



神經解剖學  
NEUROANATOMY

**BASAL NUCLEI**

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臺北醫學大學醫學系 解剖學暨細胞生物學科

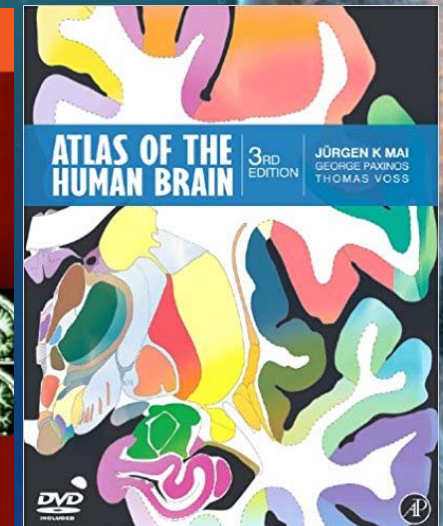
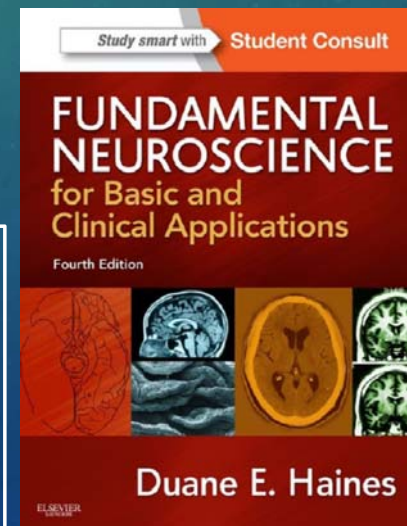
臺北醫學大學醫學院 轉譯影像研究中心

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# OUTLINE

- Components and Pathways of the Basal Nuclei
- Functions and Related Disorders of the Basal Nuclei

- **Fundamental Neuroscience (4th edition)**
  - Chapter 26: The Basal Nuclei
- **Atlas of the Human Brain (3rd edition)**

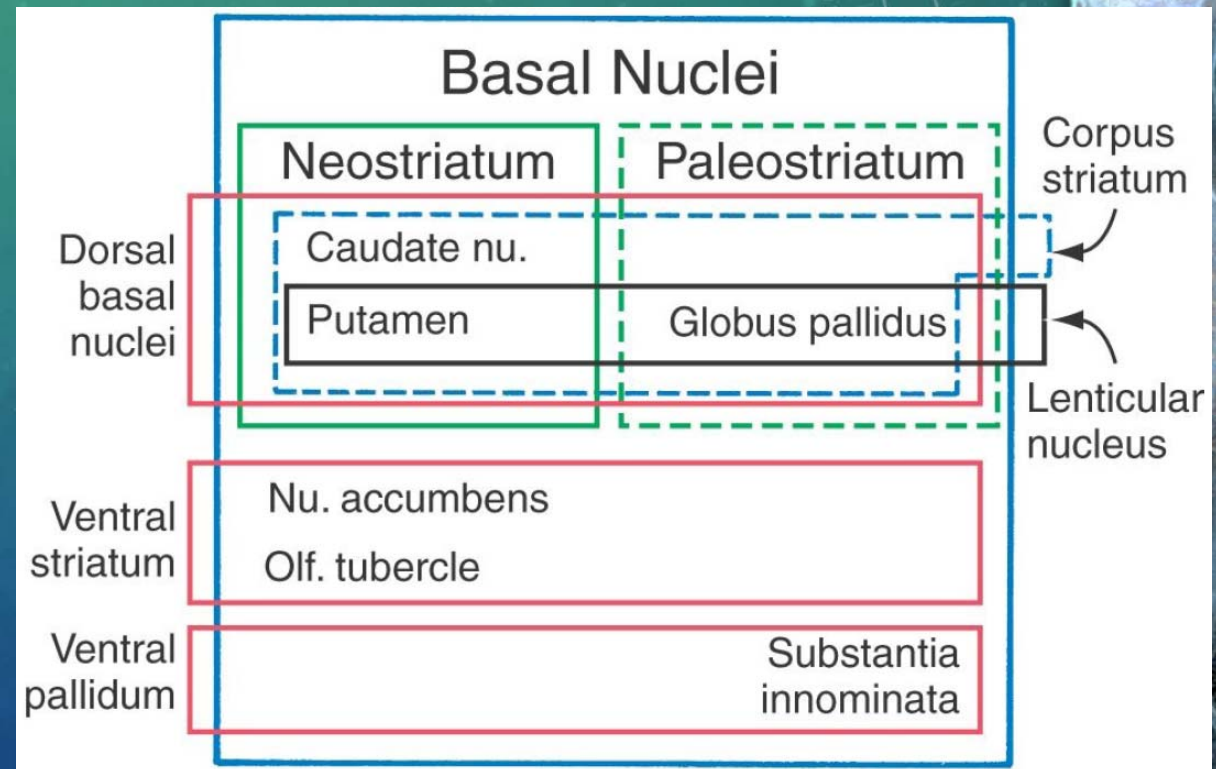


- **Striatal complex**
  - Caudate nucleus
  - Putamen
  - Nucleus accumbens
  - Olfactory tubercle
- **Pallidal complex**
  - Globus pallidus
  - Substantia innominata

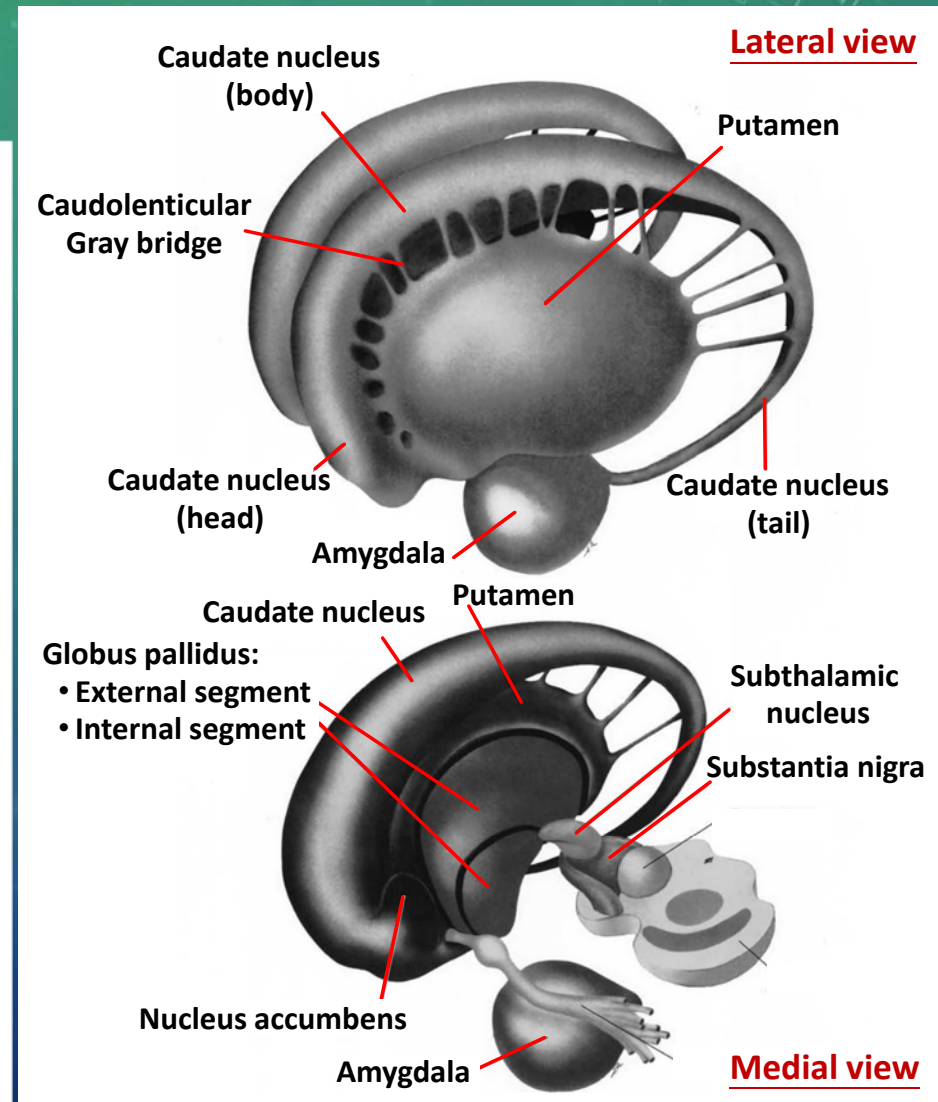
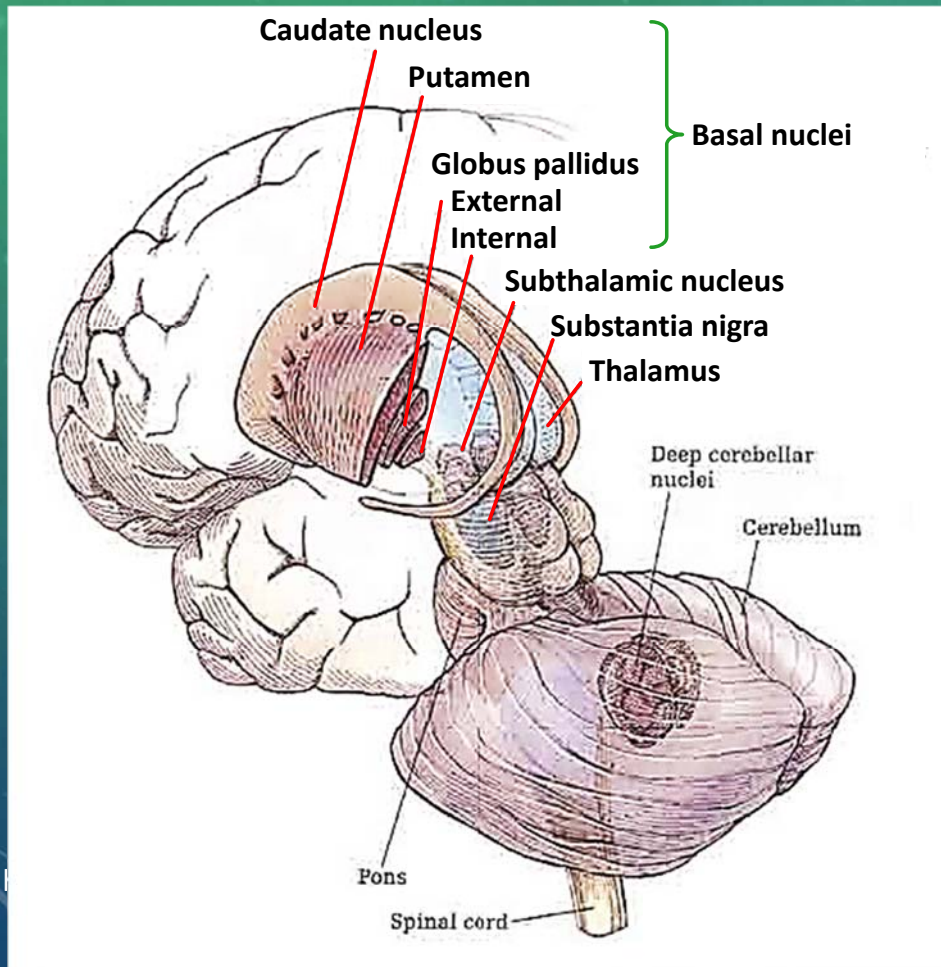
## COMPONENTS AND PATHWAYS OF THE BASAL NUCLEI

