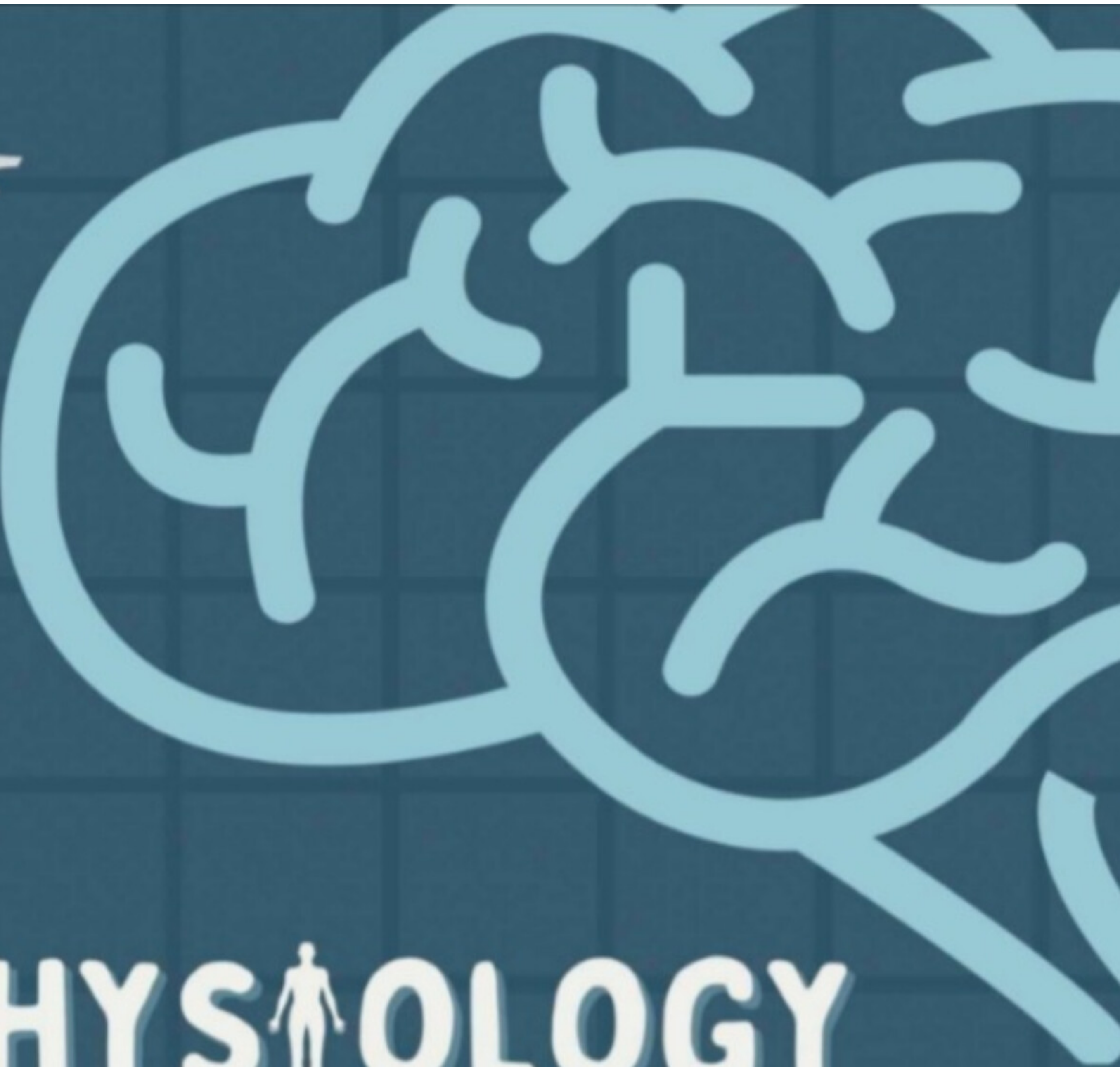


PHYSIOLOGY

SHEET NO. 6

WRITER : Doctor 019

CORRECTOR : Malek absia

DOCTOR : Faisal Mohammad

❖ Revision from last lecture :

The functional cerebellar unit (neuronal circuit of the cerebellum) is the purkinji cell and its attachments

There are two fibers in the functional unit of cerebellum (neuronal circuit)

1. Climbing fibers (came from inferior olive)
2. Mossy fibers (came from all other afferents)

The inferior olive receives two fibers

1) From the cortex (from corticospinal) tell it about intention
2) From muscles as feedback (tell it about actual movment)

