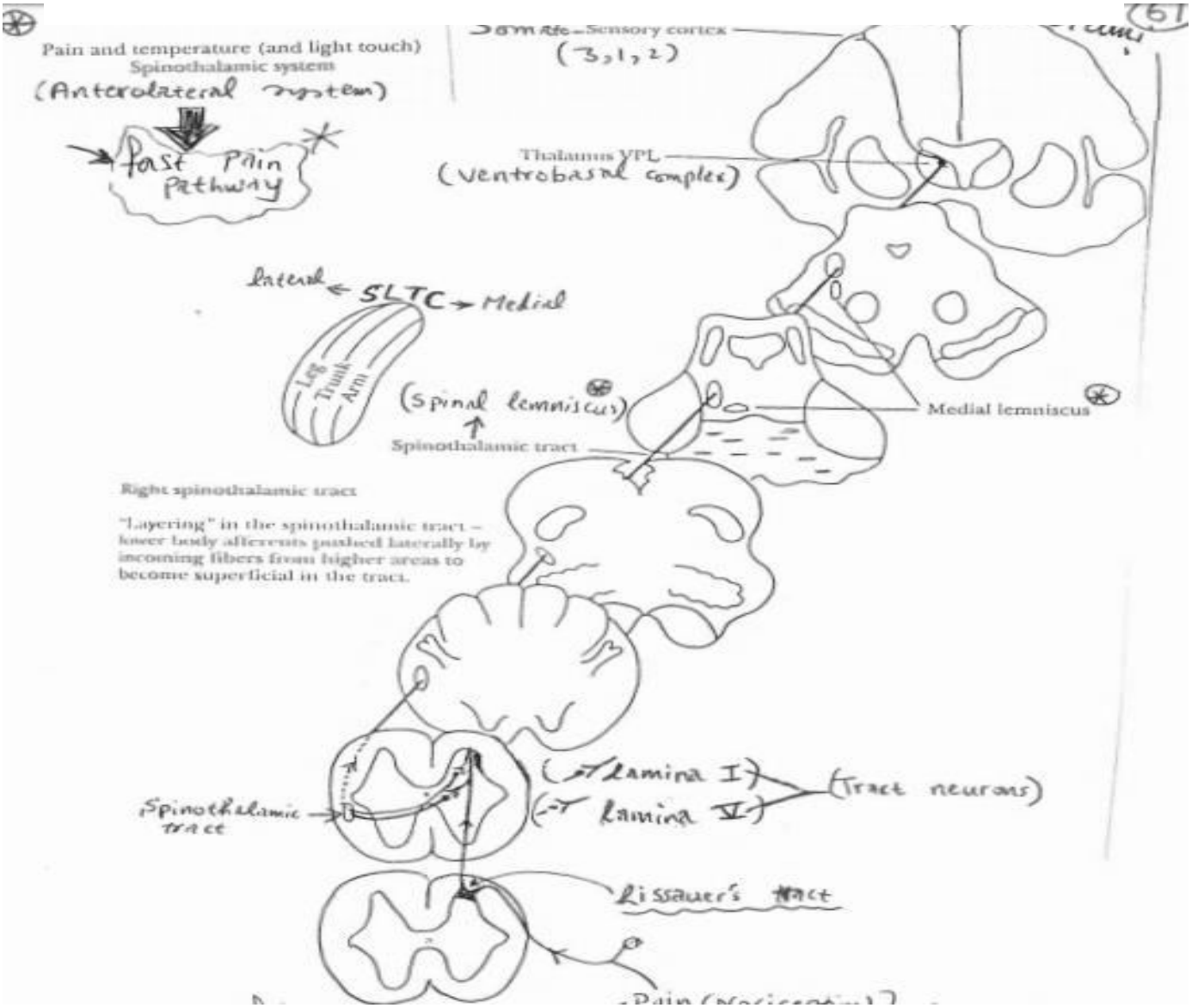
1-fast pain

2-Touch: remember; touch is transmitted through both anterolateral system and dorsal column system, so if one of these tracts gets damage, we won't lose touch; because it will be transmitted through the other tract and this means that touch is very important in our life.

