# BASAL GANGLIA

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MD Psychiatry I Year
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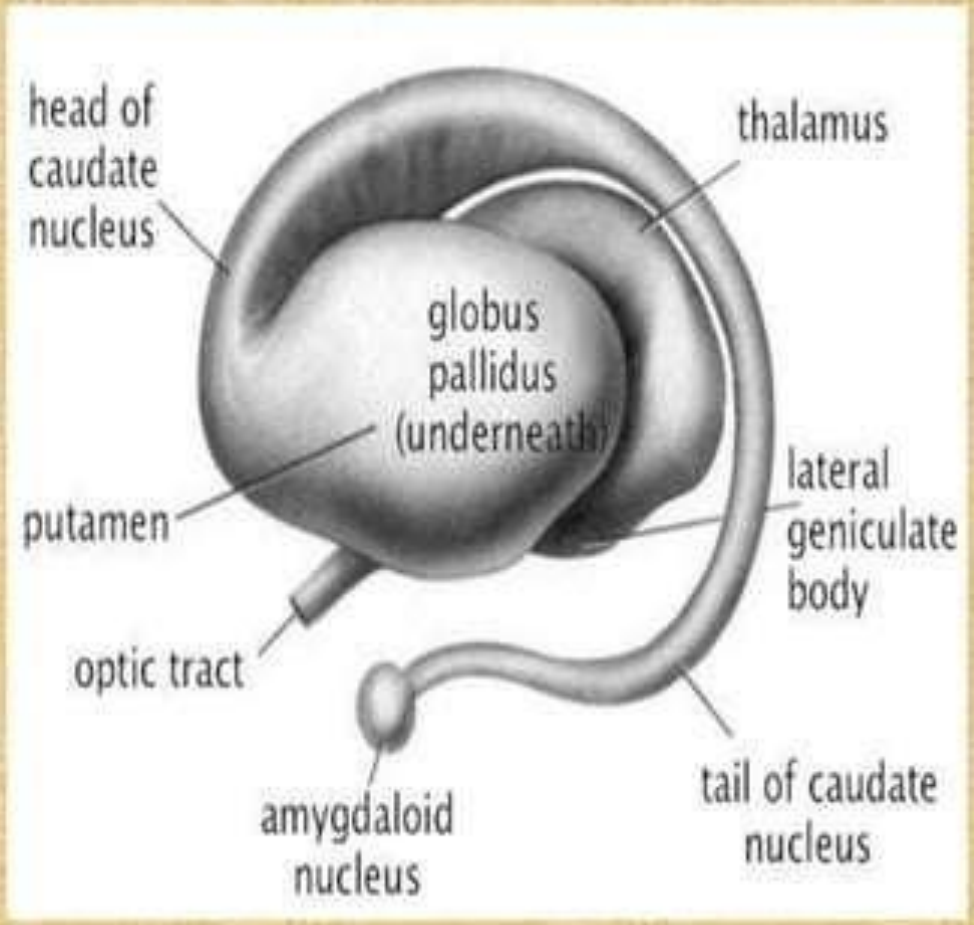
- Divisions
- Description of the individual structures
- Internal organization
- Afferent and Efferent connections
- Circutry
- Clinical correlation
- Disorders

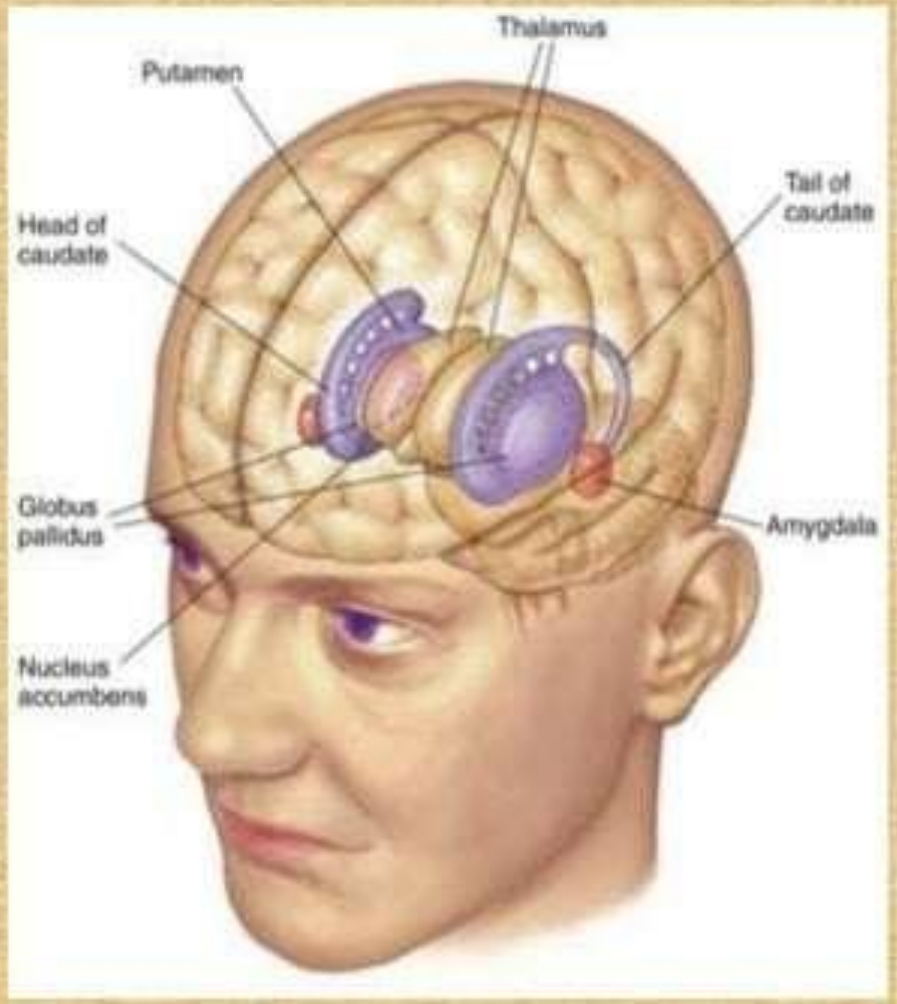
The basal ganglia are large masses of grey matter situated in cerebral hemisphere.

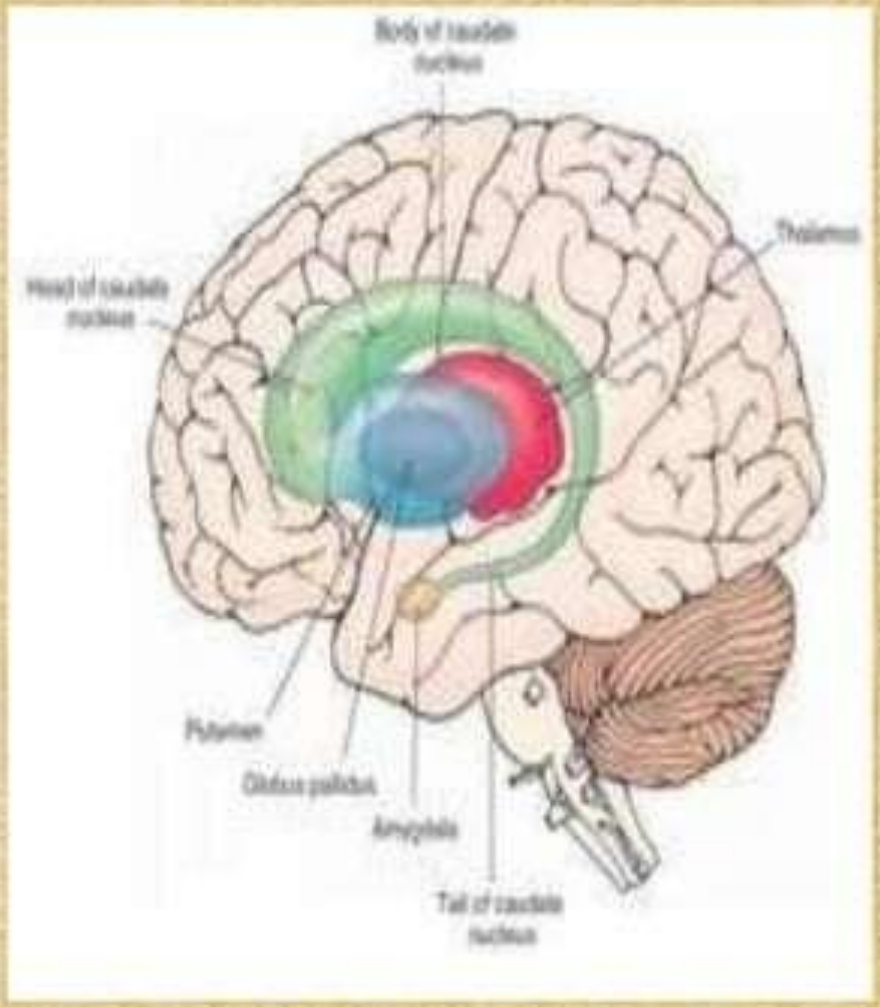
**Structures**

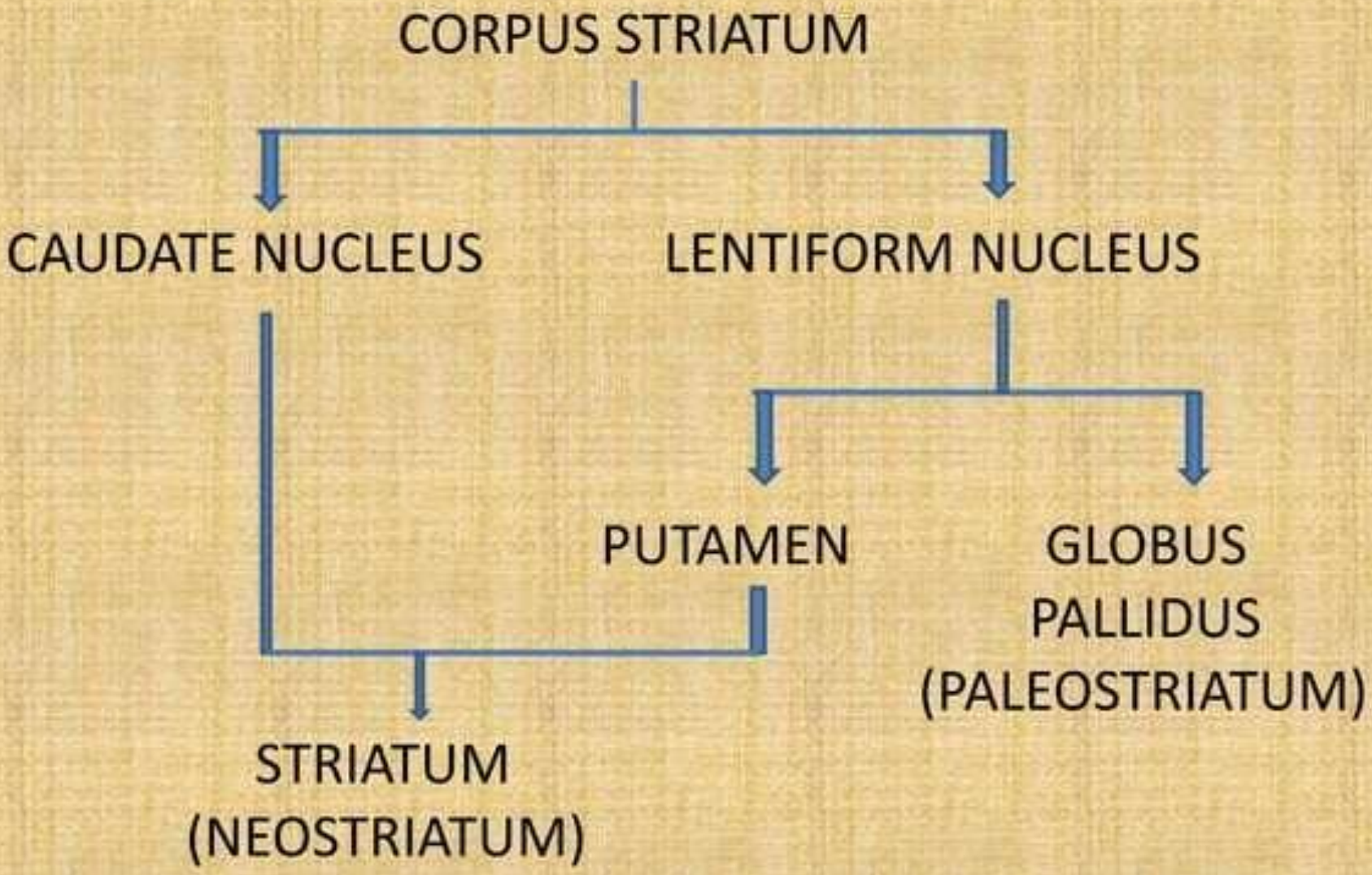
**Anatomical Divisions**

- Caudate nucleus
- Lentiform nucleus – consists of putamen and globus pallidus
- Amygdaloid nuclear complex
- Claustrum`




