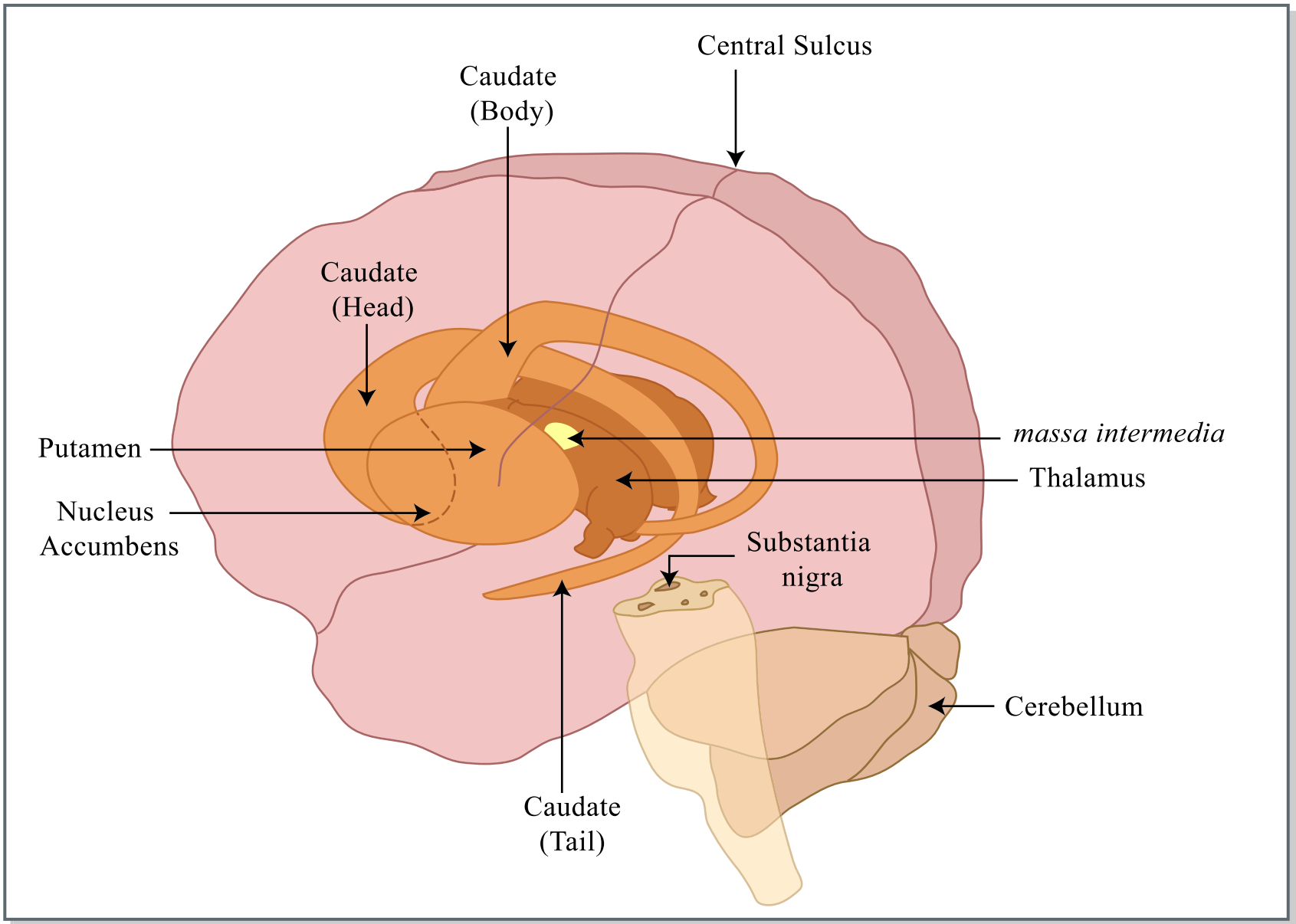
Functional Anatomy of the Basal Ganglia

- Four main nuclei

  striatum, globus pallidus, subthalamic nucleus, & substantia nigra

- Two general frameworks
  - Anatomically-based physiological models
    - Direct vs indirect pathway controling motor output
  - Systems/behavioral level
    - Functional classification according to behavioral distruption caused by focal lesions
  - Parallel Cortico-BG-cortical loops
- Major inputs: neocortex & substantia nigra
- Major output: neocortex via thalamus

