

Basal Nuclei (ganglia) Objectives:

Upon completion of this lecture you should be able to answer the following objectives.

1. State the general function of the basal nuclei.
2. State the 5 structures that are part of the basal nuclei. Which 3 nuclei are considered the corpus striatum? Which 2 nuclei make up the striatum? Which 2 nuclei make up the lentiform nucleus?
3. Identify all 5 basal nuclei on coronal or horizontal images.
4. Which of the 5 basal nuclei is considered the general outflow (output) for the system?
5. Explain the end result of what happens when the direct pathway is activated.
6. Explain the end result of what happens when the indirect pathway is activated.
7. Define the following terms:
  - akinesia
  - bradykinesia
  - ballismus
  - choreiform movements
  - athetoid movements
8. Describe the signs/symptoms that occur in a patient with Parkinson's disease, hemiballism, Huntington's disease, Sydenham's chorea.
9. If given the patient's signs/symptoms, be able to state whether the patient has Parkinson's disease, Contralateral hemiballism, Huntington's disease, or Sydenham's chorea.
10. Be able to describe where the lesion is in a patient with Parkinson's disease, Hemiballism, or Huntington's disease.

Outline:

- I. Basal nuclei overview
  - A. Function
  - B. Nuclei that are part of the basal nuclei
  - C. Neuroanatomy
- II. Basal nuclei pathways
  - A. Direct pathway
  - B. Indirect pathway
- III. Lesions
  - A. Hypokinetic disorders
    1. Parkinson's disease
  - B. Hyperkinetic disorders
    1. Subthalamic lesion
    2. Huntington's disease
    3. Sydenham's chorea

The Basal Nuclei (ganglia) consist of several groups of cell bodies that modify/adjust motor activity by sending their axonal projections to the thalamus (which will influence the motor cortex).

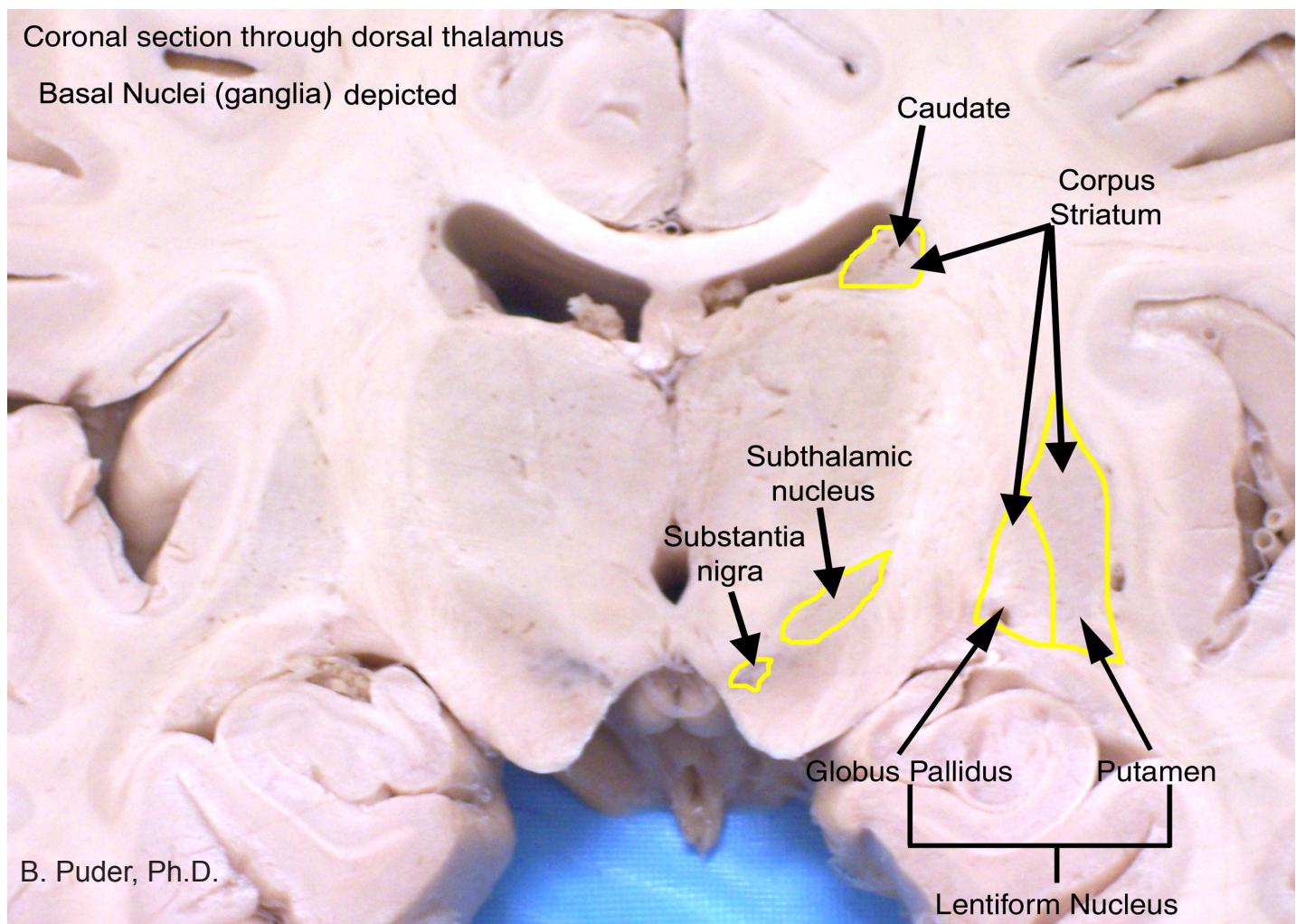
From our neuroanatomical knowledge, we know that a group of cell bodies in the CNS is called a nucleus, however, someone was not following the rules and named these structures the Basal Ganglia. The basal ganglia has recently been renamed the basal nuclei, but many clinicians and health care workers will still call these structures the basal ganglia. We will try to be hip with the times and call these structures the basal nuclei - although remember that out in the working world, some people are not as cool, so they will refer to these structures as the basal ganglia.

