Motor Systems: Lecture 4

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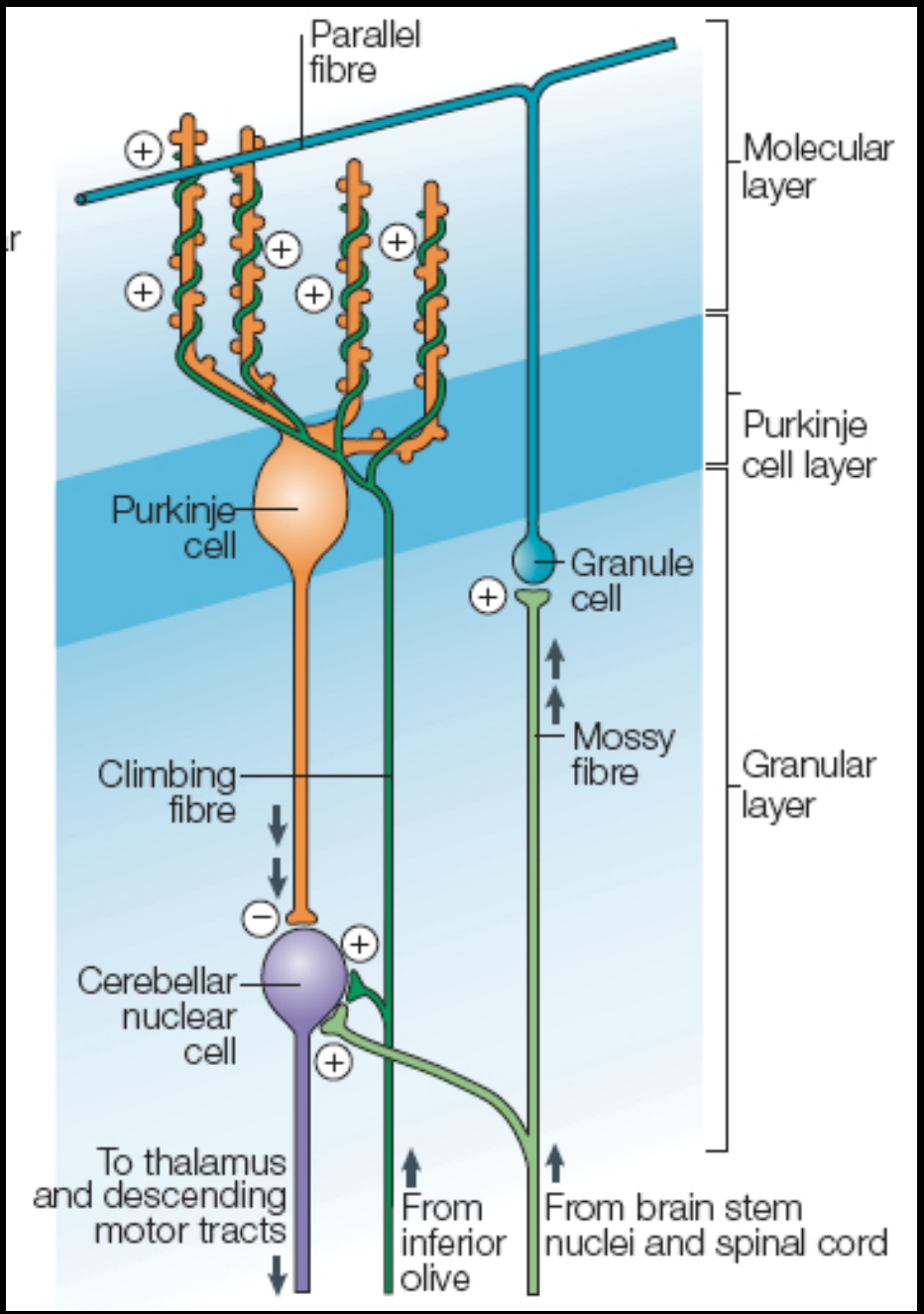
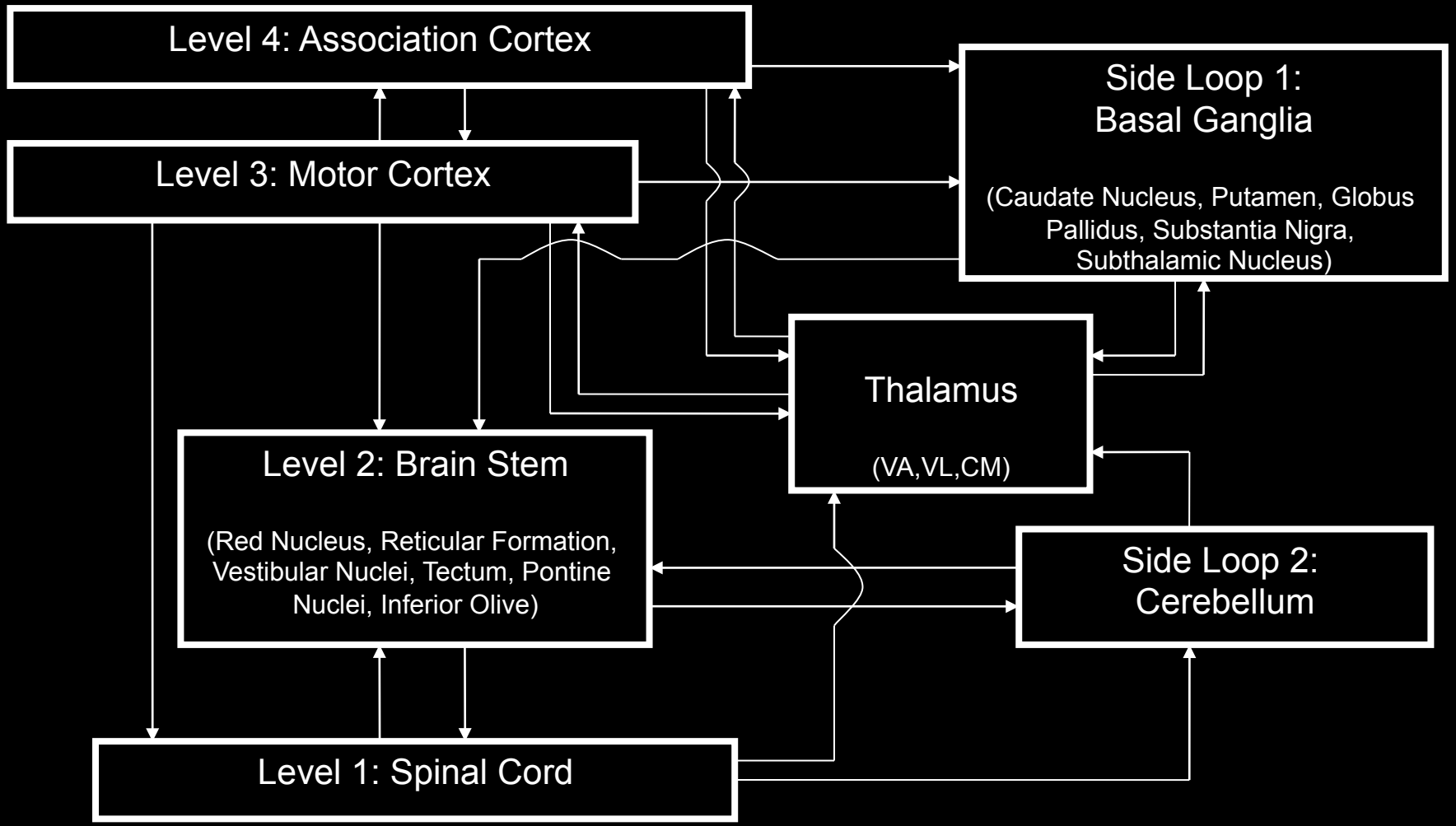
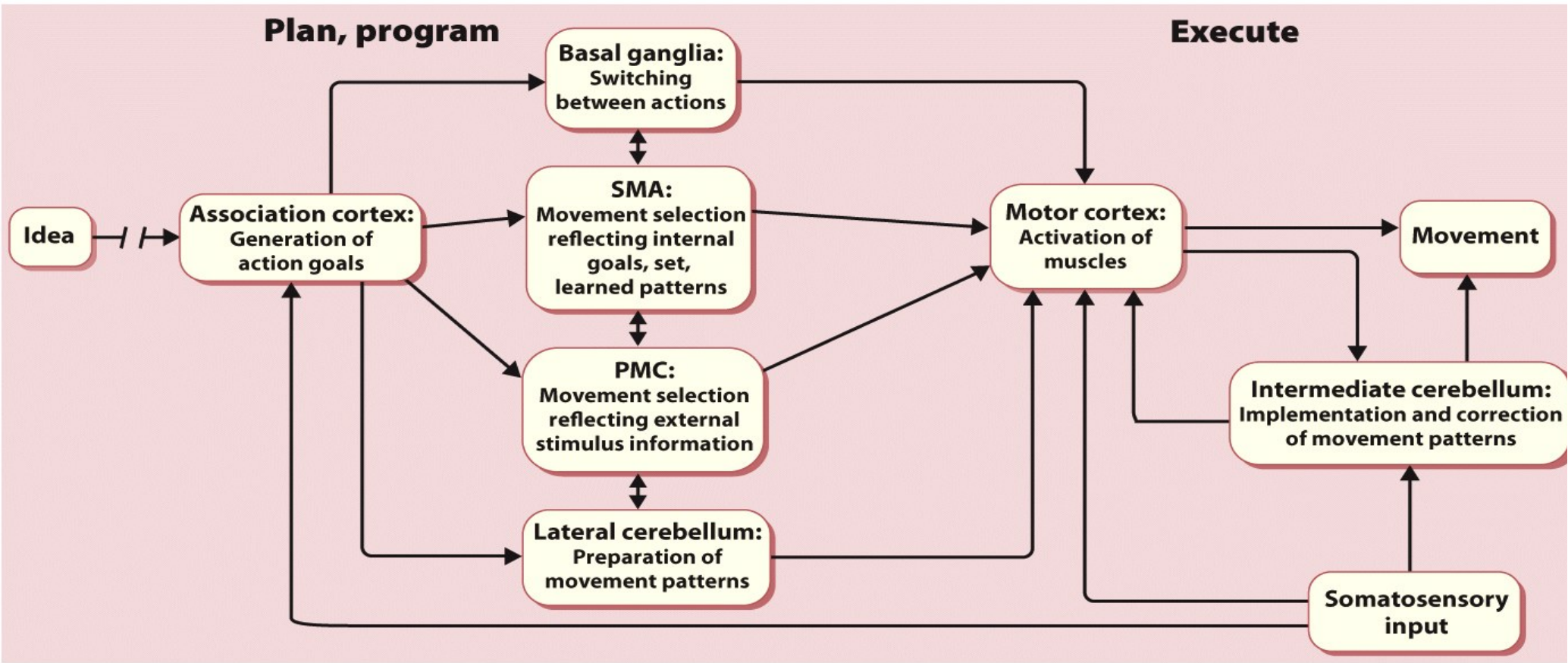
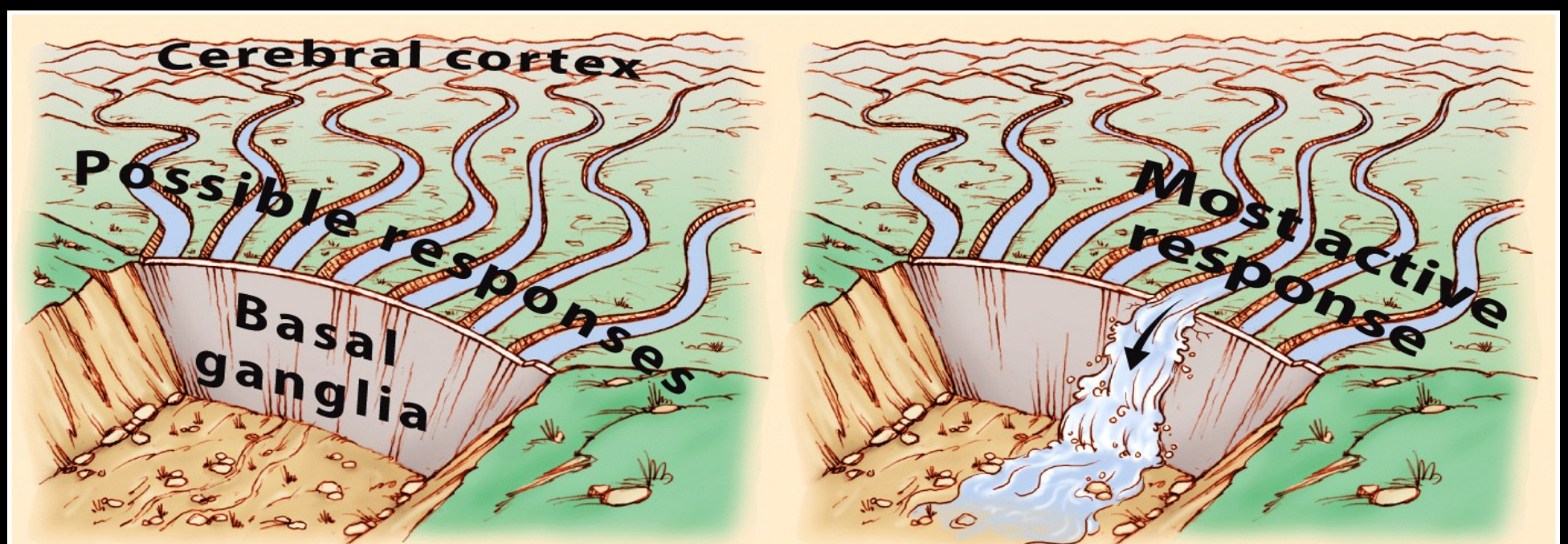

Parallel fibre
Molecular layer
Purkinje cell layer
Granular layer
Purkinje cell
Granule cell
Mossy fibre
Climbing fibre
Cerebellar nuclear cell
To thalamus and descending motor tracts
From inferior olive
From brain stem nuclei and spinal cord

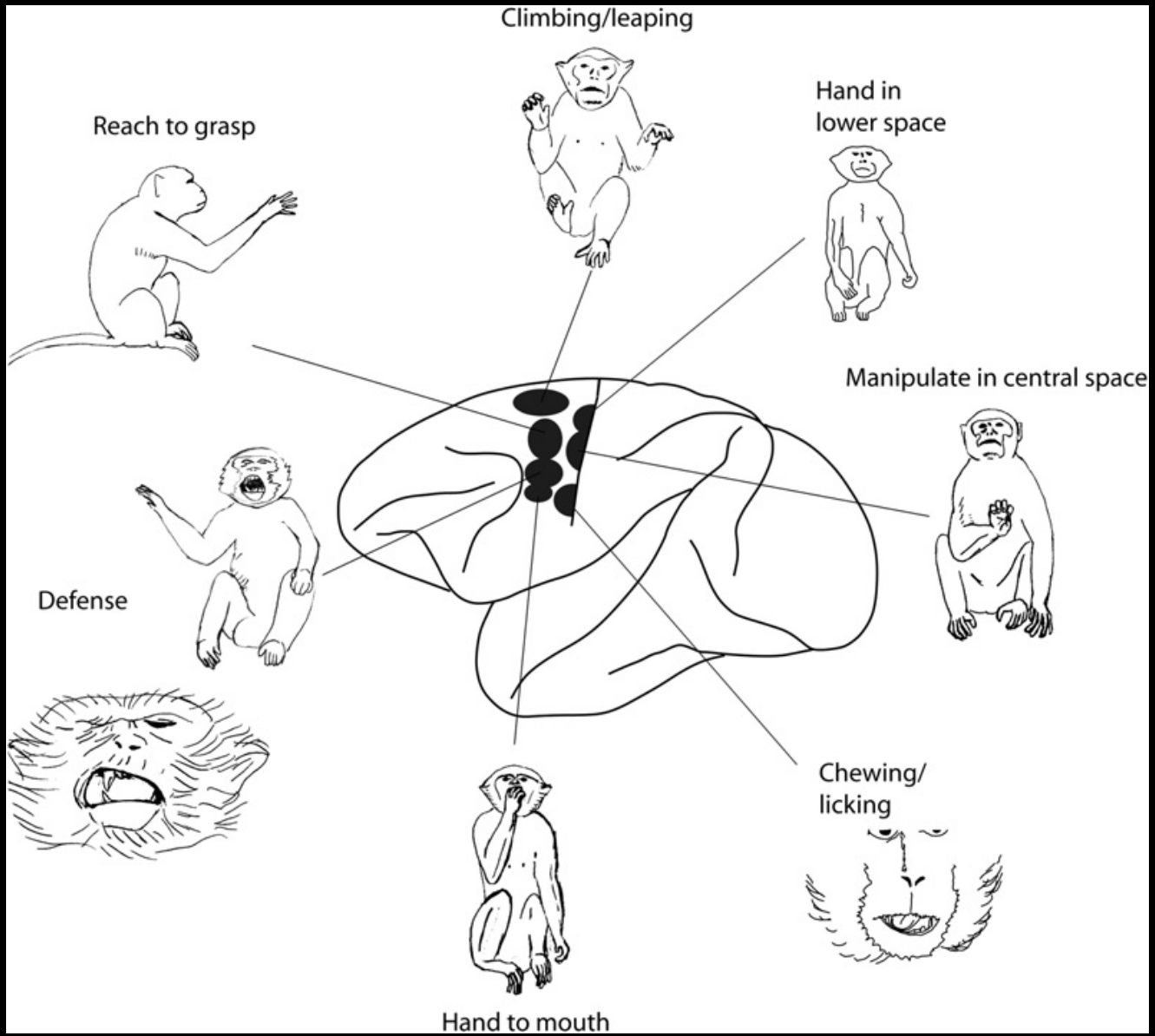
Hierarchical Organization and Functional Segregation of Central Motor Structures



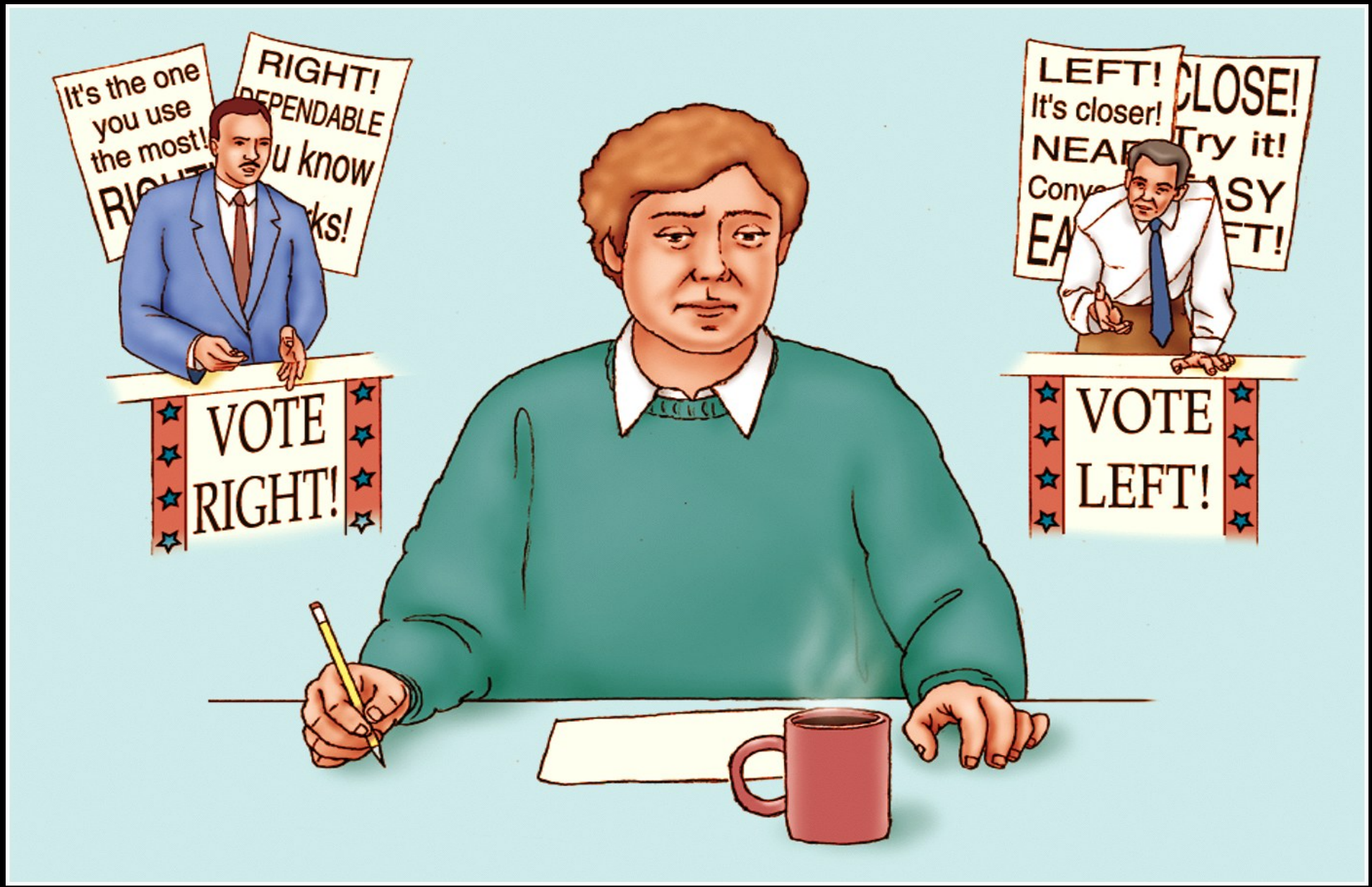

Plan, program
Execute
Basal ganglia:
Switching
between actions
Idea
Association cortex:
Generation of
action goals
SMA:
Movement selection
reflecting internal
goals, set,
learned patterns
PMC:
Movement selection
reflecting external
stimulus information
Lateral cerebellum:
Preparation of
movement patterns
Motor cortex:
Activation of
muscles
Movement
Intermediate cerebellum:
Implementation and correction
of movement patterns
Somatosensory
input

