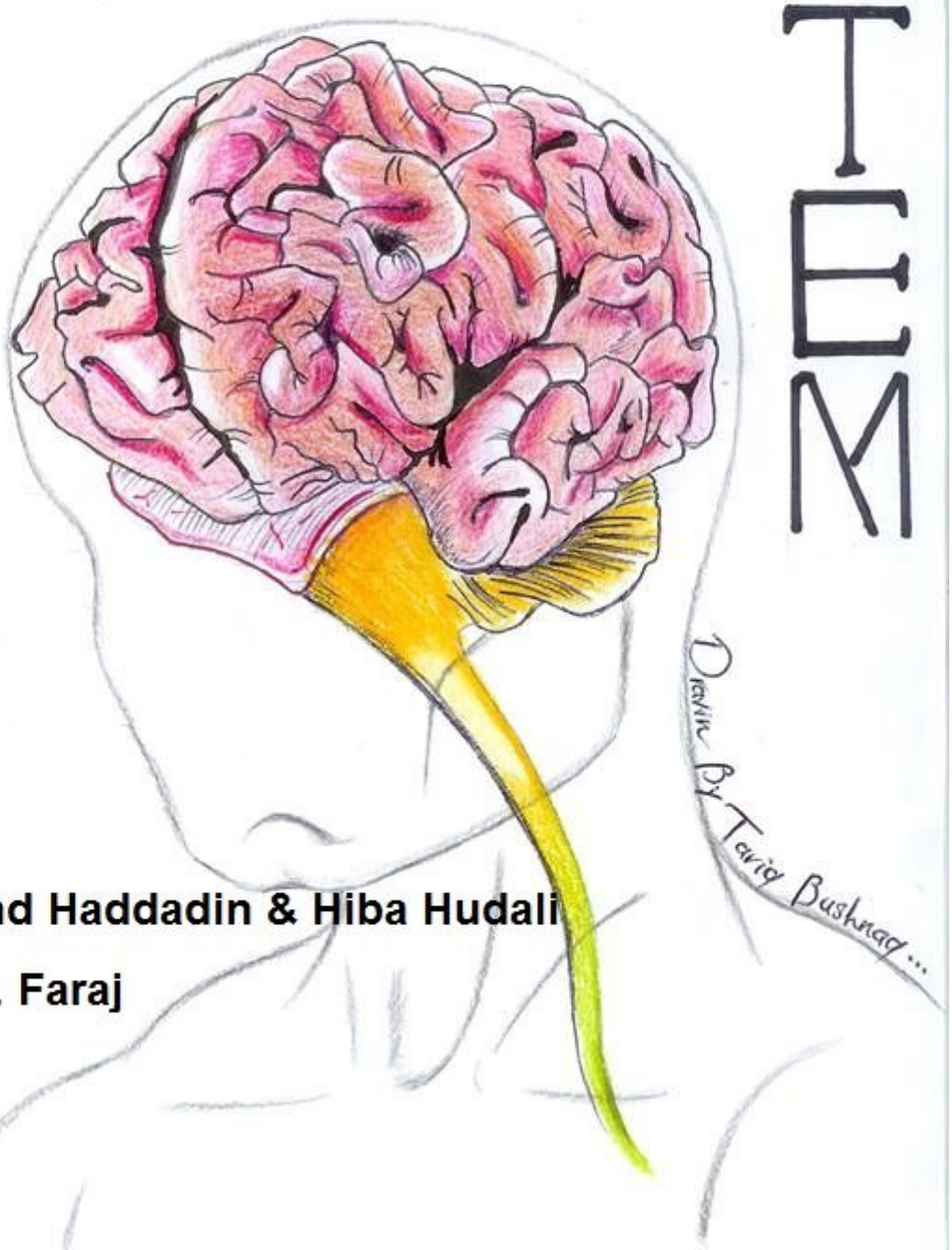
CENTRAL NERVOUS SYSTEM

- ○ Handout
- ● Sheet
- ○ Slide

- ● Anatomy
- ○ Physiology
- ○ Pathology
- ○ Biochemistry
- ○ Microbiology
- ○ Pharmacology
- ○ PBL



Drawn By Tariq Bushnaq ...

