جامعة الملك سعود
King Saud University
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Revised By
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MED437
KING SAUD UNIVERSITY

Basal Ganglia

Objectives:

- Describe functional divisions of basal ganglia.
- Elaborate Caudate and putamen circuit.
- Explain different neurotransmitters that have a role in basal ganglia functions.
- Appreciate general functions of basal ganglia.
- Diagnose basal ganglial disorders.

Done by:

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- **Special Thanks to:** Dimah Alarifi

Colour index:
important
Numbers
Extra

وَأَن لَّيْسَ لِلْإِنسَانِ إِلَّا مَا سَعَىٰ

Dr. Najeeb

Basal Ganglia

They are also called **basal nuclei**

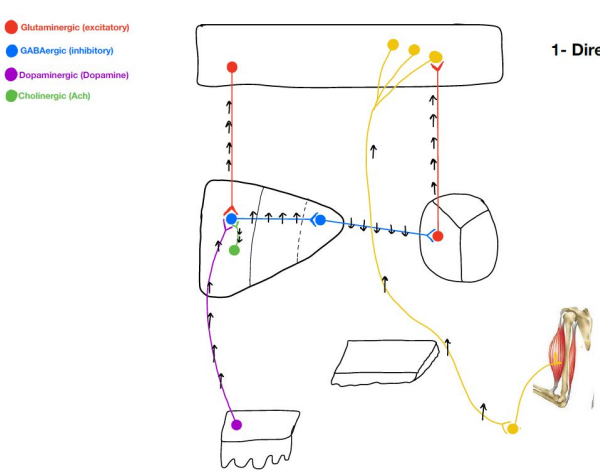
Basal ganglia : are masses of grey matter present at the base of cerebral hemispheres.
Lentiform nucleus which is one of the basal nuclei consist of:

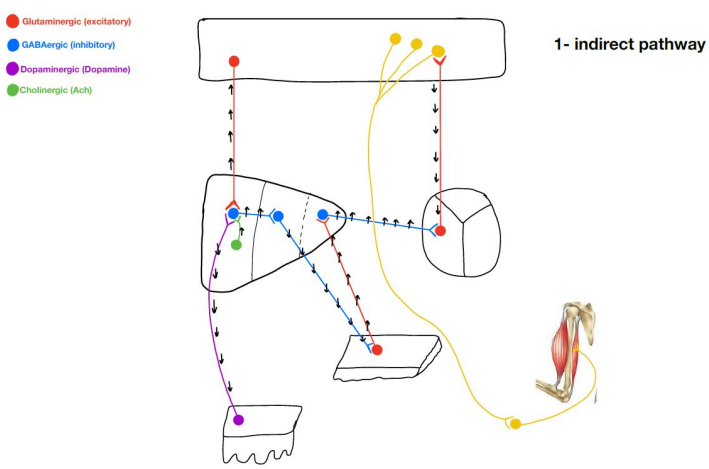
1-putamen (laterally)
2-globus pallidus (medially)

The posterior part of Substantia nigra is composed of densely packed grey matter which called substantia nigra pars compacta and we call the less densely packed anterior part substantia nigra pars reticularis
There's a special grey matter in the tail of **caudate nucleus** we call it **amygdala**
Basal ganglia are divided into :
1- traditional classification: caudate nucleus and its tail which is called amygdaloid + lentiform nucleus + claustrum
2- clinical classification: lentiform nucleus + caudate nucleus + subthalami + substantia nigra
We classified basal ganglia into 2 groups because there are some connections between the objects in each group.

- Caudate nucleus + lentiform nucleus which is composed of (putamen + Globus pallidus) is called **corpus striatum**
- Caudate nucleus + putamen of lentiform nucleus is called **neostriatum**
- Globus pallidus of lentiform nucleus alone is called **paleo striatum**

Motor plans are stored and processed mainly in basal ganglia
Motor fibers coming from cerebral cortex like corticospinal tracts are in close association with basal ganglia for programming of voluntary movements , so if you want like for example to drink a coffee the motor tracts should consult the basal ganglia first before transmitting the signal to give her permission .
Glutamate is an excitatory neurotransmitter released from special nerves in the the brain like corticostriatal and thalamocortical fibers
Striatopallidal & pallidothalamic fibers release **GABA + P SUBSTANCE**
When you are not doing any movement Globus pallidus internus is actively firing