Thalamus
Putamen
Tail of caudate
Head of caudate
Globus pallidus
Amygdala
Nucleus accumbens


Thalamus
Putamen
Amygdala


CORPUS STRIATUM
CAUDATE NUCLEUS
LENTIFORM NUCLEUS
PUTAMEN
GLOBUS PALLIDUS (PALEOSTRIATUM)
STRIATUM (NEOSTRIATUM)

- Neostriatum (the striatum) – formed by caudate nucleus and putamen
- Paleostriatum – formed by pallidum (globus pallidus)
- Archistriatum – formed by Amygdaloid nuclear complex and Claustrum

**Functional divisions of basal ganglia**

- Corpus striatum
- Subthalamic nucleus
- Substantia nigra
- Ventral striatum
- Ventral pallidum

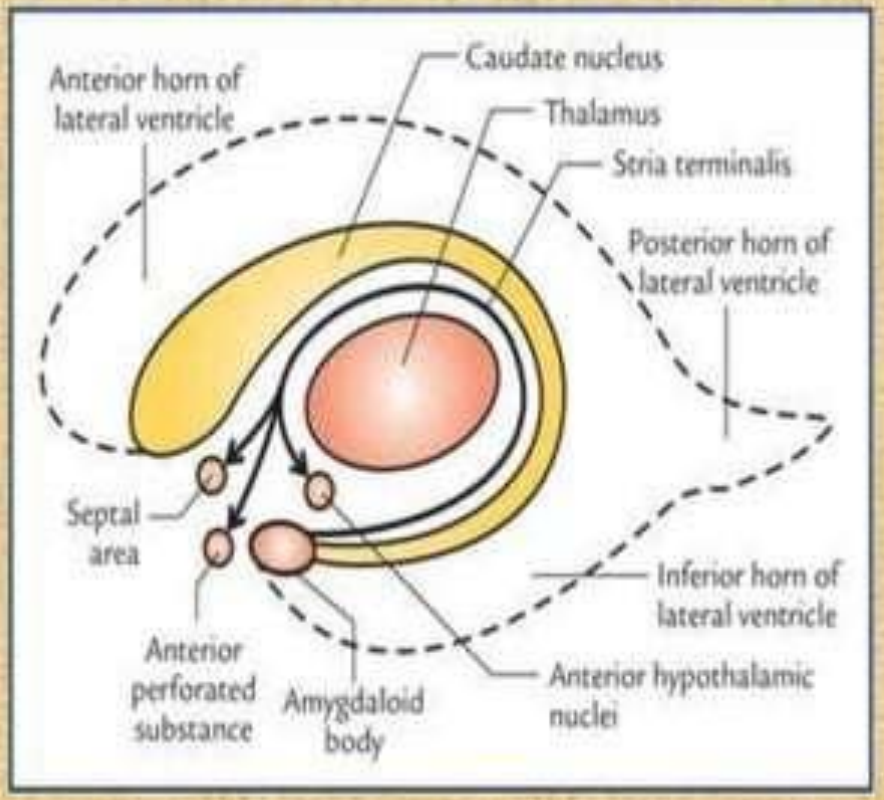
# Caudate nucleus

It is a C shaped mass of grey matter
Derived from ***telencephalon.***
Consists of large head, body and thin tail.

**Relations**

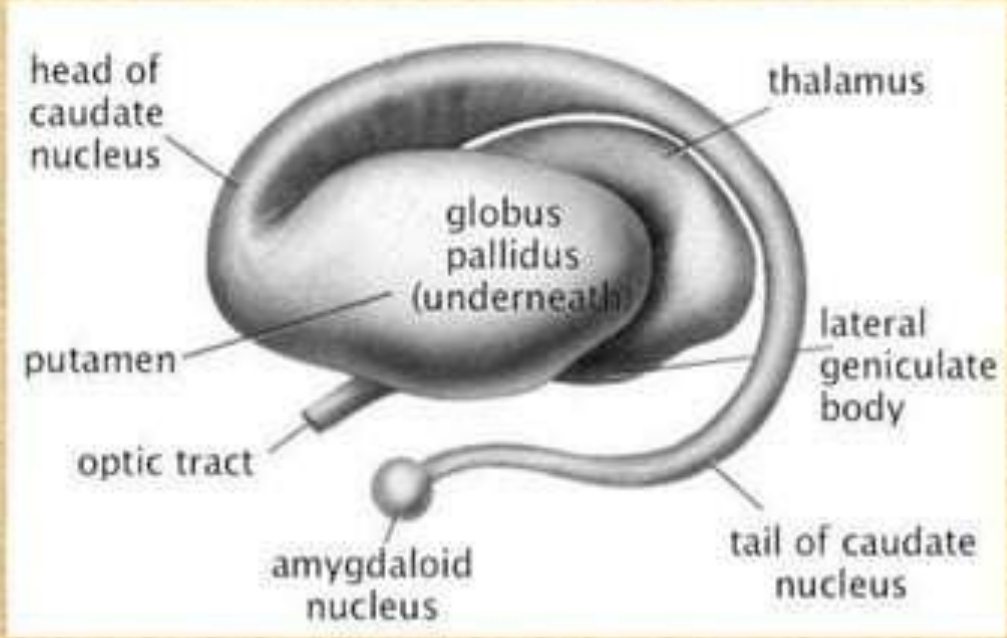
It is intimately related to the ***lateral ventricle.***

- **Head** - bulges into anterior horn of the ventricle and forms its floor. It is continuous with the putamen.
- **The body** lies in the floor of the central part of the ventricle
- **Tail** in the roof of the inferior horn of the ventricle.



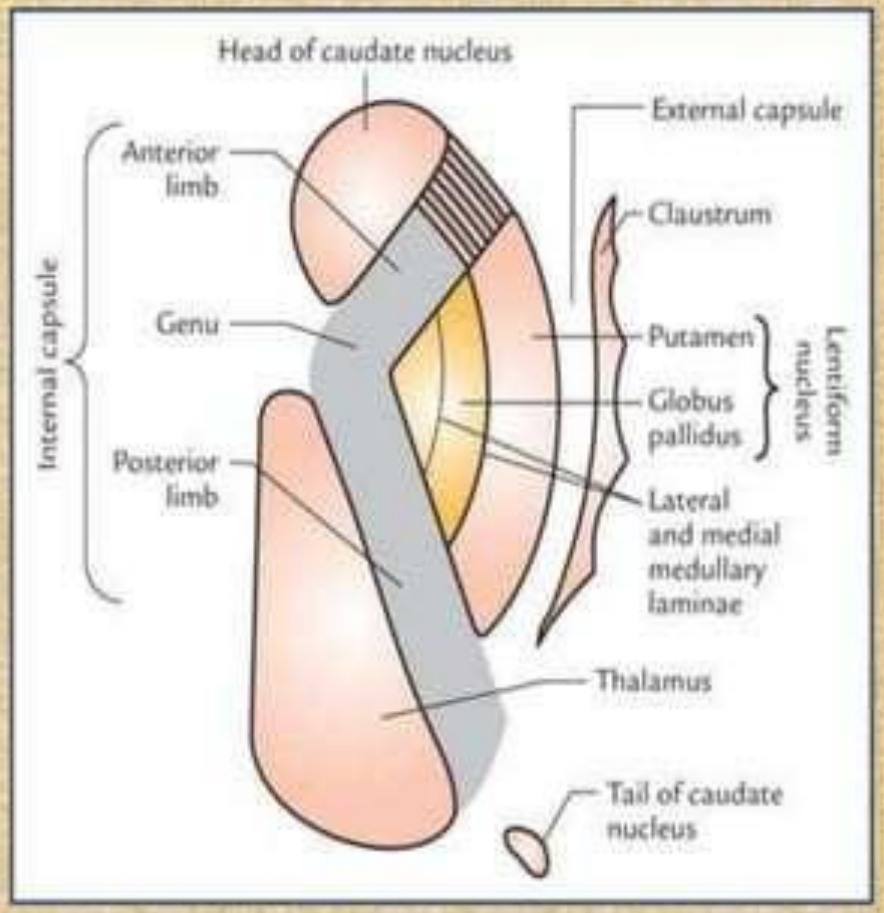
# Caudate nucleus

- The anterior part of the head is fused with the lentiform nucleus inferiorly. This region is called **fundus striati.**
- Fundus striati is continuous inferiorly with the anterior perforated substance.
- The tail lies in close relation to the amygdaloid complex.
- The body is related medially to the thalamus and laterally to the internal capsule which seperates it from the lentiform nucleus.



