



Physiology of Basal Ganglia & Regulatory Mechanisms



Color index

- **Important**
- Further Explanation

Recommendations:

- **Guyton, Ch.56 P.682**
- **Dr.Najeeb's videos**

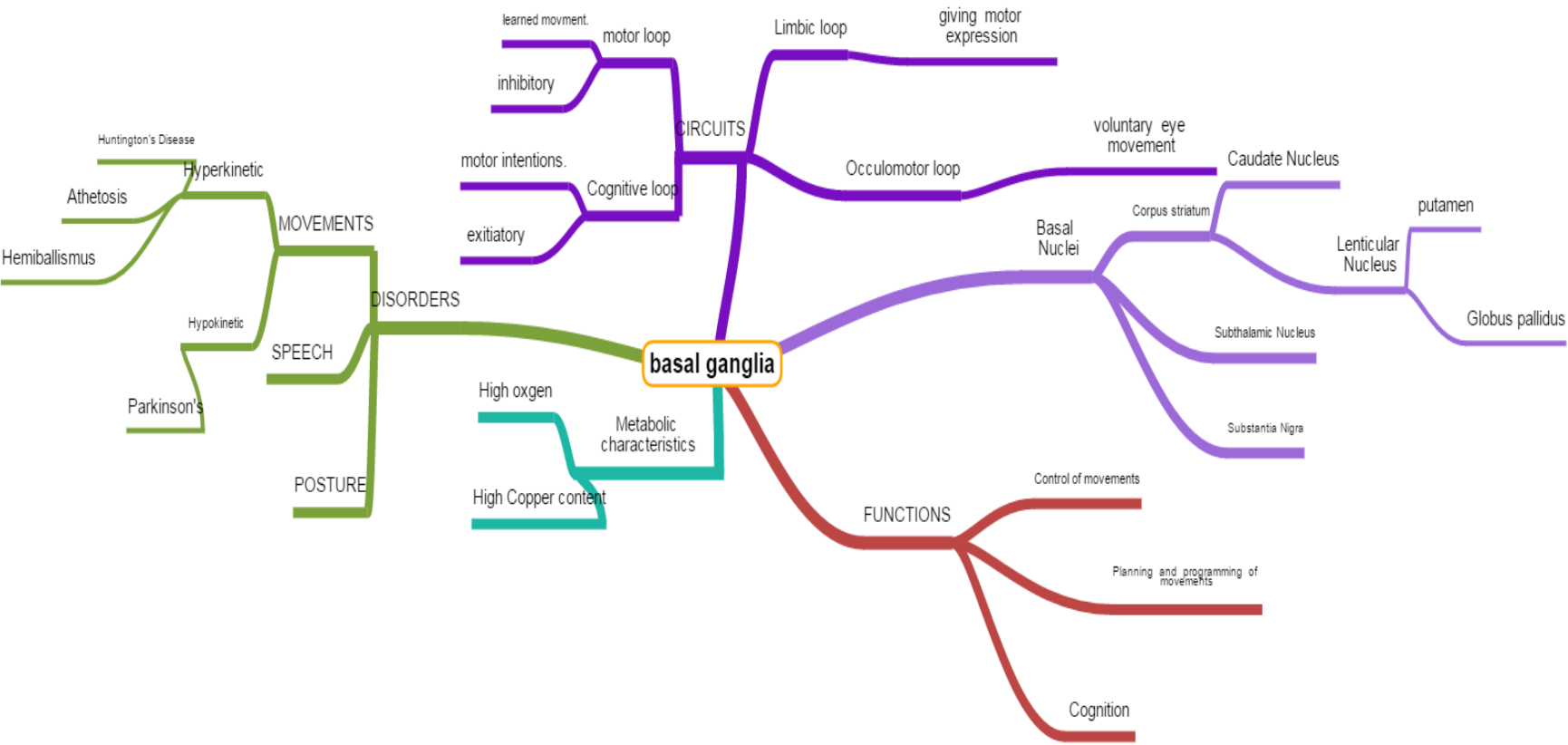
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Recommended Videos!



