Basal nuclei

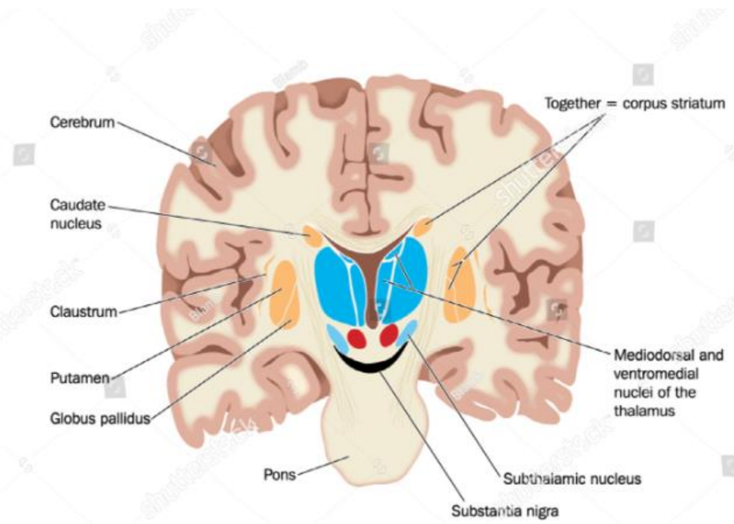
Nuclei: a collection of neuronal cell bodies inside the CNS

Basal nuclei functions:

1)along with higher cerebral centers help plan and control complex patterns of muscle movement

2) i interpret motor decisions provided by pre motor and prefrontal areas , and consequently prioritize some , and reject others and even modify the pattern of some.

Note: the basal nuclei receive an input of the cortical motor plans and send back the control signals of final plan, this requires the basal nuclei to be in direct contact with the pre motor and pre frontal cortex and related cortical areas to perform the final controlled, motor outcome ,this connection is bridged by means of neural circuits linking in between.



Basal nuclei:

1- Putamen

2- Caudate

3-Globus Palllidus (internal &external)

4-subthalamic nuclei

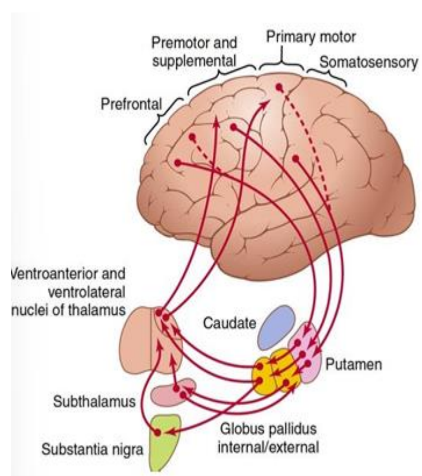
5-Substantia nigra (it anatomically belongs to the midbrain)

Note: They are all surrounded by white matter

Putamen+globus pallidus=lentiform structure

Putamen+ caudate=striatum

Note: Almost all motor corticospinal and sensory nerve fibers connecting the cerebral cortex and spinal cord pass through the space that lies between the caudate nucleus and the putamen: the internal capsule of the brain.



Putamen circuit

Putamen circuit starts and returns back to the cortex passing through the following basal structures : putamen- Globus pallidus (interna and externa) – subthalamus substantia nigra – ventroanterior and ventrolateral thalamic nuclei

Putamen circuit controls motor activity on the complex level

Input: mainly from somatosensory area; pre motor ,supplementary& pre frontal areas but not much from the primary motor cortex itself. Inputs complete all the way through basal nuclei, to the ventroanterior and ventrolateral thalamic motor nuclei

Note: This wide input aids in enabling the basal nuclei to process the best consultation and prioritization of motor plans with regard to the whole status of body, and decide which plans should be prioritized ,accomplished and approved which plans to be diminished.

Output: go mainly back to the primary motor cortex or closely associated premotor and supplementary cortex to perform the final controlled plan on the related motor units, through the thalamus.

Till reaching the thalamus ,Putamen circuit involves two pathways , the direct and indirect , which differ in the basal nuclei to pass through , and therefore their resultant control signals are completely different .

Excitation of the direct pathway has the net effect of exciting thalamic neurons (which in turn make excitatory connections onto cortical neurons). Excitation of the indirect pathway has the net effect of inhibiting thalamic neurons (rendering them unable to excite motor cortex neurons) The normal functioning of the basal ganglia apparently involves a proper balance between the activity of these two pathways.

Direct pathway:

putamen —(-ve)→ Globus Palladis interna —(-ve)→ motor thalamic nuclei.