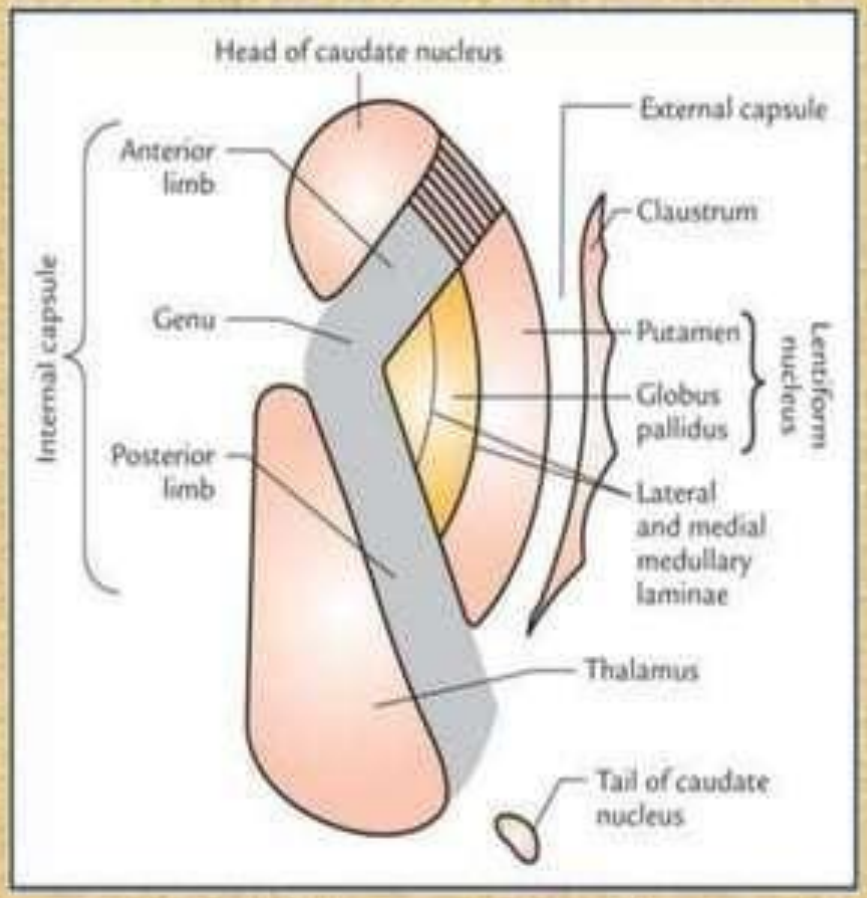
# Lentiform nucleus

- Appears triangular in the coronal section with its tip directed medially.
- Divided by a thin lamina of white matter known as ***external medullary lamina*** into
  - Lateral part- putamen
  - Medial part- globus pallidus



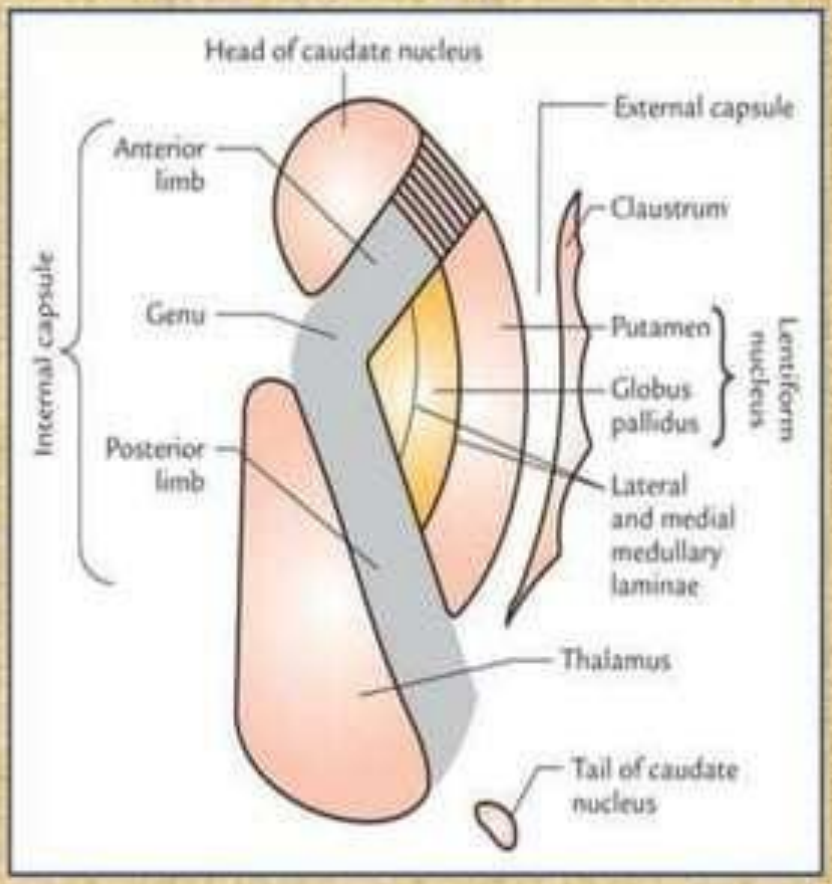
# Putamen

- Derived from ***telencephalon.***
- Lies medial to the insula
- Bounded laterally by the fibres of ***external capsule*** and medially by the globus pallidus.
- Separated from the caudate nucleus by the anterior limb of the internal capsule



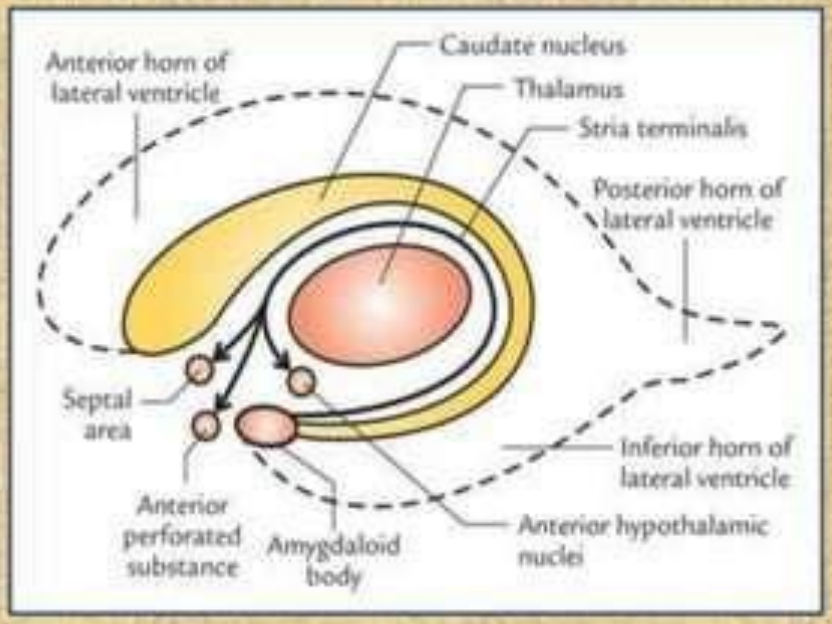
# Globus pallidus

- It is **diencephalon** in origin.
- It constitutes the inner component of the lentiform nucleus.
- The globus pallidus is subdivided into external (GPe) and internal (GPi) segments by the ***internal medullary lamina***.
- Medial – posterior limb of internal capsule seperates from the thalamus
- Lateral – putamen.



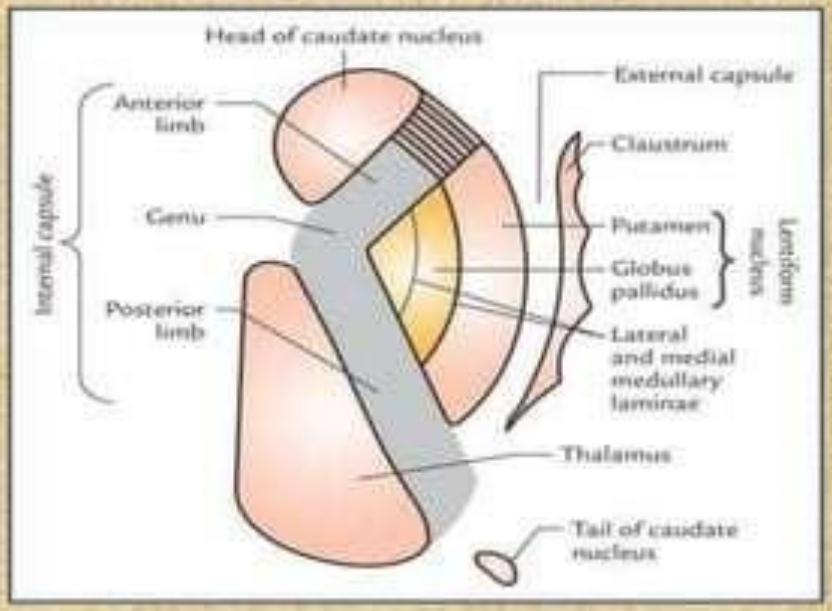
## Amygdaloid nuclear complex

- Lies in the temporal lobe close to the temporal pole.
- Lies deep to the uncus
- Related to the anterior end of the inferior horn of the lateral ventricle.



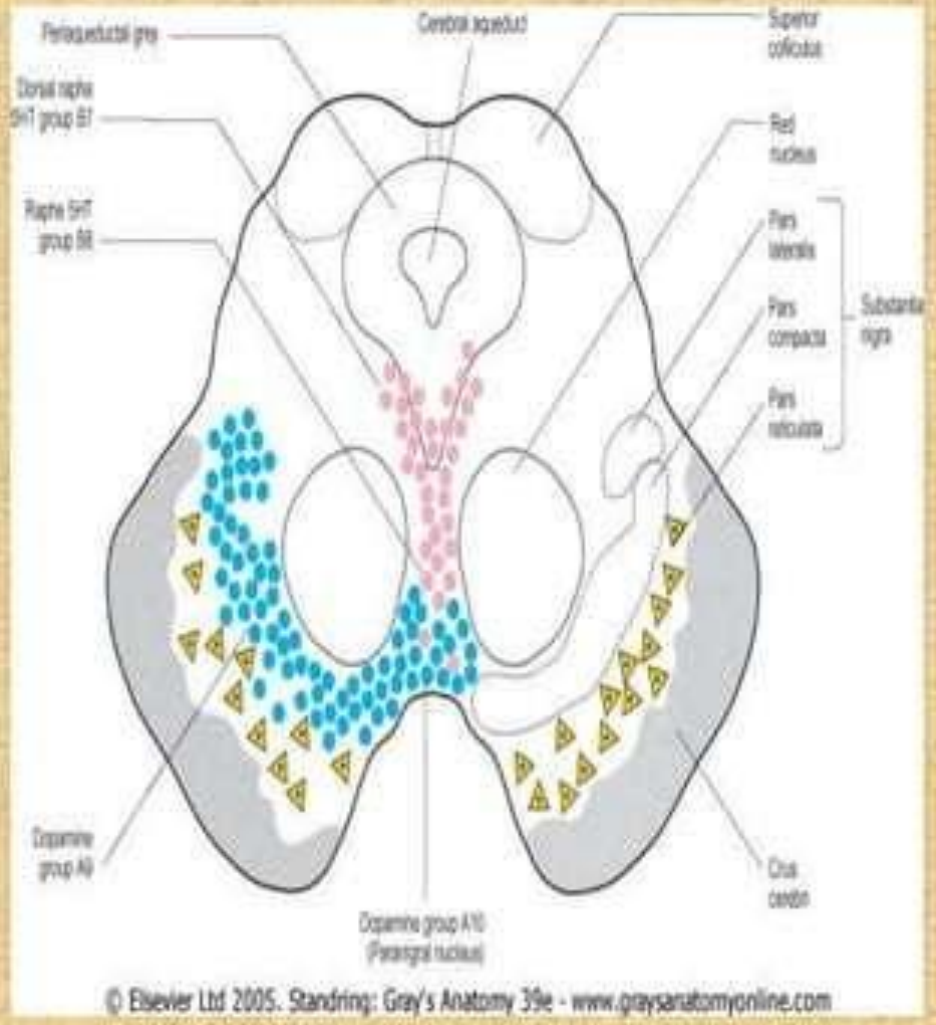

## Claustrum

- Thin lamina of grey matter lies lateral to the lentiform nucleus. It is separated from the latter by the fibres of external capsule.
- Laterally it is separated by a thin layer of white matter from the cortex of insula.
- Its connections and functions are not known.



