



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

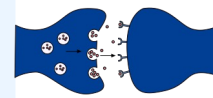


Basal Ganglia Motor Function

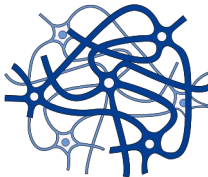
FINAL | Lecture 4

﴿إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ مَا مِنْ دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا إِنَّ رَبِّي عَلَى صِرَاطٍ مُسْتَقِيمٍ﴾

Written by: Qais Alqaisy
Ehab Alarakza



Reviewed by: Omar Ibrahim



رحلة اليقين مع سورة يس

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

إِنَّ أَصْحَابَ الْجَنَّةِ الْيَوْمَ فِي شُغُلٍ فَاكِهُونَ ﴿٥٥﴾

إن أهل الجنة في ذلك اليوم مشغولون عن غيرهم بأنواع النعيم التي يتفكحون بها.

هُمْ وَأَزْوَاجُهُمْ فِي ظِلِّ عَلَى الْأُرَائِكِ مُتَكِئُونَ ﴿٥٦﴾

هم وأزواجهم متنعمون بالجلوس على الأسرة المزينة، تحت الظلال الوارفة.

لَهُمْ فِيهَا فَاكِهَةٌ وَلَهُمْ مَّا يَدَّعُونَ ﴿٥٧﴾

لهم في الجنة أنواع الفواكه اللذيذة، ولهم كل ما يطلبون من أنواع النعيم.

سَلَامٌ قَوْلًا مِّن رَّبِّ رَحِيمٍ ﴿٥٨﴾
ولهم نعيم آخر أكبر حين يكلمهم ربهم، الرحيم بهم بالسلام عليهم. وعند ذلك تحصل لهم السلامة التامة من جميع الوجوه.

Note that some concepts were re-arranged in this file when compared to the original lecture in order to enhance scientific flow and coherence



Basal Ganglia and Motor Control

Faisal I. Mohammed, MD, PhD

Objectives

- 😊 Recognize the basal ganglia system and name its parts
- 😊 Describe how the basal ganglia system works toward control of motor movements
- 😊 Identify basal ganglia abnormalities

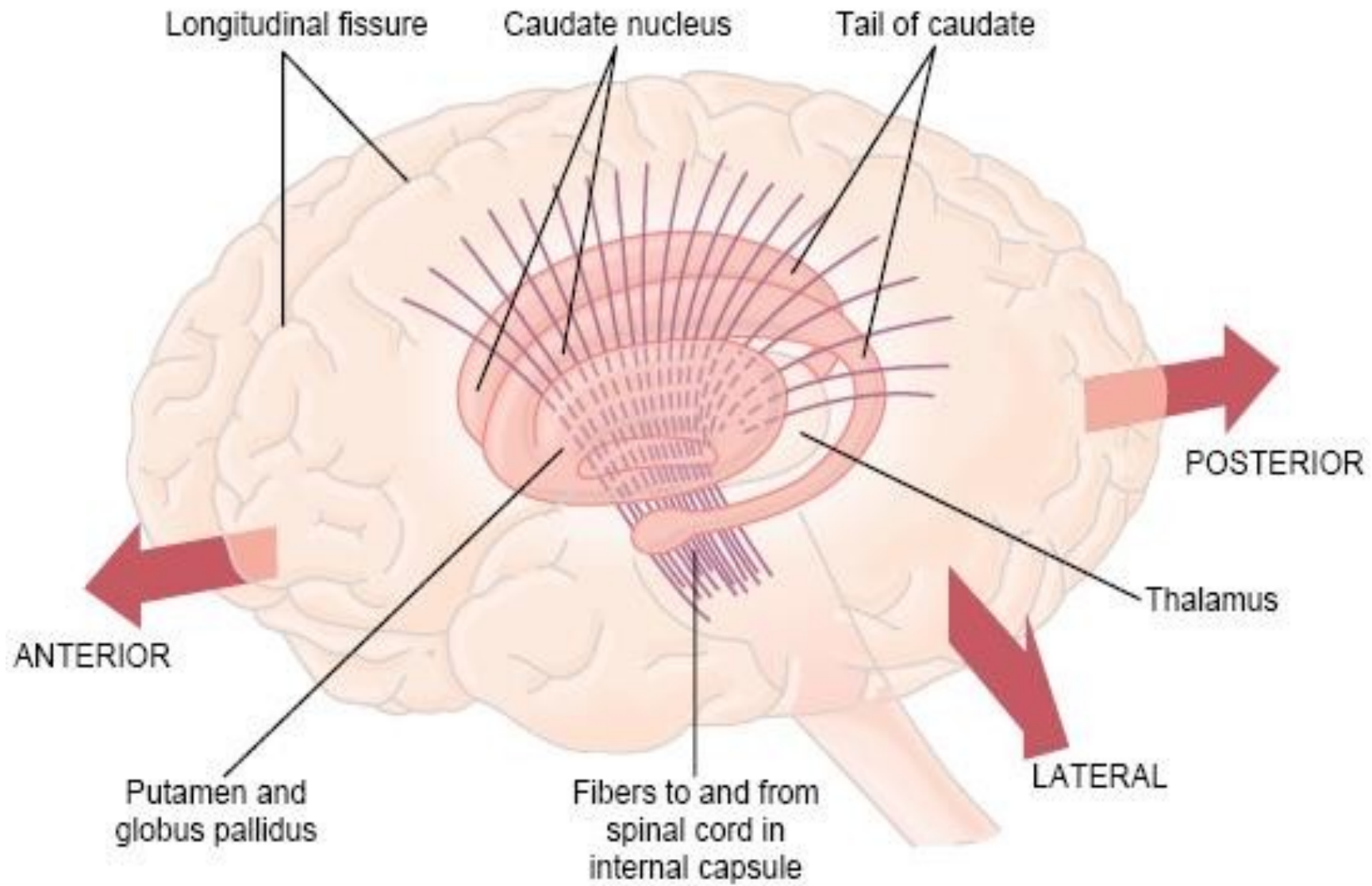
Notice that the name "Basal Ganglia" is an old name and does not follow the convention of (cns=nucleus, pns=ganglia) made for aggregations of neuronal cell bodies. In some sources you might find it correctly-reformed as "Basal Nucleus".

Basal Ganglia System

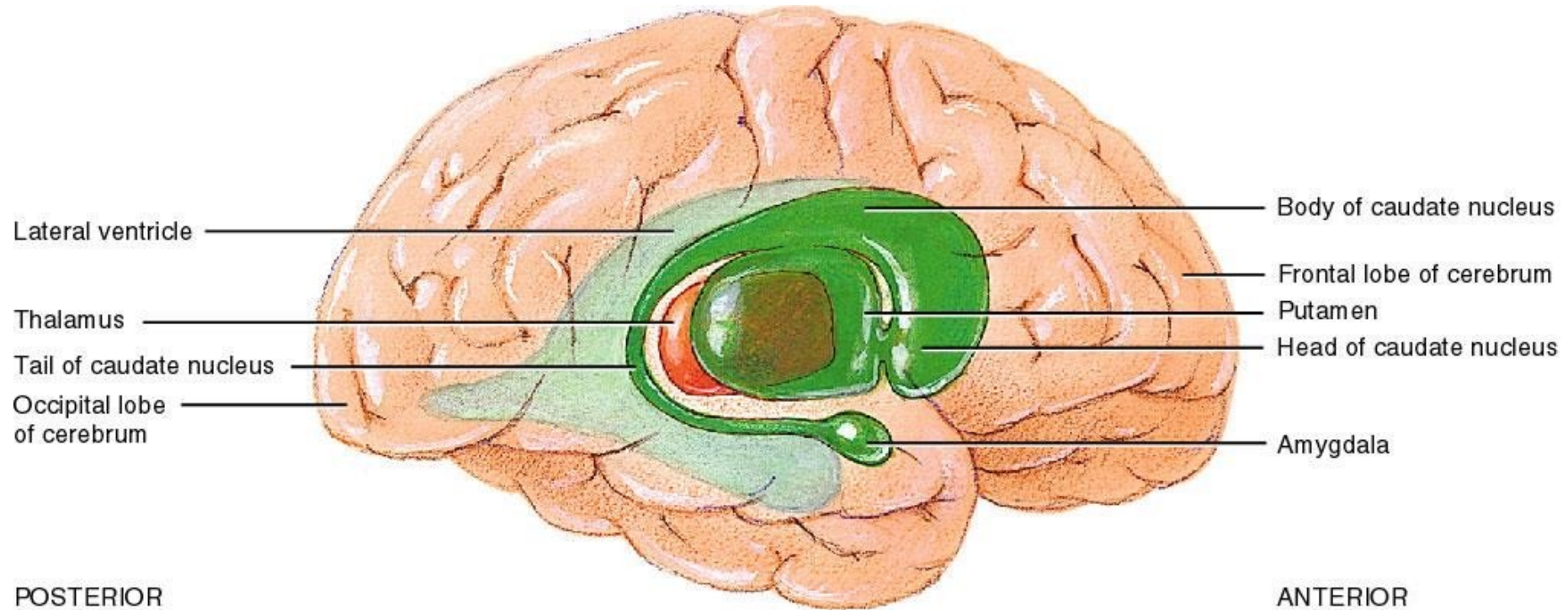
- Consist –FUNCTIONALLY- of Four Nuclei
 - Striatum (Caudate and Putamen Nuclei)
 - globus pallidus
 - substantia nigra
 - subthalamus
- The **substantia nigra** and **subthalamic nucleus** are not anatomically part of the basal ganglia proper, but they **work together with it functionally**, therefore they are included in the **basal ganglia system**.

