CNS
ANATOMY

5

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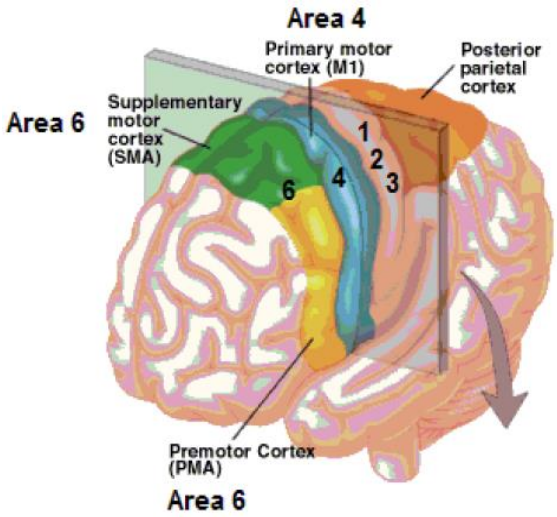
Hello everyone, 😊 in this sheet we'll start with **Motor tracts** (descending tracts)

The descending tract is divided into 2 parts: Pyramidal and Extrapyramidal tracts:

1. **Pyramidal tracts** (mainly corticospinal tracts) are responsible for: **Conscious** control of skeletal muscles movement.
2. **Extrapyramidal tracts** are responsible for: **Subconscious** control of skeletal muscles movement, like regulation of balance, muscle tone, eye, hand, and upper limb position.

When you hear the word "**subconscious**", you may think of smooth muscles! However, don't be confused; the **smooth muscles** are totally supplied by **autonomic** NS. On the other hand, the **skeletal muscles** are supplied by **somatic** NS (voluntary movements), but the **control of the skeletal muscle movement** can be on either the conscious level (you are aware of) or the subconscious (coordination / modulation) level.

The **motor system** starts from the cortex and descends downwards (opposite to sensory system). In this picture, we have the **motor cortex** which is in the frontal lobe (anterior to the central sulcus).
It is **divided into areas:** (according to Brodmann)



- **Area 4** is named pre-central gyrus (primary motor cortex). The **pyramidal** tracts descend from it mainly.
- **Area 6** which is responsible for the coordination of skeletal muscle movement. The **extrapyramidal** tracts descend from it mainly.
- Believe it or not, some motor neurons start from **Area 312** on the cortex, which is a sensory area.

Area 6 is divided into 2 parts with a huge overlap between them:

1. **The premotor area** (often most lateral): uses **external cues,** such as vision & hearing.
2. **The supplementary motor area** (most medial): uses **internal cues**, related to memory.

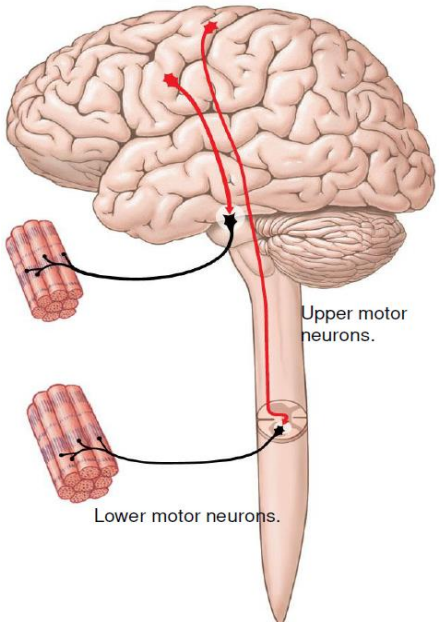
To perform a motor activity**,** we need **cues**. To understand it read the following:

An experiment was done on monkeys: they put in front of a monkey 3 electric bulbs with their switches, and they trained the monkey to click on the switch belonging to the bulb switched ON. **Now the monkey can transfer sensory data to motor activity.** Then, if the **premotor area** of the monkey was damaged but without any physical change (paralysis or blindness), the monkey **will lose the coordination** or the ability to convert his sensory data (visual input) to a motor activity.

What is the difference between area 4 and area 6?

- Imagine we have a lesion in **area 4** (mainly pyramidal tracts) → **paralysis** will happen → can't move the muscles at all.
- If the lesion was in **area 6** (extrapyramidal) → **no paralysis**, the person still can contract his muscles and do certain movements. For example, he can simply raise his hand, but he can't do fine or coordinated movements (like inserting a thread into the hole of a needle).