# Substantia Nigra

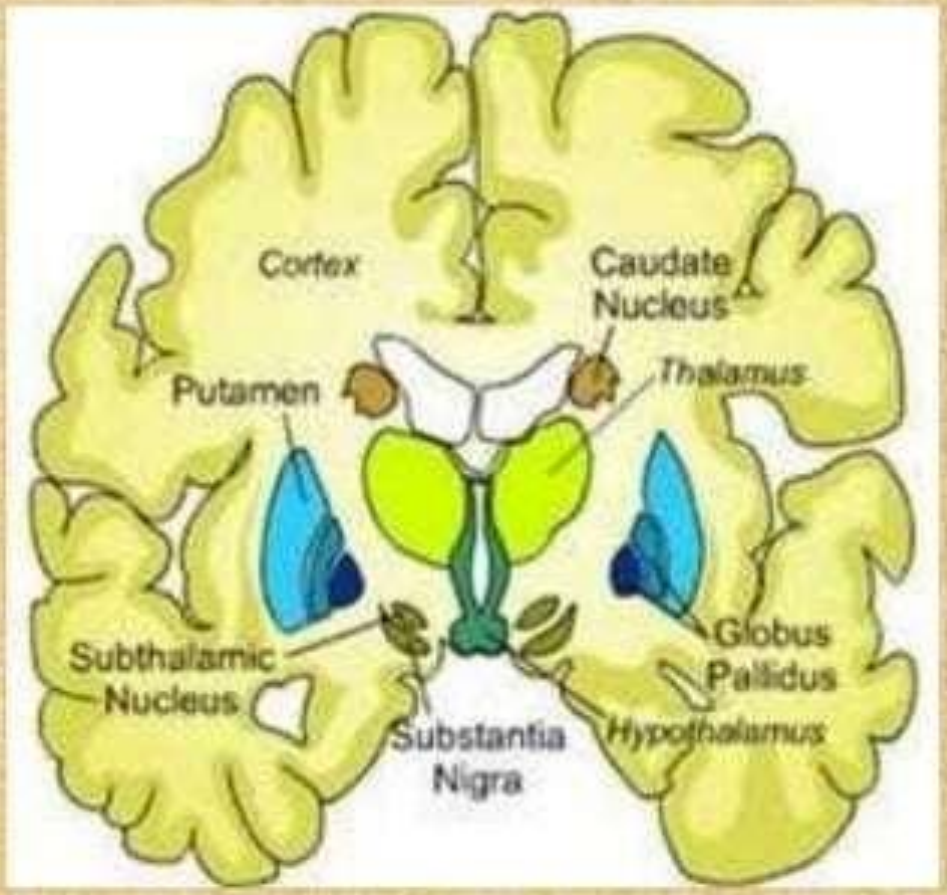
- **Mesencephalic** in origin.
- It is a large motor nucleus present in the midbrain between the tegmentum and the basis pedunculi.




- It consists of 2 parts
  - **Pars reticulata** – ventral cell sparse portion, functionally related to internal part of globus pallidus. They use the inhibitory neurotransmitter GABA.
  - **Pars compacta** – dorsal cell rich portion. Neurons here are pigmented because of the presence of ***neuromelanin***. These cells contain dopamine.

# Subthalamic nucleus

- Derived from diencephalon.
- Lies dorsomedial to the posterior limb of the internal capsule and dorsal to the substantia nigra.
- Lesion – hemiballismus



# Ventral Striatum

- Masses of grey matter lying in the region of anterior perforated substance.
- The caudate nucleus and lentiform nucleus fuse inferiorly to form the fundus striati.
- Immediately below the fundus striati is the olfactory tubercle in the anterior perforated substance.
- More medially is a mass of grey matter called the nucleus accumbens. It is closely related to the caudate nucleus superolaterally and to the septal nuclei medially.
- The ventral striatum consists of the **olfactory tubercle** and the **nucleus accumbens.**

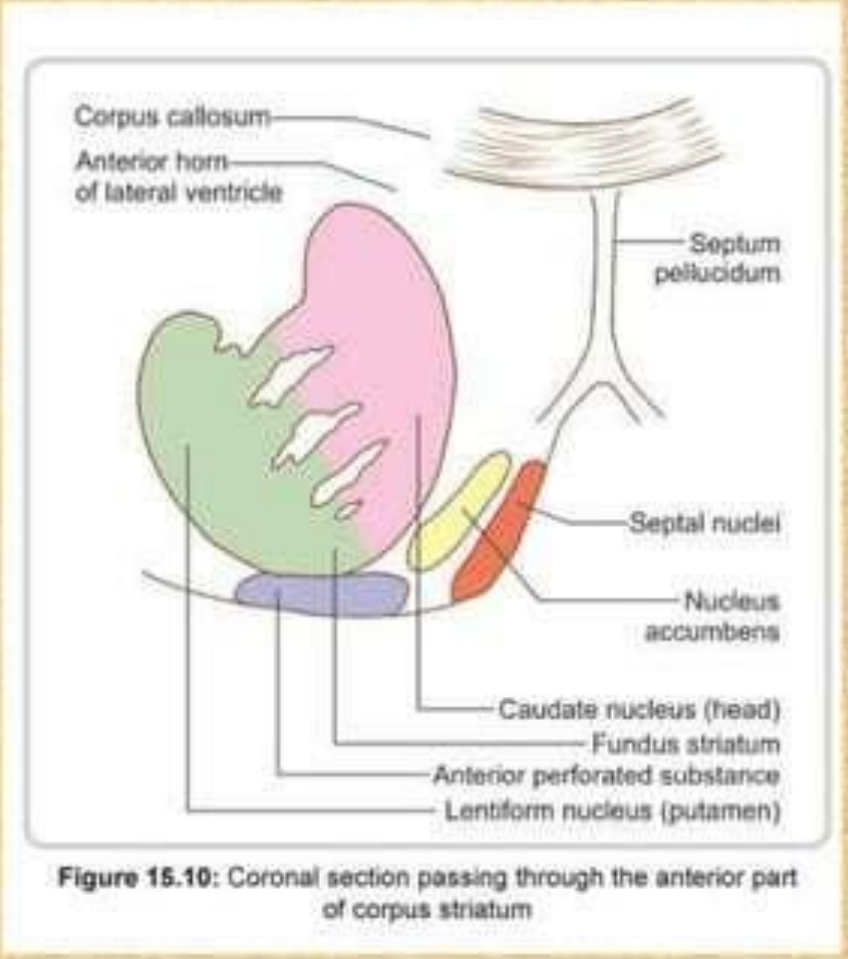



**Figure 15.10:** Coronal section passing through the anterior part of corpus striatum

# Ventral pallidum

- In coronal section, the anterior commissure runs laterally just below the head of the caudate nucleus. It cuts through the globus pallidus.

- The part of the globus pallidus lying inferior to the anterior commissure is called the ventral pallidum.

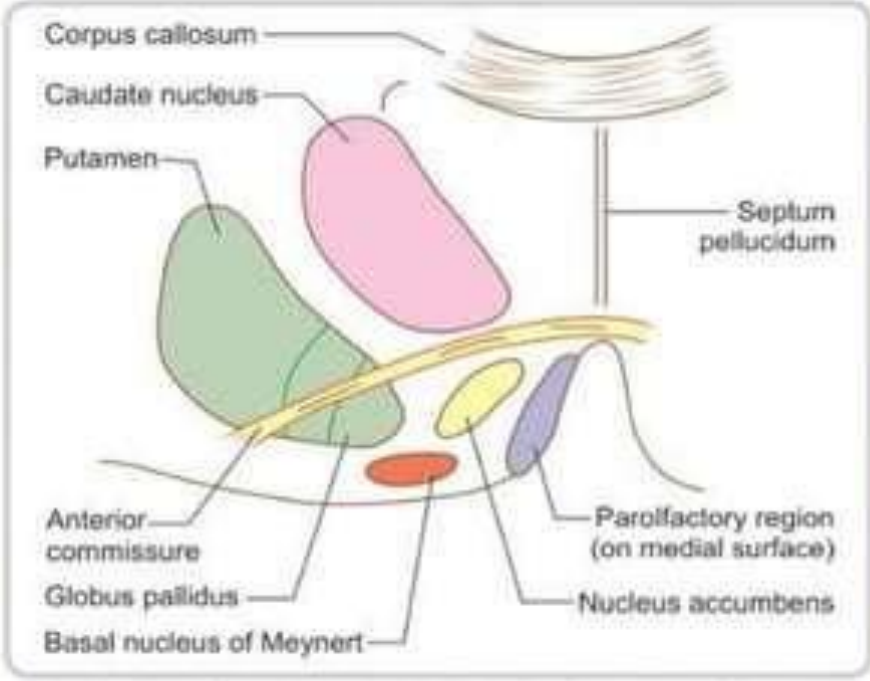
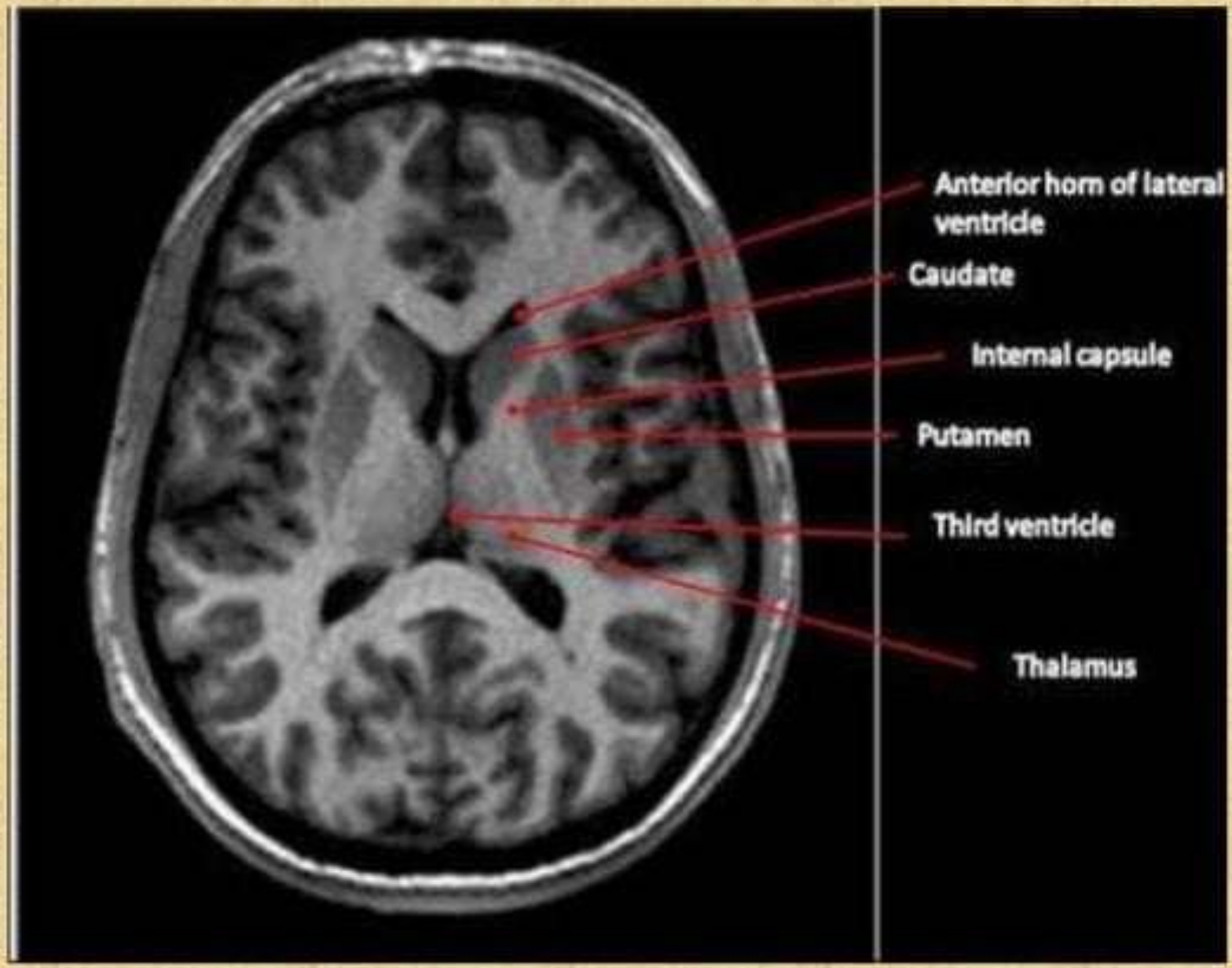