Basal Ganglia

- The next 3 slides show the anatomical and spatial position of the basal ganglia. First 2 are lateral views and the 3rd is a coronal section. Notice how you can tell the anterior from posterior aspects due to caudate's tail-and-head orientation alone (first 2 pics). The head being the closest part to the putamen. Feel free to look at the 3 pictures until you grasp the 3d configuration, also keep in mind:
- The basal ganglia is made of the striatum (Putamen+Caudate Nuclei) and the globus pallidus(g.p). Sometimes the (putamen+g.p) are referred to as the **lentiform nucleus** due to its lentil-like shape. Notice the strategic position of the basal ganglia as it surrounds the internal capsule from multiple sides. (Look at extra pic)



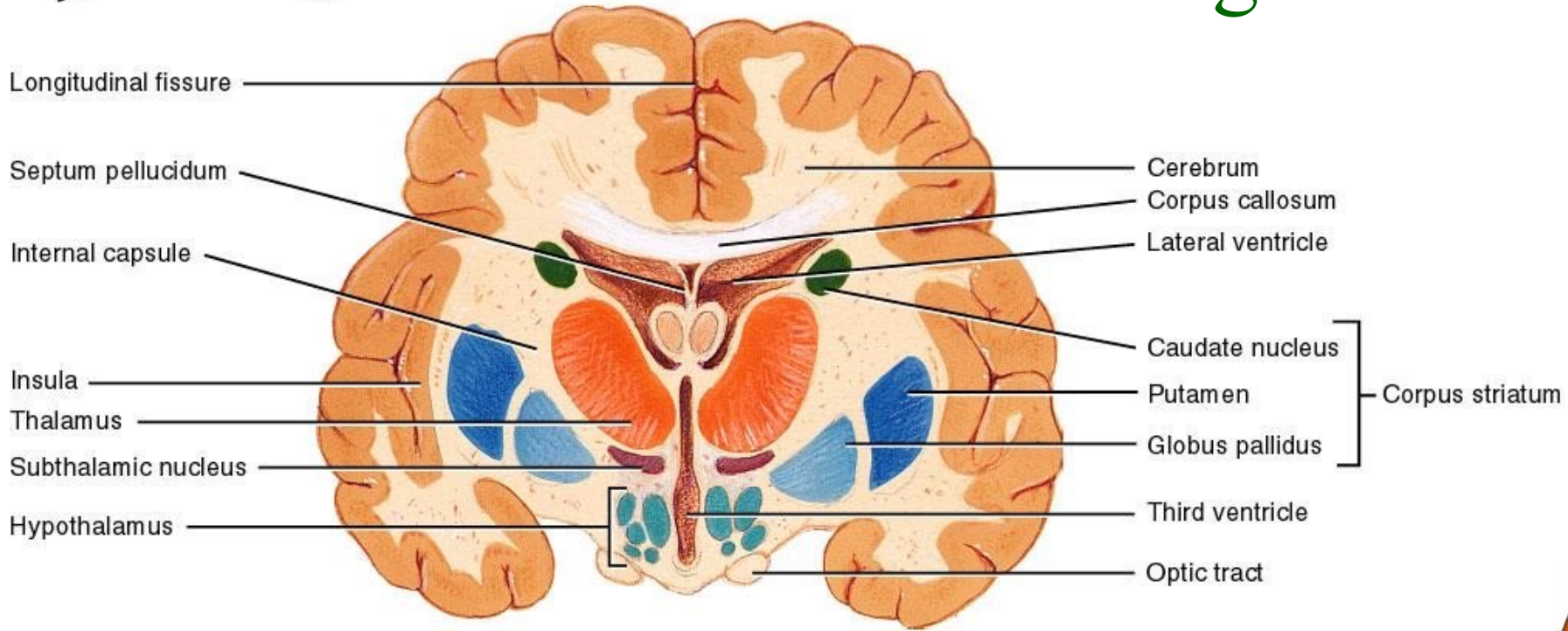
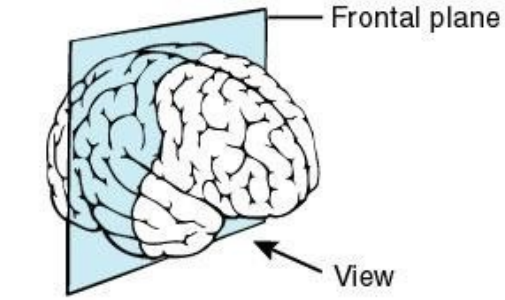
Basal Ganglia