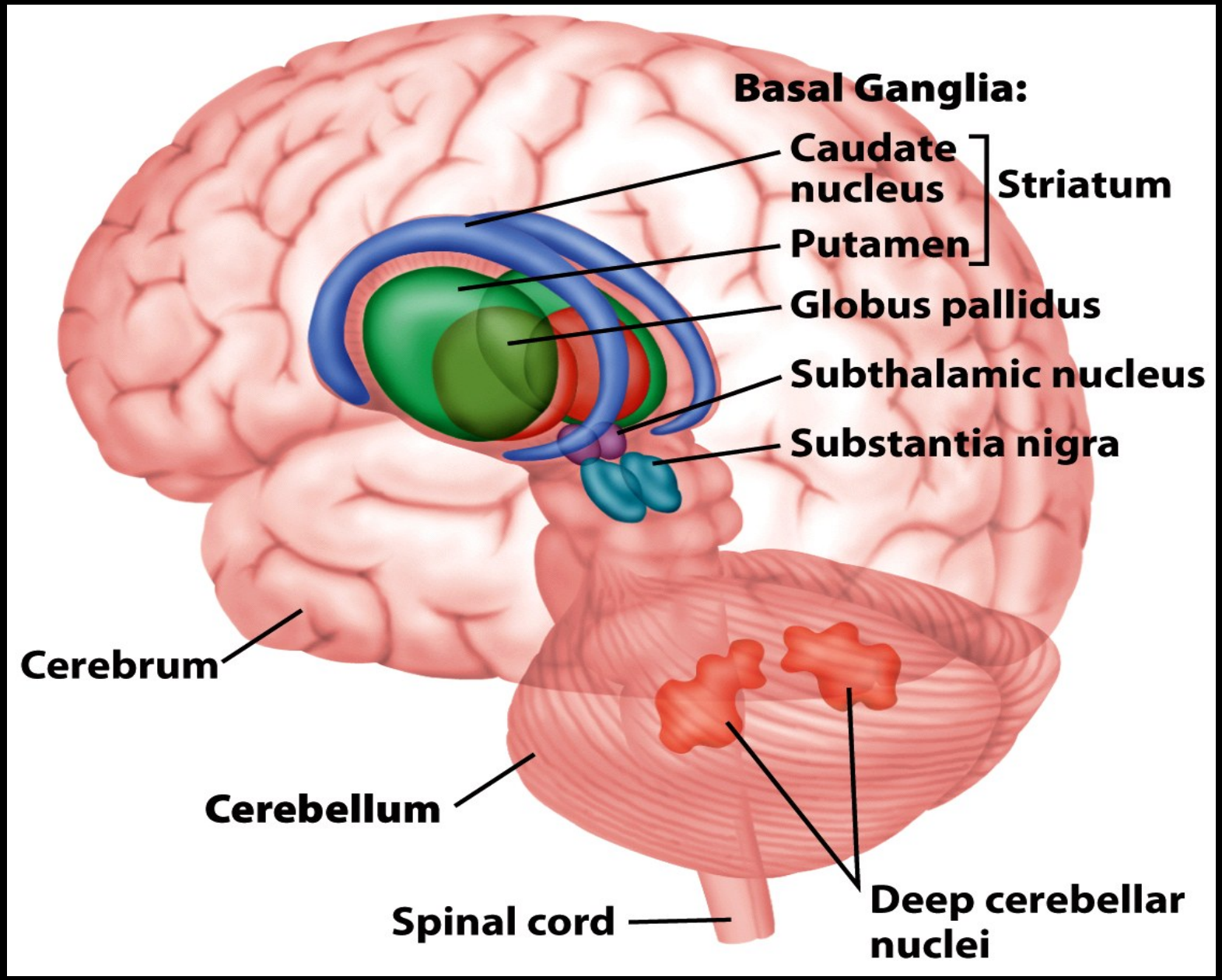

Cerebral cortex
Possible responses
Basal ganglia
Most active response

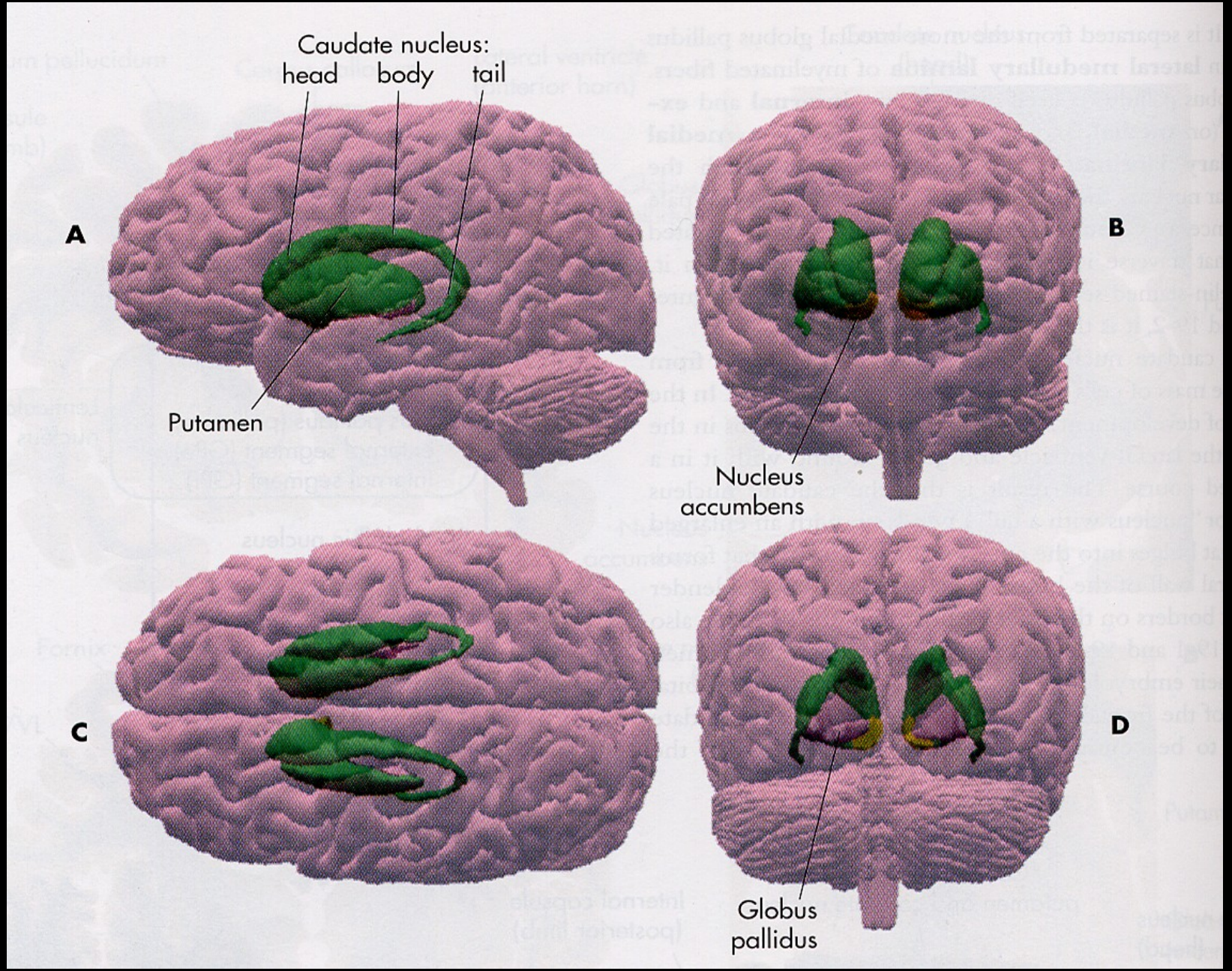
Action Zones



Aflalo & Graziano,
Neuron, 2007


It's the one you use the most!
RIGHT!
u know
ks!
VOTE RIGHT!
LEFT!
It's closer!
CLOSE!
Try it!
VOTE LEFT!


Basal Ganglia:
Caudate nucleus
Striatum
Putamen
Globus pallidus
Subthalamic nucleus
Substantia nigra
Cerebrum
Cerebellum
Spinal cord
Deep cerebellar nuclei



From J. Nolte (2002) *The Human Brain, 5th Edition*

Basal Ganglia Nomenclature

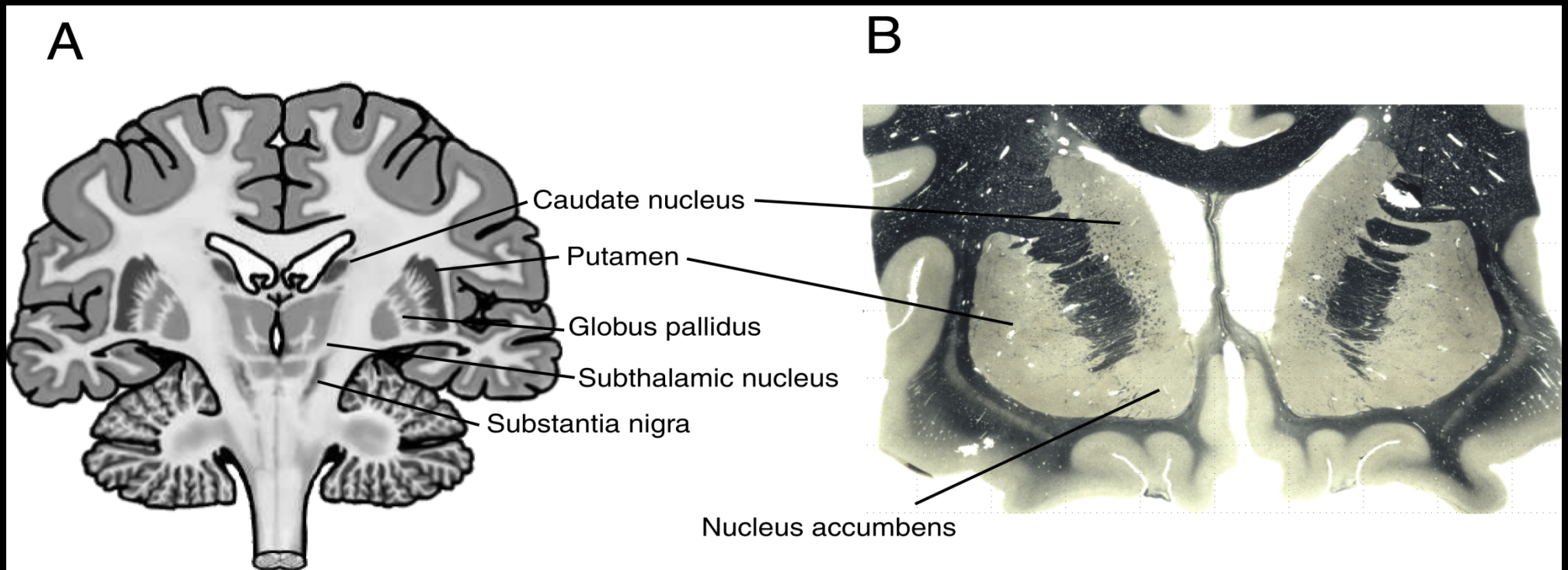
Corpus striatum

- **Lenticular nucleus**
  - **Putamen**
  - **Globus pallidus**
- **Nucleus accumbens**
- **Caudate**

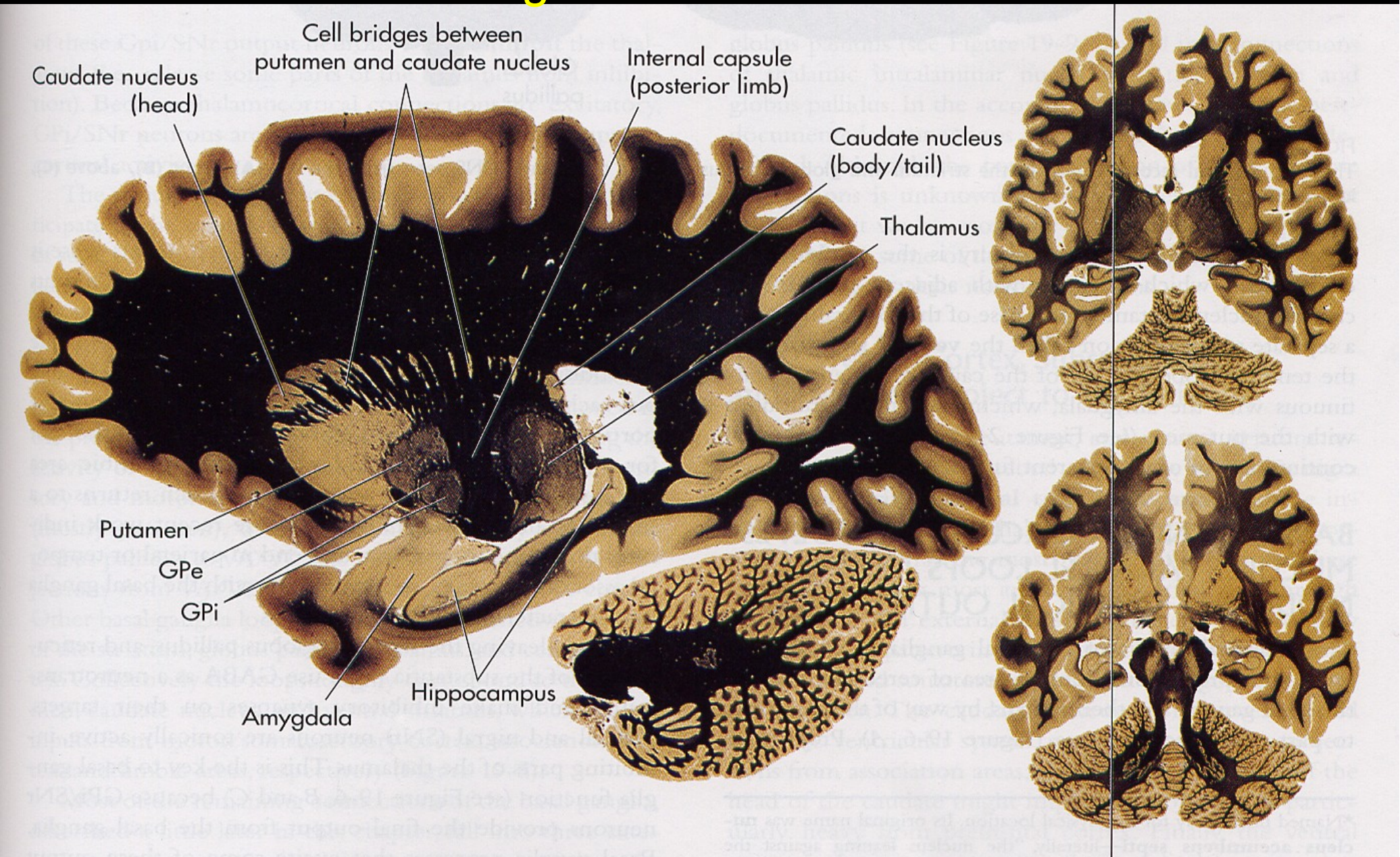
Striatum or Neostriatum

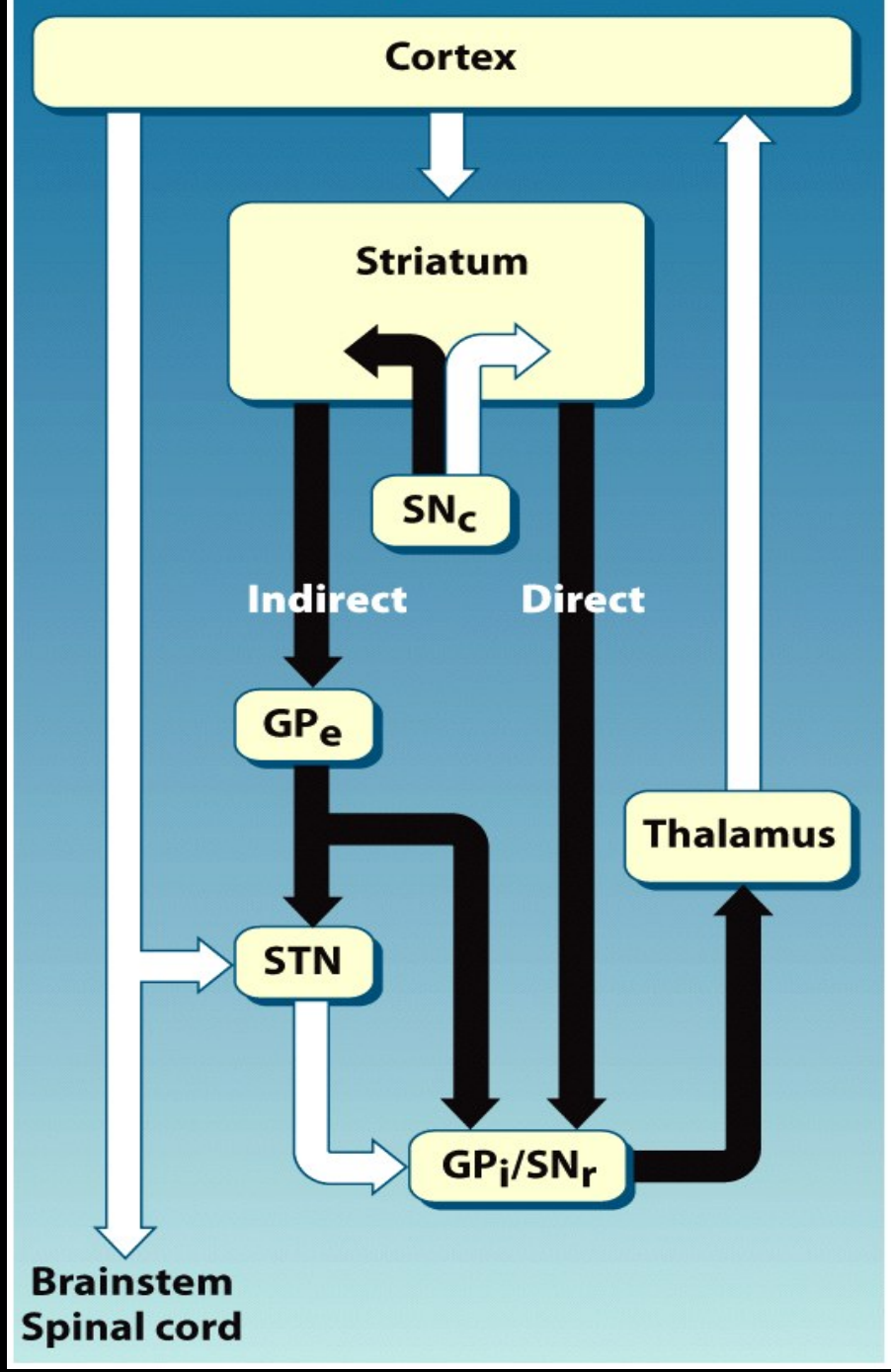
- **Subthalamic nucleus**
- **Substantia nigra (Ventral Tegmental Area)**