Done By: **Rund Haddadin & Hiba Hudali**

Dr. Name: **Dr. Faraj**

Lec #: **2**

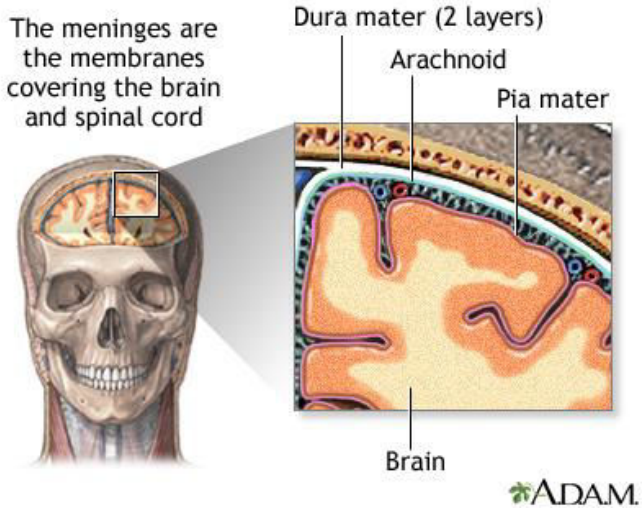
Motor pathway

On the upper part of the spinal cord we have **cervical enlargement** which includes segments: C5, C6, C7, C8, T1, and when we say (C5, C6, C7, C8, T1) we remember the origin of the brachial plexus, which supplies the muscles and skin of the upper limb.

While on the lower part of the spinal cord we have **lumbar enlargement** which extends from L2, L3, L4, L5, S1, S2 (origin of the nerves for the lower limb).

Recall that around the brain as well as around the spinal cord there are 3 layers (3 meninges):

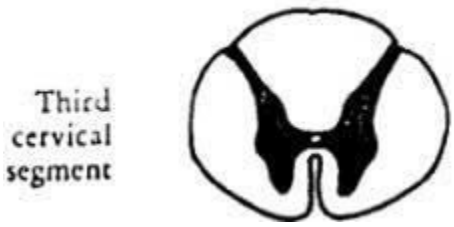
1- **Pia mater**; the closest to the brain.
2- **Arachnoid**; outside the pia mater.
3- **Dura mater**; outside the arachnoid.



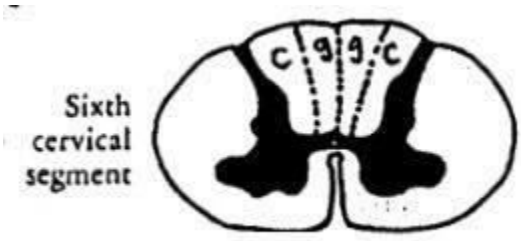
And between the pia mater and arachnoid there is an important region or space called the **subarachnoid space** and it contains cerebrospinal fluid as well as the major arteries.

Now, if you look into sections

This is a section in the upper cervical region



And this is a section in the lower cervical region



The grey matter: dorsal horn, ventral horn , and lateral horn in some regions.

The white matter: dorsal (posterior) column, lateral column, anterior column.

Grey matter

The dorsal and ventral horns contain neurons.

Neurons in the dorsal horn are mostly sensory or interneurons, whereas neurons in the ventral horn are motor (motor neurons are called alpha “bigger” and gamma “smaller”) and are also called **lower motor neurons**.

Upper motor neurons in the brain carry motor information down to the lower motor neurons.

White matter

Dorsal column transmits several types of sensation ,the most important is the proprioception.

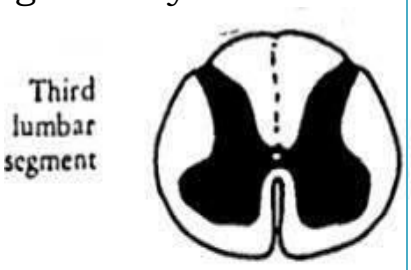
Proprioception is the sensation from muscle and joints, i.e, sensor position; your joint (elbow) is it flexed or extended?

There are 2 parts of the dorsal column; gracile tract and cuneate tract (gracile fasciculus and cuneate fasciculus in some books). The gracile tract brings sense of position (proprioception) from the lower half of the body (lower limb), whereas the cuneate receives sense of position from the upper half of the body (upper limb).

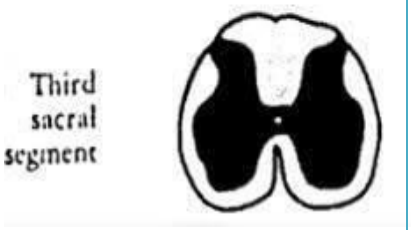
The lateral and anterior columns have sensory and motor pathways.

The white matter of the spinal cord contains ascending sensory pathways or descending motor pathways or both.

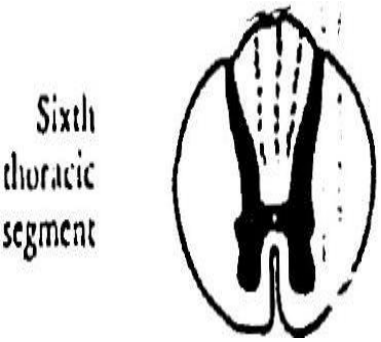
Back to the section of the lower cervical region, the anterior horn is large; because it contains large number of motor neurons that supply muscles of the upper limb.