Structures that make up the basal nuclei:

- Caudate ————— Striatum
- Putamen ——————
- Globus Pallidus ————— Lentiform nucleus
- Subthalamic nucleus - functionally related to the above structures
- Substantia nigra - functionally related to the above structures

The basal nuclei function by disinhibition (release the motor cortex from being inhibited by the thalamus).

The output of the basal nuclei is via the globus pallidus.

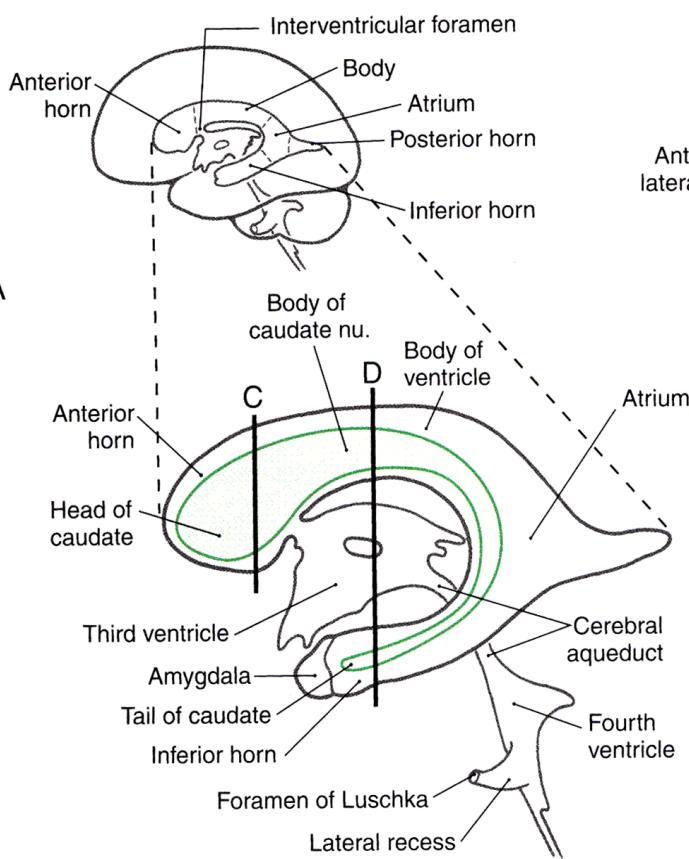
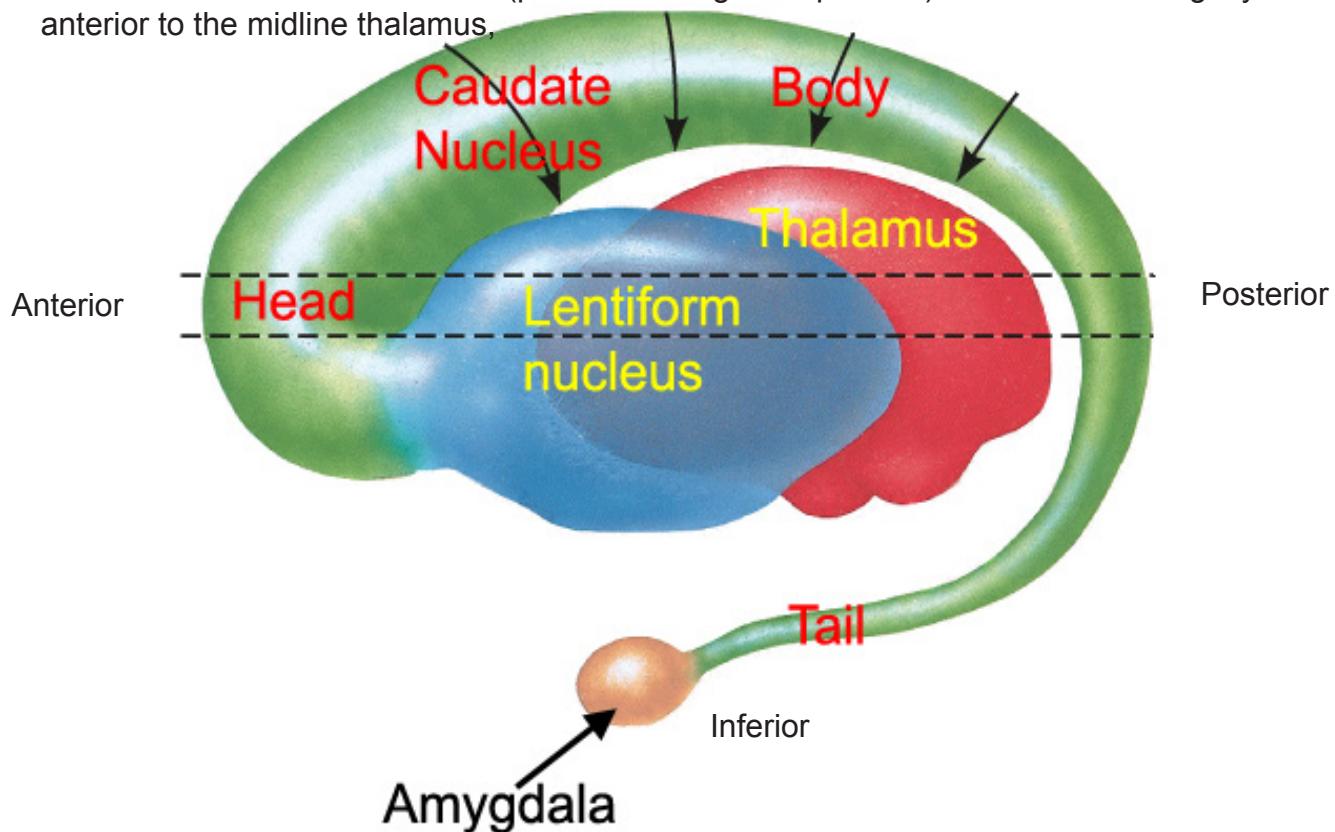


