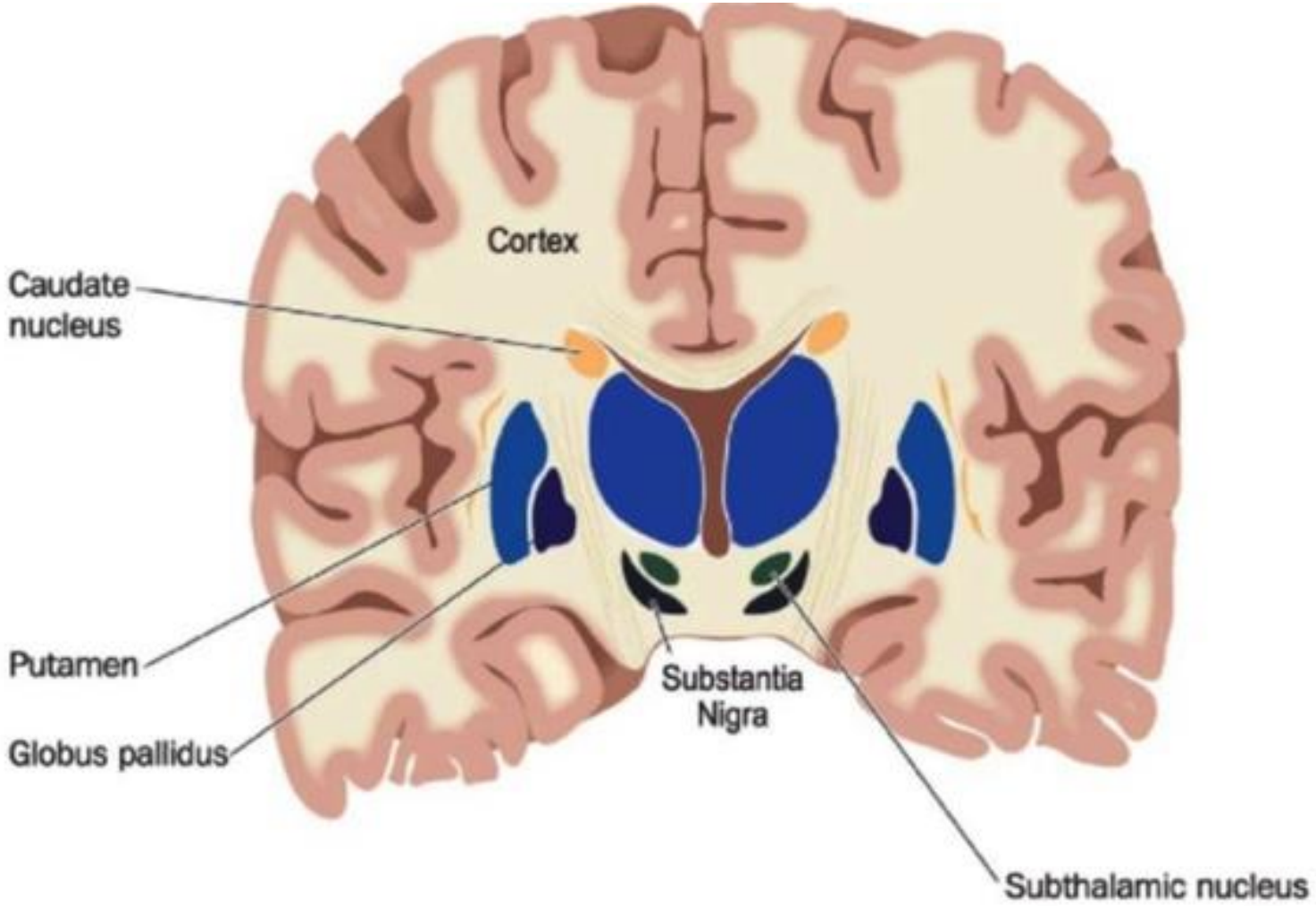
Neurophysiology

Basal nuclei

Fatima Ryalat, MD, PhD



MR Spectroscopy Findings of the Basal Ganglia in Bipolar Disorders: a Systematic Review. June 2018Current Psychiatry Reviews 14(2). Hanjing Emily Wu et al.