A quick introduction to the pyramidal tracts (conscious movement):



Starting with the **Upper motor neuron** from the **cortex** (more than one origin but mainly from area 4) → to the level of **spinal cord** → synapse with **interneuron** (lamina 8) → activation of **lower motor neuron** (its cell body in the anterior horn / lamina 9) → to **skeletal muscle**.
*Cranial nerves don't have anterior horn cells, instead they have motor nuclei. We'll talk about them later. *

- Types: **Corticospinal tracts: Anterior & lateral**.

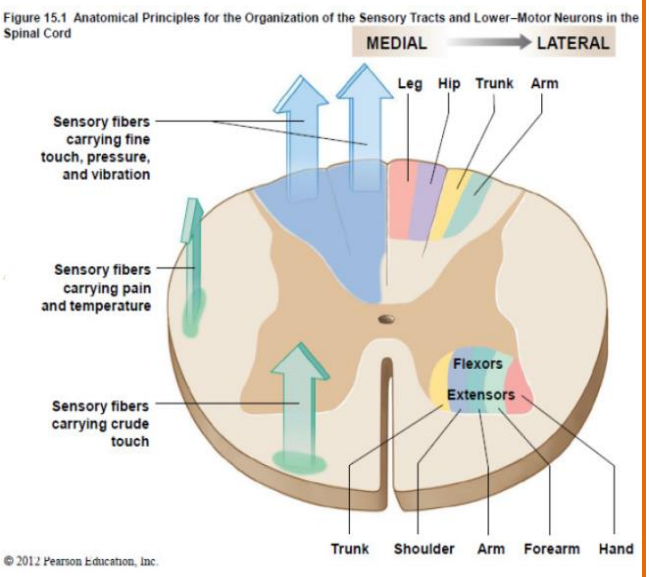
The extra-pyramidal tracts (subconscious control):
Here's some notes about them. It will be explained in details later in the sheet.

- **Vestibulospinal tracts:** Start in the vestibular nuclei in the brainstem (between lower part of the pons & upper part of medulla oblongata). The vestibular nuclei are sensory nuclei of the vestibular nerve part of the vestibulocochlear (8^{th} cranial) nerve, which is responsible of sense of balance.
- **Reticulospinal tracts:** Start in reticular formation, which is a network of neurons in the core of the brainstem.
- **Rubrospinal tracts:** (rubro=red): Start in the red nucleus (piece of gray matter that is highly vascular and located in the midbrain) and it has an important role in the control of motor system.
- **Tectospinal tracts:** (tecto=posterior aspect of midbrain). 10:00

The tracts are named because of their dimension. **Extrapyramidal** tracts arise in the brainstem and descend to the spinal cord but are **under the influence of the cerebral cortex** (area 6). So, to be more precise, they should be named cortico-Vestibulospinal, cortico-Reticulospinal, etc… (just for abbreviation we don't start with cortico-).

Anatomically, why are they named pyramidal tracts?
Pyramidal tracts pass from a part of the medulla oblongata on its anterior aspect called **pyramid** (due to its shape), and we have 2 pyramids one on the right & one on the left. (check the picture in page 4 to see the pyramid).
Extrapyramidal tracts are named so because they don't pass through these pyramids.

Motor horns:



We'll start talking generally about the **anterior horn:** The somato-tropic principle:

- The **medial** part of the anterior horn supplies the trunk & shoulder which are **medial/axial muscles** near the trunk (related to vertebral column / girdles). **(All segments).**
  Movement: mainly **upright posture and balance.**
- **Lateral** aspect supplies hand, forearm, or generally the **distal muscles. (Only enlargements).**
  Movement: **skilled movement** (writing, playing, drawing, etc.).
- Also, the anterior horn can be divided anteriorly and posteriorly:
  Extensors muscles anteriorly & **Flexors posteriorly**.

Lamina of motor system:

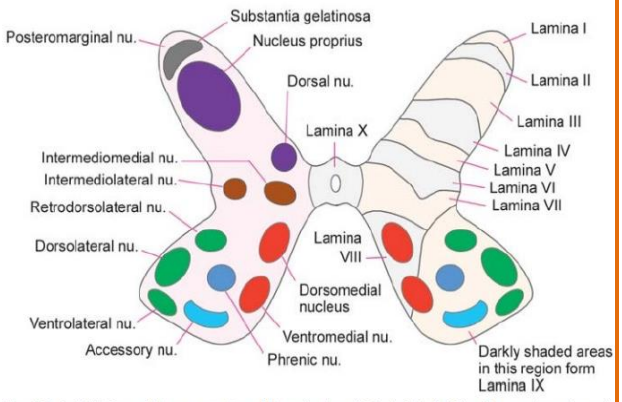


Fig. 5.2. Subdivisions of the grey matter of the spinal cord. The left half of the figure shows the cell groups usually described. The right half shows the newer concept of laminae.