The lumbar and sacral regions, the ventral horn is much bigger ;because it innervates more bulky muscles (of the lower limb) their size is bigger than the muscles of the upper limb so it needs more neurons.



The thoracic region section; thin ventral horn, thin dorsal horn. The thin ventral horn contains neurons to the muscles of the chest (small intercostal muscles) and abdomen, so the ventral horn is thin because it contains small number of neurons that supply small muscles.



The dorsal horn, above T6; gracile and cuneate tracts are present.Below T6, from T7 to L2 only the gracile tract is present.

Classification of nerve fibers

By 2 ways:

1- Roman letters (I, II, III, IV).
2- Alphabetically (A,B,C).
   - A is classified into:
   - Aα
   - Aβ
   - Aγ
   - Aδ

The larger the diameter of a nerve fiber the thicker the myelin sheath the faster the conduction. Hence, A (a diameter of 22μm) is faster than C (1μm).

Pain is conducted by Aδ and C (slow).

Inside the skeletal muscle, a receptor called **muscle spindle**responds to muscle stretch, muscle spindle is composed of sensory 1A and 2 muscle fibers, so the conduction is relatively fast in the muscle spindle.

Intermediate cells contain sensory and motor neurons, we will talk about its importance shortly.

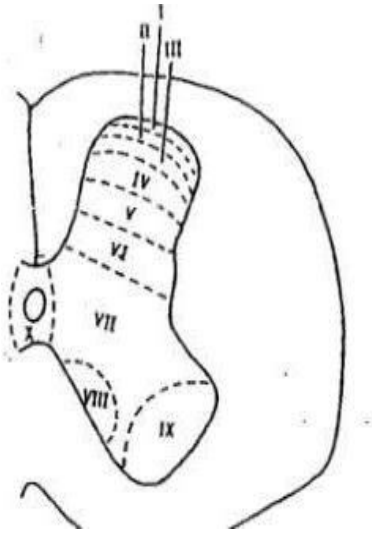
Previously, the dorsal horn was classified intonuclei; group of cells with the same function. We used to hear the terms **posterior marginal nucleus, substantiagelatinosa, nucleus proprius.**

These terms are now replaced by the scientist Rexed, he said that the neurons are not organized as groups but rather as columns, neurons within a column transmits the same sensation.

When we take a section in the column it appears as a lamina, so he classified the grey matter into ten layers (page 7 in the handout).

When we compare the old classification with the one classified by Rexed:

When we talk about the motor system lamina 9 concerns us, it contains motor neurons, their axons run along with the spinal nerve and supplies the muscles.



Laminae I to IV are concerned with exteroceptive sensations, whereas laminae V and VI are concerned primarily with proprioceptive sensations, although they respond to cutaneous stimuli. Lamina VII acts as a relay between midbrain and cerebellum. Lamina VIII modulates motor activity, most probably via the gamma neuron. Lamina IX is the main motor area of the spinal cord. It contains large alpha and smaller gamma motor neurons. The axons of these neurons supply the extrafusal and intrafusal muscle fibers respectively.

Table 5.1. Cellular Organization of Spinal Cord

Rexed terminology	Older terminology
Lamina I	Posteromarginal nucleus
II	Substantia gelatinosa
III, IV	Nucleus proprius
V	Neck of posterior horn
VI	Base of posterior horn
VII	Intermediate zone, intermediolateral horn
VIII	Commissural nucleus
IX	Ventral horn
X	Grisea centralis

Lamina 9 is classified into subgroups:

1- **Ventromedial group**, supplies the muscles at the back; e.g. erector spinae muscle extends the vertebral column. This group is present all through cervical region, thoracic region, lumbar and sacral.
2- **Dorsomedial group**, this group of motor neurons within lamina 9 is confined around (T1-L2), supplies the intercostal muscles as well as the abdominal muscles.
3- **Ventrolateral group**, present between (C5-C8) which is the brachial plexus that supplies skin and muscles of the upper limb (supplies the arm), in contrast to the lower limb, present in (L2-S2) and supplies the muscles of the thigh.
4- **Dorsolateral group**, present between (C6-C8) supplies the muscles of the forearm, also present between (L3-S3) supplies the muscles of the leg.
5- **Retrodorsolateral group**,(THE MOST IMPORTANT GROUP) present in (C8, T1) mainly T1, supplies the small intrinsic muscles of the hand (used for writing, drawing). So if the group of neurons at T1 are destroyed, it causes paralysis of the small muscles of the hand.
   In (S1,S2) supplies the small muscles of the foot.

Motor pathway

The cerebral cortex consists of **neocortex**(90%); six layered cortex, and **allocortex;** three layered cortex (10%). Allocortex includes 2 types: (Archicortex, Paleocortex).

For example, the hippocampus and the uncus are 3 layered cortex, the rest are 6 layered.

