The functional organisation of the basal ganglia

Roger Barker

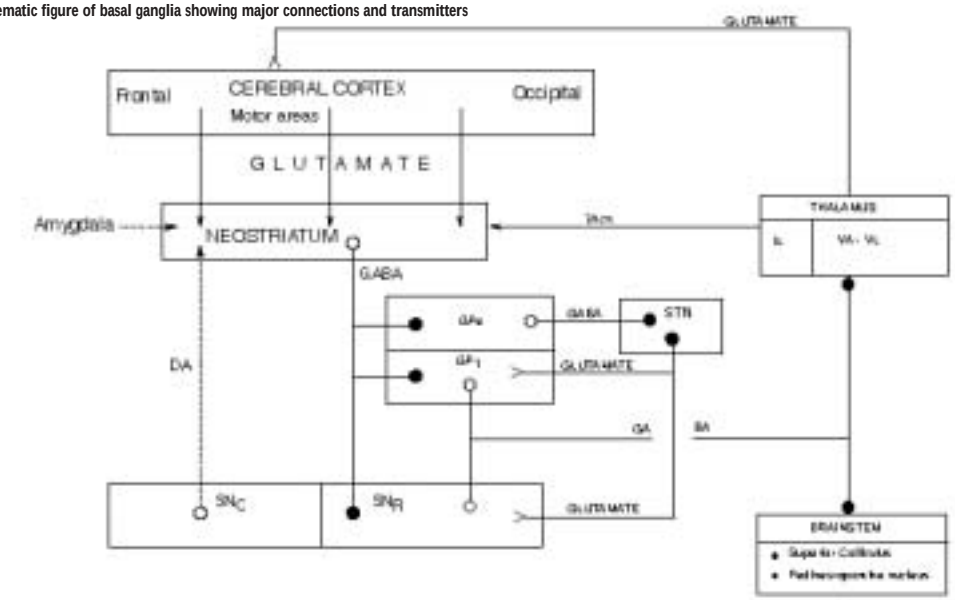
The **basal ganglia** are made up of a number of subcortical structures that includes the **caudate and putamen** (forming the **neo- or dorsal striatum), the internal and external segments of the globus pallidum (GPi and GPe respectively), the pars reticulata and compacta of the substantia nigra (SNr and SNc respectively) and the subthalamic nucleus (STN).** The neostriatum is the major receiving area of the basal ganglia and receives information from the whole cortex as well as the intralaminar nuclei of the thalamus and a dopaminergic input from the SNc. The major outflow from the basal ganglia is via the GPi and SNr to the ventroanterior and ventrolateral (VA-VL) nuclei of the thalamus which in turn project to cortical areas anterior to the primary motor cortex. In addition there is a projection to the brainstem, especially to the pedunculopontine nucleus (PPN) which may be important in locomotion, and the superior colliculus which is involved with eye movements.

The anatomy of the basal ganglia is complex and the schematic figure is a simplification of their organisation. However a number of points on the anatomical organisation of the basal ganglia need to be made.

1. The neostriatum receives from the whole cortex and intralaminar nuclei of the thalamus as well as a modulating dopaminergic input from the SNc.
2. The basal ganglia have a number of loops within them that are important. There is a striato-nigral-striatal loop with the latter projection being dopaminergic in nature. There is also a loop from the GPe to the STN which then projects back to the GPi and SNr. This pathway is excitatory in nature and is important in controlling the level of activation of the inhibitory output nuclei of the basal ganglia to the thalamus.
3. Whilst there is a marked degree of convergence and divergence of projections throughout the basal ganglia, these can be seen to form parallel pathways, which at the most simplistic level divide into a motor pathway through the putamen and a non-motor pathway through the caudate nucleus.
4. The neostriatum consists of patches or striosomes that are deficient in the enzyme acetylcholinesterase (AChE), these are embedded in an otherwise AChE rich striatum which forms the large extrastriosomal matrix. The relationship of these two components of the neostriatum to any parallel pathways is not clear.
5. There is a ventral extension of the basal ganglia that consists of the ventral striatum (nucleus accumbens), ventral pallidum and substantia innominata (NOT shown in figure for simplicity). It receives a dopaminergic input from the ventral tegmental area that lies adjacent to the SNc in the midbrain, and projects via the thalamus to the prefrontal cortex and frontal eye fields. This part of the basal ganglia is thought to be involved in non-motor functions.
6. Neurophysiologically the basal ganglia take highly processed sensory information and convert it into some form of motor programme. This is supported by the clinical disorders that affect the basal ganglia.

HYPERKINETIC MOVEMENT DISORDERS	HYPOKINETIC MOVEMENT DISORDERS
Chorea Ballismus Tics	Parkinson's disease Dystonia

Schematic figure of basal ganglia showing major connections and transmitters



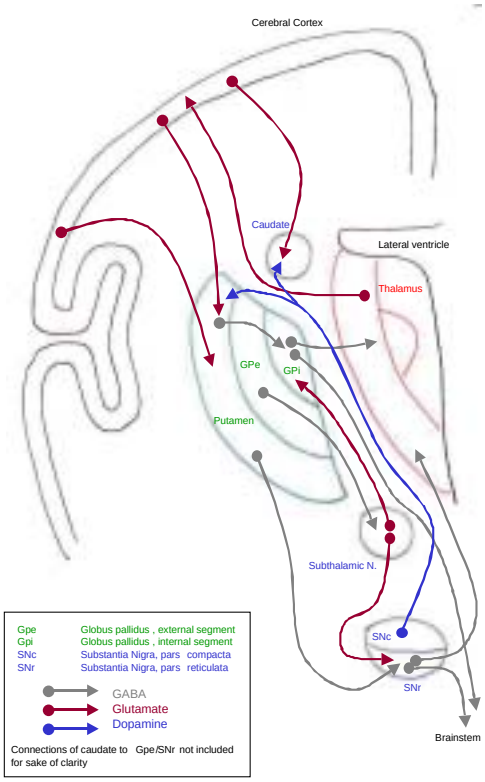
CLINICAL DISORDERS OF MOVEMENT ASSOCIATED WITH THE BASAL GANGLIA:
One of the simplest way to classify movement disorders associated with the basal ganglia is to consider whether they are hyperkinetic or hypokinetic:

Whilst the pathogenesis of many of these disorders remains obscure, detailed studies in Parkinson's and Huntington's disease has allowed schematic figures of pathological flow within the basal ganglia to be developed. These have proved to be important in some of the newer interventions especially from a neurosurgical point of view, although it must be realised that these figures are gross simplifications of the true disturbance of neuronal activity.

Recent new developments in basal ganglia:

- Anatomical analysis of substantia nigra suggests existence of distinct subdivisions - nigrosomes
- Pharmacological complexity of transmitters within basal ganglia has lead to exploration of novel mechanisms of therapy for dyskinesias in PD
- Cognitive and neuropsychiatric abnormalities are commonly seen with disorders of the basal ganglia

References
AM Graybiel (2000) The basal ganglia. Curr.Biol. 10:R509-511
Trends in Neuroscience (2000) Supplement entitled Parkinson's disease and levodopa therapy



Schematic figure showing layout of major nuclei nad connections of the basal ganglia in humans.