Basal Ganglia



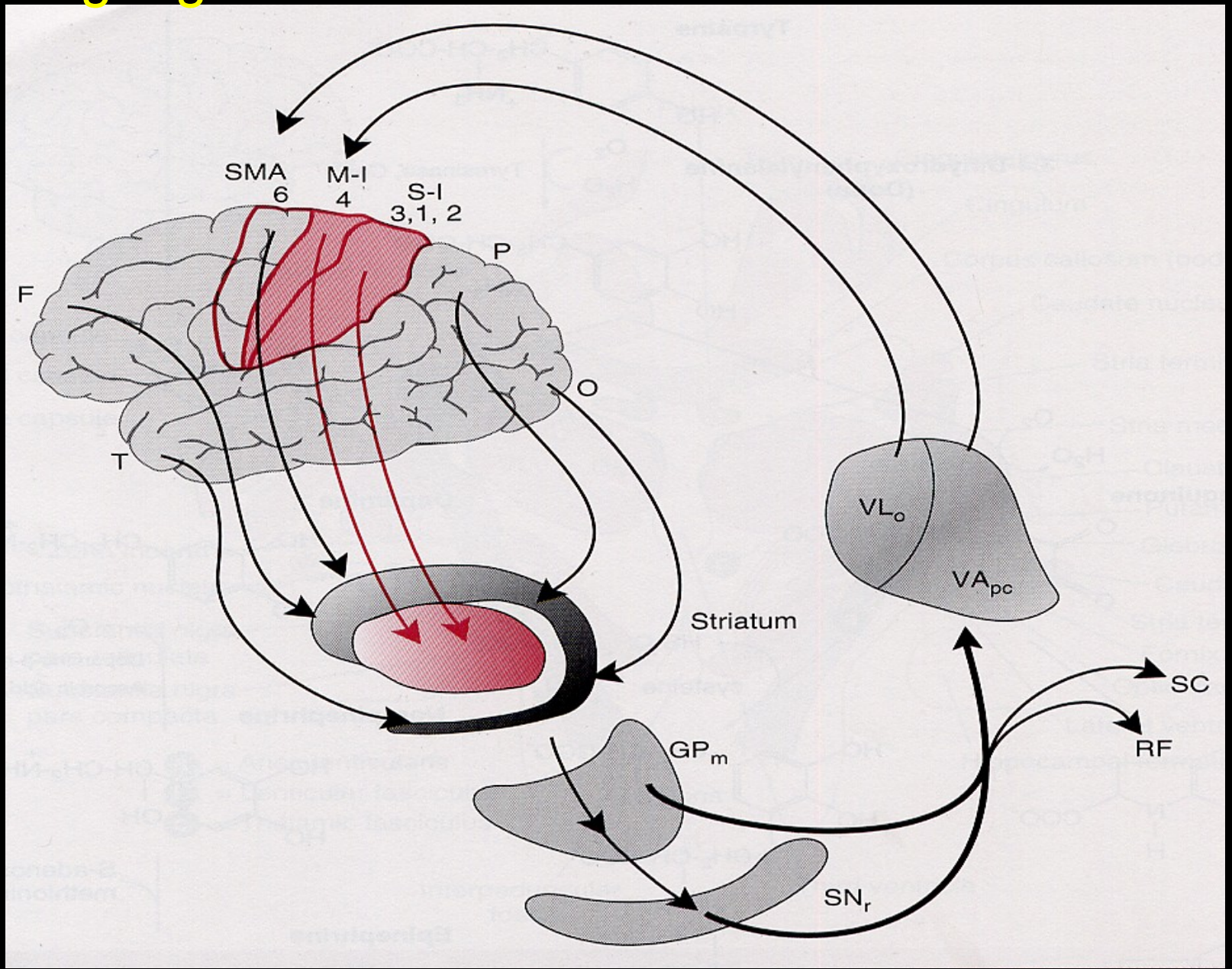
How the striatum got its name…



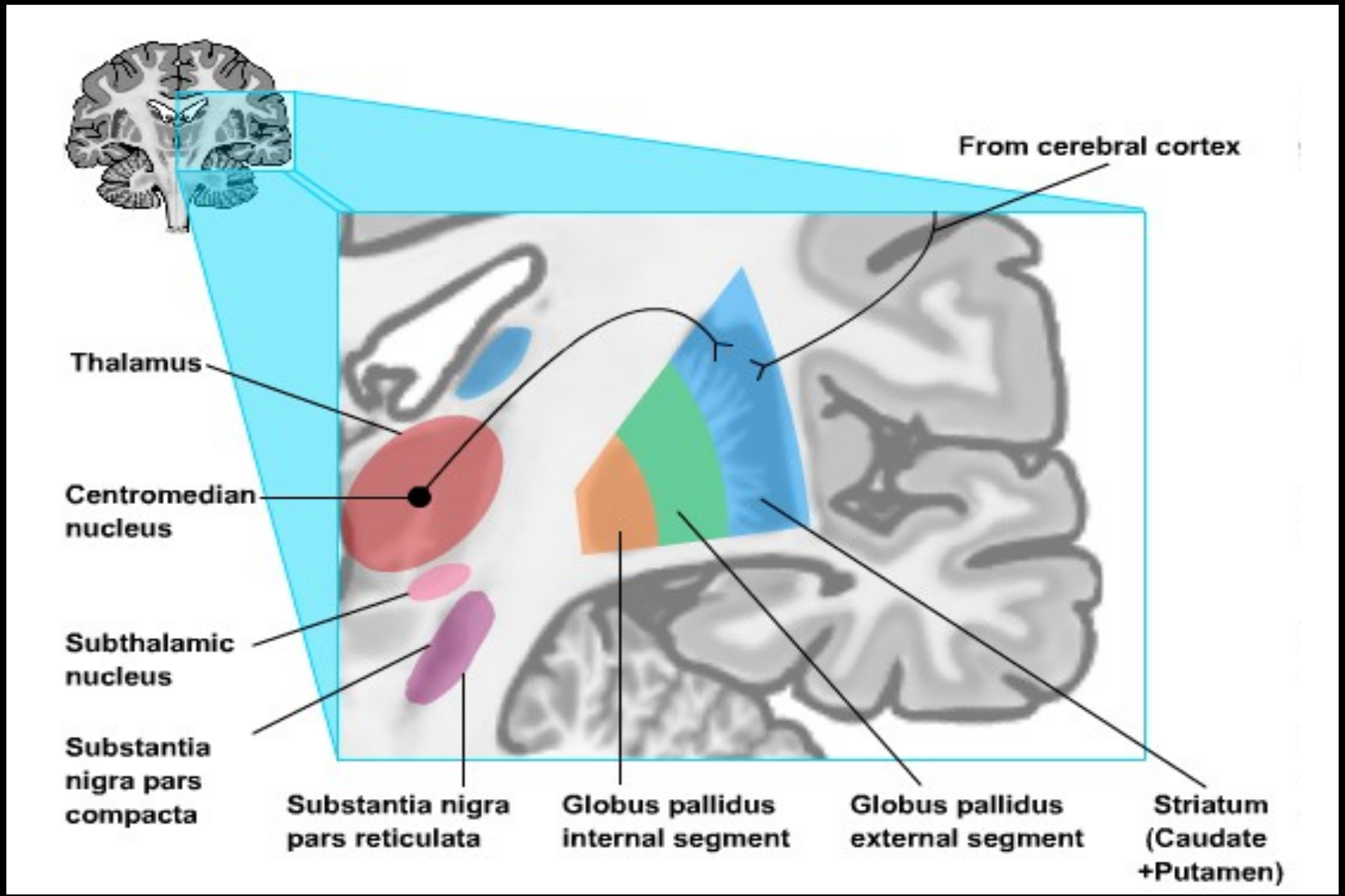


Excitatory connection
Inhibitory connection

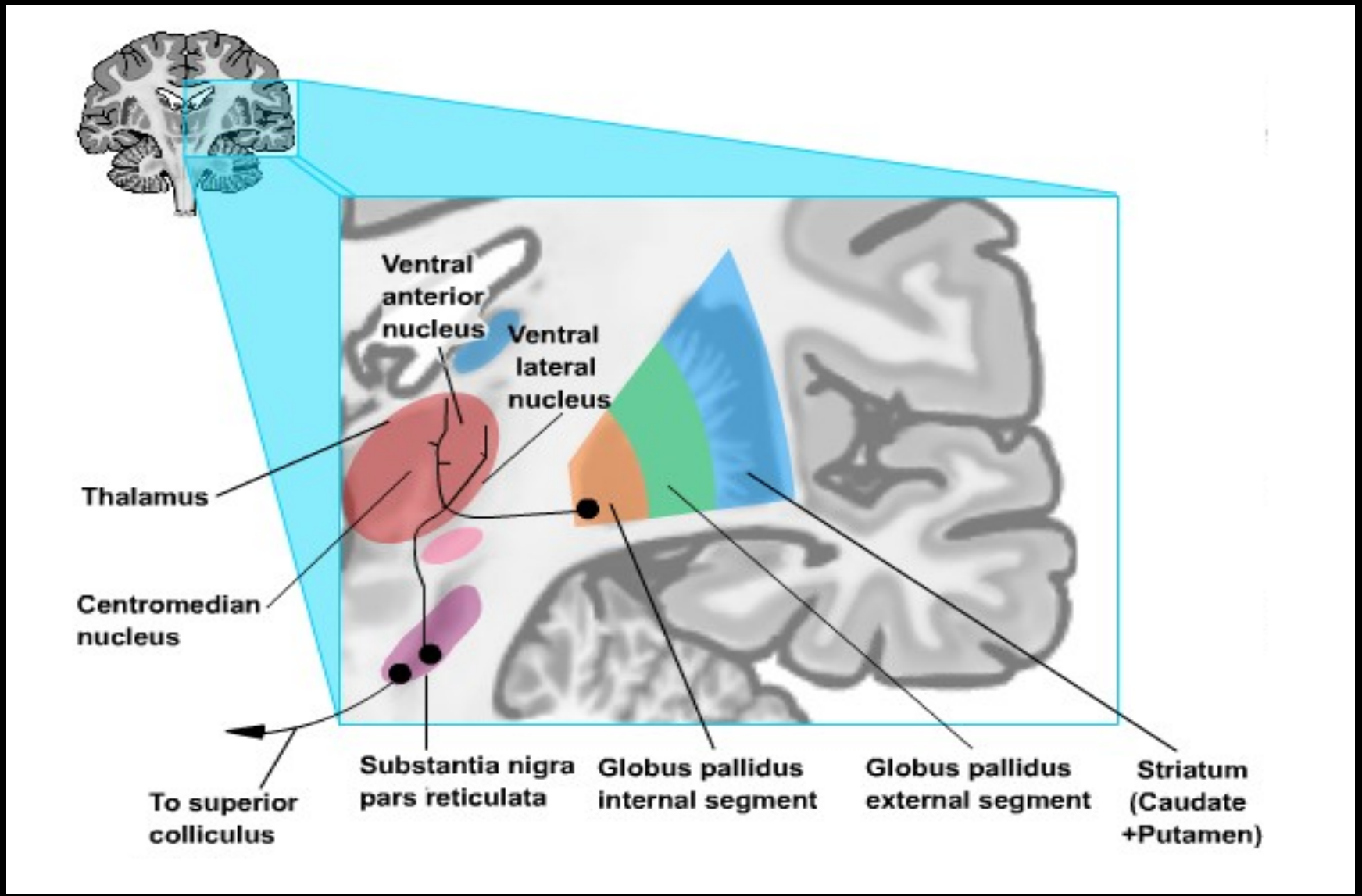
Basal ganglia have motor and nonmotor functions