Please check out this link before viewing the file to know if there are any additions/changes or corrections. The same link will be used for all of our work [Physiology Edit](#)

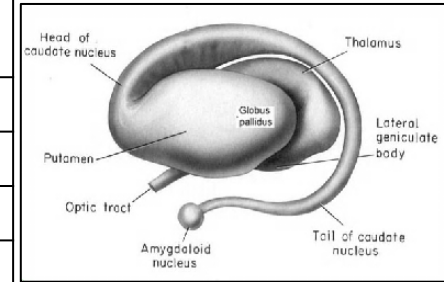


Basal Ganglia

✦ Basal ganglia are **subcortical** nuclei of grey matter located in the interior part of cerebrum near about base.

✦ Component Of Basal Ganglia:

| | |
|----------------------------|--|
| Corpus striatum | Caudate Nucleus + Lenticular Lenticular nucleus " putamen + Globus pallidus " |
| Striatum | Caudate Nucleus + Putamen |
| Palostriatum | Globus Pallidus |
| Subthalamic nucleus | Nucleus found below hypothalamus |
| Substantia nigra | Found in midbrain at all level. |



✦ Connections Basal of Ganglia :

- Main input to the basal ganglia:

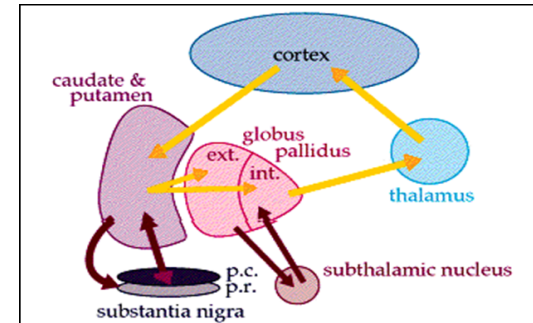
The comes from the cerebral cortex (motor area) and projects to the **Neostriatum** (a term for the caudate nucleus and putamen)

- Main output to the basal ganglia:

Is via the thalamus to the cerebral cortex (motor area)

- Connections between parts of basal ganglia

WHICH WILL BE DISCUSSED NEXT



Basic Circuits of Basal Ganglia

1. **Motor loop (Putamen circuit):** concerned with **learned movement**.

- The input from: Premotor, supplementary motor and somatosensory cortex
- The output from: Primary motor cortex, premotor and supplementary motor areas.
- Putamen circuit give feedback to thalamus then they will go to primary motor cortex, premotor , and supplementary.

2. **Cognitive¹ loop (Caudate circuit):** concerned with cognitive control of sequences of motor pattern. Basically it is concerned with **motor intentions**. The cognitive loop Likened memory with movement.

- The input from: Association area
- The out put to : Prefrontal , Premotor and Supplementary Motor.
- If there damage to caudate circuit pathway they will be either: **bradykinetic (slow movement) or akinetic (no movement)**.

3. **Limbic loop :** involved in giving motor expression to emotions like, smiling, aggressive or submissive posture.

4. **Oculomotor loop :** concerned with voluntary eye movement [saccadic movement]

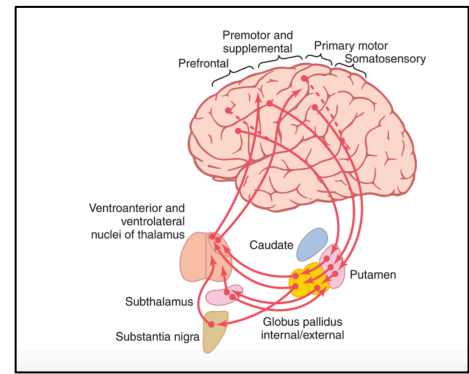
Brain stem is the one who control oculomotor loop

But all motor loop and all cognitive loop and part of limbic loop is concerned with **basal ganglia**

¹: Cognition means the thinking process of acquiring knowledge and understanding through thought, experience, and the senses.

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.



GOOFY CONNECTION 😊

Think of Putamen like patman, we know that patman is a skilled and well taught super hero.. SO putamen circuits concerned with skilled learned movement..