The layers from the outside to the inside:

1- Molecular layer; contains no cells, only axons or dendrites.
2- External granular layer.
3- External pyramidal layer.
4- Internal granular layer.
5- Internal pyramidal layer.
6- Multiform layer.

What type of neurons are present here?

May be major cells and some interneurons beside it.

- Page 6c (types of neurons):

1- Pyramidal neurons: are multipolar; has multiple dendrites, single axon and present in all layers except the first. Some of the pyramidal cells are large some are medium sized and some are small. The large cells are present in layer 5 and are called **Betz cells**and they contribute in the major motor pathway by 3%, the fibers descending from them ultimately will affect the alpha and gamma neurons that move the small muscles of the hand (skilled movement, manipulative movement).
Some fibers projects from it (collateral branches) and forms what is called commissural fibers that crosses the midline and connects cortex with other cortex on different sides, or association fibers that connects gyrus with gyrus at the same side.

2- Stellate cells: present in all layers except the first.
3- Fusiform cells: found in deep cortical laminae and their axon enters the deep white matter.
4- Horizontal cells: present in the first layer and disappears after birth, we don't know its function.
5- Martinotti cells.

Stellate and fusiform and martinotti cells are interneurons.

And the main cell is the pyramidal with its different sizes.The axon of the pyramidal forms projection fibers (corticofugal) or commissural or association. Projection fibers forming motor pathways, so the major motor pathways projects from the pyramidal, mainly the pyramidal cell.

Layer 1,5,6 are present in all types of cortex.

Layers 2,3,4 are present only in neocortex. Not present in (Archicortex, Paleocortex).

Corpus callosum is the most important commissural fiber.

Output of cerebral cortex (page 6d):

1-Corticospinal tract (moves the hands and legs).

2-Corticobulbar (moves the muscles of the face, abdomen, tongue, larynx, pharynx).

- Corticospinal and corticobulbar tracts together forms the pyramidal tract. Why do we call it pyramidal? Because as it goes down it passes through the pyramid of the medulla, NOT because it projects from the pyramidal cells.

3-Corticoreticular, from the cortex to the reticular formation(in the pons and medulla).

4-Corticopontine from the cortex to the pons.

5-Corticothalamic from the cortex to the thalamus.

Inputs to cerebral cortex:

One note you should bear in mind is that all sensory pathways must pass & synapse in a part of the thalamus known as "The nuclei of thalamus" and that occurs before reaching the cortex. It's so important to the extent that certain reference books might suggest that some senses have specific centers located within the thalamus .The olfaction was excluded but now some books says that even the olfaction has a center in the thalamus.

In one line: major inputs for the cerebral cortex are coming from the thalamus.

Now regarding the cluster of cells found within the thalamus or the nuclei of thalamus can be categorized as follows:

1) Specific thalamic nuclei.
2) Non-specific thalamic nuclei.

Now back to the first type of cells or nuclei(Specific thalamic nuclei), they are of three types: VA,VL& VP and they are called so; because they tend to send signals to specific areas within the cortex, for example

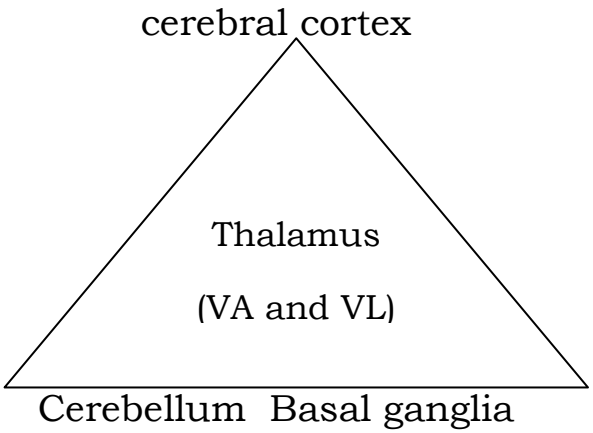
VA →area "4"

VL →area "6"

VP →area "3,1,2".

In addition to all the aforementioned facts above, each one of these cells or nuclei has a specific function like:

- VA &VL are responsible for the co-ordination between the cerebral cortex, cerebellum and the basal ganglia.



(A schematic represent for you to note that any kind of skeletal muscle movement happens through a co-ordination between the cerebral cortex, the cerebellum and the basal ganglia directed by the thalamus through its nuclei.)

- VP which is always sensory and responsible for proprioception and exteroception pass through a centre which is known as "ventrobasal complex" or simply known as VP.

Finally, regarding the second type of cells or nuclei "the non-specific", these include (intralaminar, midline and reticular nuclei) and they are related to the reticular system in other words to The Reticular Activating System "RAS", which is a part of the reticular formation, once it's activated by means of the sensory pathway & it awakens the cortex i.e. "RAS activates the cortex". So for example if RAS is damaged → the patient will go through a coma and will lose his consciousness.