- **Lamina 8:** motor **interneurons**, Commissural nucleus.
- **Lamina 9:** ventral horn, cell body of **lower motor neuron (LMN)**, divided into nuclei:
  - **Ventromedial**: all segments (extensors of vertebral column).
  - **Dorsomedial**: T1-L2 (intercostals and abdominal muscles).
  - **Ventrolateral**: C5-C8 (arm), L2-S2 (thigh).
  - **Dorsolateral**: C5-C8 (Forearm), L3-S3 (Leg).
  - **Reterodorsolateral**: (In the enlargements) C8-T1 (Hand), S1-S2 (foot) → these are responsible for skilled movement. Notice that these muscles are mainly flexors, so they're retrodorsal.
  - **Central**: Phrenic nerve (C3-C5) → activates lower motor neuron that supplies the diaphragm.

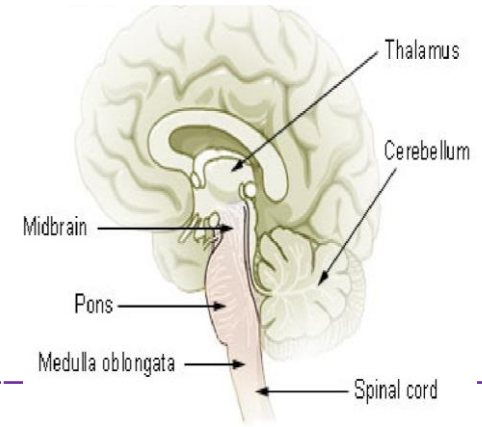
(Only ventromedial nuclei are shown in all segments, the rest are shown only in specific segments).

- **Lamina X or 10:** Surrounds the central canal – the grey commissure. Its function is still not clear and controversial (more references in lab 1).

20:00

Brain stem:

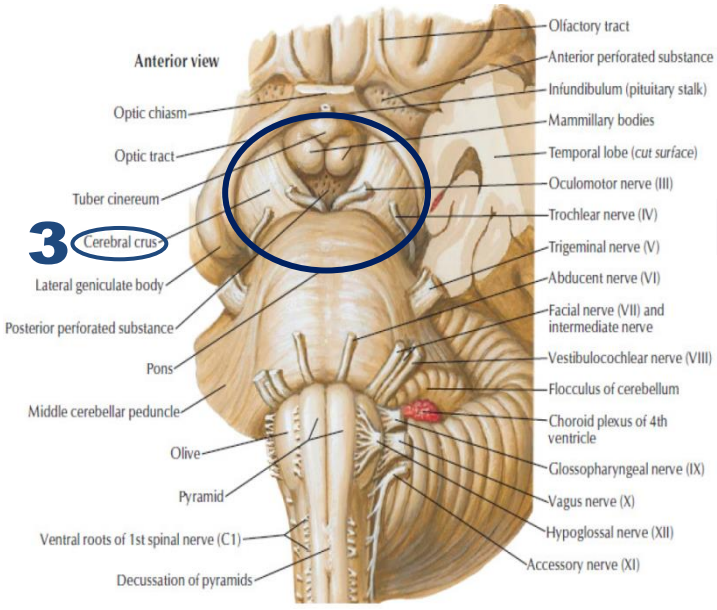
- Stalk-like in shape.
- Connects spinal cord and forebrain.
- Parts:
  1. Medulla oblongata
  2. Pons
  3. Midbrain