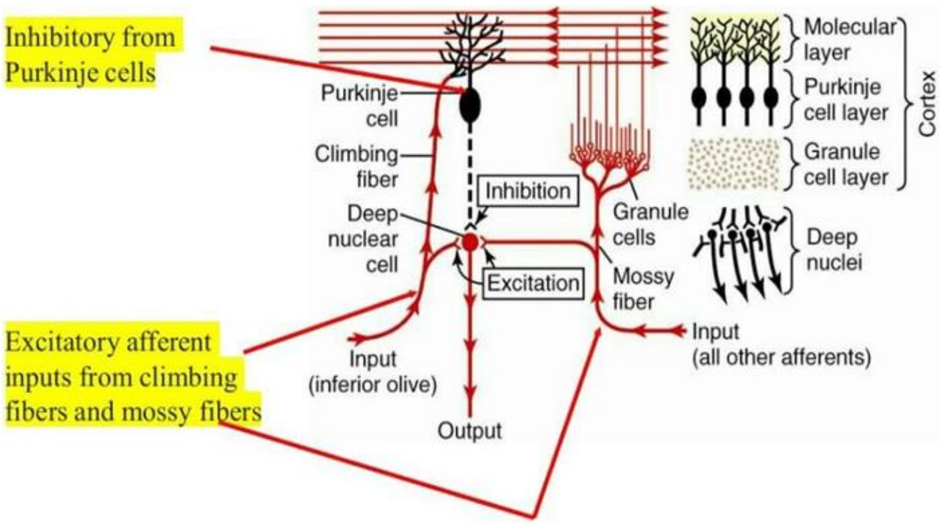
Then the inferior olive compare the actual state (from muscles) and the intended (from cortex) and send corrective commands to cerebellum through climbing fibers

- How climbing fibers stimulate the cerebellum :

It synapse with deep nuclear cells and stimulate it cause excitation then ascend to the parallel fibers and stimulate the dendrites of purkinji cause inhibitory signals to the deep nuclear cells …..so the deep nuclear cells exited first then inhibited

- How mossy fibers stimulate the cerebellum :

It synapse with deep nuclear cells and stimulate it cause excitation and ascend to the granular cells and stimulate it …then the axons of granular cells ascend to the moleculasr layer and divide to make the parallel fibers ….(the purkinji fibers impeded in these parallel fibers so the stimulation of these fibers cause stimulation of purkinji dendrites >>>>the purkinji fibers send inhibitory signals to deep nuclear cells



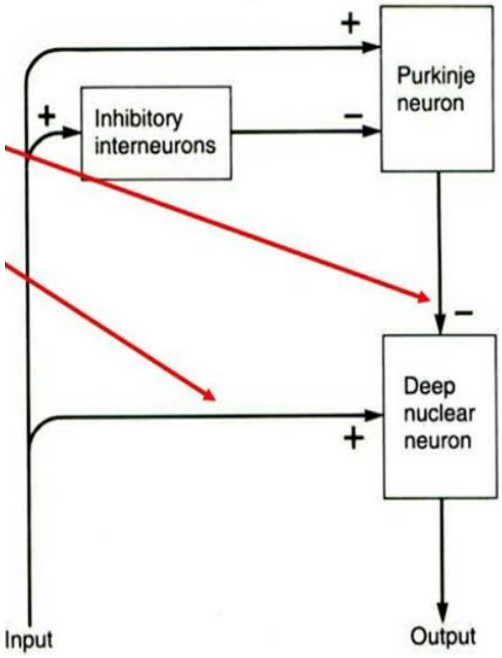
climbing fibers send branches to the deep nuclear cells before they make extansive connections with the dendrites of the purkinji cell.

They cause complex spike output to be produced from purkinji cell but

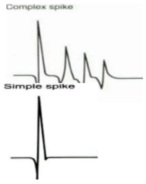
complex potential contains too many spikes, these spikes are important for learning from previous experiences (to learn how to perform certain movement for particular task)

mossy fibers terminate in granular cell layer, they cause simple spike

lateral inhibitory cells are in the molecular layer, important for sharpening the impulse



deep nuclear cell activity



- deep nuclear cell at first receives an excitatory input from both the clombing fibers and mossy fibers.
- Few milliseconds later,this is followed by an inhibitory signal from the purkinji cells.
- Normally the balance is in favor of excitation.
- Direct motor pathway via corticospinal tract is enhanced by cerebellum bu additional signals to the tract or by signals through the thalamus back to the cortex.
- How does this pattern of signals affect the motor activity?