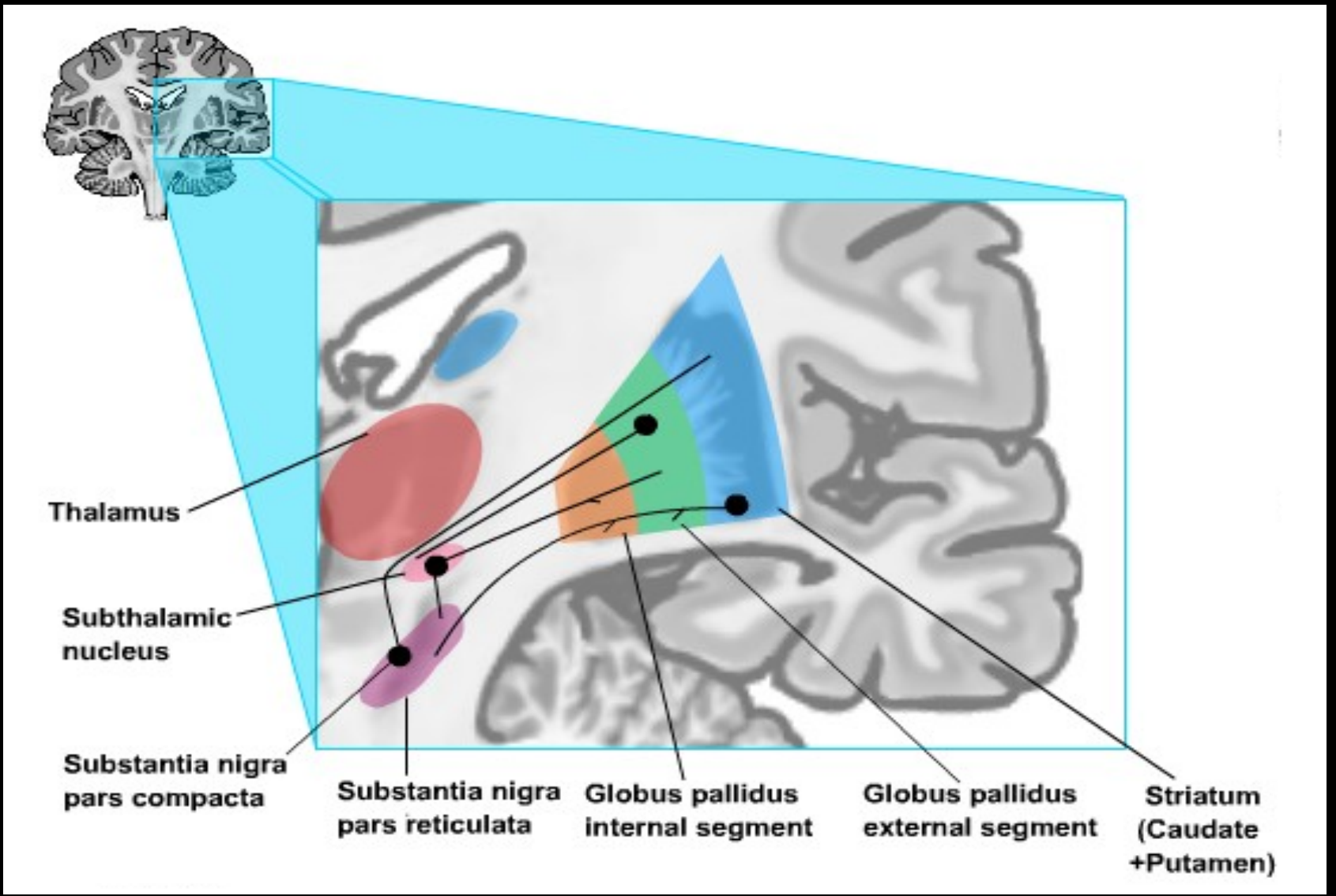
Basal Ganglia Afferents



Basal Ganglia Efferents



Basal Ganglia Intrinsic Connections

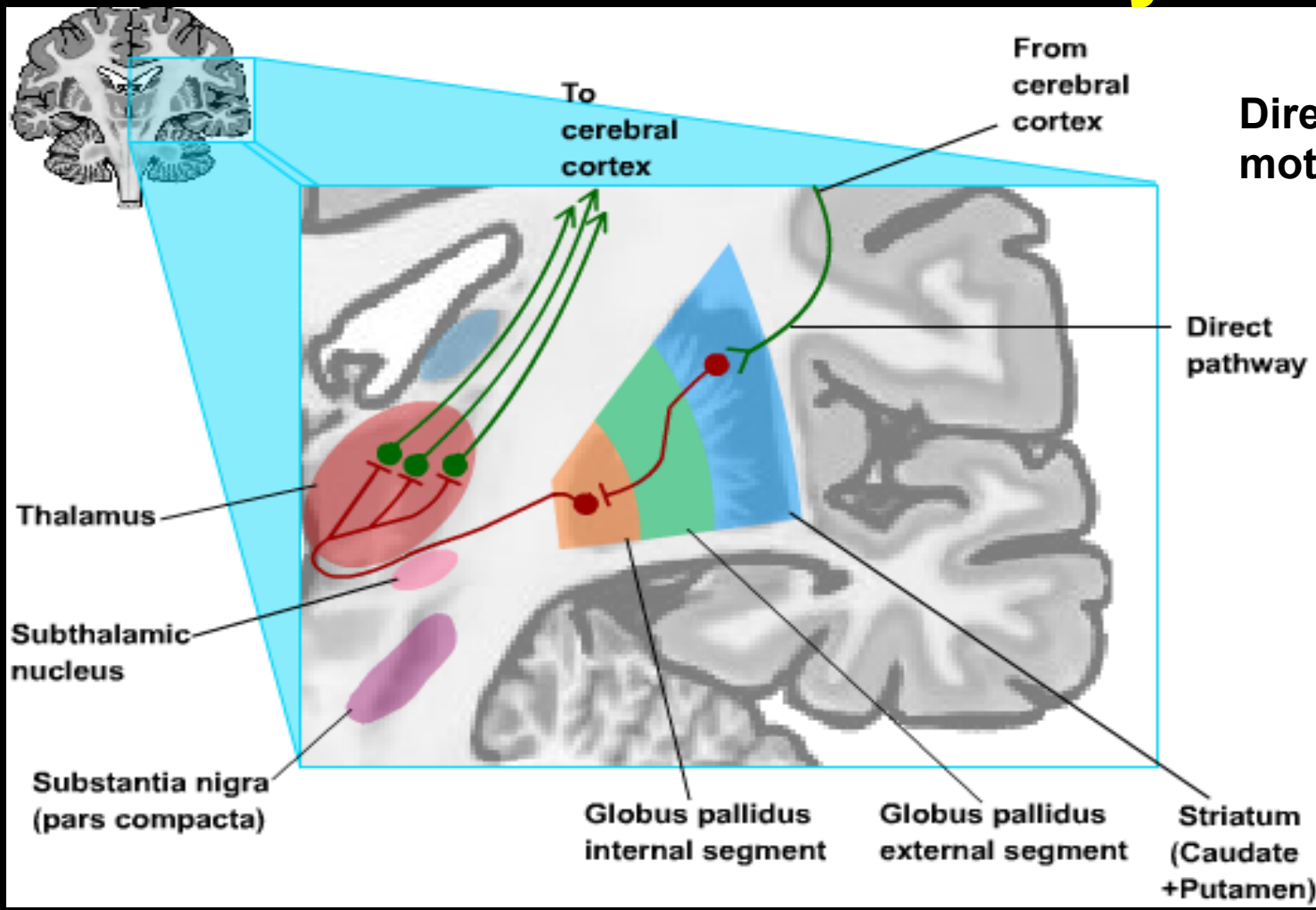


Functions

Direct Pathway: select appropriate movements

Indirect Pathway: inhibit inappropriate movements

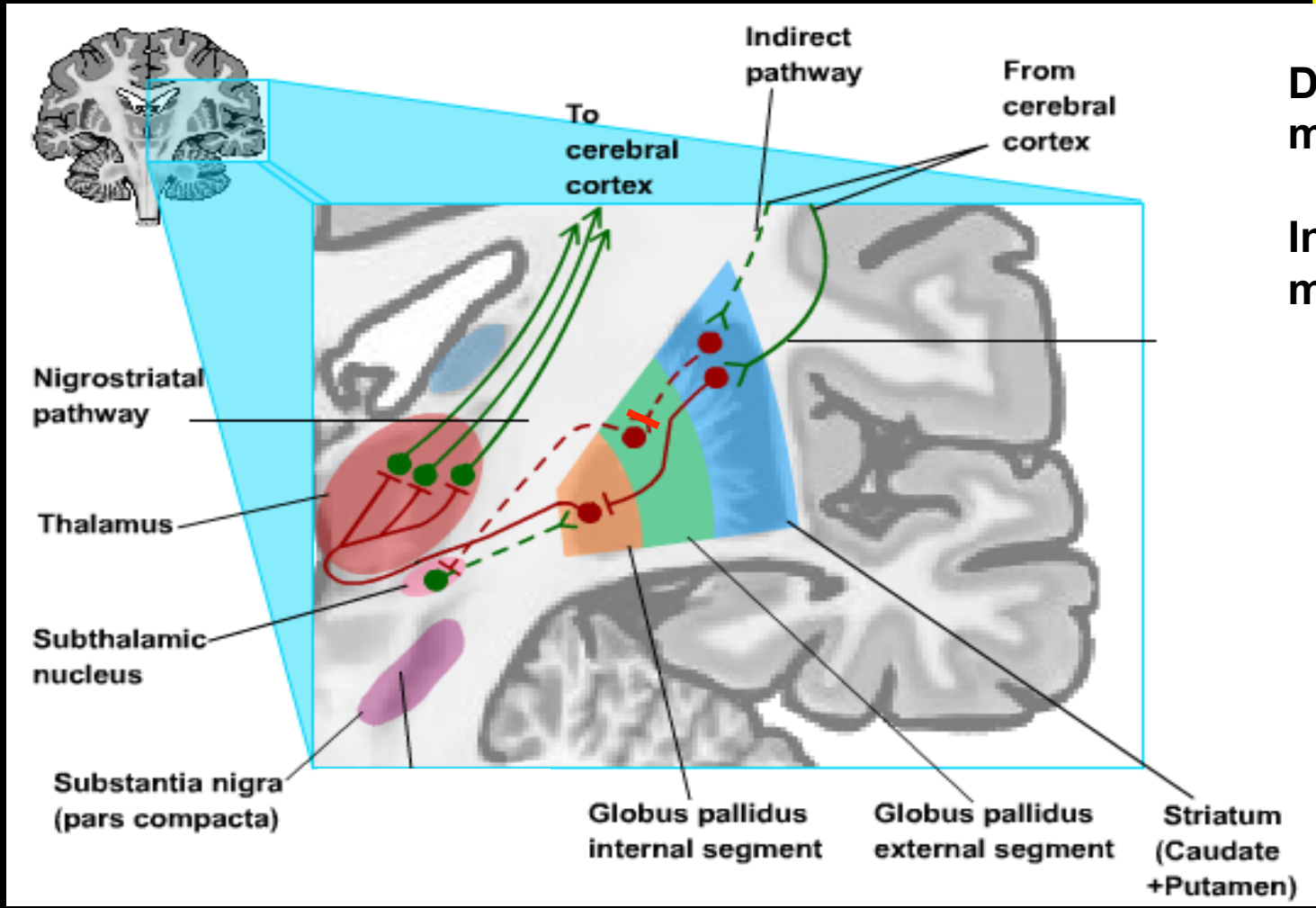
Direct Pathway



Direct Pathway excites motor cortex

E I I
Cortex → striatum → GPint → thalamus
+1 x –1 x –1 = +1

Direct and Indirect Pathways



Direct Pathway excites motor cortex

Indirect Pathway inhibits motor cortex

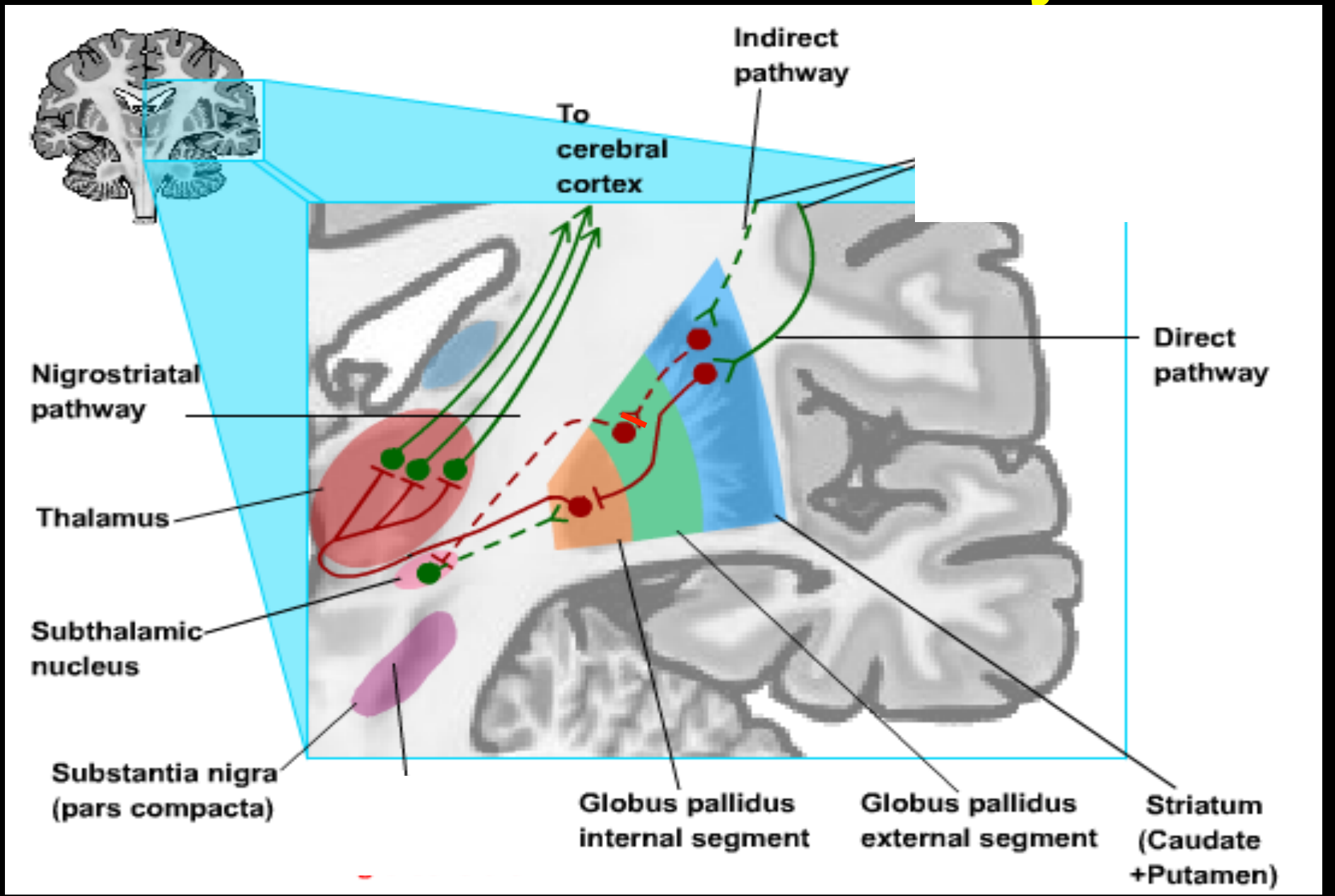
<u>Indirect Pathway</u>

E I I E I

Cortex → striatum → GPext → Subthalamic Nucleus → GPint → thalamus

+1 x –1 x –1 x +1 x –1 = –1

Direct and Indirect Pathways



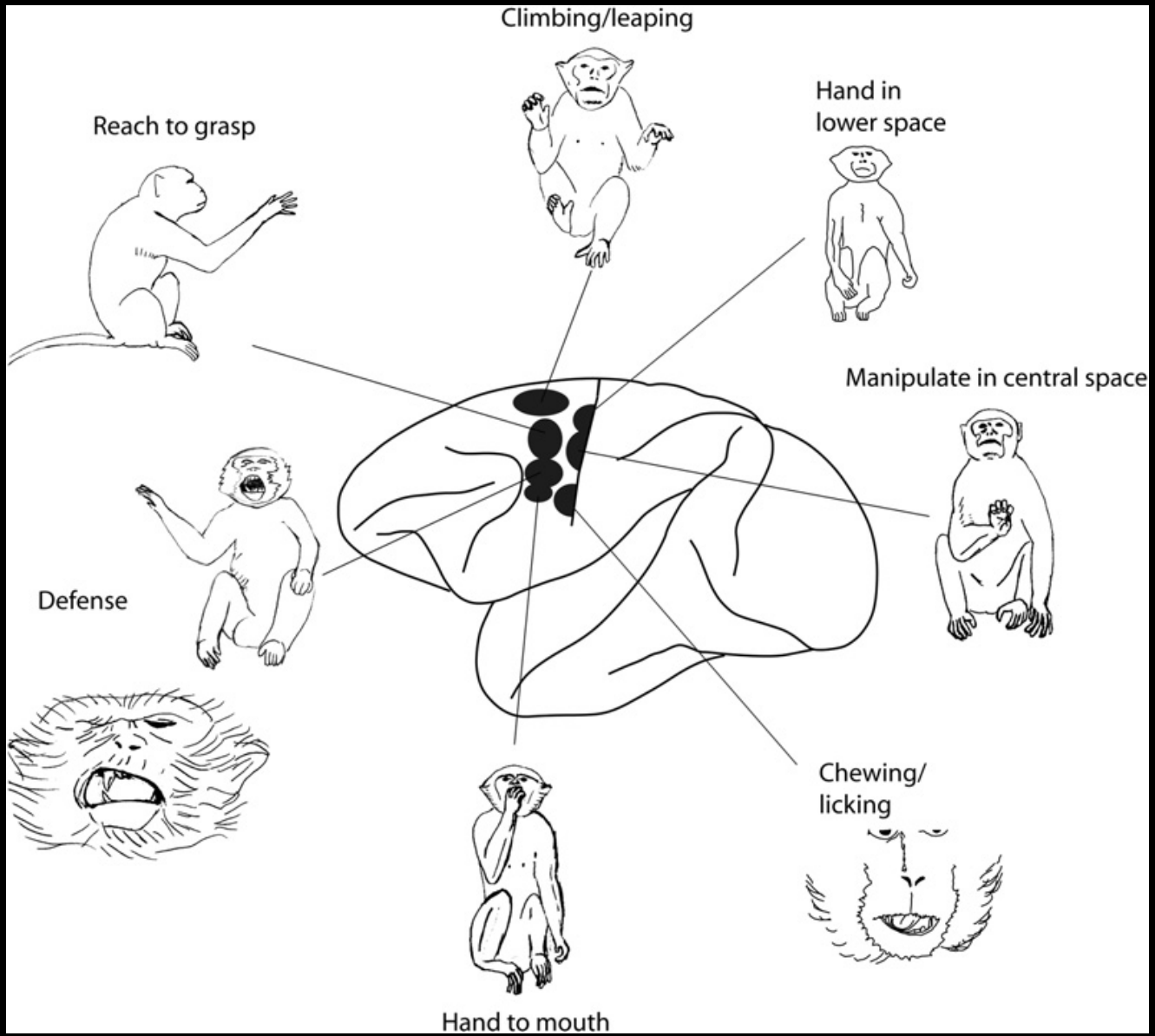
Functions of Basal Ganglia

1. Enable automatic performance of practiced motor acts

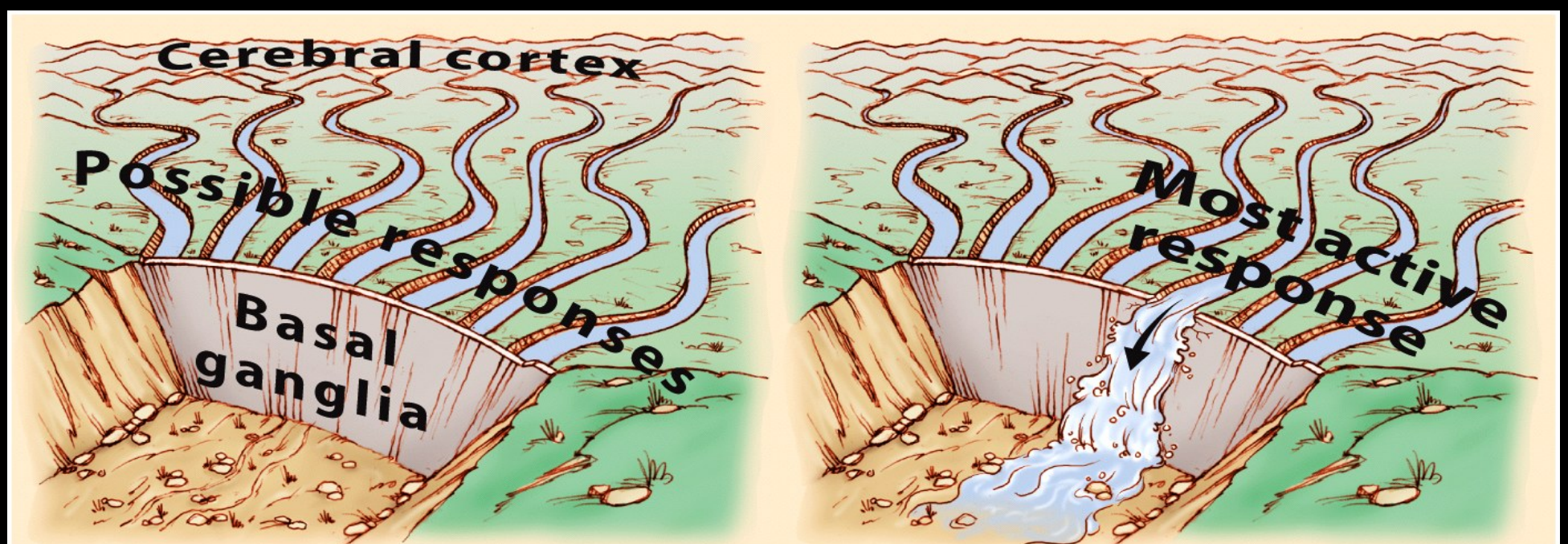
2. Gating the initiation of voluntary movements by modulating motor programs stored in the motor cortex