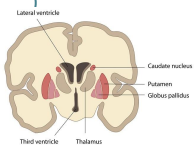




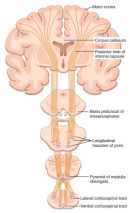
Overview of Motor Activity Control

Cerebral Cortex

Basal Ganglia



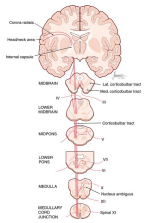
Corticospinal Tracts



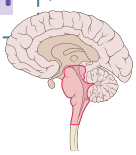
Thalamus

Cerebellum

Corticobulbar Tracts

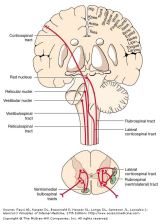


Brain Stem



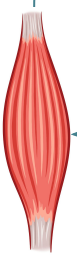
Bulbospinal Tracts

(Vestibular + Reticular)



Spinal Cord

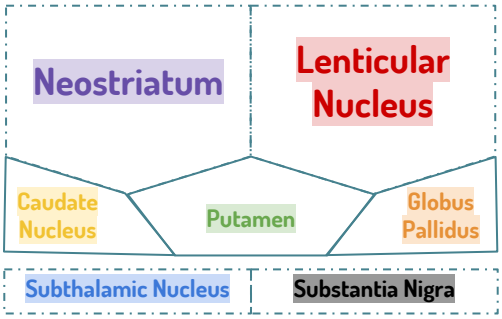
Sensory Input



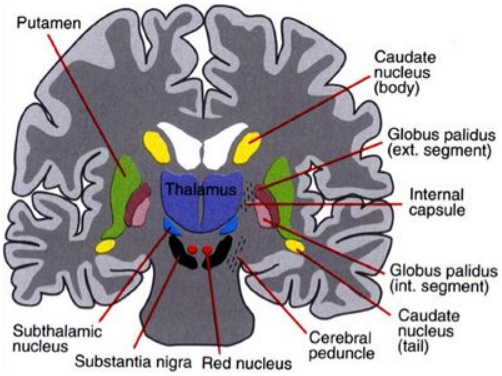
Final Common Path

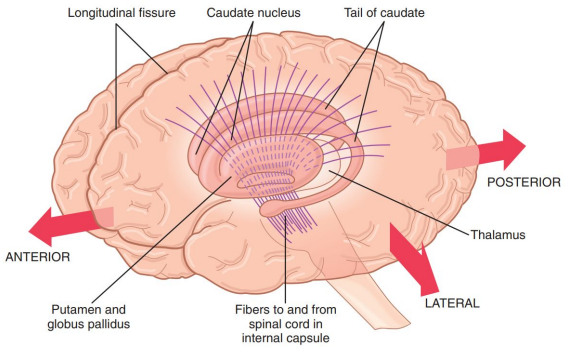
Basal Ganglia Components & Functional Anatomy

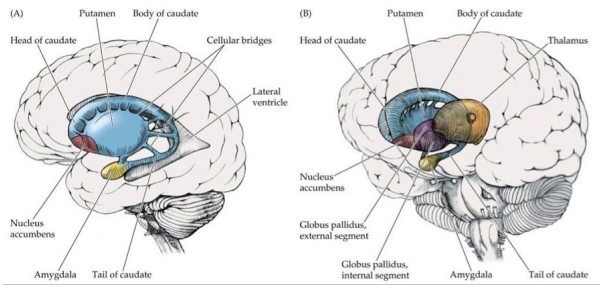
Basal Nuclei



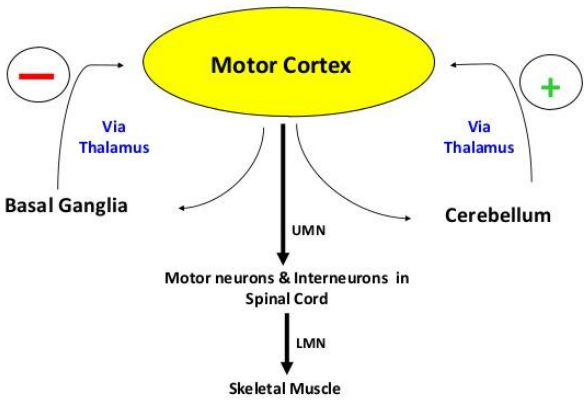
- Corpus striatum = Caudate nucleus plus lentiform nucleus.
- Neostriatum (striatum) = Caudate nucleus plus putamen.