First order neuron: always in the dorsal root ganglion. This neuron is pseudounipolar cell. The pseudounipolar cell has single process called dendraxon which splits into peripheral part which goes to the pain receptor (free nerve endings) and central part which enters the spinal cord in **the dorsal root entry zone**: "the distance between the end of dorsal root and apex of dorsal horn".
The axons (central processes) in the dorsal root entry zone ascend one or two segments in a pathway called **Lissauer's tract** before they enter the dorsal horn and synapse with the cells inside.
Then after the axons (fibers) ascend one or two segments, they will enter and synapse in neurons within lamina 1 &5 so the neurons in lamina 1&5 considered as **second order neurons** and as we said the most important feature of second order neuron is **crossing** the midline in white commissural fibers to the opposite side and ascend in the opposite side in the spinal cord forming spinothalamic tract until reaching the brain stem (medulla, pons, mid brain) then run in the brain stem close to *medial lemniscus* pathway so we call the spinothalamic tract in the brain stem **spinal lemniscus**. (So till now we know 2 lemnisci; Spinal lemniscus (spinothalamic tract) and Medial lemniscus (dorsal column). Then, the fibers of the spinothalamic tract ascend until they reach **third order neuron** in the thalamus in the ventrobasal complex VPL from body while VPM from face then from thalamus to somatosensory cortex (area 3, 1, 2) through posterior limb of internal capsule and **sensory radiation**. As we said, in order to understand what we feel and recognize the type of sensation, the impulse must reach the sensory association cortex which is area 5, 7 (superior parietal lobule or posterior parietal cortex).
Also, we said that each sensory cortex needs a nearby association cortex that allows the recognition of the sensation; area 17 (primary visual cortex) → near to it we have area 18, 19 (which enables the recognition of what we see). Area 41, 42 (primary auditory area) → near to it on the outer surface of the superior temporal gyrus we have area 22 (auditory association cortex, which is responsible for understanding of what we hear).

Receptor (free nerve endings)>> dendrite>> dorsal root ganglion >> dorsal root entry zone >> ascend one or two segment>>enter and synapse in the neurons of lamina 1&5 >> cross midline>> ascend in spinal cord and brain stem >> synapse with third order neuron in ventrobasal complex in thalamus >> end in somatosensory cortex.

* This figure is very important.



Page 61: The fibers of spinothalamic tract as they ascend in the spinal cord they don't run randomly, they ascend in a certain arrangement called **lamination**.

>>Most medial fibers from the upper limb.

>>Most lateral fibers from the lower limb and trunk.

So the arrangement from medial to lateral: cervical, thoracic, lumbar, and sacral.

يعني ببلش الاحساس من القدمين بتكون طالعة الألياف بنوصل عند الجذع، البطن والصدر، الالياف تاعته بتدفش الياف القدمين لبرا (باتجاه الخارج laterally) بنطلع بنوصل للاطراف العليا بتدخل الالياف تاعته وبتدفش الالياف السابقة laterally فبصير عنا الترتيب

Most medial → upper limb in the middle→ trunk most lateral→ lower limb

***Clinical application :

If the patient has a tumor arising from the Dura matter "meningioma" from **outside** of spinal cord, it will affect and press the fibers of lower limb (because they're located laterally). While if the tumor arises from **inside** of spinal cord "glioma for e.g.", it will affect the medial fibers which are the fibers of the upper limb.

***Important anatomical relation

The spinothalamic tract in the spinal cord is located anterior to the **denticulate ligament** which is a folding of pia matter.

The surgeon sometimes resorts to cut the spinothalamic tract in cancer patients to relieve the severe pain >> this operation is known as (anterolateral cordotomy). What helps the surgeon in finding the spinothalamic tract in this operation? Denticulate ligament.

* Lesion in the spinothalamic tract in spinal cord (tumor inside or outside) or brain stem or VPL in thalamus or in the cortex will result in >>> **contralateral loss of sensation**: fast pain, as well as cold and hot, (simple touch will be partially affected or reduced because touch is also carried by the dorsal column).

* Very important note: Contralateral loss of sensation will occur one or two segments below the level of the lesion. As we said previously, this tract doesn't synapse directly once it enters the spinal cord instead it ascends one or two segment then synapse.