Randomly mentioned notes:

- The kind of interaction occurring between the cells of the cerebral cortex hasn't been known yet.
- The major cells are the pyramidal cells which are large, medium, and small cells.
- Recall that, fibers descending from the betz cells can move the muscles of the arm.
- Recall that we have large, medium & small cells while the rest of the neurons are mainly acting as interneurons i.e. they link cells together (ex: a pyramidal cell with another pyramidal one)

Descending Tracts (Motor Pathways)

From the lecture's handout: "A tract or a pathway is a bundle of nerve fibers that have the same origin, same termination and carry the same function."

When describing any motor pathway, we must highlight the site it begins from and the site it terminates at. So any motor pathway should begin in the upper motor neurons and should terminate in the lower motor neurons.

Upper motor neurons are found in the brain, they might be in the cortex, brain stem but it's more accurate and precise to say that they are located in the cortex especially in areas: 4, 6 & 3,1,2.

Lower motor neurons are found in the brainstem (where they give rise to motor fibers in certain cranial nerves) & in the spinal cord (these are alpha & gamma motor neurons).

Now, one should ask himself, since area 3,1,2 is considered as a sensory area, how does it share in a motor pathway? And the answer would be, fibers coming down from these neurons go all the

way down to the spinal cord to the dorsal horn & by that it will block the conduction of pain sensation. HOW??

When you for example put your hand on something hot like fire, you readily pull your hand, by this movement you activate the pyramidal tract and the nerve fibers that come down, block the conduction of pain, so these have nothing to do with movement.

*Area 4 → face and limbs.

*Area 6 → axial and proximal muscles .

And this area has two parts: premotor and supplementary motor.

*Area 3,1,2 and area 5,7 → sensory areas.

We have two major motor pathways:

1- pyramidal which has two parts: corticospinal and corticobulbar.
2- extrapyramidal.

*The corticospinal ultimately will move muscles of the limbs and the corticobulbar move the muscle of the face, mastication, tongue, pharynx and larynx.

Area 4 mainly giving rise to the pyramidal and area 6 MAINLY giving rise to the extra pyramidal.

**It means that both the pyramidal and the extra pyramidal take neurons from area 4 and area 6 but the pyramidal mainly takes from area 4 and the extra pyramidal mainly takes from area 6 **

The pyramidal tract: these fibers go down from the cerebral cortex and they pass through the corona radiata and they all gather in the internal capsule ((which is a critical area, most of the strokes happen in this internal capsule, a damage happens in it and causes paralysis)) and then they go down through the brainstem under the internal capsule so they pass through the midbrain, the pons and the medulla. In the lower part of the medulla 90% of the fibers decussate which means the fibers that come from the right goes to the left and vice versa which called motor decussation or pyramidal decussation.

One axon that reaches the spinal cord → alpha and gamma → gives spinal nerve → to the skeletal muscle.

These alpha and gamma cells are lower motoneurons (or motor neurons) that perform the orders, these orders come from the upper motoneurons (area 4 and area 6).

Most of the nerve fibers in this tract (corticospinal tract) **DON'T** synapse directly on alpha and gamma, they go to the interneuron and this interneuron link them to alpha and gamma.

*Why did they go to the interneuron??

Suppose I want to flex the elbow, this process needs stimulation of the biceps and inhibition of the triceps. I can't do flexion of the elbow if I stimulate both muscles. If you stimulate the biceps → flexion, flexion

but if the triceps interfere → extension, flexion → inaccurate movement

I need to stimulate the agonist and at the same time inhibit the antagonist,

HOW?? By the interneurons.

There's an excitatory interneuron, if I stimulate it, it will stimulate the alpha of the biceps.

And also we have inhibitory interneuron, if I stimulate it,it will inhibit the antagonist.

So it's one tract which is the corticospinaltract, at the same time it stimulates a muscle and inhibits another muscle. How? By the interneurons.

So again most of the corticospinal tract doesn't synapse directly on alpha and gamma, it will use the interneurons. By these interneurons we can excite one muscle and inhibit its antagonist EXCEPT those nerve fibers that come from the Betz cells which form 3% and they go directly to alpha and gamma, and when we go directly to alpha and gamma we can stimulate specific muscle not a group of muscles.

The corticospinal tract:

Uppermotoneurons→ alpha and gamma (lower motoneurons)

**Are the alpha and gamma (the lower motoneurons) limited to the spinal cord??

No

The cranial nerves which are in the brainstem, any cranial nerve has motor fibers and also has alpha and gamma which means that there's lower motoneurons in the brainstem.

How do they get stimulated? By the corticobulbar tract.

So the corticobulbar will move your face and tongue while the corticospinal will move your arms and legs.

Look at the corticospinal and corticobulbar you can see one axon, we call it "direct pathway".

Now let's check the extra pyramidal…

It's a group of pathways or a group of tracts.