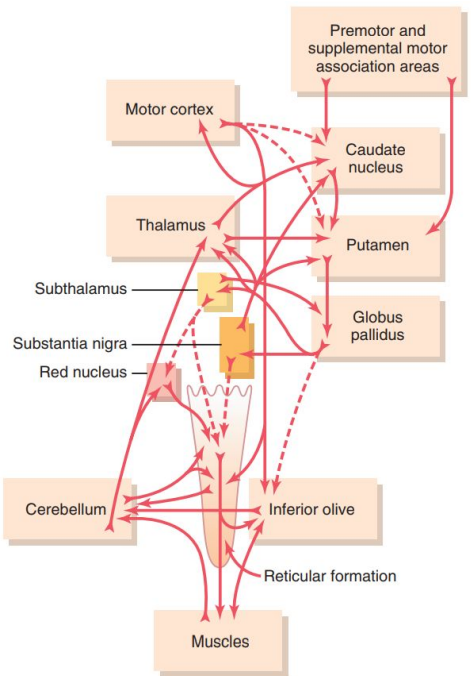
Basal Ganglia Connections



Modulation of motor activity by Basal Ganglia & Cerebellum

Basal Ganglia Connections

Complex Circuitry of Motor Control

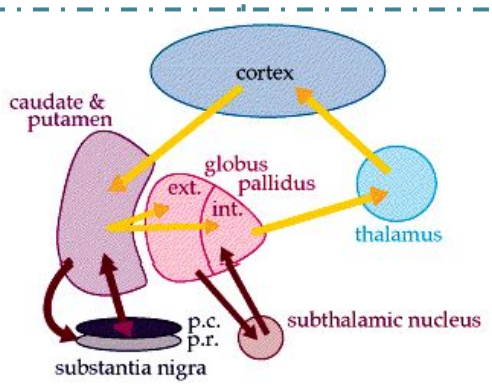


3 Connections to Remember

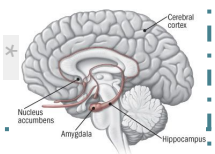
1- Main input	To the basal ganglia
2- Main output	From the basal ganglia
3- Connections	Between parts of basal ganglia

Main Input & Output to The Basal Ganglia

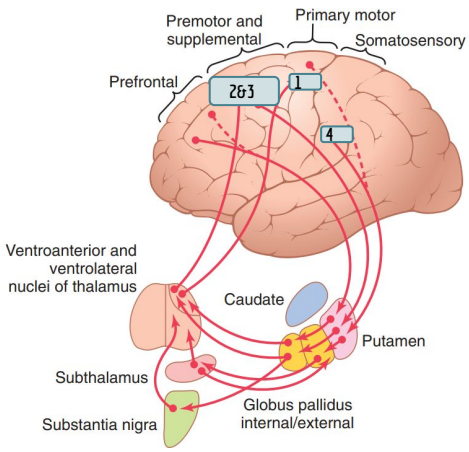
Input	Output
Directly connected to cortex	**Not Directly connected to cortex**
Comes from the cerebral cortex (motor area) and projects to the **NEOSTRIATUM** (a term for the **caudate nucleus and putamen**)	Is via the thalamus to the cerebral cortex (motor area) Unlike **cerebellum**, which sends information directly to cortex



Basic Circuits of Movements Control

Loop	Description
Motor loop (Putamen Circuit)	- Concerned with learned movement. Ex: When digging a nail into wood for a while, you get used to it and you don't need to think every time, putamen circuit is involved in this type of movement.
Cognitive loop (Caudate circuit)	- Concerned with cognitive control of sequences of motor pattern. - Basically it's concerned with motor intentions. - Note: Cognition means thinking process using sensory input with information already stored in memory. Ex: when a Carpenter (نجّار) is asked to build a detailed decorate, he thinks a lot because it's not a repetitive task, which needs a full thought process for every movement, caudate circuit is involved here.
Limbic loop	- Involved in giving motor expression to emotions like, smiling, aggressive or submissive posture (via **nucleus accumbens*** reward circuit). * part of Limbic system near the head. 
Oculomotor loop	- Concerned with voluntary eye movement **[saccadic movement]**

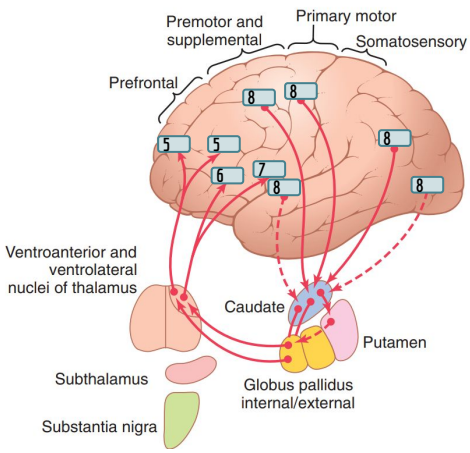
The Putamen Circuit



Outputs	Inputs
1. Primary motor Cortex 2. Premotor 3. Supplemental motor Areas	2. Premotor Cortex 3. Supplemental motor Areas 4. Somatosensory Cortex