**Figure 15.11:** Composite diagram showing the region of the ventral thalamus. Actually, all structures shown cannot be seen in any one vertical plane

Thus,

- Dorsal striatum – caudate nucleus and putamen
- Ventral striatum – olfactory tubercle and nucleus accumbens
- Dorsal pallidum – globus pallidus
- Ventral pallidum – part below the anterior perforated substance


Anterior horn of lateral ventricle
Caudate
Internal capsule
Putamen
Third ventricle
Thalamus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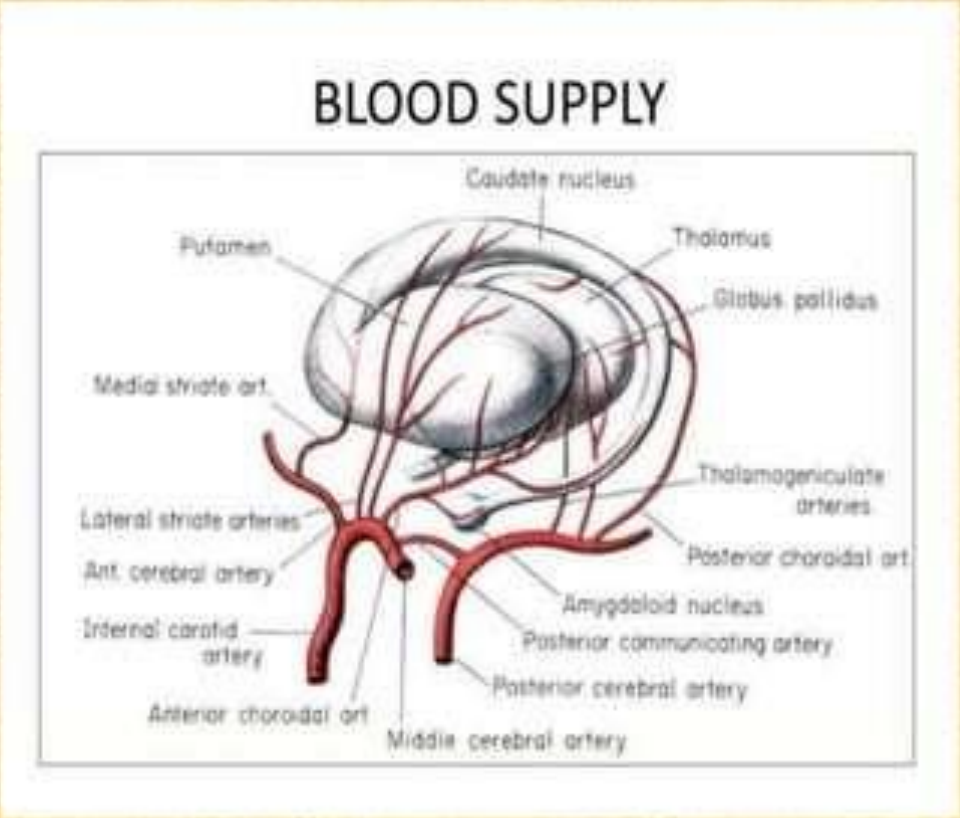
# Blood supply

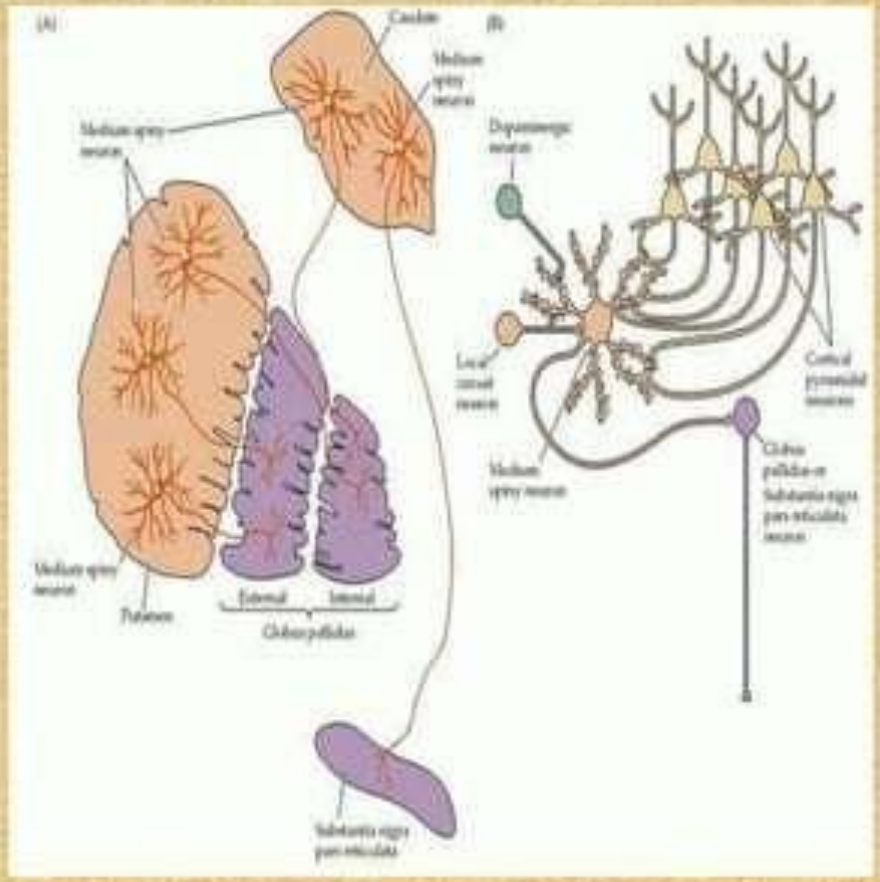
- Lenticulostriate branches of middle and anterior cerebral arteries.
- Anterior choroidal branch of internal carotid artery.



# Internal Organization

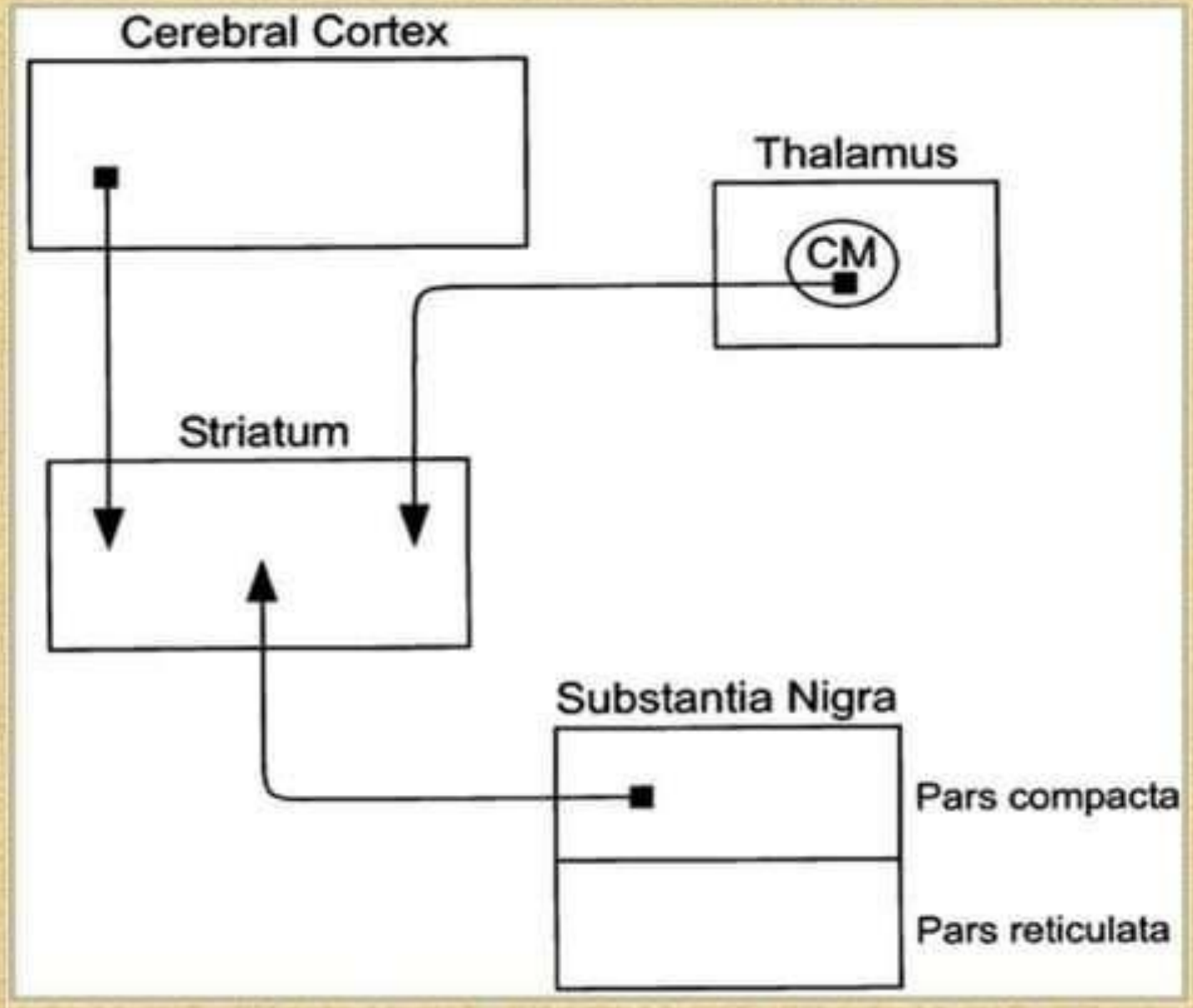
- Caudate nucleus and putamen are frequently referred together because of their common charecteristics. They are composed of histologically identical cells.
- Most neurons are ***medium spiny neurons*** – medium sized cells that possess spines on their dendrites.
- Others are medium aspiny neurons, large spiny and aspiny neurons.
- In striatum,

  Zones that contain low density of AChE enzymatic activity surrounded by areas rich in AChE activity. AChE rich areas are called **matrix.** AChE poor areas are called **striosomes**.



# Afferent connections

- From cerebral cortex arising primarily from the pyramidal cells of the layers V, VI via **corticostriate** fibres. These are glutaminergic.
  - sensorimotor cortex ⟹ putamen
  - association regions ⟹ caudate nucleus
  - Prefrontal regions ⟹ head of the caudate nucleus
- The intralaminar nucleus particularly central median nucleus of thalamus via **thalamostriate** fibres
- The pars compacta of the substantia nigra via **nigrostriate** fibres. They are dopaminergic.