Basal nuclei

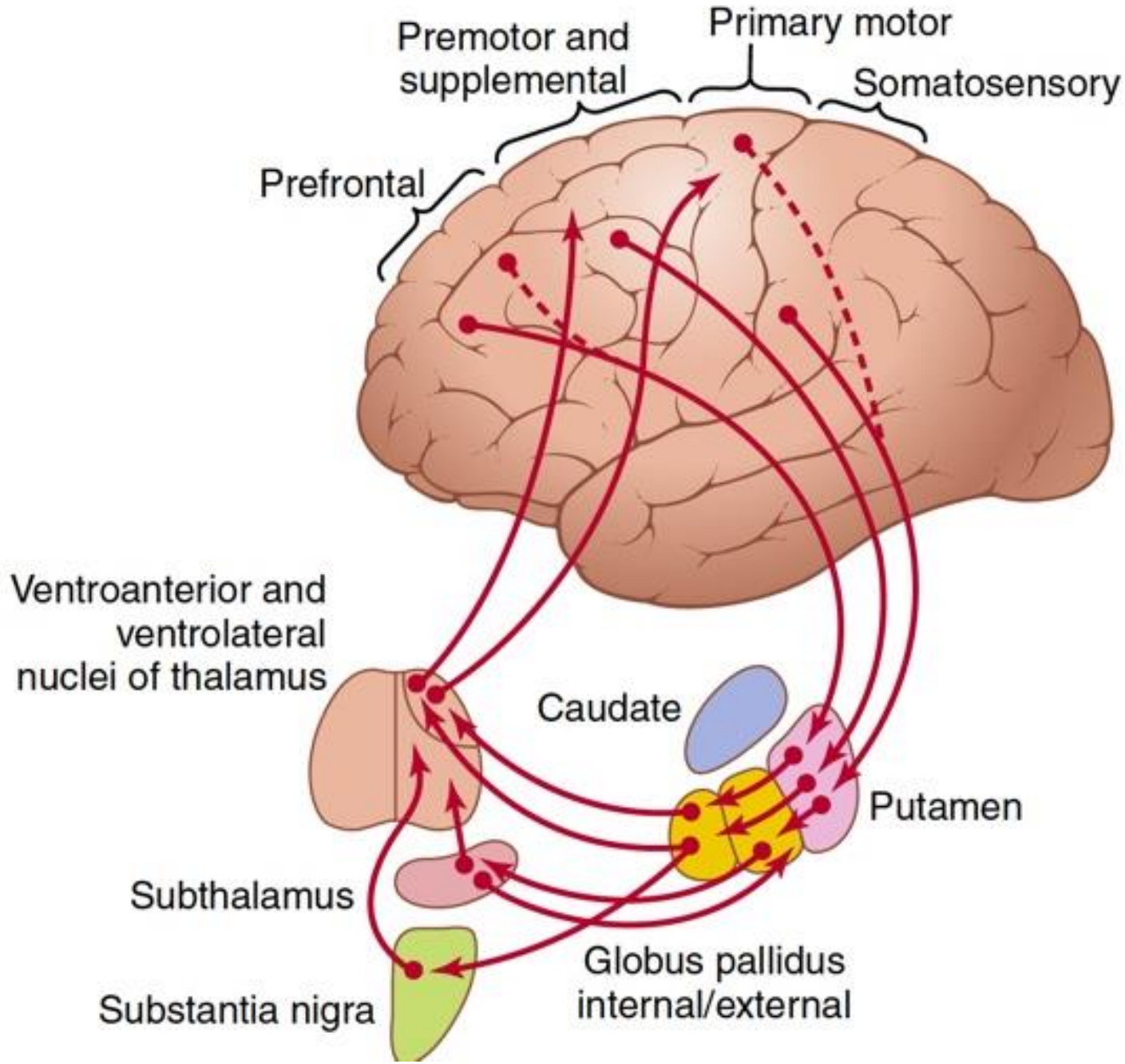
- The basal nuclei help plan and control complex patterns of muscle movement.
- They control relative intensities of the separate movements, directions of movements, and sequencing of multiple successive and parallel movements to achieve specific complicated motor goals.

- the basal nuclei receive most of their input signals from the cerebral cortex and also return almost all their output signals back to the cortex.

- Almost all motor 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. An intimate association between the basal nuclei and the corticospinal system for motor control.

Putamen circuit

- One of the principal roles of the basal ganglia in motor control is to function in association with the corticospinal system to control complex patterns of motor activity.