They come from area 6, those axons go down and synapse in the brainstem on some neurons and those neurons continue the pathway until it reaches alpha and gamma. And we call this an "indirect pathway".

So we have direct and indirect pathways!

What are the extra pyramidal pathways?

1- Rubrospinal tract: "rubro" means red, there's a nucleus in the midbrain called the red nucleus, so the rubrospinal tract originates from fibers that come from this red nucleus. So apparently this tract starts from the midbrain and ends in the spinal cord, but the red nucleus receives orders from the cortex, so to be more accurate we call this pathway "**corticorubrospinal**".
2- Reticulospinal tract: it begins in the reticular formation in the pons and medulla and ends in the spinal cord, but the reticular formation receives orders from the cortex so to be more accurate we call it **"corticoreticulospinal".**
3- Vestibulospinal tract.
4- Tectospinal tract.

So this is the difference between the pyramidal and the extra pyramidal, the pyramidal passes through pyramid of the medulla while the extra pyramidal passes outside it. And ultimately (eventually) ,BOTH will reach and influence the activity of the lower motoneurons (alpha and gamma) mostly by the interneurons, so that we can stimulate the agonist and inhibit the antagonist.

((Any motor pathway begins in the upper motor neurons in the cortex and ends in the lower motor neurons either in the spinal cord or in the brainstem))

The corticospinal tract ends in the spinal cord

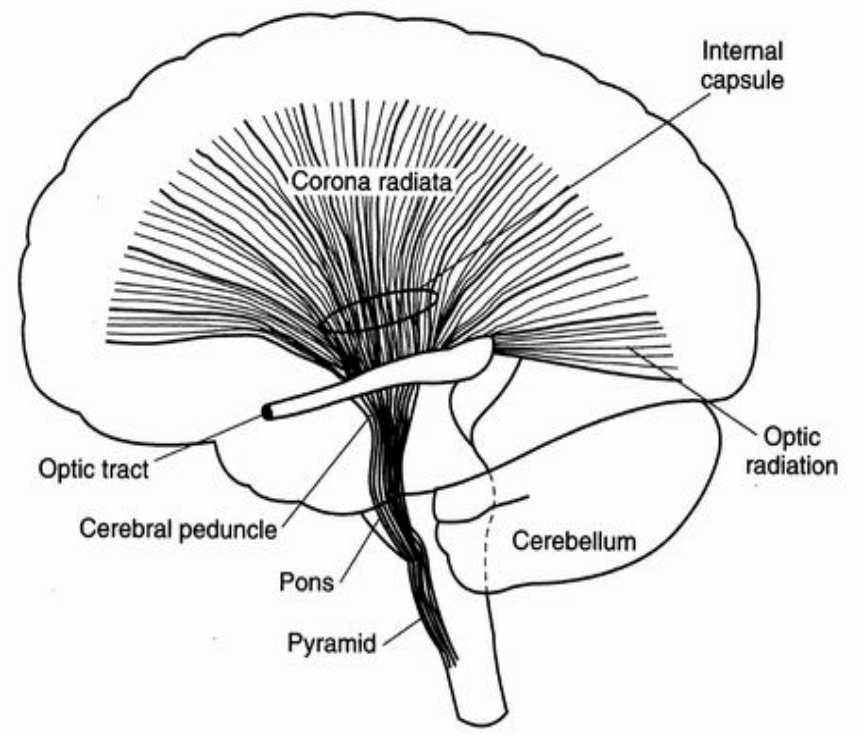
So the corticospinal tract begins mainly in area 4 and a little in area 6 and a little in (3,1,2).

Mainly the pyramidal (corticospinal and corticobulbar) begins in area 4.

How the body is represented in area 4??

The face in the lower parts then the upper limb then the lower limb above and inside. (All of that in area 4 which is in the frontal lobe of the cerebral cortex)

Now the axons go down separately to from the corona radiata like a chinese fan =P



Chinese fan

Then these axons will accumulate in a very veryveryvery important area which is the internal capsule. An interruption in the blood supply inside this capsule lead to hemiplagia (an extensive paralysis of the contralateral half of the body). Then under the internal capsule they run in the midbrain then the pons then the medulla. At the lower part of the medulla what happens??

80-90% of these fibers decussate (cross), how do they decussate? go backwards

These fibers which decussate (from right to left) form a tract called "**LATERAL CORTICOSPINAL TRACT**" or (dorsolateral) which is the most important motor pathway in your body.

So how the lateral corticospinal tract is formed??

90% of the fibers in the corticospinal decussate at the lower part of the medulla.

Now this tract will continue downwards in the white matter of the spinal cord (the lateral column). And they will go to their target which is the lower motor neurons. So they enter and synapse in alpha and gamma (as we said mostly indirectly by the inter neurons so we can stimulate the agonist and inhibit the antagonist).