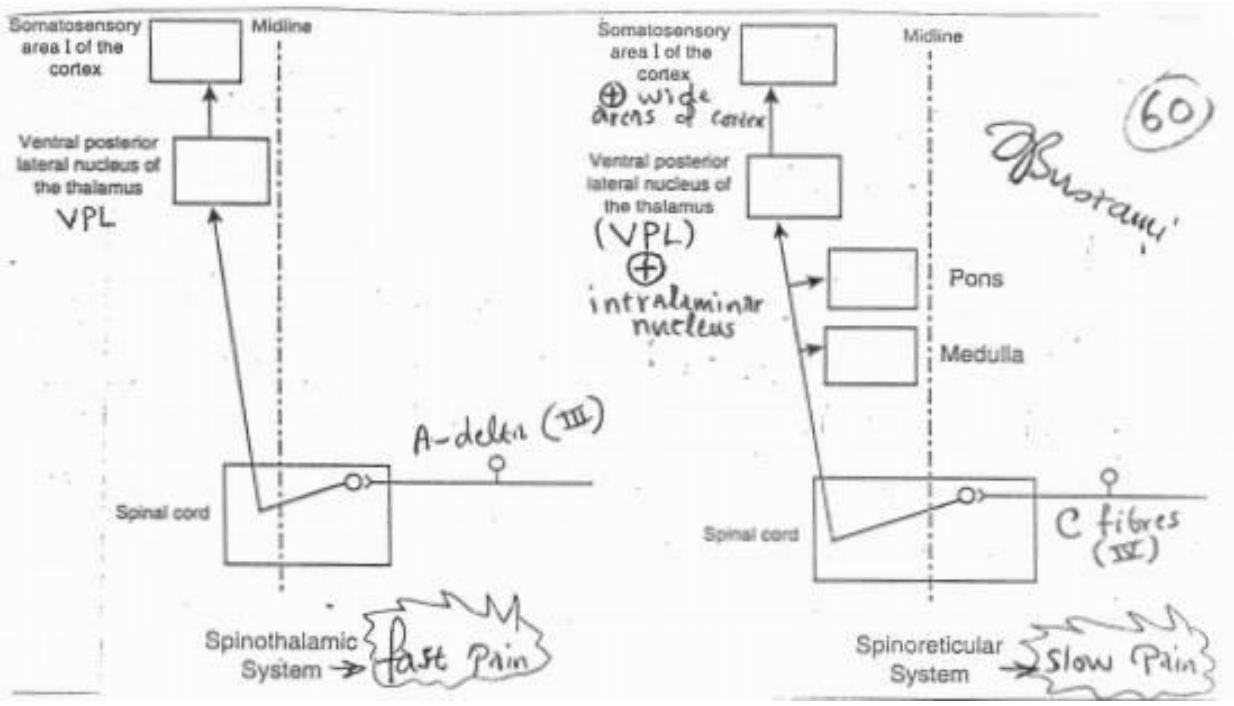
For example: if there's a cut/lesion in the spinal cord at the level of T8, we will predict a loss of sensation at T10 and below it.

* Remember that:

- Spinothalamic tract: crossing happens in the spinal cord (in the white commissure).
- Dorsal column system: crossing happens in the medulla.

Compare between two types of pain:

Fast pain	Slow pain
Type 3 fibers: A delta (faster)	Type 4 fibers: C fibers (unmyelinated → slowly conducting).
The first order neuron: in the dorsal root ganglion.	The first order neuron: in the dorsal root ganglion.
The second order neuron: in the spinal cord, gray matter, in the dorsal horn, lamina **1&5**. And the most important characteristic of the 2nd order neuron is CROSSING in the spinal cord.	The second order neuron: in the spinal cord, gray matter, in the dorsal horn **lamina 1&2**. (Some books say lamina 6&7 but the doctor check it and he's sure that it's lamina 1&2). And the most important characteristic of the 2nd order neuron is CROSSING in the spinal cord.
Then the fibers ascend in the spinal cord and ascend in the brain stem till reaching the thalamus.	When this pathway ascends in the brain stem to reach the thalamus, in its way it gives collateral branches to the reticular formation, so sometimes this pathway is called **spinoreticular tract;** it activates the reticular formation. Once RF is activated, it will activate and awaken the cortex and the cortex say>> يا مريض اصحى خذ الدوا عشان تتخلّص من الألم.
Third order neuron : VPL in thalamus	Third order neuron : VPL in thalamus and intralaminar nucleus (which is part of the reticuloactivating system)
ends in the VPL in the thalamus	ends in the thalamus; in the VPL and intralaminar nucleus and reticular formation } Awaken the cortex
From thalamus, goes to area 3,1,2 in the cortex	From thalamus, goes to wide areas of cortex
Called Spinothalamic tract	Called Spinoreticular



- Spinothalamic tract involves many pathways:
  1. Ventral and lateral spinothalamic (old names, the new name is ALS = the same as spinothalamic)
  2. Spinoreticular which differs from the spinothalamic that it gives the intralaminar nucleus in the thalamus and RF in addition to the VPL nucleus and goes to wide areas of the cortex while the spinothalamic only gives the VPL nucleus in the thalamus and goes to area 3,1,2 of the cortex.
  3. **Spinomesencephalic tract** from spinal cord (or from the receptors) to the mid brain, to periaqueductal gray matter specifically. (Periaqueductal gray matter is "gray matter around cerebral aqueduct"). This pathway has an important function in endogenous pain pathway.
  4. **Spinocervical pathway**: it is a spinothalamic tract, ascends in the same side; some people who have damage in spinothalamic tract but still feel pain how? By this tract that ascends in the same side.

In general these pathways (Spinomesencephalic tract and Spinocervical pathway) are not well developed. So we concentrate on spinothalamic tract which conducts fast pain and spinoreticular tract which conducts slow pain.

☺يعطيكم العافية

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