Premotor and supplemental
Primary motor
Somatosensory
Prefrontal
Ventroanterior and ventrolateral nuclei of thalamus
Caudate
Putamen
Subthalamus
Globus pallidus internal/external
Substantia nigra

Putamen circuit

- the putamen circuit has its inputs mainly from the parts of the brain adjacent to the primary motor cortex but not much from the primary motor cortex itself.

- Then its outputs do go mainly back to the primary motor cortex or closely associated premotor and supplementary cortex.

Direct vs indirect pathway

- There are two distinct pathways that process signals through the basal ganglia: the direct pathway and the indirect pathway.

- These two pathways have opposite net effects on thalamic target structures.

- Excitation of the direct pathway has the net effect of exciting thalamic neurons (which in turn make excitatory connections onto cortical neurons).

Direct vs indirect pathway

- 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.

https://nba.uth.tmc.edu/neuroscience/m/s3/chapter04.html

Nigrostriatal projection

- An important pathway in the modulation of the direct and indirect pathways is the dopaminergic, nigrostriatal projection from the substantia nigra pars compacta to the striatum.
- Direct pathway striatal neurons have D1 dopamine receptors, which depolarize the cell in response to dopamine.
- In contrast, indirect pathway striatal neurons have D2 dopamine receptors, which hyperpolarize the cell in response to dopamine.

https://nba.uth.tmc.edu/neuroscience/m/s3/chapter04.html

Nigrostriatal projection

- The nigrostriatal pathway thus has the dual effect of exciting the direct pathway while simultaneously inhibiting the indirect pathway.
- 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).

https://nba.uth.tmc.edu/neuroscience/m/s3/chapter04.html

Nigrostriatal projection

- The loss of these dopamine neurons in Parkinson's disease causes the poverty of movement 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 pathway, with a subsequent pathological global inhibition of motor cortex areas.

https://nba.uth.tmc.edu/neuroscience/m/s3/chapter04.html

Globus pallidus

- lesions in the globus pallidus frequently lead to spontaneous and often continuous writhing movements of a hand, an arm, the neck, or the face. These movements are called **athetosis**.

Subthalamus

- A lesion in the subthalamus often leads to sudden flailing movements of an entire limb, a condition called **hemiballismus**.

Putamen

- Multiple small lesions in the putamen lead to flicking movements in the hands, face, and other parts of the body, called **chorea**.