(a) Lateral view of right side of brain

14.13a

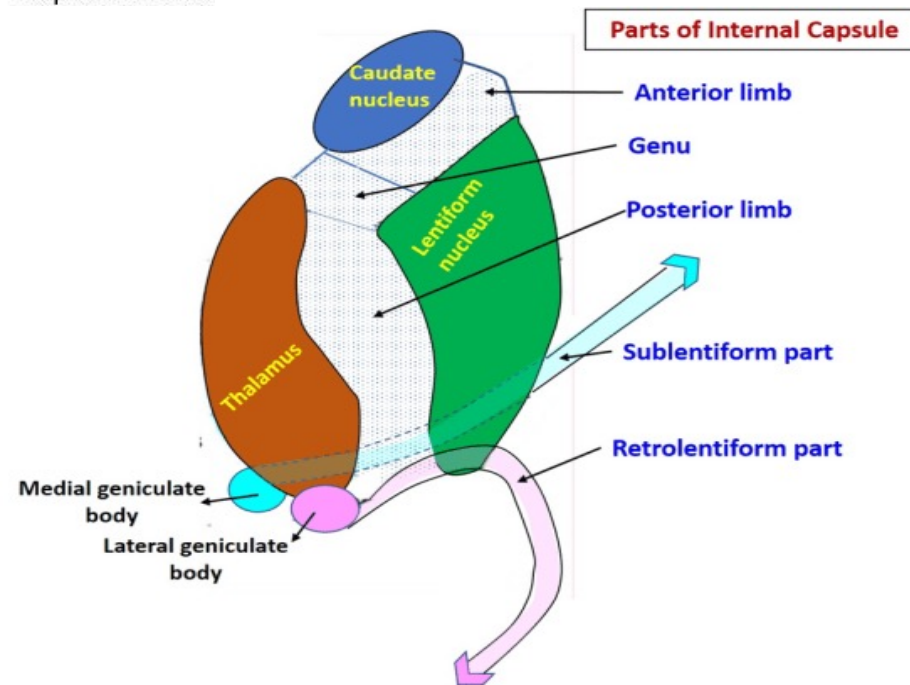
Basal Ganglia



(b) Anterior view of frontal section

14.13b

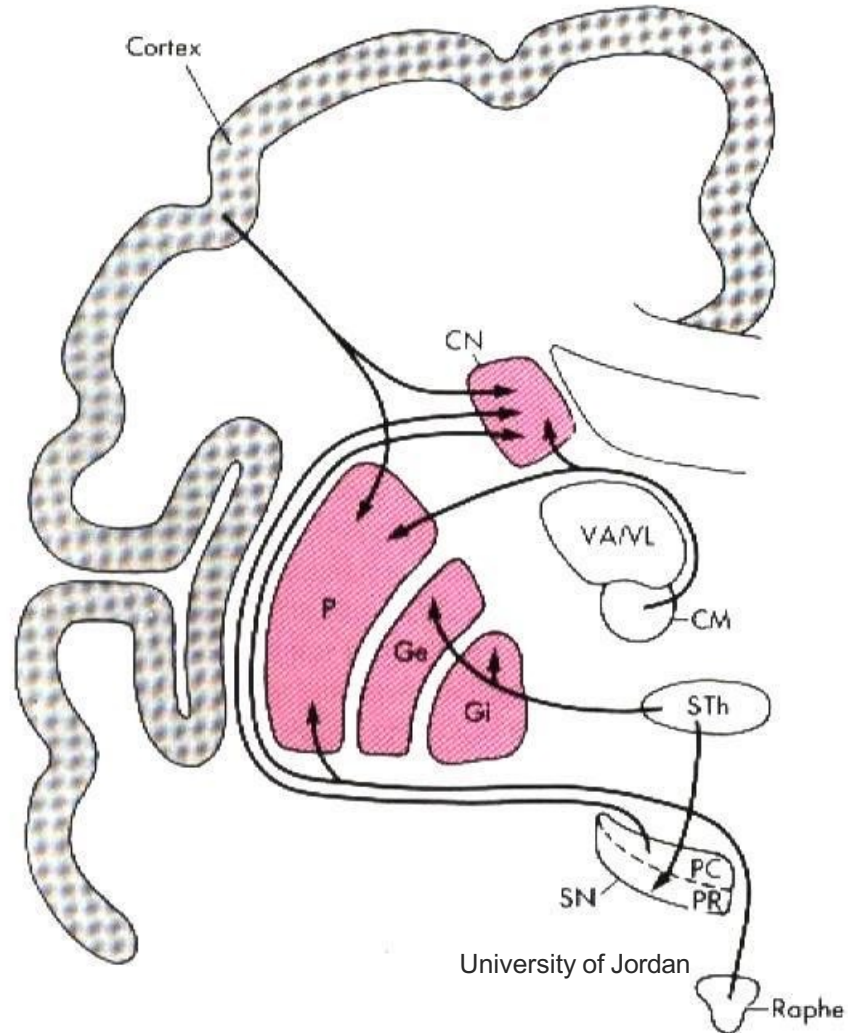
An extra pic for the internal capsule:



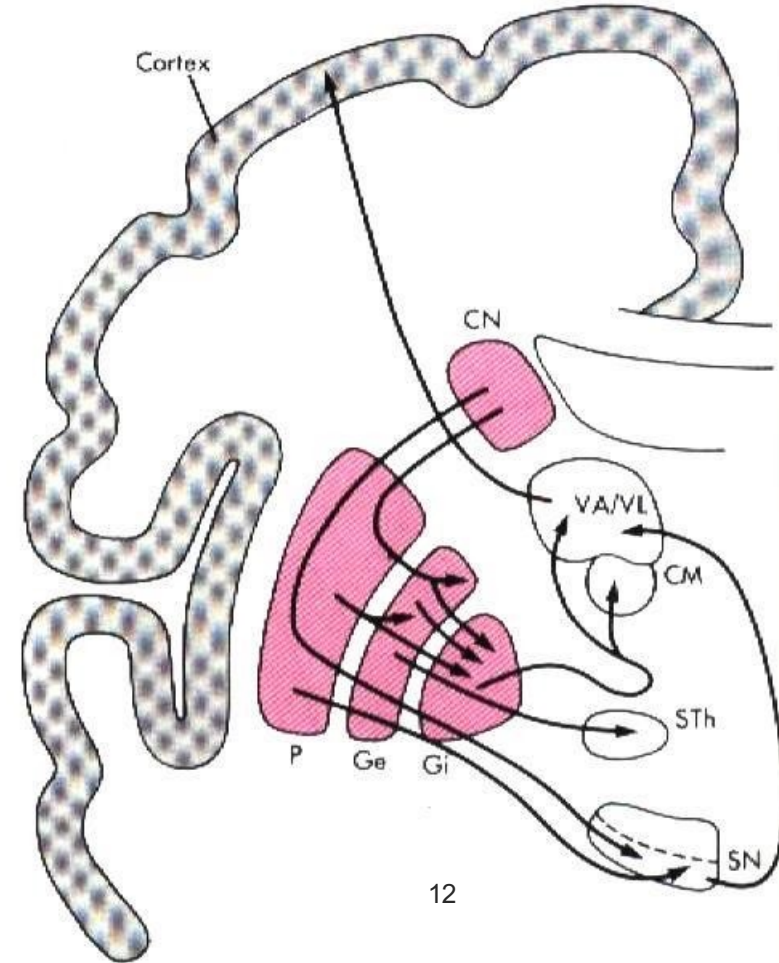
More details in
upcoming slides...

Basal ganglia Afferents and Efferents

Into basal ganglia
(afferents)



From basal ganglia
(efferents)



Basal ganglia Afferents

- Afferents:
 - Cerebral cortex to caudate and putamen
 - Substantia nigra pars compacta to putamen and caudate
 - Subthalamic nucleus to globus pallidus and to substantia nigra pars reticulata
 - Centromedial nucleus of the thalamus to putamen and caudate
 - Raphe magnus nucleus to putamen and caudate *See next slide...*

Basal Ganglia Overview

➤ Roles of the Basal Ganglia:

- **Intiation of Complex Movement Patterns and some Skilled Movements**
- **Motor Cognition (Choosing the appropriate movements pattern, timing and scaling of the movements after processing the current sensory and motor input, ex: deciding that running is the "Cognitively Correct" action to do when you face a lion, and initiating the "Movement Patterns" at the "Correct Timing and Scale" needed to do this action)**
- **However, little to be known about the exact function of each part of the basal ganglia separately**

➤ Neural Pathways of the Basal Ganglia:

- **Most afferent fibers to the basal ganglia arise from the cerebral cortex and return also to the cerebral cortex - Relaying in the Ventrolateral and Ventroanterior nuclei of the Thalamus first-, so the basal ganglia controls motor action "indirectly" through the cortex.**

➤ General concepts before digging deep into the basal ganglia pathways:

- **The GPi (globus pallidus internus) is Tonicly Inhibiting the thalamus through the continuous release of GABA**
- **This keeps the thalamus suppressed at rest → No Cortical Stimulation → No Motor Action**
- **The Striatum has the ability to inhibit the GPi by releasing GABA**
- **The Subthalamic Nucleus (STN) has the ability to activate the GPi by releasing Glutamate, however this STN is tonically inhibited by the GPe (Globus Pallidus Externum) by releasing GABA**
- **This makes the movement dependent on: How much the GPi is inhibited**
- **↓ GPi activity → ↓ inhibition on thalamus → ↑ movement**
- **↑ GPi activity → ↑ inhibition on thalamus → ↓ movement**

**Basal ganglia = initiation and selection of movement patterns.
Cerebellum = coordination and correction of already executed movements.**

Neural Pathways of the Basal Ganglia

➤ **Direct Pathway (= Gas Pedal (Movement ON → Goal: Inhibit GPi → Allow Movement))**

