Systemic Module

CNS

“Anatomy”

Basal Ganglia

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Basal Ganglia

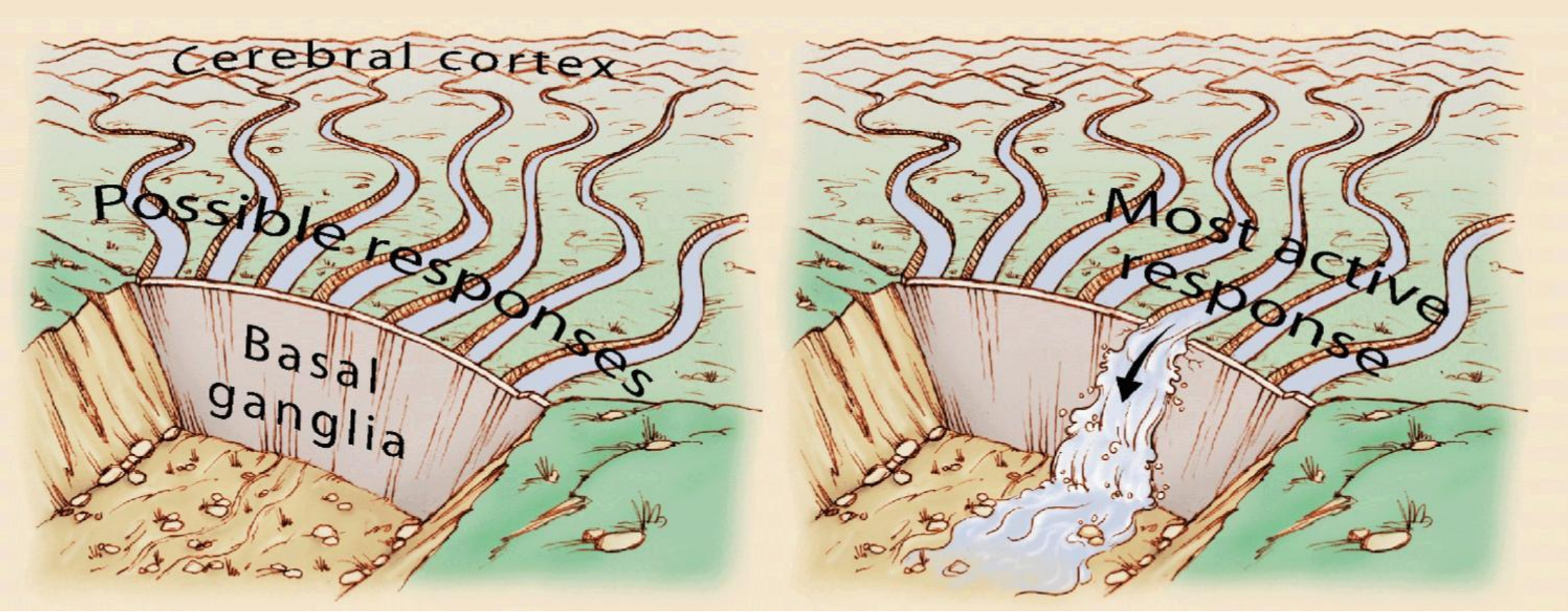
- The basal nuclei (basal ganglia) are large masses of gray matter situated in the cerebral hemispheres that have **motor function of great importance.**

- They are motor relay nuclei in charge of **producing smooth and precise muscle activity**. They work in conjunction with the cerebellum to regulate complex motor output.

What do the Basal Ganglia do?

- Basal ganglia are involved in generation of **goal-directed voluntary movements**:
  - *In order to execute purposeful movements,* a small number of **motor plans** in the brain (primary motor and premotor cortices) need to be promoted and integrated, while others that impair or stop the execution of the desired movement must be suppressed.

The signal becomes increasingly focused and specific as it passes through the basal ganglia.

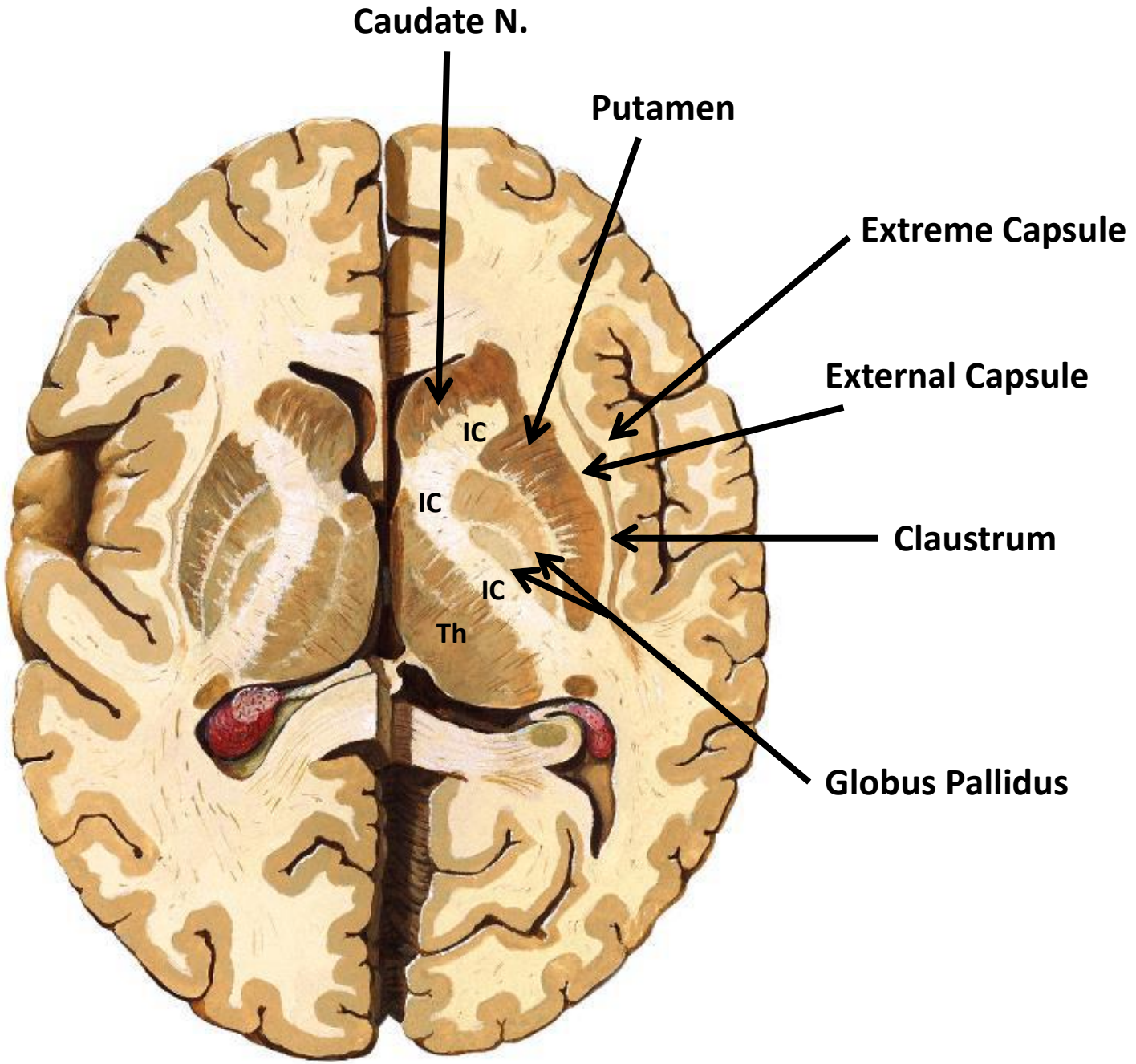

Cerebral cortex
Possible responses
Basal ganglia
Most active response

Basal Ganglia

- ***Anatomically,*** the basal ganglia are made of three distinct nuclei**:**
  - **The caudate nucleus.**
  - **The putamen.**
  - **The globus pallidus.**

- Two other regions are ***functionally*** associated with the basal ganglia**:**
  - **The subthalamic nucleus.**
  - **The substantia nigra.**

- The caudate and the putamen together are referred to as the **striatum.**
- While the putamen and globus pallidus are referred to as the **lentiform nucleus.**


Caudate N.
Putamen
Extreme Capsule
External Capsule
IC
IC
IC
Th
Claustrum
Globus Pallidus