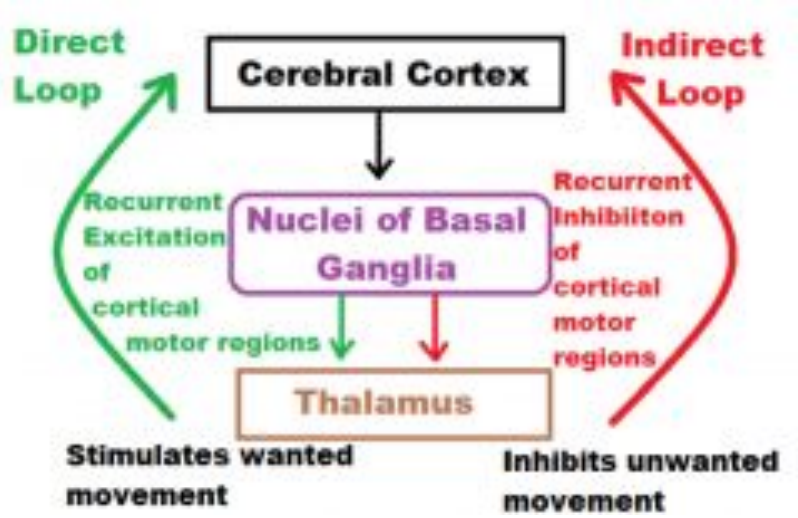
- This circuit has to be completed before movement is initiated

The Caudate Circuit



Outputs	Inputs
5. Prefrontal 6. Premotor 7. Supplemental motor Areas	8. Association Areas

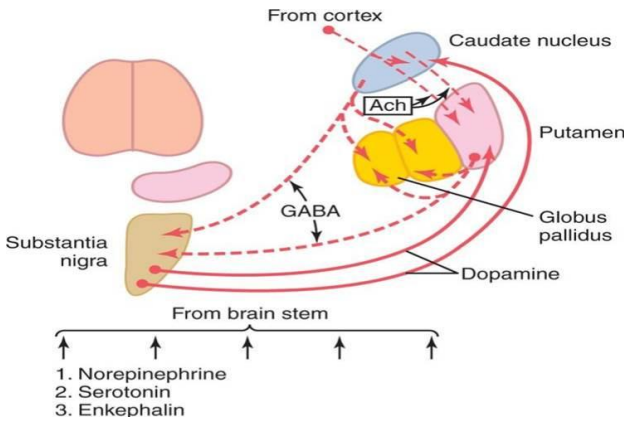
Basal Ganglial Neurotransmitters & Pathways (Direct and Indirect)



Neurotransmitters in Basal Ganglia Circuits

Dopamine	GABA	Acetylcholine
From SN to Putamen and Caudate nucleus	From these nuclei to globus pallidus and SN	From cortex to caudate nucleus and putamen counterbalance DA.

- **Several NTs (NA, 5HT, Enk)** from the brain stem.
- **Multiple excitatory glutamate** pathways (not shown) that balance the inhibitory effects of GABA, Dopamine and 5HT.
- **Enkephalin** are also present and may act as co-transmitters.

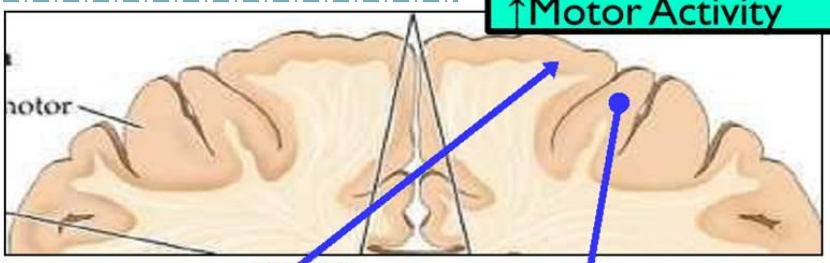


Direct Basal Ganglial Pathway

Result

Direct connection of basal ganglia and cortex **via thalamus.**

↑Motor Activity



GLU +

Cortico-striatal fibers

GLU +

Decrease secretion of GABA

↓GABA -

Thalamus

GPe

GPi -

St

DA1+

↑ GABA

DA from the SNPC activates **DA1** receptors in striatal Neurons of the direct pathway