• **Steps:**

1. **Cortex → Striatum (Releases Glutamate (Excitatory Neurotransmitter) → Activates Striatum)**
2. **Striatum releases GABA at the GPi → Inhibits GPi → Less GABA released by the GPi at the Thalamus = Less Inhibition of the Thalamus → More stimulation of the Thalamus to the Cortex → Motor Action Stimulated**

(This concept is called “**Disinhibition**”, i.e.: The constant inhibition that was mediated by the GPi on the thalamus to inhibit the movement has been inhibited, **Inhibition of the Inhibition** in order to allow movements to occur)

➤ **Indirect Pathway (= Brake Pedal (Movement OFF → Goal: Activate GPi → Suppress Movement))**

• **Steps:**

1. **Cortex → Striatum (Releases Glutamate (Excitatory Neurotransmitter) → Activates Striatum)**
2. **Striatum releases GABA at the GPe → Inhibits GPe → ↓ GABA released on STN → Less inhibition of the STN = ↑ release of Glutamate on the GPi = More activation of the GPi = ↑ GABA at the Thalamus = Increased inhibition of the Thalamus = Less stimulation from Thalamus to Cortex → Motor activity suppressed**

(This is essentially the **opposite of disinhibition**, eventually causing **More Inhibition** the the Thalamus leading to **Movement Inhibition**)

Basal ganglia Afferents

The doctor gave a brief analysis of the Raphe Magnus in relation to the Basal ganglia system, however, without proper background it might sound confusing at first. This is an organized summary after referring to sources:

Raphe Magnus which has to do with Pain modulation is by nature of that function related to the cognitive function of the brain (they work together) . Cognitive function is related to thoughts, knowledge, etc... Since the basal ganglia system is majorly involved in cognitive function that means it should also be related to important sensation-oriented nuclei because cognition is built upon sensory analysis. E.g if you see a lion you fear it. R.M doesn't carry "sensory" input to B.G, dr probably means that pain control and cognitive function are logically related if you look at the big picture. Raphe Magnus sends inhibitory signals to alleviate pain through the descending opioid system within the spinal cord and uses Serotonin as its neurotransmitter. Here lies the logic of why the raphe magnus in medulla oblongata is involved (afferents) with the basal ganglia.

Feel free to check the lecture for this specific part if you wish to eliminate doubts. At about 10:30.

Haven't found any source linking the Raphe magnus to the basal ganglia just as the doctor has mentioned

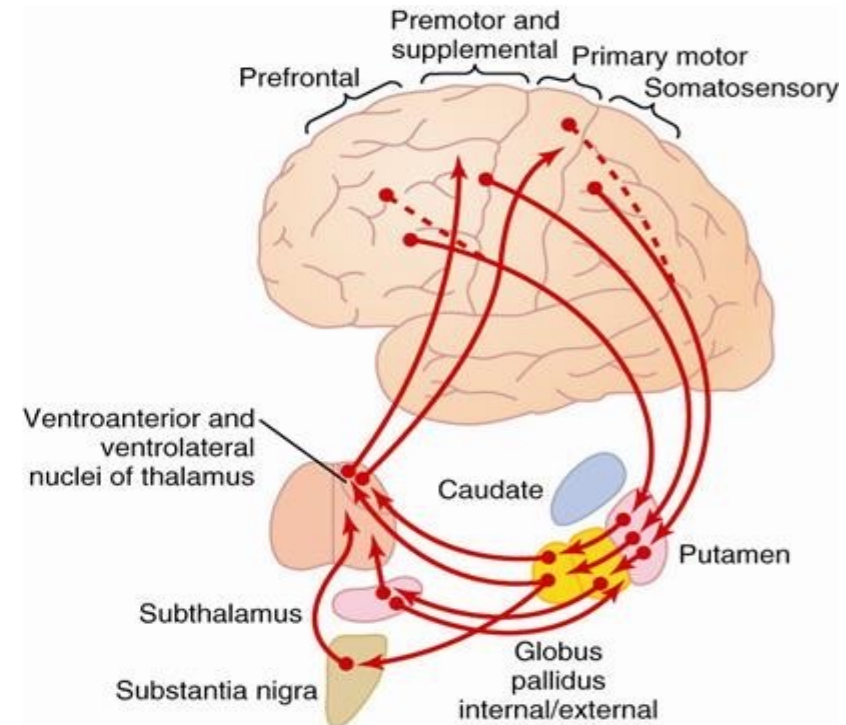
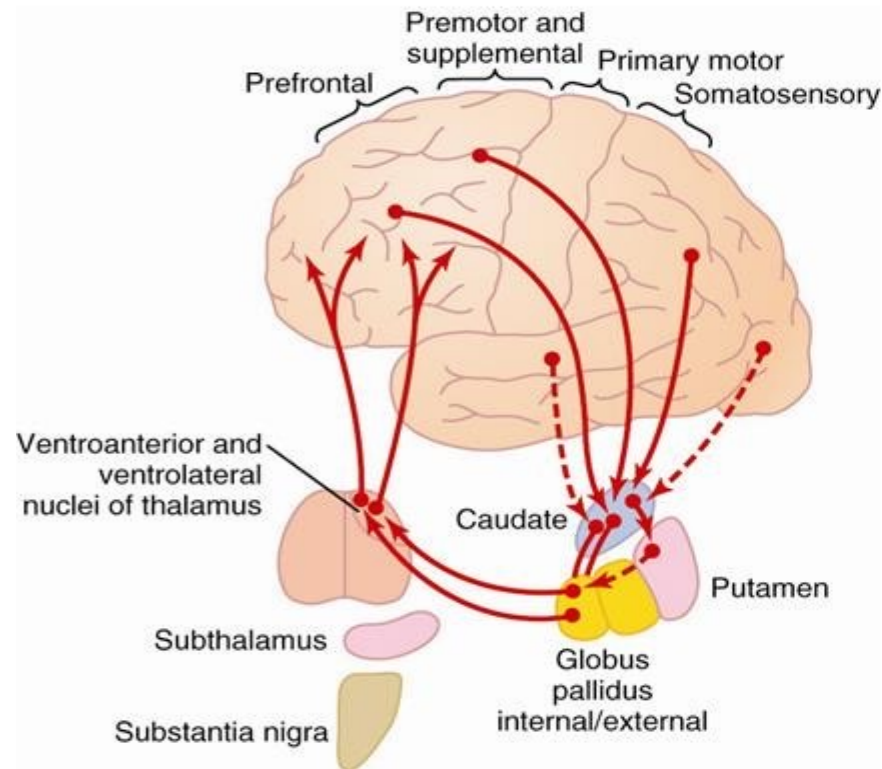
Basal ganglia Efferents

- Efferents:
 - Putamen and caudate to globus pallidus
 - Putamen and caudate to substantia nigra pars reticularis
 - Globus pallidus to subthalamic nucleus
 - Globus pallidus to ventroanterior and ventrolateral nuclei of the thalamus

Basal ganglia Efferents

- Despite putamen and caudate being parts of the same striatum, there are differences between them. In terms of efferents and afferents we call each set of those associated with either the putamen or caudate as a “circuit”. This sets the 2 of them functionally distinct. The caudate circuit receives afferents from the secondary/association areas of the cortex which have to do with the cognitive aspect of the motor activity. It also gives efferents back to these same areas. While the putamen receives fibers from and sends back to the primary areas of the brain which are related more towards motor activity initiation rather than “meaning” of these movements.
- Higher cerebral cortical functions = the complex abilities that make behavior intelligent, purposeful, and adaptable, mainly handled by the cerebral cortex, especially association areas.
- Take a look at the distribution of each circuit in the brain in the next slide.

The basal ganglia are the principle subcortical components of a family of parallel circuits linking the thalamus with the cerebral cortex



Motor Function of the Basal Ganglia

- control of *complex patterns* of motor activity
 - writing
 - using scissors
 - throwing balls
 - shoveling dirt
 - some aspects of vocalization

Function of the Basal Ganglia?