Notice that the inhibitory "putamen to the Globus palladis interna" signal suppresses the inhibitory effect of the subsequent signal from "Globus palladis interna to the thalamic nuclei " Ultimately the inhibitory effect of basal nuclei on thalamus is diminished , and motor thalamic nuclei can perform their excitatory glutamate-mediated output on the planning motor fibers which sent this input , and the basal approval is confirmed towards the premotor and primary cortical areas . Therefore; the net effect of direct pathway is said to be excitatory ; in which motor plans are approved and the related skeletal excitation-contraction coupling takes place

Indirect pathway:

- The indirect pathway passes through putamen. —(-ve)→ Globus pallidus external —(-ve)→ Sub thalamic —(+ve)→ Globus pallidus interna —(-ve)→ motor thalamic nuclei .

initially "putamen to Globus pallidus externa " inhibitory signal suppresses the inhibitory "globus pallidus externa to sub thalamic"signal . Soon after, the sub thalamic nucleus is excited to perform its extraordinary basal excitatory effect on the inhibitory" Globus pallidus interna" , this collectively allows the inhibitory signal of "Globus pallidus interna to thalamus" to take place . And the thalamus is inhibited from producing its excitatory effect on the motor plan , and the basal rejection is confirmed , no skeletal excitation-contraction coupling is there . That's why the indirect putamen pathway is said to be inhibitory , it shunts the signal to the sub thalamic nuclei to re-obtain the inhibitory basal effect

note: Neuronal-transmitted signals in between basal nuclei in the circuit are all inhibitory, in which GABA neurotransmitter is critical , except for the sub thalamic Globus palladis interna signal.

After analyzing the general input to the neural circuit, signals of appropriate motor activities are transmitted to be integrated in the direct pathway to be excited and fired , whereas the inappropriate activities are turned off through

Nigrostriatal projection

An important pathway in the modulation of the direct and indirect pathways is the dopaminergic(dopamine releasing) nigrostriatal projection from the substantia nigra pars compacta to the striatum (again to the putamen).

1)Direct pathway striatal neurons have D1 dopamine receptors, which depolarize the putamen cell in response to dopamine.

2)indirect pathway striatal neurons have D2 dopamine receptors, which hyperpolarize the cell in response to dopamine.

Nigrostriatal projection generally has an excitatory effect on both direct and indirect signals of motor plans .Because of this dual effect, excitation of the nigrostriatal pathway has the net effect of exciting cortex by two routes, by exciting the direct pathway (which itself has a net excitatory effect on cortex) and inhibiting the indirect pathway (thereby disinhibiting the net inhibitory effect of the indirect pathway on cortex).

The loss – degeneration- of these dopamine neurons and consequent impairment of – direct and indirect-excitatory dopaminergic signals on different levels in Parkinson's disease causes the poverty of movement , as inhibitory indirect signals will override , that characterizes this disease, as the balance between direct pathway excitation of cortex and indirect pathway inhibition of cortex is tipped in favor of the indirect inhibitory pathway, with a subsequent pathological global inhibition of motor cortex areas, therefore, Parkinson's patients suffer from problematic initiation, along with slowing of movement.

lesions

- **globus pallidus**: spontaneous & continuous writhing movements of hand,arm, neck & face. aka**: Athetosis**
- **subthalamus**: lesions in it lead to sudden failing movements of an entire limb. aka:**Hemiballismus**
- **putamen**: flicking movemnts in the hands , face,& other parts. aka:**Chorea**
- **substantia nigra**: extremly severe disease of rigidity.akenesia & tremors. aka:**Parkinson's disease**

The caudate circuit

This circuit plays a major role in cognitive control of motor activity.

The term cognition means the thinking processes of the brain, using both sensory input to the brain plus information already stored in memory.

the caudate nucleus extends into all lobes of the cerebrum

input: from association areas of the cerebral cortex overlying the caudate nucleus

Passing through Striatum, Caudate nuclei , plans in the caudate circuit reach Globus Pallidus interna before continuing to the thalamus, the only relying station toward the prefrontal cortical area which specializes in cognition-based motor decision making .(Almost none of the returning signals passing directly to the primary motor cortex) Instead, the returning signals go to the accessory motor regions in the premotor and supplementary motor areas that are concerned with building sequential patterns of movement lasting 5 seconds or more instead of exciting individual muscle movements

cognitive control of motor activity determines subconsciously, and within seconds, which patterns of movement will be used together to achieve a complex goal that might itself last for many seconds, through caudate circuit (determines timing and scaling)

Two important capabilities of the brain in controlling movement are to

(1) determine how rapidly the movement is to be performed (timing)

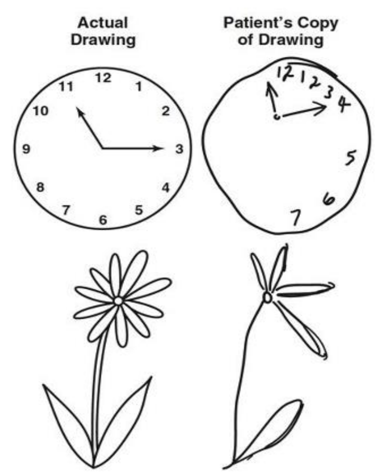
(2) control how large the movement will be.(scaling)

In patients with severe lesions of the basal ganglia, these timing and scaling functions are poor

Posterior parietal cortex

An important cortical area that collaborates with the basal nuclei , which is the locus of the spatial coordinates of objects or of body parts . for motor control of all parts of the body, as well as for the relationship of the body and its parts to all its surroundings.

