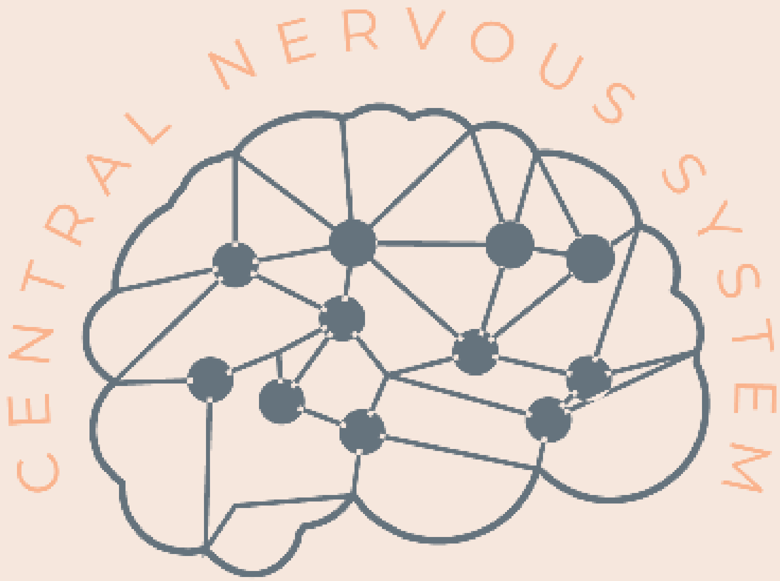

Physiology

Sheet no. 4

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Motor system – Motor of the spinal cord

Before we start talking about the motor function of the spinal cord, let's first take a quick look at the motor system and the incredible connections taking place inside it:
[please refer to the pictures for better understanding]

1- Motor command

For any motor function (movement) to occur, the nervous system has motor command that comes **from the cerebral motor cortex to the spinal cord** and these descending tracts (**corticospinal**) are called also **pyramidal tracts** and that's because they pass through the pyramids of medulla oblongata.

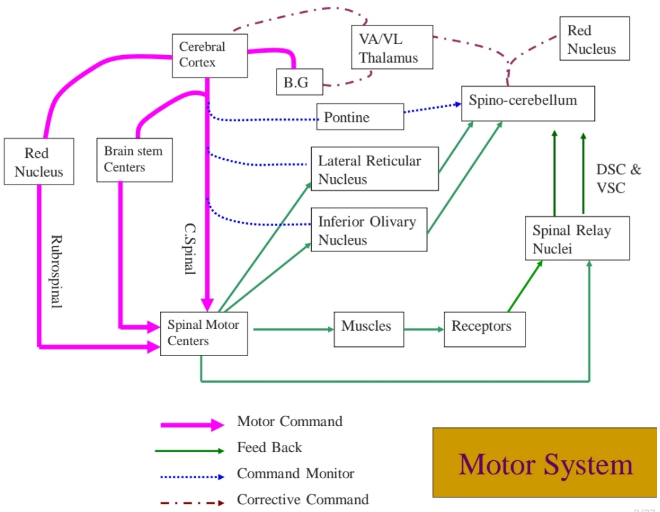
The neuronal fibers coming from the cortex ending in the spinal cord are considered **upper motor neurons**, while the neuronal fibers going out from the spinal cord to reach the muscles are called **lower motor neurons**.

There are other origins for the motor commands such as the brain stem and the red nucleus that send neuronal fibers to the spinal cord in order to control the activity of the muscles.

cerebellum get informed by 2 different signals which are the intention command <from th cortex> and the muscle feedback and has the order to compare them then the correction

2- Motor command intension

At the same time, there are some tracts going from the cortex to the cerebellum through the brain ster like the corticopontocerebellar, corticoreticulocerebellar, corticolivarycerebellar tracts. And these tracts are telling the cerebellum about the intended movements. (= the movements we want to do)



3-motor command monitor/ feedback system

a- Inside the muscles we have receptors (**muscle spindles/ stretch receptors**, **Golgi tendon organs**) that are connected to sensory (afferent) neuronal fibers that goes to the spinal cord relay nuclei.

muscle spindle receptors sense the change in the length (static) and the rate of that change (dynamic).
Golgi organs sense the change in the force (static) and the rate of change (dynamic).
The density of the receptors is proportional to the importance of the signals/
information they collect. Important sensations have a high density of receptors. Muscles
that are used most often like muscles working against the gravity (antigravity muscles)
have a lot of muscle spindles and Golgi tendon organs

ventral spinocerebellar tracts (bilateral) whereas dorsal spinocerebellar tracts (ipsilateral)

b- From the spinal cord they go to the cerebellum through **ventral and dorsal spinocerebellar tracts** to tell the cerebellum what is exactly happening down at the level of the muscles.

corrective command

c- Then the cerebellum will do its job and send orders through the (ventroanterior **VA** and ventrolateral **VL** parts) to the cerebral cortex to monitor the motor commands.