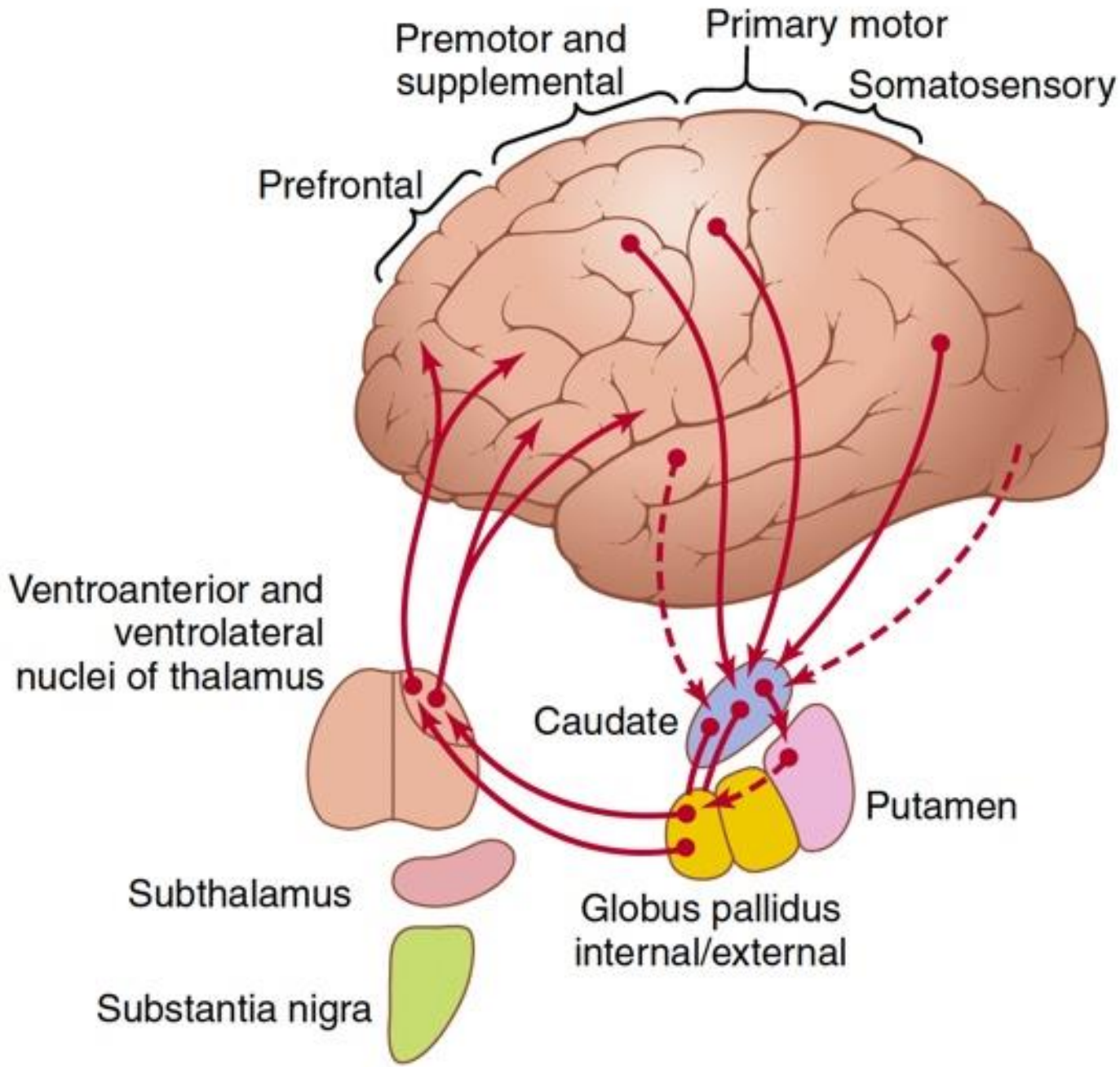
Substantia nigra

- Lesions of the substantia nigra lead to the common and extremely severe disease of rigidity, akinesia, and tremors known as **Parkinson's disease**

The caudate circuit

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

- Most of our motor actions occur as a consequence of thoughts generated in the mind, a process called cognitive control of motor activity.
- The caudate nucleus plays a major role in this cognitive control of motor activity.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The caudate circuit

- the caudate nucleus extends into all lobes of the cerebrum.

- the caudate nucleus receives large amounts of its input from the association areas of the cerebral cortex overlying the caudate nucleus, mainly areas that also integrate the different types of sensory and motor information into usable thought patterns.

The caudate circuit

- 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.

The caudate circuit

- 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.

Timing and scaling of movement

- Two important capabilities of the brain in controlling movement are to
- (1) determine how rapidly the movement is to be performed
- (2) control how large the movement will be.

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

Posterior parietal cortex

- the basal ganglia do not function alone; rather, they function in close association with the cerebral cortex.

- One especially important cortical area is the posterior parietal cortex, which is the locus of the spatial coordinates 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.