☒ At the beginning of motion there are excitatory signals sent into the motor pathways by deep nuclear cells to enhance movement ,followed by inhibitory signals milliseconds later.

☒ Provides a damping function to stop movement from overshooting its mark (more than the intended movement)

☒ Resembles a delay-line type of electronic circuit for negative feedback.

☒ Turn on_turn off function :-

at the beginig of motion :cerebellum contribute to the rapid turn on signals for agonist muscles and turn off af antagonist

at the end of motion :it does the opposite sequence of signals ,so the agonist muscl will be inhibited , and the antagonist muscle will be exited

❖ **Correction of motor error**

#Precise motor movements must be learned, and the cerebellum is important to learning skilled motor movements like writing,speaking,driving

#when a child starts writing, he will hold the pen tightly and may perforate the paper,this is because his movement now is cortical movement(coarse, pendular) not skilled movement, after while the

Cerebellum will learn how to produce the proper movement , and writing become smooth.

- How does learning occur?

Climbing fiber's input adjusts the sensitivity of the Purkinje cells to stimulation by parallel fibers.

This changes the long-term sensitivity of the Purkinje cell to mossy fiber input (i.e., from muscle spindle, Golgi tendon, proprioceptor).

This adjusts the feedback control of muscle movement, and by time, the movement becomes finer.

Learning usually causes anatomical changes, but it may also cause functional changes (membrane proteins, neurotransmitters).

- The role of inferior olivary complex: It receives input from the *corticospinal tract* and *motor centers of the brain stem,* and *sensory information from muscles and surrounding tissue* (from large tactile receptors) detailing the movement that occurs.
- Inferior olivary complex can act as a cerebellum by itself, it compares intent with actual function, if a mismatch occurs, output to cerebellum through climbing fibers is altered to correct mismatch (usually there is a mismatch), correction output will go to the thalamus then to the cortex, the cortex will produce a corrected command.

Motion control by the cerebellum

- Most cerebral cortical motions are pendular, there is inertia and momentum, so the muscle will not stop at the intended position [Tremor].
- To move a limb accurately it must be accelerated and decelerated in the right sequence.
- Cerebellum calculates momentum and inertia and initiates acceleration and braking activity to produce the intended movement.
- It can calculate it because muscle spindle & Golgi tendon organ sends feedback about the rate of change.
- If the cerebellum was destroyed, the patient will have pendular movement [Action tremor].
- Predictive and Timing Function of the Cerebellum:

- Motion is a series of discrete sequential movements. ○ The *planning* and *timing* of sequential movements is the function of the lateral cerebellar hemisphere.
- This area communicates with *premotor* and *sensory cortex* and corresponding area of the *basal ganglia* where the plan originates.
- The lateral hemisphere receives the plan and times the sequential events to carry out the planned movement (programed movement).

Cerebellar voluntry control

See image 4 at the end of sheet

- Muscles spindle & Golgi tendon sends feedback to the intermediate zone (also called spinocerebellar zone since it receives input passing through the spinal cord).
- Motor cortex & red nucleus sends motor command to the muscle through corticospinal tract & rubrospinal tracts.
- The actual movement will be sent back to the cerebellum.
- Corrective commands will be sent through the thalamus (VA, VL) to the cortex, the corrected output will go to the muscle.
- Note that the cerebellum does not send fibers directly to the muscle, but it passes through the thalamus to the cortex, then the cortex will send impulse to the muscle. The corrective command may be sent to the cortex hundreds of times before the movement starts (corrective signal is very fast).

Integration of Motor Control

- Spinal cord level: preprogramming of patterns of movement of all muscles (i.e., withdrawal reflex, walking movements, etc.).
- Brainstem level: maintains equilibrium by adjusting axial tone.
- Cortical level: issues commands to set into motion the patterns available in the spinal cord + controls the intensity and modifies the timing.
- Cerebellum: function with all levels of control to adjust motor activity, equilibrium, and planning of motor activity.
- Basal ganglia: functions to assist cortex in executing subconscious but learned patterns of movement, and to plan sequential patterns to accomplish a purposeful task.