DA2 -

Thalamocortical Neurons are disinhibited

Nigro-striatal fibers

STh N

SNPC

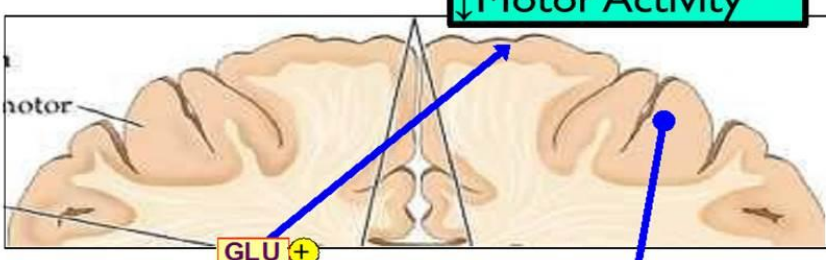
subthalamic

substantia nigra pars compacta

Indirect Basal Ganglial Pathway

Result

↓Motor Activity



GLU +

GLU +

↑GABA -

Thalamus

GPe

St

GPi -

↑ GABA

DA2 -

DA1+

GLU +

↓GABA -

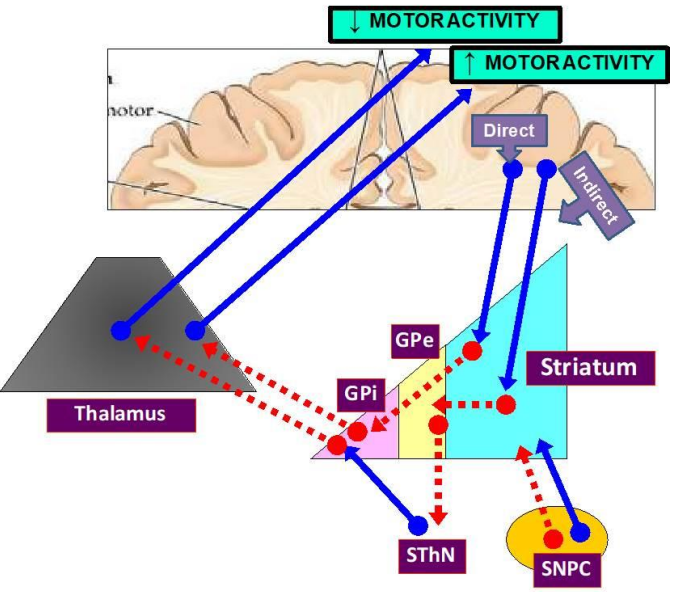
Subthalamic Neurons are disinhibited

STh N

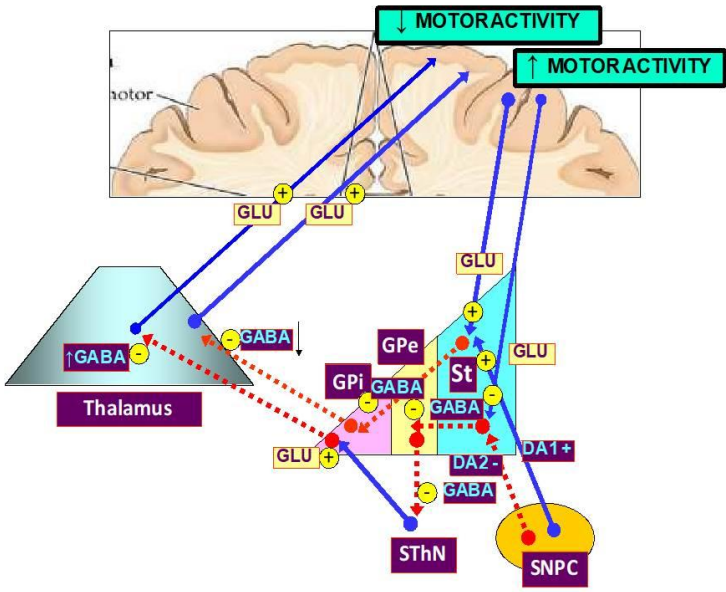
SNPC

DA from the SNPC activates **DA2** receptors in striatal Neurons in the indirect pathway

Both Direct & Indirect Basal Ganglial Pathway



Direct increase motor activity facilitate movement



Indirect decrease motor activity
"suppress the movement"

Basal Ganglia Functions

- Control of movements
- Planning and programming of movements
- Cognitive control in movements

The Putamen Circuit

Executes Learned Patterns of Motor Activity:
Basal ganglia function in association with the corticospinal system to control complex patterns of motor activity.

Examples are:
– writing of letters of the alphabet.
– cutting paper with scissors
– hammering nails
– shooting a basketball through a hoop
– passing a football
– throwing a baseball
– the movements of shoveling dirt
– most aspects of vocalization
– controlled movements of the eyes
– virtually any other of our skilled movements, most of them performed subconsciously.

The Caudate Circuit

Cognitive Control of Sequences of Motor Patterns

Cognition means the thinking processes of the brain, using both sensory input to the brain plus information already stored in memory .Thoughts are generated in the mind by a process called cognitive control of motor activity.