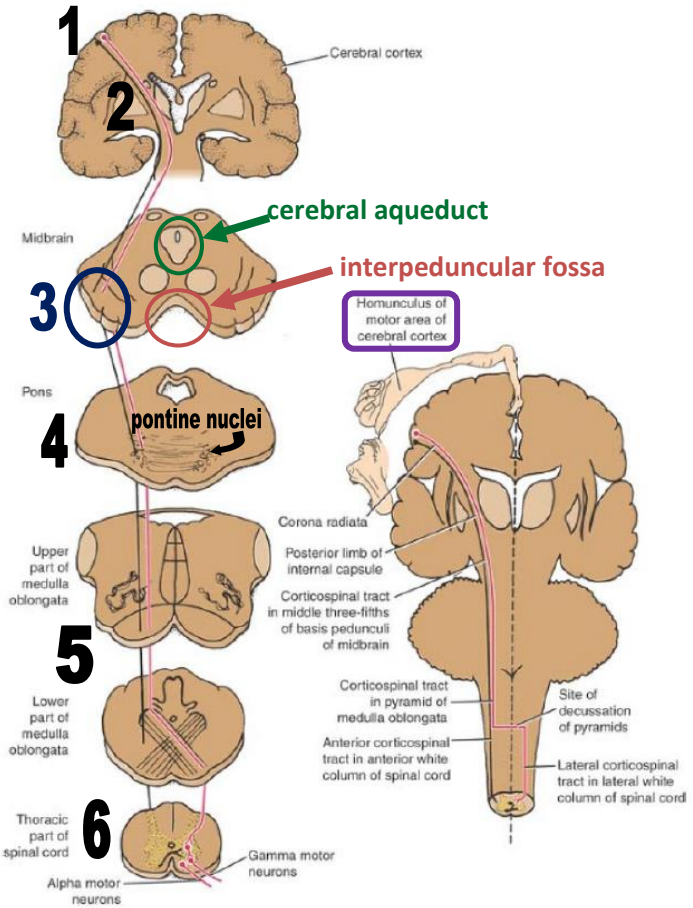


First, Pyramidal tracts: Corticospinal tracts pathway

Both anterior and lateral corticospinal tracts start from the precentral gyrus of **cerebral cortex,** mainly **area 4** (frontal lobe):

1. Fibers will descend from **corona radiata**
2. To **internal capsule** (between thalamus + caudate nucleus medially and lentiform nucleus laterally)
3. To the **brainstem** (specifically; midbrain). Fibers will pass through middle 3/5th (1/5th medial & 1/5th lateral are preserved) of the **crus cerebri** (part of the white matter) or named **basis pedunculi** of the midbrain.





NOTICE **The homunculus (like the sensory system).**

Remember that the homunculus is not necessarily proportional to real size. The hand is exaggerated because it can do a lot of motor activities and skilled movements, so it has many motor units. The leg doesn't have sophisticated movements so its representation in the cortex is small.

4. Let's continue our journey, the fibers descend from the crus cerebri of the midbrain→ to reach the **pons**. Inside it, we have pontine nuclei (collection of separate cell bodies). Here the fibers well scatter between the pontine nuclei in the anterior (basilar) part.

Here, the **corticospinal tract** will **interfere** with another pathway called **middle cerebellar peduncle** which goes from the **cerebrum** → to the **pons** → to the **cerebellum** (the cerebro-ponto-cerebellar pathway). This pathway goes horizontally at the same time the corticospinal pathway descends vertically.

5. Then, fibers will descend from pons → to **medulla oblongata,** and fibers will recollect again and form the anterior aspect of the medulla which is the **pyramid**. (Hence this tract is called pyramidal tract!)
   In the **lower part of the medulla**, fibers will split up:
   A. **Majority** of the fibers (85% approximately) will **cross-over** to the opposite side (primary motor decussation). These fibers are called **lateral corticospinal tract**.
   B. **The rest (15%)** descend **ipsilaterally** and are called **anterior corticospinal tract.**

6. Then fibers will descend to the level of the **spinal cord**:
   A. **The lateral corticospinal tracts** descend in the lateral funiculus of the spinal cord to the **lateral part** of the anterior horn and then supply the **lateral muscles**.
   B. **The anterior corticospinal tracts** cross-over at the level of the spinal cord and go to the **medial part** of the anterior horn to supply the **axial muscles**.

(((See the picture in the previous page that summaries the whole pathway of the corticospinal tract)))

Summary of the difference between lateral & anterior corticospinal tracts	
Anatomically: (the level of crossing-over)	
Lateral: lower part of medulla oblongata	**Anterior**: level of spinal cord
Functionally: (supplied muscles)	
Lateral: lateral muscles→ skilled movement	**Anterior**: axial muscles→ posture and balance

30:00

Some notes about Lateral corticospinal tract (LCST):

- LCST fibers synapse with **alpha** and **gamma** motor neurons (will talk about it in another lecture).
- As we said, **lateral** corticospinal tracts are responsible of **skilled movement**, and the most sophisticated movements are done by the hand, so the fibers are distributed as:
  - **55%** of the fibers will end up in the **Cervical** region (hand).

- ➢ **20%** in the **Thoracic** (trunk- the least).
- ➢ **25%** in the **Lumbar & Sacral** (foot-lesser extent than the hand).