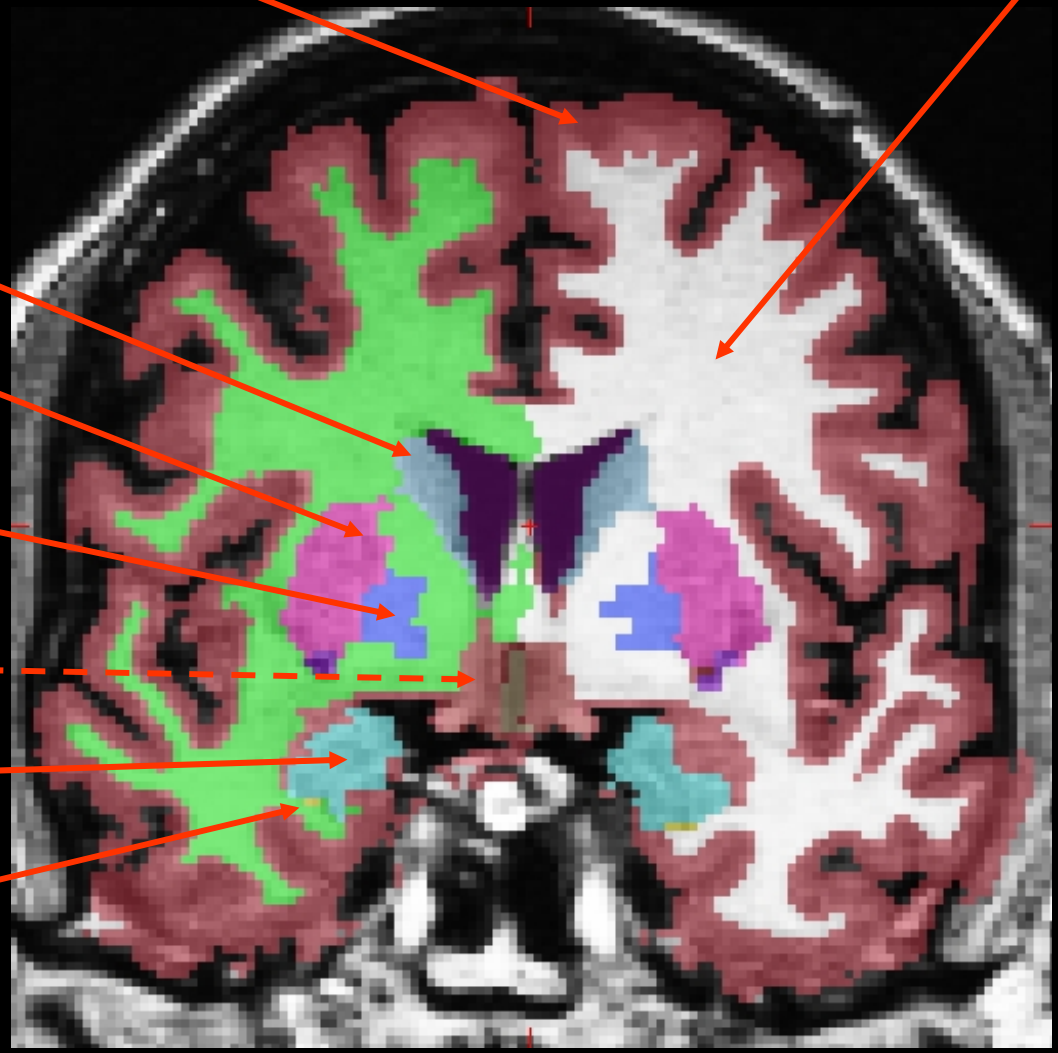
Overview: Basal Ganglia & thalamus



Herrero et al (2002)

Figure by MIT OCW.