NOTE :

Putamen circuit for subconscious movement

- مثلا لو اكتب حرف الالف كم مرا واكون متجاهله اذا حرف الالف كبير او صغير بدون نمط معين (يعني نفس اذا كان الانسان يهوجس ويشخبط بالورقه) او مثلا لو معاي مقص وابي اقص ورقه بدون حركه او قص معين هذا يعتبر putamen circuit لكن لو مثلا الدكتور قال لي مرا اكتب حرف الالف كبير والي بعده اكتب حرف بي صغير هنا بيبيلي اركز وبعد اذا ابي اقص الورقه بقص معين او حركه معين بيبيلي تركيز وهذا يصير

Caudate Circuit

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, and (3) even attempting to climb a tree.

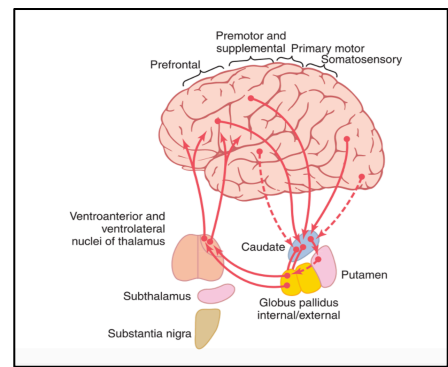
Thus, cognitive control of motor activity determines subconsciously, and within seconds, which patterns of movement will be used together to achieve a complex goal

- **Change the Timing and to Scale the Intensity of Movements**

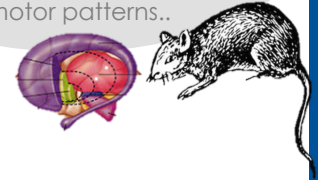
Two important capabilities of the brain in controlling movement are:

- To determine how rapidly the movement is to be performed and
- To control how large the movement will be.

Example: 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



GOOFY CONNECTION 😊
Cudate N looks like a rat (Head & tail) we know that rats when they see a piece of cheese they will think and plan a sequence of moves in order to get it. SO Caudate circuit concerned with cognitive control of motor patterns..



Basal Ganglia Pathways

Direct & Indirect

Direct Pathway “Excitatory Pathway”

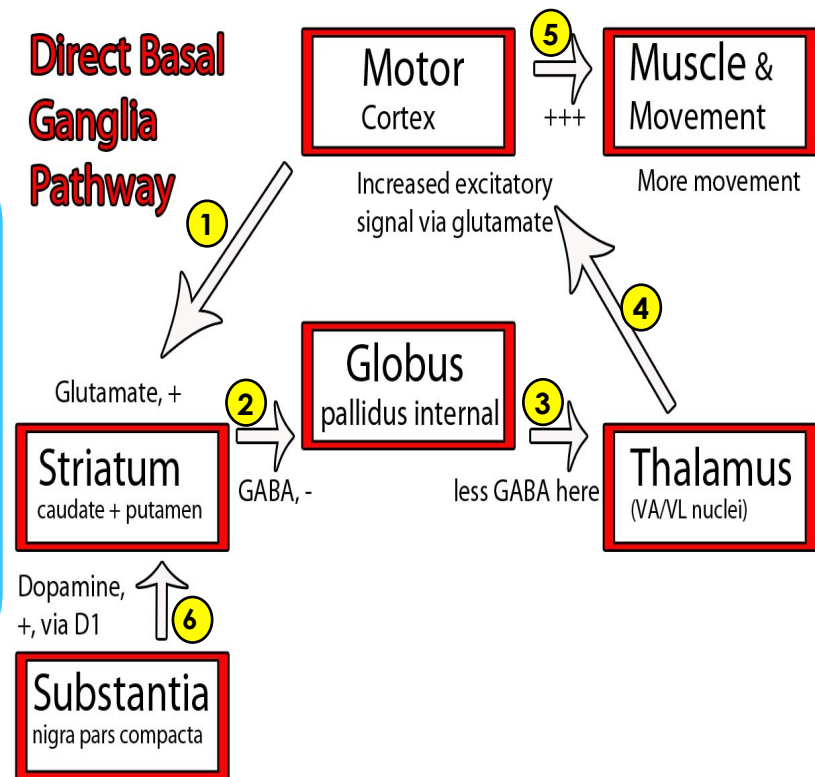
- 1 Motor cortex send **Excitatory** (↑Glutamate) input to St
- 2 St send **inhibitory** (↑GABA) input to **Gpi**.
- 3 Gpi sends **less inhibitory** (↓GABA) input to Thalamus.
- 4 Thalamus send **excitatory**(↑Glutamate) input back to the motor cortex
- 5 **The output of direct pathway is Excitatory = Increases motor activity.**

Substantia Nigra and Dopamine involvement:

- 6 SNPC make connection with striatum by release DA at **DA receptor 1** which is excitatory.