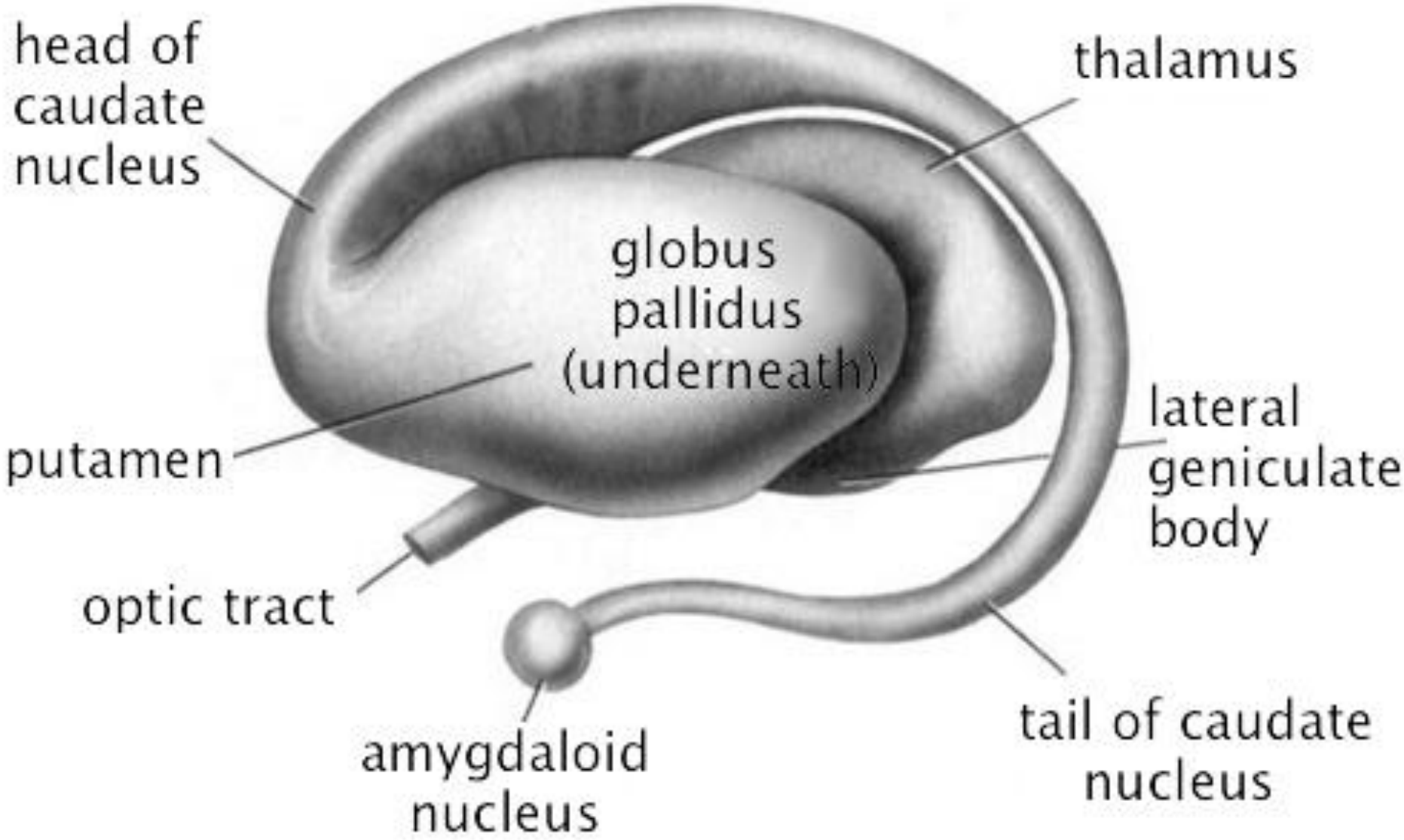
The Caudate Nucleus

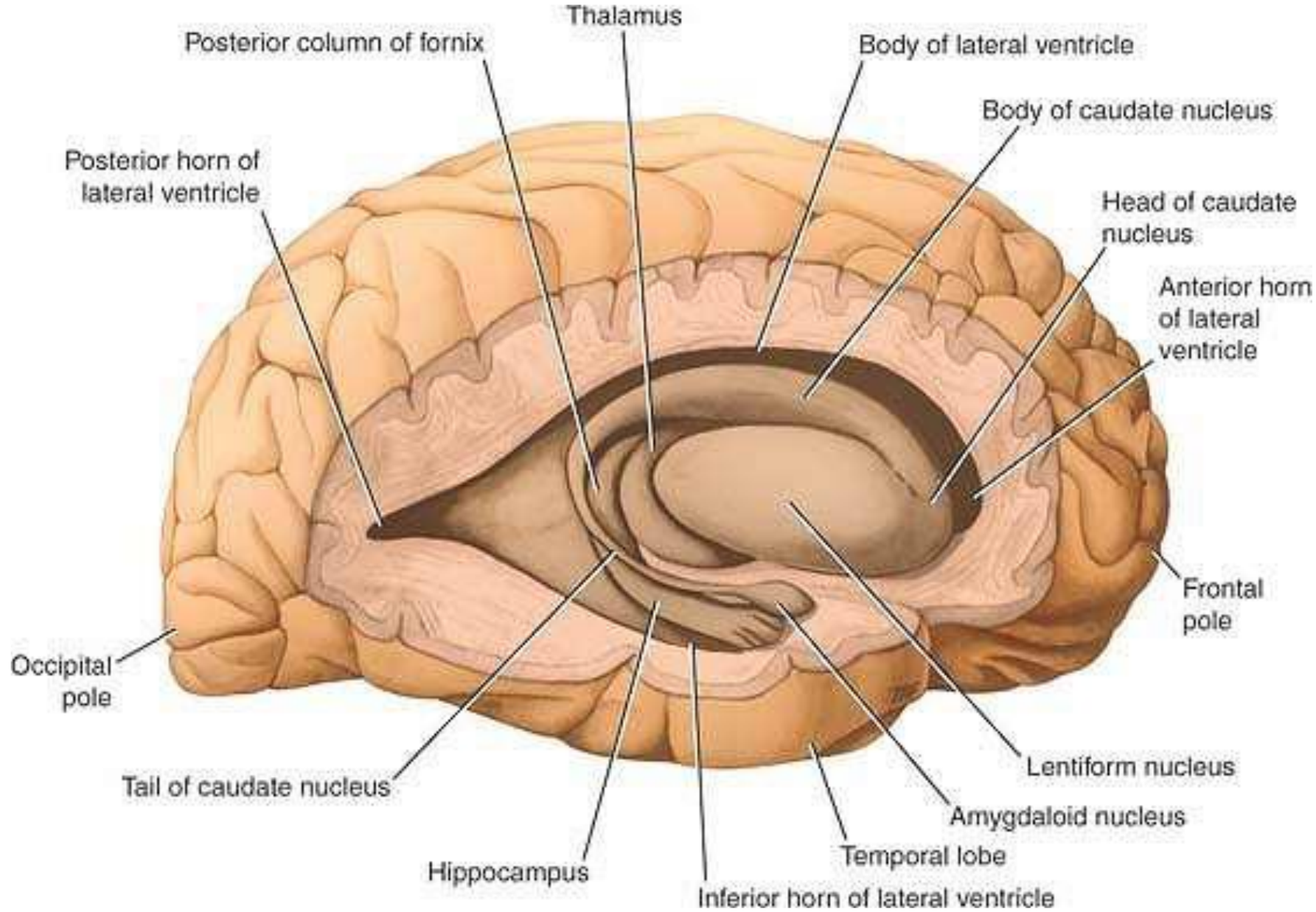
- It is a C shaped mass of grey matter and consists of **a head**, **a body** and **a tail**.

1. **The Head:** Large and rounded , forms the lateral wall of the anterior horn of the lateral ventricle, fused inferiorly with the Putamen of the lentiform nucleus.

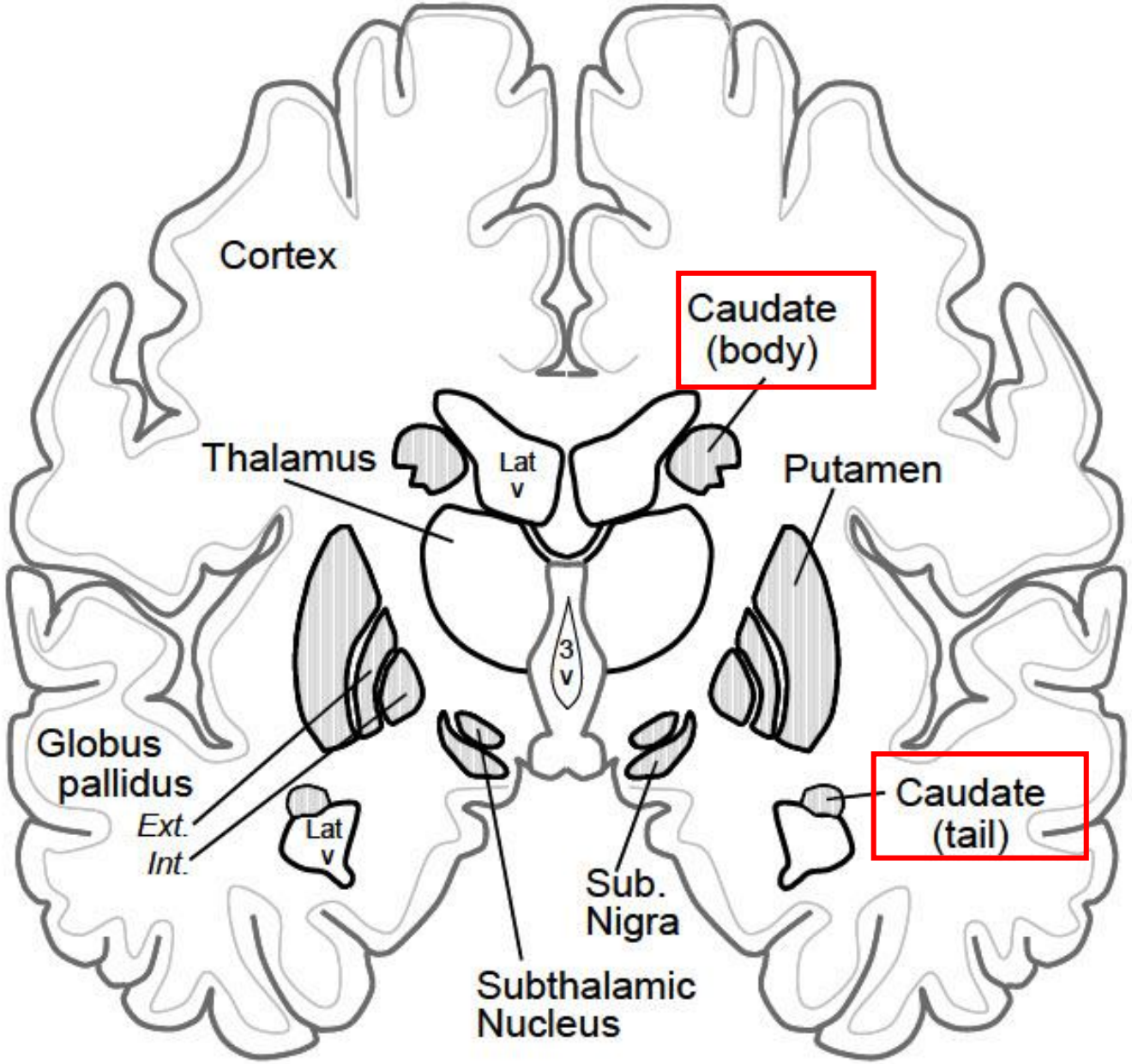
2. **The Body:** Long and narrow, continuous with the head in the region of the interventricular foramen, *forms part of the floor of the body of the lateral ventricle.*

3. **The Tail:** Long and slender, *forms part of the roof of the inferior horn of the lateral ventricle*, terminates anteriorly in the **amygdaloid nucleus.**

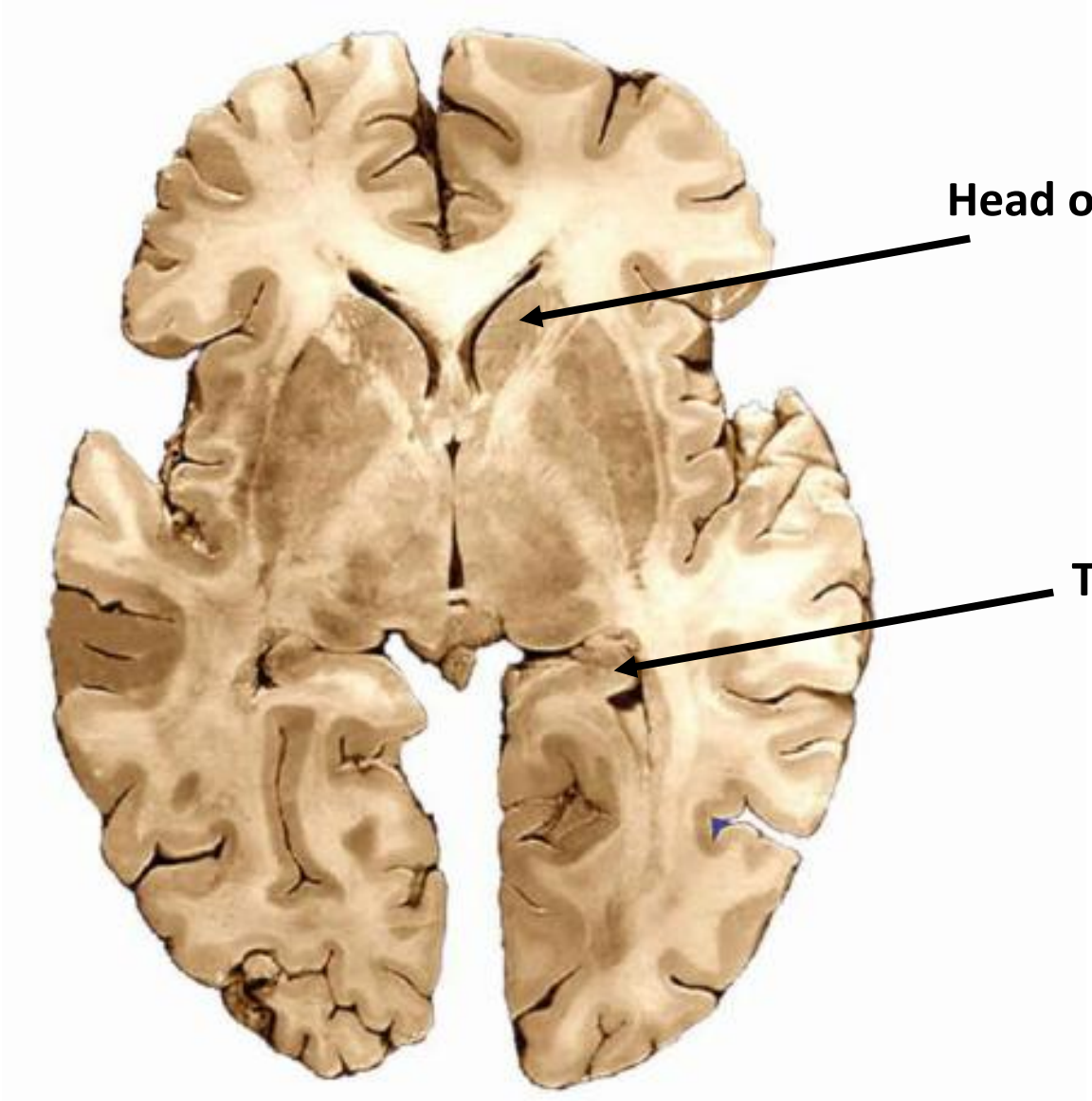

head of caudate nucleus
thalamus
globus pallidus (underneath)
putamen
lateral geniculate body
optic tract
amygdaloid nucleus
tail of caudate nucleus


Thalamus
Posterior column of fornix
Body of lateral ventricle
Body of caudate nucleus
Posterior horn of lateral ventricle
Head of caudate nucleus
Anterior horn of lateral ventricle
Frontal pole
Occipital pole
Tail of caudate nucleus
Lentiform nucleus
Amygdaloid nucleus
Temporal lobe
Hippocampus
Inferior horn of lateral ventricle

The Caudate appears twice in many frontal brain sections. This is because the Caudate curves around with the lateral ventricle. The head of the Caudate is most anterior.