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
  - Topograpic projections from motor/somatosensory cortices to putamen
- Longitudinal
  - Trans-striatal projections from association cortices to caudate

Tripartate pattern

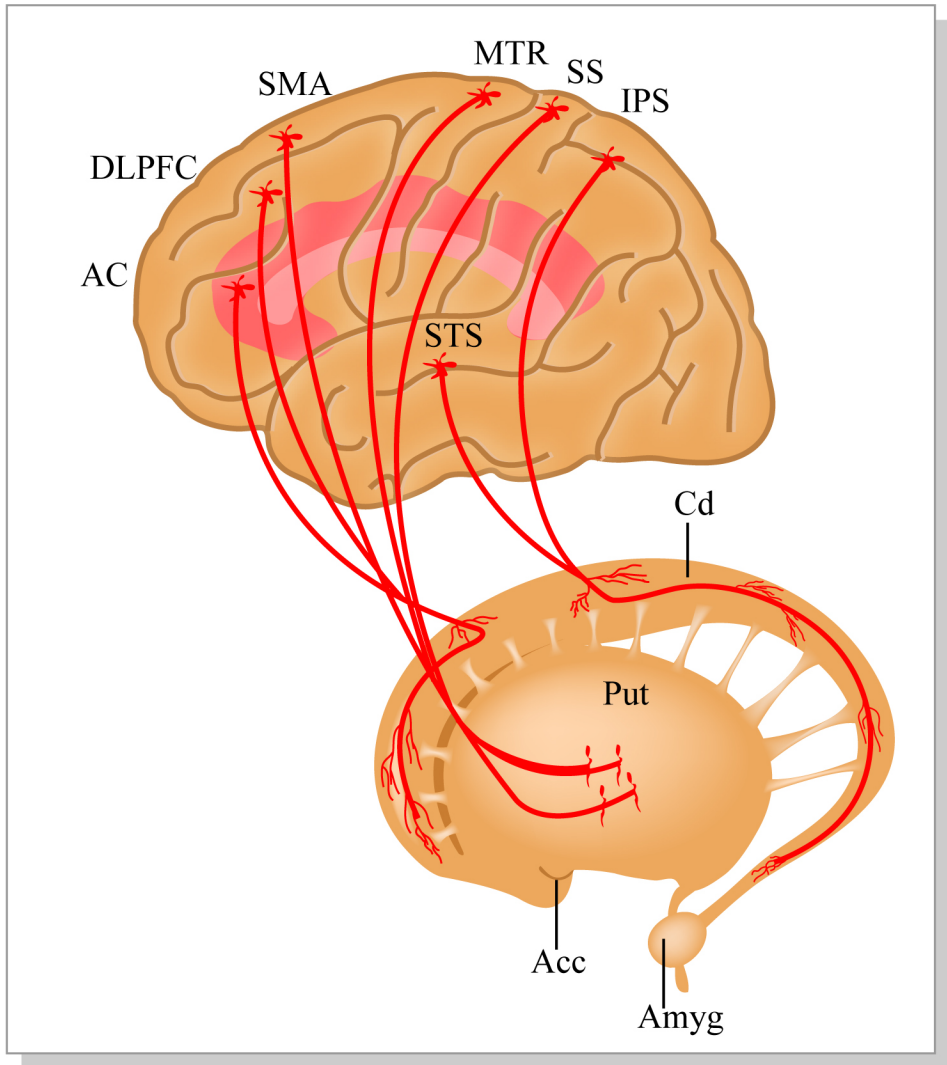


Figure by MIT OCW.