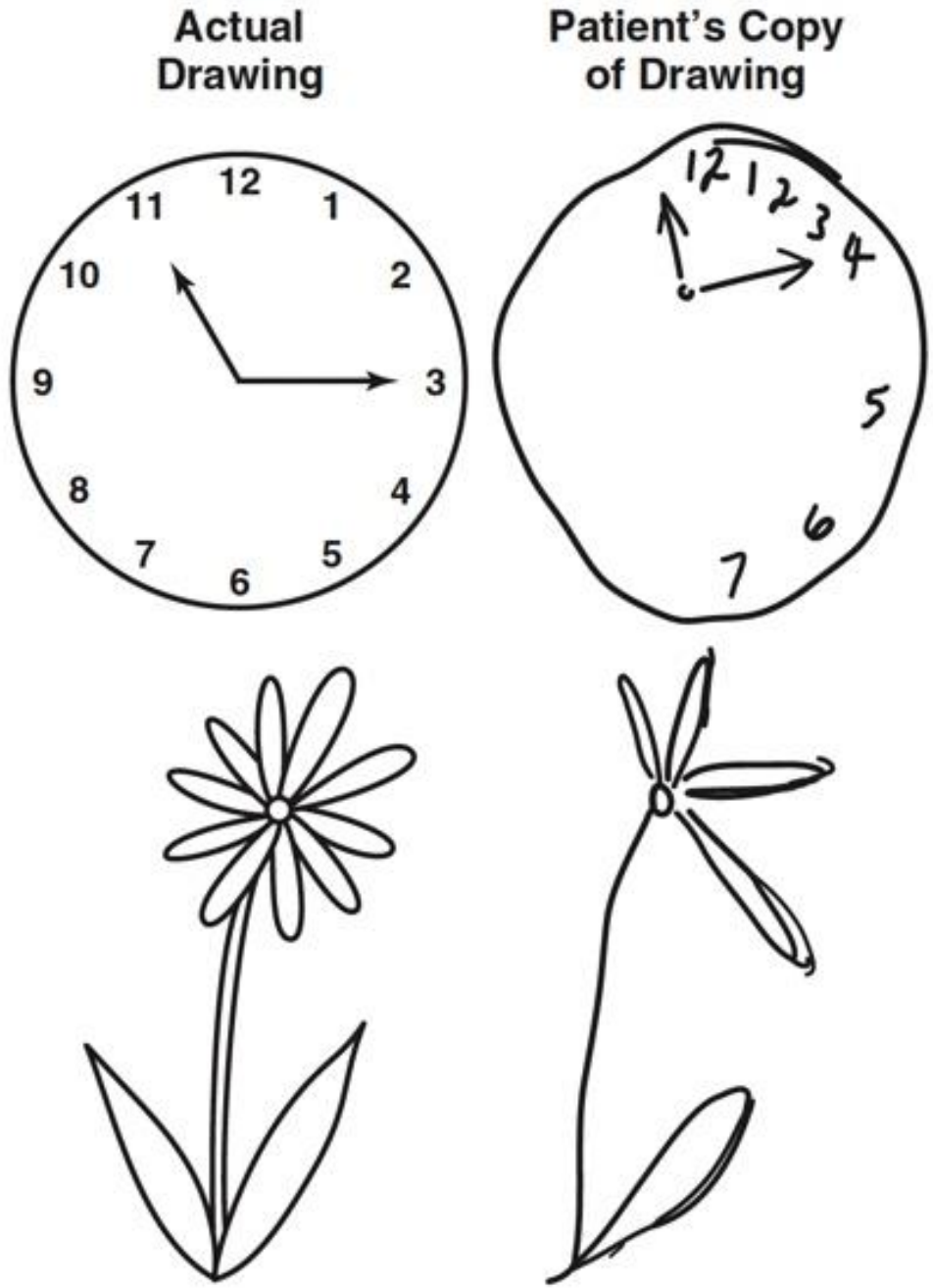
Posterior parietal cortex

- Damage to this area does not produce simple deficits of sensory perception, such as loss of tactile sensation, blindness, or deafness.

- Instead, lesions of the posterior parietal cortex produce an inability to perceive objects accurately through normally functioning sensory mechanisms, a condition called **agnosia**.

Posterior parietal cortex

- Also, such a person 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.