Coronal section



Horizontal section

The Lentiform Nucleus

- Its large *lens shaped* nucleus, appears triangular (Wedge-shaped) in cross sections, divided by a thin layer of white matter into :

  1. A larger, darker outer portion, the **Putamen**
  2. An inner lighter portion, the **Globus pallidus**

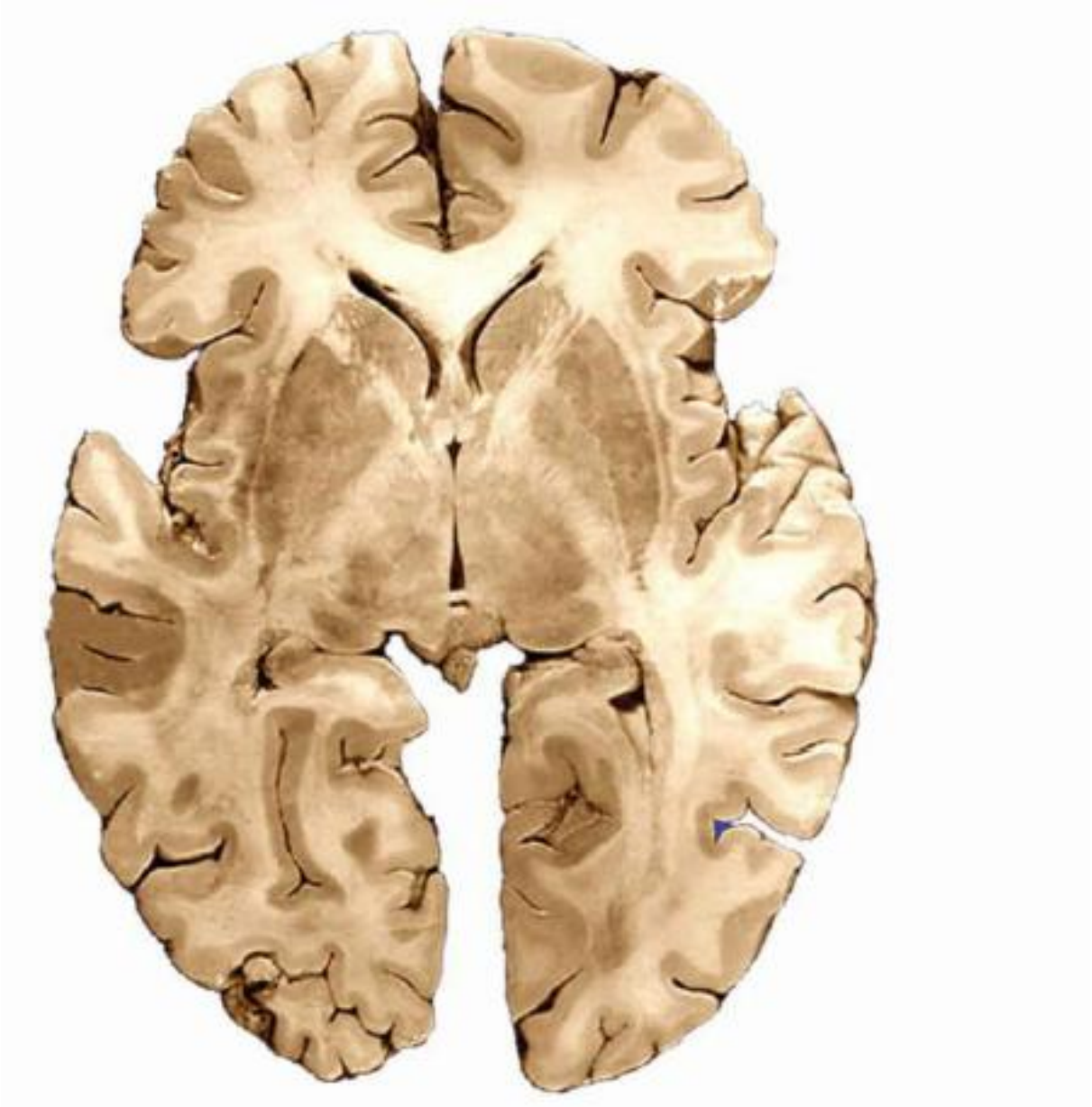
- **Related medially** to the *internal capsule*, which separates it from the Caudate nucleus and the thalamus.

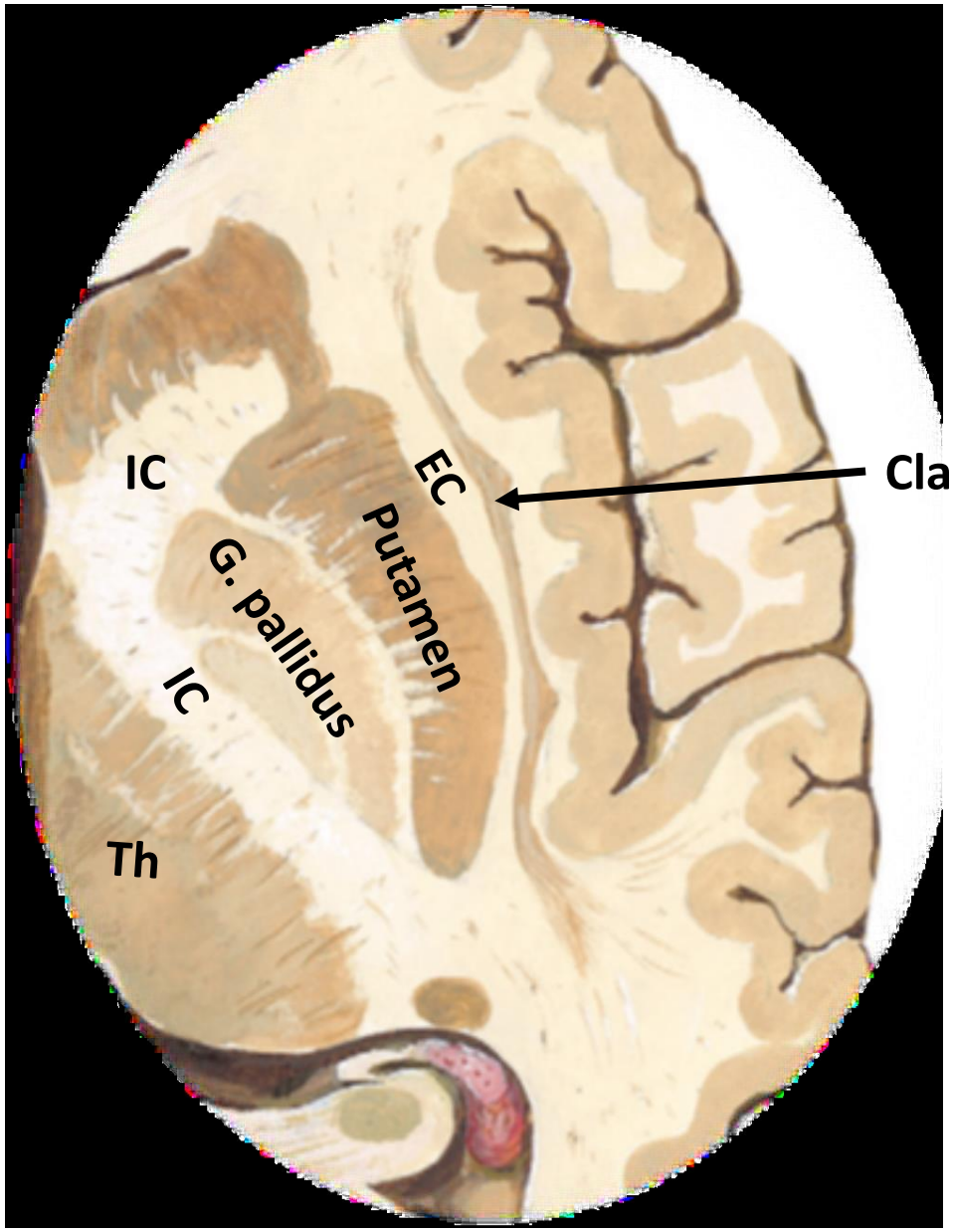
- **Related laterally** to *external capsule* separating it from the claustrum.

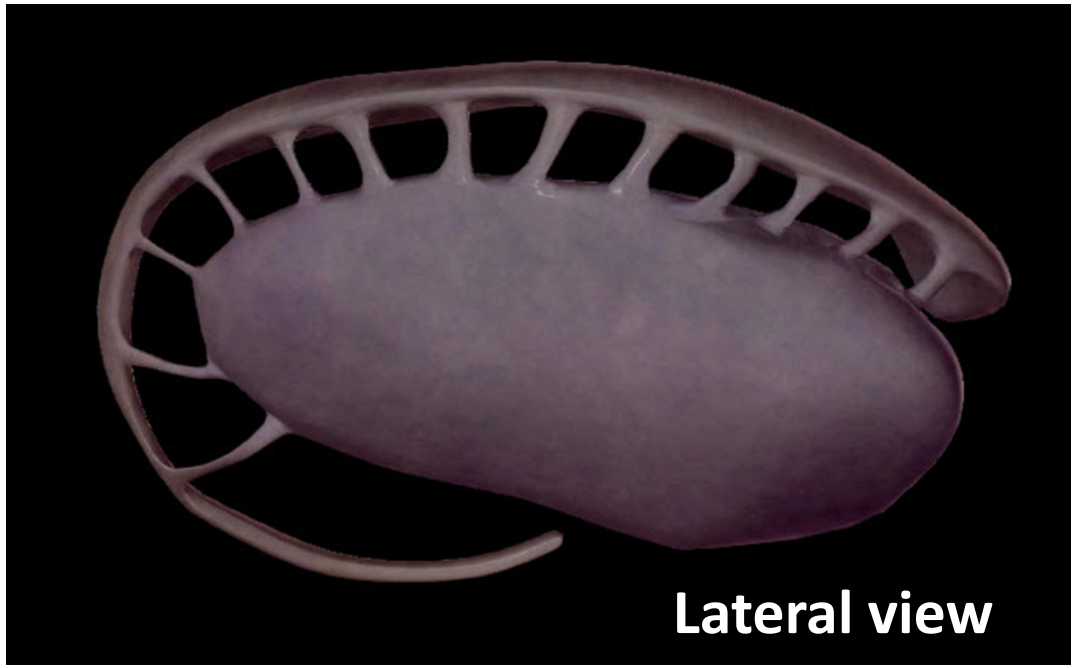
Contd ….