Saint-Cyr (2003) *J. Int. Neuropsych. Soc.*

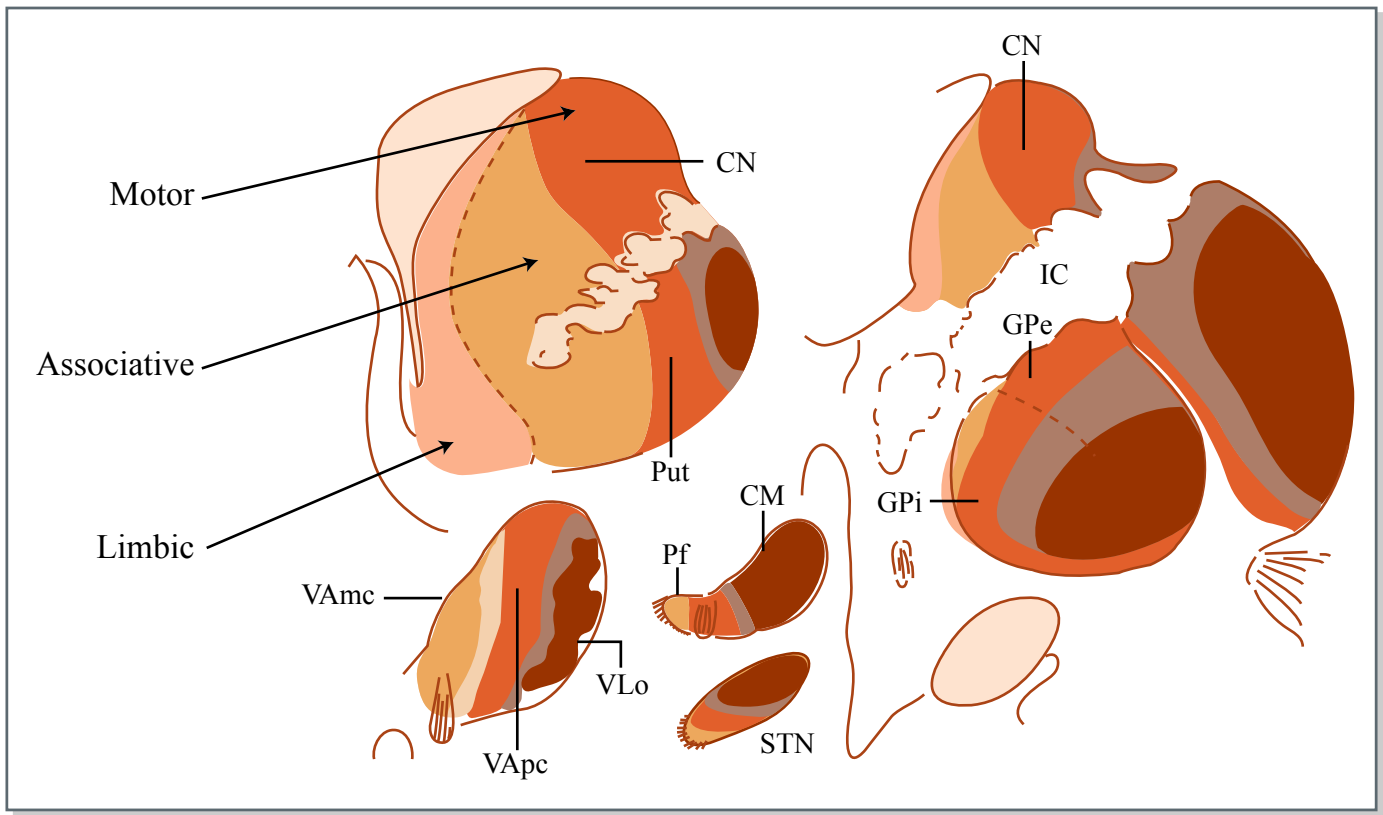
Tripartate input/output organization

"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)