- not much is known about the specific functions of each of these structures
- thought to function in *timing and scaling* of motion and in the **initiation of motion**
- most information comes from the result of damage to these structures and the resulting clinical abnormality

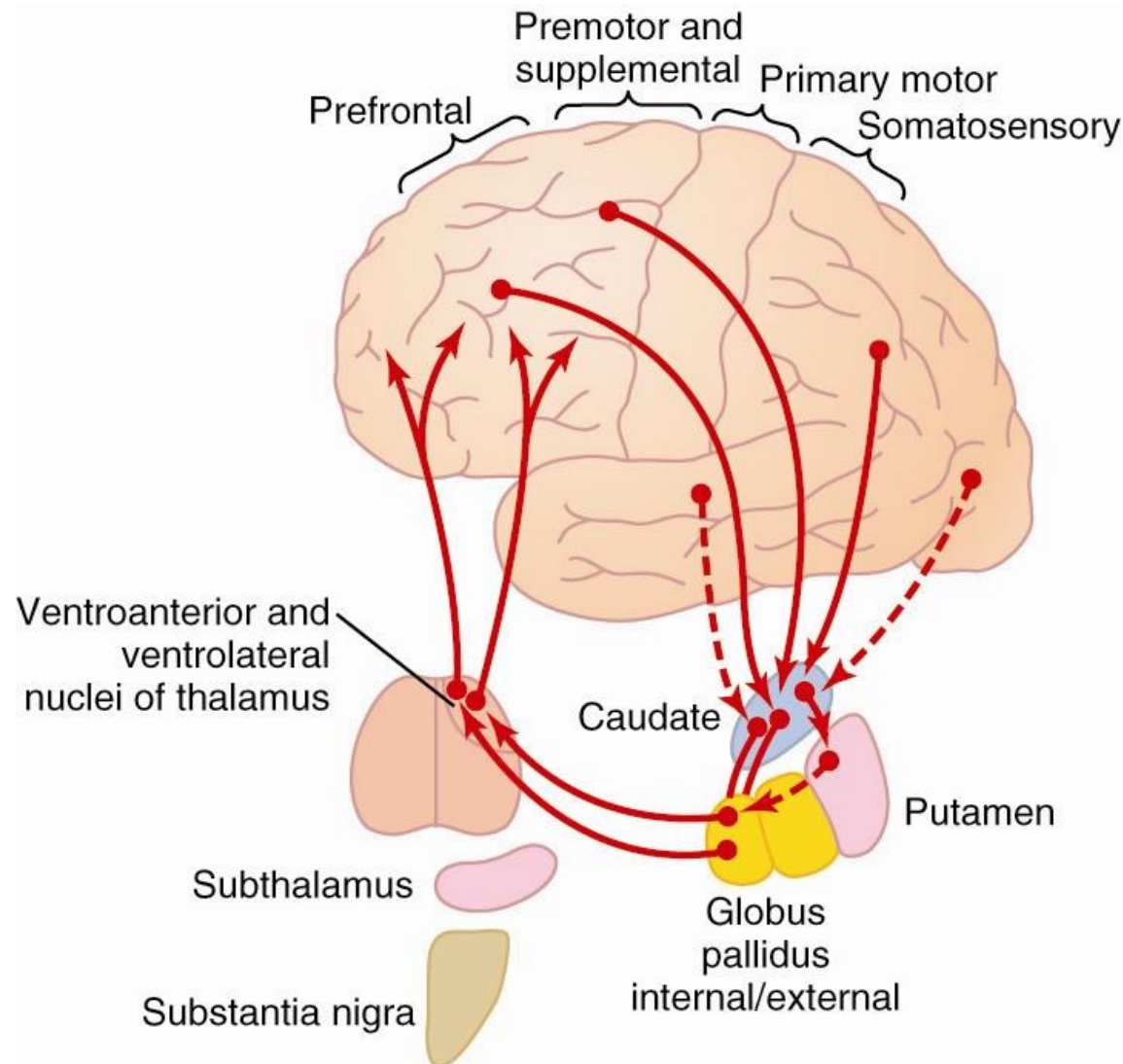
See next slide...

The easiest way to study neurological and brain function is to assess damage to certain parts and compare with control.

Function of the Basal Ganglia?

- The basal ganglia is responsible –along with other parts of the brain– of timing and initiation of movements. Damage –as in Parkinson disease– to this structure results in problems with initiation of movements. Which is why patients seem slow and their movements are rather rigid and not as “automatic” as we find it to be. It takes constant effort to move in a certain manner. Their speech, facial expressions and tone of voice are slow and hard to change. A constant –hardly changing– voice tone is referred to as Monotonous.
- The following 2 slides discuss some information regarding the 2 circuits.

Caudate Circuit

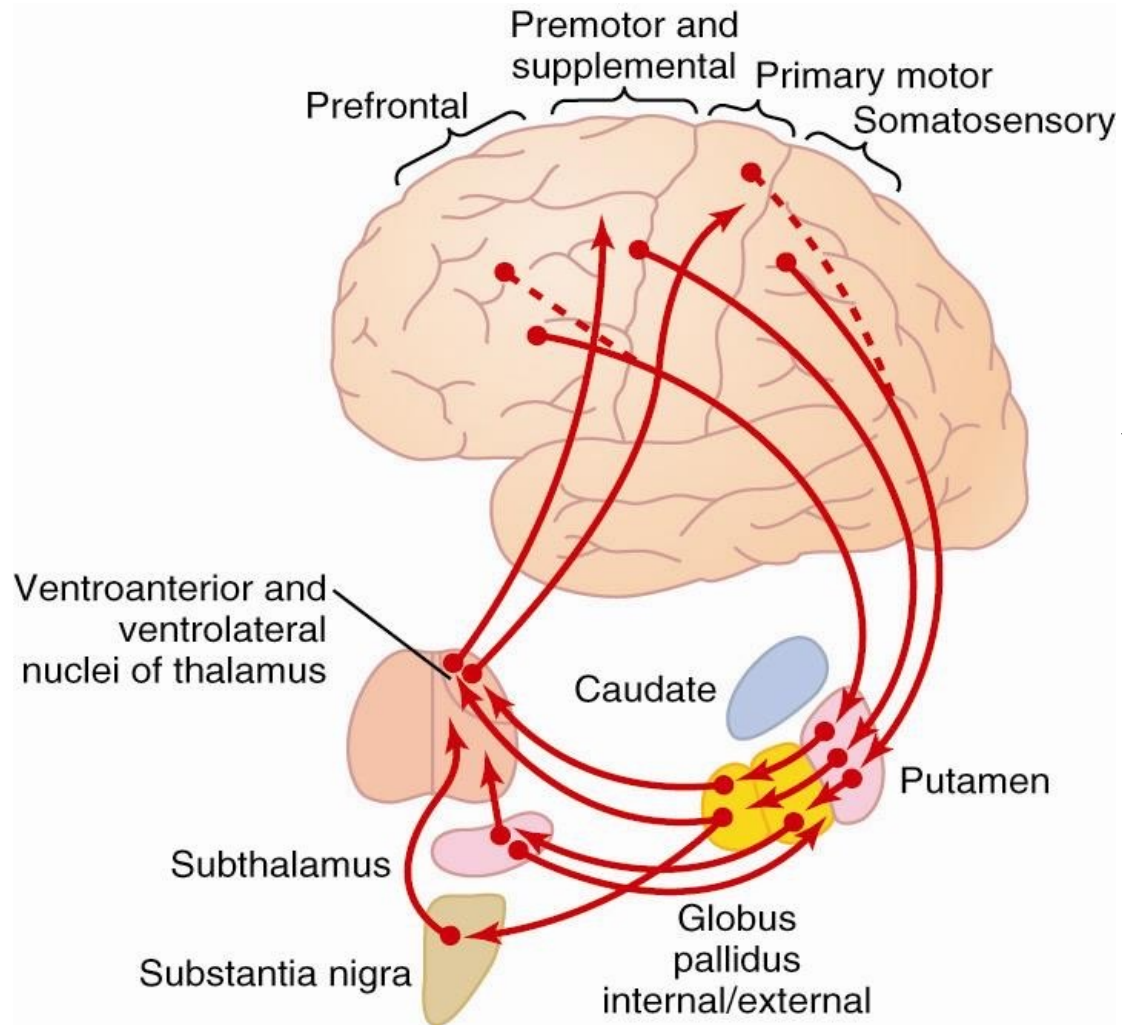


Caudate extends into all lobes of the cortex and receives a large input from association areas of the cortex