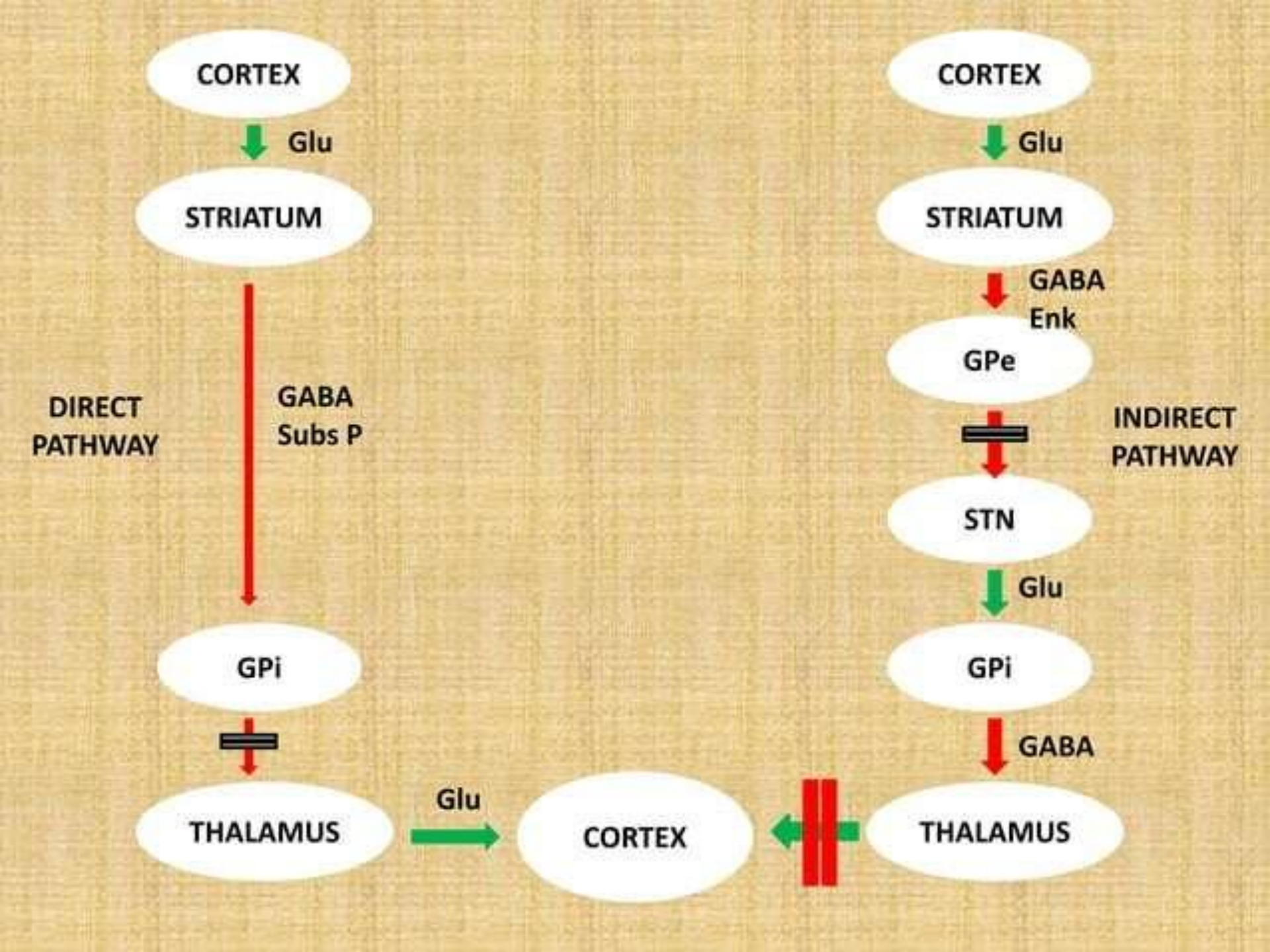

Cerebral Cortex
Thalamus
CM
Striatum
Substantia Nigra
Pars compacta
Pars reticulata

# Afferent connections

- Noradrenergic fibres from the locus ceruleus
- Serotoninergic fibres from the raphe nuclei (in the reticular formation of the midbrain)
- Afferents from limbic cortical areas, hippocampus and the amygdala terminates in the ventral striatum.
- The afferents from the cerebral cortex and the thalamus provide the striatum with various modalities of sensory information.
- Disruption of the input pathways is associated with movement disorders like parkinsons disease.

# Internal processing

- The direct pathway – increased motor activity
- The indirect pathway – decreased motor activity
- The intrinsic circuitry of the basal ganglia is disrupted by a severe loss of neurons in the striatum in Huntington's disease.


CORTEX
Glu
STRIATUM
DIRECT PATHWAY
GABA Subs P
GPi
THALAMUS
Glu
CORTEX
CORTEX
Glu
STRIATUM
GABA Enk
GPe
INDIRECT PATHWAY
STN
Glu
GPi
GABA
THALAMUS

# Efferent connections

- The main output is concentrated upon the pallidum and on the substantia nigra.
- Outflow from **globus pallidus** forms four bundles

1. Fasciculus lenticularis – arises from inner segment of globus pallidus and enters the subthalamic region.
2. Ansa lenticularis – arises from both the inner and outer segments of the globus pallidus and enters the subthalamic region where it meets the dentato rubrothalamic fibres and the fasciculus lenticularis. The union of the three tracts is called ***fasciculus thalamicus*** which terminates in the ventralis anterior, ventralis lateral and centro median nuclei of the thalamus.
3. Subthalamic fasciculus- consists of reciprocal connections between the globus pallidus and nucleus subthalamicus.
4. Pallidonigral fibres – pass to the substantia nigra

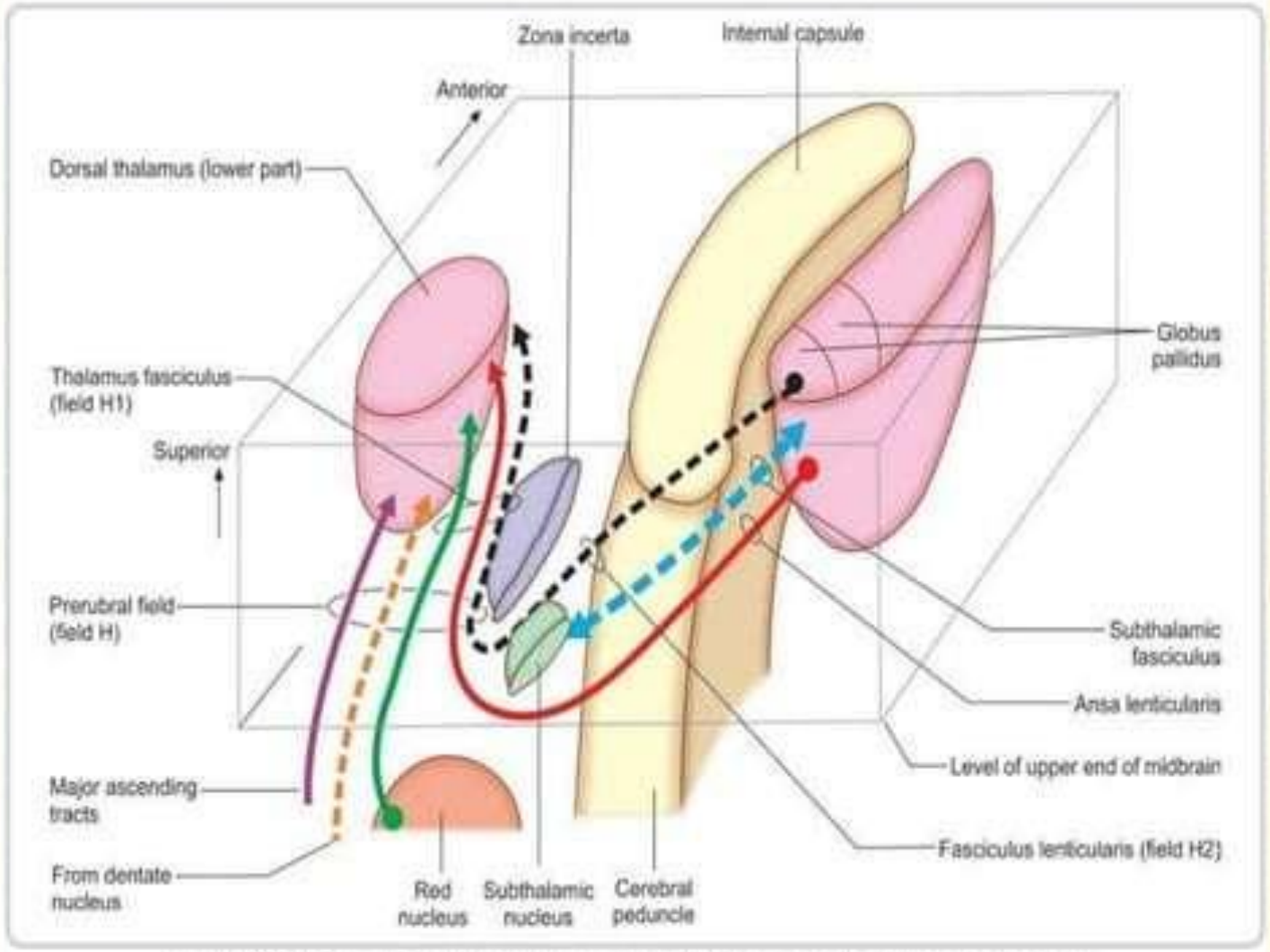
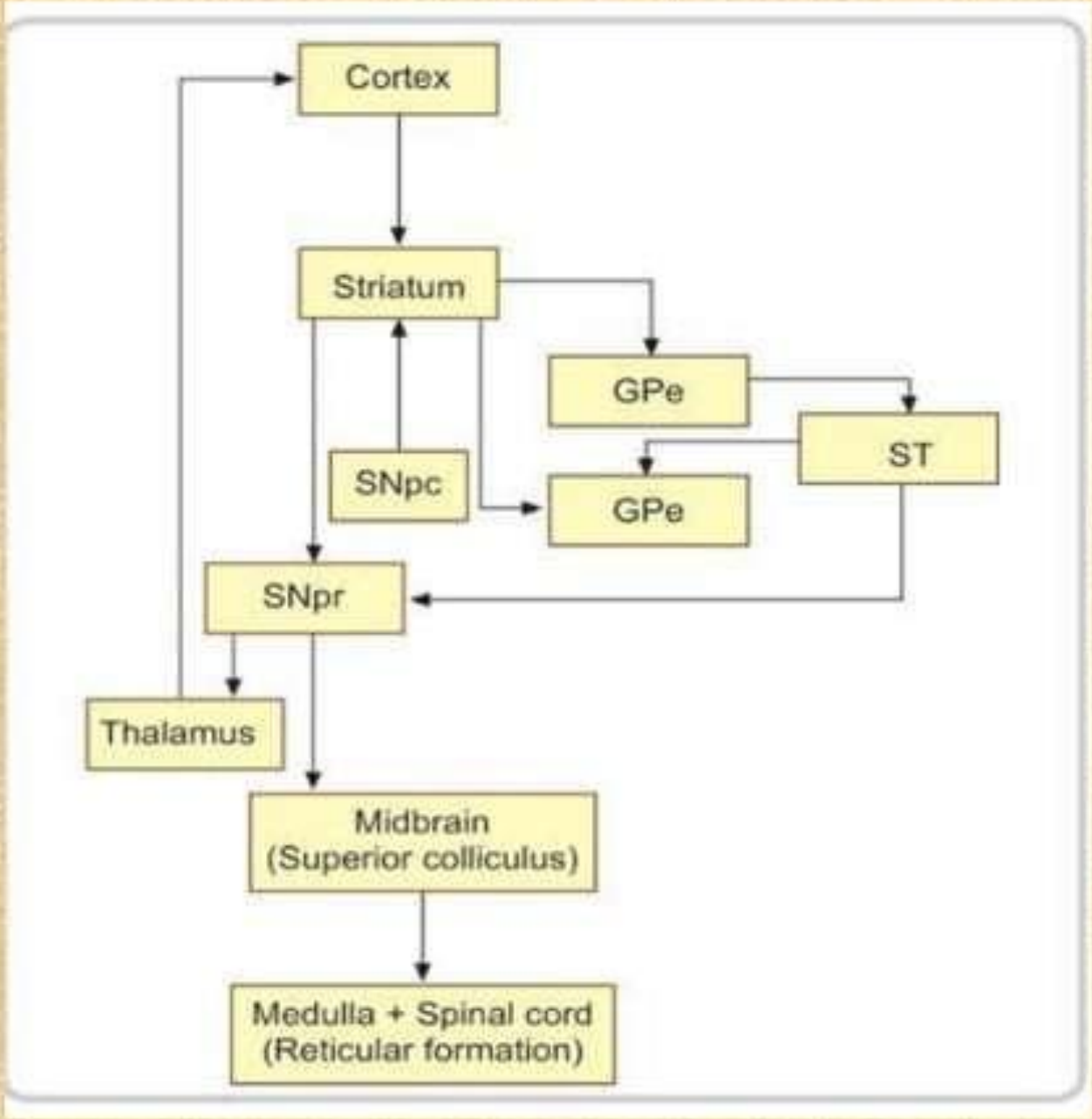