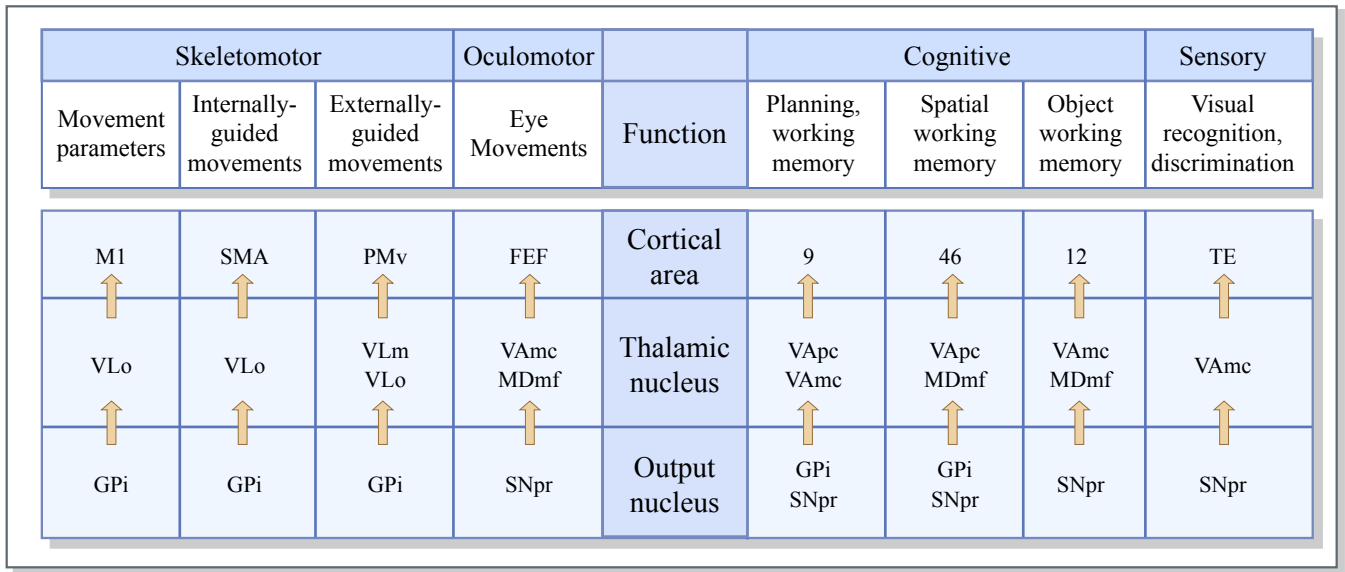
Figure by MIT OCW.

Multiple parallel loop model

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

Middleton & Strick (2000)

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



Skeletomotor			Oculomotor		Cognitive			Sensory
Movement parameters	Internally-guided movements	Externally-guided movements	Eye Movements	Function	Planning, working memory	Spatial working memory	Object working memory	Visual recognition, discrimination
M1	SMA	PMv	FEF	Cortical area	9	46	12	TE
VLo	VLo	VLm VLo	VAmc MDmf	Thalamic nucleus	VApc VAmc	VApc MDmf	VAmc MDmf	VAmc
GPi	GPi	GPi	SNpr	Output nucleus	GPi SNpr	GPi SNpr	SNpr	SNpr

Figure by MIT OCW.