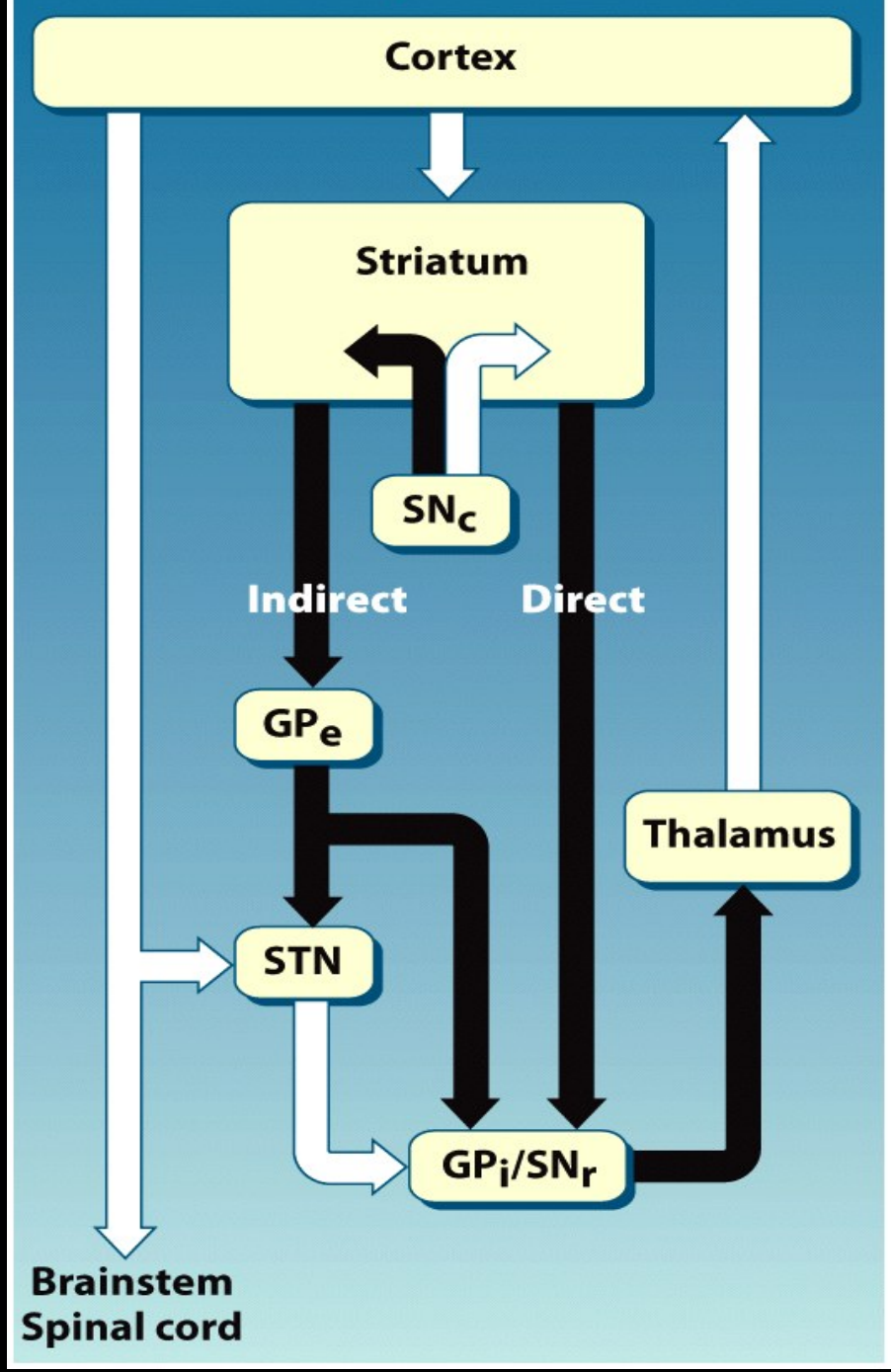
3. Cognitive functions

Action Zones



Aflalo & Graziano,
Neuron, 2007


Cerebral cortex
Possible responses
Basal ganglia
Most active response



Excitatory connection
Inhibitory connection

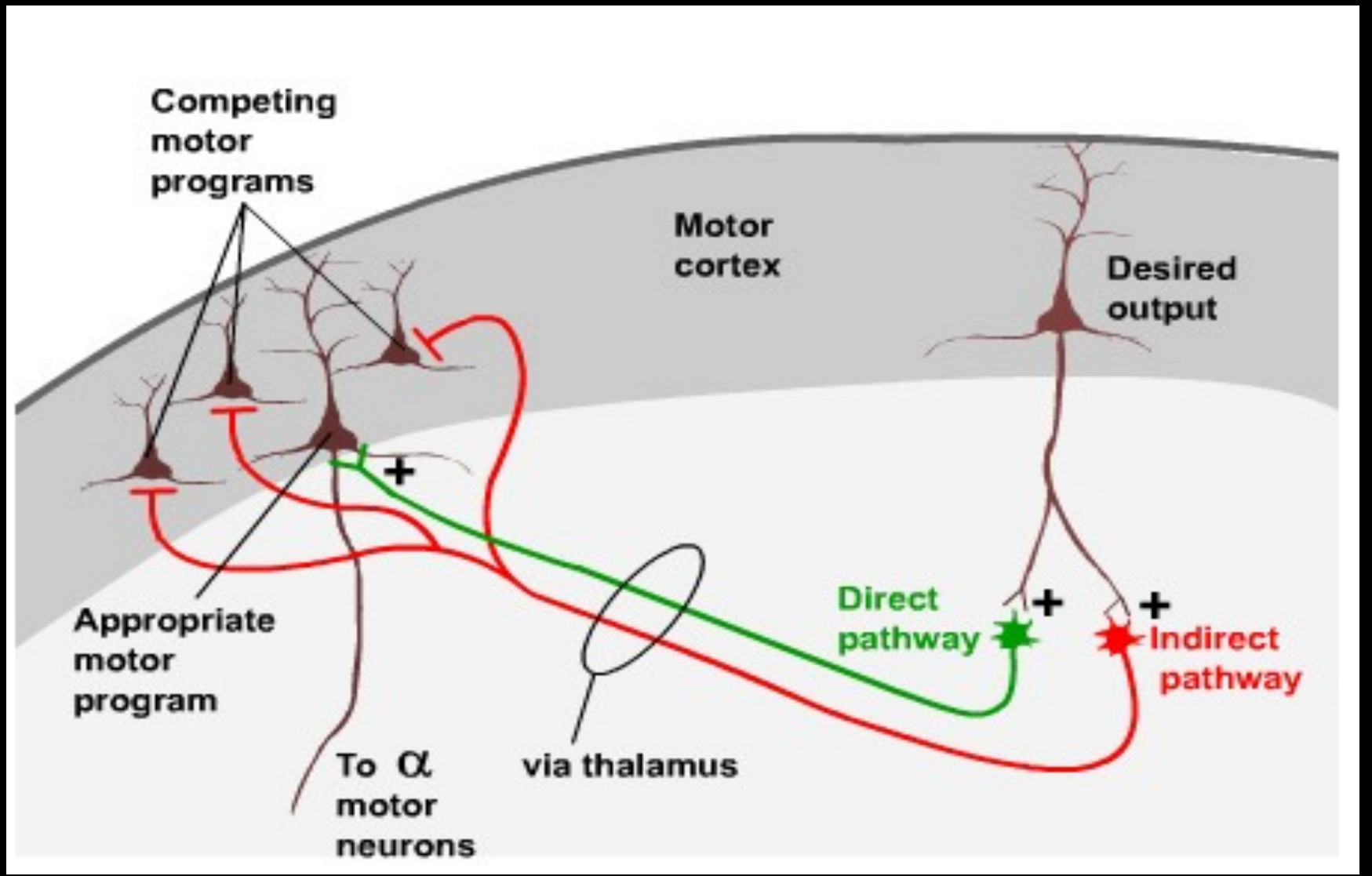
Functions of Basal Ganglia

1. Enable automatic performance of practiced motor acts

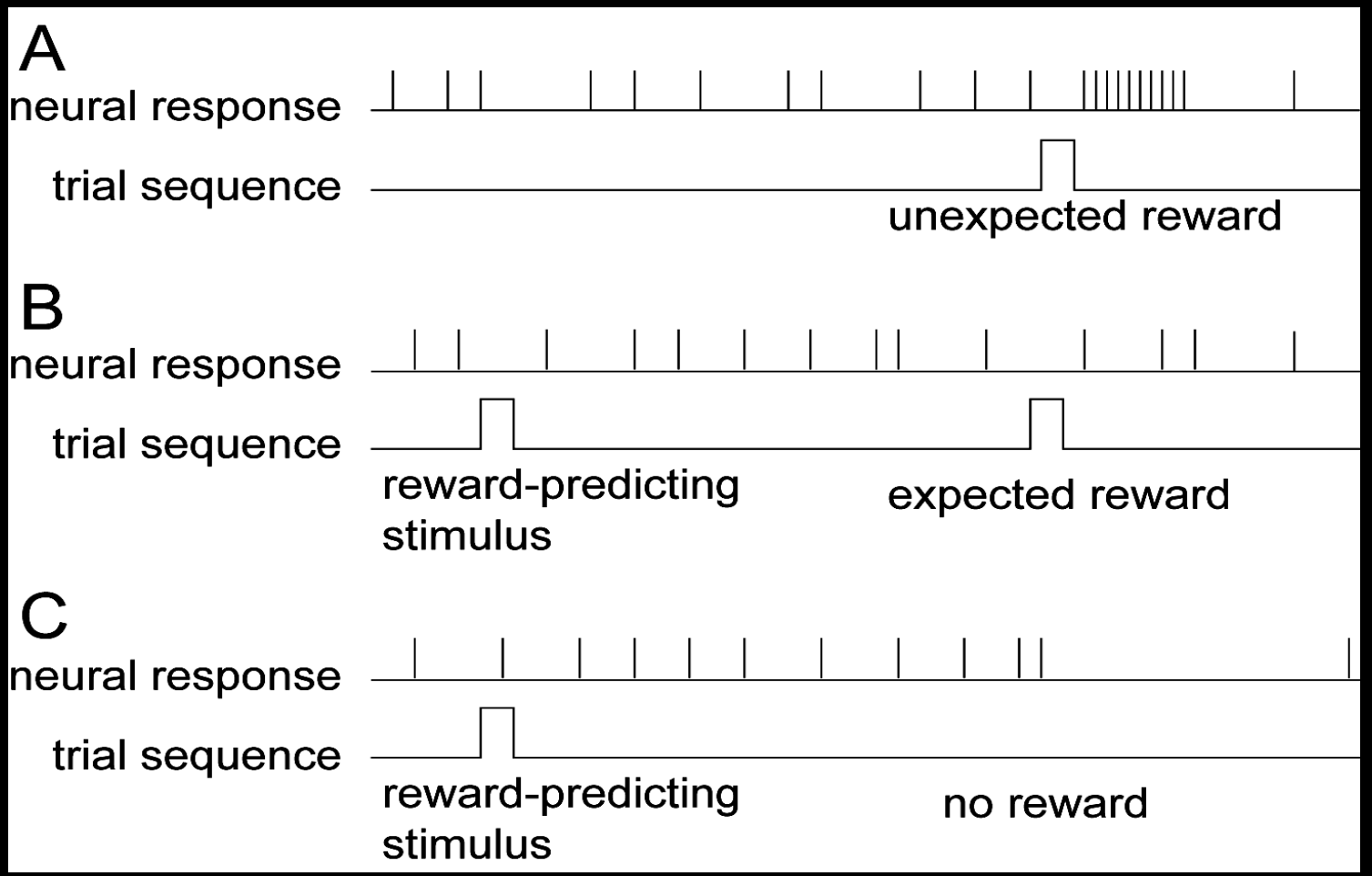
2. Gating the initiation of voluntary movements by modulating motor programs stored in the motor cortex

3. Cognitive functions

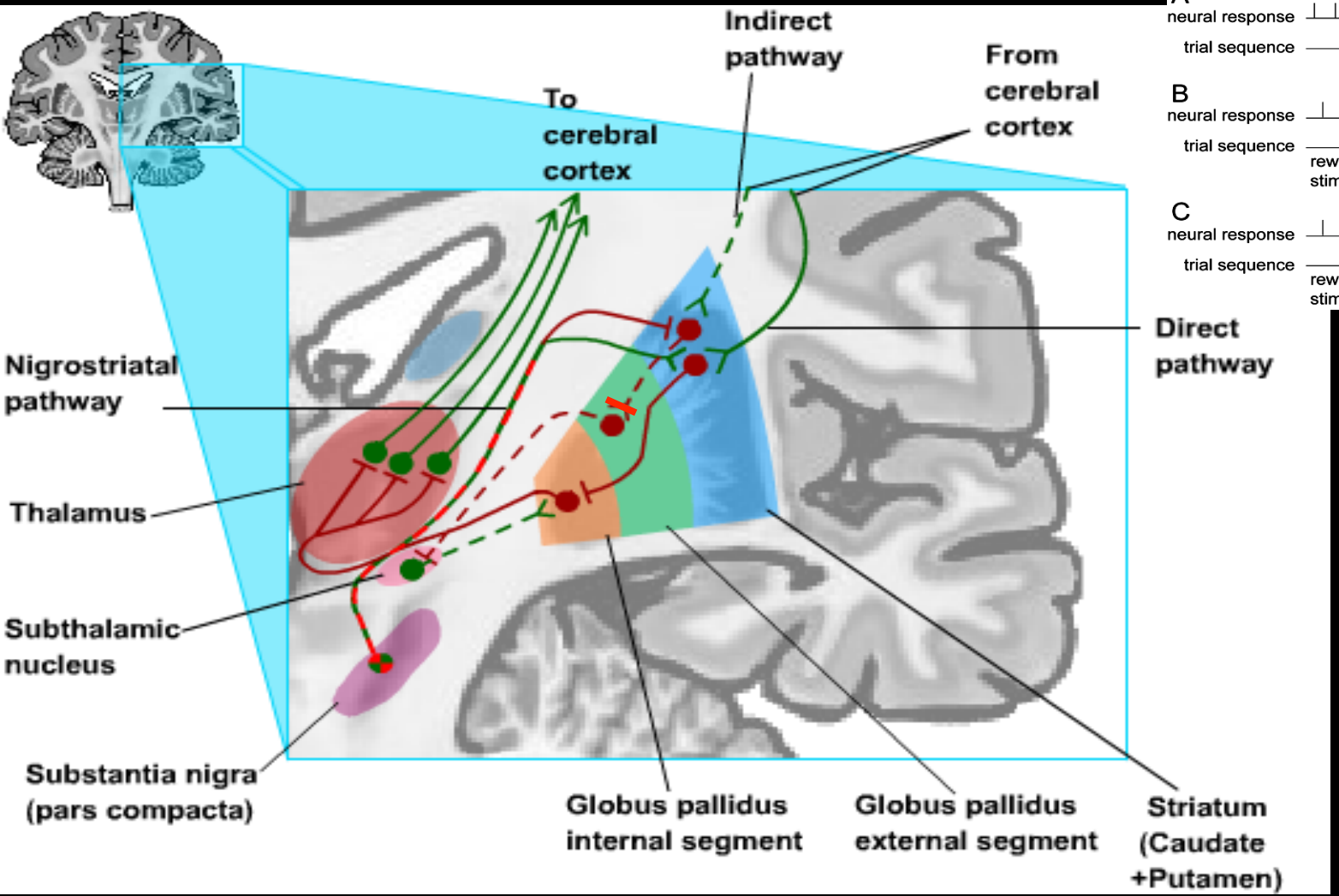
Role of the basal ganglia in exciting one motor program via direct pathway and inhibiting competing programs via indirect pathway

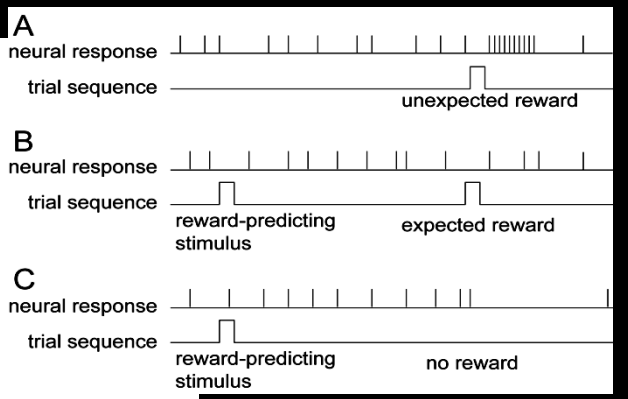


Dopamine neurons of substantia nigra signal unexpected reward or unexpected absence of reward



Dopaminergic Input from Substantia Nigra





Functions of Basal Ganglia

1. Enable automatic performance of practiced motor acts

2. Gating the initiation of voluntary movements by modulating motor programs stored in the motor cortex

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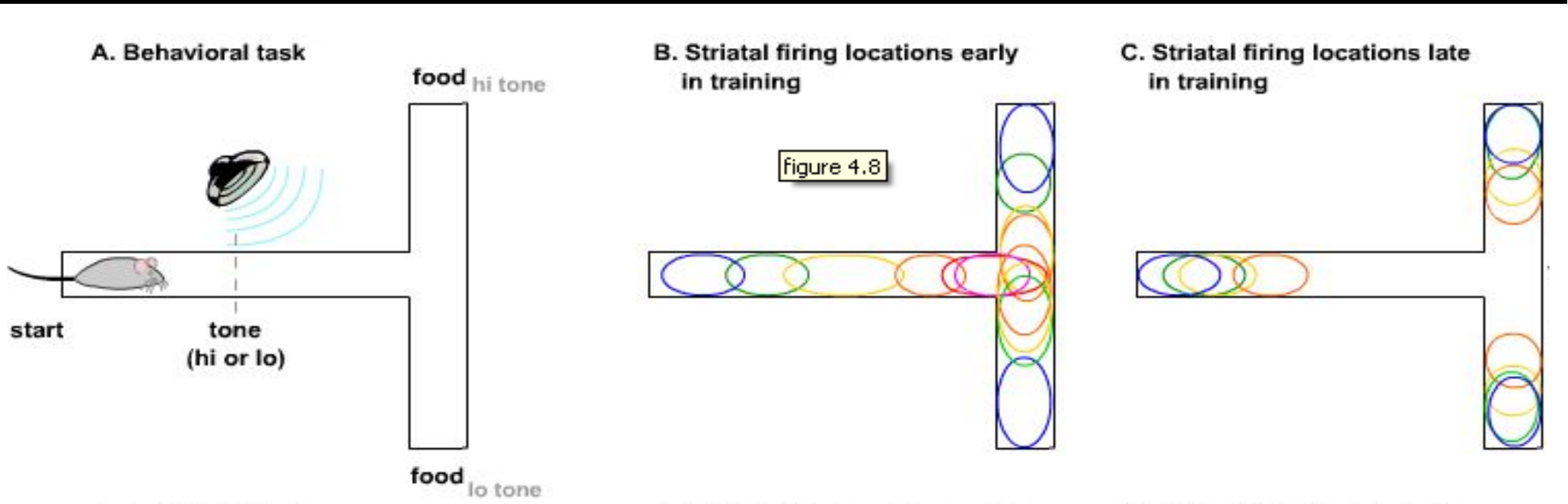
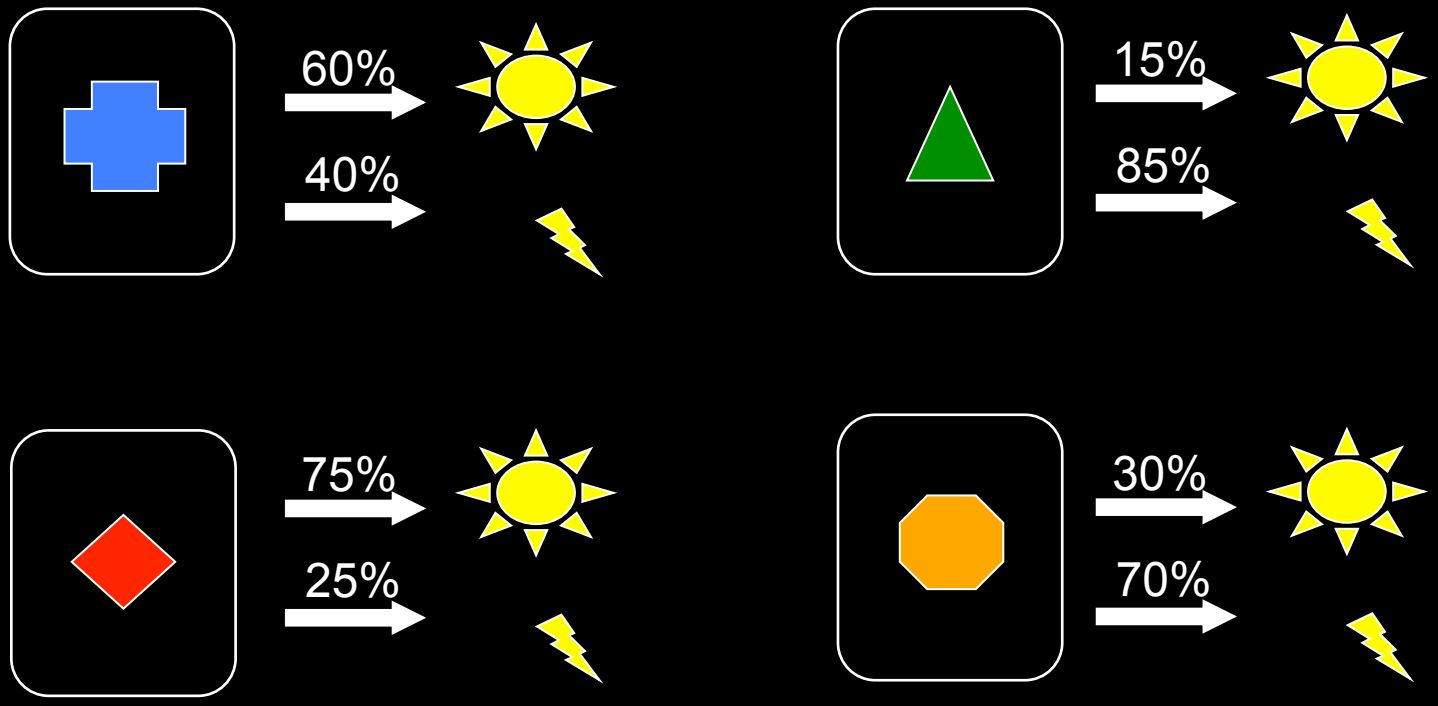
Striatal Neurons and Response/Habit Learning



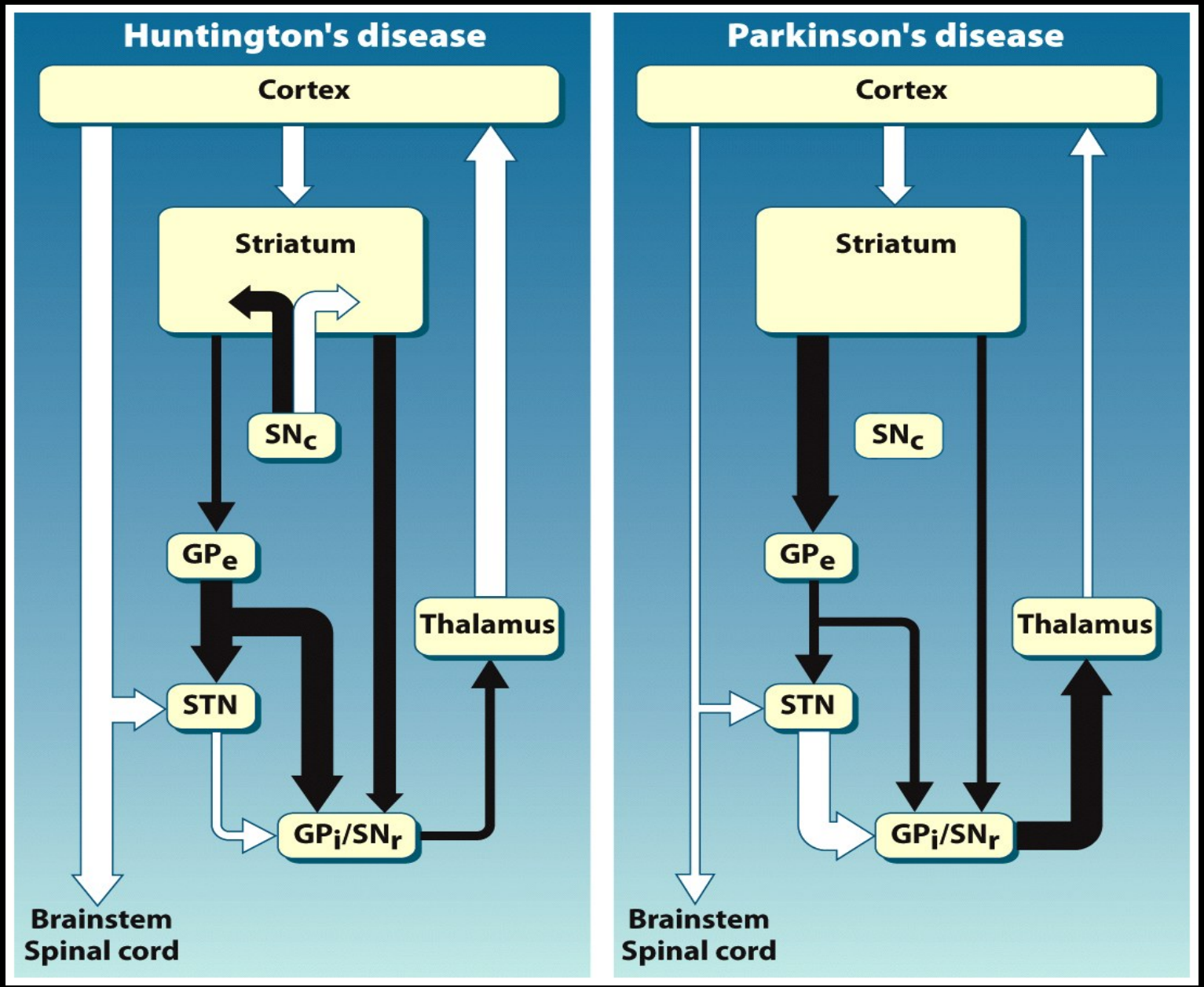
Jog et al. (1999) Building Neural Representations of Habits. *Science* 286: 1745-1749.