Where do you find it in the spinal cord??

In the lateral column near the dorsal horn.

Can you find it in the cervical region or thoracic or lumbar or sacral??

IN ALL OF THEM

This lateral corticospinal tract, suppose in the cervical region containing 1000 fibers and when we reach the sacral region it contains 250, where did the 750 go??

They enter and synapse in the alpha and gamma (75% approximately)

55% (550 fibers) → synapse in alpha and gamma in the cervical region (C5, C6, C7, C8, T1) so they stimulate alpha and gamma in the cervical region which means that they will activate muscles of the upper limb proximal as well as distal but MAINLY the distal.

So what's the function of the lateral corticospinal tract??

Activate and stimulate the muscles of the upper limb mostly the **distal flexor muscles** WHY??

Cuz how do you make a grip? By the flexors.

To handle → flexors

To release the grip → extensors

When this tract is damaged on the left side, the right side will be affected and his right hand becomes weaker. So we ask the patient for example to fasten his shoes or draw something, he won't be able to do it! All the skilled movement will be lost for good!

20% of the fibers will synapse in alpha and gamma of the thoracic.

Because the intercostals muscles are small and doesn't need a lot of fibers to work

25% of the fibers will synapse in alpha and gamma of the lumbosacral.

Now you may ask yourself that your lower limbs have big muscles such as gluteus maximus and quadriceps, so why there's only 25% that synapse in the lumbosacral??

Well it's not the size of the muscle that matters!It's all about the skilled movements! And these large muscles don't do skilled movements as the muscles of the hand for example.

We said that **90%** of the fibers in the corticospinal decussate at the lower part of the medulla to form the lateral corticospinal tract.

So there's **10%** left!

These 10% will continue downwards in the anterior column and will form a tract called "**VENTRAL CORTICOSPINAL TRACT" or ventromedial.**

We also said before that the lateral corticospinal tract affect the upper and the lower limbs but mainly the hand (skilled movement).

The fibers that comes out from the ventral tract affect the alpha and gamma on same side and on the opposite side too!

*Which alpha and gamma?? MEDIALY

*Which muscles will be affected?? The axial and the proximal muscles

So the ventral tract affects the axial and the proximal muscles!

A stroke in the internal capsule will damage the corticospinal tract and will lead to weakness or paralysis depending on the intensity of the injury. (Paresis or paralysis in the upper limb and the lower limb).

After 2 or 3 days ,we ask the patient to grip something, he can't do it;because he lost the skilled movement for good!

But when you ask him to raise his hand, he will! Or for example you ask him to walk, maybe he will walk a few steps. So, how did he do that?? By the ventral corticospinal tract!

*Lateral corticospinal tract → mainly on the distal muscles

*Ventral corticospinal tract → axial and proximal muscles

The largest parts of our skeletal muscles are supplied by the alpha.

The muscle spindle is a specialized skeletal muscle fiber.

*The greater part of the skeletal muscles fibers are extrafusal→ alpha.

*Inside the spindle are intrafusal→ gamma.

Now if you left the alpha alone it will give extensive stimulation and continuous contraction →convulsions.

So we have to control it in a way or another!

Most of our neurons are **overactive**, so I should limit its activity, HOW??

Near the alpha there's a cell called renshaw cell.

The axon of the alpha (collateral branch of alpha) synapse on ranshaw cell and activates it, this activated cell will send an axon that inhibits the alpha.

((So the alpha axons activate the renshaw cells, and the renshaw cells limit the activity of alpha))

If we inhibit the activity of renshaw cells by damaging it for example, what happens??

Continuous activation of alpha and continuous contraction. " المريض بخشب "

There was a drug called strychnine that was used for patients who have impotence, so the doctor tell the patient to take only for example two drops ,but some people take more than two for example 10 drops, so this drug inactivates the renshaw cells so there's no limitation on alpha.

The corticospinal tract affects the muscles on the opposite side.

By looking at the corticobulbar tract in figure 12.8 in the handout, you can see that it will go to alpha and gamma in the brainstem. ((we call the mother cells of the motor nerve "nucleus")). So the motor nucleus of the trigeminal is considered to be as alpha andgamma in the corticospinal tract .
Most of the cranial motor nerves receive corticobulbar fibers from both sides so when one side is damaged it still can be activated by the other side EXCEPT the lower face, its nucleus receives only contralateral, so if it's damaged it will lead to paralysis.

