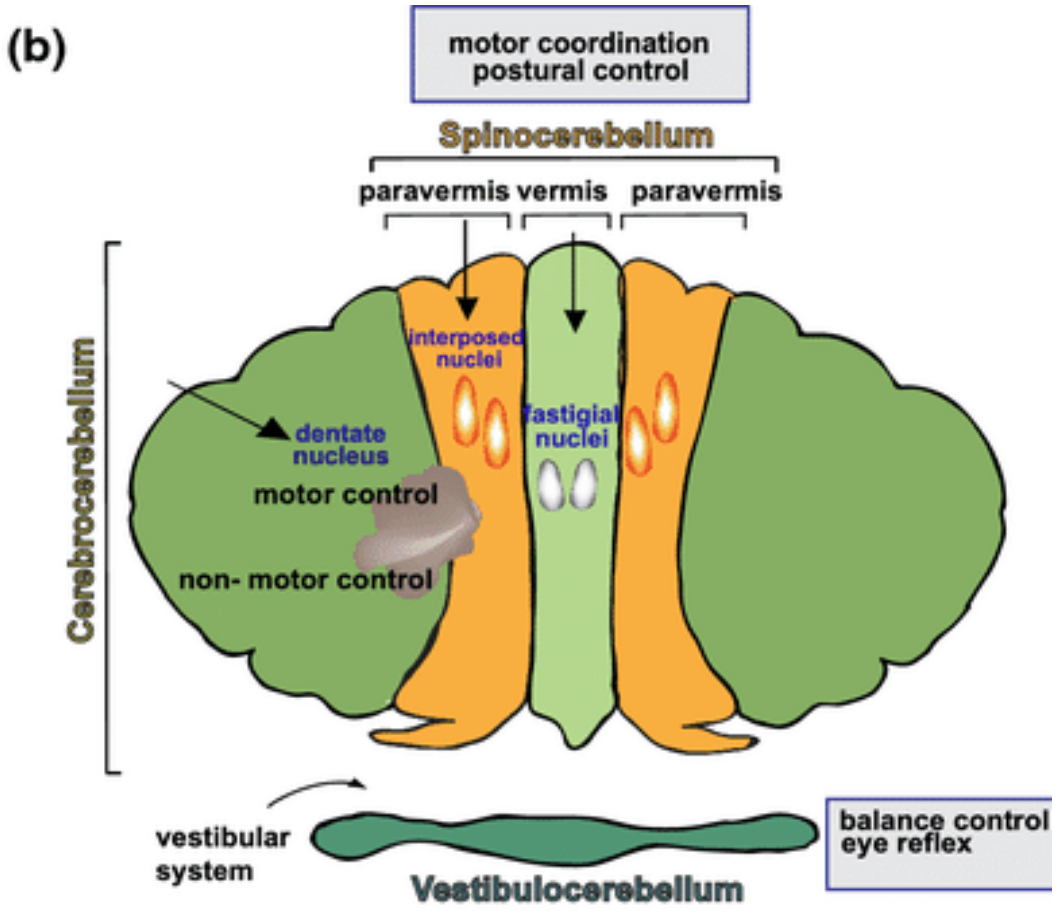
Cerebellum



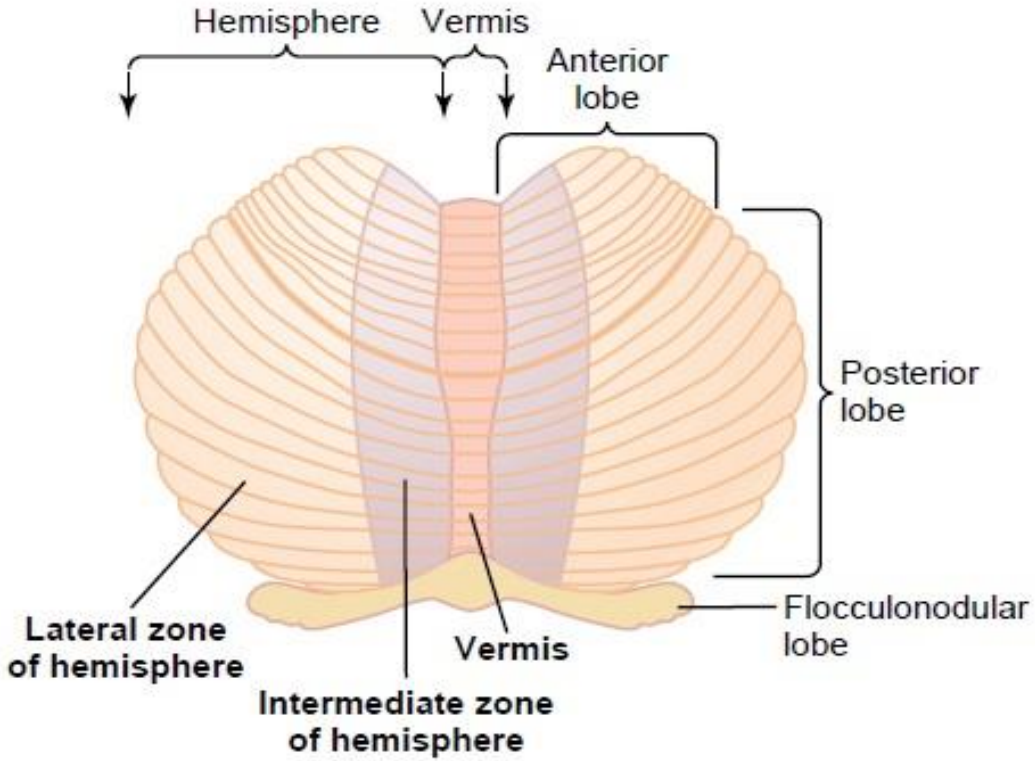


Figure 56–2

Functional parts of the cerebellum as seen from the posteroinferior view, with the inferiormost portion of the cerebellum rolled outward to flatten the surface.

• The cerebellum consists of an outer layer of gray matter (the cortex), internal white matter (input and output fibers).

• It has three pairs of deep nuclei:

✓ the fastigial nucleus,

✓ the interposed nucleus(globose and emboliform)

✓ the dentate nucleus.

• All the inputs to the cerebellum go first to one of these three deep cerebellar nuclei and then go on to the cortex.

• All the outputs of the cerebellum go back to the deep nuclei, before going on to the cerebral cortex or the brainstem.

• ➢ ➢

Divided into three phylogenetic zones

a) **Flocculonodular lobe (Vestibulocerebellum).**
b) **Vermis and Intermediate Hemispheres (Spinocerebellum).**
c) **Lateral Hemispheres (Cerebrocerebellum).**

Flocculonodular lobe (Vestibulocerebellum)

- Receives inputs from both the visual system and the vestibular system.
- Its outputs return to the vestibular nuclei.
- It functions in the control of the axial muscles, which are used in equilibrium control.
- If a patient experiences dysfunction in this system, one observes an **ataxic gait, wide-based stance and nystagmus.**

Vermis and Intermediate Hemispheres (Spinocerebellum).

- receive proprioceptive and cutaneous inputs from spinal cord (via the spinocerebellar tracts), in addition to visual, vestibular , and auditory information.
- There are four spinocerebellar tracts that relay information from the spinal cord to the cerebellum.
- Two tracts relay information from the arms and the neck and two relay information from the trunk and legs.
- Outputs:

✓ **brainstem reticular formation.**

✓ **Vestibular nuclei.**

✓ **Thalamus and motor cortex.**

✓ **Red nucleus in the midbrain.**

- **Functions of spinocerebellum**:

1) Correct for deviations from an intended movement through comparing feedback from the spinal cord with the intended motor command.

2) Modulate muscle tone: through the continuous output of excitatory activity from the fastigial and interposed nucleus, which modulates the activity of the gamma motor neurons to the muscle spindles. Lesions in these nuclei : **hypotonia**.

3) Involved in feedforward mechanisms to regulate movements(send information to brain to prepare to incoming order).