# BASAL NUCLEI

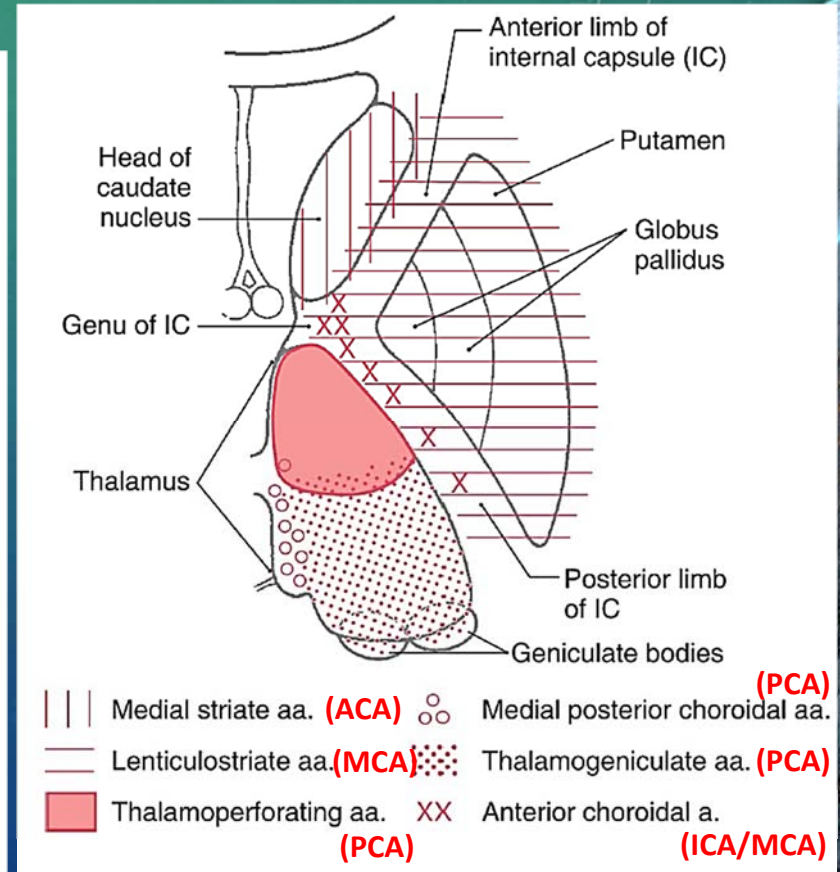
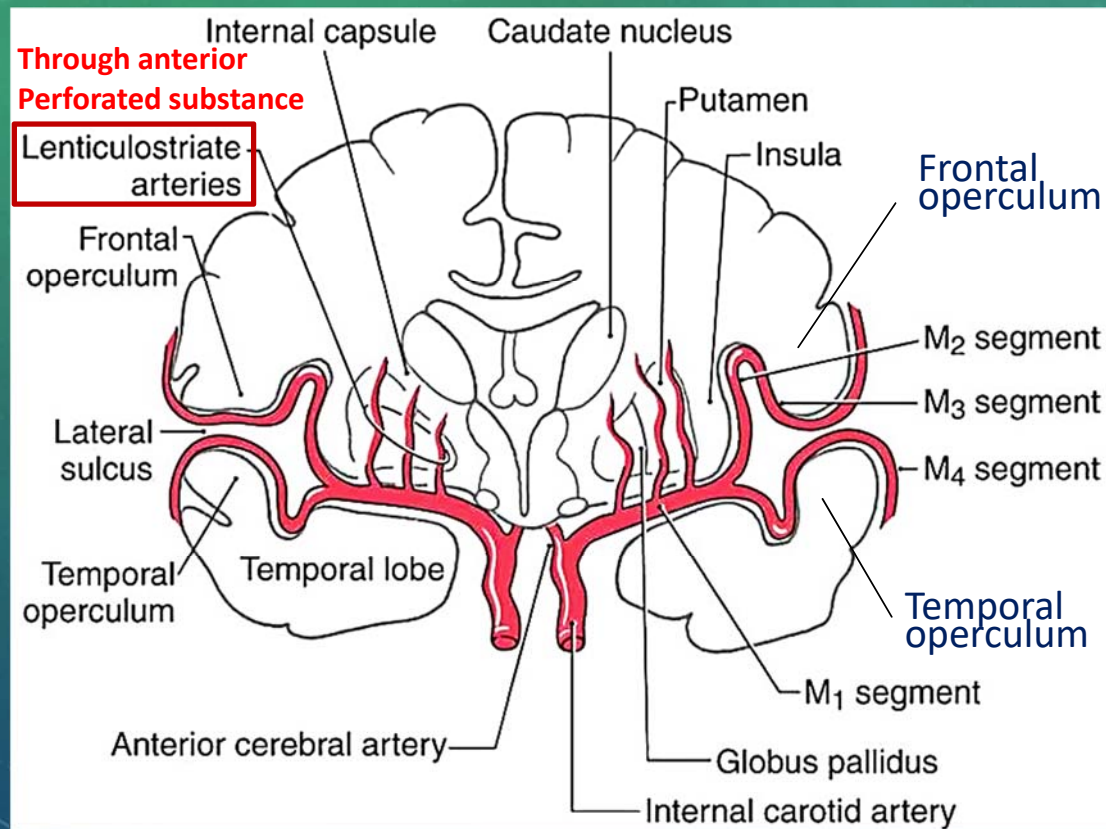
- **Dorsal basal nuclei:** the caudate and lenticular nuclei
- **Ventral striatum:** the nucleus accumbens plus parts of the adjacent olfactory tubercle
- **Ventral pallidum:** the substantia innominata



# BASAL NUCLEI

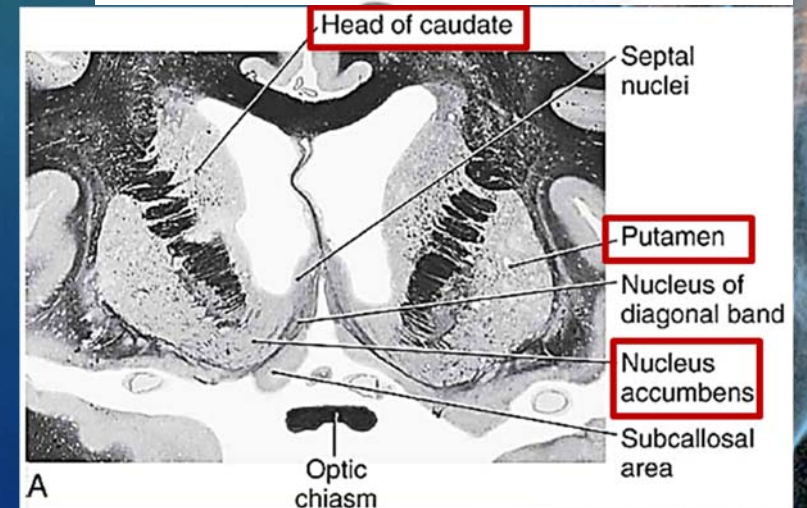
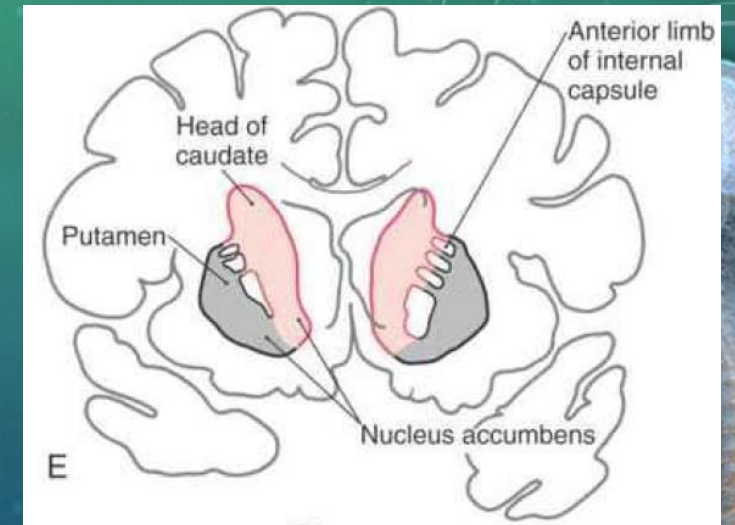


# BLOOD SUPPLY



# STRIATAL COMPLEX

- **Striatal complex**
  - Caudate nucleus
  - Putamen
  - Nucleus accumbens
  - Olfactory tubercle

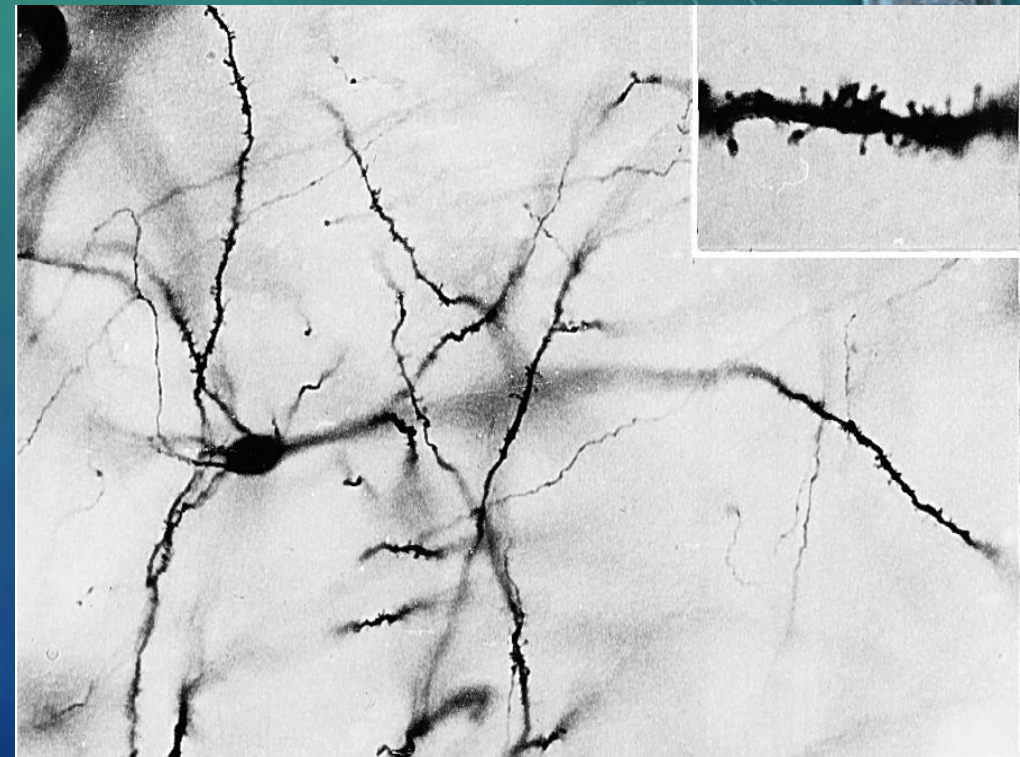


# STRIATAL COMPLEX

- Caudate nucleus
- Putamen
- Nucleus accumbens
- Olfactory tubercle

- **Medium spiny neuron (MSN)**

- Medium-sized cell bodies
- Large numbers of spines on the dendrites
- GABAergic neuron
- **GABA**:  $\gamma$ -aminobutyric acid (GABA), an inhibitory neurotransmitter

