# **The Basal Ganglia**

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#### **Basal Ganglia**

Vu, D. (1998) Basal ganglia [Lecture handouts]. University of NSW. 21 September, 1998.

- The basal ganglia refer to those structures when damaged cause extrapyramidal syndromes.
- It includes:
- The caudate nucleus; 1.
- The putamen,
  The globus pallidus,
- The subthalamic nucleus,
- 5. And substantia nigra.

Putamen + Globus Pallidus = Lenticular (or lentiform) Nucleus Caudate Nucleus + Lenticular Nuclei = Corpus Striatum Caudate Nucleus + Putamen = Neostriatum or Striatum

#### **Topography of the Basal Ganglia**

#### Lenticular Nucleus

• The lenticular nucleus is shaped somewhat like a wedge cut out of a sphere.

#### Putamen

- The putamen (L. husk) is approximately coextensive with the insula and forms the outermost portion of this wedge.
- It is separated from the more medial globus pallidus by a thin lateral medullary lamina.

# **Globus** Pallidus

- The globus pallidus is itself divided into medial and lateral portions. This is by the medial medullary lamina.
  - The globus pallidus has a distinctive pale appearance (i.e., dark appearance in myelin-stained sections) due to the large numbers of myelinated fibres that traverse it, terminate in it and originate in it.



#### **Caudate Nucleus**

• The caudate nucleus is in the wall of the lateral ventricle and grows with it in a C-shaped course. It has an enlarged head that bulges into the anterior horn. Its body that forms the lateral wall of the body of the ventricle. The slender tail of the caudate borders on the inferior horn.

- Embryologically, the caudate nucleus and putamen arise from the same mass of cells.
- In the adult, the caudate nucleus and the putamen retain their embryological continuity.
- This is just above the orbital surface of the frontal lobe.
- Here, the head of the caudate appears to be continuous with the anterior part of the putamen.
- In the temporal lobe, the tail of the caudate nucleus is continuous with the amygdala, which is in turn continuous with the putamen.
- These physical continuities are of no apparent significance, however.



#### **Connections of the Basal Ganglia**

• The principle circuit of the basal ganglia is a loop:

Multiple cortical areas --> corpus striatum --> thalamus --> one of the cortical areas

- There are multiple versions of this loop.
- They are all similar in principle but each using different cortical areas and a distinctive portion of the corpus striatum.
- Each loop includes at least a portion of the frontal lobe and returns to a frontal area.
- The remaining connections of the basal ganglia fall into 3 categories:
- 1. GPL --> Subthalamic nuclei --> GPM
- 2. Striatum --> Substantia nigra --> Striatum
- 3. Striatum --> Pallidum --> CM of thalamus --> Striatum

#### Striatum

- The striatum (caudate + putamen) receive inputs from 3 sources:
- 1. The cerebral cortex;
- 2. The intralaminar nuclei of the thalamus (centromedian, which receives input from the motor cortex);
- 3. And the substantia nigra.

#### **Cortical Afferent Fibres**

• The fibres originating in the **cerebral cortex** (corticostriate fibres) are by far the most massive bundle. They end in a **roughly topographical pattern** in the striatum:

Motor and somatosensory cortex --> Putamen

Association areas --> Caudate Nucleus (esp. prefrontal cx --> head of caudate)

- Now the putamen projects to premotor and supplementary motor areas of cortex via the globus pallidus and thalamus.
- It is thus involved in most of the motor functions of the basal ganglia.
- The caudate nucleus projects to mostly prefrontal areas via the globus pallidus and thalamus.
- It is involved more prominently in cognitive functions and less is movement.

#### Nigral Afferent Fibres

• The substantia nigra projects to all areas of the striatum.

It does so in a point-to-point fashion by way of very fine dopaminergic fibres.

• Destruction of the nigrostriatal pathway is the major factor causing Parkinson's disease.

# Thalamic Afferent Fibres

 The intralaminar nuclei, especially the centromedian and parafascicular nuclei project to the striatum. Many of these fibres have collateral branches that end in the cerebral cortex.

The thalamostriate pathway is well-developed in primates but their function is mainly unknown.



#### **Globus** Pallidus

Afferents to the Globus Pallidus

- Afferents to both segments of the pallidum arise in the striatum and the subthalamic nuclei.
- The subthalamic nucleus lies across the internal capsule from the globus pallidus. Small bundles of fibres cross the internal capsule and connect these two nuclei. These fibres are collectively called the subthalamic fasciculus.