Agnosia : inability to spatially perceive objects or body parts accurately on one side of the body through normally functioning sensory mechanisms due to lesions of the posterior parietal cortex .(they simply forget this side would exist, and aren't aware of this defect)

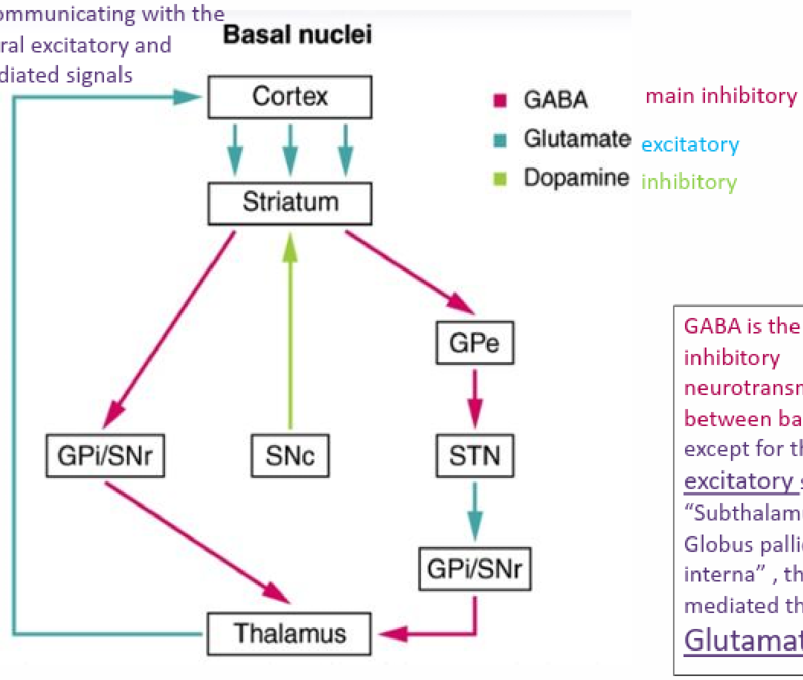


Note: a person with agnosia will always try to avoid using his or her left arm, left hand, or other portions of his or her left body for the performance of tasks; the person may not even wash this side of the body (personal neglect syndrome), almost not knowing that these parts of the body exist

So in between basal nuclei or communicating with the surrounding structures are several excitatory and inhibitory neurotransmitter-mediated signals

Substantia nigra controls basal nuclei through inhibitory dopamine

“Thalamic to Cortical“ signal is always excitatory by means of glutamate.



GABA is the main inhibitory neurotransmitter between basal nuclei , except for the excitatory signal from “Subthalamus to Globus pallidus interna” , that is mediated through Glutamate.

diseases affecting the basal nuclei:

Parkinson’s disease	Huntington’s disease	Tourette syndrome
It is a is disease of substantia nigra Symptoms: 1-motor (in photo)  2-cognitive:memory loss, dementia,depression and behavioral changes. 3- Rigidity (increase in the muscle tone)because there is a relationship between basal nuclei and the reticular formation(reticulospinal pathway)	an inherited (Autosomal Dominant) disorder in which the caudate nucleus and putamen degenerate, with loss of neurons that normally release GABA or ach. **Key sign:** chorea , in which rapid, jerky movements occur involuntarily limbs and without purpose. Progressive mental deterioration also occurs. Symptoms of HD often do not appear until age 30 or 40. Death occurs 10 to 20 years after symptoms first appear	**Features:** 1-involuntary body movements (motor tics) 2- the use of inappropriate or unnecessary sounds or words (vocal tics). **Cause: unknown,** could be a dysfunction of the cognitive neural circuits between the basal nuclei and the prefrontal cortex

Note: Some psychiatric disorders, such as schizophrenia and obsessive compulsive disorder, are thought to involve dysfunction of the behavioral neural circuits between the basal nuclei and the limbic system.

Functions of basal nuclei

Initiation of movements	**Suppression of unwanted movements**	**Regulation of muscle tone**	**Regulation of nonmotor processes**
Neurons of the basal nuclei receive input from sensory, association, and motor areas of the cerebral cortex. Output from the basal nuclei is sent by way of the thalamus to the premotor area, which in turn communicates with upper motor neurons in the primary motor area, then activate the corticospinal and corticobulbar tracts to promote movement.	suppress unwanted movements by tonically inhibiting the neurons of the thalamus that affect the activity of the upper motor neurons in the motor cortex. When a particular movement is desired, the inhibition of thalamic neurons by the basal nuclei is removed, which allows the thalamic neurons to activate the appropriate upper motor neurons in the motor cortex	Neurons of the basal nuclei send action potentials into the reticular formation that reduce muscle tone via the medial and lateral reticulospinal tracts. Damage or destruction of some basal nuclei connections causes a generalized increase in muscle tone	he basal nuclei influence several nonmotor aspects of cortical function, including sensory, limbic, cognitive, and linguistic functions. For example, the basal nuclei help initiate and terminate some cognitive processes, such as attention, memory, and planning In addition, the basal nuclei may act with the limbic system to regulate emotional behaviors