Clinical Abnormalities of the cerebellum

- All signs of cerebellar diseases are ipsilateral since there is double crossing from cortex to pons and back to cortex.
- Cerebellar diseases cause motor abnormalities because the movement becomes cortical, and the impulse is either more or less than intended.
- So, when the patient moves his muscle forward (for example) he will notice that he is moving his muscle more than he need, so the cortex tries to make another reversed impulse and move the muscle backward, but also it will be moved more the intended, so the muscle keeps moving back & forth until it reach the intended position.
- This is what we call Tremor, it occurs during intention [while you are trying to perform an intended movement].
- Tremor that occurs in the extensor & antigravity muscles makes the body movement like dancing; this case is called Ataxia.
- Ataxia & Intention Tremor happens due to failure to predict motor movement, patients will overshoot intended target & past pointing. ○ Past pointing: when you ask the patient to put his finger on his nose while his eyes are closed, he will hit different points on his face before he reaches his nose. ○ Disequilibrium (if the vermis is damaged), ataxic (staggering/drunken/wide) gait (he will separate his legs apart from each other).
- Dysdiadochokinesia/Adiadochokinesia: abnormality in the rapid agonistantagonist movement lead to failure of orderly progression of movement.
    - When you ask the patient to do supination & pronation of hands, he will have difficulty in doing that (Dysdiadochokinesia) or will not be able to do it at all (Adiadochokinesia).
- Dysarthria: abnormality in the rapid agonist-antagonist movement also leads to failure of orderly progression in vocalization, the patient will have stuttering speech.
- Cerebellar nystagmus: intention tremor of the eyes when trying to fix on object.
    - When you ask the patient to look at a certain line, you will notice that his eyes are moving right & left.

Tremor in skeletal or ocular muscles in cerebellar abnormalities occurs when the patient wants to perform an intended movement.

Basal Ganglia and Motor Control

Basal ganglia are subcortical gray matter nuclei found deep in the brain. The correct name is **Basal nuclei** (not ganglia) because they are a collection of cell bodies and dendrites (gray matter) inside the CNS. But they got this name when they were discovered. It is important to know that basal ganglia do not send descending/ ascending fibers, they only have fibers in the brain (upper fibers).

Structure of Basal ganglia system:

consist of four nuclei:

1-**Striatum:** Caudate and Putamen

2-Globus Pallidus

3-Substantia Nigra

4-Subthalamus

- 3 + 4 are related **functionally** not structurally to the basal ganglia

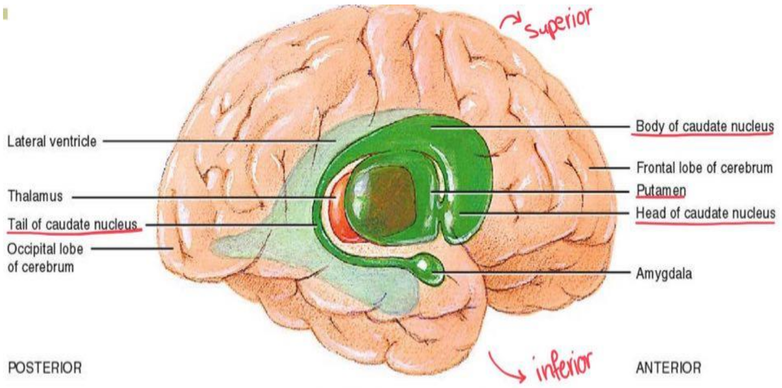
- Lentiform (lenticular) nucleus: Putamen + Globus Pallidus

- Corpus striatum: Striatum (Caudate and Putamen) + Globus Pallidus

-Caudate nucleus has a head, body and tail.

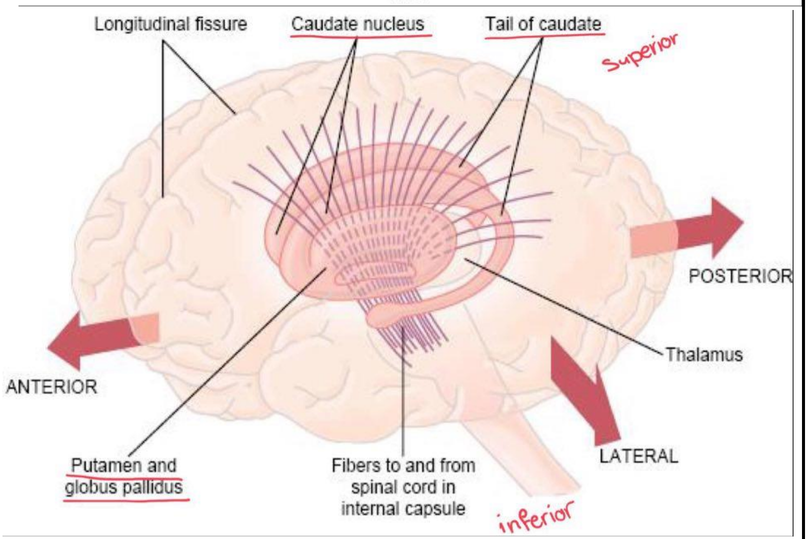
- Globus Pallidus is divided into two part: **Globus Pallidus Internus** (GPi) and **Globus Pallidus Externus** (GPe)