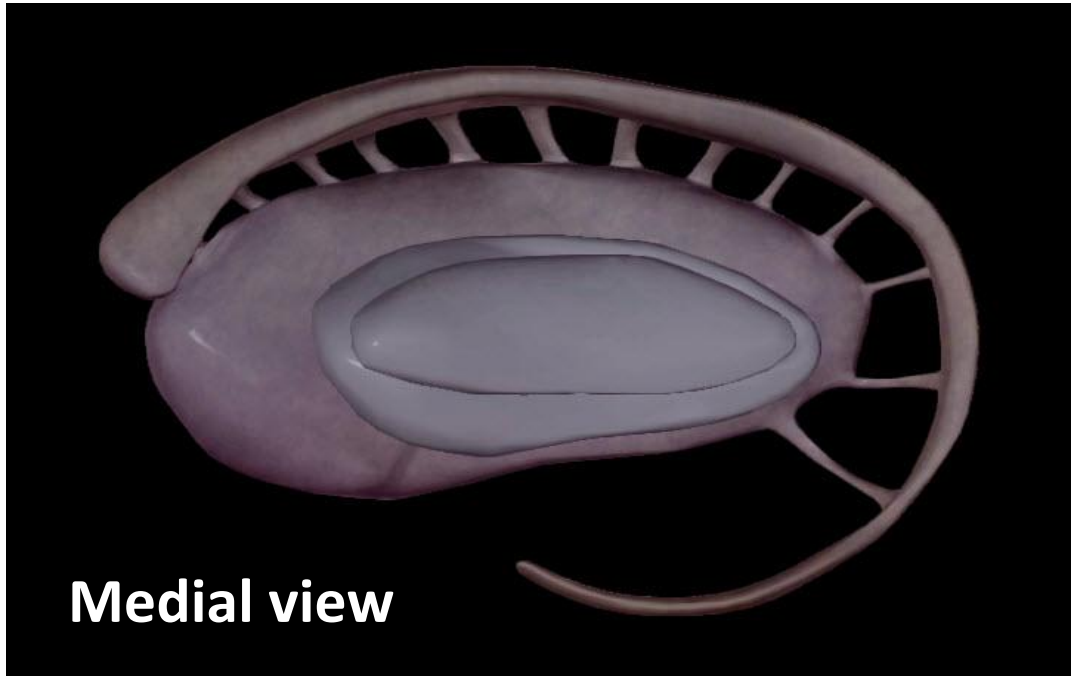
- The ***Globus pallidus (GP)*** has 2 different parts,
  - Globus pallidus externa (GPe)
  - Globus pallidus interna (GPi)

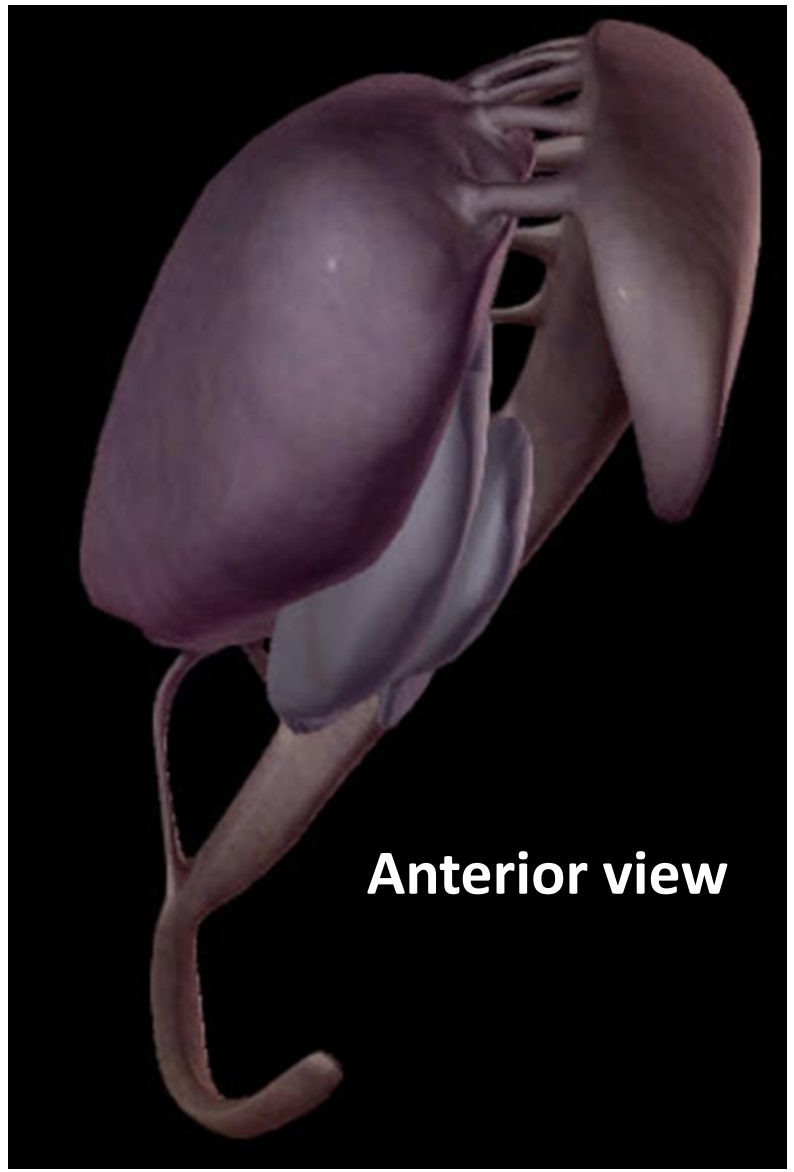
- GPi (internal) contains the output neurons of the basal ganglia circuit. They project to ipsilateral motor thalamus (VA,VL).




IC
EC
Claustrum
Putamen
G. pallidus
IC
Th

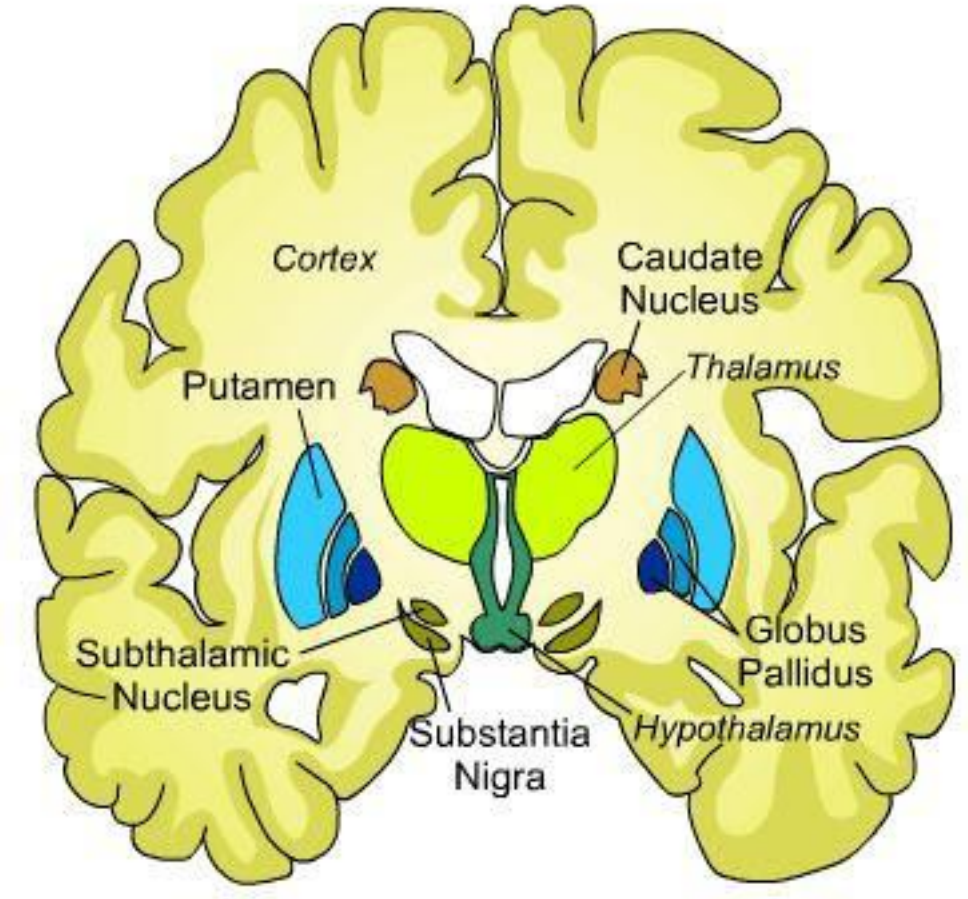

Lateral view

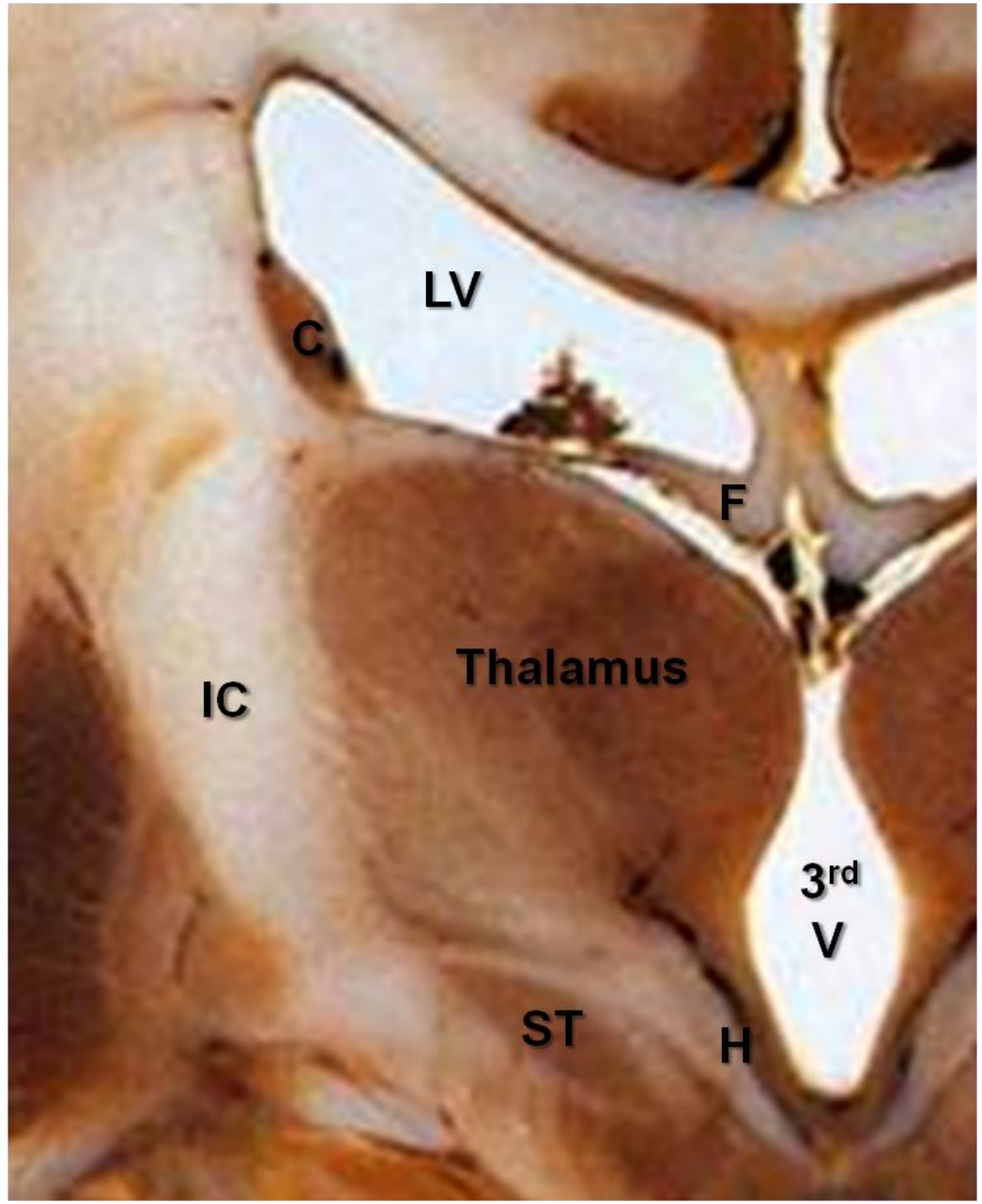

Medial view


Anterior view

Subthalamic Nucleus

- Biconvex mass of grey matter located caudal to thalamus and dorsal to substantia nigra.
- Separated from thalamus by Zona inserta.