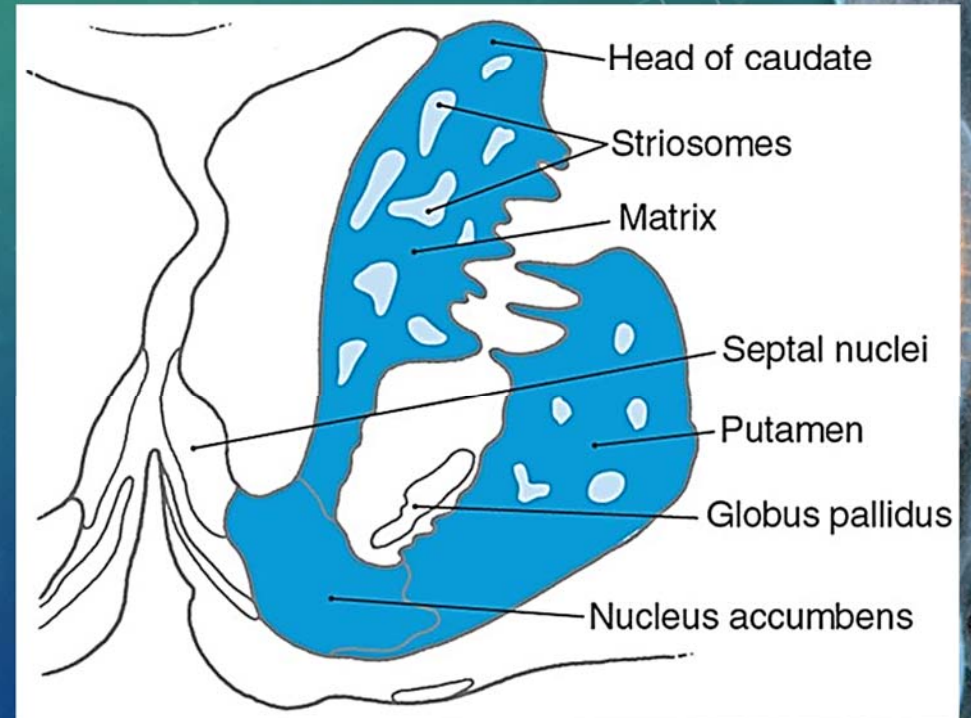




# STRIATAL COMPLEX

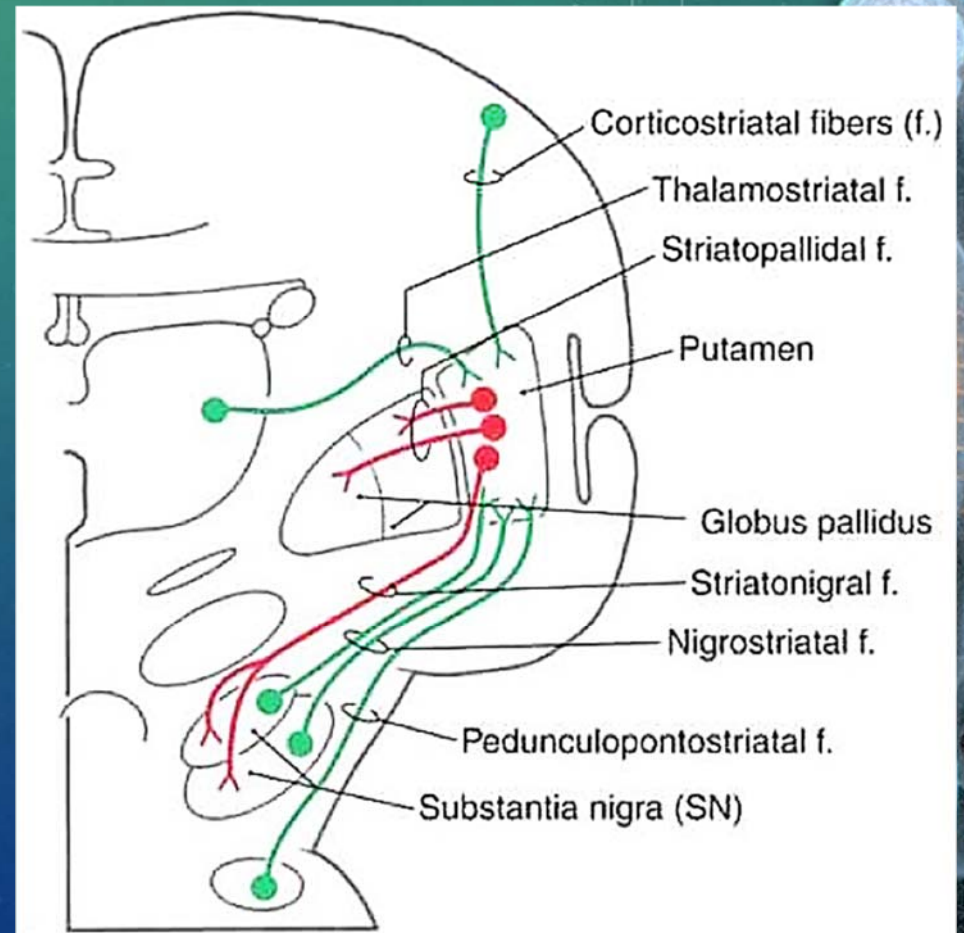
- Caudate nucleus
- Putamen
- Nucleus accumbens
- Olfactory tubercle

- **Striosomes (Patches)** of striatal complex
  - Most prominent in the head of the caudate.
  - Acetylcholinesterase-poor regions
- Striosomes are surrounded by **matrix**
  - Matrix contains high concentrations of acetylcholine.



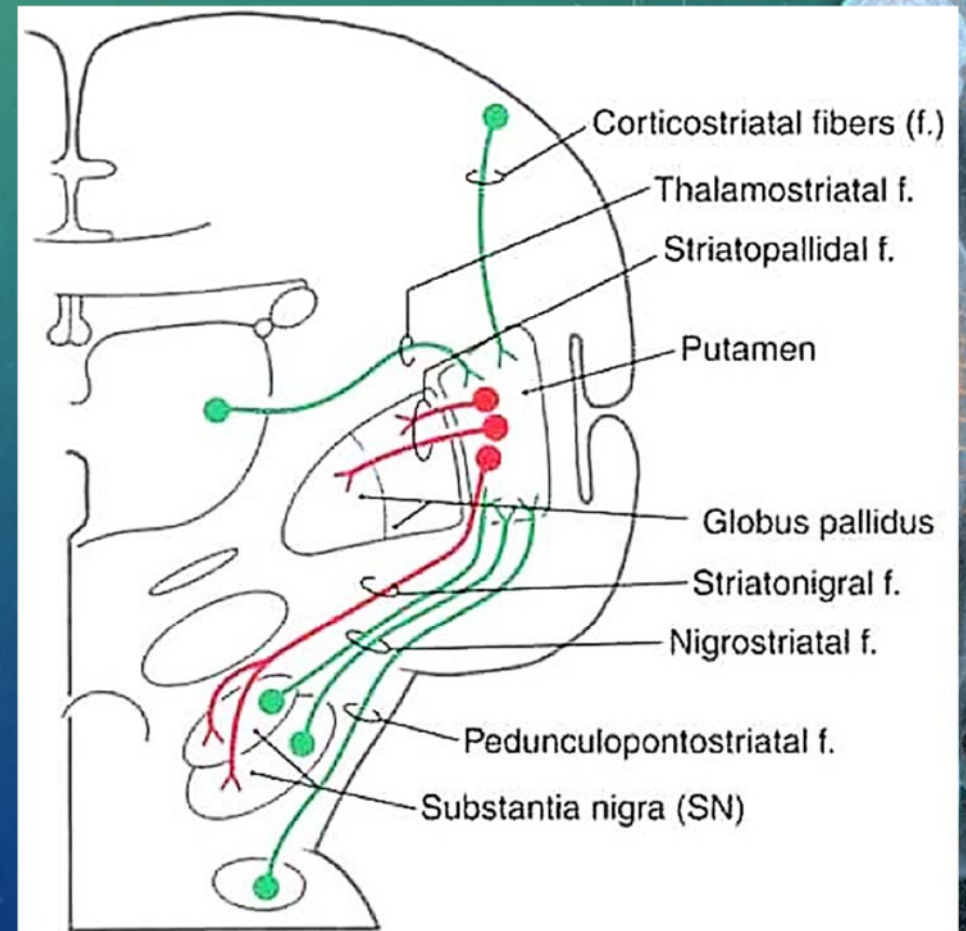
# CONNECTIONS OF STRIATAL COMPLEX

- **Afferent projections**
  - Cerebral cortex → corticostriatal fibers → putamen (**Major afferent**)
  - Thalamus → thalamostriatal fibers → putamen
  - Substantia nigra → nigrostriatal fibers → putamen
  - Parabrachial pontine reticular formation → pedunculopontostriatal fibers → putamen

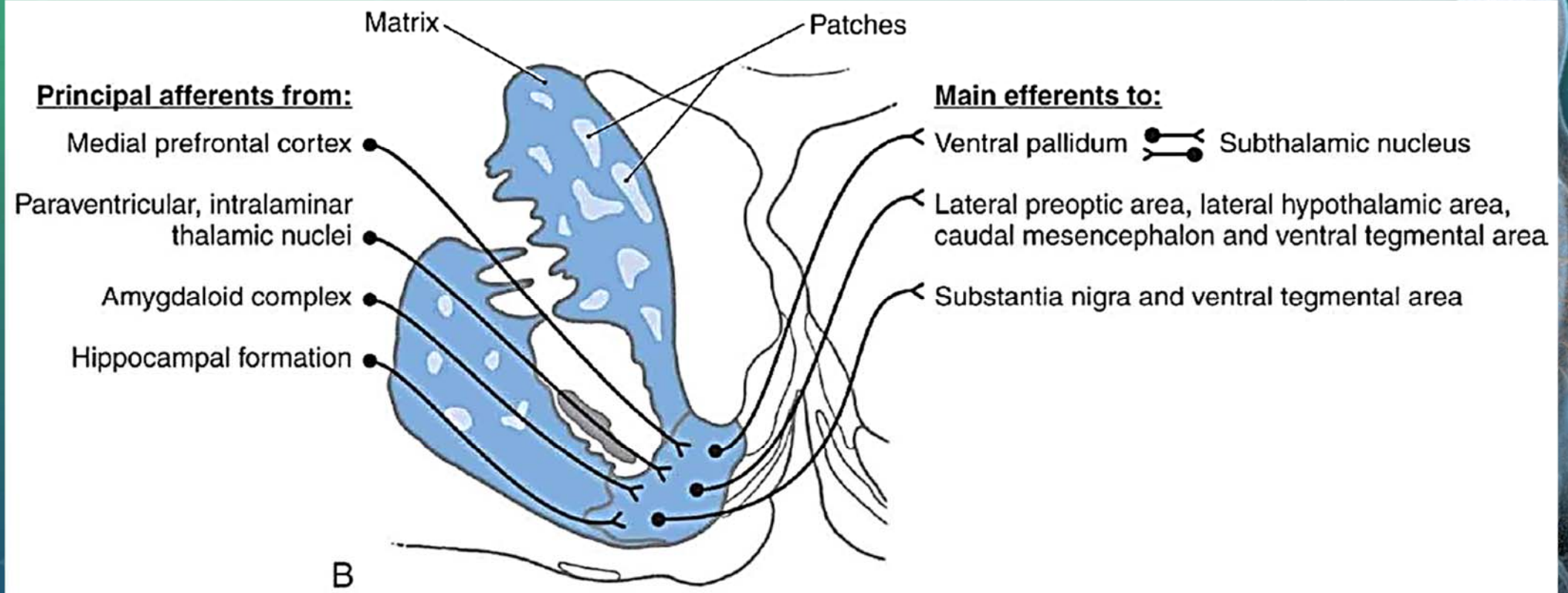


# CONNECTIONS OF STRIATAL COMPLEX

- Efferent projections
  - Putamen → striatopallidal fibers → globus pallidus
  - Putamen → striatonigral fibers → Substantia nigra



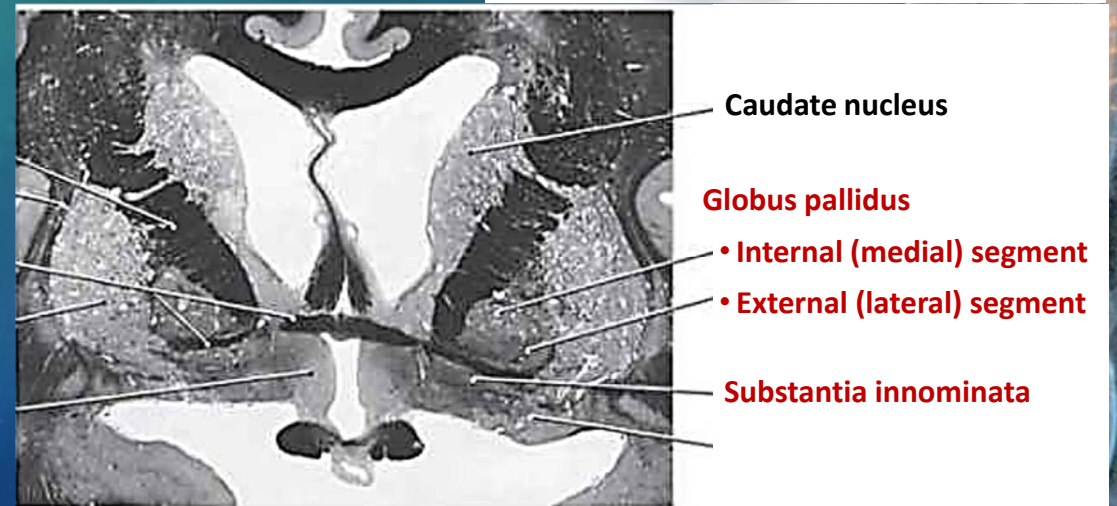
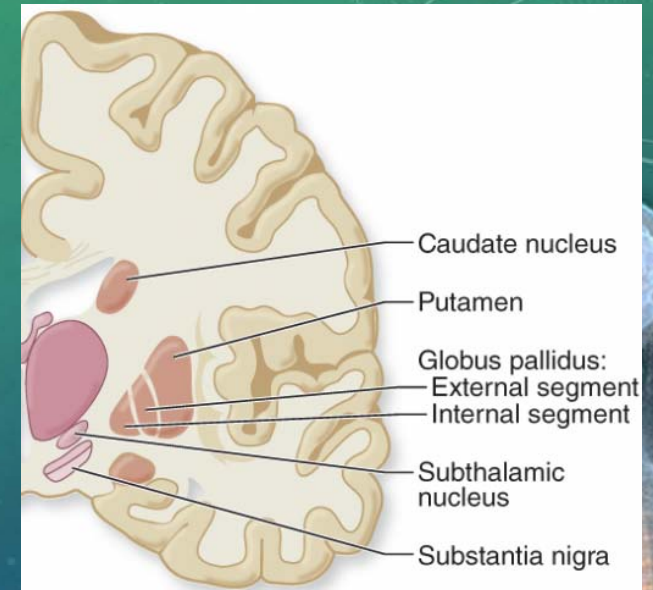
# CONNECTIONS OF NUCLEUS ACCUMBENS



# PALLIDAL COMPLEX

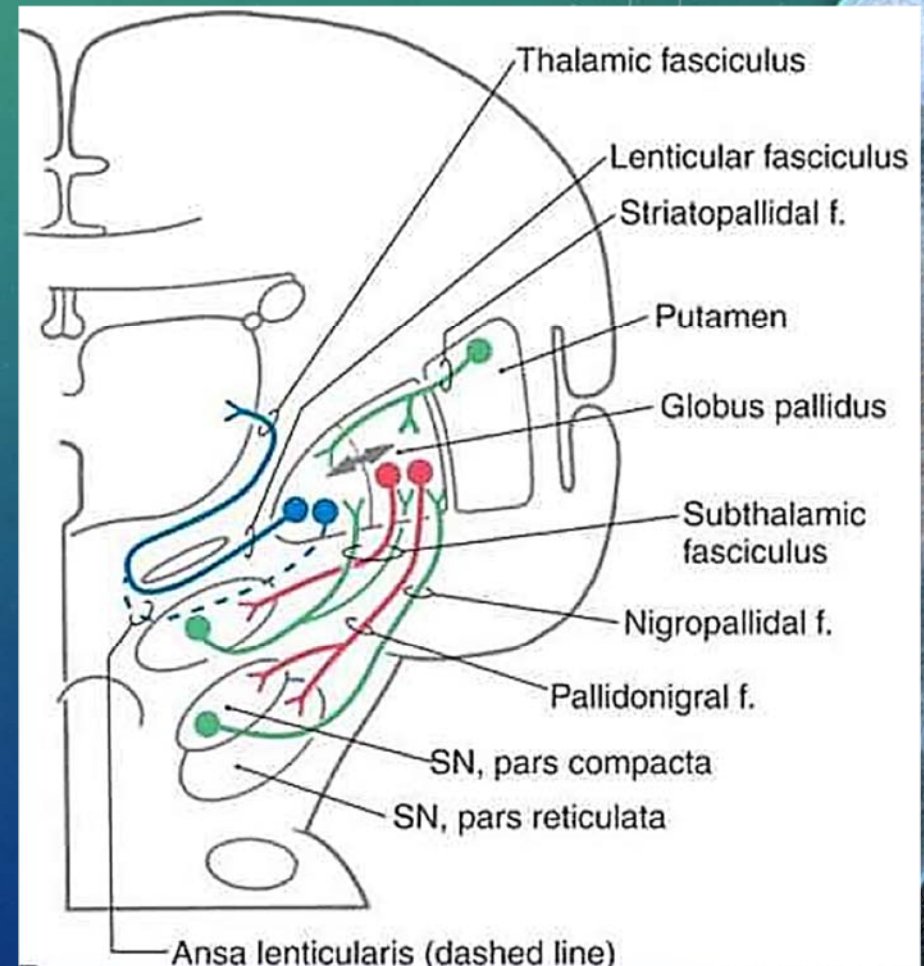
- Pallidal complex
  - Globus pallidus
  - Substantia innominata

- Contains primarily GABAergic neurons with high rates of spontaneous activity.
- These cells tonically inhibit their targets.