- LCST synapses <u>mainly</u> by **interneurons** in **lamina 8 (mainly)**, but **also 4, 5, 6, 7** (in the **dorsal** horn). So, lamina 4-7 are not purely sensory; one theory is that these tracts that supply lamina 4-7 mainly come from **cortex area 312** (not 4) (talked about it in page 1). Another theory is that these are related to the control of **pain** (that can be avoided by certain movements).
- Exception: **3%** of upper motor neurons **directly synapse** with lower motor neuron (**without interneuron**). These originate from **giant cells of betz** in the fifth layer of area 4 (recall: first 4 layers of the cortex=input, 5&6 = output) and they are responsible of **very fine movements** (less synapses = more **accurate** movement).

Corticonuclear Tract (Corticobulbar):

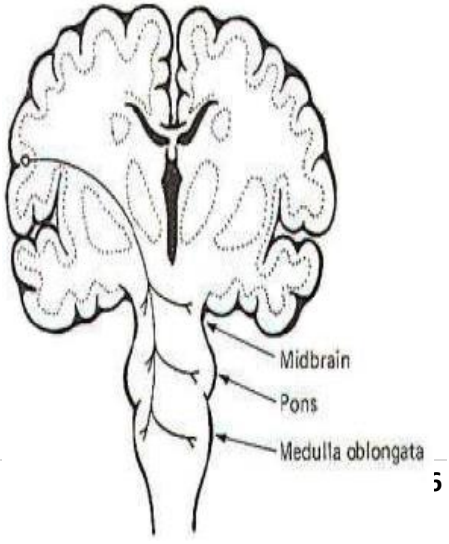
Cranial nerves and muscles of the head & neck area

In the **brainstem** where **cranial nerves** arise, there is no anterior & dorsal horns as in spinal cords. Instead, there is nuclei called **motor nuclei**. This collection of cell bodies in the brainstem can do the same function **as the anterior horn** (having cell bodies of the lower motor neuron that supply skeletal muscles in the head and neck area).
Fibers descend from the **cortex (lower ¼)** to a **nucleus** (motor nucleus), hence the name **Cortico-nuclear Tract**. (you can refer to the homunculus picture to see where the head and neck exist on the cortex)

Muscles supplied by cranial nerves (have motor part):
Hypoglossal nerve → Tongue
Facial nerve (7th) → Motor to muscles of facial expression: orbicularis oris, orbicularis oculi, zygomaticus major and minor, risorius, platysma, buccinator.
Trigeminal nerve (5th) → Muscles of mastication, tensor tympani, tensor veli palatini, Anterior belly of digastric, mylohyoid.
Oculomotor nerve (3rd) → Motor to all muscles of the eye except 2 muscles, superior oblique (by **trochlear nerve**) and lateral rectus (by **abducent nerve**).

The descending fibers terminate in the motor nuclei of the following cranial nerves in:

- The **Midbrain**: **Oculomotor** (3rd cranial) & **trochlear** (4th cranial).
- The **Pons**: **trigeminal** (5th cranial).
- **Ponto-medullary junction** (between the pons and medulla): **abducent** (6th cranial) & **facial** (7th cranial).
- The **Medulla**: **9-12th** cranial nerves. 40:00



As we said about the **corticospinal tracts**, eventually at the end of both the lateral and anterior corticospinal tracts (despite the level of crossing), the right cortex controls the left side of the body and vice versa (**contralateral**).

However, the **corticonuclear tract** input is neither ipsilateral nor contralateral, it's **BILATERAL!** What does bilateral input mean? The corticobulbar fibers from one side of the brain project to the motor nuclei on **both** sides of the brainstem. For example, the **right** trigeminal nerve's nucleus takes fibers from **the right and the left** sides of the brain. Also, the **left** trigeminal takes from the **two sides** of the brain.

But we have 2 exceptions to the bilateral corticonuclear input:

❖ Part of **facial** nerve (**7**th cranial) which supplies the **LOWER facial muscles**.

❖ Part of the **hypoglossal** nerve (**12**th cranial) which supplies the **genioglossus muscle**.

These exceptions are **contralateral** not bilateral (same as the spinal).

Do we consider **corticonuclear** tracts **pyramidal** or **extrapyramidal** tracts?

As we said, pyramidal tract is named so because it passes through the pyramids (parts of the medulla). So, **anatomically** speaking, corticonuclear tracts **can't** be considered pyramidal as they don't pass through the pyramids of the medulla.

But **functionally** (which is more **important** than the anatomical aspect), corticonuclear are **similar** to corticospinal tracts.