Actual Drawing
Patient's Copy of Drawing
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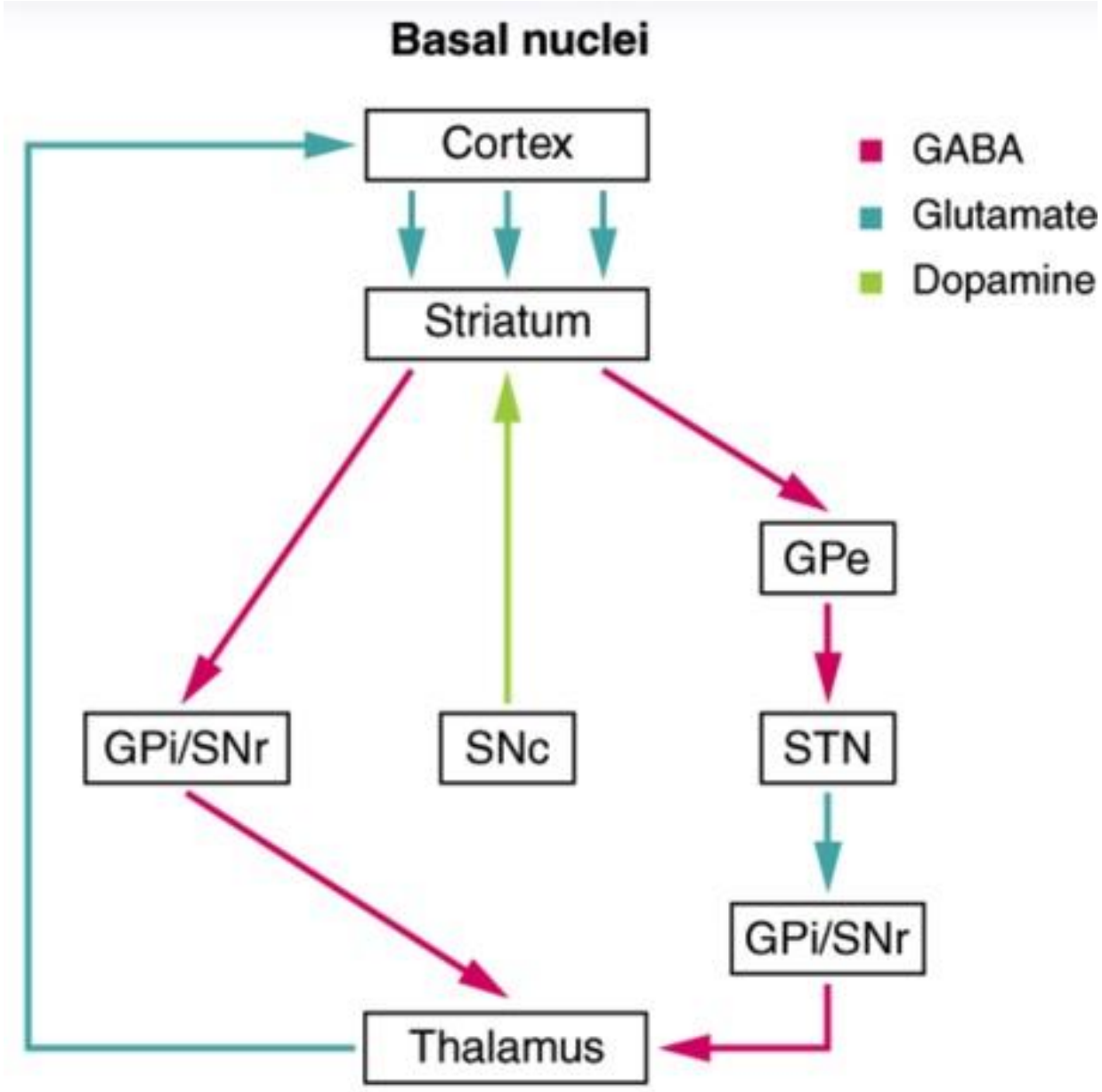


https://www.nursinghero.com/study-guides/garrettcollege-ap1/the-central-nervous-system

Parkinson's disease

https://stanfordmedicine25.stanford.edu/the25/parkinsondisease.html

Huntington’s disease

- Huntington disease is an inherited disorder in which the caudate nucleus and putamen degenerate, with loss of neurons that normally release GABA or acetylcholine.
- A key sign of HD is chorea, in which rapid, jerky movements occur involuntarily 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.

Tourette syndrome

- characterized by involuntary body movements (motor tics) and the use of inappropriate or unnecessary sounds or words (vocal tics).
- Although the cause is unknown, research suggests that this disorder involves a dysfunction of the cognitive neural circuits between the basal nuclei and the prefrontal cortex.

Psychiatric disorders

- 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.

Initiation of movements

- The basal nuclei play a major role in initiating movements.
- 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.

Suppression of unwanted movements

- The basal nuclei 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.

Regulation of muscle tone

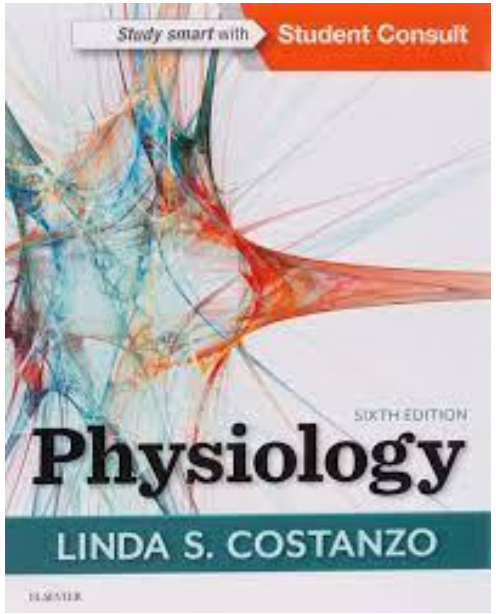
- Neurons of the basal nuclei send action potentials into the reticular formation that reduce muscle tone via the medial and lateral reticulospinal tracts.