[receptors -> spinal cord -> ventral and dorsal spinocerebellar tracts -> cerebellum -> thalamus VA/VL -> cerebral cortex]

Remember that the sensory (ascending) tracts go to the cerebral cortex through the ventral basal complex (VPL, VPM) of the thalamus.

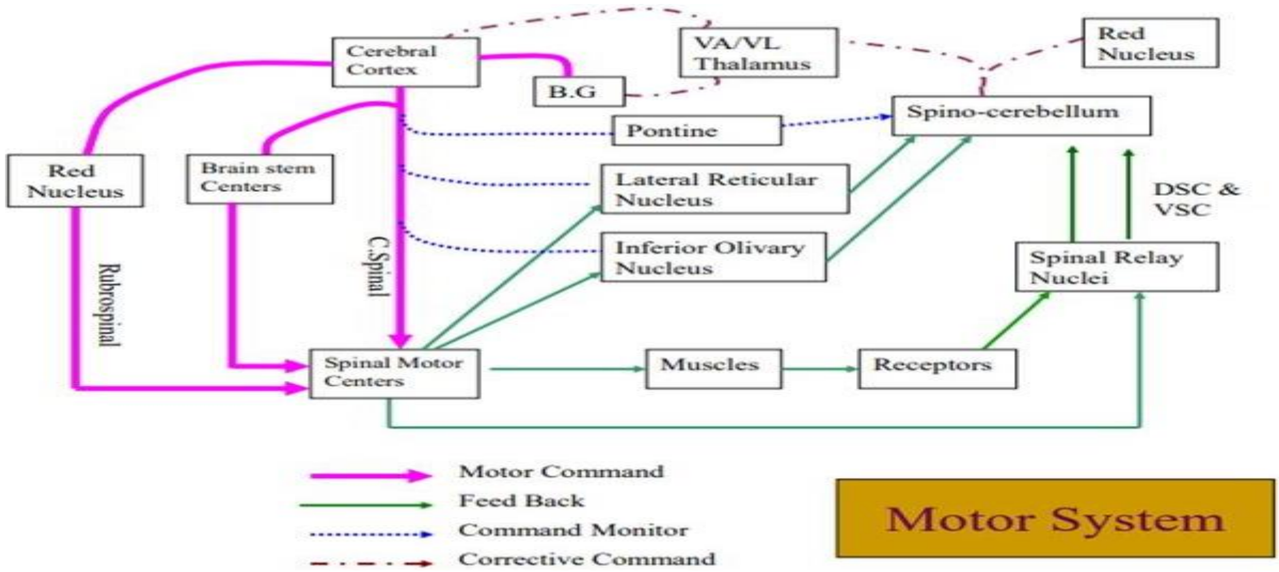
d- Feedback can also be through **inferior olivary nucleus** and lateral reticular nucleus

4-Correction process

What will the cerebellum do with this information? It **compares** motor command intension with motor command monitor/ feedback system to see if they meet or not. And if they don't meet, the cerebellum will send orders to the cerebral cortex to correct it.

by which the cerebellum makes the movements smooth and well directed,, if the cerebellar correction is absent then the movement is said to be corticall which is coarse and pendular (tremors)

Intention tremor(during movement)



Why all of this is happening ? Usually the cerebral motor cortex doesn't send exact signals to the spinal cord (corticospinal tract), it sends either more or less than what is intended, so the muscles react more or less than what is intended. The cerebellum will know what is going on the level of the muscles (motor command monitor) and what is the movement we were trying to do (motor command intension) and is going to correct it by sending orders to the cerebral motor cortex through the thalamus [the secretary of the cerebral cortex]. This correction process is **continuous and very fast**, we don't feel that the muscle movement is hectic [having tremors –> *intention* tremor].

cortical

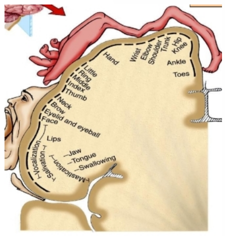
➔ We can say that if the *movements* come from the cortex without the correction and the monitoring from the cerebellum, they *will be pendular* [= with a lot of tremors], and that's what exactly happens *when there is disease or damage of the cerebellum.*

when the cerebellum acts normal way we do not notice the tremor although there are fine tremor but they're unremarkable because the cerebellarcorrection occurs in a fast and continuous manner.