Mostly projects to globus pallidus, no fibers to subthalamus

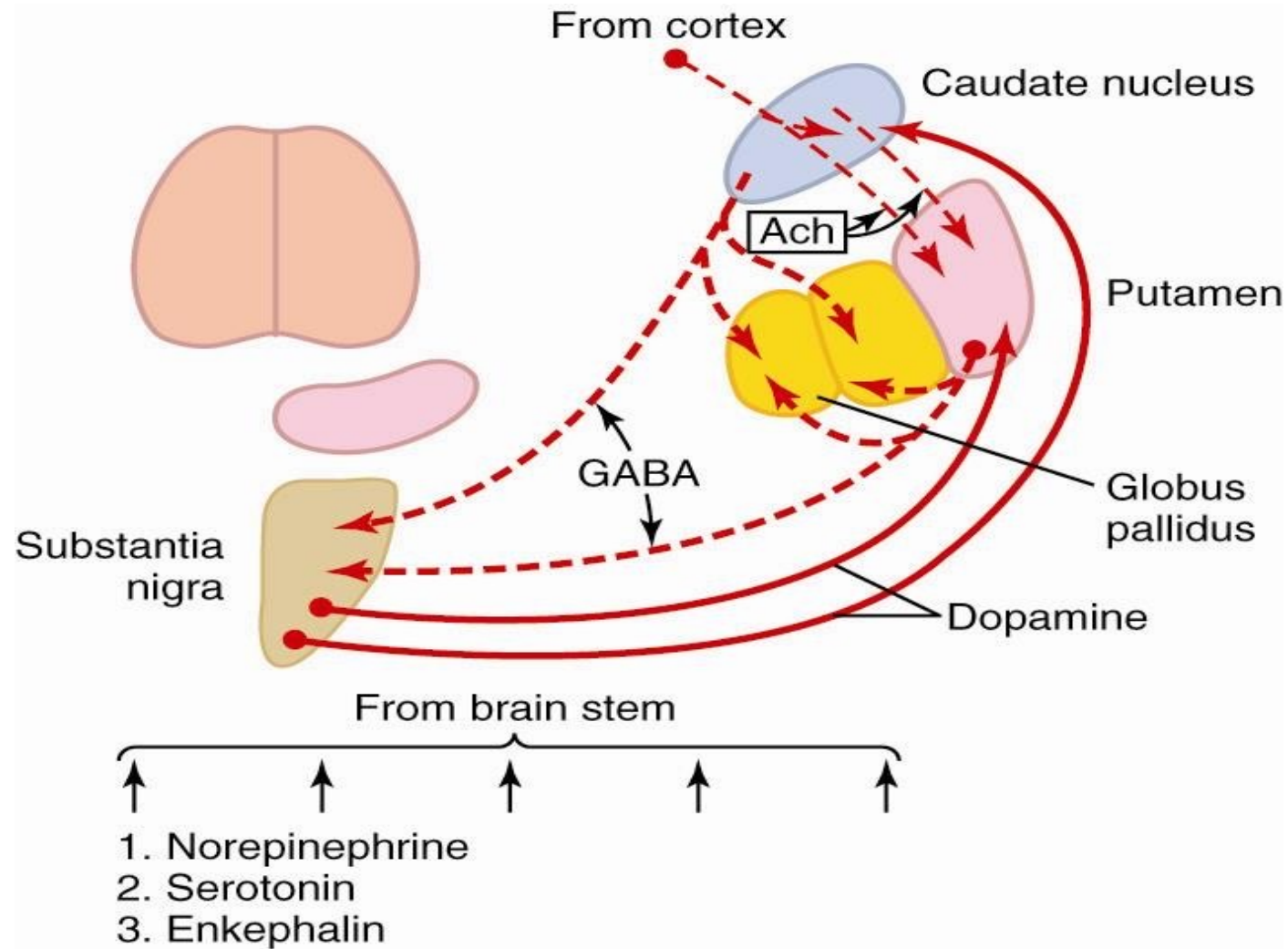
Most motor actions occur as a result of a **sequence of thoughts**. Caudate circuit may play a role in the **cognitive control of motor functions**

Putamen Circuit

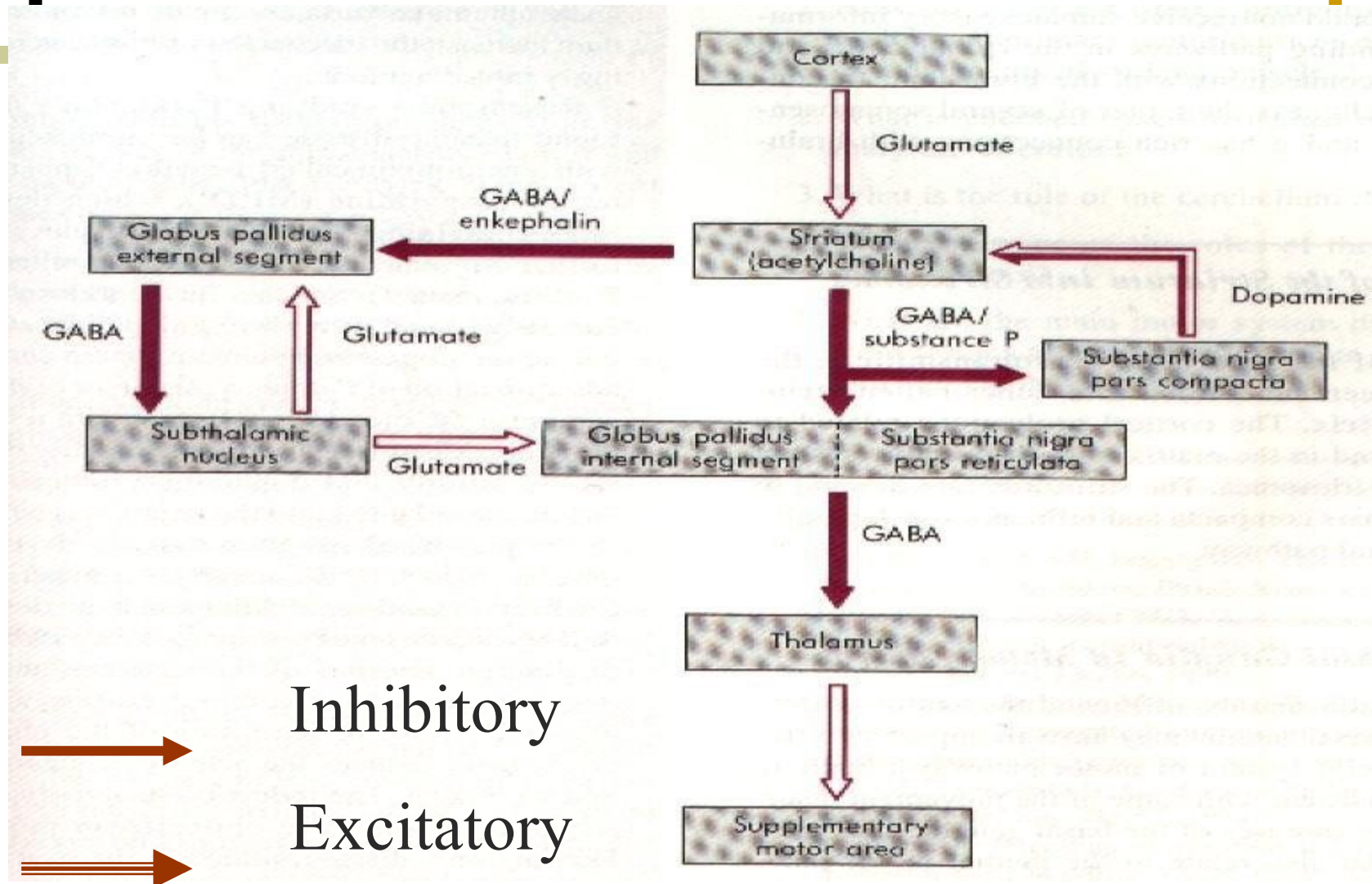


Mostly from premotor and supplemental motor cortex to putamen then back to motor cortex.