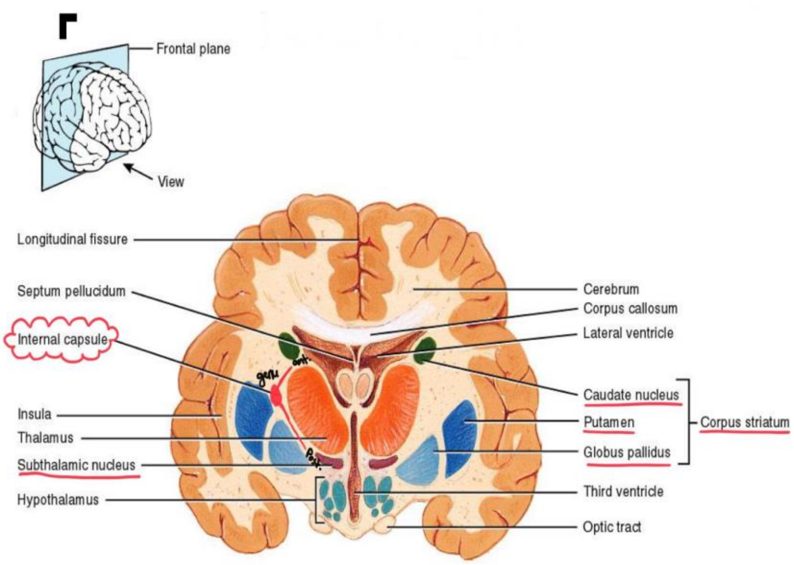
- **internal capsule**: white matter structure between Putamen and Globus Pallidus in one side and Thalamus and Caudate in the other side. It consists of three parts and is V-shaped when cut horizontally, in a transverse plane: 1- the bend in the V is called the **Genu** (means elbow) and it contains the corticobulbar fibers going form the cortex to the nuclei of the cranial nerves 2- **anterior limb** (sensory fibers) 3- **posterior limb** (motor fibers)



(a) Lateral view of right side of brain

14.13a





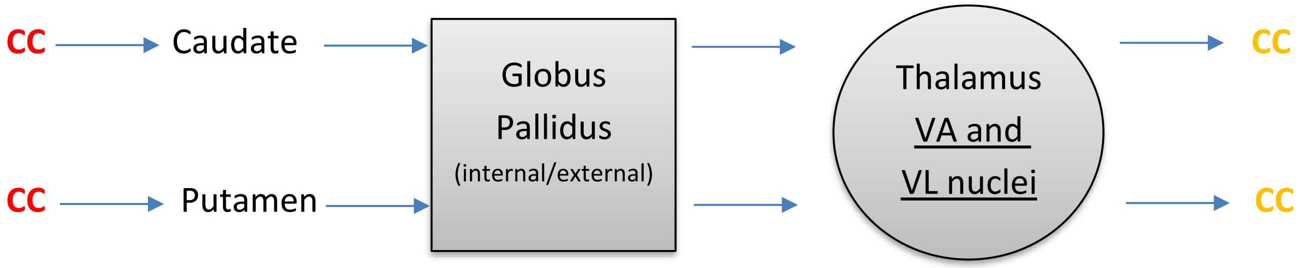
(b) Anterior view of frontal section

14.13b

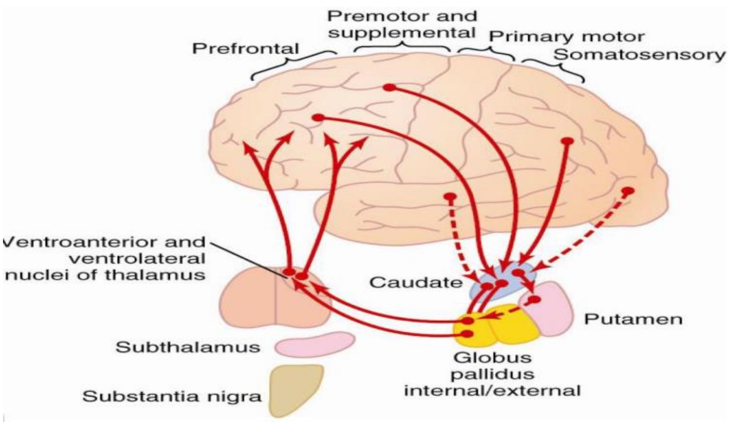
Basal ganglia Afferents and Efferents:

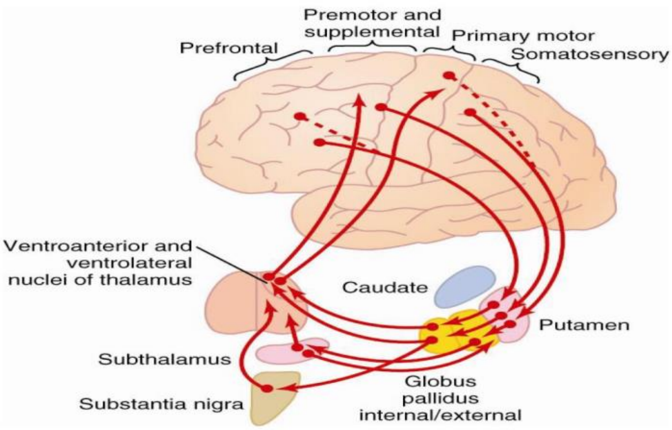
<u>The basal ganglia are the principle subcortical components of a family of parallel circuits linking the thalamus with the cerebral cortex.</u>

To understand this topic easily, let us start by studying the two main circuits present in the basal ganglia system. Any circuit should start and end in the same area and this applies on these circuits also; they start and end in the cerebral cortex.



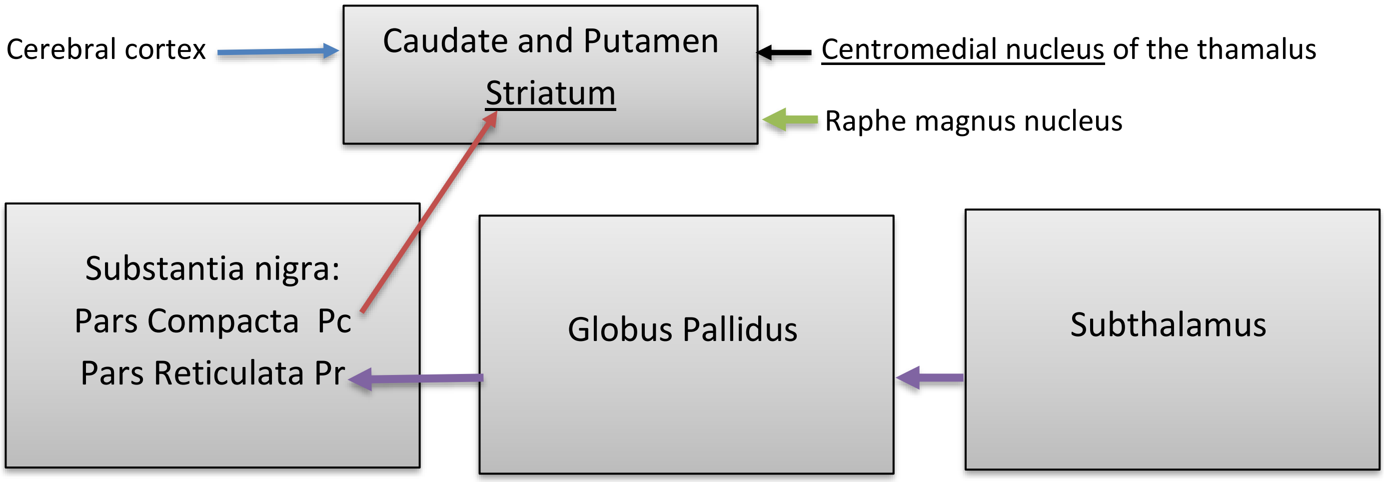
Caudate Circuit	Putamen Circuit
extends into **all lobes of the cortex** and receives a large input from the **association area of the cortex**. [prefrontal, premotor and supplement, primary motor, parietal (somatosensory), temporal (auditory), occipital (visual)].	Receives mostly from **premotor and supplemental motor cortex** [does not receive from the association areas]
To caudate nucleus	To putamen nucleus
Mostly projects to Globus Pallidus, no fibers to subthalamus.	some fibers project to Globus Pallidus then to the subthalamus and substantia nigra.
Goes back to the cerebral cortex through the thalamus, *particularly to the* ***premotor and supplementary motor areas***.	Goes back to the cerebral cortex through the thalamus, *especially to the* ***primary motor area***
What the caudate circuit does is integration of all the information from different lobes and association areas to conduct ***a plan*** *about the motor movement we are going to respond with*. That is, most motor actions occur as a result of **a sequence of thoughts**. Caudate circuit may play a role in **the cognitive control of motor functions.**	*What the putamen circuit does is receiving the plan from the caudate circuit and performing the motor movements we must do.*