Left lateral view of the caudate nucleus - notice it's "C" shape.

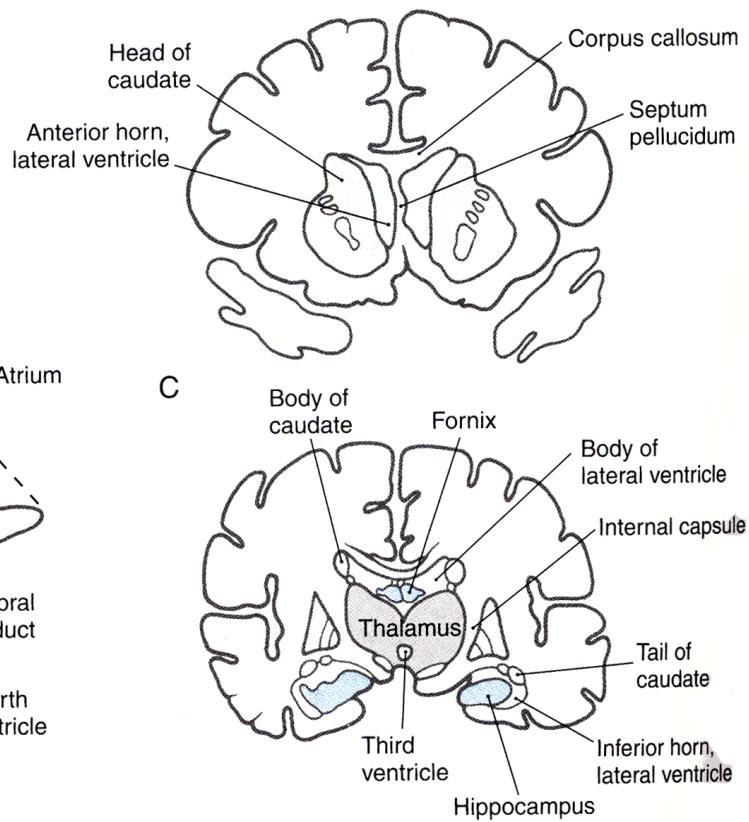
There is a head, body and tail parts to the caudate nucleus.

The caudate nucleus makes the lateral wall of most of the lateral ventricles.