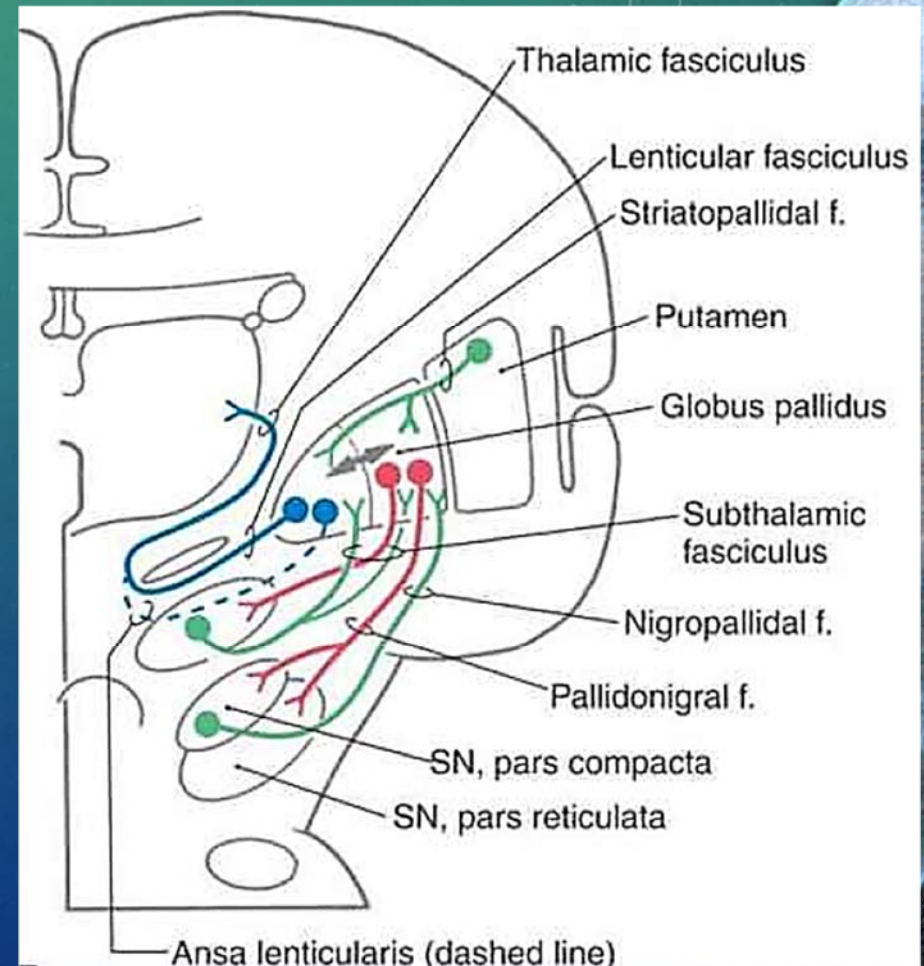
# CONNECTIONS OF GLOBUS PALLIDUS

- Interconnections between internal and external segments
  - Pallidopallidal fibers
- **Afferent** projections
  - Striatal complex → striatopallidal fibers → globus pallidus (**Major afferent**)
  - Subthalamus nucleus → subthalamopallidal fibers → globus pallidus
  - Substantia nigra, pars compacta → nigropallidal fibers → globus pallidus



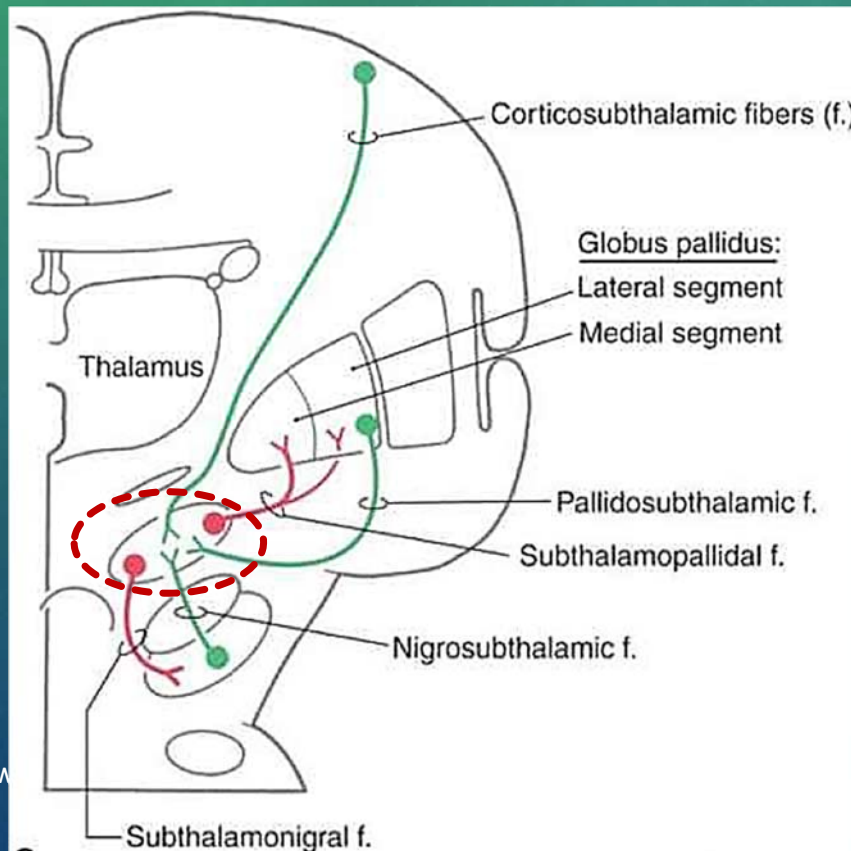
# CONNECTIONS OF GLOBUS PALLIDUS

- Efferent projections
  - Internal segment of globus pallidus → pallidothalamic fibers → thalamus
  - External segment of globus pallidus → pallidosubthalamic fibers → subthalamic nucleus
  - External segment of globus pallidus → pallidonigral fibers → substantia nigra
- Pallidothalamic fibers
  - Lenticular fasciculus
  - Ansa lenticularis→ Thalamic fasciculus

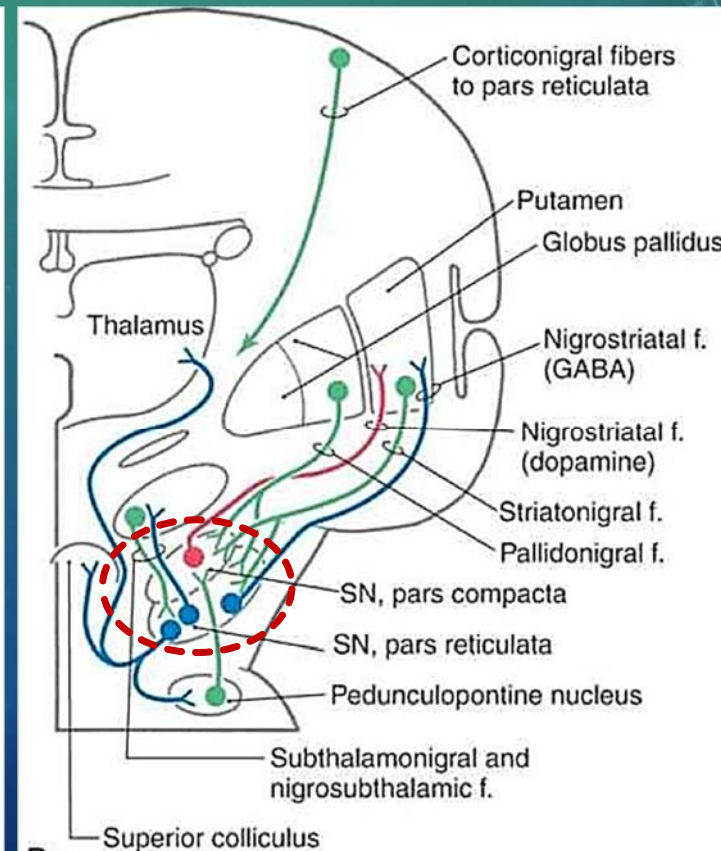


# SUBTHALAMUS NUCLEUS & NIGRAL COMPLEX

Connections of Subthalamus  
(**glutamate** neurotransmitter)



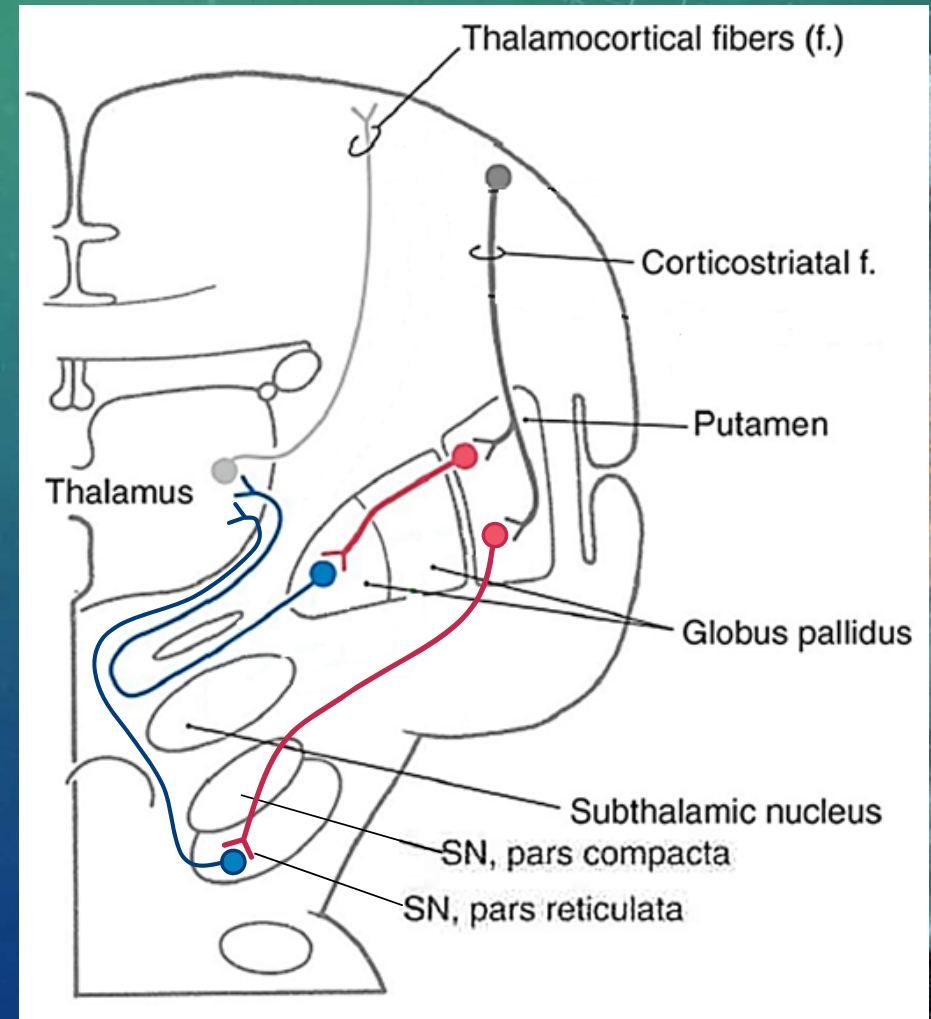
Connections of Substantia nigra  
(**dopamine** neurotransmitter)