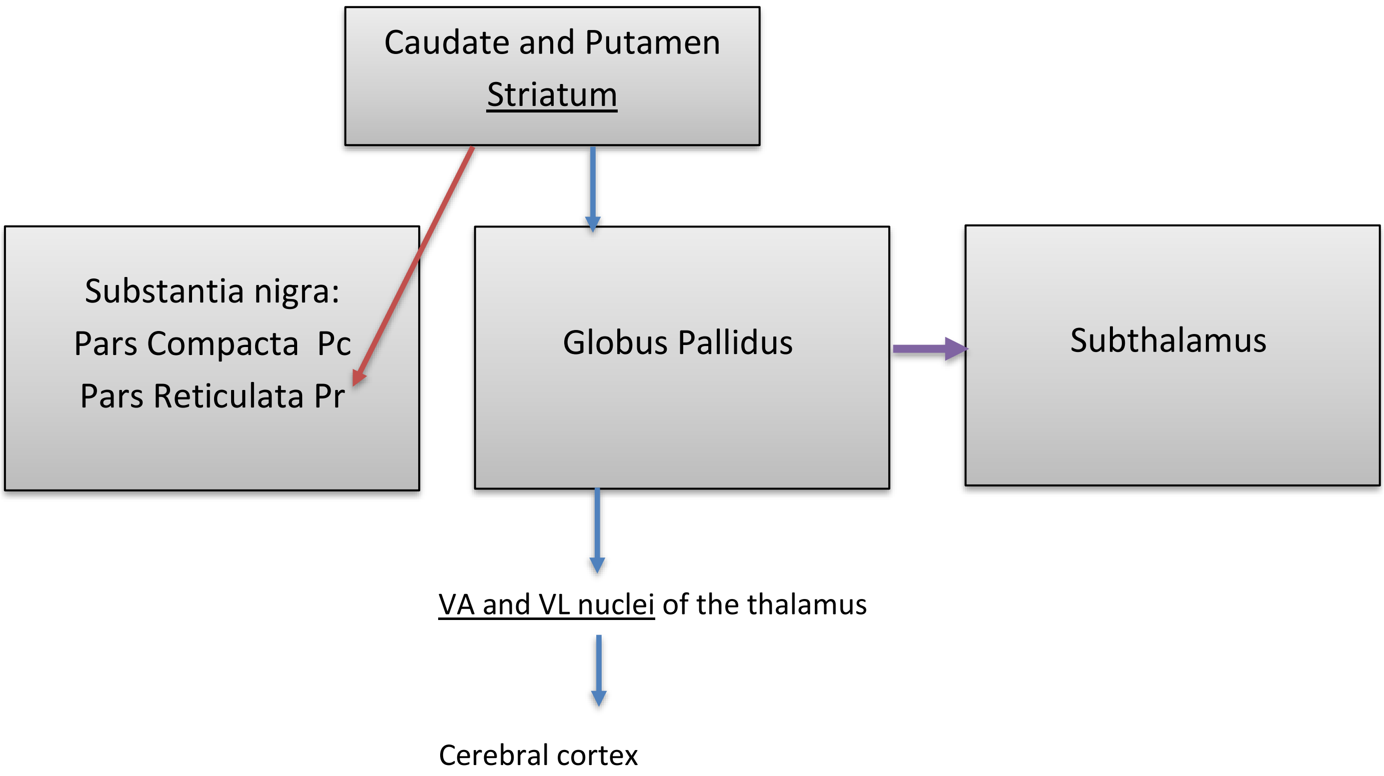
These two circuits can tell us some information about the basal ganglia afferents and efferents, but there is more.

Basal ganglia afferents:



Remember that: the centromedial nucleus of thalamus is sensory, while the VA and VL nuclei of the thalamus are motor. The centromedial nucleus and raphe magnus nucleus are related to pain pathways, which indicates that the basal ganglia have a role in cognitive funtion (emotional part of pain).