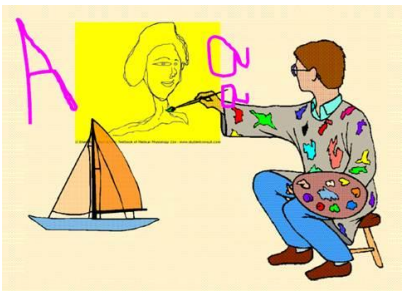
Example: A person seeing a lion approach and then responding instantaneously and automatically by (1) turning away from the lion
(2) beginning to run
(3) even attempting to climb a tree.

- Thus, cognitive control of motor activity determines subconsciously, and within seconds, which patterns of movement will be used together to achieve a complex goal

Change the Timing and to Scale the Intensity of Movements

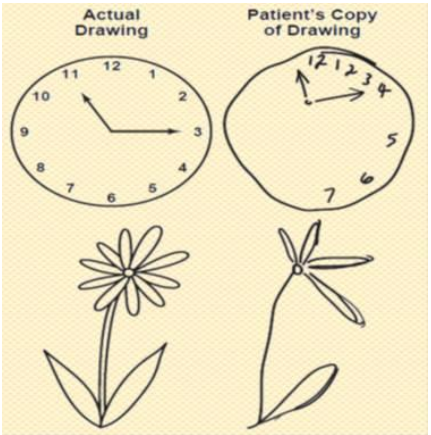
▪ Two important capabilities of the brain in controlling movement are :
(1) to determine how rapidly the movement is to be performed and
(2) to control how large the movement will be.

- For instance, a person may write the letter "a" slowly or rapidly. Also, he or she may write a small "a" on a piece of paper or a large "a" on a chalkboard. Regardless of the choice, the proportional characteristics of the letter remain nearly the same



Damage to Caudate Circuit Results in 4

- Inability to organize pattern of movements to achieve a complex goal.
- Inability to write or draw figures with fixed scale.
- Loss of timing and scaling of movements.



BASAL GANGLIA

1. DISORDERS MOVEMENTS (ATAXIA Rate, Range, Force, Direction)
2. SPEECH
3. POSTURE
4. GAIT
5. MENTAL ACTIVITY OTHERS

Movement Disorders

Hyperkinetic

Chorea
- Huntington's Disease
- Saint Vitus Dance (Sydenham's Chorea)
- Athetosis
- Dystonia
- Hemiballismus/Ballismus
- Tardive Dyskinesia
- Wilson's Disease

Lesions affect Indirect Pathway Predominantly

Hypokinetic

Parkinson's Disease
- Drug Induced eg; MPTP induced
- Dopamine receptor blockers eg; Neuroleptics & antipsychotic drugs

Movement Disorder	Features	Lesion
Chorea	Multiple quick,random Movements,usually most Prominent in the appendicular muscles	Atrophy Of The Striatum. Huntington Chorea
Athetosis	Slow Writhing movements,which are usually more severe in the appendicular muscles	Diffuse Hypermyelination of corpus striatum and thalamus
Hemiballismus	Wild Flinging Movements Of half of the body	Hemorrhagic Destruction **contralateral** subthalamic. Hypertensive Patients
Parkinsonism	Pill Rolling tremor of the Fingers at rest ,leadpipe rigidity and akinesia	Degeneration of Substantia Nigra