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

Major Output:Thalamus

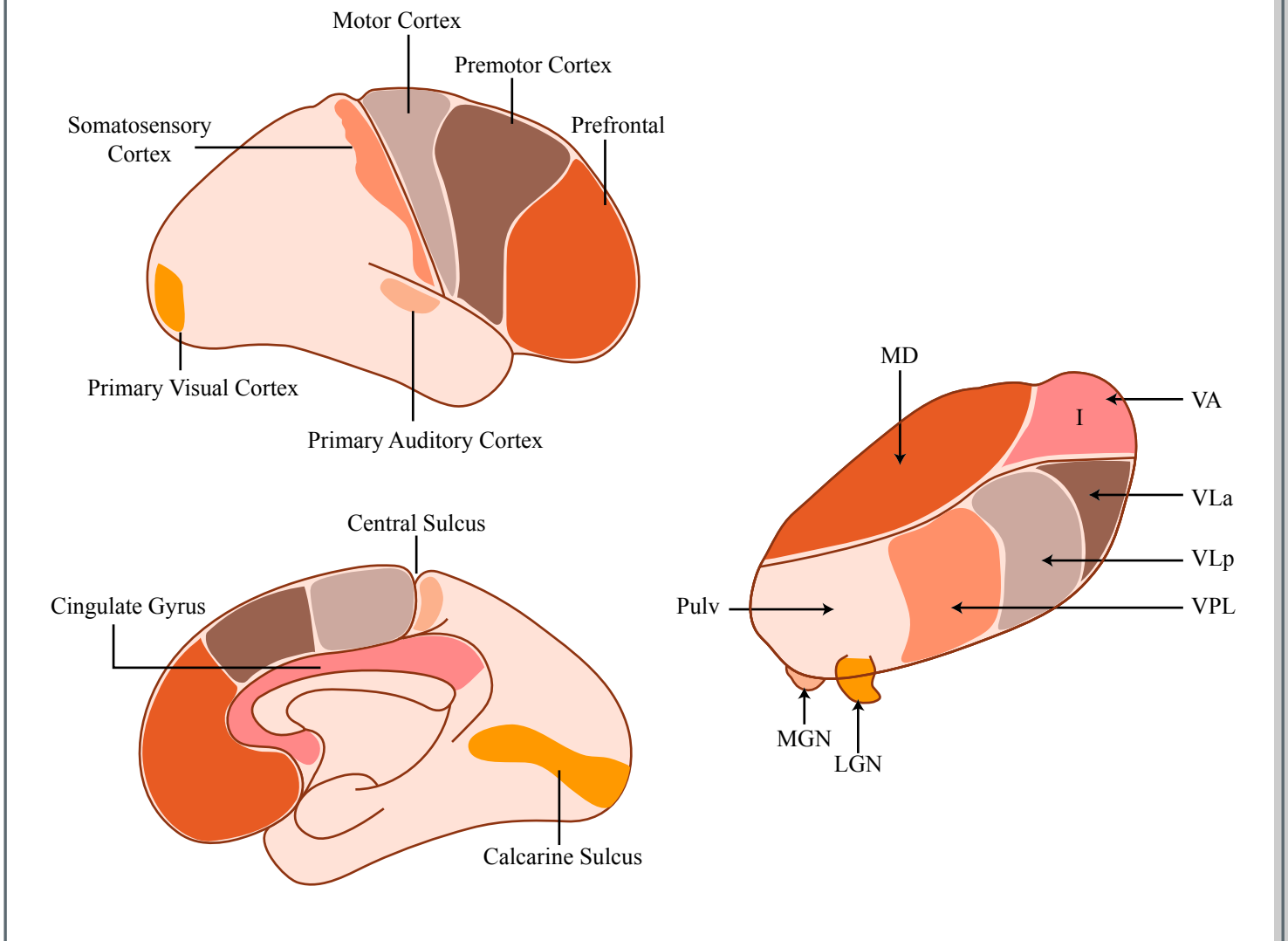


Figure by MIT OCW.