Lateral Hemispheres (Cerebrocerebellum).

- **Inputs**: from the pontine nuclei in the brainstem, which relay information from wide areas of the cerebral cortex (sensory, motor, premotor and posterior parietal).
- **Outputs**: to the thalamus and then to the motor, premotor, and prefrontal cortex .
- It has motor and non-motor functions.

motor and non-motor functions

- Involved in the planning or preparation of movement and the evaluation of sensory information for action as a part of the motor learning process.
- Participate in programming the motor cortex for the execution of movement.

e.g Lateral cerebellar lesions disrupt the timing of movements, so that joints are moved sequentially rather than simultaneously. This deficit is referred to as Decomposition of movement(no smooth / fragmentation).

- Non motor functions, including cognition .

The primary functions of the cerebellum

- Regulation of movement, coordination of the movements (Reversing the movement from agonist to antagonist).
- Timing.
- error detector, and corrector functions.
- Regulation of postural control and balance
- Regulation of muscle tone.
- Motor learning.
- Cognitive function.

N.B Cerebral blood flow has shown that there is an increase in cerebellar activity when subjects are asked only to imagine making a movement.

- Lesions have been noted to produce typical patterns of **impaired motor function and balance and decreased muscle tone.**

Comparator and error-correcting mechanism

- The cerebellum compares the commands for the intended movement transmitted from the motor cortex with the actual motor performance of the body segment.
- This occurs by a comparison of information received from the cortex with that obtained from peripheral feedback mechanisms.
- The motor cortex and brainstem motor structures provide the commands for the intended motor response **(internal feedback).**
- Peripheral feedback during the motor response is provided by muscle spindles, Golgi tendon organs, joint and cutaneous receptors, the vestibular apparatus, and the eyes and ears (**external feedback).**
- This feedback provides continual input regarding posture and balance, as well as position, rate, rhythm, and force of slow movements of peripheral body segments.
- If the input from the feedback systems does not compare appropriately (i.e., movements deviate from the intended command), the cerebellum supplies a corrective influence. This effect is achieved by corrective signals sent to the cortex, which, via motor pathways, modifies or corrects the ongoing movement (e.g., increasing or decreasing the level of activity of specific muscles).

Feedforward control

- Is the sending of signals in advance of movement to ready a part of the system for incoming sensory feedback or for a future motor command.
- It allows for anticipatory adjustments in postural activity.
- An example of a feedforward system is the preadaptation for exercise, changing the activity of postural muscles and of the vascular system in order to ready the body for the movement when it occurs.
- e.g Salivation in response to taste or smell or even thought of food.

Feedback

- Is response-produced sensory information received **during or after the movement** and is used to **monitor movement output for corrective actions.**
- To determine presence of error or used directly in the modulation of movements reflexively(during the movement).
- To determine the success of the response and contribute to motor learning(after the movement).
- Before the movement as information about the initial position, or perhaps to tune the spinal apparatus(**Feedforward).**
- During the movement, when it is either monitored for the presence of error or used directly in the modulation of movements reflexively (**Feedback).**
- After the movement to determine the success of the response and contribute to motor learning (**Feedback).**