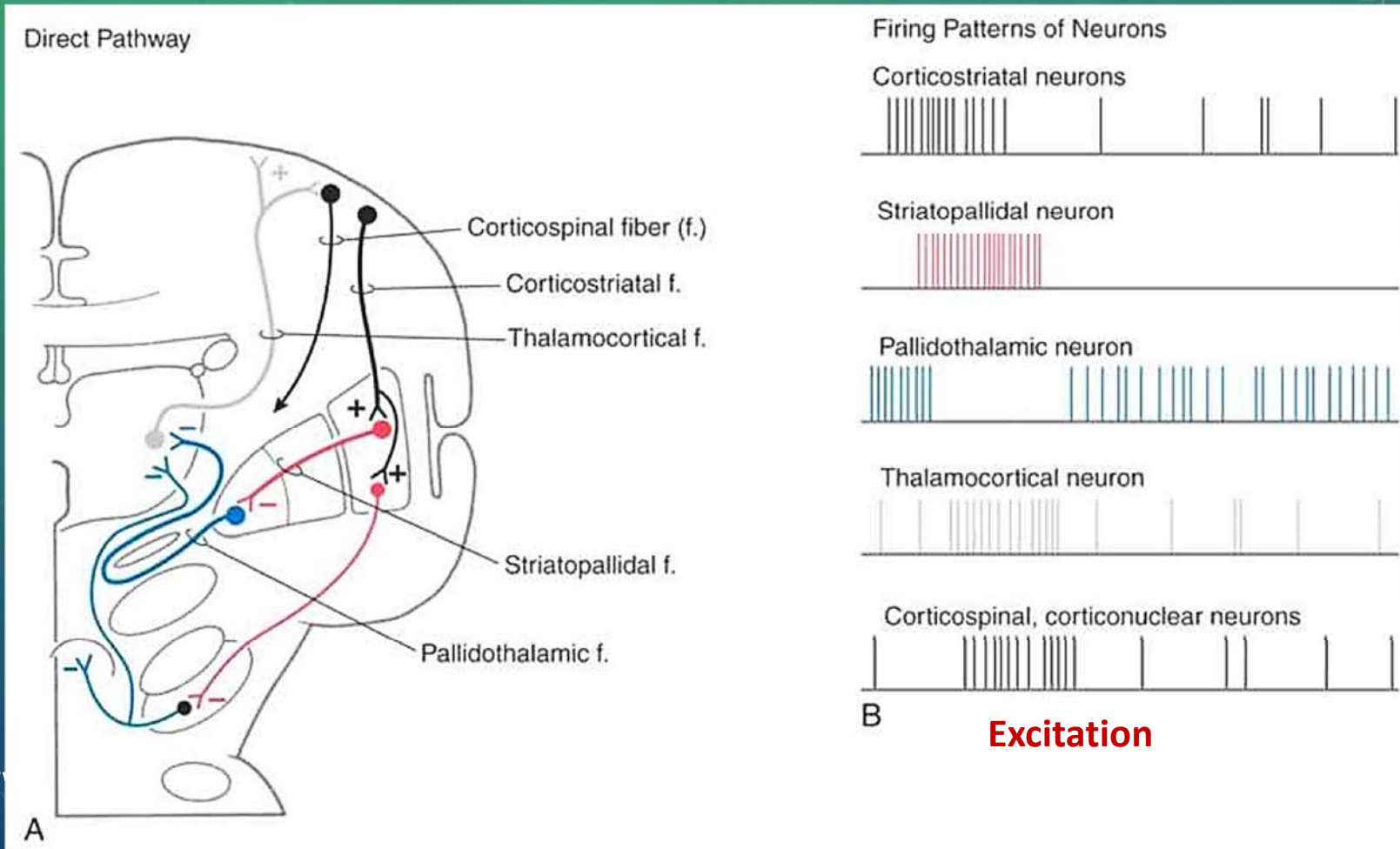


## DIRECT PATHWAYS

- The **direct pathway** facilitates a flow of information through the **thalamus**.
- Corticostriatal fibers (+), striatopallidal fibers (-), pallidothalamic fibers (-).
- Corticostriatal fibers (+), striatonigral fibers (-), nigralthalamic fibers (-).



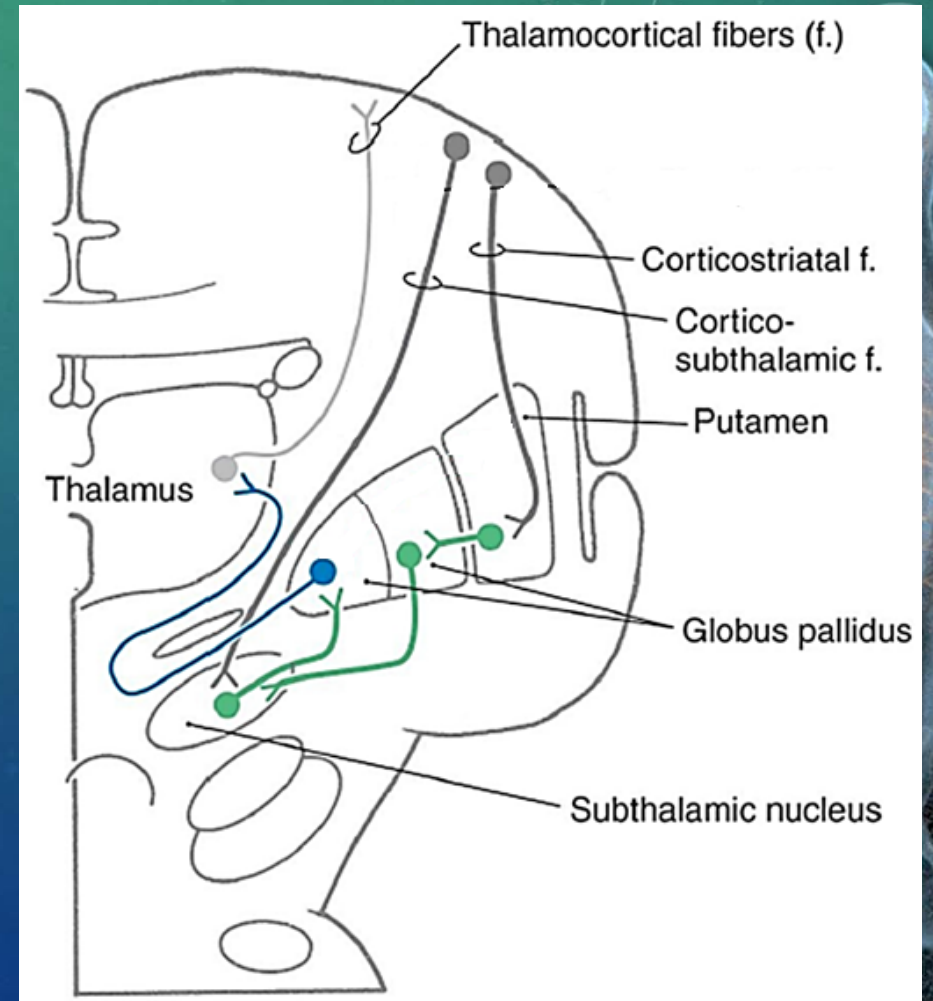
# DIRECT PATHWAYS



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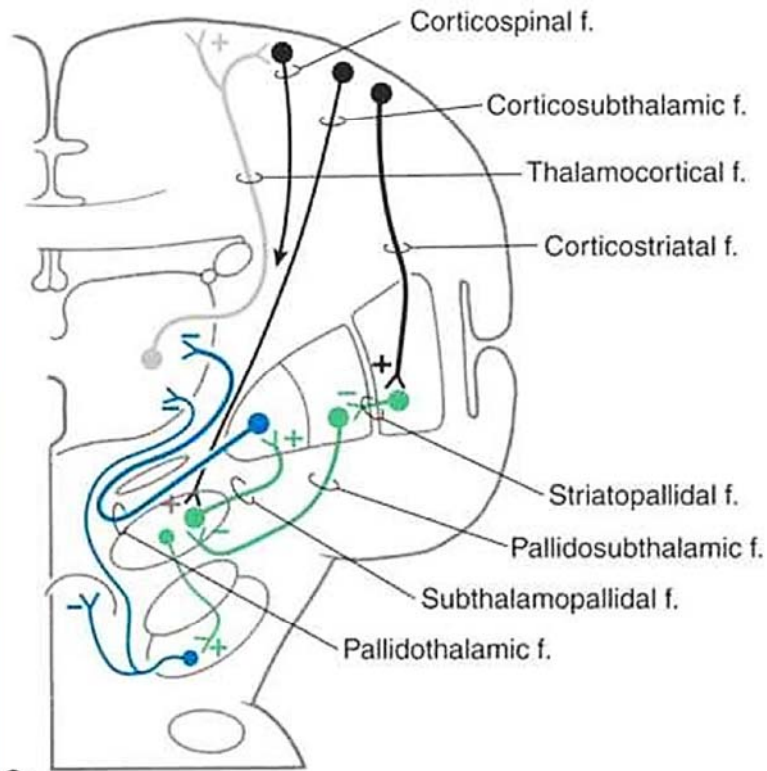
## INDIRECT PATHWAYS

- The **indirect pathway inhibits** the flow of information through the **thalamus**.
- Corticostriatal fibers (+), striatopallidal fibers (-), pallidosubthalamic fibers (-), subthalamopallidal fibers (+), pallidothalamic fibers (-)
- Corticosubthalamic fibers (+), subthalamopallidal fibers (+), pallidothalamic fibers (-)

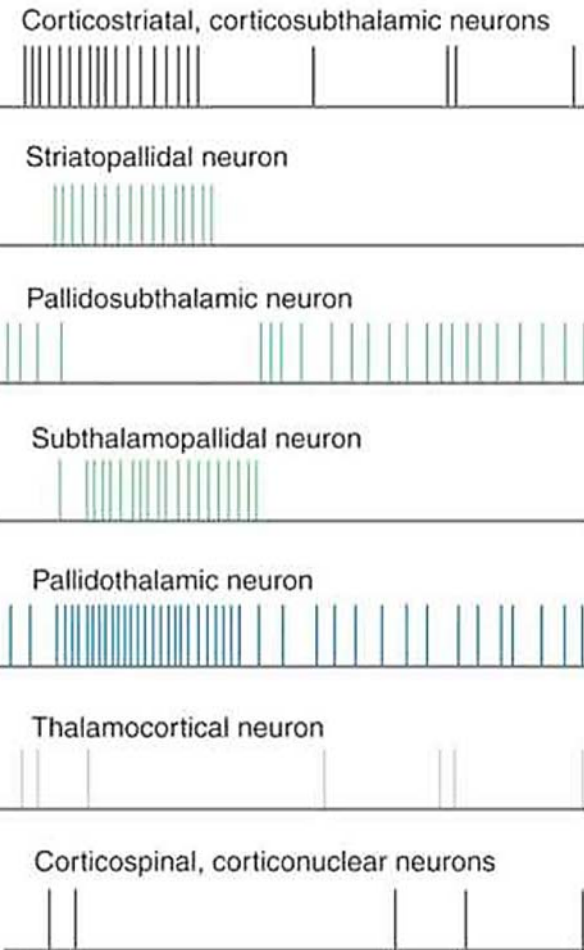


# INDIRECT PATHWAYS

Indirect Pathway



Firing Patterns of Neurons



**Inhibition**

<http://www.y>

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# BASAL NUCLEAR FUNCTION

- **Thalamic disinhibition:** The function of the direct pathway is to release the thalamus from its pallidal inhibition.
- **Subthalamic disinhibition:** In the indirect pathway, the subthalamic nucleus is released from inhibition by the lateral pallidal segment.

## BALANCE

Direct pathway ↔ Indirect pathway



# FUNCTIONS AND RELATED DISORDERS OF THE BASAL NUCLEI

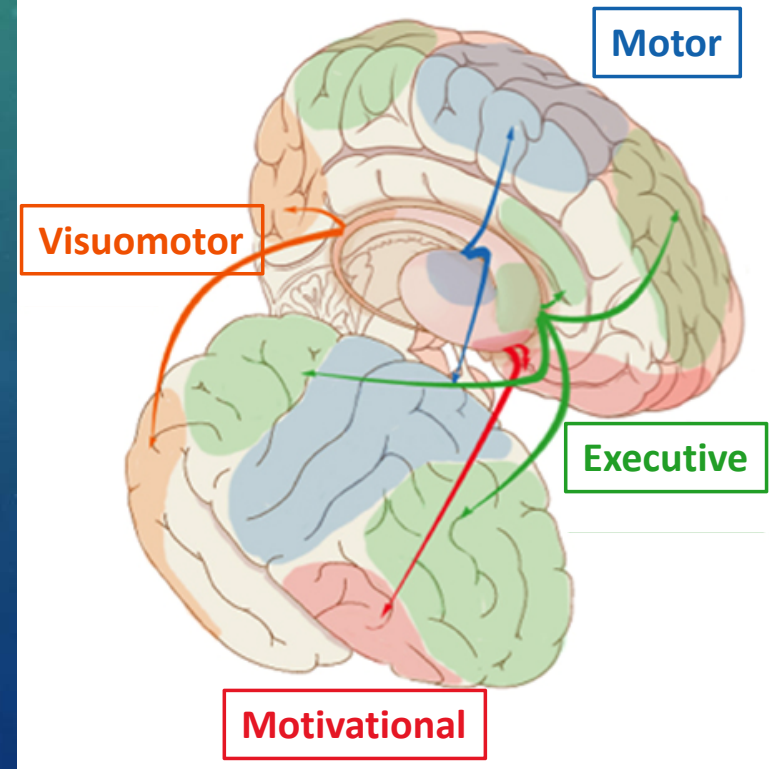
# PARALLEL CIRCUITS

Each circuit is an independent channel that processes information from one functional type of cortex by way of its own areas of the basal nuclei and thalamus and returns to the appropriate functionally related part of cortex.