مثلا تتابع الصور المكونة لمقطع فيديو بسرعه وباستمرار فنراها وكأنها مشهد مستمر .

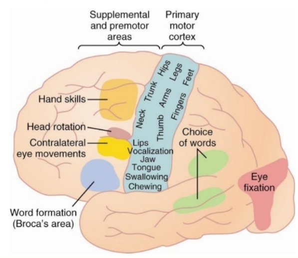
the tremors caused by cerebellum lesion are called *action tremors* which occur only during movement and absent during rest.
other types of tremors: resting tremors hyperthyroidism tremors stress tremors.

Motor Cortex
Divided into 3 sub areas
primary motor cortex (non programmed movements)
has unequal topographic representation. it's Located in the precentral
gyrus of the frontal lobe. More cortical area is devoted to those muscles
involved in skilled, complex or delicate movements, that have more motor units <i.e the cortical representation is proportional to the No of motor units>


(b) Frontal section of primary motor area in right cerebral hemisphere

premotor area (programmed movements)
its topographical organization similar to primary motor cortex, stimulation results in movement of muscle groups to perform a specific task andworks in concert with other motor areas.
supplemental motor area
topographically organized, simulation often elicits bilateral movements.
it functions in concert with premotor area to provide attitudinal, fixation or positional movement for the body.
it provides the background for fine motor control of the arms and hands by premotor and primary motor cortex.

Motor Areas of the Cortex

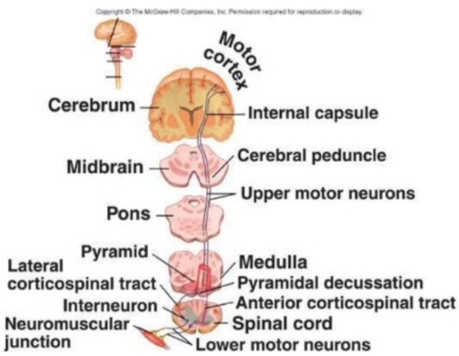


Specialized Areas of the Motor Cortex
Broca's area damage causes decreased speech capability another closely associated area controls appropriate respiratory function for speech.
eye fixation and head rotation area for coordinated head and eye movements.
hand skills area damage causes motor apraxia the inability to perform fine hand movements.

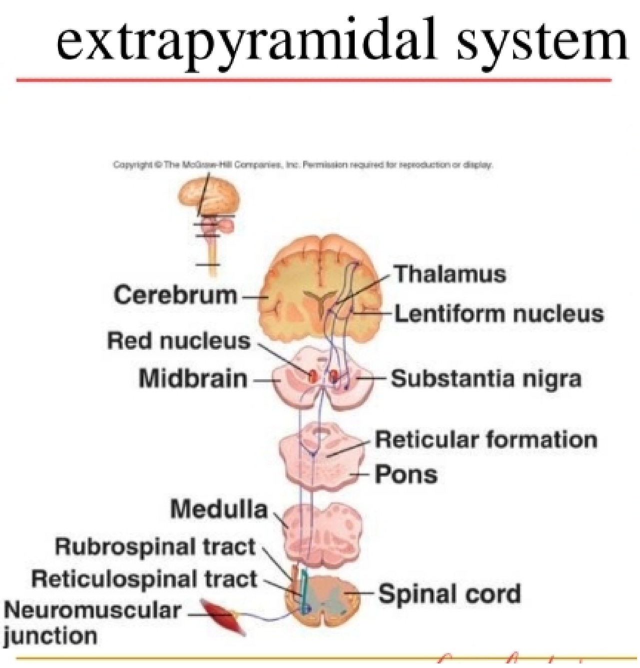
Transmission of Cortical Motor Signals takes place by two different ways
1)Direct pathway : corticospinal tract for discrete detailed movement like fine movements of the hand and foot.
Corticospinal Fibers 34,000 Betz cell fibers, make up only about 3% of the total number of fibers, 97% of the 1 million fibers are small diameter fibers which conduct background tonic signals and transmit feedback signals from the cortex to control intensity of the various sensory signals to the brain.
mainly from the motor areas of the cortex reaching to the brainstem between basal ganglia and the
thalamus ,,, reaching the area called internal capsule that has: 1) genu from which the fibers coming from the cortex reach the cranial nuclei (corticopulbar fibers)
2)Ant.limb : sensory fibers Pass through
3) pos.limb from where we continue the motor fibers which descend till medulla oblongata where we have the Pyramid fibers at which We have the crossing event (pyramidal dicassation)
from one side to the other for the majority of fibers , since
some ofwhich does not cross there they cross elsewhere In the spinal cord.