So, the final answer is: **corticonuclear tracts can be considered pyramidal tracts.**

Secondly, Extrapyramidal tracts (subconscious control) have 4 types:

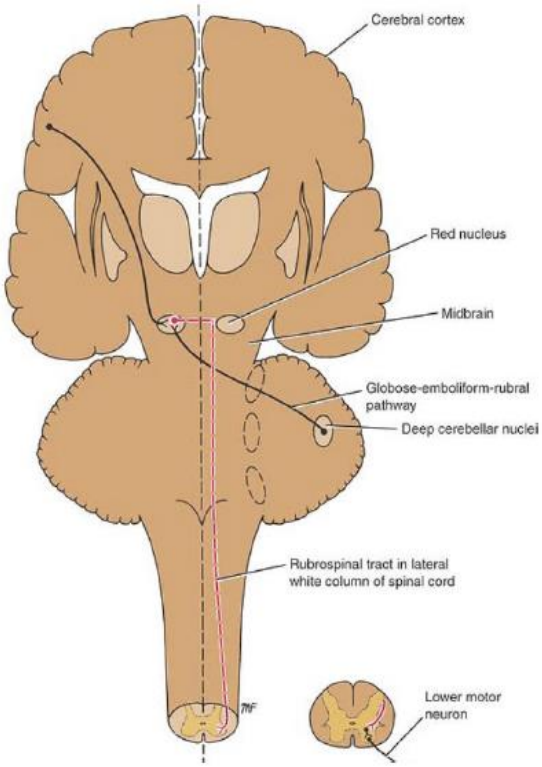
- **Rubrospinal tracts.**
- **Reticulospinal tracts.**
- **Vestibulospinal tracts.**
- **Tectospinal tracts.**

Extrapyramidal tracts' general function is **coordination**. These motor pathways are complex and multisynaptic, and regulate:

- Axial muscles that maintain balance and posture.
- Muscles controlling coarse movements of the proximal portions of limbs.
- Head, neck, and eye movement.

If you are **writing** something on the board, this movement needs a skilled movement of the hand, but you also need **coordination** from the trunk and shoulder girdle (axial muscles).

Don't forget that Extrapyramidal tracts **arise in the brainstem** but are under the **influence of the cerebral cortex.**



1) Rubrospinal tracts:

- Rubro- means red in Latin. It refers to the **red nucleus** located in the midbrain at the level of superior colliculus.
- Synapses with alpha and gamma through interneurons.
- Red nucleus receives input from **cerebral cortex** and **the cerebellum**.
- **Cerebellum** is a very important receiver of data from the spinal cord; we talked about the spinocerebellar tract which has a muscle-joint sense by muscle spindle & tendon.
- So, cerebellum is very aware of your **current position.**
- **The cerebellum has 4 deep cerebellar nuclei**:
  - ✓ Dentate nucleus.
  - ✓ Emboliform nucleus.
  - ✓ Globose nucleus.
  - ✓ Fastigial nucleus.

(mnemonic: Don't Eat Greasy Food)

- The 2nd and 3rd nuclei (**Emboliform and Globose**) are called **interposed nuclei**. There is a pathway that emerges from them, **the globose-emboliform-rubral pathway** which runs from deep cerebellar → to red nucleus.

Rubrospinal tract descends from the **red nucleus** → to **spinal cord** through **lateral white column**, which is related to the activity of **lateral corticospinal tract** (an exception of the extrapyramidal types). So, the **rubrospinal tract** (extrapyramidal) + **lateral corticospinal** (pyramidal) → are collectively named **lateral motor system**.

- ❖ Its function is to **facilitate the activity of flexors (excitatory)** and **inhibit the activity of extensors (inhibitory). (**notice that the movement of **skilled muscles is mainly flexion).**
- ❖ Supplies the distal flexor muscles mainly with little effect on the proximal muscles (exception to extrapyramidal tracts).
- ❖ Very early crossing (at the level of the nucleus).

2) **Reticulospinal tracts:** reticular formation in the core of the brainstem.

- ➢ The reticular formation in the **pons** is called **pontine reticulospinal tract**.
- ➢ The reticular formation in the **medulla** called **medullary reticulospinal tract.**

We separate them because their function is different.