- **Motor (sensorimotor) loop**
- **Executive (Associative) loop**
- **Motivational (limbic) loop**
- **Visuomotor (oculomotor) loop**

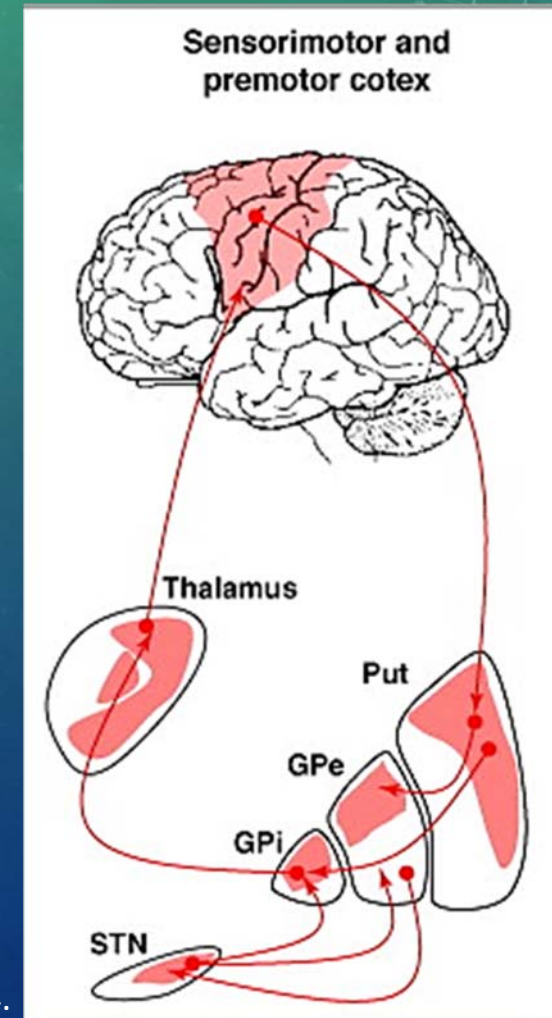
Cerebral cortex → Basal nuclei → Thalamus

## Corticostriatal Loops



# MOTOR LOOP Motor control

- Cerebral cortex
  - Supplementary motor, primary motor, premotor, and somatosensory cortices
- Basal nuclei
  - Putamen (Put), internal segment of the globus pallidus (GPi)
- Thalamus
  - Oral part and medial portion of ventrolateral nucleus
- Brainstem motor centers



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Krack et al. Trends in neurosciences. 2010;33(10):474-84.

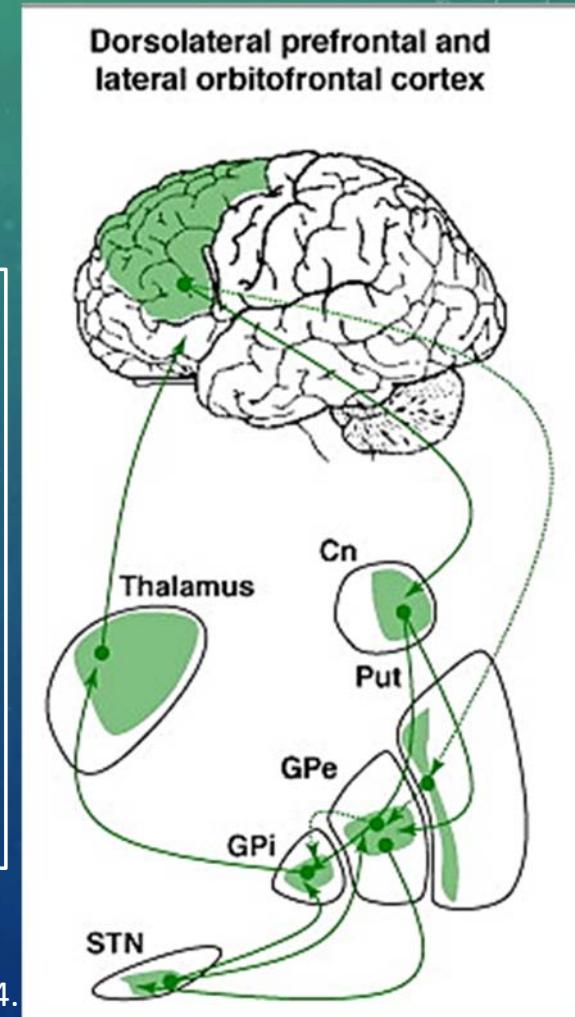


# EXECUTIVE LOOP Multiple tasks, learning, selection

- Cerebral cortex
  - Dorsolateral prefrontal and posterior parietal cortices
- Basal nuclei
  - Caudate nucleus (Cn), Putamen (Put), internal segment of the globus pallidus (GPi)
- Thalamus
  - Parvicellular region of ventroanterior nucleus
  - Parvicellular region of dorsomedial nucleus
- Brainstem motor centers

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Krack et al. Trends in neurosciences. 2010;33(10):474-84.

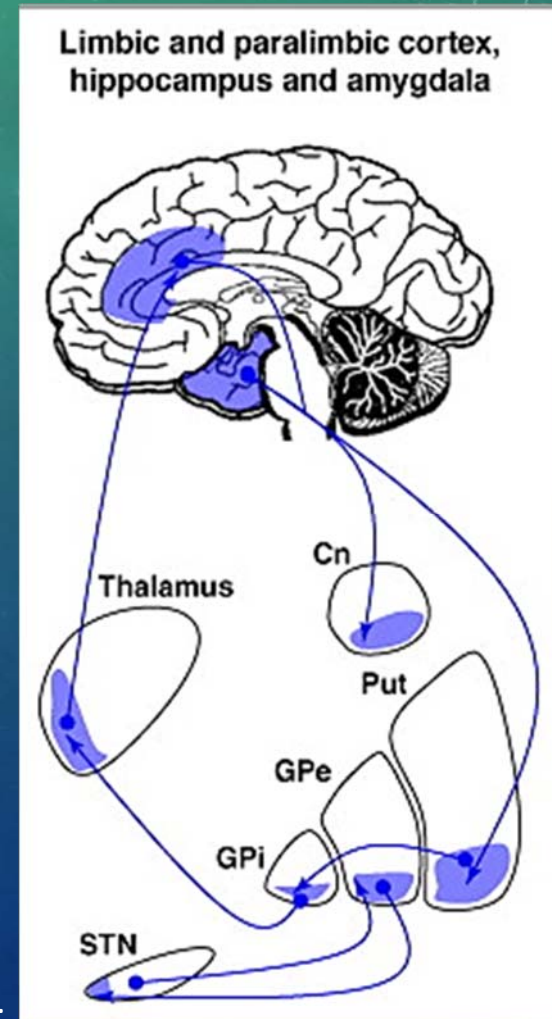


# MOTIVATIONAL LOOP Wanting and emotion

- • Cerebral cortex
  - Lateral orbitofrontal, anterior cingulate, medial prefrontal cortices, amygdala, and hippocampus
- Basal nuclei
  - Caudate nucleus (Cn), Putamen (Put), internal segment of the globus pallidus (GPI), and nucleus accumbens
- Thalamus
  - Magnocellular portion of ventroanterior nucleus
  - Magnocellular and posteromedial portions of dorsomedial nucleus

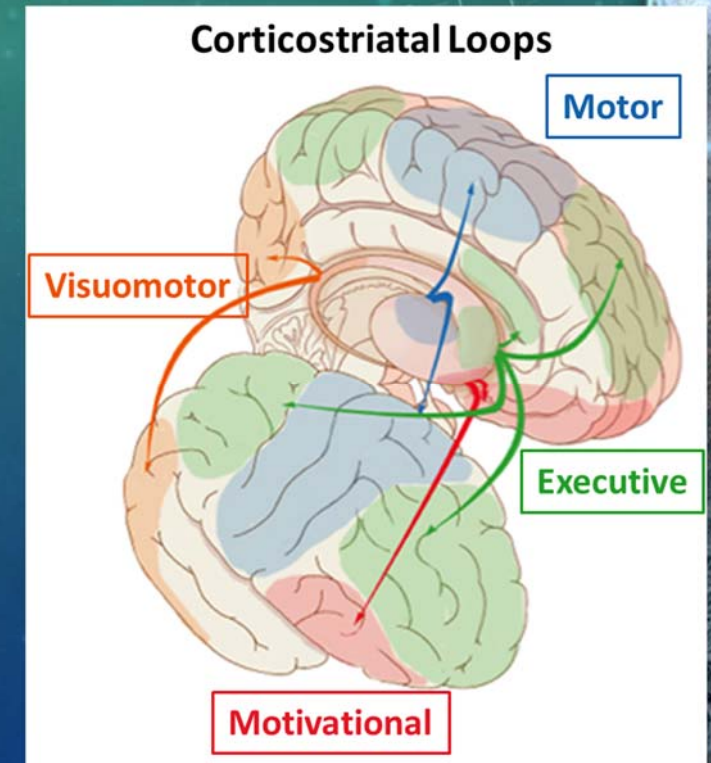
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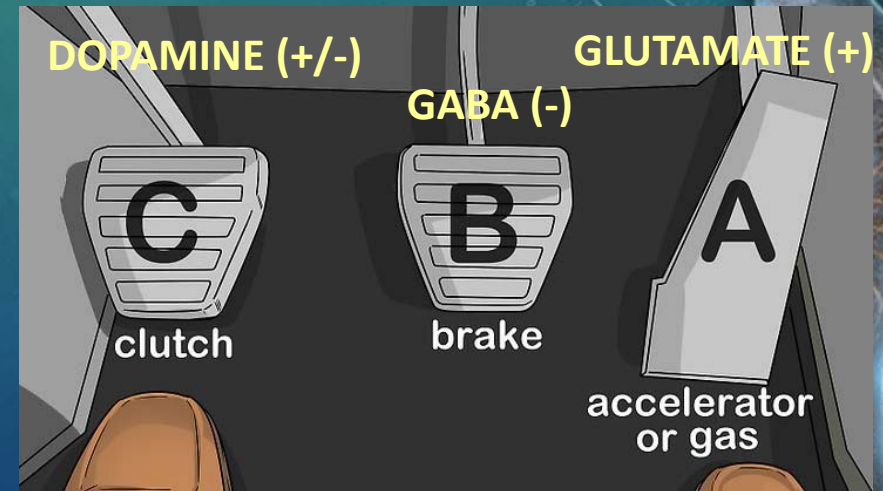
# VISUOMOTOR LOOP Visual functions and eye movements

- • Cerebral cortex
  - Frontal eye fields and visual portions of the temporal cortex
- Basal nuclei
  - Caudate nucleus (Cn), Putamen (Put), internal segment of the globus pallidus (GPi)
- Thalamus
  - Magnocellular portion of ventroanterior nucleus
  - Parvicellular region of dorsomedial nucleus
- Superior colliculus in midbrain ←