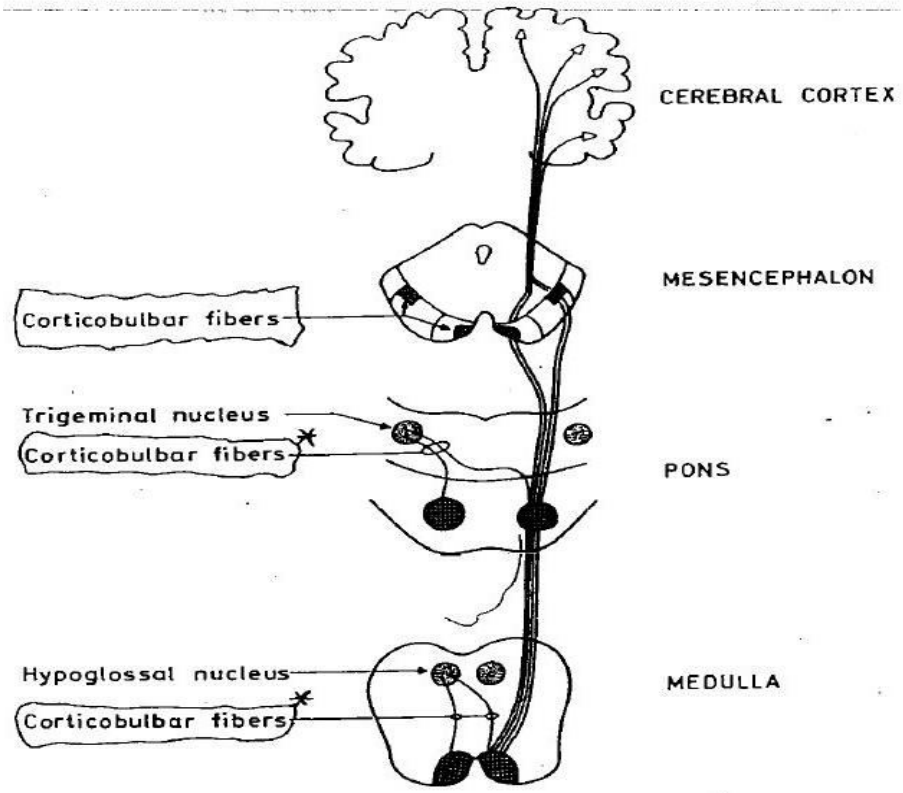


Figure 12.8. Schematic diagram of the corticobulbar pathway.

The old concept says that the hypoglossal nucleus receives fibers from both sides, while the new concept says that it only receives from the contralateral and doesn't receive from the same side.

While the other nerves for example the vagus nerve ,which supply the muscles of pharynx and larynx, so if paralysis occurs we won't be able to breathe or swallow. So the nucleus of the vagus nerve which send nerves to the pharynx and larynx receive stimulation from corticobulbar of the opposite side and the same side so that if one is damaged the other side will compensate.

THE END

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**And a special thanks to Yousef Abdeh for helping and Mohammed Nawaiseh for correcting :D

Past paper questions (Question 1 & 3 are not included in this lecture, they will be explained in the next lectures)

1)All of the following regarding SMA (supplementary motor area) and PMA (premotor area) are correct EXCEPT:

(a) Involved in programming of movement.

(b) Neither is involved in the medial motor system.

(c) Neither receive a direct input from the cerebellum or basal ganglia.

(d) Lesion in the premotor area results in grasp response.

(e) They control mainly the proximal and axial muscles.

2)Lesion in the right internal capsule and left frontal eye field will result in:

(a) Left-sided hemiplegia, deviation of the eyes to the left, and deviation of the mouth to the right.

(b) Monoplegia in the upper limbs associated with deviation of the eyes to the right.

(c) Paraplegia as well as loss of pain sensation.

(d) Monoplegia in the upper limbs associated with deviation of the eyes to the left.

(e) Loss of all sensory modalities from the upper limbs.

3)Cut in the dorsal afferent root, and stimulating the gamma motor neurones will result in:

(a) Decrease in intrafusal muscle fiber length with increased stretch reflex for the same muscle.

(b) Decrease in intrafusal muscle fiber length with increased stretch reflex for the antagonist muscle.

(c) Decrease in length of intrafusal muscle fiber.

(d) Decrease in length of intrafusal and extrafusal muscle fibers.

(e) Tension in golgi tendon organ.

1.	2.	3.
b	a	c

4)**Wrong** statement: **answer**→Following a stroke by 2 weeks, a patient is able to walk due to the extrapyramidal tracts.

5)choose the **correct** about **pyramidal tract**: **answer**→only 20% do not decussate at the lower medullary pyramid

Lap questions;

##pointer at **pyramid** of **medulla**, which is**false**:
a- contains corticospinal and corticobulbar tracts
b- lesion result in flaccid paralysis
c- lateral to it inferior cerebellar peduncle <<< answer

Medial surface of cerebral hemisphere, which of the following is false about pointed structure:

a- paracentral lobule: lesion result in paralysis of both lower limbs
b- optic chiasm: anterior to pituitary
c- upper half of medulla: 90% of corticospinal fibers decussate at this level.<<< answer