Notice that the lentiform nucleus (putamen and globus pallidus) sits lateral and slightly anterior to the midline thalamus,

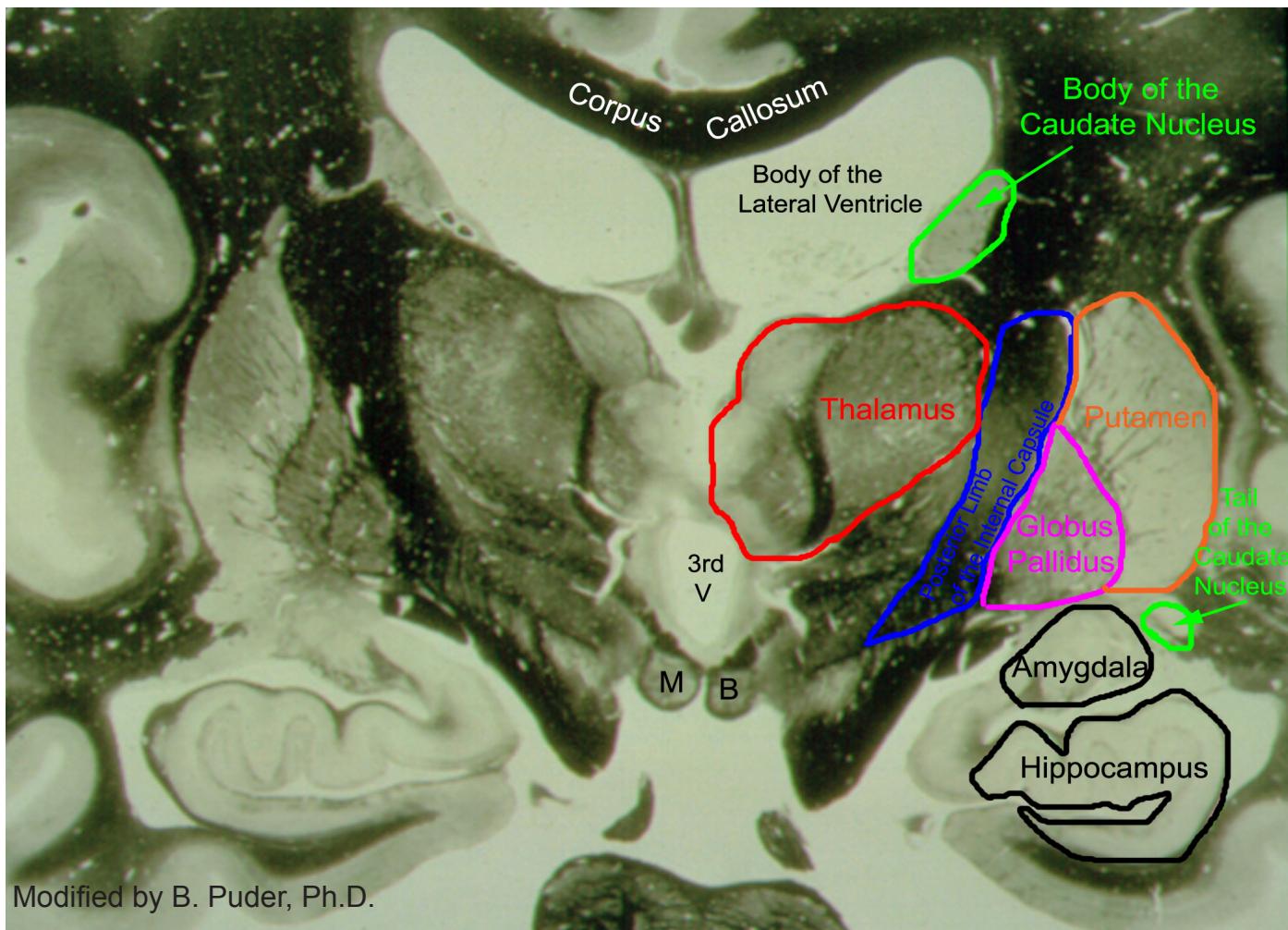


B

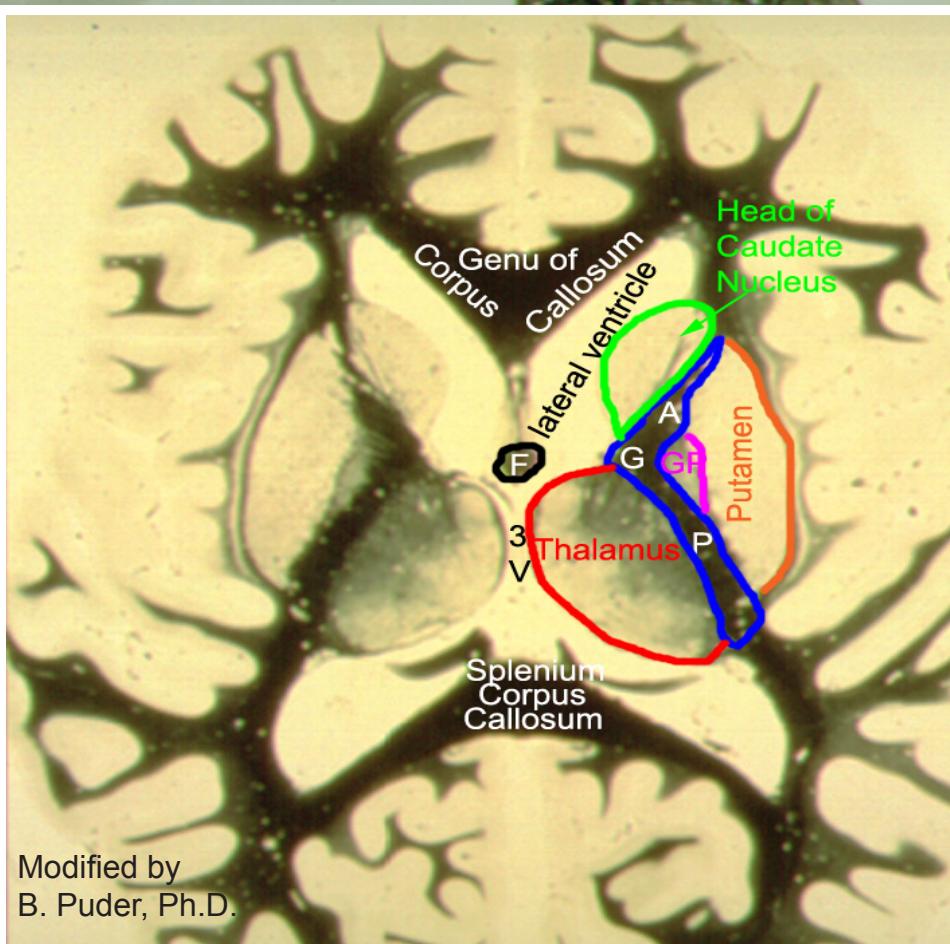


D

Coronal section through thalamus depicting basal nuclei