Basal Ganglia

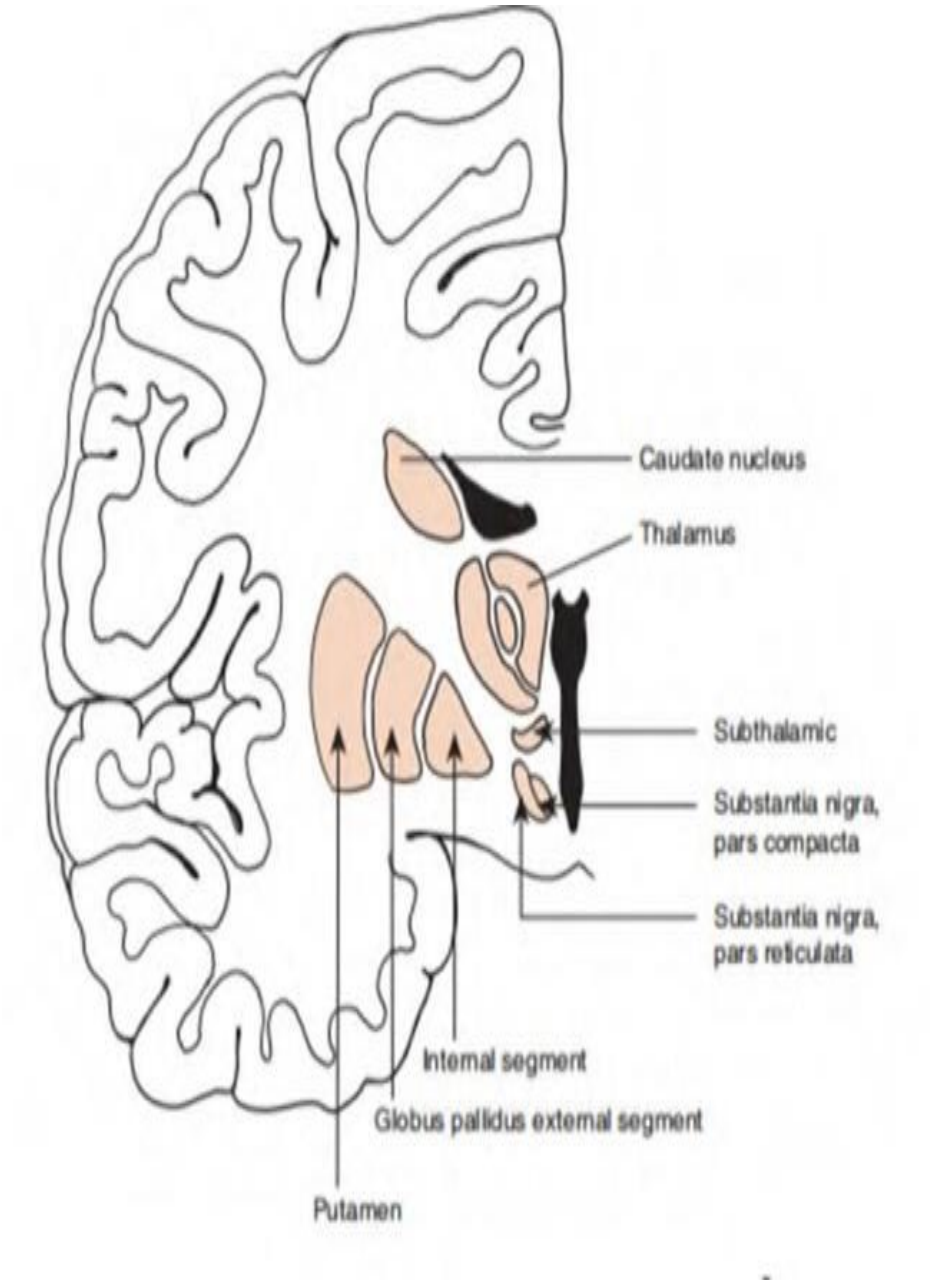
The basal ganglia are a group of nuclei located at the base of the cerebral cortex.