the motor fibers Continue to thespinal cord in the
Lateral column (contralaterally), lateral cortico spinal tract (the one which cross) forming 90% of all motor fibers,
or to the Ant.column Ant.corticospinal tract (hasn't crossed yet)10% of motor fibers
most of it (Ant.corticospinal) crosses at the level of spinal cord and some do not.
so at the end the majority of the motor fibers cross to be working contralaterally .

pyramidal system



2) Indirect pathway(extrapyramidal): signals to basal ganglia, cerebellum, and brainstem then to the spinal cord. their function is coordination of head & eye movements, coordinated function of trunk & extremity musculature to maintaining posture and balance.they do Synapse in some intermediate nucleus rather than directly with lower motor neurons.



Other Pathways from the Motor Cortex:

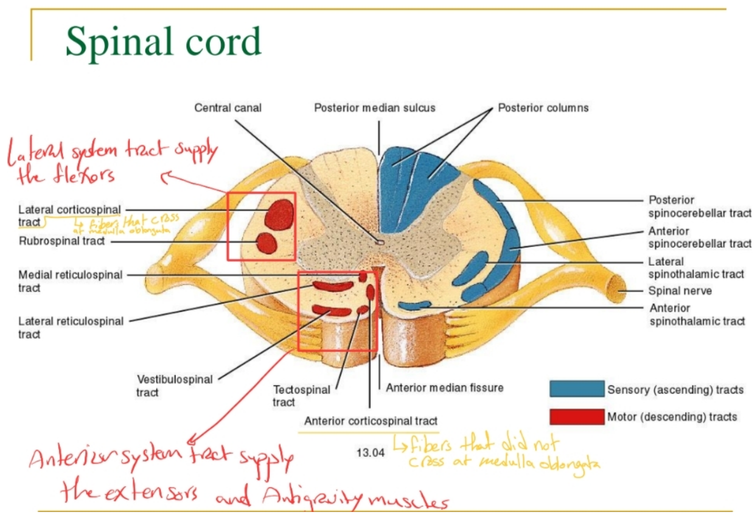
⬛ Betz collaterals back to cortex sharpen the boundaries of the excitatory signal

⬛ Fibers to caudate nucleus and putamen of the basal ganglia

⬛ Fibers to the red nucleus, which then sends axons to the cord in the rubrospinal tract

⬛ Reticular substance, vestibular nuclei and pons then to
the cerebellum

⬛ Therefore the basal ganglia, brain stem and cerebellum receive a large number of signals from the



Excitation of Spinal Motor Neurons
Motor neurons in cortex reside in layer V. Excitation of 50-100 giant pyramidal cells is needed to cause muscle contraction. Most corticospinal *bers synapse with interneurons...Some corticospinal and rubrospinal neurons synapse directly with alpha motor neurons in the spinal cord especially in the cervical enlargement These motor that synapse directly with neurons innervate muscles of the *ngers and hand.

Lesions of the Motor Cortex

- Primary motor cortex - loss of voluntary control of discrete movement of the distal segments of the limbs (upper motor neuron damage -> hypertonia)/(lower motor neuron damage ->hypotonia)
- Basal ganglia lesion - muscle spasticity from loss of inhibitory input from accessory areas of the cortex that inhibit excitatory brainstem motor nuclei.

Incoming Sensory Pathways to Motor Cortex including:
* Subcortical fibers from adjacent areas of the cortex especially from somatic sensory areas of parietal cortex and visual and auditory cortex.
*Subcortical fibers from opposite hemisphere which pass through corpus callosum.

Subcortical fibers are mainly from the layers 1,2,3

* Somatic sensory fibers from ventrobasal complex of the thalamus (i.e., cutaneous and proprioceptive fibers).
*Ventrolateral and ventroanterior nuclei of thalamus for coordination of function between motor cortex, basal ganglia, and cerebellum.
*Fibers from the intralaminar nuclei of thalamus (control level of excitability of the motor cortex), some of these may be pain fibers.

Sensory Feedback is Important for
Motor Control provides Feedback from muscle spindle, tactile receptors, and proprioceptors fine tunes muscle movement,
then Length mismatch in spindle causes auto correction.

- Compression of skin provides sensory feedback to motor cortex on degree of effectiveness of intended action.