St: Striatum
Gpi: Globus Pallidus Internal
DA: Dopamine
SNPC: Substantia Nigra Pars Compacta
SNPR: Substantia Nigra Pars Reticulata

Direct Basal Ganglia Pathway



Inhibitory NT here is : GABA
Excitatory NT here is : Glutamate

Basal Ganglia Pathways

Direct & Indirect

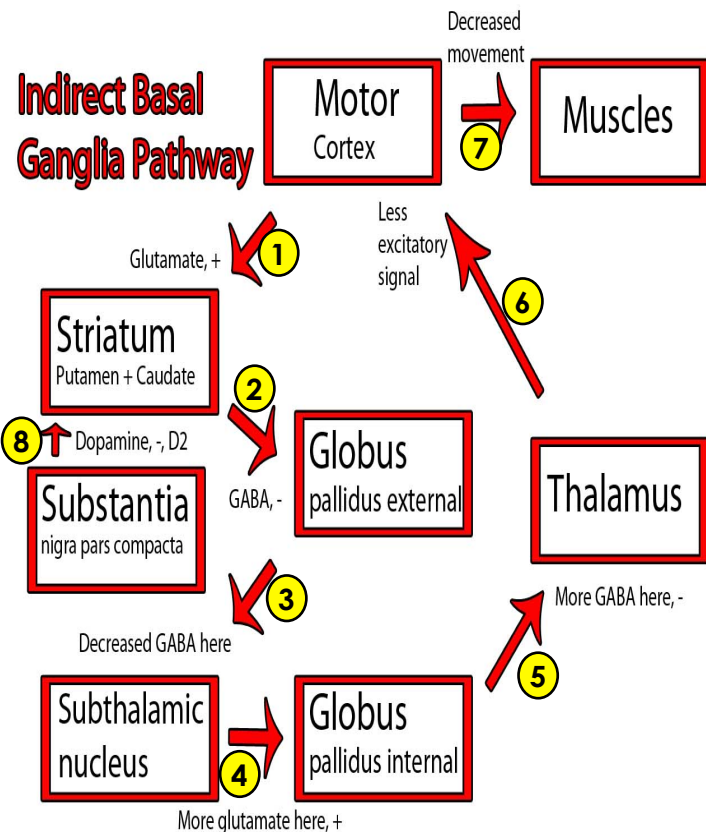
Indirect Pathway “Inhibitory Pathway”

- 1 Motor cortex send Excitatory (↑Glutamate) input to St.
- 2 St sends inhibitory (↑GABA) input to **Gpe**.
- 3 Then Gpe sends less inhibitory (↓GABA) input to **STN**.
- 4 STN project excitatory (↑Glutamate) input to Gpi.
- 5 Gpi send inhibitory (↑GABA) input to thalamus.
- 6 The thalamus then send less excitatory (↓Glutamate) input back to motor cortex.
- 7 The output of indirect pathway is inhibitory = decreases motor activity.

Substantia Nigra and Dopamine involvement:

- 8 SNPC make connection with striatum by release DA at **DA receptor 2** which is inhibitory.

Gpe: Globus Pallidus External
STN: Subthalami Nucleus



You have to check this video :
<http://youtu.be/82oIHBGDoil>
very helpful

MORE ABOUT WILSON'S DISEASE

Wilson's disease, also known as hepatolenticular degeneration, is a rare genetic disorder caused by the buildup of copper. Small amounts of copper exist in the body and are released through the urine. In Wilson's disease, the copper cannot leave the body so it accumulates in certain organs.

Neurological symptoms result from copper buildup in the brain and include:

- Memory impairment
- Gait disturbance
- Vision impairment
- Psychosis
- Tremor



✧ Metabolic Characteristics:

- High Oxygen consumption.
- High Copper content.

Wilson's disease (Copper intoxication):

- ✓ Autosomal Recessive
- ✓ Copper binding protein **Ceruloplasmin** is low
- ✓ Lenticular degeneration occurs.