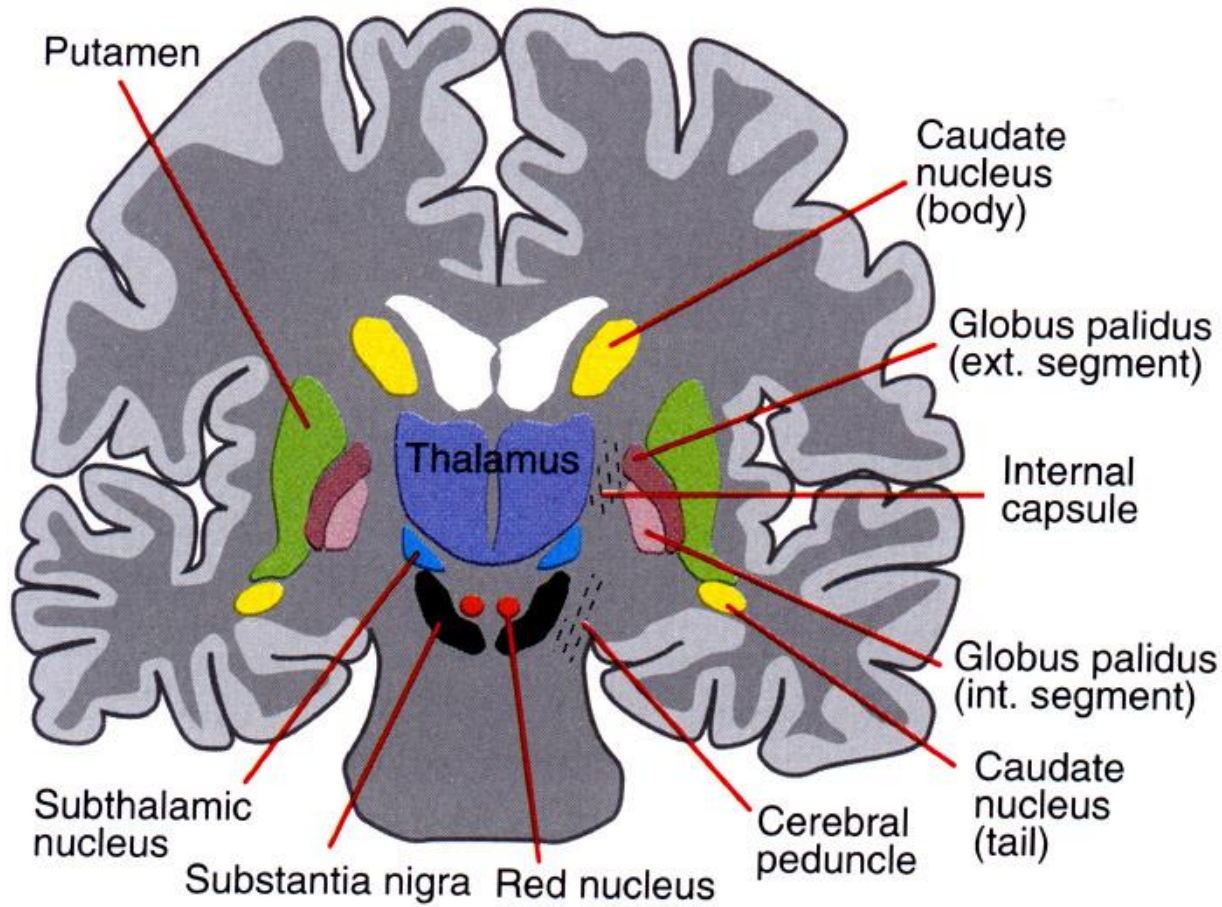
The three main nuclei (anatomical) of the basal ganglia are

- ✓ **caudate nucleus**
- ✓ **putamen**
- ✓**Globus pallidus(internal-external).**
- ✓Corpus striatum (caudate and putamen).
- ✓Lenticular / lentiform nucleus (putamen & globus pallidus).

The two functional nuclei

- ✓**the subthalamic nucleus.**
- ✓**the substantia nigra**




Putamen
Caudate nucleus (body)
Globus palidus (ext. segment)
Thalamus
Internal capsule
Globus palidus (int. segment)
Caudate nucleus (tail)
Subthalamic nucleus
Substantia nigra
Red nucleus
Cerebral peduncle

- Patients with damage to the basal ganglia are not paralyzed but have problems with the coordination of movement.
- It is a part of the extrapyramidal motor system, which was believed to act in parallel with the pyramidal system (the corticospinal tract) in movement control.
- Pyramidal problems as relating to spasticity and paralysis.
- Extrapyramidal problems were defined as involuntary movements (tremors/dyskinesia/athetosis/ chorea) and rigidity.
- The pyramidal and extrapyramidal systems are not independent, but work together in controlling movements.