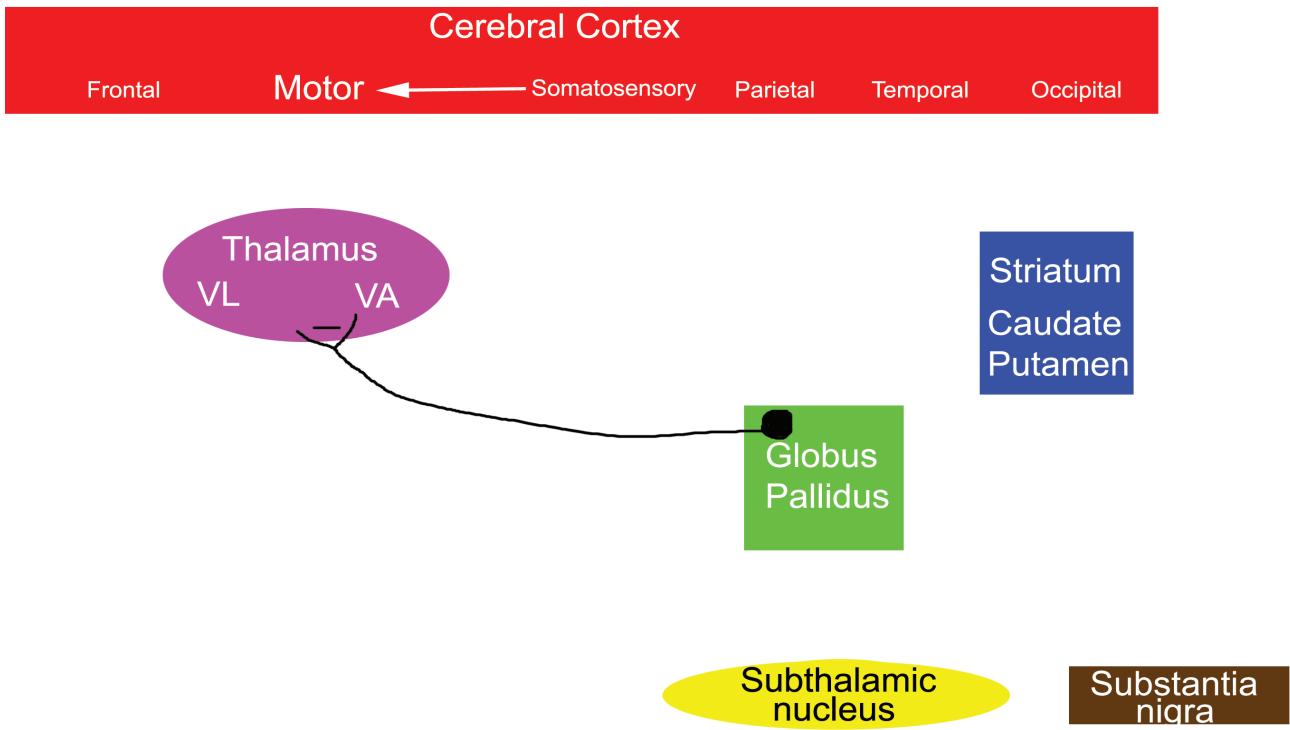
Horizontal section through thalamus depicting the corpus striatum



There are 2 basal nuclei pathways:

- The direct pathway
- The indirect pathway

Cheesy Schematic by  
B. Puder, Ph.D.