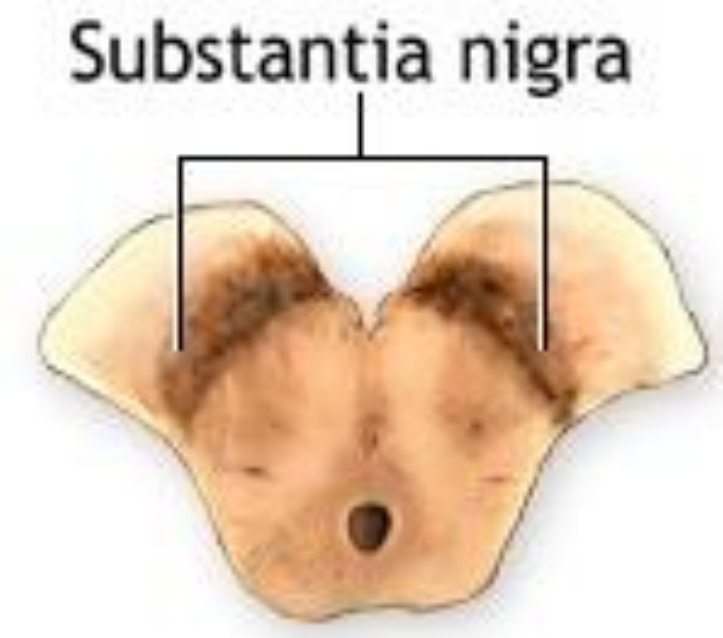


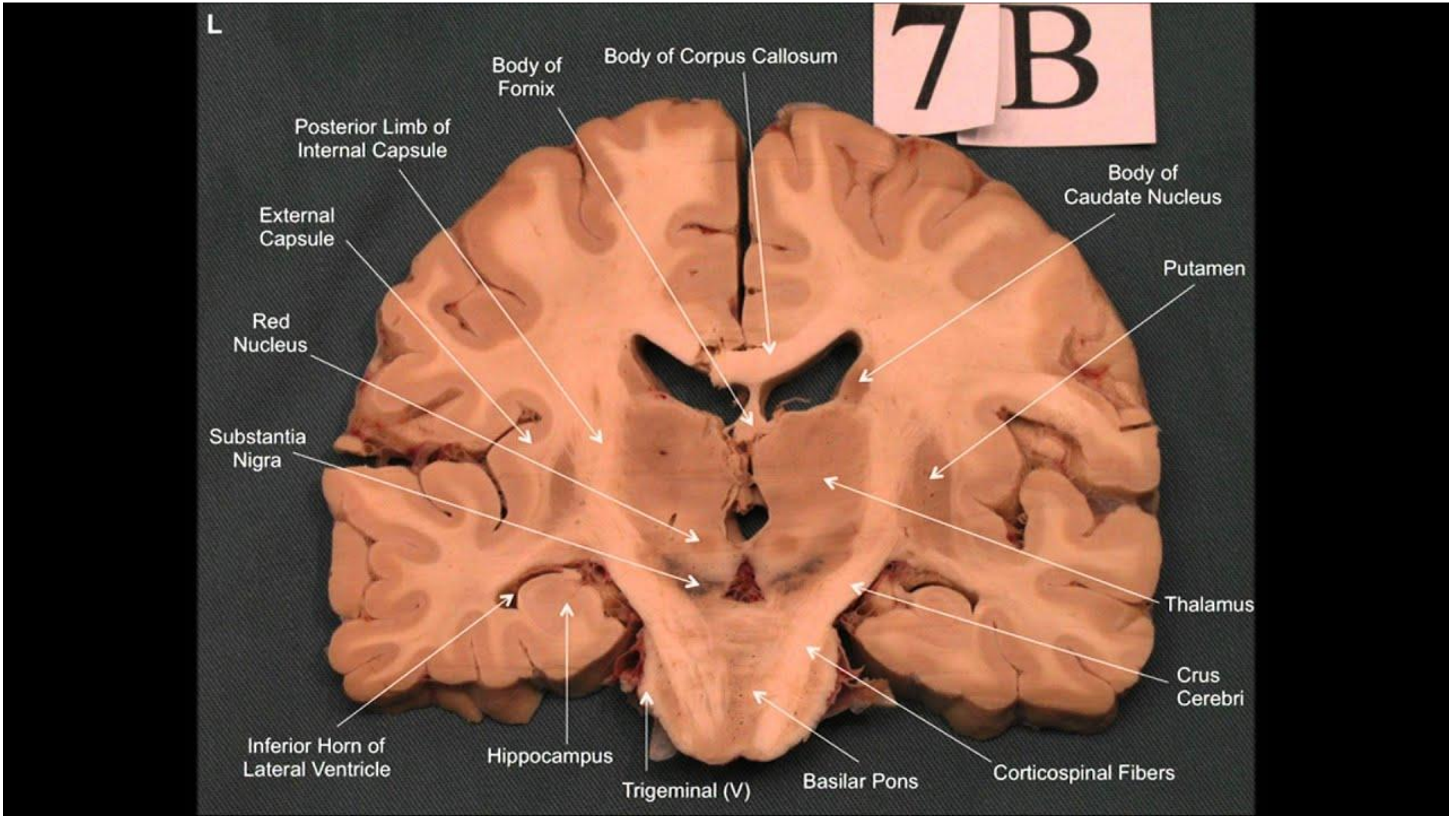

LV
C
F
Thalamus
IC
3rd
V
ST
H

Substantia Nigra

- Motor nucleus located in the midbrain.
- Made up of small unpigmented and large pigmented nerve cells contains ***neuromelanin***.
- **Divided into 2 parts:**

1. **Pars compacta:** contains dopaminergic (75%) and cholinergic (25%) neurons.
2. **Pars reticularis**: contains GABAergic neurons.




L
7B
Body of Fornix
Body of Corpus Callosum
Posterior Limb of Internal Capsule
Body of Caudate Nucleus
External Capsule
Putamen
Red Nucleus
Substantia Nigra
Thalamus
Crus Cerebri
Inferior Horn of Lateral Ventricle
Hippocampus
Trigeminal (V)
Basilar Pons
Corticospinal Fibers

Function of Basal Ganglia

The basal ganglia help to:

1. **Programming of voluntary movement:** Instruction of learned movements are stored in the basal ganglia. When a learned movements is to be carried out the information is transmitted to the thalamus from there to the preemptor area and then to the motor cortex.
2. **Inhibit the unwanted and inappropriate voluntary movements.**
3. **Facilitate the required and appropriate movements.**
4. **Involved in motor learning (New learned movements).**
5. **Control automatic movements, like swinging of arms during walking.**

For achieving specific, smooth and complicated motor function.

Function of Basal Ganglia

- **Organization of movement:**
  - **What type? >>>>** Cerebral cortex
  - **How to perform? >>>>>** Basal ganglia + Cerebellum
  - **Assist in regulation >>>>>** Thalamus
- The balance between the cerebellum and the basal ganglia allows smooth, coordinated movement, and a **disturbance in either system will show up as movement disorders.**

Function of Basal Ganglia

The deficits tend to fall into one of two categories:

– The presence of inessential unwanted movements

» OR

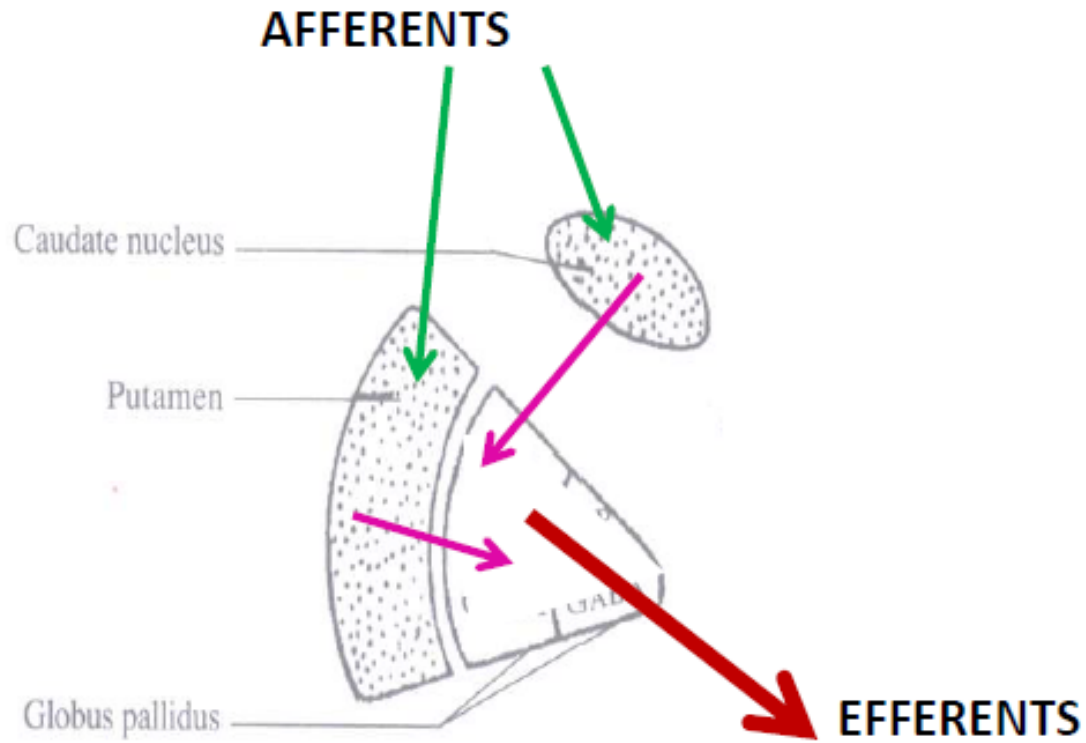
– An absence or difficulty with intended movements.