Inputs & Outputs

Inputs

- The main input nuclei of the basal ganglia complex are the caudate and putamen.
- Their primary inputs are from:

Sensory, motor, and association areas (Alexander & Crutcher, 1990).

Outputs

- Major output areas: The internal segment of the globus pallidus (internal GP) and the substantia nigra (SN) .
- Their outputs terminate in:

The prefrontal, supplementary, and premotor cortex areas, by way of the thalamus.

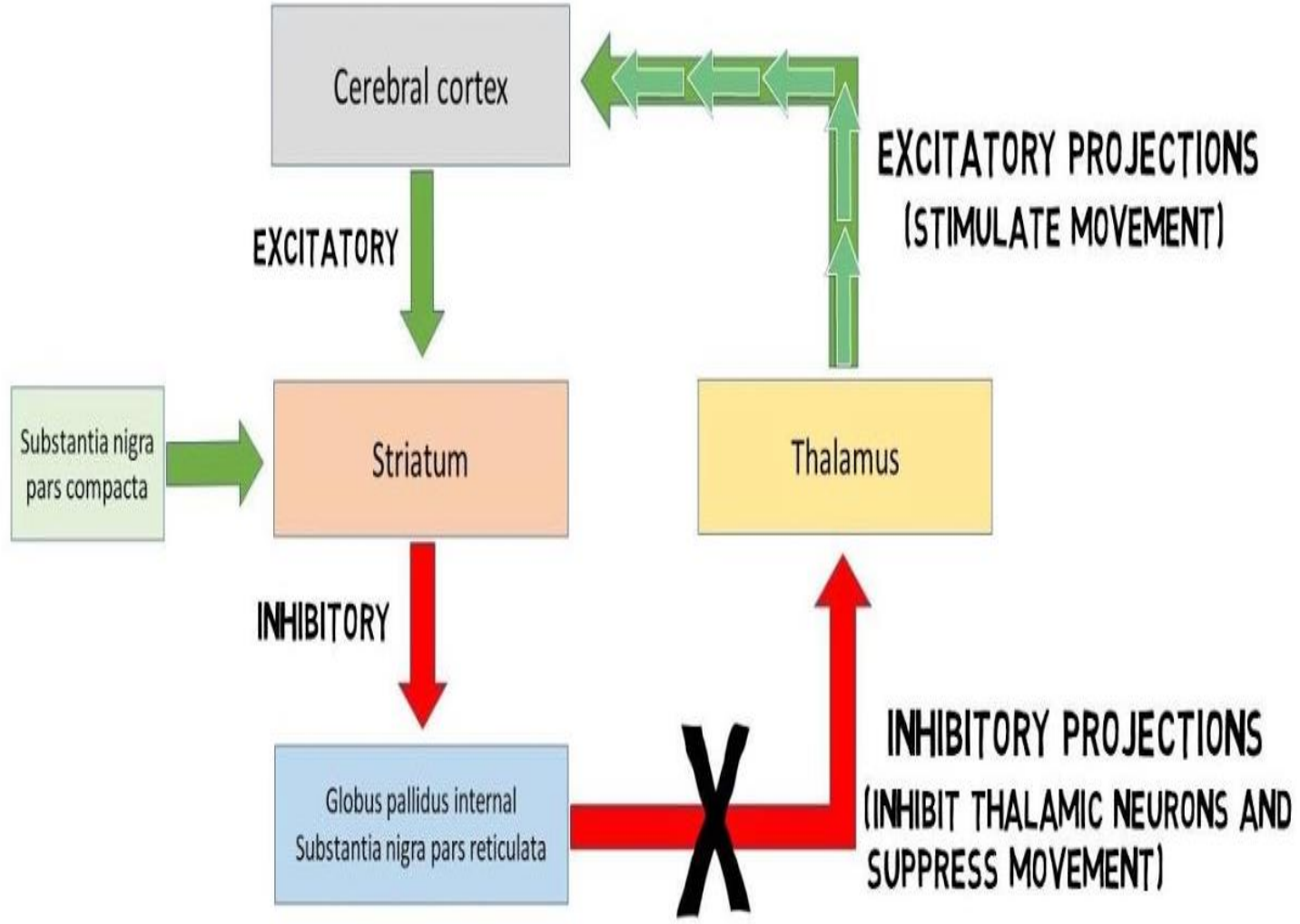
Basal ganglia loops/circuits

- BG engages in several parallel circuits or loops, only a few of which are motor(**The direct motor loop & Indirect loop).**
- It consist of four different functional circuits that also include the thalamus and the cortex.