**Figure 12.28:** Schematic 3-dimensional diagram of ventral thalamic region to show some of its features

# Efferent connections

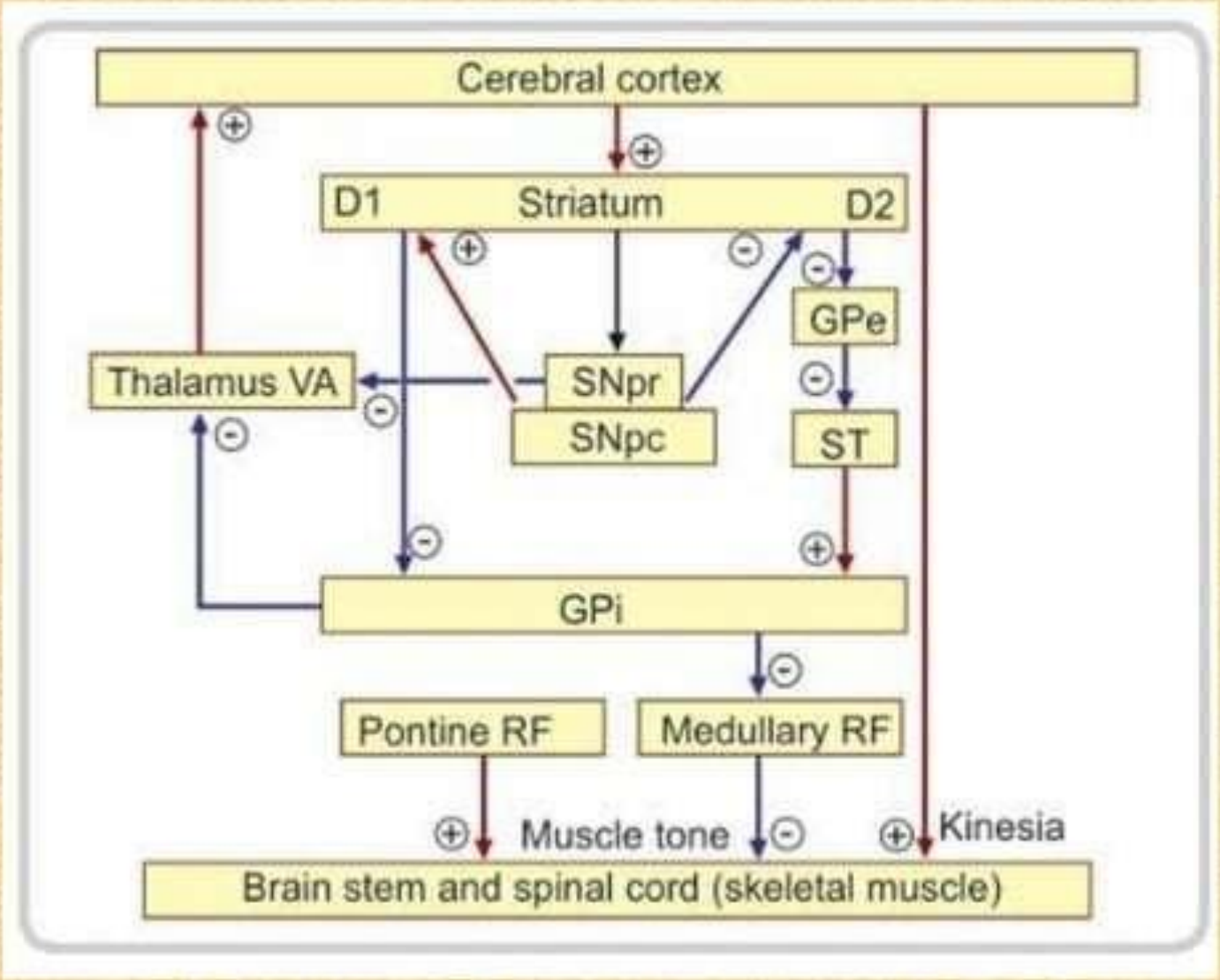
## Substantia Nigra

- **Pars compacta**
- Sends a dopaminergic projection to the striatum.
- A projection from striatum ends in pars reticularis.
- Pars reticulata receives fibres from pallidum directly or after relay in the subthalamic nucleus or in the pedunculopontine nucleus.
- **Pars reticularis**
- Projects to the ventral lateral and ventral anterior nucleus of the thalamus.These impulses are relayed to premotor and prefrontal areas of the cortex.
- Other efferents reach the superior colliculus. They are relayed from there to the reticular formation of the medulla and to the spinal cord.


Cortex
Striatum
GPe
ST
SNpc
GPe
SNpr
Thalamus
Midbrain
(Superior colliculus)
Medulla + Spinal cord
(Reticular formation)

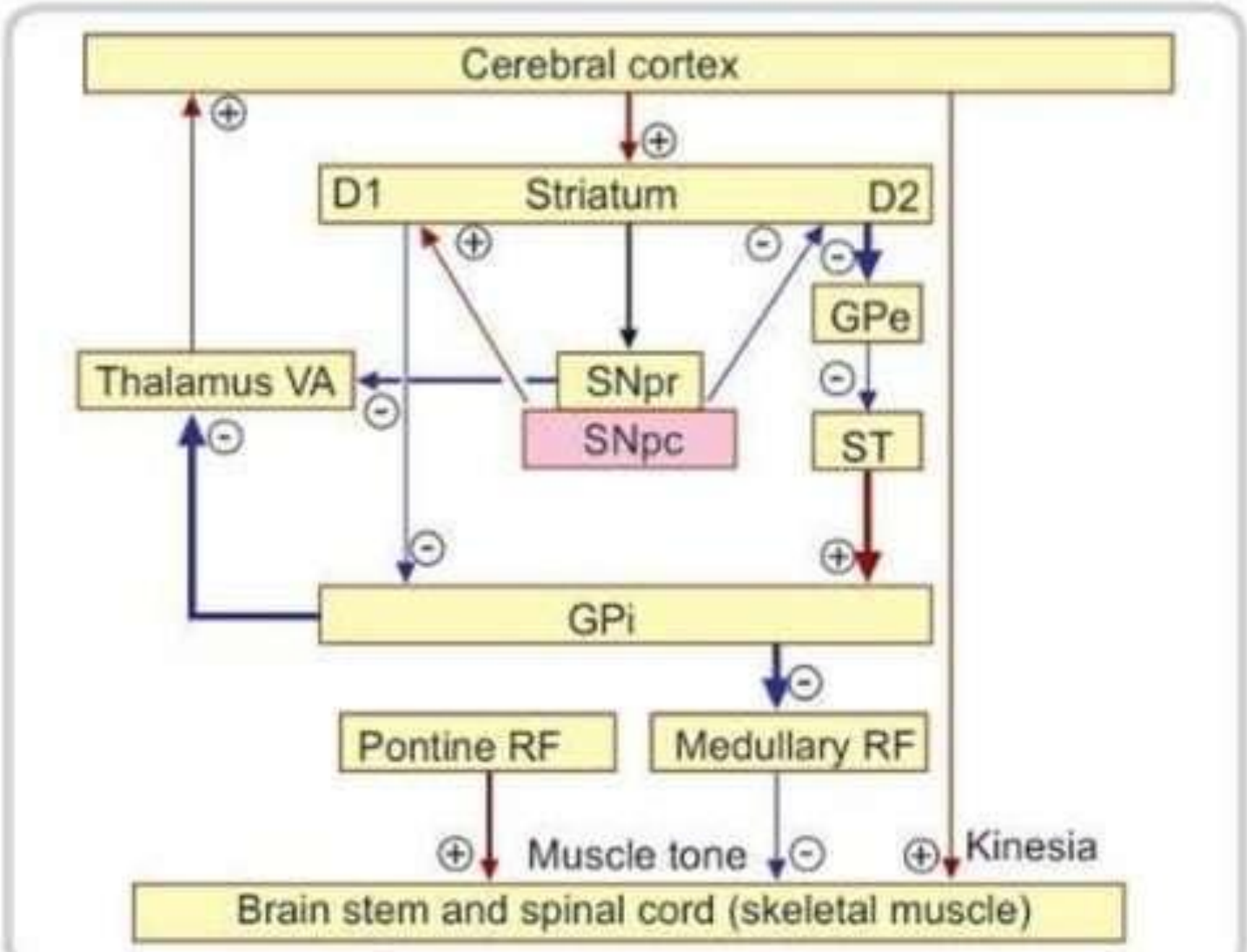
# Circuitry of corpus striatum

- Starting from pars compacta, nigrostriate fibres liberate dopamine at their terminal.
- Dopamine acts as a facilitatory neurotransmitter in the striatum when the receptors are D1.
- It acts as a inhibitory neurotransmitter in the striatum when the receptors are D2.
- Striatal D1 neurons inhibits GPi through a direct path.
- Striatal D2 neurons facilitates GPi through a indirect path. This balances the impulses reaching the GPi.
- GPi normally inhibits the thalamus. Thalamus facilitates the the cortex which causes the normal kinesia.
- GPi inhibits medullary reticular formation, which normally inhibits the muscle tone.
- Impulses from pontine reticular formation increases muscle tone. A fine balance between the pontine and medullary reticulospinal tracts maintains normal muscular tone.