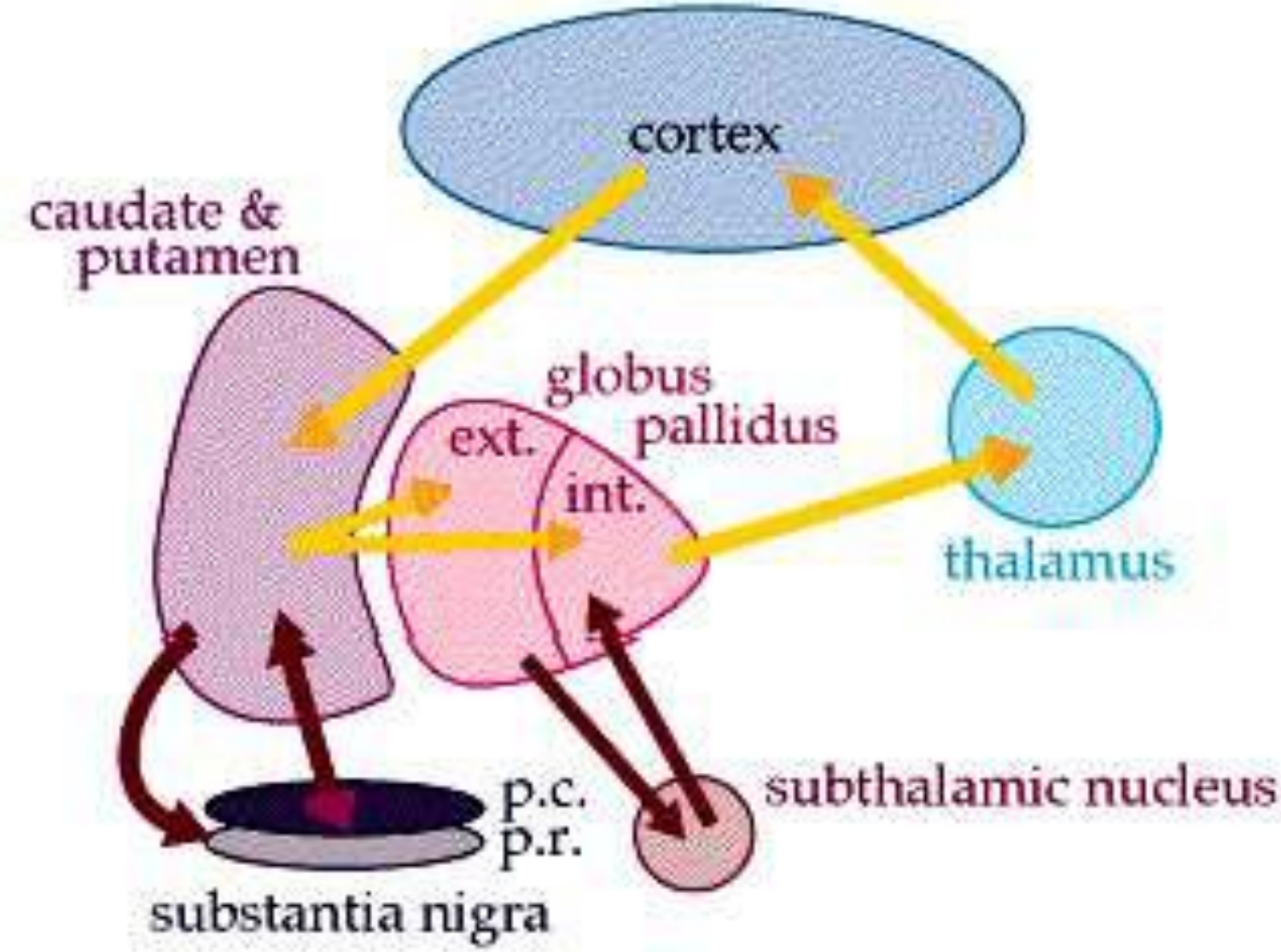
Connections of Basal Ganglia

- The **caudate** and **putamen** *receive all the afferents (input) of basal ganglia.*
  - *These inputs come mainly from motor cortical areas.*
  - Efferent from caudate and putamen mainly go to **Globus pallidus**
- The **GPi** *contains the output neurons of the basal ganglia circuit*.
  - They project to ipsilateral VA and VL of thalamus.

CONNECTIONS

- **Afferent-** Caudate Nucleus & Putamen
- **Efferent-** Globus Pallidus




cortex
caudate &
putamen
globus
pallidus
ext.
int.
thalamus
p.c.
p.r.
subthalamic nucleus
substantia nigra