A. **Pontine reticulospinal tract:**

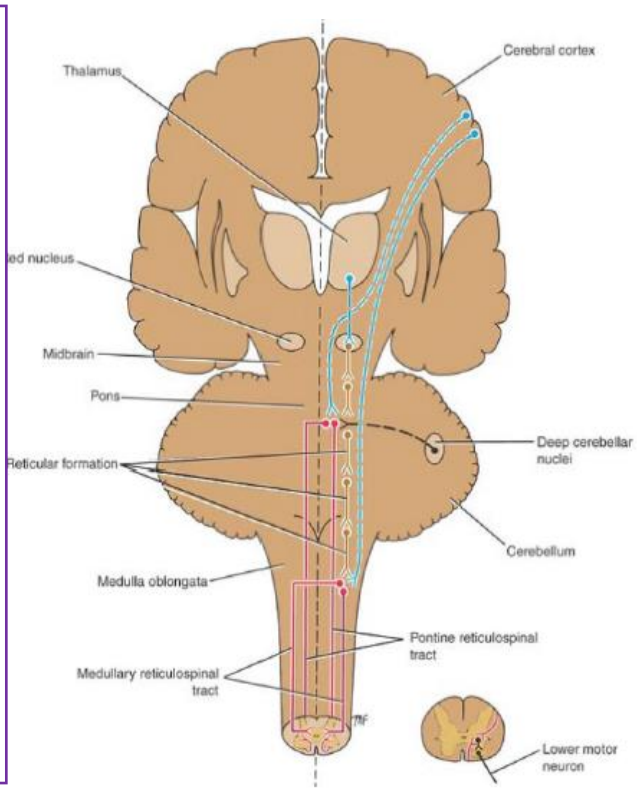
- ❖ From the reticular formation in the **pons** → to the **anterior white column.**
- ❖ The fibers stay **uncrossed.**
- ❖ This tract is **tonically active** which means that there is continuous firing, but the **effect of the cortex on it is inhibitory.** This is called the **mechanism of disinhibition** and it is very important. See the following explanation 50:00

It's like the mechanism of the car:

- If the car is on a downhill, it will be under the power of gravity (or momentum).
- If you want to stop it, you should just press on the breaks.
- If you want to speed up, you should only stop pressing on the break. The car will speed up on its own because it's on a downhill.

Just like that, this system is **tonically active** and the effect of the cortex on it is **inhibitory**.

If you remove the inhibitory effect of the cortex (this is called **decorticate**), overfiring and more activation of the reticulospinal tract will occur.



- ❖ **Function** of the pontine reticulospinal tract: **activate** the axial and proximal limb **extensors** (antigravity muscles) so you can **stand upright**. In the upright position:
  - ✓ The **knee joint** is very **extended.**
  - ✓ The **quadriceps femoris** (which is anterior to knee joint) is **contracted.**

B. **Medullary reticulospinal tract:** (the medullary and pontine reticulospinal tracts work opposite to each other, as agonist and antagonist).

- ❖ **Some** fibers **cross** and **some do not cross**.
- ❖ In the **lateral white column.**
- ❖ Function: **Inhibit** the axial and proximal limb **extensors.**
- ❖ **Normally under stimulation.**
- ❖ **Lateral reticulospinal tract.**
- ❖ **NOT** tonically active.

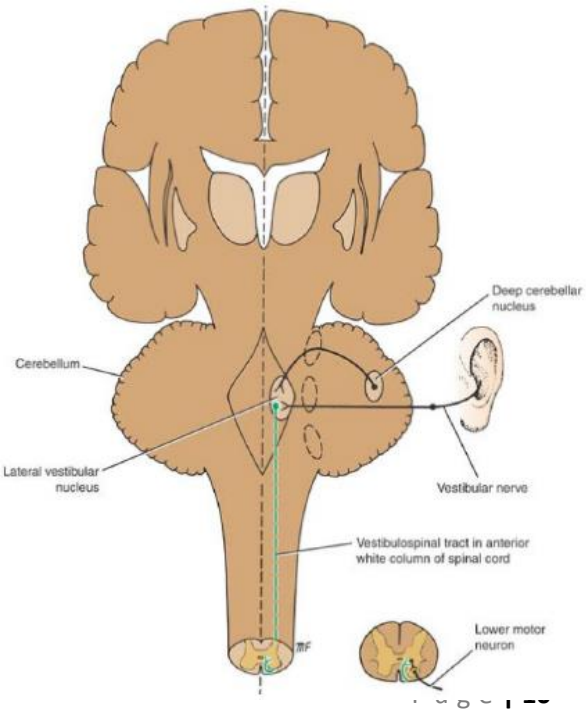
Autonomic motor system has preganglionic & postganglionic fibers. The preganglionic **cell bodies are in the lateral horn** (parts of them are in lamina 7) under the control of higher centers, mainly the **hypothalamus (**not the cortex). The fibers descending from higher centers that are related to autonomic activity, as the hypothalamus, to the lateral horn cells **are thought to pass through the reticulospinal tract**, especially the **medullary** part. So, it has descending autonomic fibers, thus providing a pathway by which the hypothalamus can control the sympathetic and sacral parasympathetic outflow.