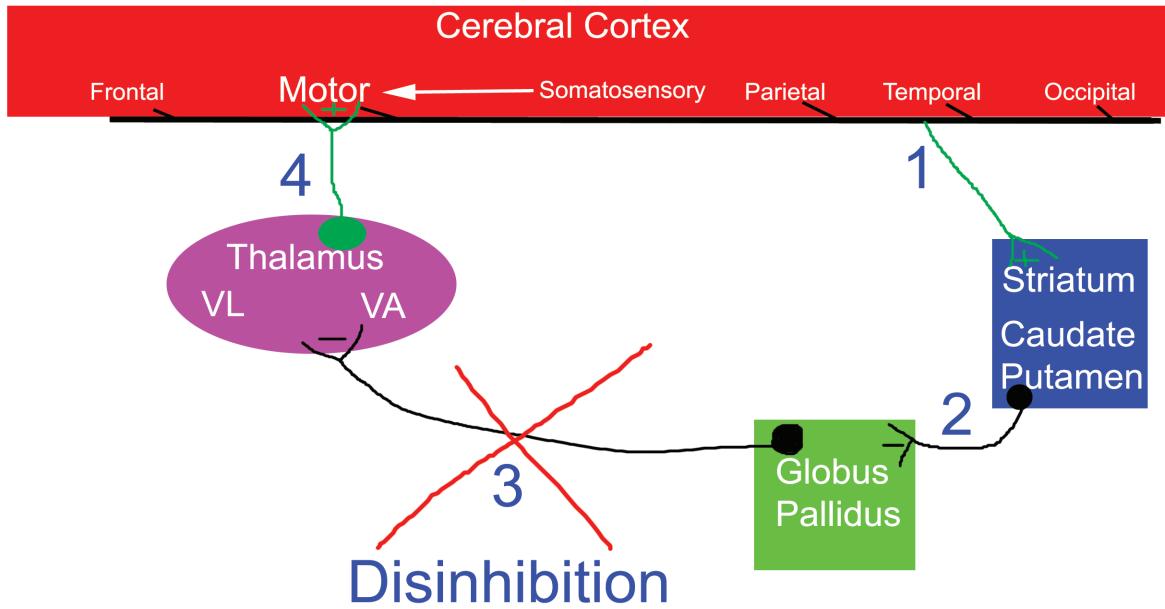
Schematic diagram of the basal nuclei.

The globus pallidus has the ability to tonically fire an action potential, thus inhibiting the VA/VL of the thalamus.

This occurs when there is no excitatory input from the cerebral cortex to the striatum.

## Direct Pathway

Cheesy Schematic by  
B. Puder, Ph.D.