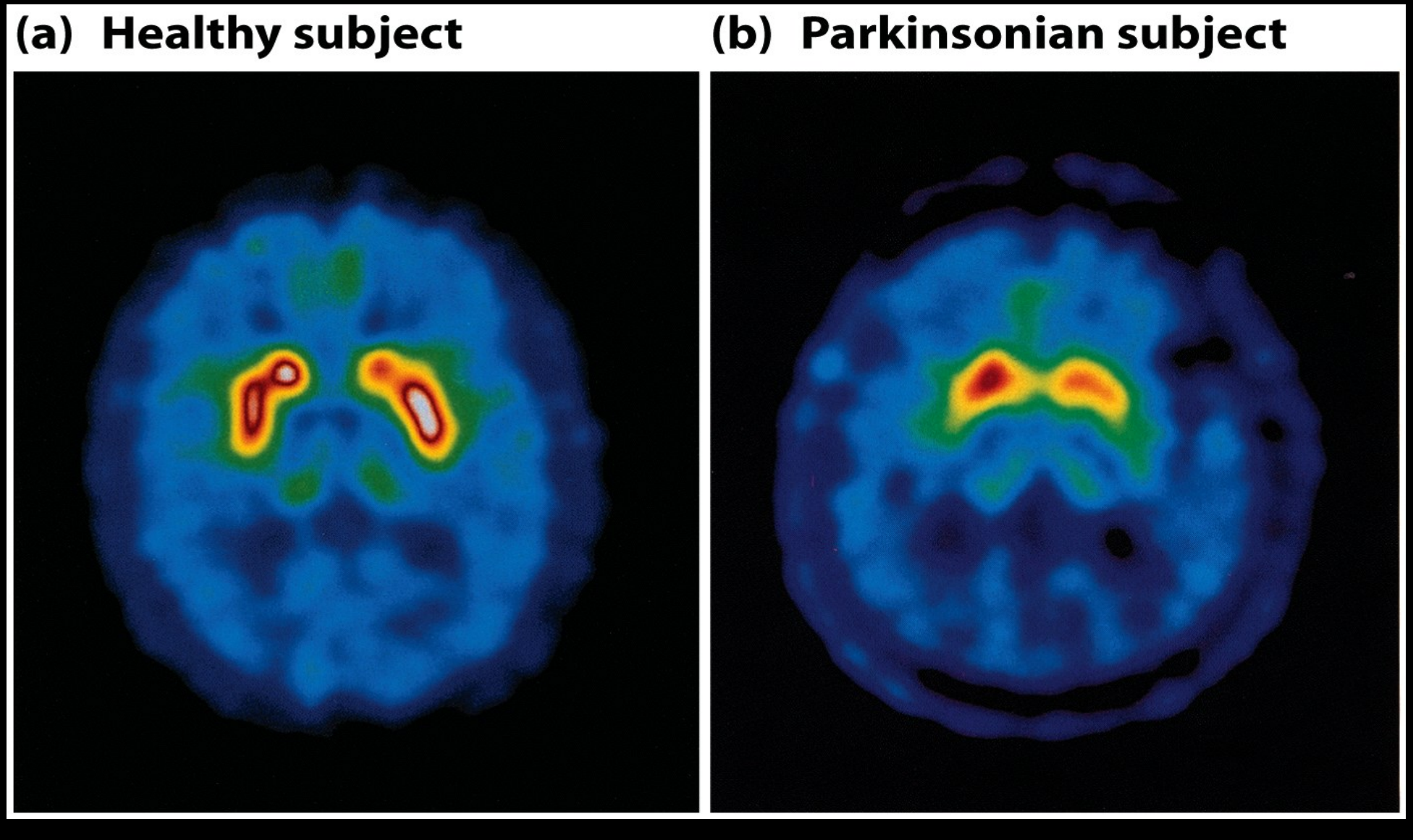
Basal Ganglia Damage Impairs Probabilistic Classification Task

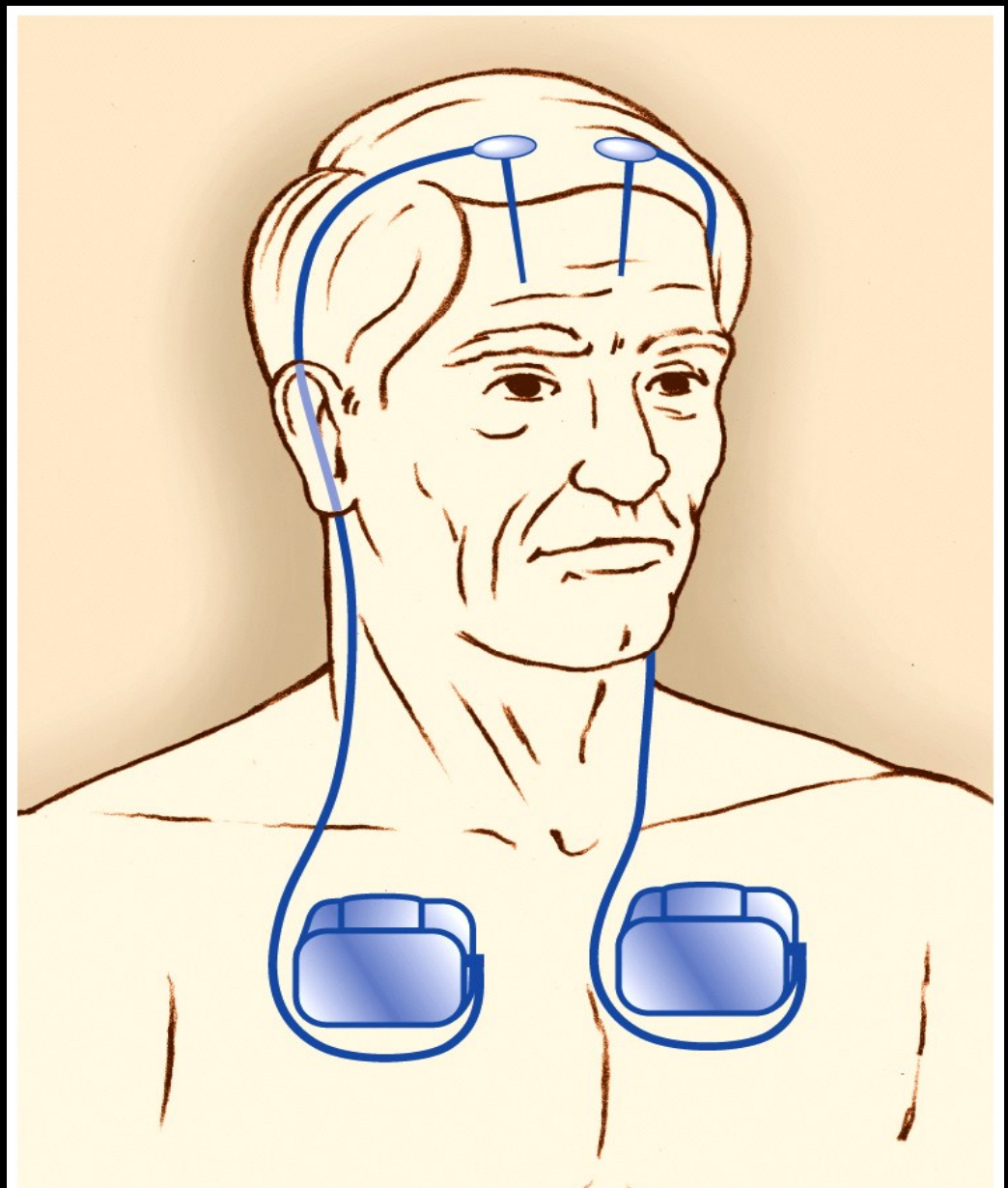


Disorders of Basal Ganglia

1. Huntington's Disease
2. Parkinson's Disease


Huntington's disease
Cortex
Striatum
SNc
GPe
STN
GPi/SNr
Thalamus
Brainstem
Spinal cord
Parkinson's disease
Cortex
Striatum
SNc
GPe
STN
GPi/SNr
Thalamus
Brainstem
Spinal cord


(a) Healthy subject
(b) Parkinsonian subject



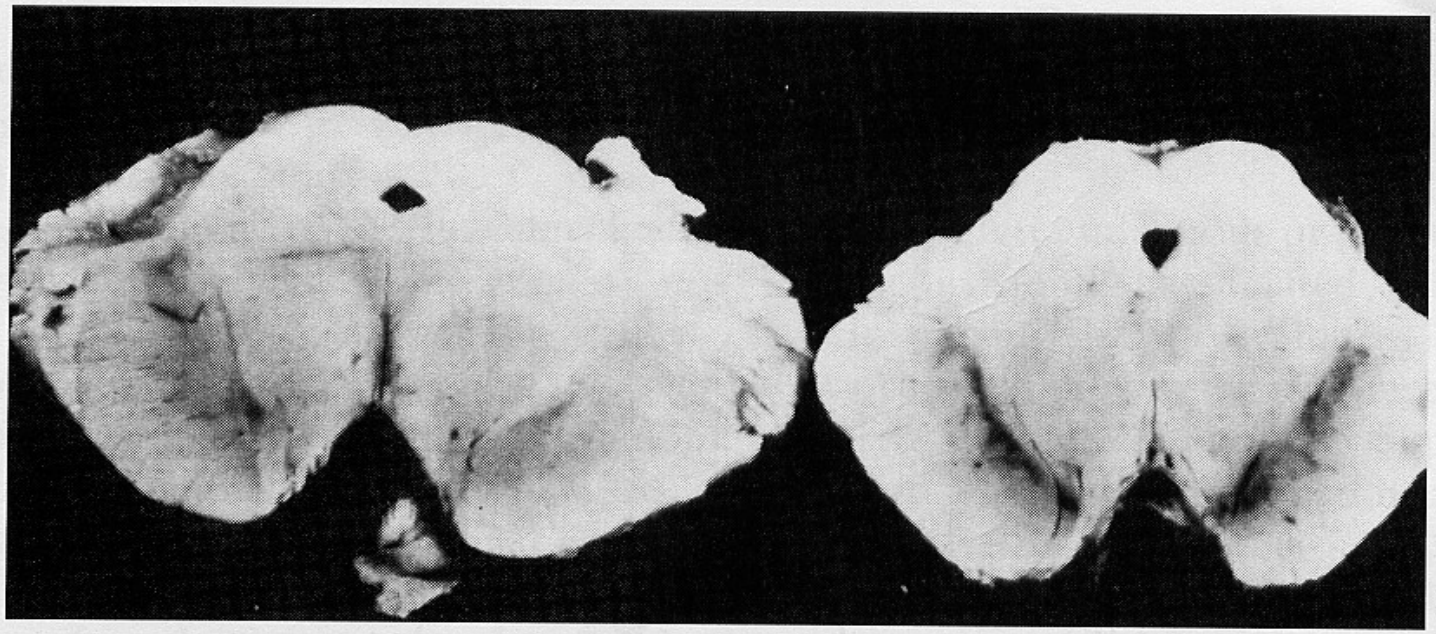
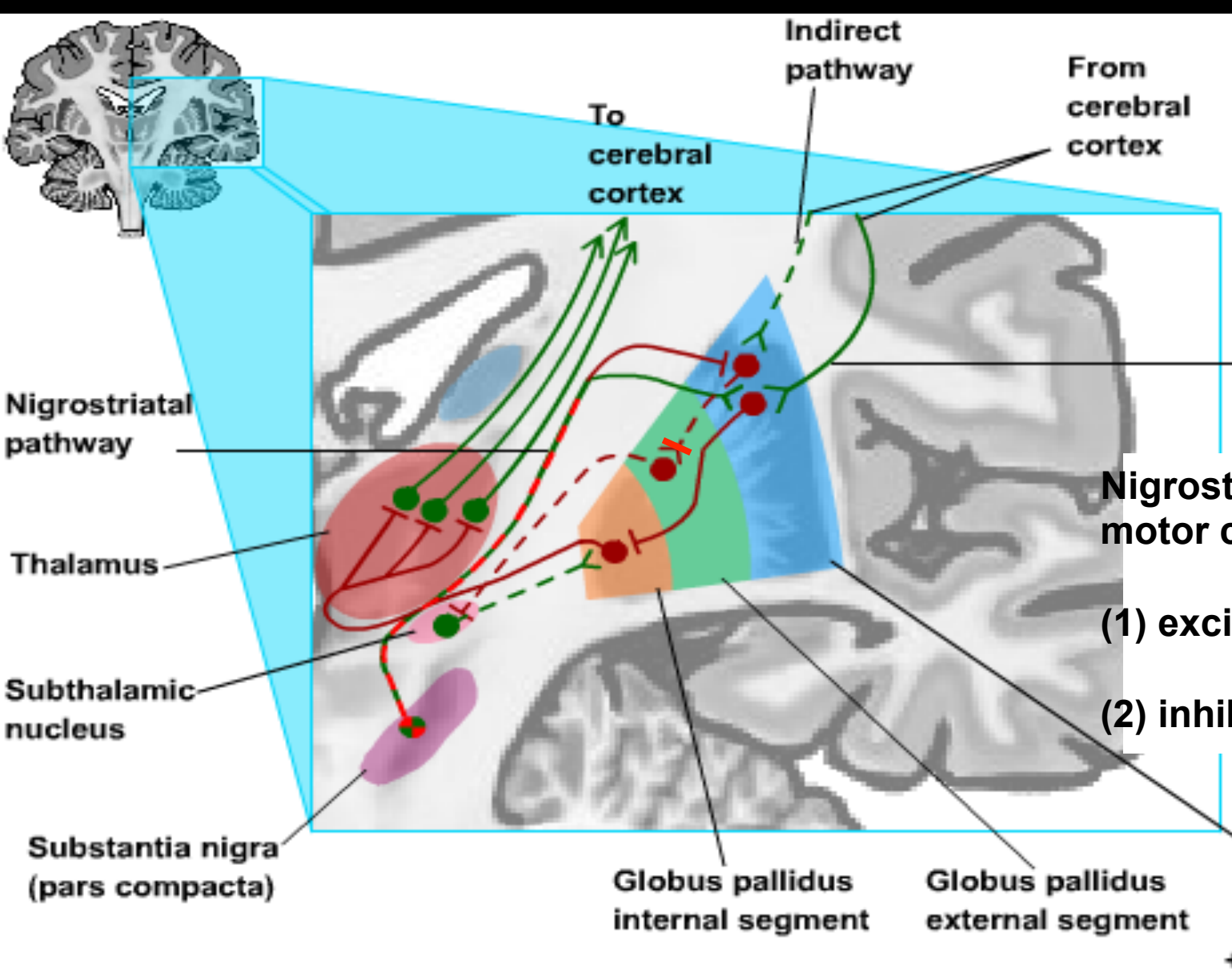


Figure 8.13 Parkinson's disease pathology

From Kingsley RE (2000) *Concise Text of Neuroscience, 2nd Ed.*

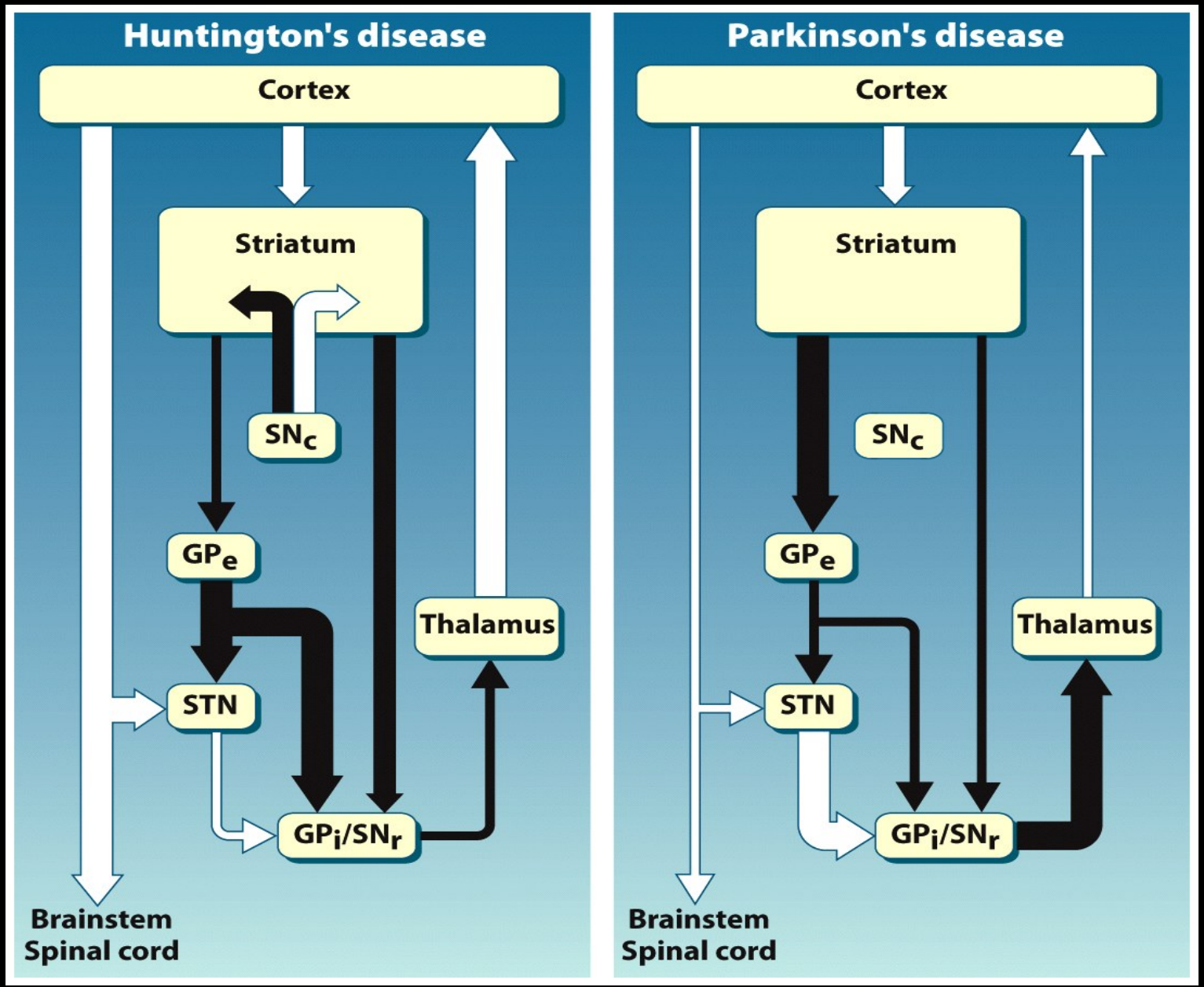
Dopaminergic Input from Substantia Nigra