Herrero et al (2002)

Basic Neuropathology

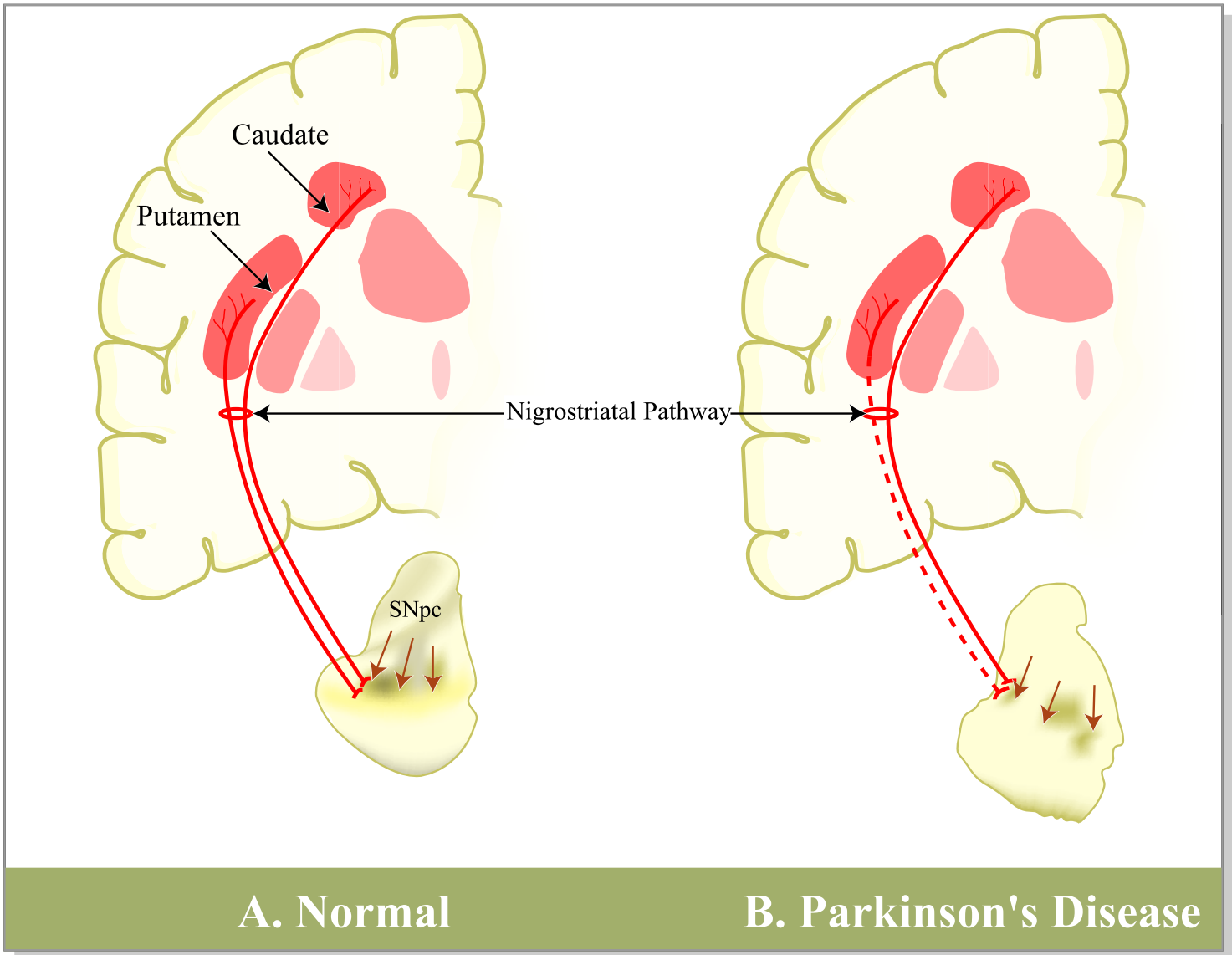


Figure by MIT OCW.