Basal Ganglia Efferents:



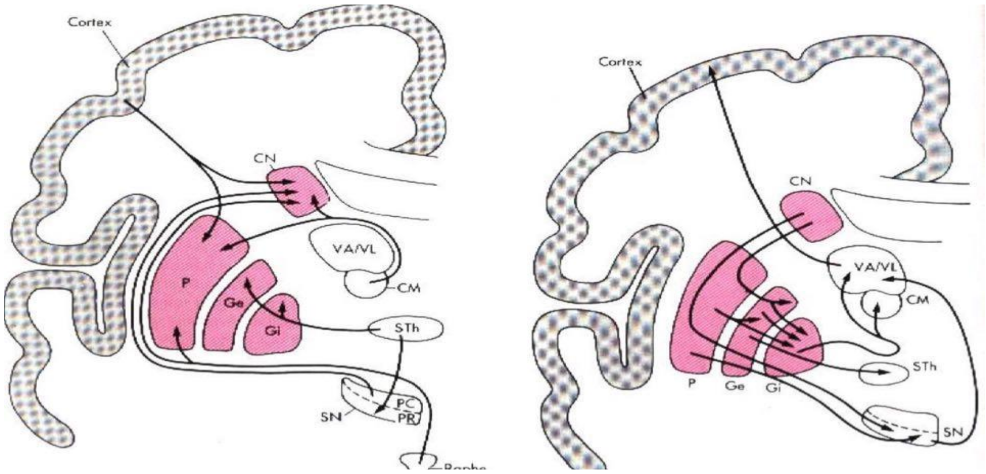

Cortex
CN
VA/VL
CM
P
Ge
Gi
STh
SN
PC
PR
Cortex
CN
VA/VL
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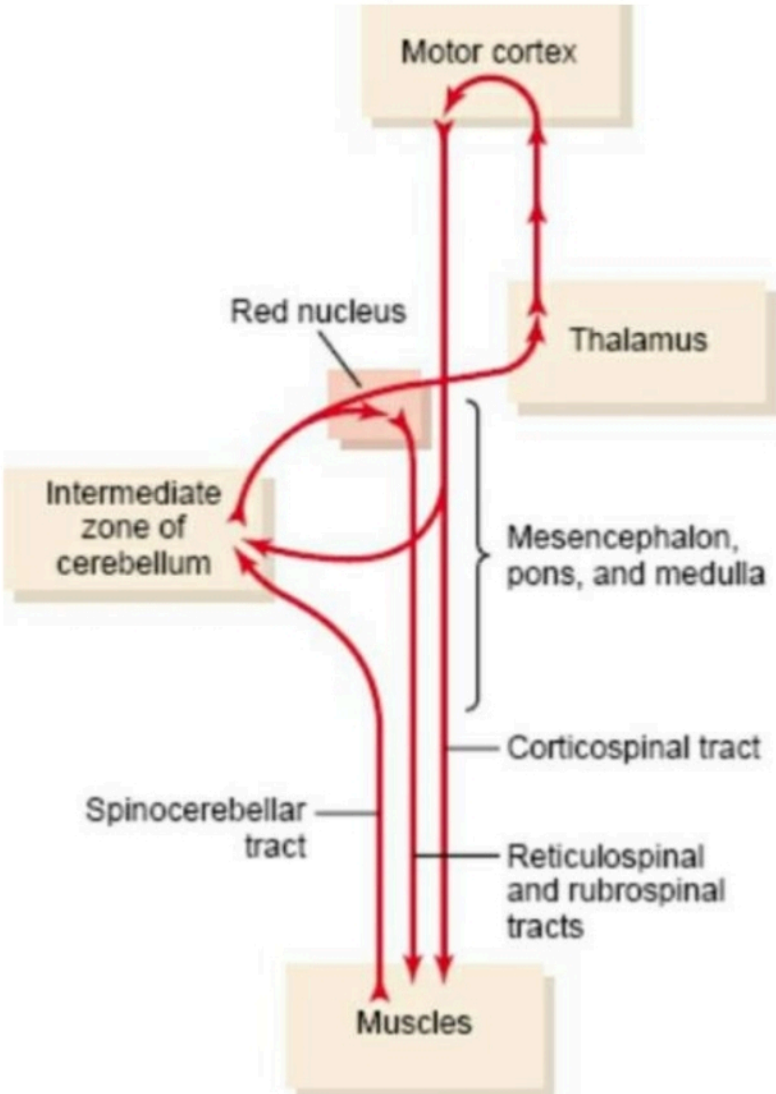
Image 4➡️


Motor cortex
Red nucleus
Thalamus
Intermediate zone of cerebellum
Mesencephalon, pons, and medulla
Corticospinal tract
Spinocerebellar tract
Reticulospinal and rubrospinal tracts
Muscles