Parkinson's Disease

Described by James Parkinson

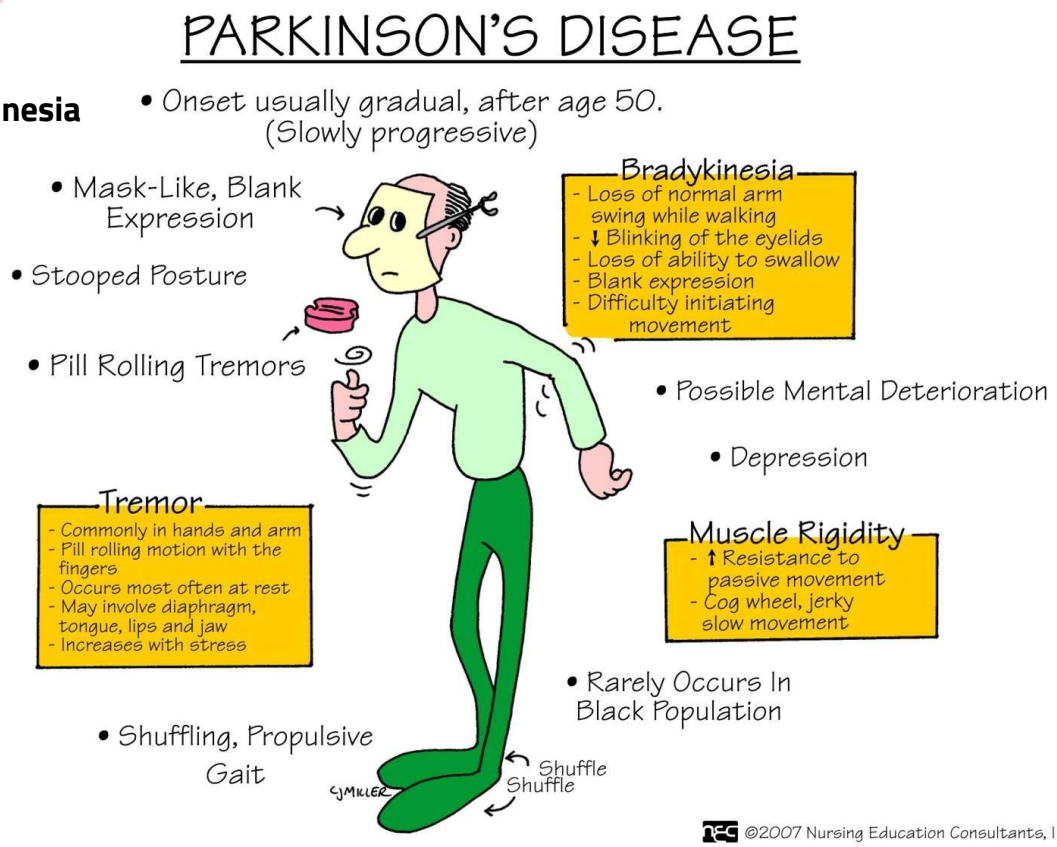
- Degeneration of dopaminergic nigrostriatal neurons (60-80 %).

- Phenothiazine (tranquilizers drugs)

.▪Methyl-Phenyl-Tetrahydropyridine (MPTP). The oxidant MPP+ is toxic to SN.

Five cardinal features

– Tremor
– Rigidity
– Akinesia & Bradykinesia
– Postural Changes
– Speech Change



Metabolic characteristics Doctor Fawziah said:"It is for your information"

- High Oxygen consumption .
- High Copper content in Wilson's disease (Copper intoxication):
- Autosomal Recessive
- Copper binding protein Ceruloplasmin is low
- Lenticular degeneration occurs and patient develops choreiform movements and dystonia

Shahid Qs

Q1a: in spasticity why there is clasp knife pattern?

A1a: increase muscle stretch initially causing difficulty in movement, once initiated the excessive stretch of the muscle stimulate golgi tendon which inhibit it.

" B/c the brain will think that the muscle is going to be tear "

Q1b: why it doesn't happen to rigidity

A1b: b/c both agonist+antagonist are involved at the same time

Q2a: if corticospinal tract "only" is transitioned, what will happen to the tone of the muscle ?

A2a; hypotonia

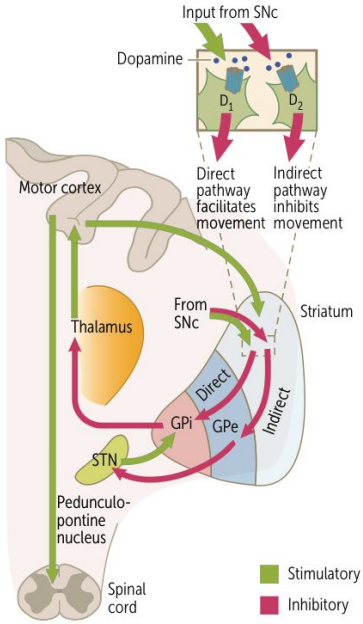
Q2b: Why?

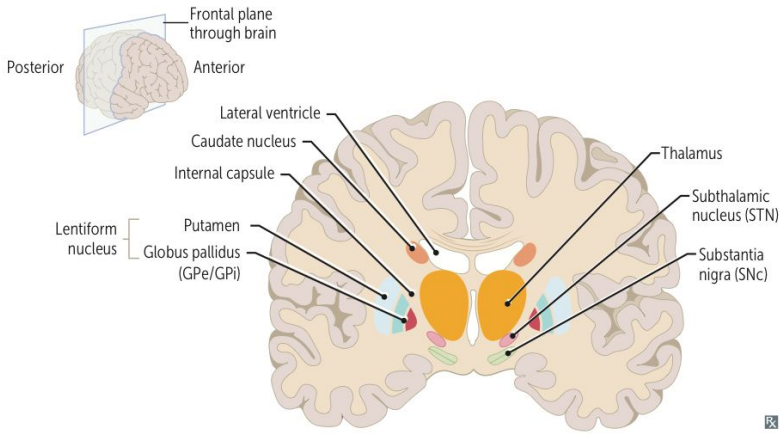
A2b: "pure" corticospinal tract lesions always cause hypotonia but clinically we don't see it B/C pure cortico spinal lesion is very rare , it will always involve Extrapyramidal tracts , and B/C of those tracts involvement , there is hypertonia

Basal ganglia

Important in voluntary movements and making postural adjustments.
Receives cortical input, provides negative feedback to cortex to modulate movement.
Striatum = putamen (motor) + caudate (cognitive).
Lentiform = putamen + globus pallidus.