- Damage or destruction of some basal nuclei connections causes a generalized increase in muscle tone.

Regulation of nonmotor processes

- The 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.

References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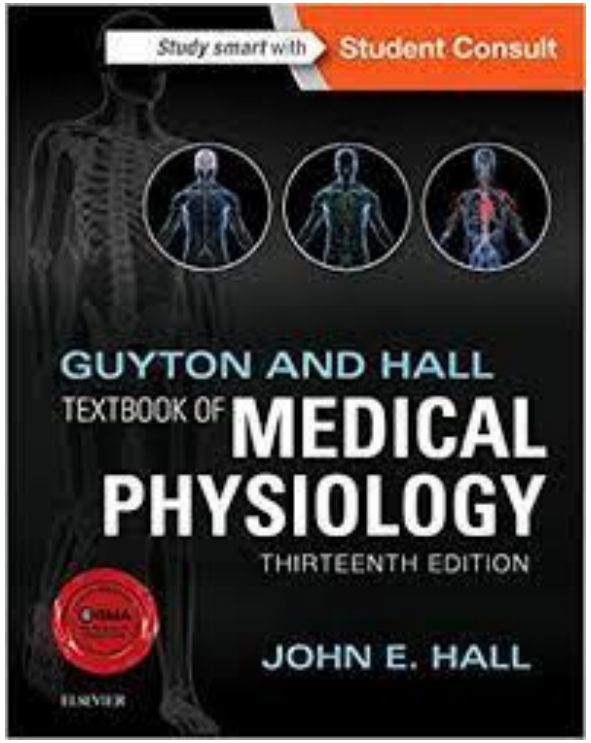
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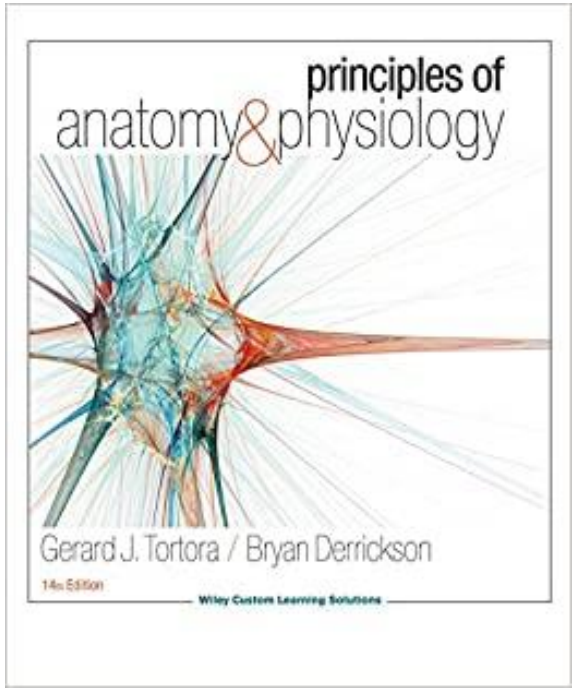
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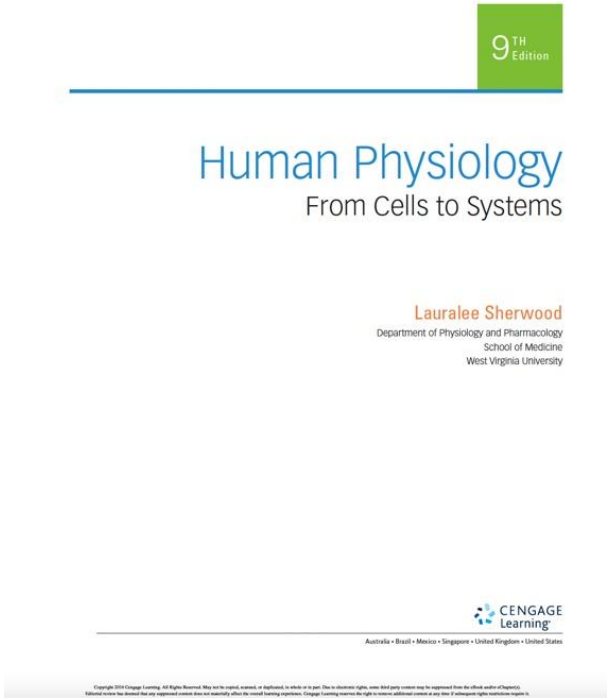
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