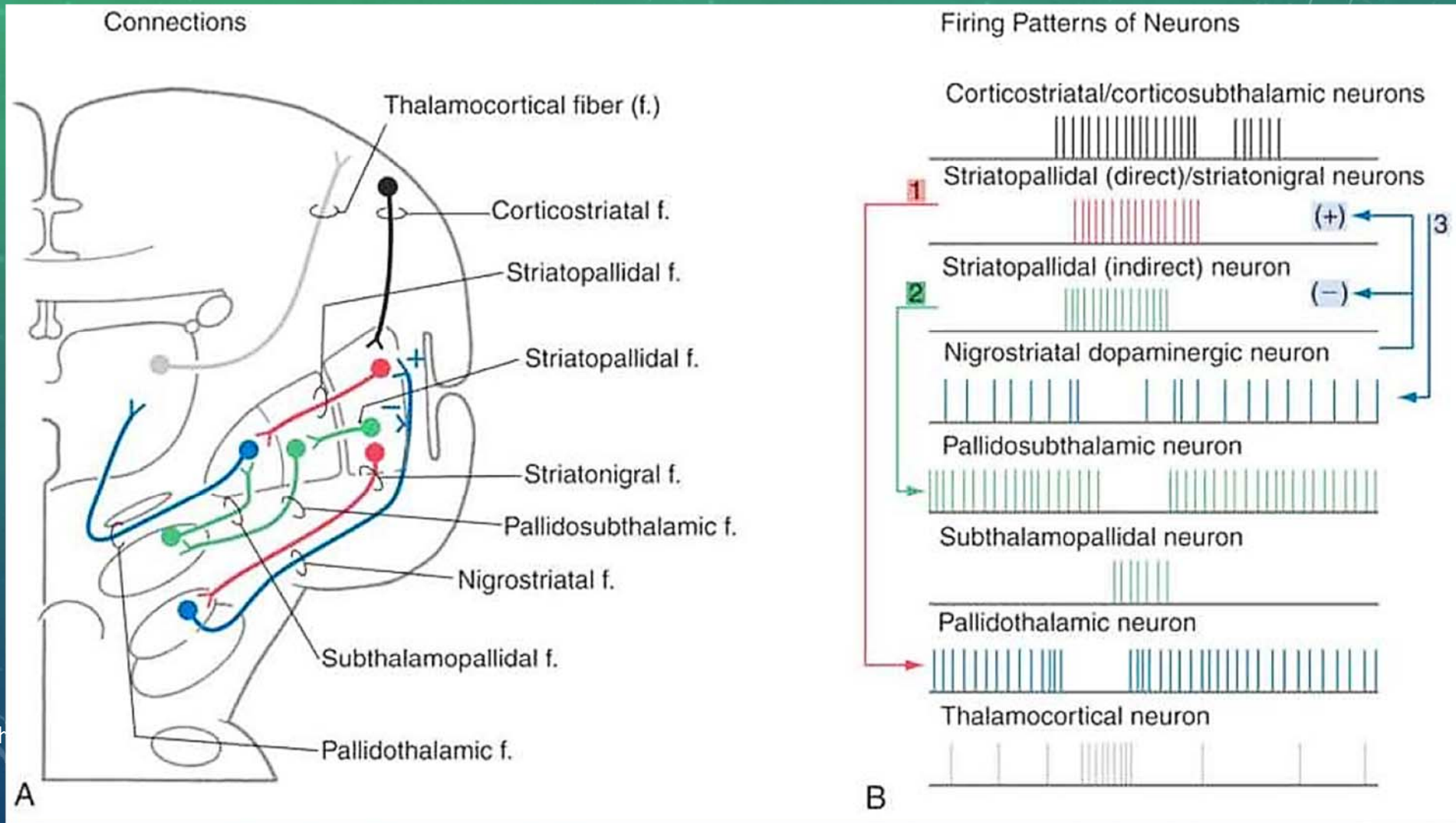


# INTEGRATED FUNCTION OF BASAL NUCLEI

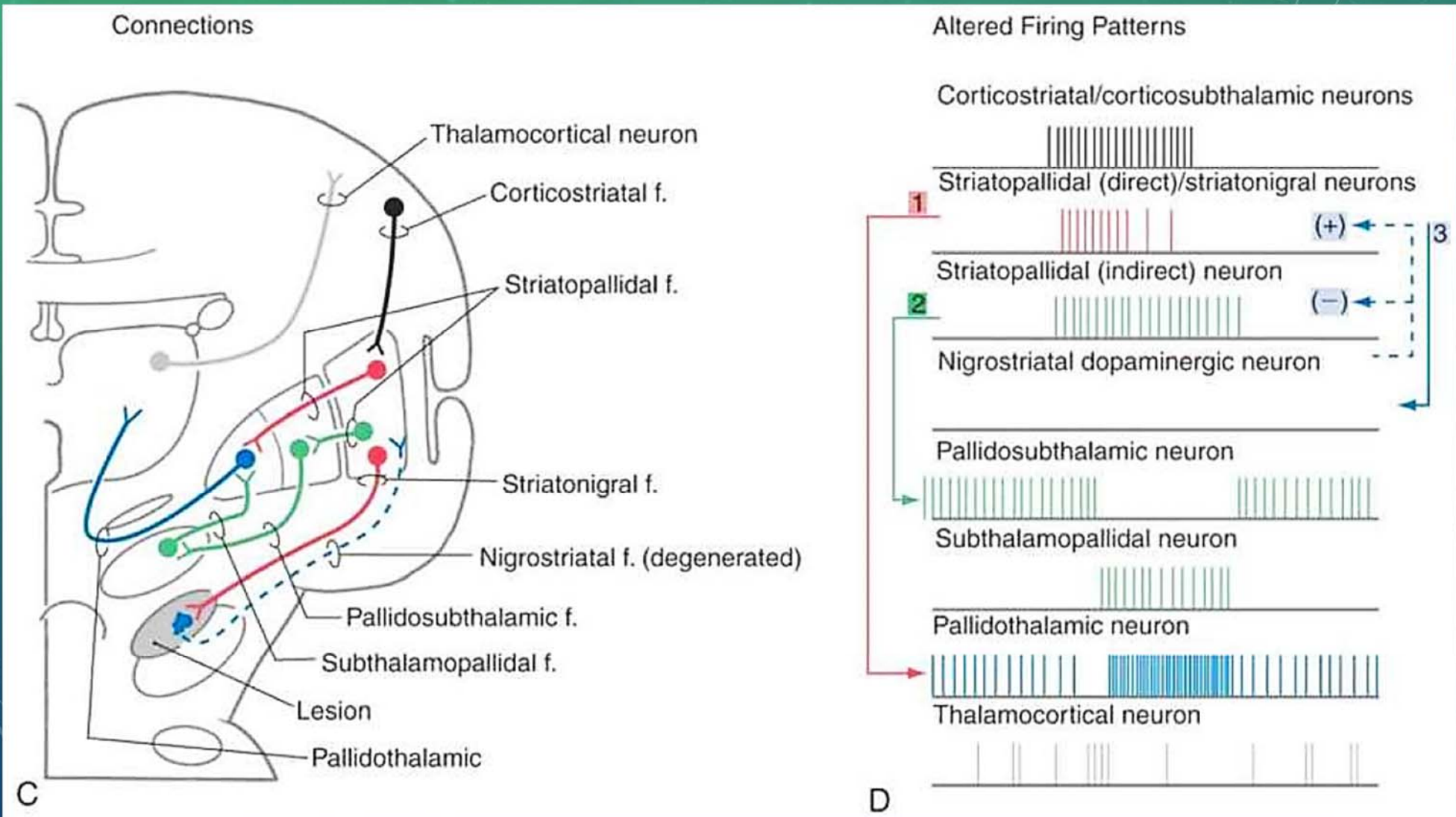
- The activity in the cerebral cortex activates the striatopallidal neurons in **both the direct and indirect pathways**.
- Careful balance of the activity between the two pathways modulates the amount of time which the **thalamocortical neurons** are activated.
- The modulation between the direct and indirect pathways is controlled by **dopaminergic loop (neostriatum ↔ substantia nigra)**



# INTEGRATED FUNCTION OF BASAL NUCLEI

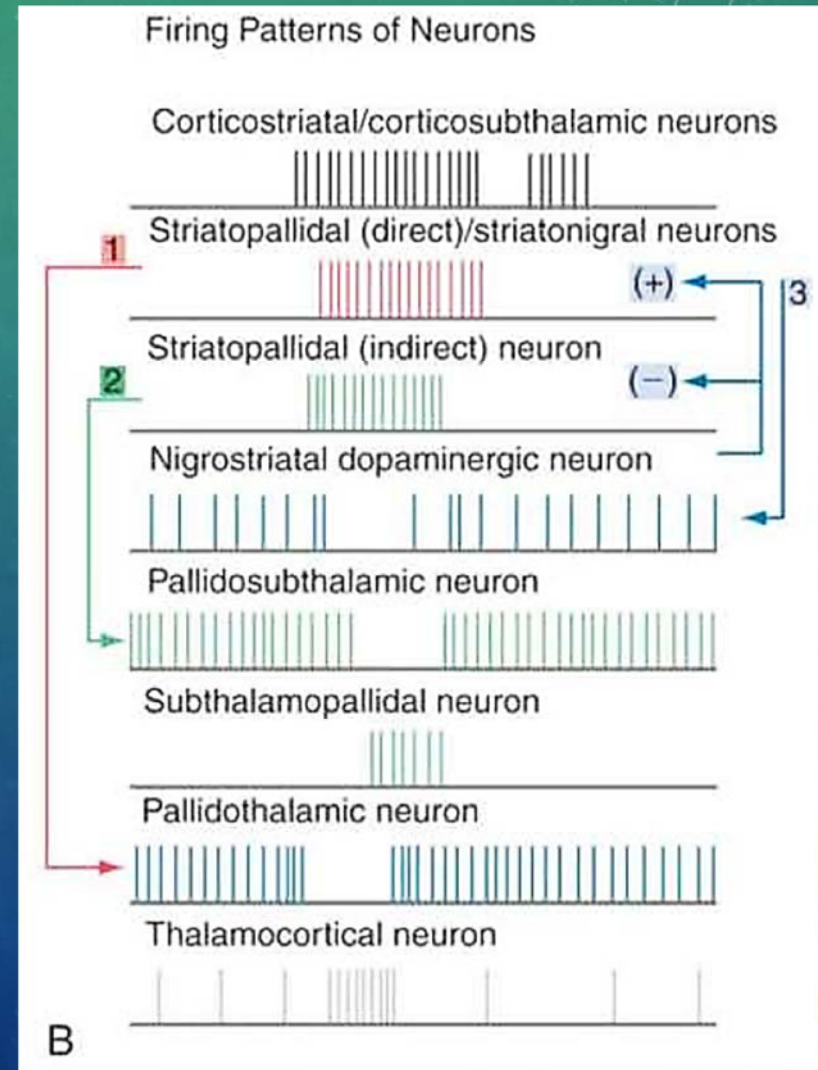


# LOSS OF DOPAMINERGIC NIGRAL CONNECTIONS



# DOPAMINERGIC LOOP

- **Direct pathway** uses **D1 receptors** → excitation of the striatopallidal neurons.
- **Indirect pathway** uses **D2 receptors** → inhibition of the striatopallidal neurons.



# RELATED DISORDERS – HUNTINGTON DISEASE

- A genetic disorder (short arm of chromosome 4) that generally begins to appear at 35 to 44 years of age; death occurs 10 to 15 years after onset.

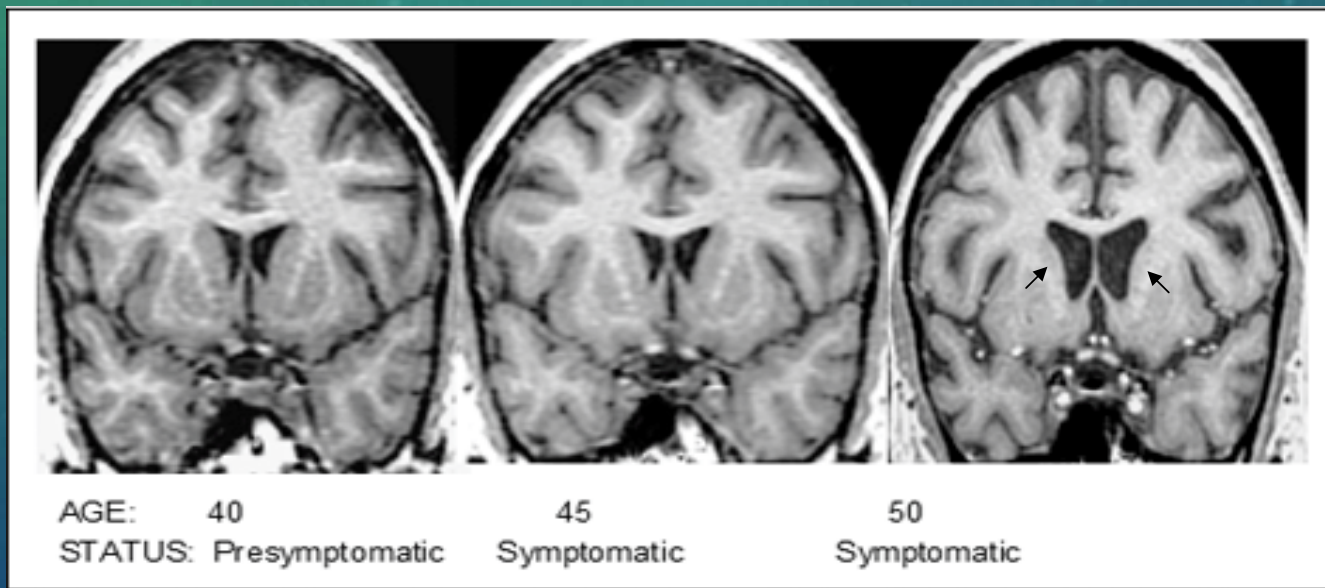
Early stage	Middle stage	Late stage
<ul style="list-style-type: none"><li>• Clumsiness</li><li>• Involuntary twitching</li><li>• Lacking coordination</li><li>• Depression</li><li>• Irritability</li></ul>	<ul style="list-style-type: none"><li>• Choreiform</li><li>• Memory loss, forgetfulness</li><li>• Slurred speech</li><li>• Swallowing difficulty</li></ul>	<ul style="list-style-type: none"><li>• Dependent on others</li><li>• High risks for choking, falling and heart failure.</li></ul>