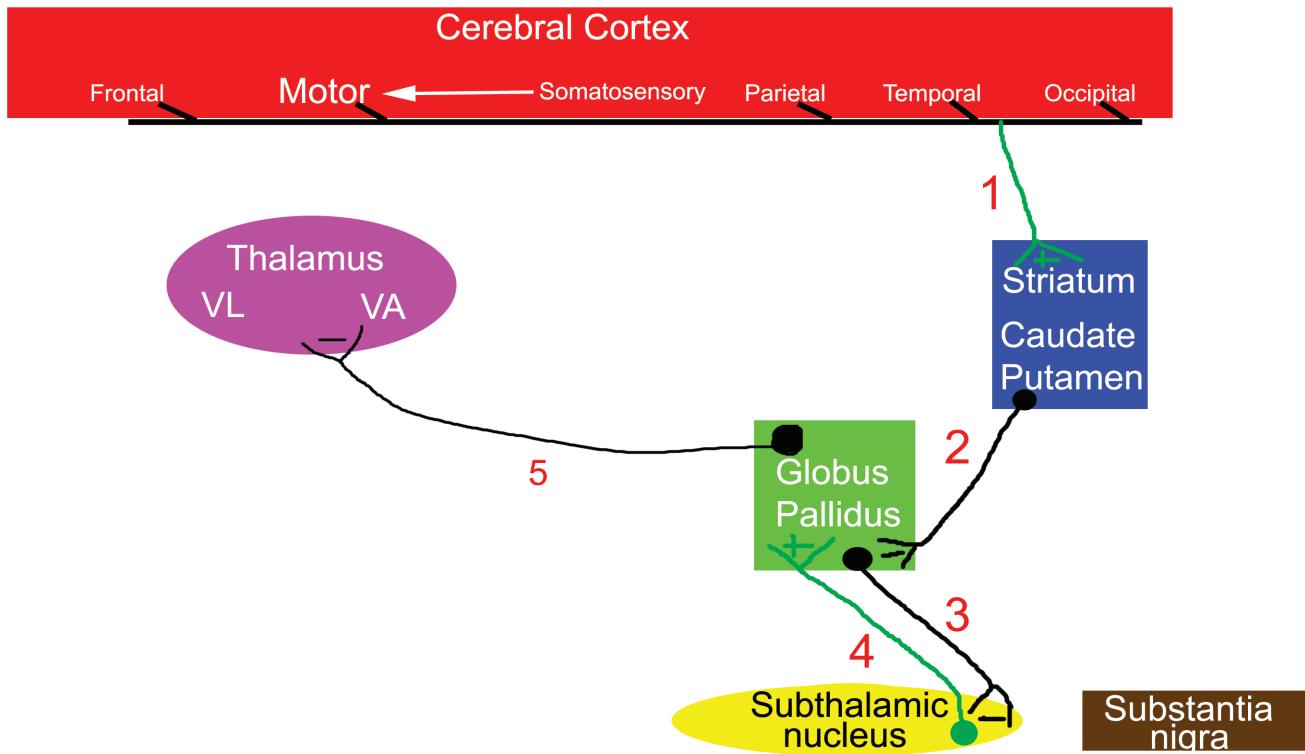


### Direct Pathway:

1. Neurons from the cerebral cortex project their axons and synapse on the striatum.  
The cortical axons release glutamate, an excitatory neurotransmitter which activates the neurons in the striatum.
2. The neurons in the striatum are excited and project to the globus pallidus and release GABA, an inhibitory neurotransmitter onto the neurons in the globus pallidus.
3. The GABA released onto the globus pallidus inhibits the globus pallidus, which, usually, when excited, releases GABA onto the thalamus to inhibit the thalamus. Because the globus pallidus is inhibited, this results in disinhibition, or excitation of the thalamus.
4. The disinhibition allows the neurons of the VA and VL of the thalamus to fire and release glutamate, an excitatory neurotransmitter onto the cerebral cortex.

***Activation of the direct pathway causes increased motor cortex activity and increased movement.***

## Indirect Pathway



### Indirect Pathway:

1. Neurons in the cerebral cortex project their axons to the striatum and release excitatory neurotransmitter, glutamate.
2. The neurons of the striatum are excited and release inhibitory neurotransmitter, GABA onto the globus pallidus.
3. Neurons in the globus pallidus release GABA (inhibitory NT) onto the subthalamic nucleus.
4. Neurons in the subthalamic nucleus release glutamate (excitatory NT) onto globus pallidus.
5. Globus pallidus releases GABA onto VA and VL of the thalamus to inhibit the thalamus.

***Activity in the indirect pathway causes a decrease in motor cortex activity and decreased movement.***

Lesions within the basal nuclei

Lesions along the indirect and direct pathway result in movement disorders.

These lesions can cause:

Hypokinetic disturbances

Hyperkinetic disturbances

### Hypokinetic disturbances

Lesions of the striatum, lose connections between the striatum and globus pallidus which results in allowing the globus pallidus to inhibit the VL of the thalamus which results in decreased motor activity.

Types of hypokinetic disturbances include:

akinesia - impairment in the initiation of movement

bradykniesia - reduction in the velocity and amplitude of movement (it really is activation of the antagonist muscles and not really a decrease in muscle activity)

### Clinical Aspect

#### Parkinson's disease

Parkinson's disease is considered a hypokinetic disorder with both akinesic and bradykinesic disturbances.

It is caused by the loss of Dopaminergic neurons in the substantia nigra (later followed by serotonin and noradrenaline losses).

Onset of disease is between 45-65 years

signs/symptoms include:

slight asymmetrical gait

vague clumsiness of the hands

decreased eye blinking, blank stare

decreased arm swing

tremor at rest, pill rolling movement with fingers

cogwheel rigidity (increased muscle tone)

