Functional Anatomy of the Basal Ganglia

• Four main nuclei
  \textit{striatum, globus pallidus, subthalamic nucleus, & substantia nigra}

• Two general frameworks
  – Anatomically-based physiological models
    • Direct vs indirect pathway controlling motor output
  – Systems/behavioral level
    • Functional classification according to behavioral disruption caused by focal lesions
  – Parallel Cortico-BG-cortical loops

• Major inputs: neocortex & substantia nigra
• Major output: neocortex via thalamus
Overview: Basal Ganglia & thalamus

Caudate (Body)
Caudate (Head)
Putamen
Nucleus Accumbens
Central Sulcus
massa intermedia
Thalamus
Substantia nigra
Cerebellum

Striatum = Caudate nucleus and putamen
Pallidum = Ext. and Internal segments of globus pallidus
Midbrain dopamine Inputs

SN: Substantia Nigra
VTA: ventral tegmental area
SC: sup. Colliculus
RD: red nucleus

Section of brainstem stained for tryosine hydroxilase (DA)
Glutamate Input: Cortex

Organizing principles

Proximity
Topographic projections from motor/somatosensory cortices to putamen

Longitudinal
Trans-striatal projections from association cortices to caudate

Tripartate pattern

Tripartate input/output organization

“The neurologist’s, psychologist’s & psychiatrist’s basal ganglia” (Saint-Cyr, 2003)

- Neurologists → movement disorders
- Psychologists → cognitive operations
- Psychiatrists → behavioral & emotional disorders

Nakano et al. (2000)

Figure by MIT OCW.
Multiple parallel loop model

- Alexander et al (1986) proposed as many as five separate cortico-BG-cortical circuits

  1. Motor
  2. Oculomotor
  3. Cognitive
  4. Lateral frontal
  5. Emotional

- Complete segregation unlikely given anatomy
- Main point: The basal ganglia isn’t just a motor structure

Middleton & Strick (2000)

Figure by MIT OCW.
Basic Neuropathology

A. Normal
B. Parkinson's Disease

Figure by MIT OCW.

Lewy Bodies

- Intraneuronal inclusions
- Stain positively for synuclein & ubiquitin
- Found in SN, locus coeruleus, nucleus basalis, cerebral cortex, & olfactory bulb
Cortico-BG-Cortical Circuitry

Cerebral Cortex

+ + +

D1 D1

D2 D2

Met-Enk Met-Enk

GPe GPe

GPi GPi

SP SP

SO+SI SO+SI

DA DA

DA

GPe GPe

SNpc SNpc

SNpc SNpc

STN STN

CONTROL PARKINSONIAN SYNDROME

Figure by MIT OCW.