Efferents to the Globus Pallidus

- Although the two segments have similar inputs, their efferents are distinct and separate.
- The external segment projects through the subthalamic fasciculus to the subthalamic nucleus.
- The **internal segment** projects mainly to the **thalamus** through **2** collections of fibres.
- The lenticular fasciculus runs directly through the internal capsule and then passes medially as a sheet of fibres between the subthalamic nuclei and zona incerta.
- At the medial edge of the zona incerta, it makes a hairpin turn in a dorsolateral direction and enters the thalamus.
- The ansa lenticularis (L. ansa, loop) loops around the medial edge of the internal capsule.
- It joins the lenticular fasciculus in the thalamic fasciculus, which enters the thalamus.
- The thalamic fasciculus ends in a variety of thalamic nuclei:
- Fibres related to movement control --> VL/VA
- Related to the caudate nucleus and prefrontal
  The others --> CM and parafascicular nuclei. Related to the caudate nucleus and prefrontal cortex --> DM and part of VA



#### Subthalamic Nucleus

- The principle contacts of the subthalamic nucleus consist of:
- . Interconnections with the globus pallidus;
- 2. And some efferent projections to the substantia nigra.
- These connections form the substrate of an indirect route through the basal ganglia.
- This plays a major role in determining the **output** of the globus pallidus.

#### Substantia Nigra

- The substantia nigra is actually composed of 2 parts:
- 1. A dorsal compact part, containing closely packed, pigmented neurons;
- 2. And a reticular part, nearer the cerebral peduncle containing more loosely packed neurons, which are non-pigmented.

# Reticular Part of the Substantia Nigra

- This resembles in many respects a displaced portion of the globus pallidus.
- It receives inputs from the striatum and the subthalamic nucleus.
- It projects to the VL/VA and DM nuclei of the thalamus.
- In fact, it is a more important route for information from the caudate nucleus to reach the thalamus than is the globus pallidus.
- Also, there are projections from the substantia nigra to the superior colliculus and reticular formation.
- This is probably one way in which the basal ganglia influences eye movements.

# Compact Part of the Substantia Nigra

• The **pigmented neurons** in this part use **dopamine** as their neurotransmitter.

They project in a **precisely organised topographic** fashion to the caudate nucleus and putamen. The **dopaminergic** endings in the **striatum** ultimately **modulate the output** from the globus pallidus.



# The Direct Pathway (GABA-Substance P)

Inhibitory to GPM & Substantia nigra --> less inhibition to Thalamus --> movements are facilitated by exciting Premotor and Supplementary motor areas which then project to the Motor cortex

# Indirect Pathway (GABA-enkephalin)

Inhibitory to GPL --> less inhibition of Subthalamic nucleus --> more excitation of GPM --> more inhibition of Thalamus --> less excitation of Premotor and Supplementary motor areas --> movements are inhibited.

• Lesion of subthalamic nucleus --> less inhibition of movements --> hemiballismus.

#### **Dopaminergic Pathway**

- This is from the substantia nigra via the nigrostriatal pathway.
- It excites the direct pathway.
- It inhibits the indirect pathway.
- Thus, it facilitates movement.



# Functional Aspects of the Basal Ganglia

# Chorea

• Patients with chorea (G. dance) exhibit a series of nearly continuous rapid movements of the face, tongue and limbs (distal portions).

These movements often resemble fragments of normal voluntary movements.

• There are 2 types of chorea, Sydenham's and Huntington's.

#### Sydenham's Chorea

• This type of chorea (also known as Vitu's dance) may be caused by acute rheumatic fever.

#### Huntington's Disease

• This is an **autosomal dominant hereditary disorder** characterised by **neuronal degeneration** that is particularly severe in the **striatum**, especially the caudate nucleus.

Typically, symptoms first appear as between the ages of 30-50.

- Symptoms follow:
- 1. Firstly, personality changes;
- Then choreiform movements which gradually become more pronounced;
- 3. Which are followed by developing dementia.
  - The defective gene has been localised to the short arm of chromosome 4.

### Athetosis

• Athetosis (G. without position) is characterised by **slow**, **writhing movements** that are most pronounced in the **hands** and **fingers**.

The patient may be unable to keep the affected limb in a fixed position.

- The responsible lesion seems to be in the striatum.
- All intermediate forms between chorea and athetosis are seen.

#### Hemiballismus

• The most prominent characteristic of hemiballismus (G. jumping about) is **wild**, **flailing movements** of one **arm** or **leg**. The responsible lesion is in the **contralateral** subthalamic nucleus (indirect pathway).

#### Parkinsonism

• The symptoms to this are variable in relative severity and onset. They include:

- 1. A resting tremor, characteristically involving the hands in a "pill-rolling" movement that diminishes during voluntary movement and increases during emotional stress;
- 2. The **rigidity** is caused by **increased tone** in **all muscles** though strength is nearly normal and reflexes are not particularly affected;

- 3. And difficulty in moving (bradykinesia, or slow movements and hypokinesia, or few movements) is shown by decreased blinking, expressionless face and absence of arm movements associated with walking.
  - The rigidity in Parkinsonism may:
- 1. 2. Be **uniform** throughout a range of movements imposed by the examiner (*plastic* or *lead-pipe rigidity*);
- Or be interrupted by a series of brief relaxations (cog-wheel rigidity).
- Also, bradykinesia and hypokinesia are fundamental deficits and not the result of rigidity. ٠
- Patients whose rigidity is not pronounced can nevertheless have great difficulty moving. ٠