Neurotransmitters in the Basal Ganglia

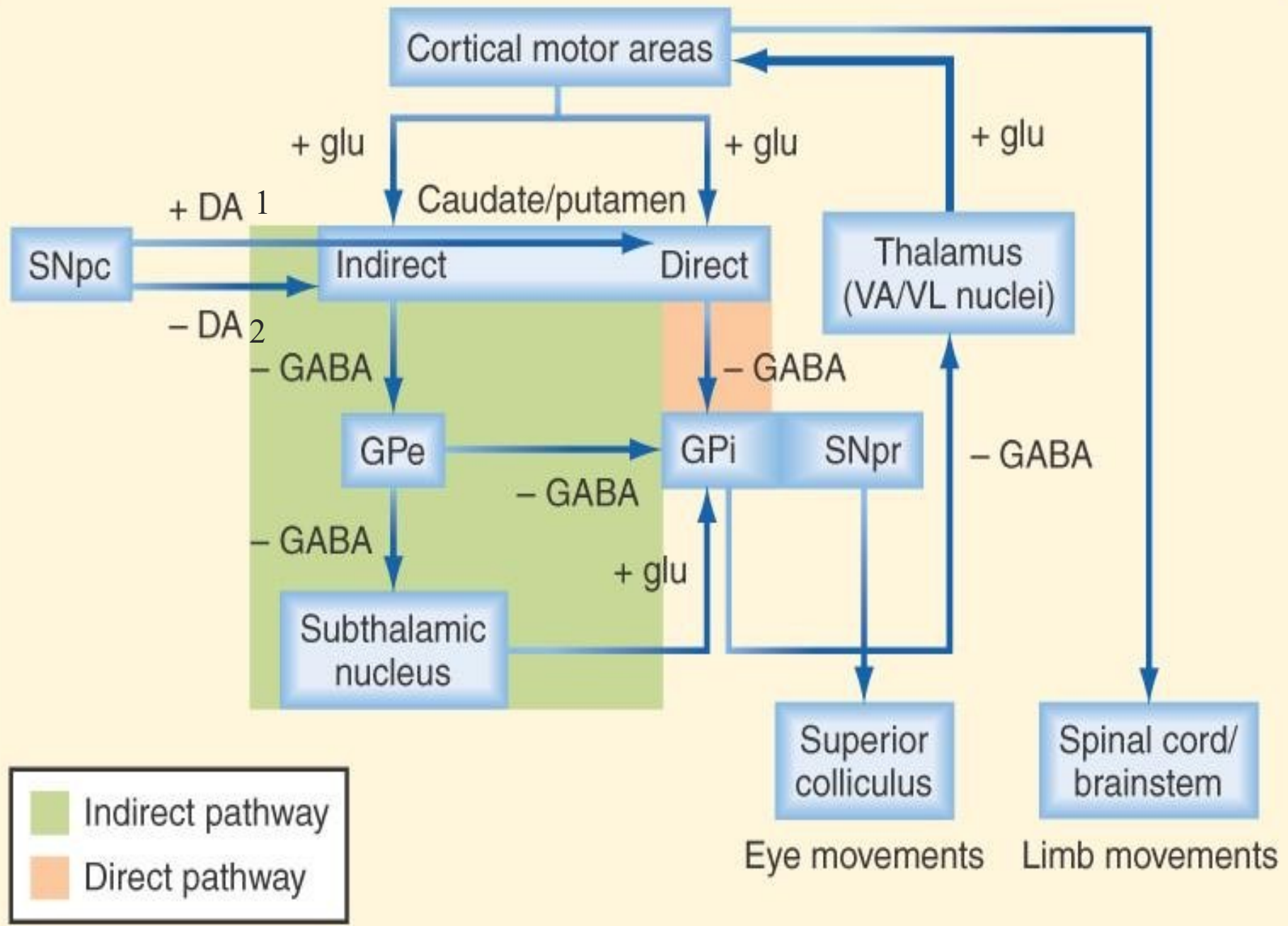


Basal Ganglia circuits and Neurotransmitters



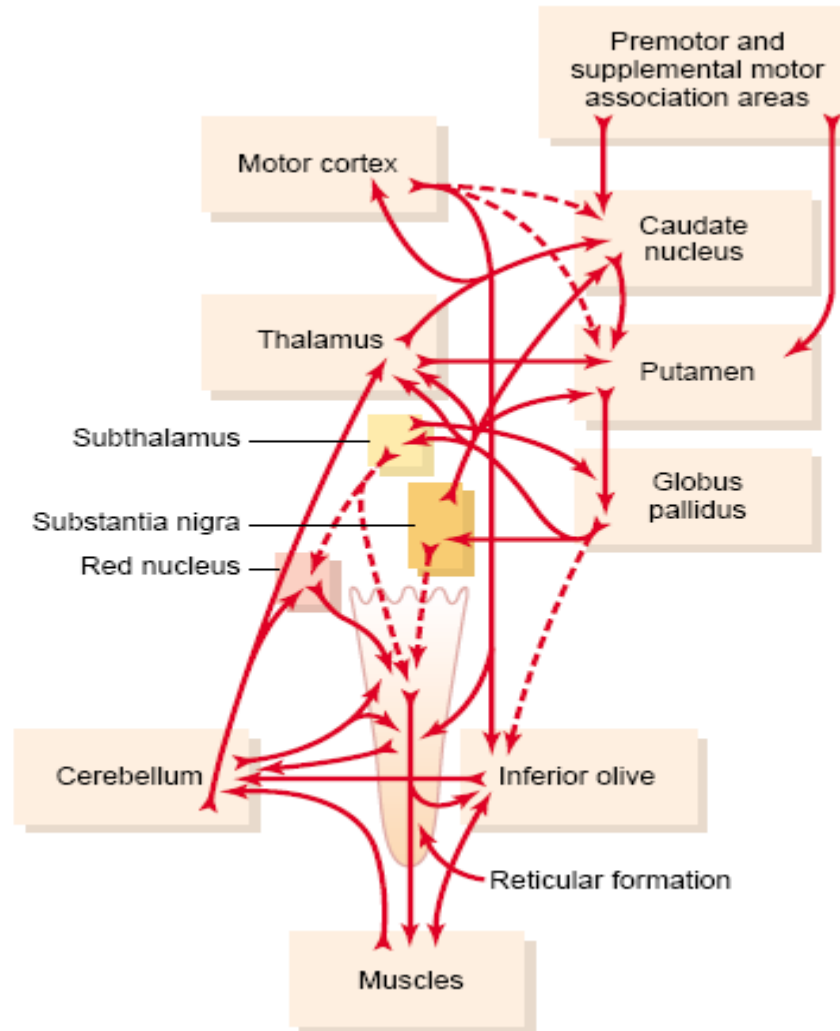
Further explanation of the figure

- **The substantia nigra** releases dopamine, which is considered here to have an **inhibitory effect on the striatum**. This inhibition of the striatum leads to reduced activity of the direct pathway (**Inhibition of the Gas Pedal**), which in turn results in increased inhibition of the thalamus and therefore decreased motor activity.
- **In Parkinson's disease**, there is a loss of dopaminergic neurons, so there is less dopamine and therefore less inhibition of the striatum. This makes the system more active at rest, leading to the development of rigidity as well as a resting tremor, classically described as the **“pill-rolling” tremor**. This tremor is present at rest and decreases with voluntary movement, in contrast to cerebellar tremors, which typically appear during movement (action tremor) rather than at rest.



A

Motor control of the Basal Ganglia



Basal Ganglia Lesions

Although the overall function of the basal ganglia is well understood, the exact role of each individual nucleus is not fully defined.