Cerebral cortex
D1
Striatum
D2
GPe
Thalamus VA
SNpr
SNpc
ST
GPi
Pontine RF
Medullary RF
Muscle tone
Kinesia
Brain stem and spinal cord (skeletal muscle)

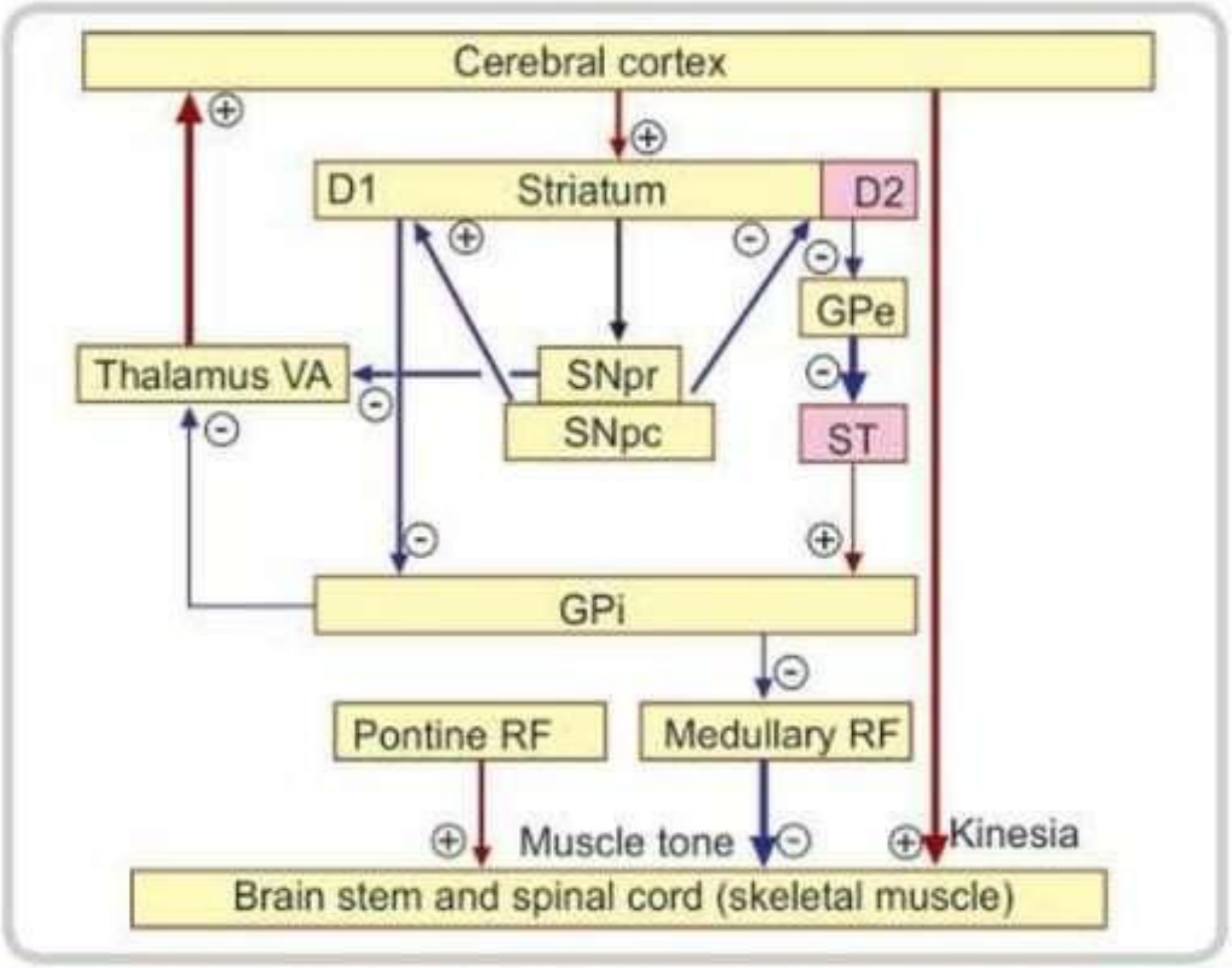
# Circuitry of corpus striatum in Parkinson's disease.

- There is destruction of substantia nigra.
- The inhibitory impulses sent from GPi to medullary reticular formation is stronger than normal causing an imbalance between the pontine and medullary reticulospinal tracts causing hypertonia.
- Inhibition of thalamo cortical pathway results in hypokinesia.
- The pin rolling movements at rest is due to resting discharge of dentate nucleus of cerebellum to the VL nucleus of the thalamus.


Cerebral cortex
D1
Striatum
D2
GPe
Thalamus VA
SNpr
SNpc
ST
GPi
Pontine RF
Medullary RF
Muscle tone
Kinesia
Brain stem and spinal cord (skeletal muscle)

# Circuitry of corpus striatum in chorea and ballismus

- The pathways for muscle tone and kinesia reverse when compared to Parkinsons.
- Destruction of the D2 neurons in striatum causes chorea.


Cerebral cortex
D1
Striatum
D2
GPe
Thalamus VA
SNpr
SNpc
ST
GPi
Pontine RF
Medullary RF
Muscle tone
Kinesia
Brain stem and spinal cord (skeletal muscle)

# Functions

- Pallidum eloborates the simple motor and postural mechanisms of the brain stem into complex autonomic motor behavior.
- Centre for expression gestures and reactive movements.
- The striatum eloborates and smoothens the coarser motor integrations of the pallidum.
- The subthalamic nucleus, red nucleus, substantia nigra have a synergistic action and integrates stereotyped behavior and controls complex muscular movements.
- Also process information related to emotions, motivations, and cognitive functions.

# Clinical correlation

Various kinds of abnormal movements are seen in neurological disorders involving the basal ganglia.

The movements could be

- Hyperkinetic, hypotonic (chorea, athetosis, ballismus)
- Hypokinetic, hypertonic (parkinsons)

# Tremors

- Regular oscillating movement about a joint due to synchronous contraction of the agonist and antagonist muscles.
- Types of tremors

1. Rest tremors

- Movements occurs in a relaxed supported extremity
- Reduced by ambulation
- Distinctive in parkinsonism

2. Postural tremors

- Sustained posture elicit tremors e.g outstretched hands
- A coarse irregular rapid postural tremor is seen in metabolic encephalopathy.

3. Intentional tremors

- Active limb oscillates more prominently on reaching target

# Chorea

- Rapid involuntary purposeless dancing movements of the limbs.
- Chorea affects the proximal joints, while that of the athetosis affects the distal joints.
- Sydenhams chorea- the pathology is seen in the striatum
- Huntington's chorea- autosomal dominant degenerative disease of the striatum and cerebral cortex

**Athetosis**

Continuous slow writhing movements with a propensity to affect the arms and hands.

**Ballism**

Hemorrhagic ivolvement of the subthalamic nucleus.

Involuntary and violent, flinging movements of large amplitude

Hemiballism – involves one half of the body , caused by lesions in the subthalamic nucleus of the opposite side.

When restricted to one limb it is called as monoballism.

**Dystonia**

Sustained or repetitive involuntary muscle contractions frequently causing twisting movements with abnormal postures.


InShOt

# Basal ganglia in psychiatric disorders

## OCD

- There is evidence of basal ganglia dysfunction in imaging studies. Both increase and decreased volumes of caudate nucleus is reported.
- Most patients showed an increased blood flow to the caudate.
- Increased caudate metabolism will reduce the effect of the treatment of OCD.

# AUTISM

- Enlargement of caudate nucleus upto 8% . The greater caudate volume is proportional to the increased total brain volume.
- Motor, communicative, and social impairments are associated with shape abnormalities in the basal ganglia.
- Glutamate dysfunction in basal ganglia is associated with autism.

# ADHD

- Neuroimaging studies show evidence of striatal dysfunction in ADHD.
- Teicher and colleagues concluded that ADHD may be related to functional abnormalities in the putamen.
- Boys with ADHD showed a significantly smaller volume of basal ganglia compared with typically developing boys.

# SCHIZOPHRENIA

- In striatum, there are anomalies of dopamine, synthesis, storage and release.
- Striatal dopaminergic system is overactive. There is an increase in the presynaptic dopamine function indicating an increase in the dopamine synthesis capacity.
- There is an increase in the striatal D2 receptors.
- In substantia nigra, there is a higher variability of tyrosine hydroxylase level, increase in homovanillic acid, increase in glutamate receptor subunits.

# DEPRESSION

- Functional imaging studies have shown pathological interactions in amygdala, ventral striatum and prefrontal cortex in depression.
- Regional cerebral blood flow, glucose metabolism in amygdala are increased.
- Nucleus accumbens is also involved in affective disorders.
- Caudate hyperintensities are found in elderly patients of depression

# ADDICTION

- Amygdala is a critical structure in addiction.
- Nucleus accumbens is also important in drug re inforcement and addiction.

# NEUROPSYCHIATRIC DISORDERS

# Parkinson's disease

- A neurodegenerative disease associated with loss of dopaminergic neurons in the Substantia Nigra pars compacta.
- IN 1817, JAMES PARKINSON described paralysis agitans in his "ESSAY ON THE SHAKING PALSY".
- Parkinson's disease affects movement, producing motor symptoms.
- Non-motor symptoms, which include

I. autonomic dysfunction,

II. neuropsychiatric problems (mood, cognition, behaviour or thought alterations),

III. sensory and sleep difficulties, are also common. Some of these non-motor symptoms are often present at the time of diagnosis and can precede motor symptoms.

Characteristic triad

- Resting tremor
- Rigidity
- Bradykinesia

Others – gait and postural disturbances

Psychiatric manifestations

- Depression, apathy, anxiety, psychosis.


Blank facial expression
Forward tilt to posture
Slow, monotonous, slurred speech
Reduced arm swinging
Rigidity and tremor of extremities and head
Short, shuffling gait

# Huntington’s disease

- Huntington's disease (formerly Huntington's chorea) is an autosomal dominant neurodegenerative disorder characterized by midlife onset, a progressive course, and a combination of motor, psychiatric, and cognitive symptoms.
- First described by George Huntington in 1872.
- The disease is caused by a **CAG** (trinucleotide) repeat expansion mutation in the huntingtin gene on chromosome 4.

❑Primary involuntary movement abnormality

• Chorea or choreoathetosis

❑Associated voluntary movement abnormalities

• Visual tracking,

• fine motor movements,

• gait disturbances

❑Decreased facial expression, difficulty in swallowing, chewing, speaking, sleep disturbance, impairment in cognition and memory, subcortical dementia

❑Psychiatric manifestations

•Higher rates of suicide

•Depression

•Mania

•Personality change

# Wilson's disease

- Autosomal recessive disorder in which mutations in the **gene atp7b** result in abnormal accumulation of copper in the liver, basal ganglia, and other tissues.
- Neuropsychiatric pathophysiology:

- When copper deposits in the basal ganglia specifically in the lenticular nucleus, there is cell death.

- Neurological findings

- Tremor, dystonia, rigidity, choreoathetosis, bradykinesia, masked faces, micrographia, frontal lobe disorder, subcortical dementia.

- Psychiatric manifestations

- Personality changes, depression, suicidality, anxiety disorders, psychotic disorders.

# Progressive supranuclear palsy

- Gradual deterioration and death of specific volumes of brain.
- Affects subthalamic nucleus, substantia nigra and globus pallidus and other areas.
- Neurons display neurofibrillary tangles which are clumps of tau protein.
- Neurological findings

  Symmetric bradykinesia, axial rigidiy, postural instability with falls, dysarthria, dysphagia, paralysis of downward vertical gaze, neck dystonia.
- Psychiatric manifestations

  Subcortical dementia with bradyphrenia, memory deficits, predominant frontal lobe dysfunction with executive and attention deficits, frontal behavioral disturbances of apathy and disinhibition, sleep disturbances, depression, emotional lability including pathological laughter and crying, irritability.

# Fahr's syndrome

- Idiopathic basal ganglia calcification
- Genetically dominant, inherited neurological disorder most commonly affects lentiform nucleus and Gpi.
- Occurs in 3$^{rd}$ to 5$^{th}$ decade.
- Deteriorization of motor function and speech, seizure, involuntary movement, dementia, headache, visual impairment.
- Unsteady gait, slurring of speech, difficulty in swallowing ,clumsiness, fatiguability.

# Basal ganglia stroke

- Changes in the body movement, rigidity, stiffness, tremor, ataxia, difficulty in swallowing, smiling, speech.
- Cognitive impairment – poor attention, memory impairment
- Personality changes – frustration ,anxiety, loss of interest, loss of motivation, depression, anger.
- **Right basal ganglia stroke**
- Anosognosia – unable to perceive the severity of deficit, left side neglect, visuospatial hemineglect, constructional apraxia.
- **Left basal ganglia stroke**
- Apathy (lack of interest), memory impairment, major depression.

# References


1. Comprehensive textbook of Psychiatry - Kaplan and Sadocks.
2. Textbook of Neuroanatomy - I.B. Singh
3. Postgraduate Textbook of Psychiatry - Ahuja

# Thank You