✧ Functions of Basal Ganglia :

- Control of movements
- Planning and programming of movements
 - Cognition

Basal Ganglia Disorders

Will affect:

- **Movements**

(ataxia **rate, range, force, direction**)

(In parkinson's disease the hand writing will be

Difficult and accessory movement is decrease

And difficult to initiation and stop of movement)

- **Speech**

- **Posture**

- **Gait**

- **Mental activity**

- **Others..**





Movement Disorders

Hyperkinetic

- *Hemiballismus
- *Huntington's Disease
- *Athetosis

Hypokinetic

- *Parkinson's Disease
The main loss in case of parkinson's disease is the inhibitory pathway
- *Drug Induced
(Neuroleptics, MPTP)

| Movement Disorder | Features | Lesion |
|---|--|---|
| Chorea Huntington Chorea  | Multiple quick, random movements, usually most prominent in the appendicular muscles. <i>(Michael Jackson's dance)</i> | Atrophy of the striatum |
| Athetosis  | Slow writhing movements, which are usually more severe in the appendicular muscles <i>(Indian dance)</i> | Diffuse hypermyelination of corpus striatum and thalamus |
| Hemiballismus  | Wild flinging movements of half of the body <i>Arabic dance -as they move their shoulders-</i> | Hemorrhagic destruction of contralateral subthalamic n. Hypertensive patients |
| Parkinsonism  | Pill rolling tremor of the fingers at rest, lead pipe rigidity and akinesia | Degenration of Substantia Nigra |

Parkinson's Disease

Degeneration of **dopaminergic nigrostriatal neurons** (60-80 %).
 Loss of DA → Lose excitatory effect on direct, lose inhibition of indirect
 Overactive GPi and overactive STN → increased inhibition of motor thalamus

❖ **Cause of parkinson's could be by toxin like :**

- Phenthiazines (tranquilizers drugs) .
- Methyl-Phenyl-Tetrahydro-Pyridine (MPTP). The oxidant MPP+ is toxic to SN.

❖ **Features:**

- Tremor
- Rigidity
- Akinesia & Bradykinesia
- Postural Changes
- Speech Changes



Huntingtons Disease

Hereditary , autosomal dominant .

❖ **Causes:** The loss of GABAergic neurons at caudate & putamen, which will leads to chorea.

❖ **Features :**

- Jerky movement of hands toward end of reaching an object.
 - Chorea
- Slurred speech and incomprehensive.
- Progressive Dementia

1- Which one is correct about metabolic characteristic ?

- A. High o₂ consumption
- B. High copper content in wilsons disease
- C. Copper binding protein ceruloplasmin is high
- D. Lenticular degeneration occurs

2- Which one is the cause of wilsons disease ?

- A. High copper
- B. Low copper
- C. High o₂
- D. Low o₂

3- Which part of basal ganglia is effected in case of Parkinsonism ?

- A. Striatum
- B. Substantia nigra
- C. Subthalamic neuron
- D. Corpus striatum

4- Cognitive associated with what ?

- A. Emotions
- B. Voluntary eye movement
- C. Motor intention
- D. Learn movement

5- Which one of this part is not involve in basal ganglia ?

- A. Thalamus
- B. Subthalamus
- C. Lenticular nucleus
- D. Corpus straitum

6- The main input to basal ganglia ?

- A. Substantia nigra
- B. Cerebral cortex
- C. Thalamus
- D. Globus pallidus

7- The main output to basal ganglia ?

- A. Substantia nigra
- B. Cerebral cortex
- C. Thalamus
- D. Globus pallidus

8- Which one of these neurotransmitter is consider with inhibition ?

- A. Glutamate
- B. Dopamin 1
- C. Dopamin 2
- D. Acetylcholin

1- List four disease that will happen in case of any part of basal ganglia is effected ?

- 1-Chorea
- 2-Athetosis
- 3- Hemiballismus
- 4- Parkinsonism

2- Function of basal ganglia ?

- 1-Control of movements
- 2-Planning and programming of movements
- 3-Cognition

3- Describe the direct pathway of excitation ?