Nigrostriatal pathway excites motor cortex by

(1) exciting Direct Pathway

(2) inhibiting Indirect Pathway


Huntington's disease
Cortex
Striatum
SNc
GPe
STN
GPi/SNr
Thalamus
Brainstem
Spinal cord
Parkinson's disease
Cortex
Striatum
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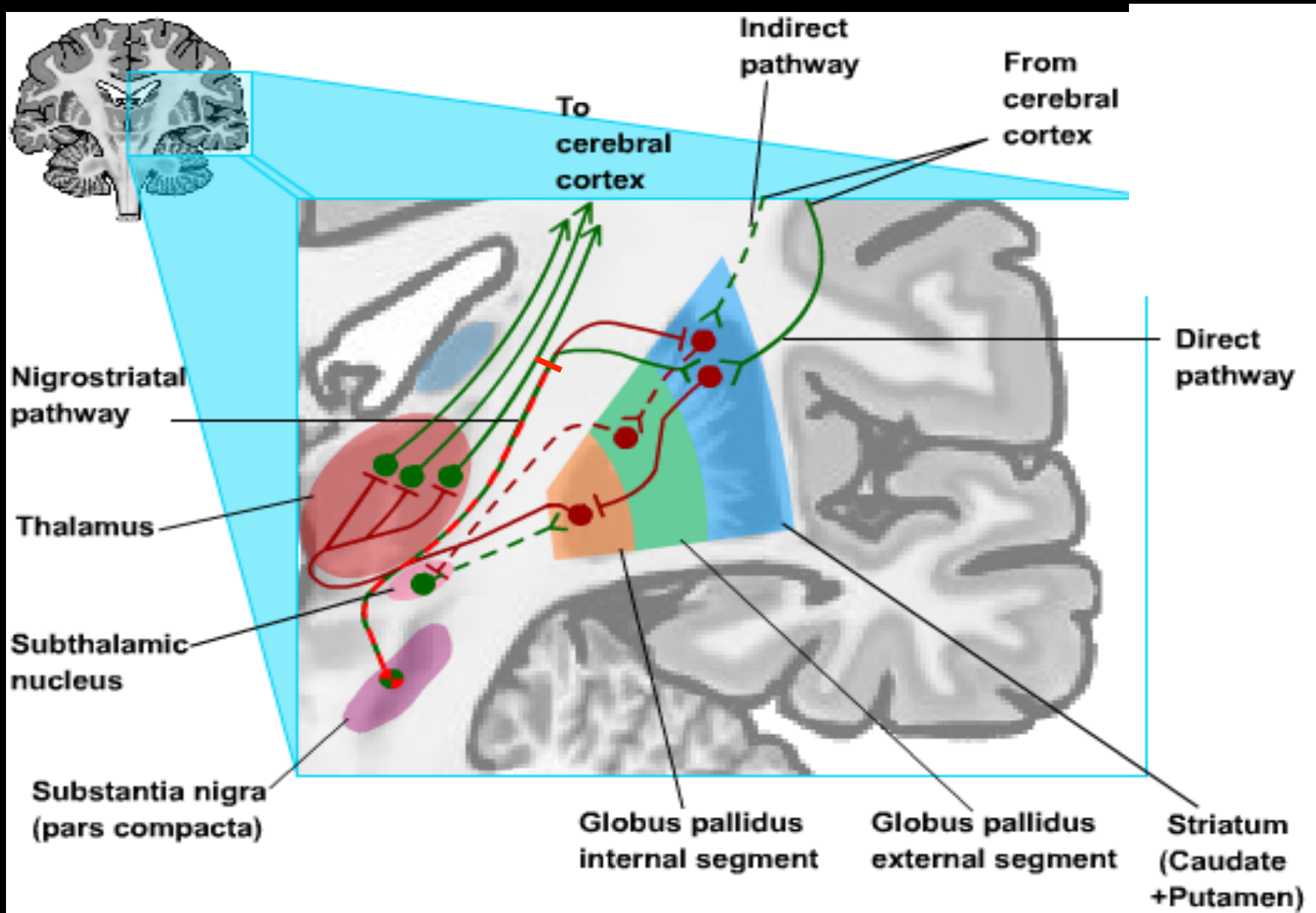
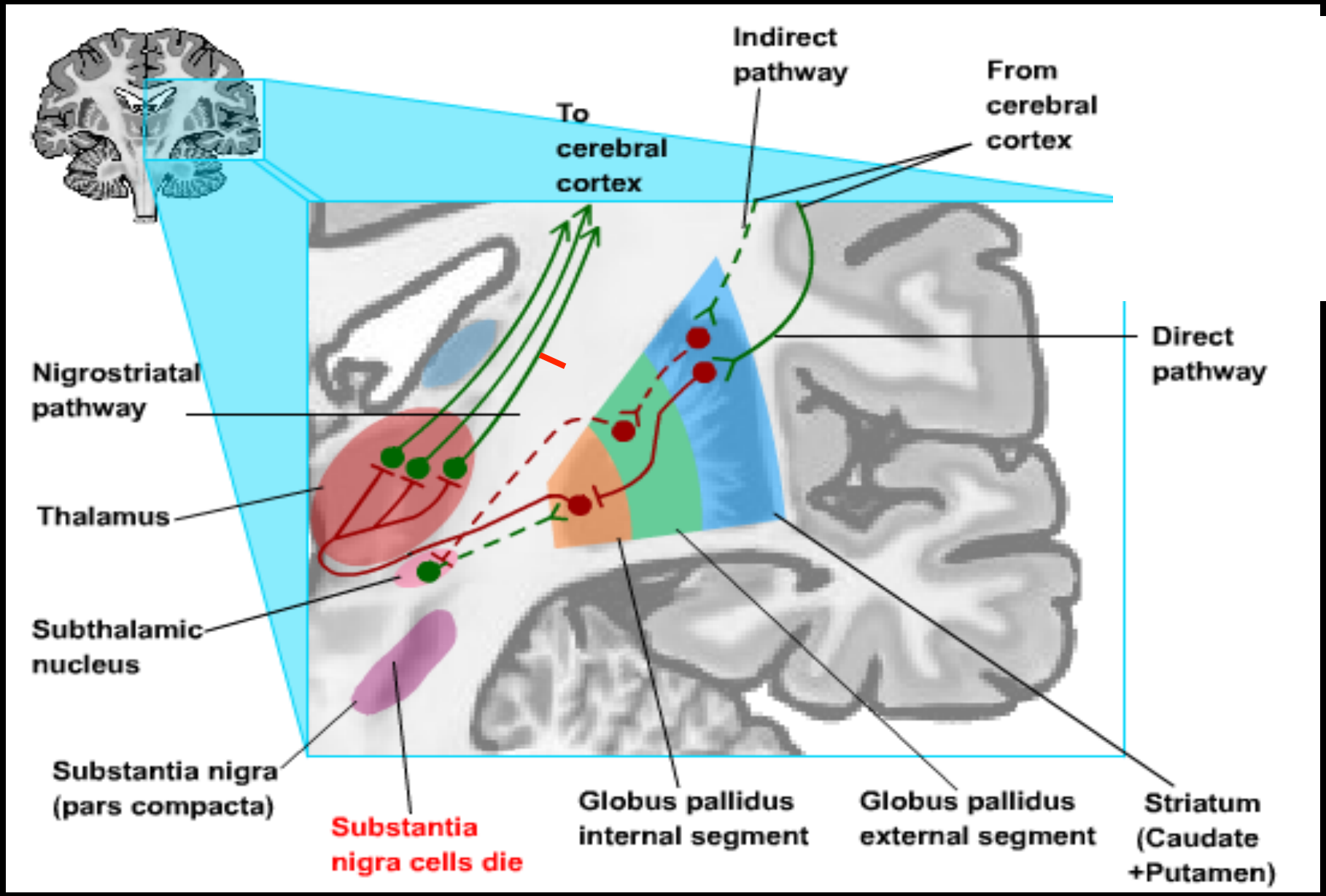
GPe
STN
GPi/SNr
Thalamus
Brainstem
Spinal cord