1) The skeletomotor circuit (including the premotor cortex, supplementary motor cortex and primary motor cortex).
2) The oculomotor circuit (including the frontal and supplementary eye fields of the cortex).
3) The prefrontal circuits (cognitive & personality).
4) The limbic circuit(memory motivation/behavior/ sexual activity).

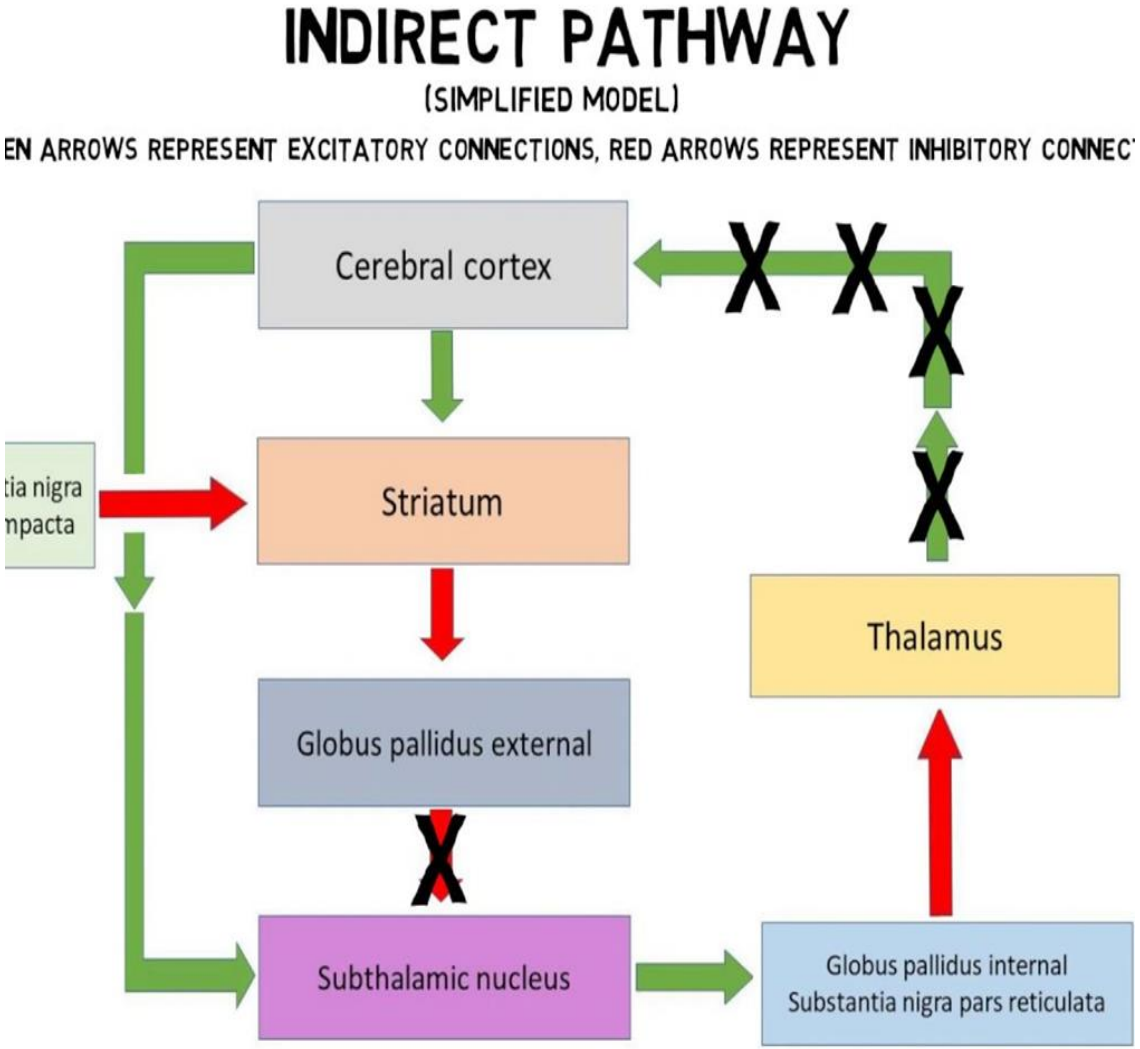
The direct motor loop(excitatory)