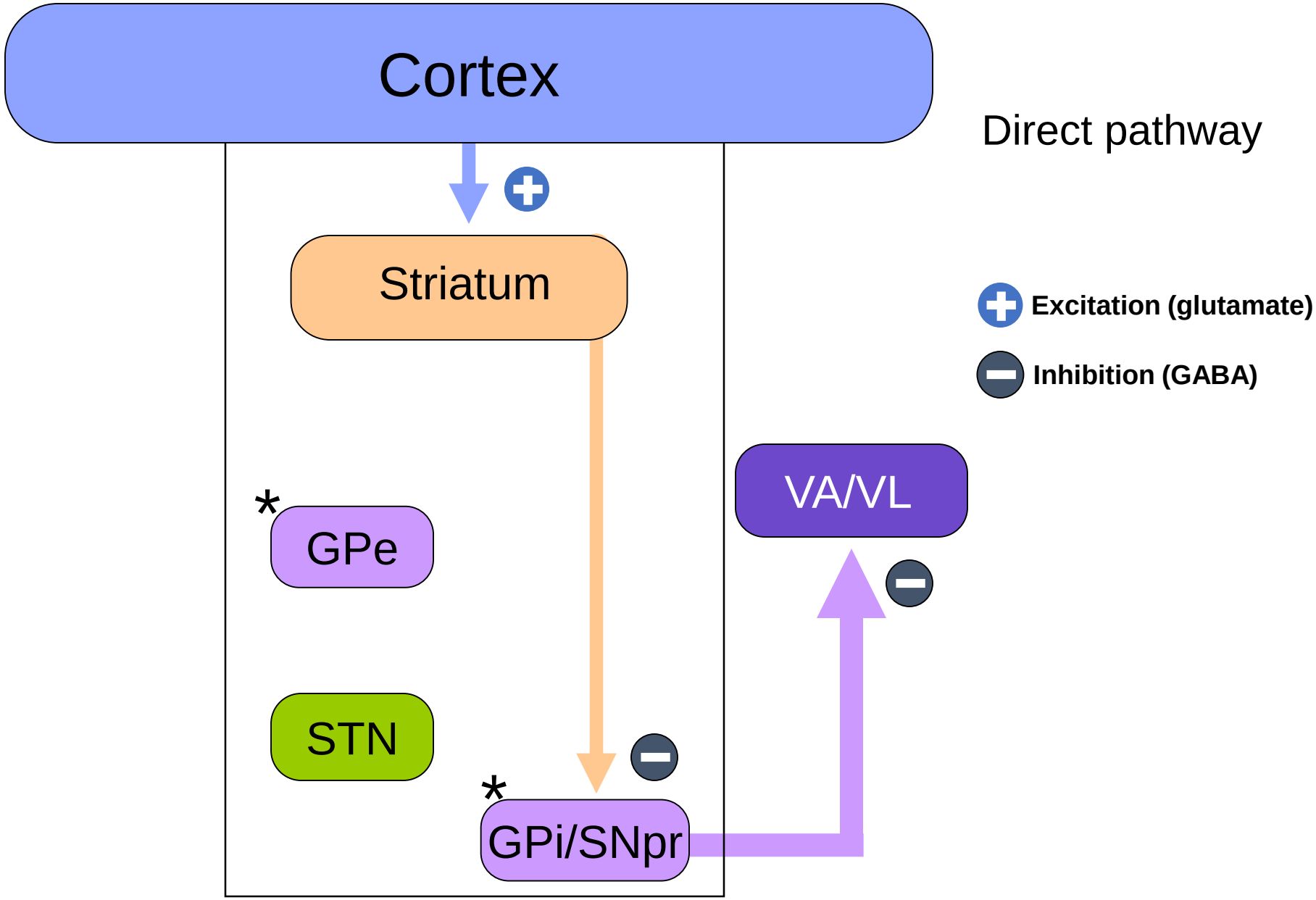
Functional Neuronal Circuits or Loops

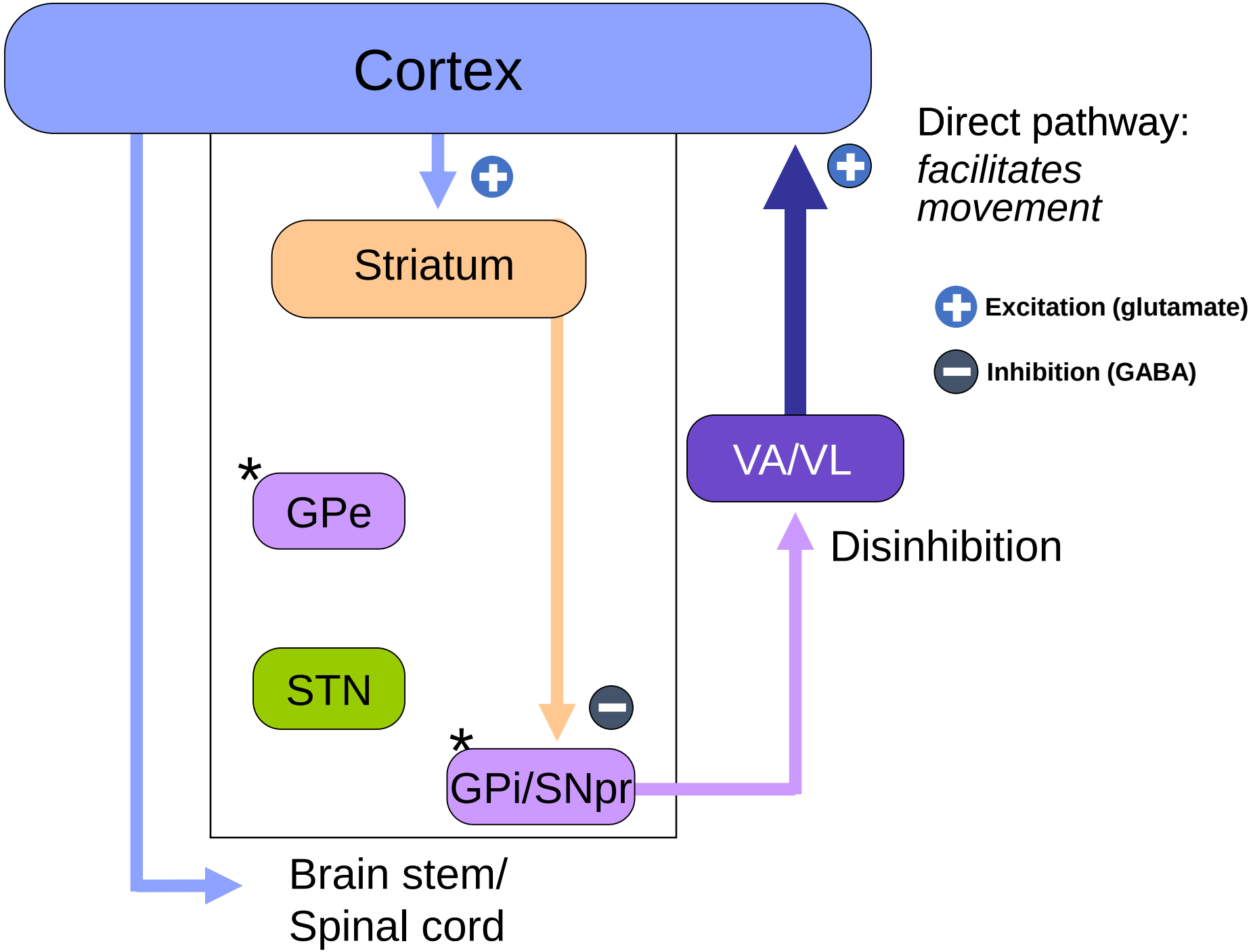
Direct pathway

➢ Striatal cells project directly to GPi

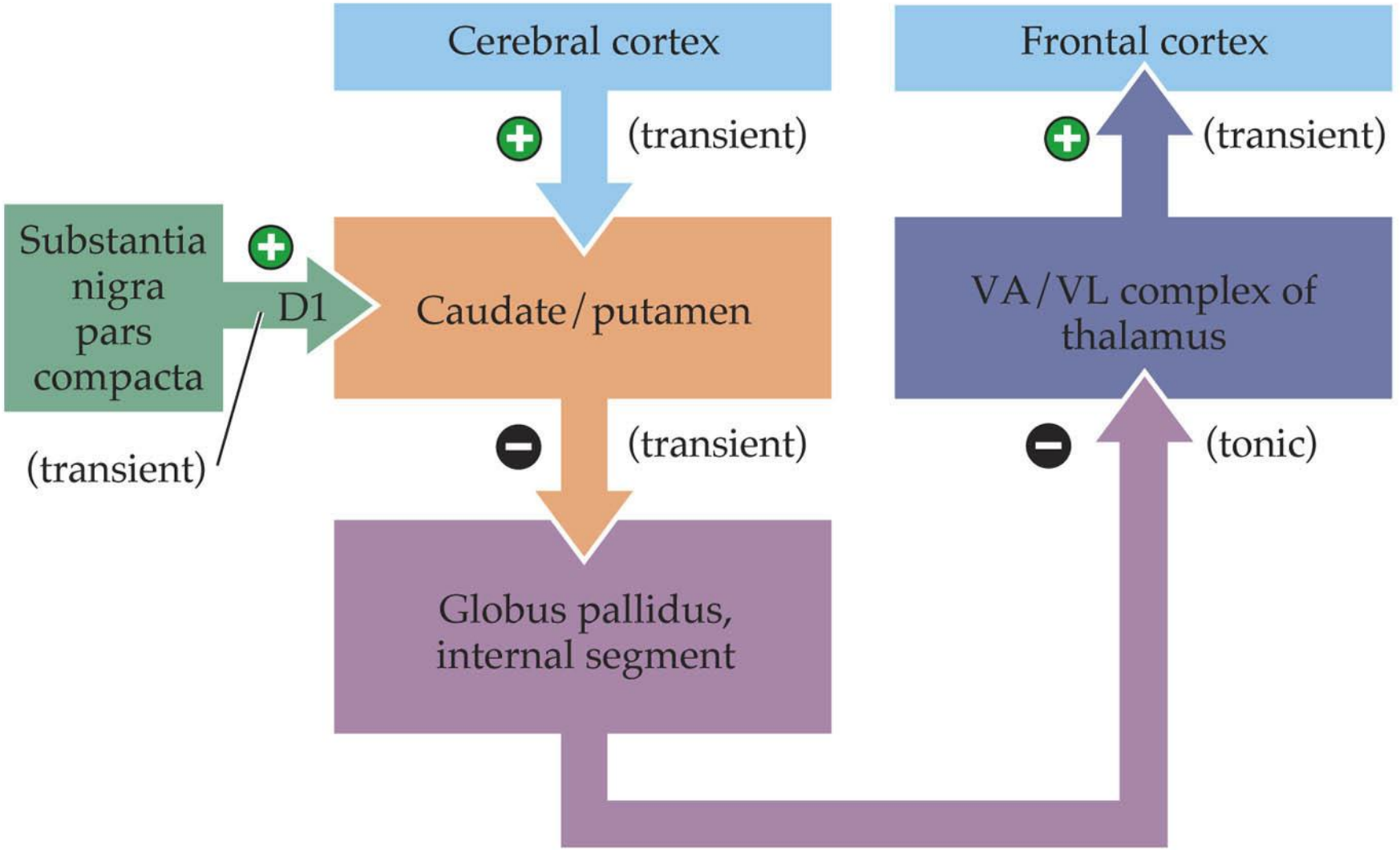
➢ The consequence of this pathway is *to* ***INCREASE*** ***the excitatory drive from thalamus to cortex.***

- The cortical projections to the striatum use the excitatory transmitter **Glutamate**. When they are activated, these cortical projections ***excite*** striatal neurons.
- This excitatory input is enough to turn on the striatal cell. This striatal cell uses the inhibitory transmitter GABA and its axon passes to, and inhibits, a cell in GP(internal). The cells in GP(internal) that project to VA/VL also use GABA.


Cortex
Striatum
GPe
STN
GPi/SNpr
VA/VL
Direct pathway
Excitation (glutamate)
Inhibition (GABA)


Cortex
Striatum
GPe
STN
GPi/SNpr
VA/VL
Brain stem/
Spinal cord
Direct pathway:
facilitates
movement
Excitation (glutamate)
Inhibition (GABA)
Disinhibition

Direct Pathway



Functional Neuronal Circuits or Loops

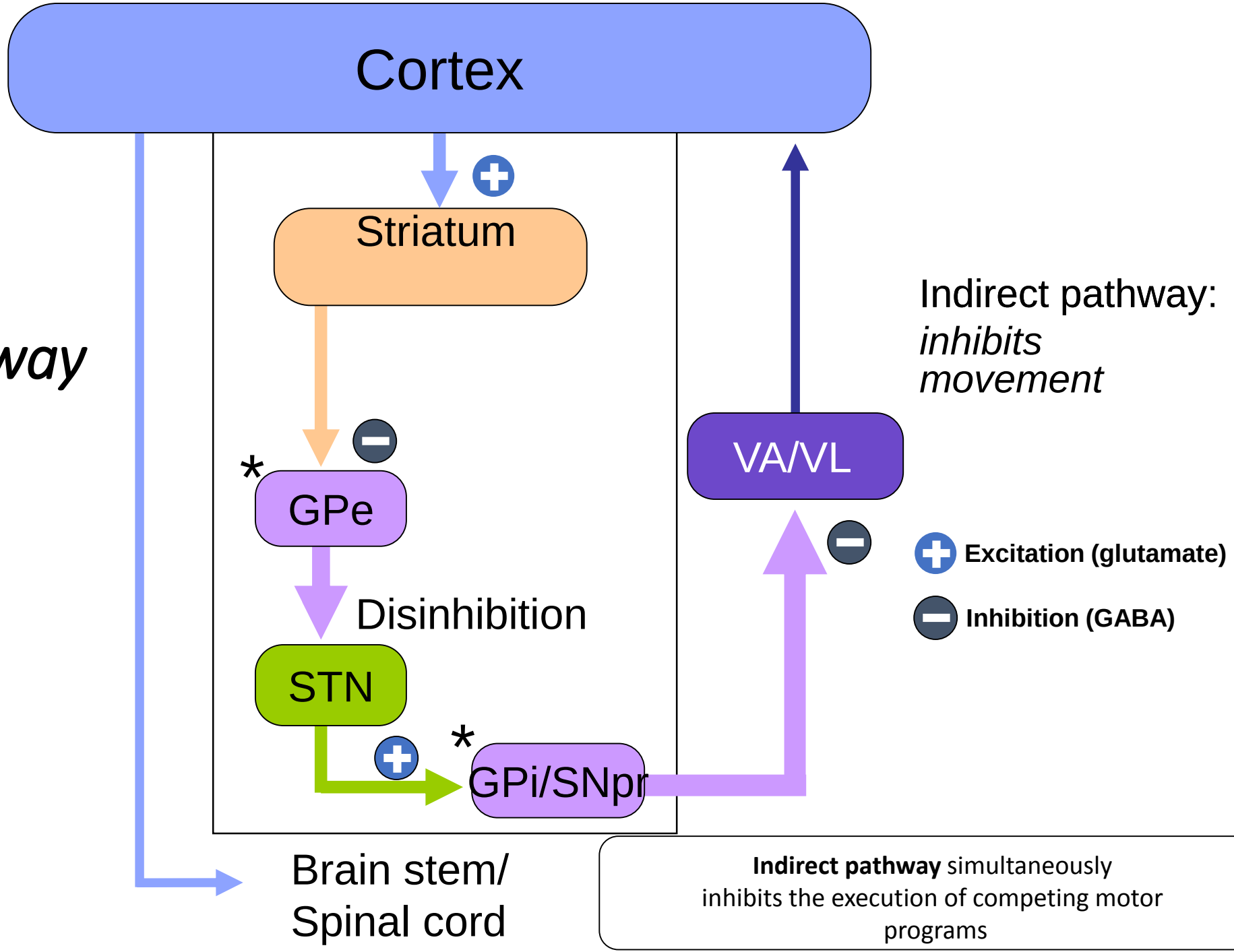
Indirect pathway

- Striatal cells project indirectly to GPi (through GPe and STN)

- The consequence of this pathway is *to* ***DECREASE*** ***the excitatory drive from thalamus to cortex.***

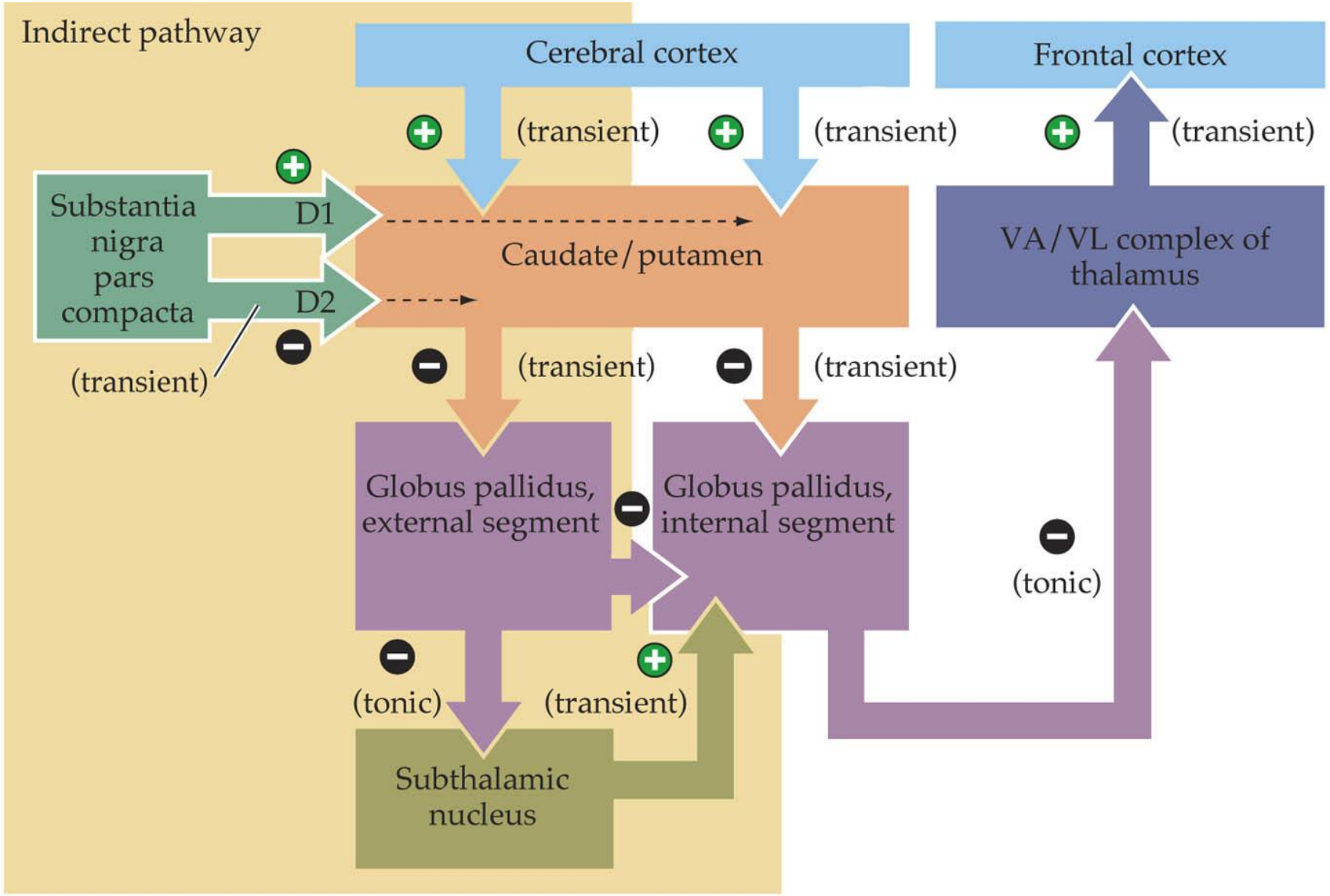
- Indirect pathway *simultaneously inhibits the execution of competing motor programs.*

Indirect Pathway



Indirect pathway simultaneously inhibits the execution of competing motor programs

Direct and indirect pathways



Functional Neuronal Circuits or Loops

Role of SNpc:

Direct pathway: The pars compacta sends **excitatory input** to the striatum via D1 (Dopamine receptor) pathway that excites and activates the striatum.

Indirect pathway: The pars compacta sends **inhibitory input** to the striatum via D2 pathway that inhibits and deactivates the striatum.