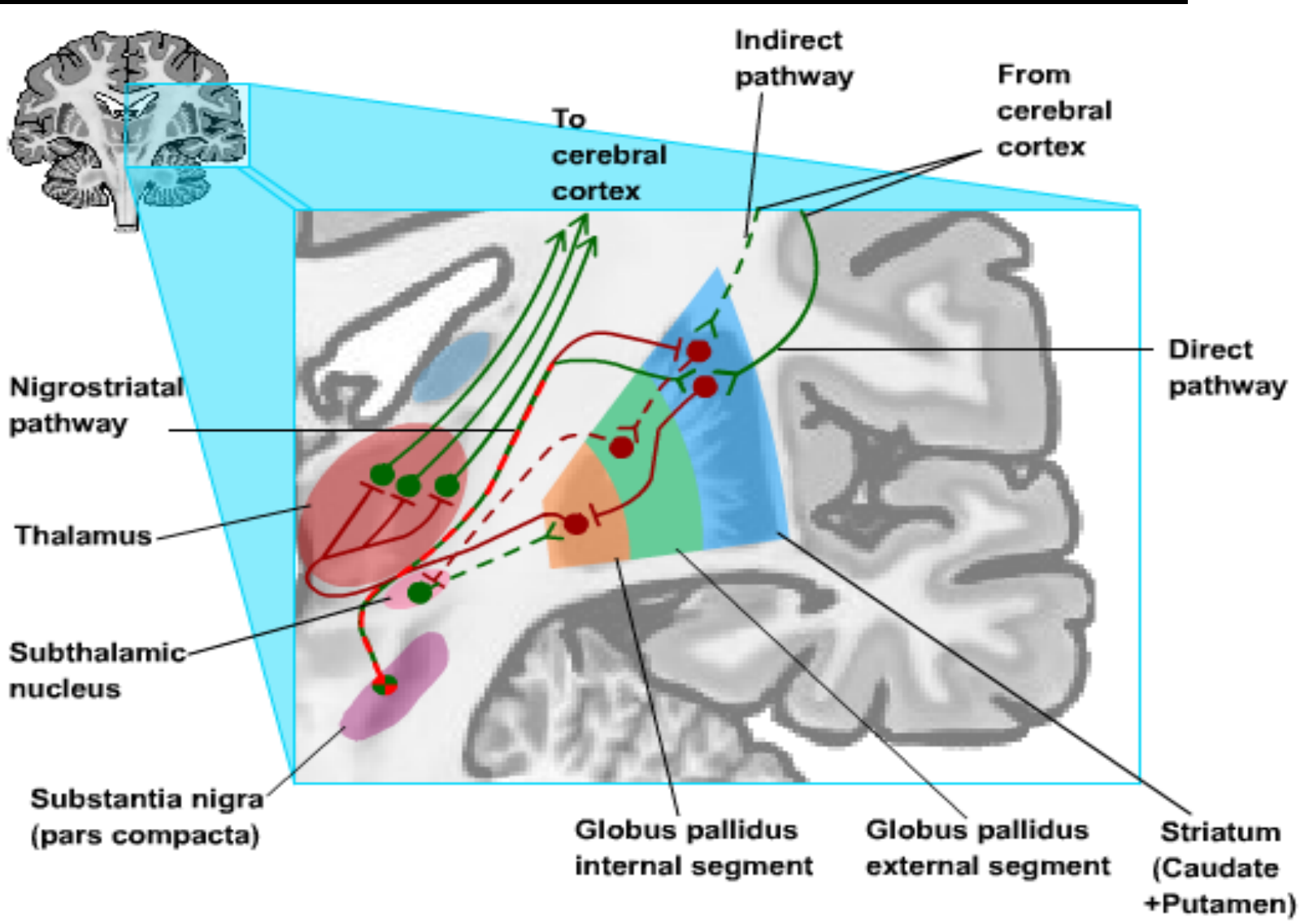
Parkinson's Disease



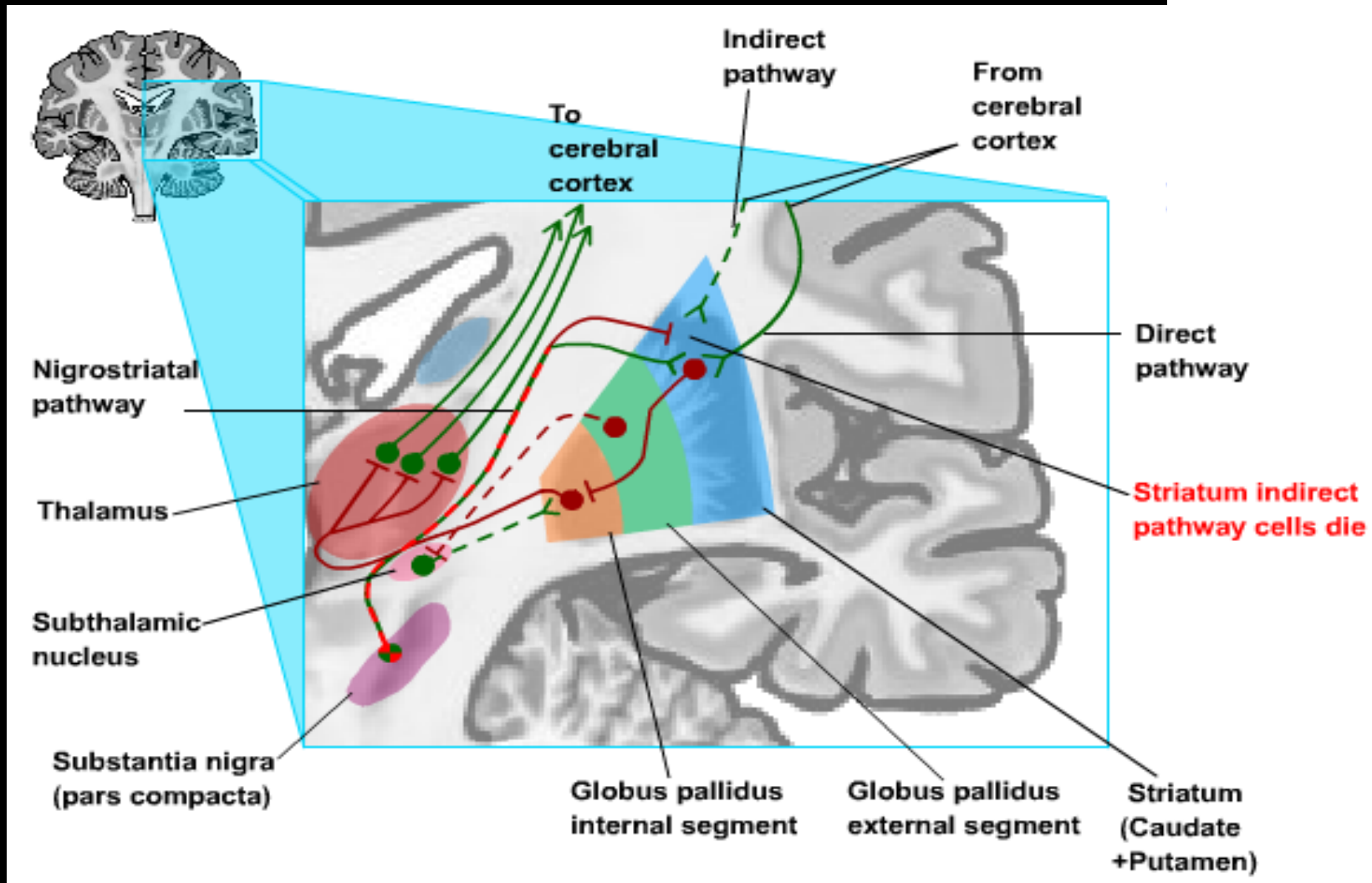
Parkinson's Disease

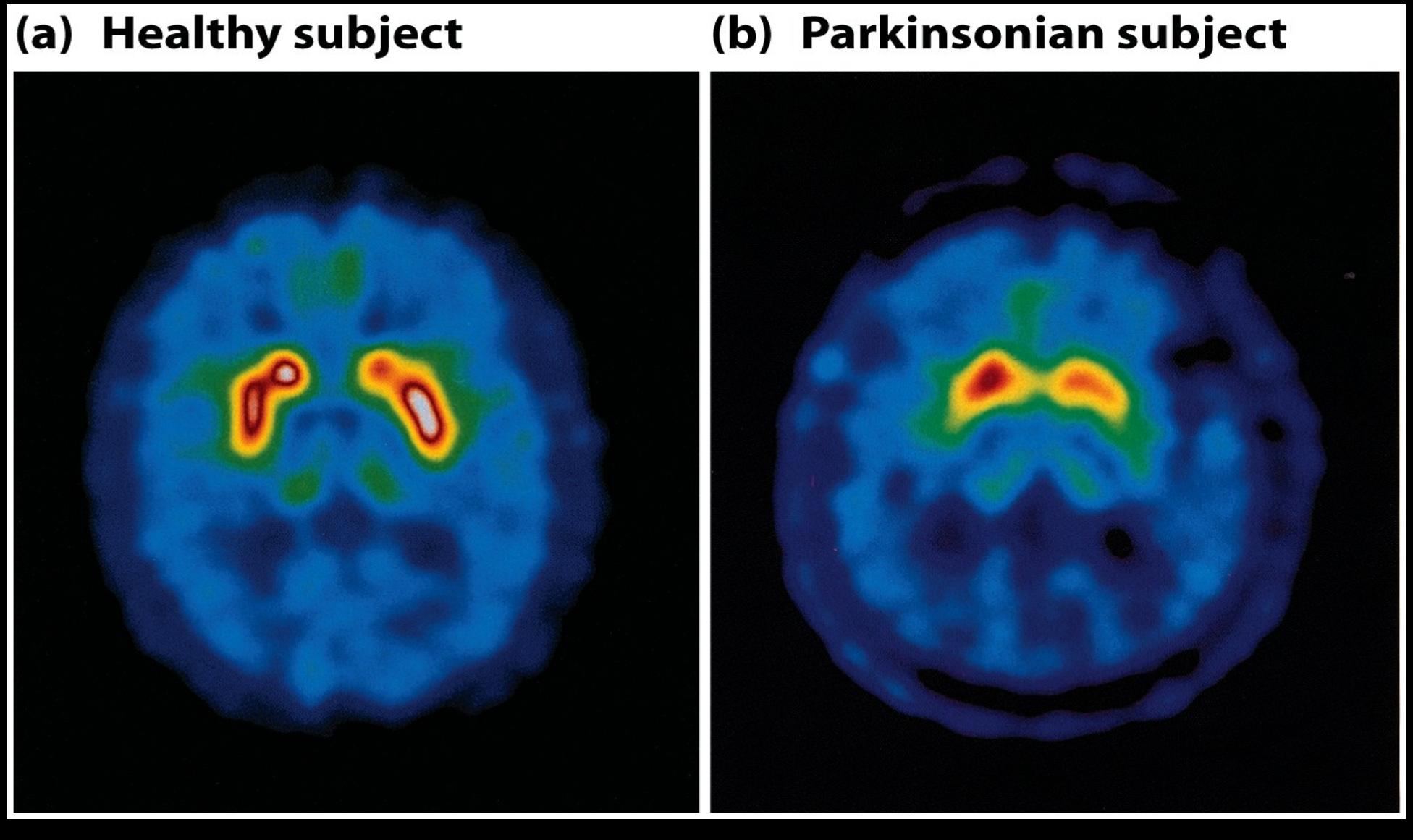


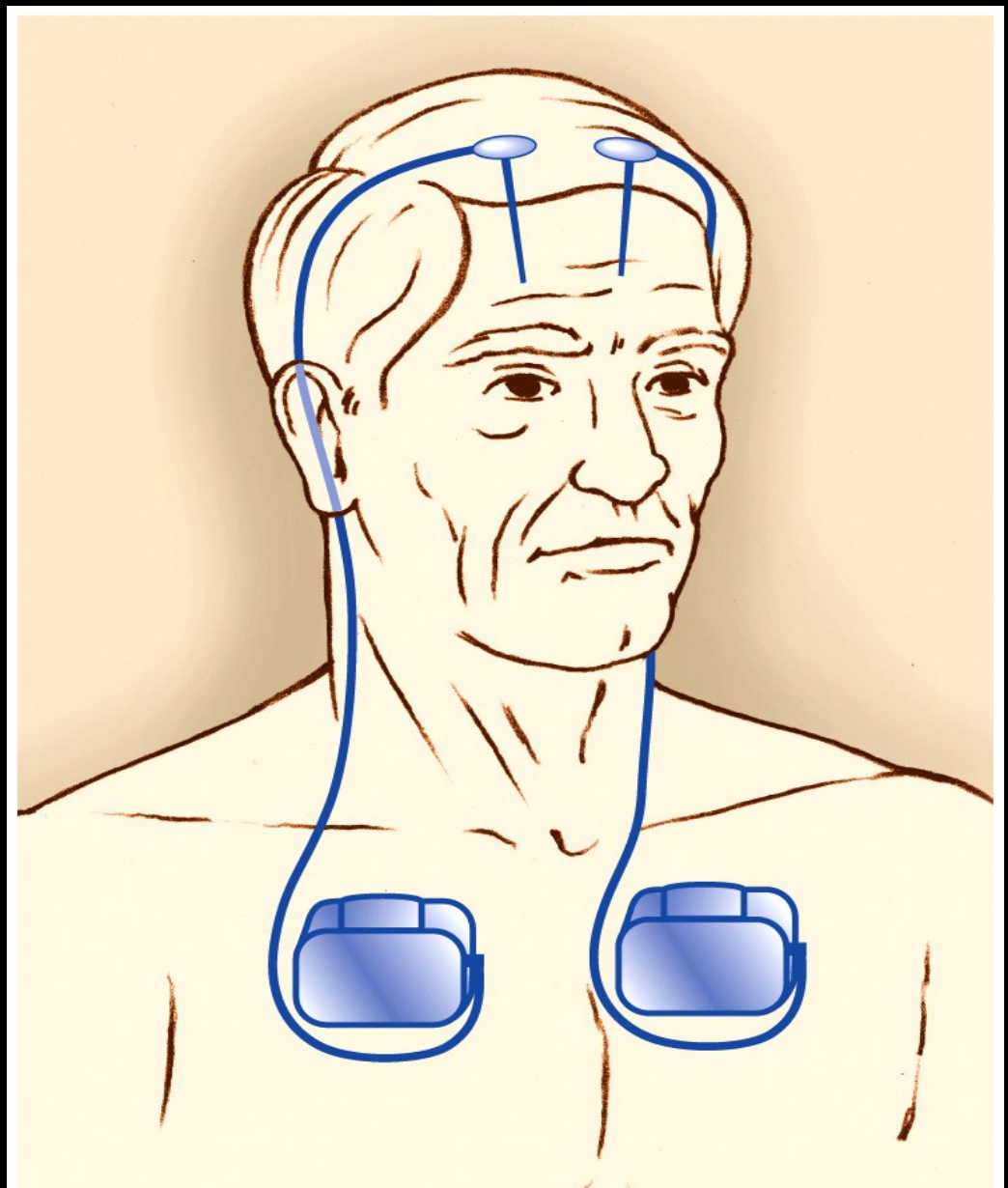
Huntington's Disease



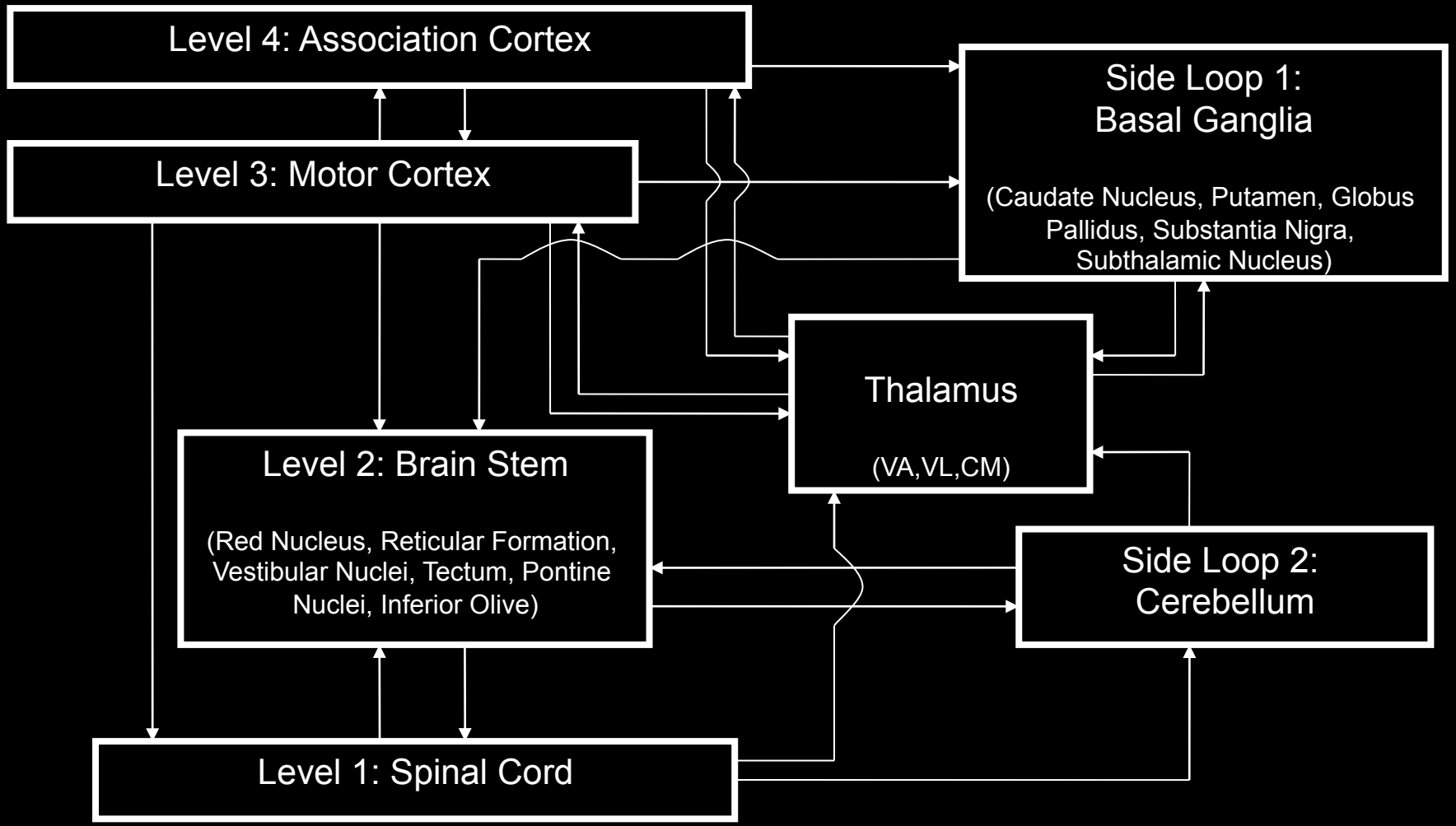
Huntington's Disease

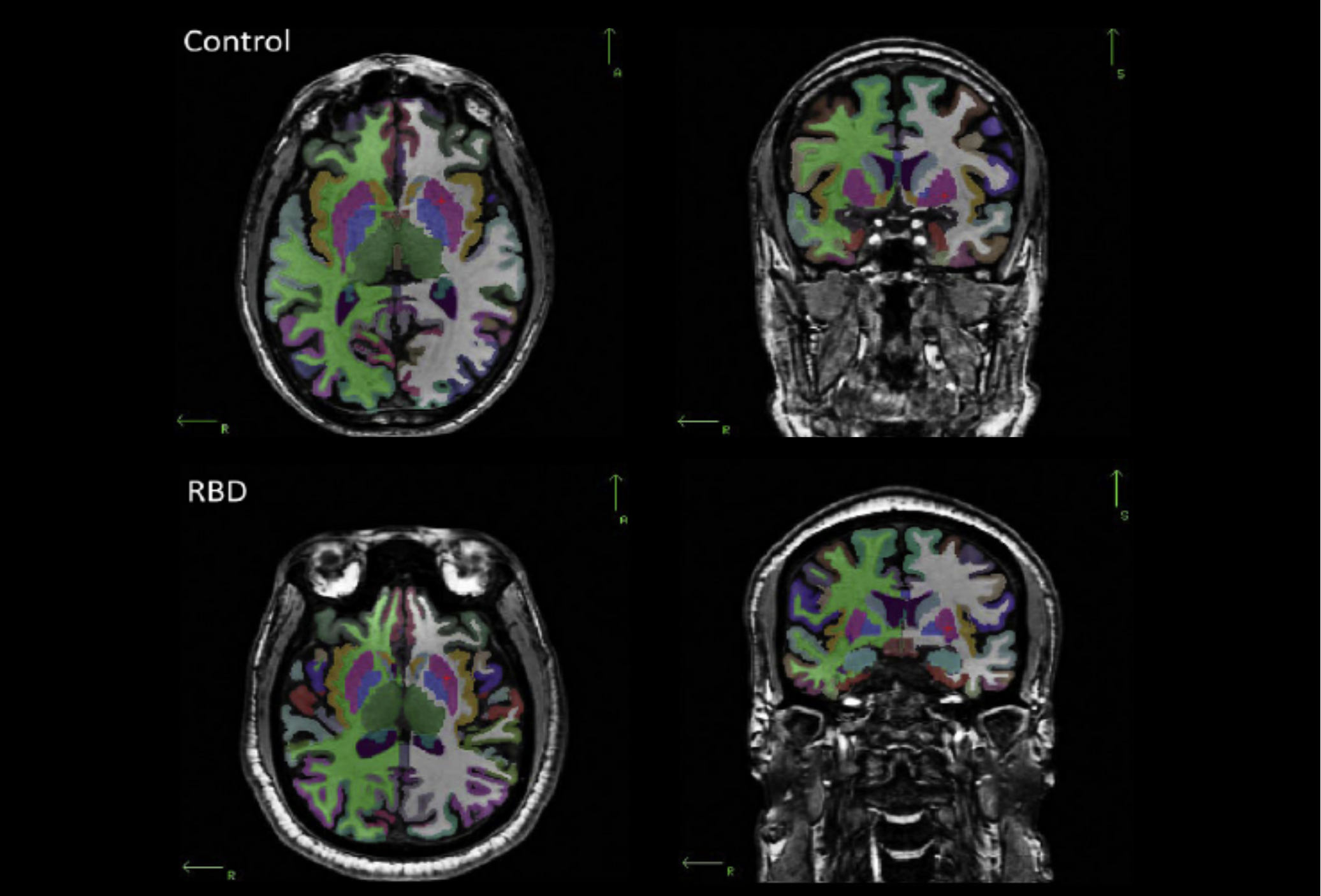



(a) Healthy subject
(b) Parkinsonian subject



Hierarchical Organization and Functional Segregation of Central Motor Structures




Control
A
R
S
R
RBD
A
R
S
R

Decreased Putamen Volumes in RBD

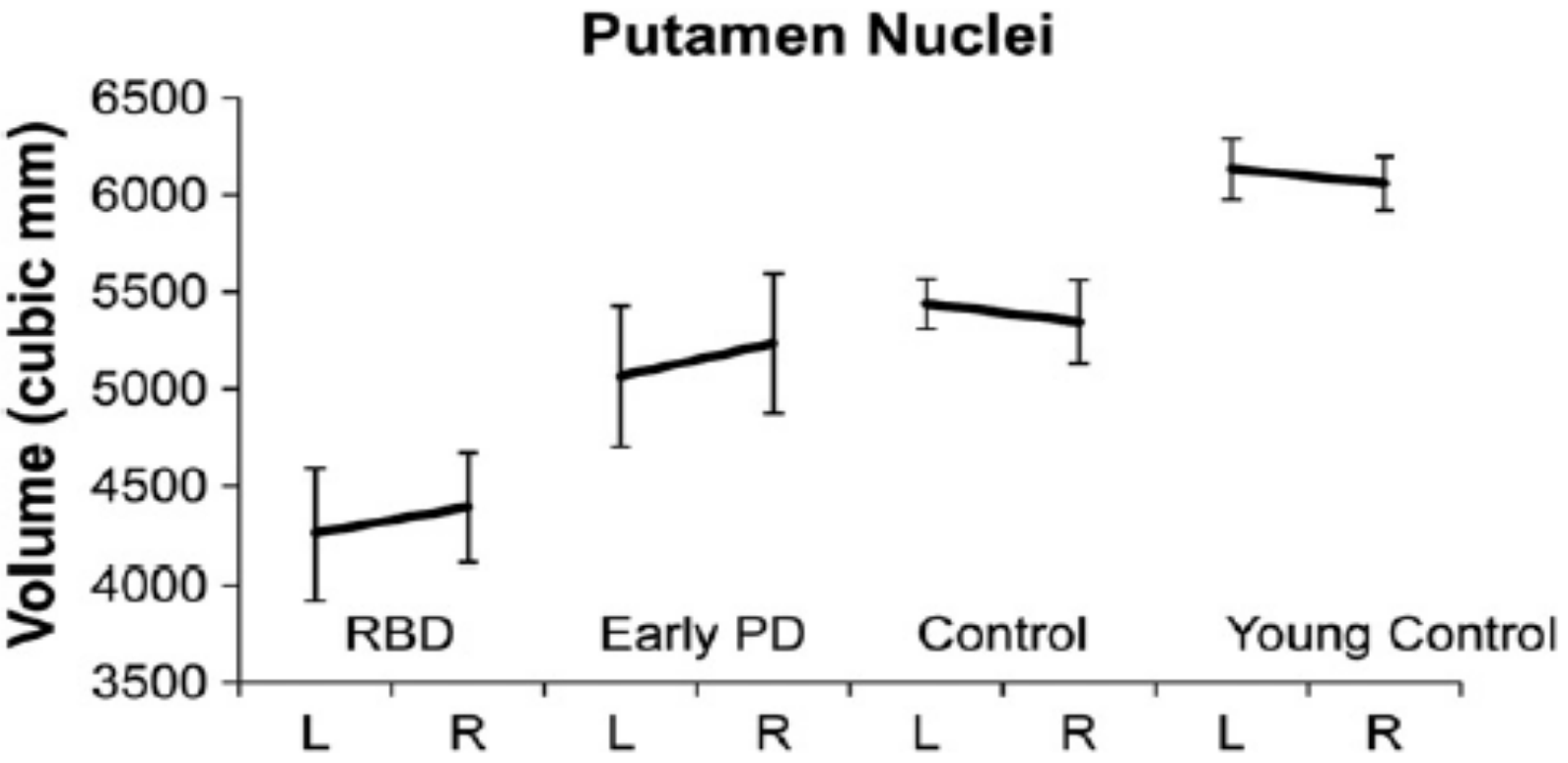
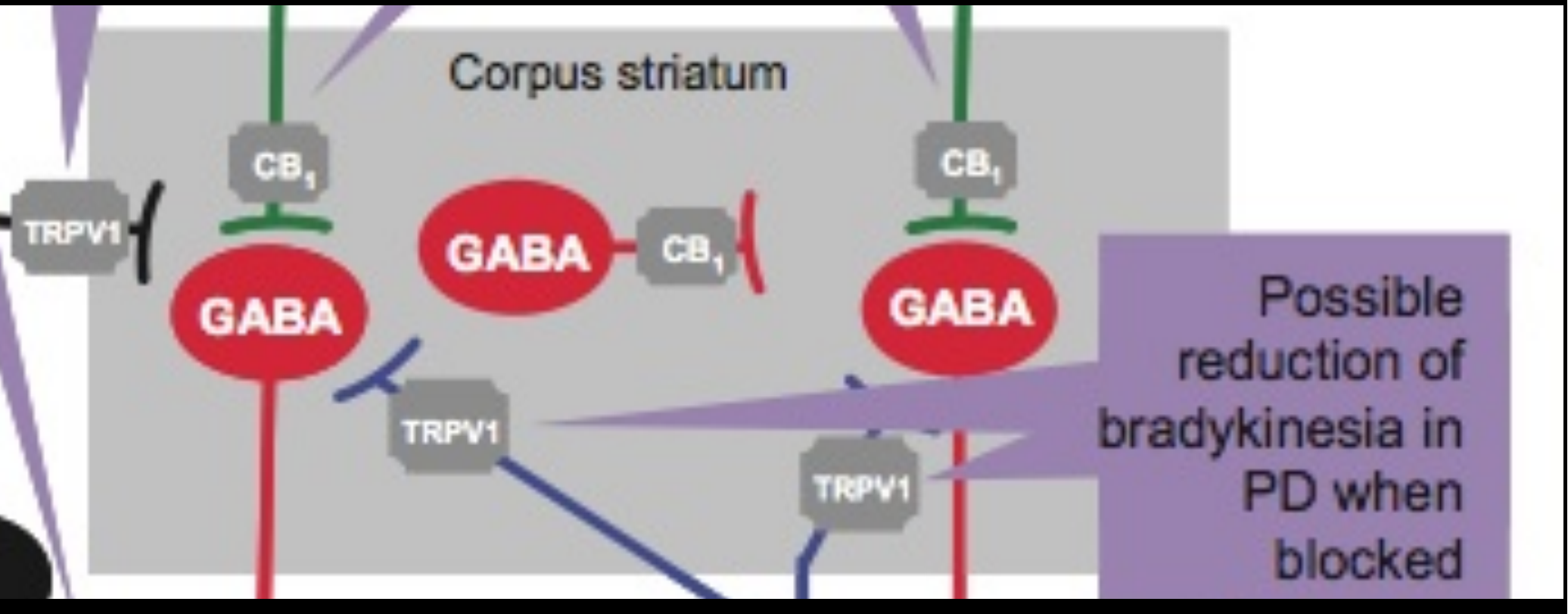
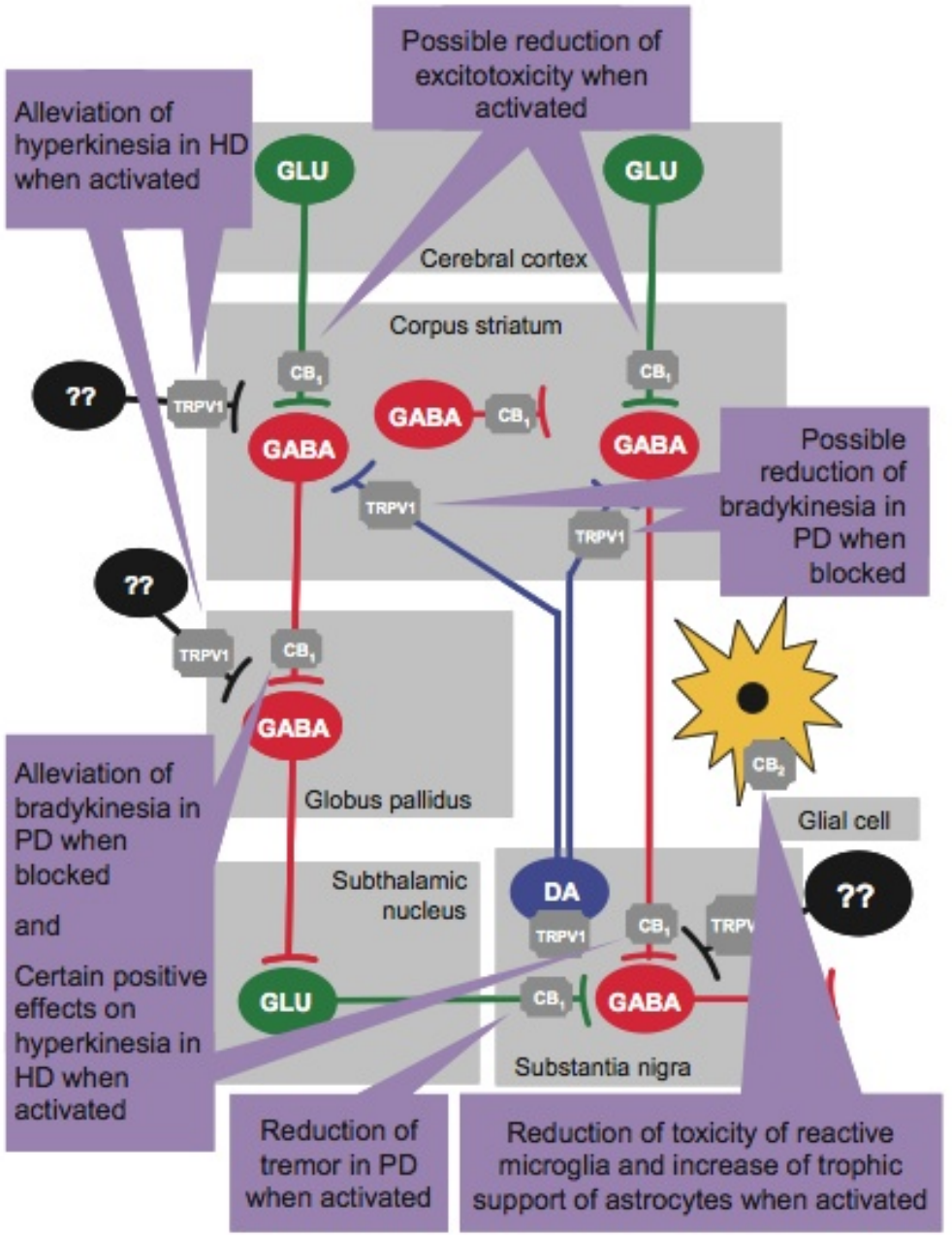


Fig. 3. Putamen Nuclei Volumes. Illustrated are raw left (L) and right (R) putamen volumes (mm^3) for each group. The RBD group had reduced volumes compared to the other groups. Data are displayed as mean (sem).

Ellmore, T.M., Hood, A.J., Castriotta, R.J., Stimming, E.F., Bick, R.J., Schiess, M.C., 2010.
Reduced volume of the putamen in REM sleep behavior disorder patients.
Parkinsonism Relat Disord 16, 645-649.


Corpus striatum
CB1
CB1
TRPV1
GABA
GABA
CB1
GABA
TRPV1
TRPV1
Possible reduction of bradykinesia in PD when blocked


Possible reduction of excitotoxicity when activated
Alleviation of hyperkinesia in HD when activated
GLU
GLU
Cerebral cortex
Corpus striatum
??
TRPV1
CB1
GABA
CB1
GABA
CB1
GABA
Possible reduction of bradykinesia in PD when blocked
TRPV1
TRPV1
??
TRPV1
CB1
GABA
Globus pallidus
CB2
Glial cell
Alleviation of bradykinesia in PD when blocked
and
Certain positive effects on hyperkinesia in HD when activated
Subthalamic nucleus
DA
TRPV1
CB1
??
GLU
CB1
GABA
Substantia nigra
Reduction of tremor in PD when activated
Reduction of toxicity of reactive microglia and increase of trophic support of astrocytes when activated