D_1-Receptor = D1Rect pathway.
Indirect (D_2) = Inhibitory.





Direct (excitatory) pathway—SNc input stimulates the striatum, stimulating the release of GABA, which inhibits GABA release from the GPi, disinhibiting the thalamus via the GPi (↑ motion).
Indirect (inhibitory) pathway—SNc input stimulates the striatum, releasing GABA that disinhibits STN via GPe inhibition, and STN stimulates GPi to inhibit the thalamus (↓ motion).
Dopamine binds to D_1, stimulating the excitatory pathway, and to D_2, inhibiting the inhibitory pathway → ↑ motion.

Read me! I will help you to remember important points

The Caudate Circuit. = Cognitive Control

For Parkinson remember " TRAPS"
-Tremor
– Rigidity
– Akinesia & Bradykinesia
– Postural Changes
-Speech Change

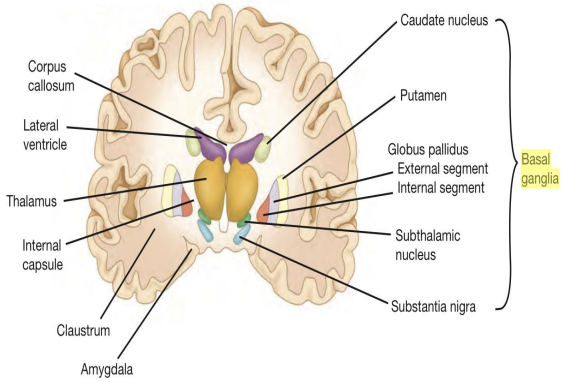


FIGURE 6-20. **Major structures of the basal ganglia.**

Wilson's disease (Copper intoxication):
لو قسمنا كوبر لكلمتين تطلع
بر (per)
اقراها بالعكس بوك (poc)
واللي بيبر ابوه هو الابن (son)

Dopamine	GABA	Acetylcholine
From SN to Putamen and Caudate nucleus	From these nuclei to globus pallidus and SN	From Cortex to caudate nucleus and putamen counterbalance DA.

Also when you study pharmacology don't forget to park your benz!(one of park inson treatments is BENzoatropine

1. Which one of the the following is not considered to be part of the basal ganglia?
   A. Caudate nucleus
   B. Dentate nucleus
   C. Substantia nigra
   D. Globus pallidus
2. Which one of the following loop concern with learning movement?
   A. Putamen circuit
   B. Caudate circuit
   C. Limbic loop
   D. Oculomotor loop
3. Which one of the following NTs secreted by Substantia nigra to putamen and caudate nucleus?
   A. Acetylcholine
   B. Dopamine
   C. GABA
   D. Serotonin
4. Which component of basal ganglia plays a major role in the control of cognitive motor activity?
   A. Globus pallidus
   B. Substantia nigra
   C. Caudate nucleus
   D. Subthalamic nucleus
5. In the indirect basal ganglia pathway there is:
   A. Increase in the motor activity
   B. Decrease in the motor activity
6. In the direct basal ganglia pathway which one of the following neuron is disinhibited?
   A. Cortico-striated neuron
   B. Subthalamic neuron
   C. Nigro-striated neuron
   D. Thalamocortical neuron
7. Which of the following considered a hypokinetic Motor disorder?
   A. Athetosis
   B. Parkinson's Disease
   C. Chorea
   D. Huntington's Disease
8. A patient presented with Slow Writhing movements in the appendicular muscles the Movement Disorder is ?
   A. Athetosis
   B. Chorea
   C. Hemiballismus
   D. Tardive Dyskinesia
9. The condition of athetosis result when which one of the following areas of the brain is dysfunctional?
   A. Globus pallidus
   B. Substantia nigra
   C. Ventral anterior complex of the thalamus
   D. Putamin
10. Which one of the following considered as a feature of Parkinson's disease?
   A. Multiple and Quick random movement
   B. Spasticity
   C. Wild flinging movement of half of the body
   D. rigidity

Answers:
1. B
2. A
3. B
4. C
5. B
6. D
7. B
8. A
9. A
10. D