- it consists of signals transmitted from the cortex to putamen to globus pallidus, to ventrolateral (VL) nucleus of the thalamus , and back to cortex mainly **supplementary motor area (SMA).**
- Cortex >>>Putamen/caudat >>>Globus Pallidus (internal) ,SN >>>VLN of thalamus >>> facilitate Cortex.
- **Cortex >>>+++ (glutamate) striatum** connect with **SN (dopamine) >>>----Globus Pallidus (internal) >>>------ (GABA) VLN of thalamus >>> facilitate Cortex.**
- The BG thus serves to activate the cortex via a positive-feedback loopand assists in the initiation of voluntary movement.



Indirect loop(inhibitory)

- This indirect loop serves to decrease thalamocortical activation.
- Cortex>> striatum>> globus pallidus external>>subthalamic nucleus>> substantia nigra, globus pallidus internal >> thalamus>> inhibit cortex.
- Cortex>> striatum connect to SN (dopamine) >>>>---------- globus pallidus external>>--------- subthalamic nucleus>>+++ globus pallidus internal >>>> -------thalamus >> inhibit cortex.



others

- The BG projection >>> superior colliculus >>> assists in regulation of saccadic eye movements (lesion problem in eye movement control).
- The BG projection >>> reticular formation >>> assists in the regulation of Trunk and limb musculature (via extrapyramidal pathways).

•The BG projection >>> reticular formation >>> assists in the regulation of :

- ✓ Trunk and limb musculature (via extrapyramidal pathways)
- ✓ Sleep and wakefulness arousal.

• Other circuits in the BG are involved with memory and cognitive functions (prefrontal area).

Basal Ganglia functions

1. Initiation(to SMA), preparation and regulation of gross intentional movements.
2. Planning and execution of complex motor responses.
3. Facilitation of desired motor responses while selectively inhibiting others(direct , indirect loops).
4. The ability to accomplish automatic movements and postural adjustments (reticular formation).
5. Control of saccadic eye movements(oculomotor circuit).
6. Non motor : Executive functions, including organizing behaviors using verbal skills in problem solving and mediating socially appropriate responses(prefrontal circuit)(lesion lead to obsessive-compulsive disorder).
7. Control of motivated behavior (involving circuits for reinforcing stimuli for behaviors),and procedural learning/ automatic movement (The limbic circuit).
8. Maintaining normal background muscle tone.
9. Inhibitory effect on both the motor cortex and lower brainstem.
10. Influencing some aspects of both perceptual and cognitive functions.

Basal ganglia lesion

- Poverty and slowness of movement.
- Disorders of muscle tone and postural reflexes.
- Parkinson‘s disease symptoms include resting tremor, increased muscle tone or rigidity, and slowness in the initiation of movement (akinesia) as well as in the execution of movement (bradykinesia).
- The tremor and rigidity may be due to loss of inhibitory influences within the basal ganglia.
- Other diseases of the basal ganglia produce involuntary movements

Cerebellum and basal ganglia

- Basal ganglia may be particularly concerned with internally generated movements, while the cerebellum is involved in visually triggered and guided movement.

N.B Parkinson‘s disease with frozen gait syndrome (difficulty initiating or maintaining gait) can use visual cues to improve their walking . That suggests that this may be due to the use of alternative pathways from the cerebellum to trigger and guide the movements.