Basal Ganglia disorders

Manifestations

Two types:

Hypokinetic

– Increased tone & rigidity

Ex: **Parkinsonism**

Hyperkinetic

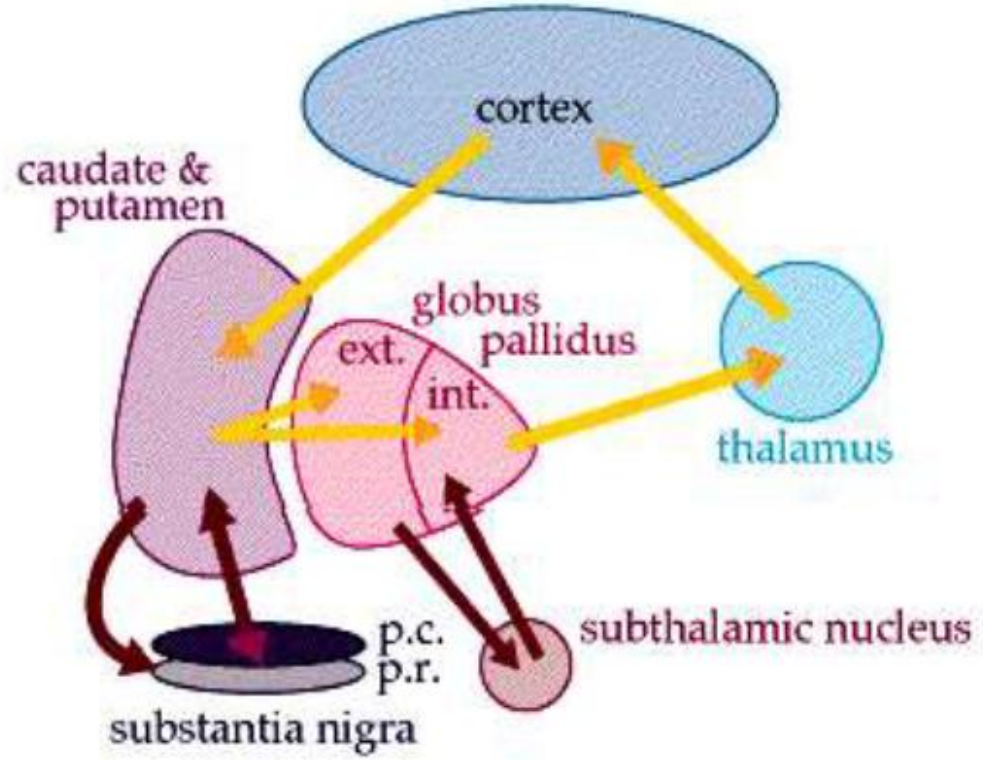
– Abnormal involuntary movements

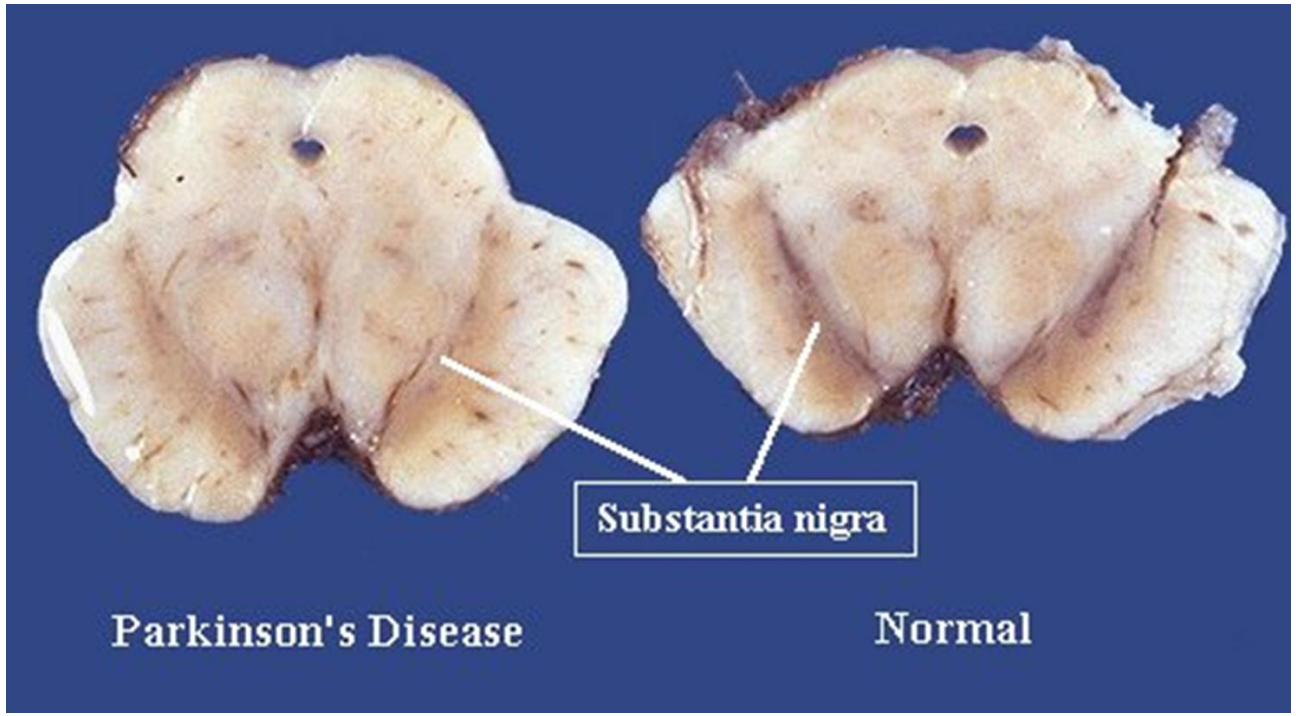
Ex: **Athetosis, Chorea & Hemiballism**

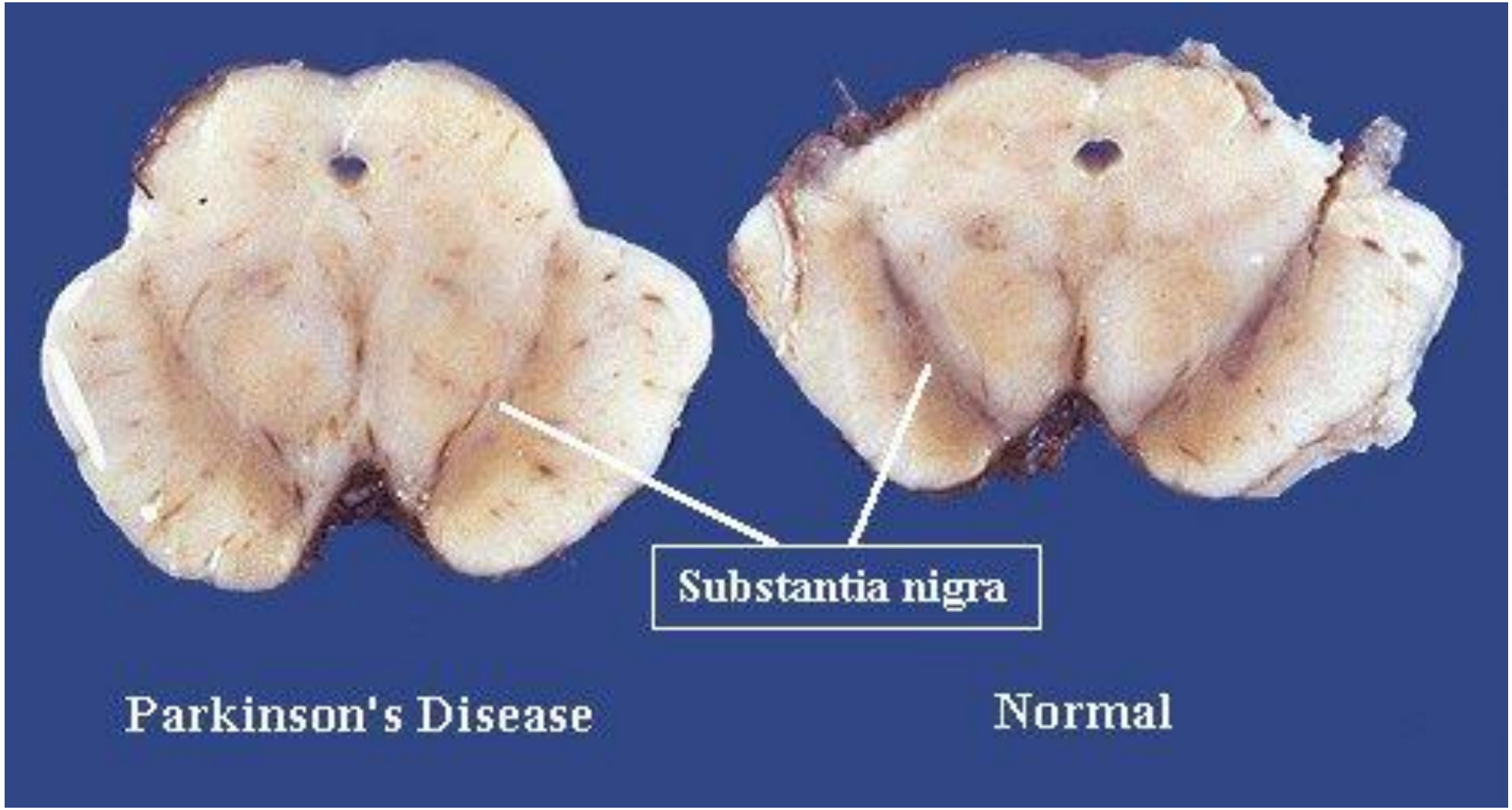
Parkinson disease

Organic basis of Parkinson's disease:

– Degeneration of dopaminergic neurons from the substantia nigra (Nigrostriate fibres)





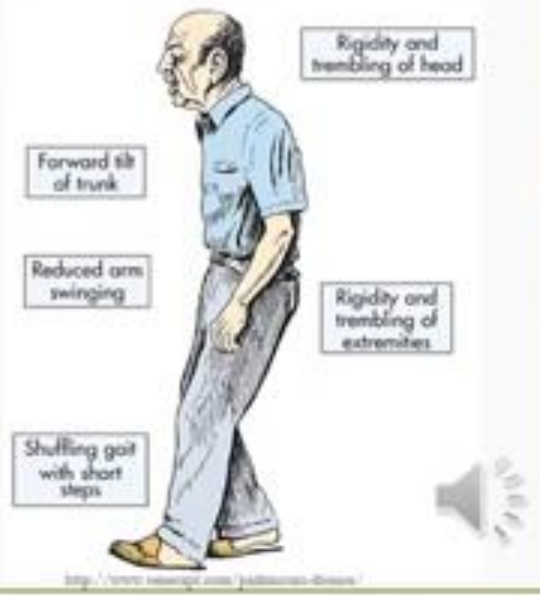

Substantia nigra
Parkinson's Disease
Normal

- Parkinson disease is characterized by:

1. **Rigidity and slowness**: Caused by increased muscle tone
2. **Resting Tremor**
3. **Mask-like facies:** loss of facial expression.
4. **Shuffling gait:** Difficulty in taking initial steps (short and quick steps).

What Does it Look Like?

- Decreased stride length & arm swing – slow shuffling pattern with foot flat strike
- Increased cadence rate and double limb support duration
- Increased flexion of trunk & knees, with partially flexed elbows
- Difficulties initiating walking & may freeze mid-stride
- May include festination – involuntary inclination to take accelerated steps, with difficulty stopping



Athetosis

- Slow writhing (twisting and squirming movements), snake-like movements, especially of the fingers and wrists.

- Due to damage of **Putamen.**

Chorea

- Sudden jerky and purposeless movements.
- Due to Degeneration of Striatum.
- Tow types:

1. **Sydenham's chorea:**
   - In childhood
   - A complication of rheumatic fever.
   - Scattered minute hemorrhage and capillary emboli in striatum).
2. **Huntington's chorea:**
   - In middle age.
   - An inherited disorder.

Hemiballismus

- A sudden wild flail-like (Swing Widely) movement of one limb.
- Due to degeneration of **Subthalamic nucleus** of opposite side.

Thank you

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