Information send to **putamen** from **cortex** by corticostriatal fiber which **release the glutamine** to excitatory the fiber from putamen to **internal globus pallidus** to release **more GABA** . GABA in **inhibitory** the fiber from from internal globus to **thalamus** to release less GABA . Decrease GABA in thalamus cause **stimulate** for fibers from thalamus to **cortex** (thalamocortical neuron) to release the **glutamine** and excitatory the cortex -> **increase motor activity**

4- Describe the indirect pathway of inhibition ?

Information send to **putamen** from **cortex** by corticostriatal fiber which **release the glutamine** to excitatory the fibers from putamen to **external globus pallidus** to **release more GABA** . GABA in **inhibitory** the fibers from external globus to **subthalamic nucleus** to release **less GABA** . Decrease GABA in subthalamic nucleus cause stimulate for fibers from subthalamic nucleus to **internal globus pallidus** to release the **glutamine in Gpi** and stimulate fibers from internal globus pallidus to **thalamus** to release **more GABA** in thalamus . Increase GABA in thalamus cause inhibition for fibers from thalamus **to cortex** (thalamocortical neuron) --> **doesn't** release the **glutamine** → **inhibition** the cortex → **decrease motor activity**

❖ Basal ganglia

is groups of subcortical neurons the effects of basal ganglia on motor activity are generally inhibitory

❖ Function of basal ganglia :

starting ,stopping motor functions , inhibiting unwanted movement.
It changes the timing and scales the intensity of movements

❖ Basal ganglia circuit :

1. Putamen circuit is inhibitory “ indirect connect to cortex “
2. Caudate circuit is excitatory “ direct connect to cortex “

❖ Lesions of the basal ganglia

produce effects on contra lateral side of the body
Damage to basal ganglia **does not cause paralysis**.
It's only results in abnormal movements

❖ Basal Ganglia Disorders:

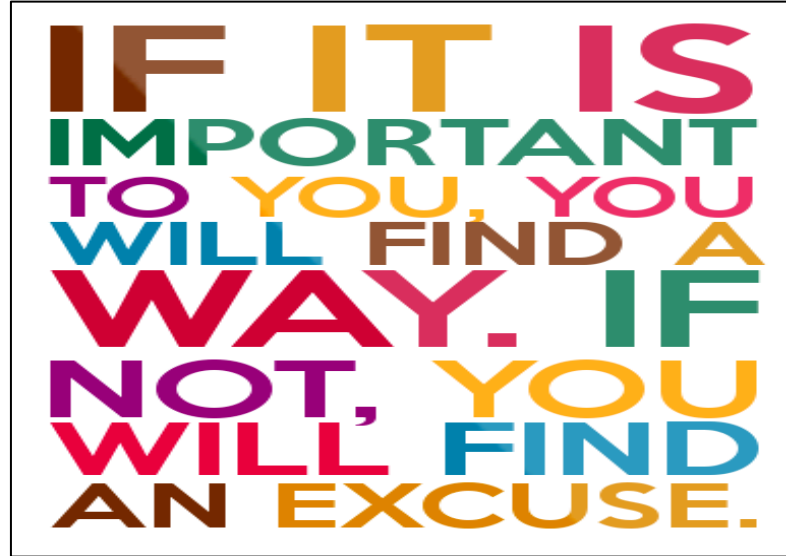
| Disorder | Features | Etiology |
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| Chorea (Huntingtons) | Multiple quick, random movements. | Atrophy of the striatum . |
| Athetosis | Slow writhing movements. | Hypermyelination of corpus striatum and thalamus . |
| Hemiballismus | Wild flinging movements of half of the body. | Hemorrhagic destruction of contralateral subthalamic n. |
| Parkinsonism | Pill rolling tremor of the fingers at rest, lead pipe rigidity and akinesia . | Degeneration of Substantia Nigra . |

THANK YOU FOR CHECKING OUR WORK!

BEST OF LUCK

Done By:

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اللهم إني أَسْتُوْدِعُكَ مَا قَرَأْتُ وَ مَا حَفِظْتُ وَ مَا
تَعَلَّمْتُ، فَرُدَّهُ عِنْدَ حَاجَتِي إِلَيْهِ، إِنَّكَ عَلَى كُلِّ شَيْءٍ قَدِيرٌ،
حَسْبُنَا اللَّهُ وَ نَعْمَ الْوَكِيلُ ...