However, certain specific movement dysfunction patterns arise when these areas are damaged.

Lesions of Basal Ganglia

Additional Picture

Athetoid/ Dyskinetic CP

- **Fluctuating tone**
 - involves abnormal involuntary movements
 - that disappear during sleep and increase with stress.
 - Interferes with speaking, feeding, reaching, grabbing, and any other skills
 - 20% of the CP cases,



■ Globus pallidus

- athetosis - spontaneous writhing movements of the **distal muscles** (hand, arm), neck, and face. So, the patient will have a **snake-like movements**.

■ Putamen

- chorea – involuntary flicking movements of the hands, face, and shoulders

■ Substantia nigra

- Parkinson's disease - **rigidity, resting tremor, akinesia (slow movement) /dyskinesia** (abnormal movement) and **abnormal facial expression**
- loss of dopaminergic input from substantia nigra to the caudate and putamen

- **Cogwheel rigidity** is a type of muscle stiffness where resistance to movement is intermittent, giving a “ratchet-like” feel when the limb is moved.
- **lead-pipe rigidity** is smooth and constant, with uniform resistance throughout the movement.

Lesions of Basal Ganglia

■ Subthalamus

- hemiballismus - sudden flailing movements of the entire limb
- ✓ The subthalamic nucleus regulates **coarse, general movements, but not precise ones.**
- ✓ A lesion in the subthalamus causes contralateral **hemiballismus**—wide, violent, flinging movements on the opposite side of the body.

■ Caudate nucleus and Putamen

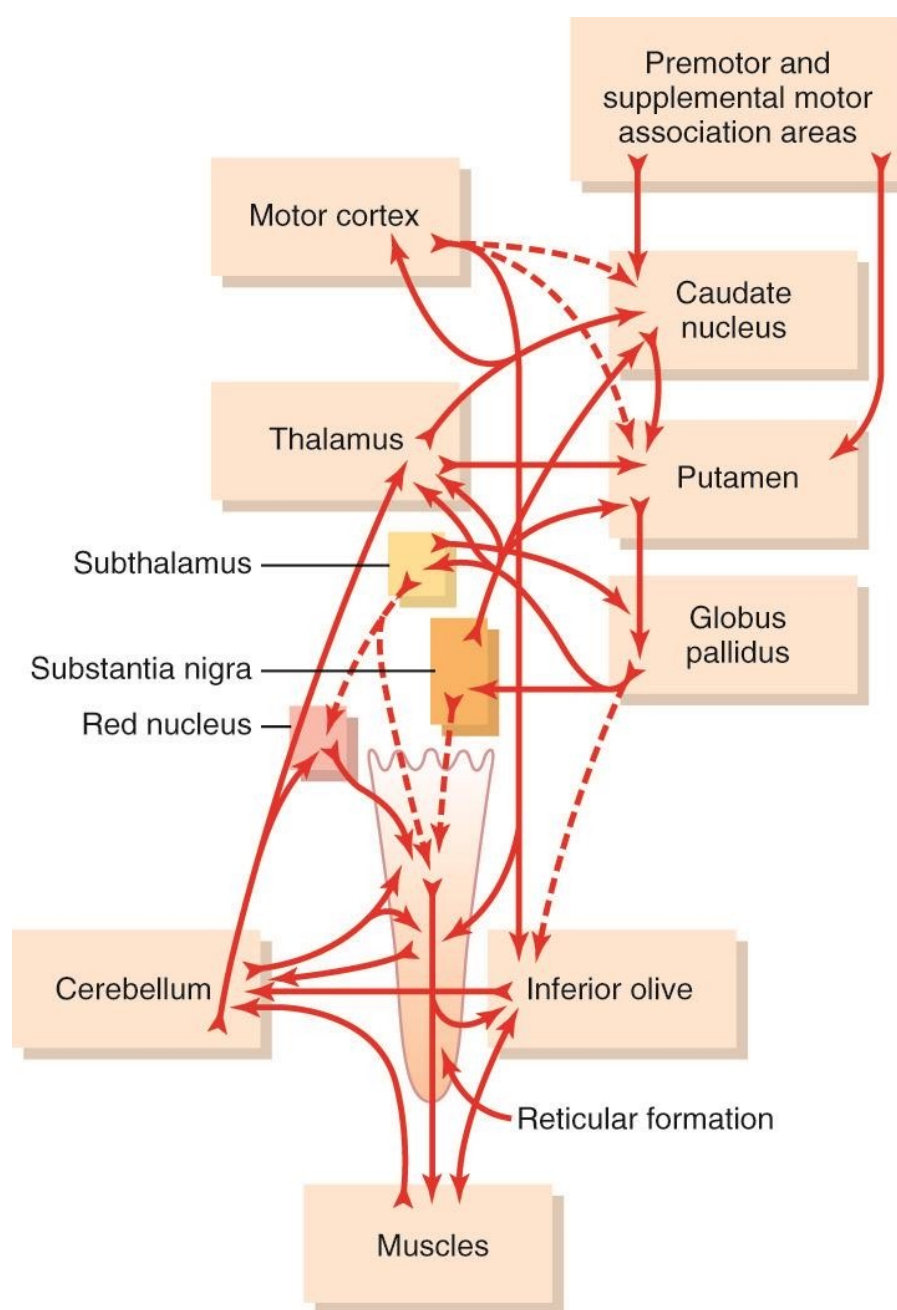
- Huntington's chorea - loss of GABA containing neurons to globus pallidus and substantia nigra
- ✓ Huntington disease is an **autosomal dominant disorder**
- All signs and symptoms of basal ganglia diseases are **contralateral** to the lesion in contrast to cerebellar lesions which are **ipsilateral**

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

Integration of Motor Control

- Cerebellum
 - function with all levels of control to adjust cord 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



Overall scheme for integration of motor function

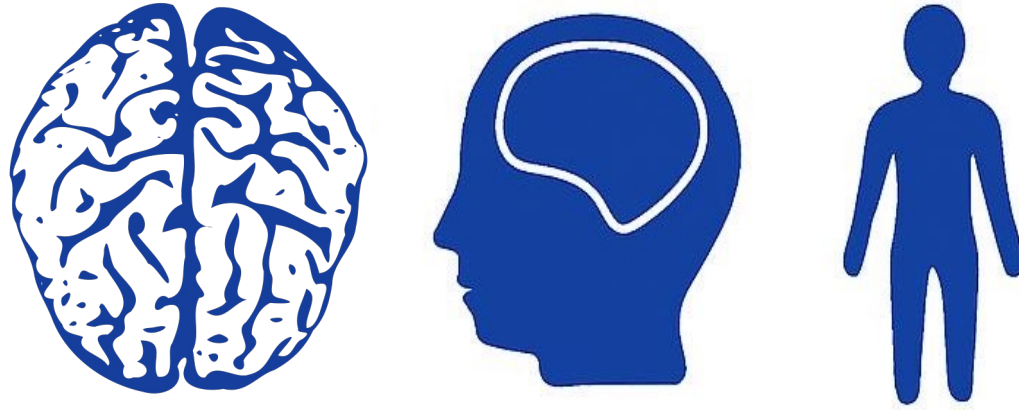
ثلاثون يومًا ومسرى نبينا لا يُرفع فيه أذان ولا حتى يُذكر فيه اسم الله
ثلاثون يومًا وحرمننا الثالث مُغتصب لم يشهد معنا لا صيامًا ولا قيامًا ولا حتى عيدًا
ثلاثون يومًا والمسجد الأقصى يشكو ذلنا وهواننا وصمتنا إلى الله رب العالمين

اللهم أقصانا، اللهم أقصانا، اللهم أقصانا



Thank You





**PHYSIOLOGY
QUIZ
LECTURE #**

External Resources

رسالة من الفريق العلمي

Additional sources:

1- [Ninja Nerd](#) (Highly Recommended)

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقه من فتنة القبر وعذاب النار،
أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.

Scan the QR code or click it for FEEDBACK



Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			