Dauer & Przedborski (2003)

Lewy Bodies

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

Cortico-BG-Cortical Circuitry

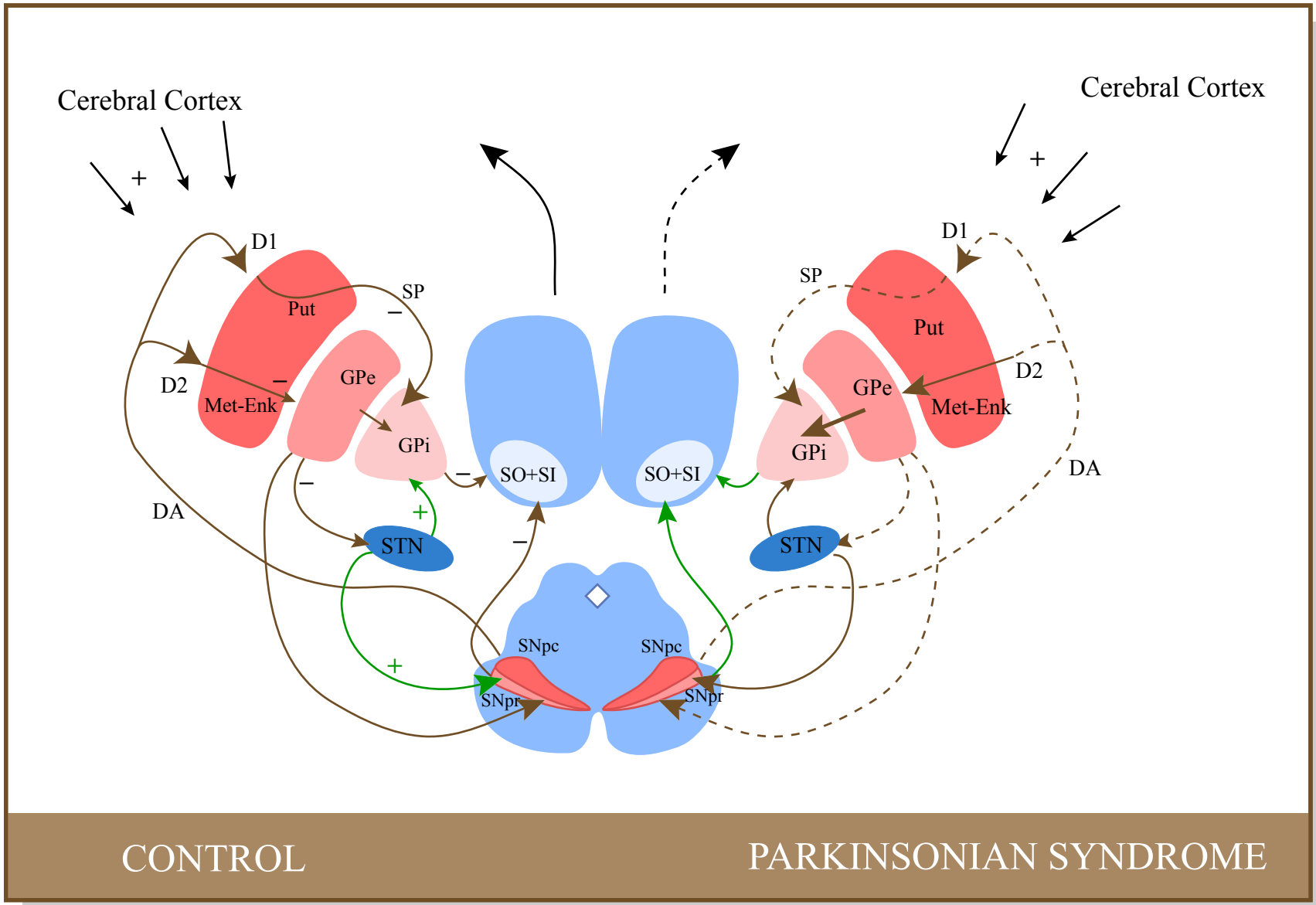


Figure by MIT OCW.

Herrero et al (2002)