# RELATED DISORDERS – HUNTINGTON DISEASE

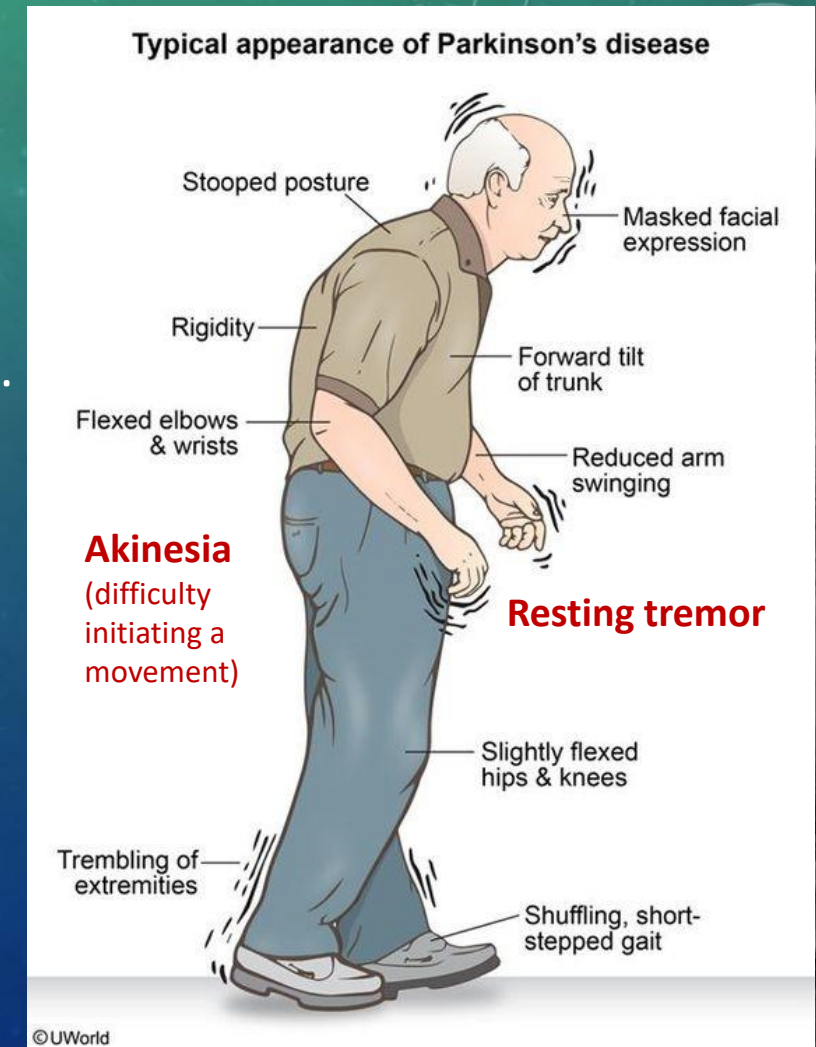
- Decrease in the size of the striatal complex caused by **loss of about 90% of all striatal neurons.**



# RELATED DISORDERS – PARKINSON DISEASE

- Most adult patients with Parkinson disease appear initially symptoms in the age range of 45 to 65 years.
- This disorder is characterized by a progressive onset of **movement** and **affective disturbances**.

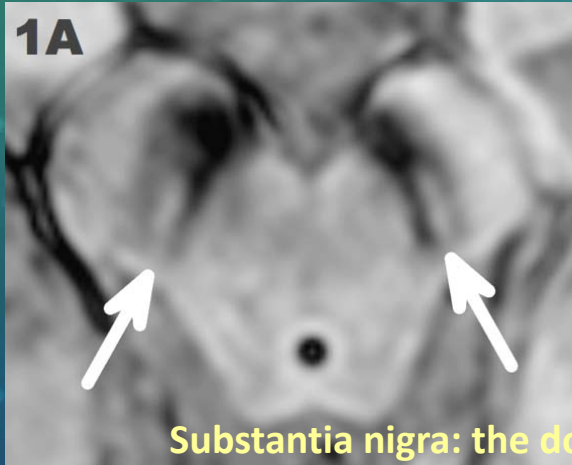
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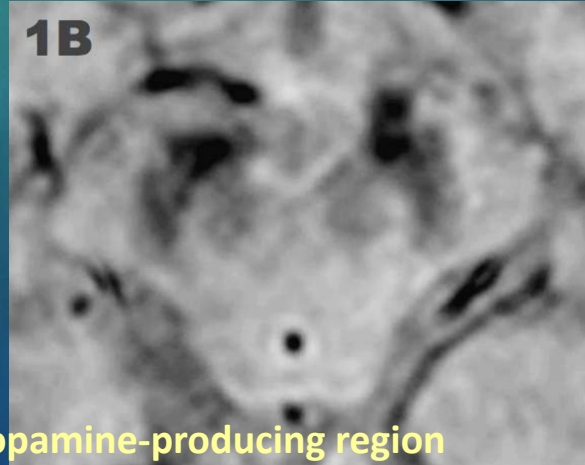
# RELATED DISORDERS – PARKINSON DISEASE

- Clinical symptoms usually appear after approximately 70% to 80% of **nigral neurons** and their corresponding **dopamine** are lost.

Healthy individual

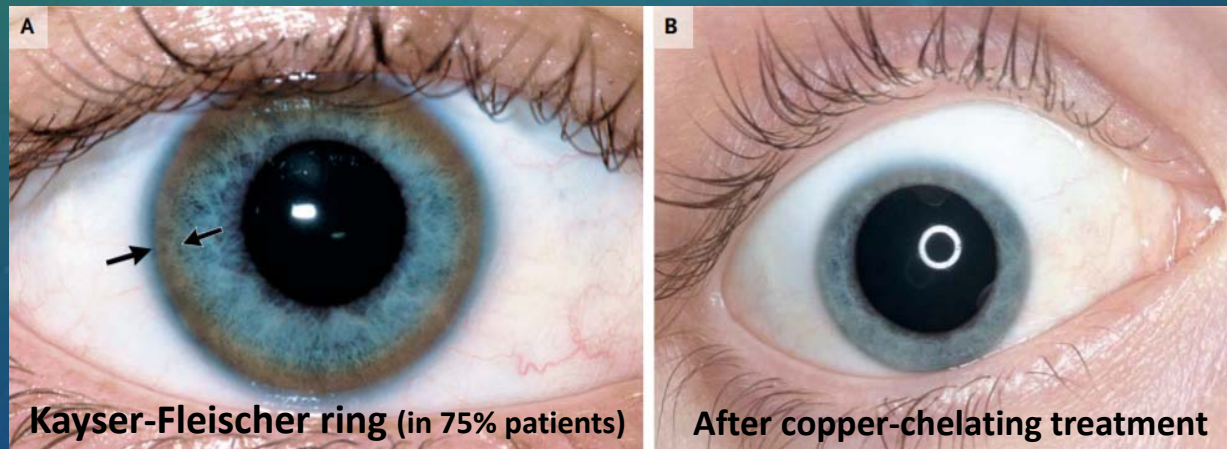


Parkinson's disease



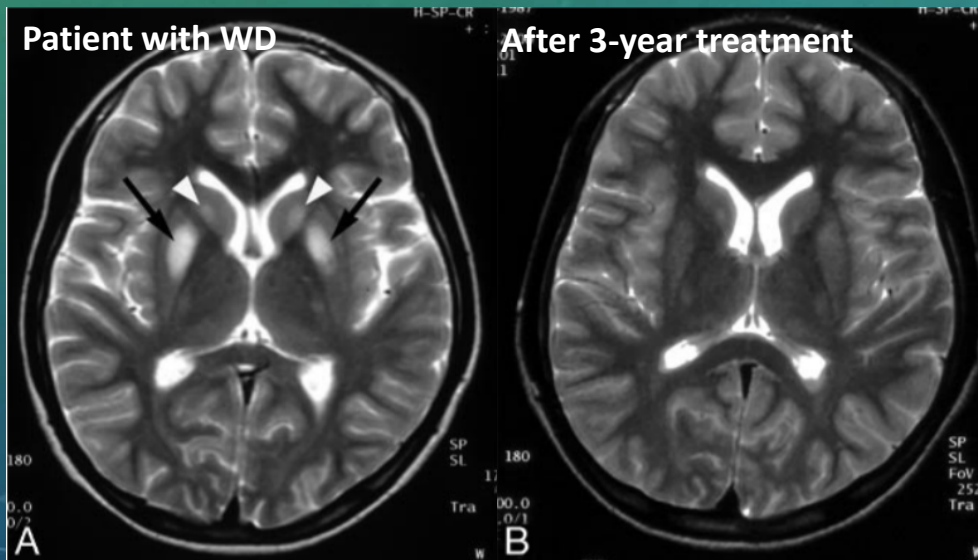
## RELATED DISORDERS – WILSON DISEASE

- A genetic disorder (long arm of chromosome 13); typically onset between 11 and 25 years of age.
- A disorder of **copper metabolism** → accumulation of the metal in the liver and damage to various areas of the brain; Also known as **hepatolenticular degeneration**.

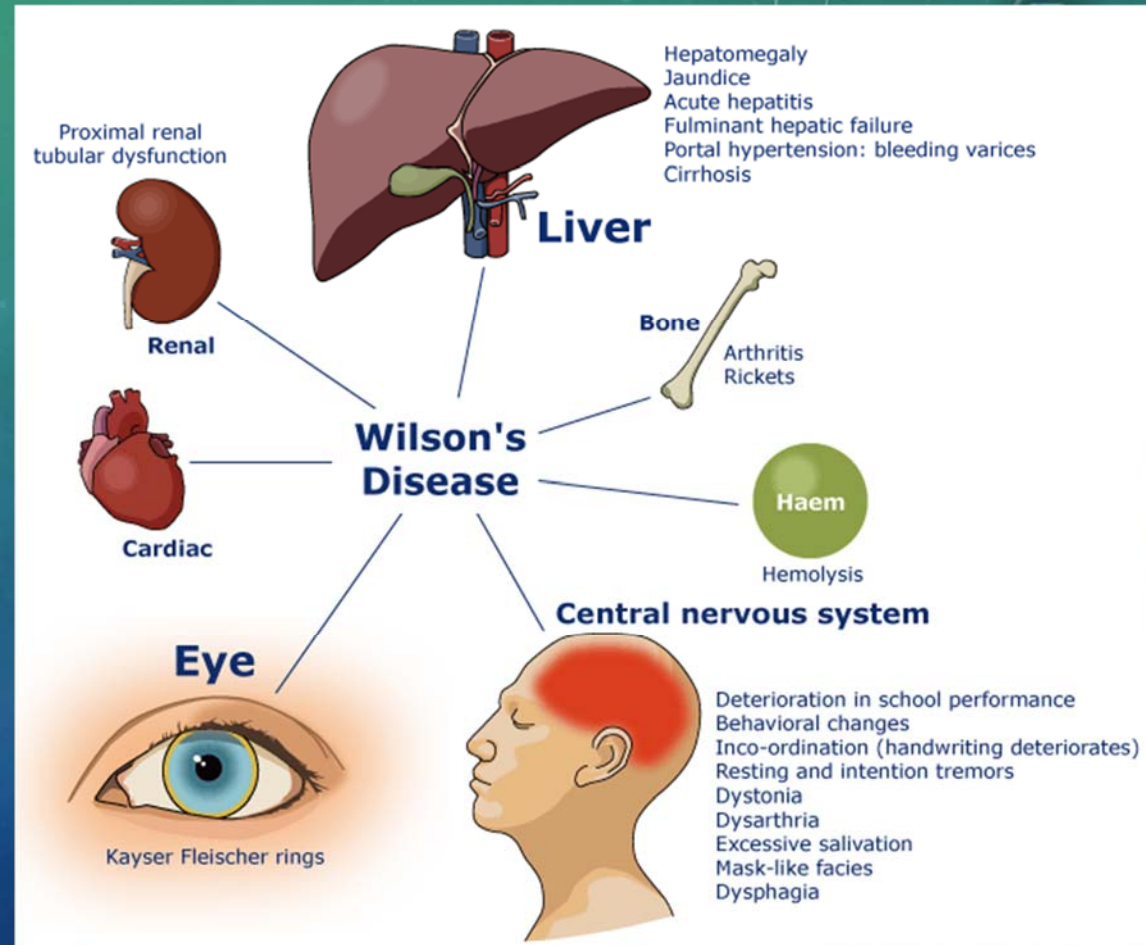


# RELATED DISORDERS – WILSON DISEASE

- Symptoms and MRI features (loss of neurons, axonal degeneration, and increasing numbers of protoplasmic astrocytes).



Kim et al. AJNR 2006;27(6):1373-8.



<https://www.thinglink.com/scene/751801798536200194>

12/4 教學評量 16:50，請同學務必到課。

**THE END**

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