flexed posture

paucity of movement

shuffling of feet when starting to walk

#### Treatment:

give the drug L-Dopa with carbidopa

ablative surgery of globus pallidus or ventral thalamus

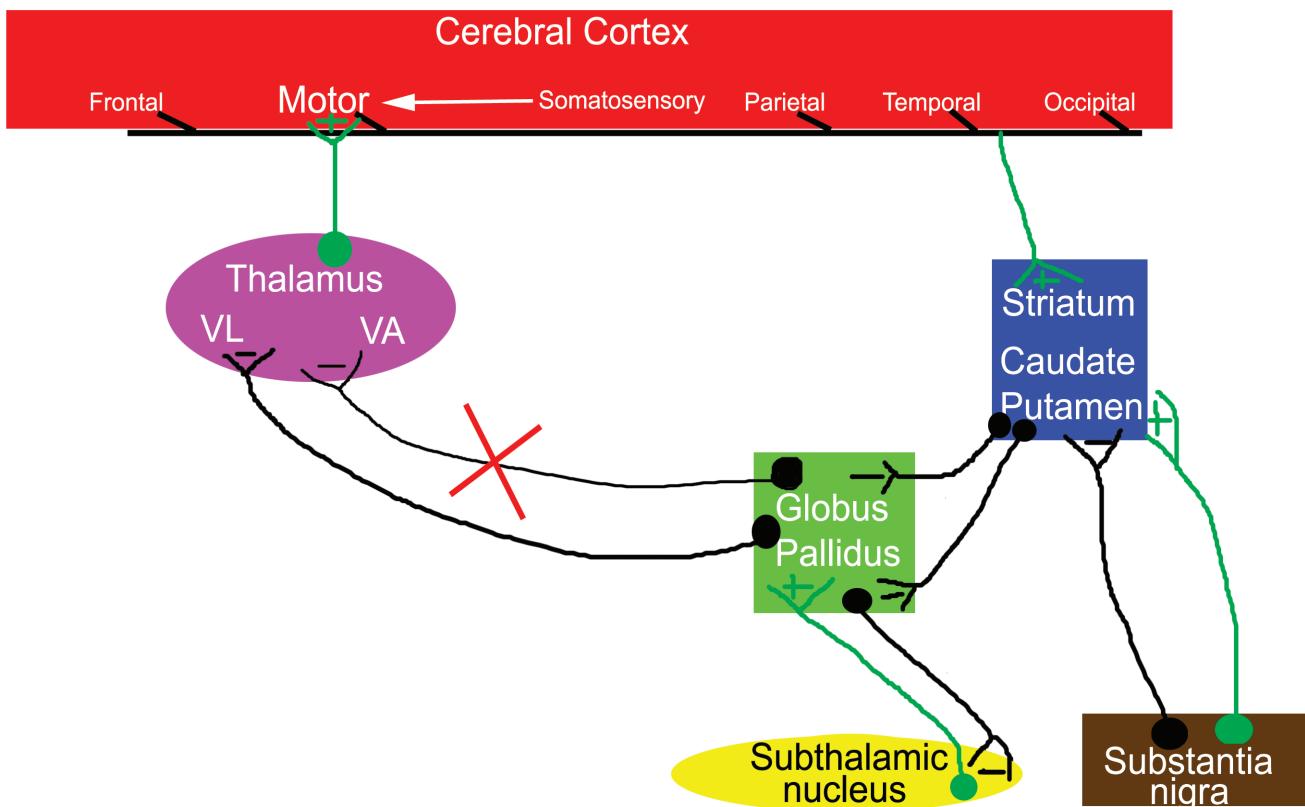
surgery to implant electrodes in thalamus, globus pallidus, subthalamus

### Interesting story

Back in the 80's a group of people in their 20's appeared to have Parkinson's disease, which is a very early onset for the disease. As it turns out, they were drug users who took some drugs that were contaminated and contained the chemical MPTP (1 methyl - 4 phenyl - 1,2,3,6 tetrahydropyridene). This drug causes similar effect as Parkinson's disease and was then used in experiments to study and understand more about Parkinson's disease.

## Parkinson's Disease

Cheesy Schematic by  
B. Puder, Ph.D.



Dopamine is released from the neurons of the substantia nigra to the striatum.

Dopamine can bind to D1 or D2 receptors which can elicit an excitatory response on the direct pathway or an inhibitory response on the indirect pathway.

In Parkinson's disease, there is a loss of dopaminergic neurons in the substantia nigra which leads to problems in the direct and indirect pathways, thus causing decreased activity in the direct pathway and increased activity in the indirect pathway.

Thus hypokinetic and hyperkinetic movement disorders are seen in Parkinson's patients.

## Hyperkinetic disturbances

There are 3 main types of hyperkinetic disturbances (dyskinesias)

1. Ballismus
2. Choreaform movements
3. Athetoid movements

### Ballismus

seen as hemiballism because occurs on one side of the body  
it is an uncontrolled flinging of the upper or lower extremity  
Occurs from a lesion of the subthalamic nucleus on the contralateral side

### Choreaform movements

Irregular, brisk, dance-like movements of the limbs, may also occur in the face  
decrease in muscle tone  
Is an indirect Basal nuclei pathway lesion  
is seen in patients with Huntington's disease, or overtreated Parkinson's disease

### Athetoid movements

writhing of distal portions of the extremity, slow writhing movements - more common in upper extremity and hands and face  
Is a direct Basal nuclei pathway lesion

## Clinical Aspect

### Huntington's disease

Huntington's disease is a genetic disorder that causes hyperkinetic disturbances  
Onset of disease is 35-40 years of age, death occurs within 10-15 years thereafter  
There is a 90% loss of striatal neurons and a loss of the neurotransmitter GABA  
Upon MRI images, the head of the caudate is flattened and small

Early symptoms include:

- absentmindedness
- irritability
- depression
- clumsiness, falls

Later symptoms include:

- Choreaform movements
- Cognition and speech decline
- Severe dementia
- Psychological disorders

### Sydenham's chorea

Autoimmune disease that affect children

It is a consequence of rheumatic fever caused by a streptococcal infection

Occurs 6 months after infection and lasts 3-6 weeks

Symptoms include:

- Chorea that is flowing and restless
- Muscular weakness
- Hypotonia
- May also have behavioral complications:
  - Obsessive/compulsive problems
  - attention deficit
  - irritability