3) **Vestibulospinal tracts:** start from **vestibular nuclei** in the **brainstem,** specifically **pons** and medulla beneath the floor of 4th ventricle, which are **sensory nuclei**. As we said in previous lectures, the sensory neurons synapse in the dorsal horn.
The vestibular nuclei receive afferent (sensory) fibers from:

- ➢ The **inner ear,** from the **vestibule** (semicircular canals) which has liquid and hair cells that are affected by movement of the head (firing), by the vestibular nerve. So, it's responsible for the **sense of balance**.
- ➢ Input from **deep cerebellar nucleus** (Fastigial nuclei).

So, the data received to the vestibular nucleus is related to your **position** and **gravity**.

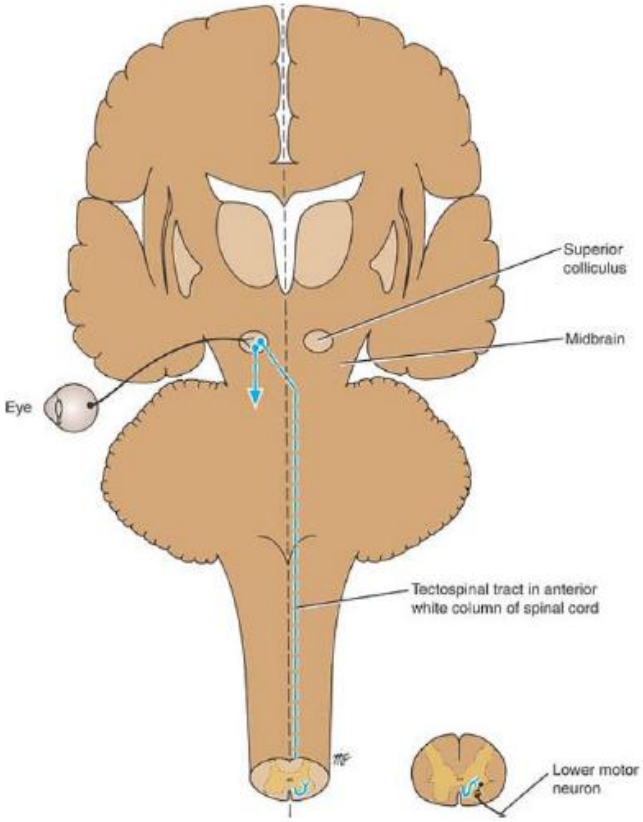
- ✓ This tract descends **uncrossed** through the **anterior white column.**
- ✓ **Function**: (similar to pontine reticulospinal) **Facilitate** the activity of **extensor** muscles and **inhibit** the activity of **flexor** muscles in association with the **maintenance of balance**.
  - **Vestibulospinal tracts + Pontine reticulospinal tract → help you to stand in the upright position.**
  - **Opposite to them: Medullary reticulospinal tract.**



When you are lying down, the **cerebellum** knows your **position** (due to its muscle-joint sense), and the **vestibular** system knows the relation between your head and the **gravity** (tilted or raised). When it's activated, this will help you overcome the gravity and stand in an upright position.

4) Tectospinal tracts:

- **Tectum** is the **posterior aspect of the midbrain** and is divided into 4 colliculi:
  - 2 superiors (related to visual reflexes). We'll talk about the superior colliculus.
  - 2 inferiors (auditory reflexes).
- Mainly crossed.
- It descends in the anterior white column close to anterior median fissure.
- Recall that in the **sensory** system we have an ascending tract: the **spinotectal tract**. Its reflex is **spinovisual** (if you walk over a foreign object, you will immediately look at it) However, here we have the opposite.
- Its function: The **reflex movement of the head & neck** in **response to visual stimulus**. (**visuospinal** reflex).
  For example, if you are sitting and your friend suddenly throws a ball towards your head, when you **see** the ball your reflex will be **moving your head away spontaneously**.
- Because the head & neck area is supplied by **upper cervical segments**, the majority of fibers of this tract terminate in the **anterior gray column of upper cervical segments of spinal cord.**



To summarize the lecture:

The motor pathways are classified into:

- **Medial Motor system:** axial & proximal muscles. It includes:
  - Anterior corticospinal tract (pyramidal).
  - Extrapyramidal pathway in general.
- **Lateral Motor system:** distal muscles mainly. It includes:
  - Lateral corticospinal tract.
  - Rubrospinal tract: distal muscles mainly (and proximal). (Exception).

Good luck ☺