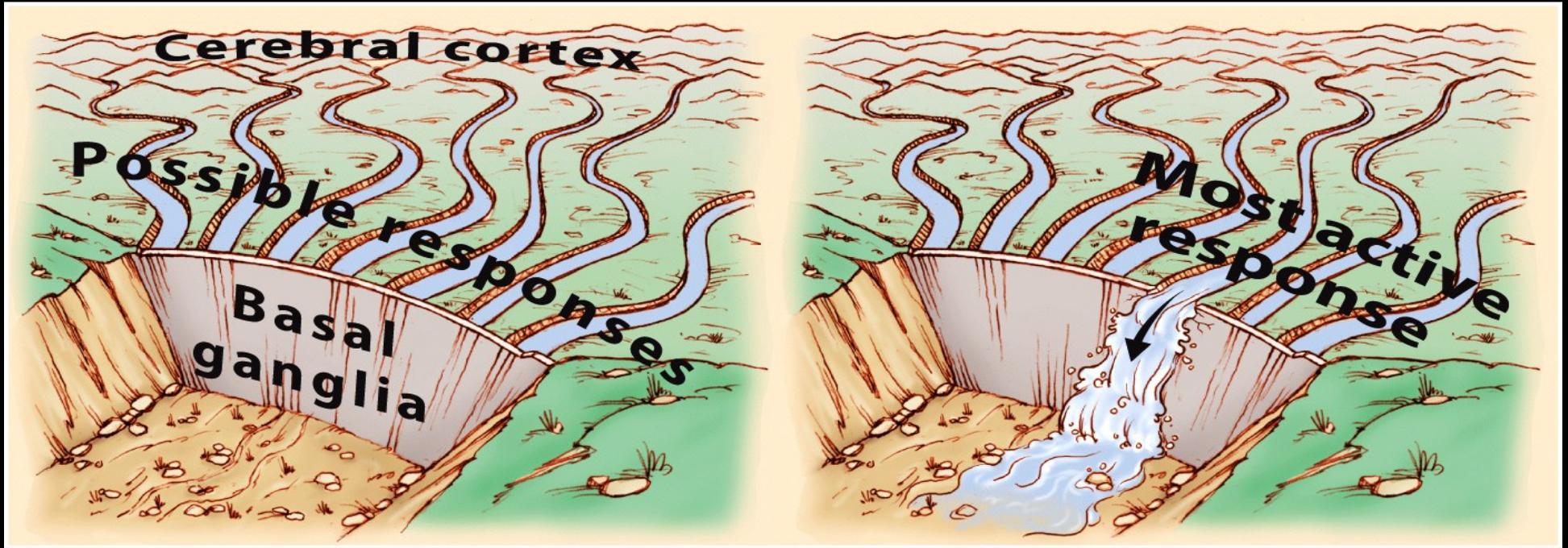


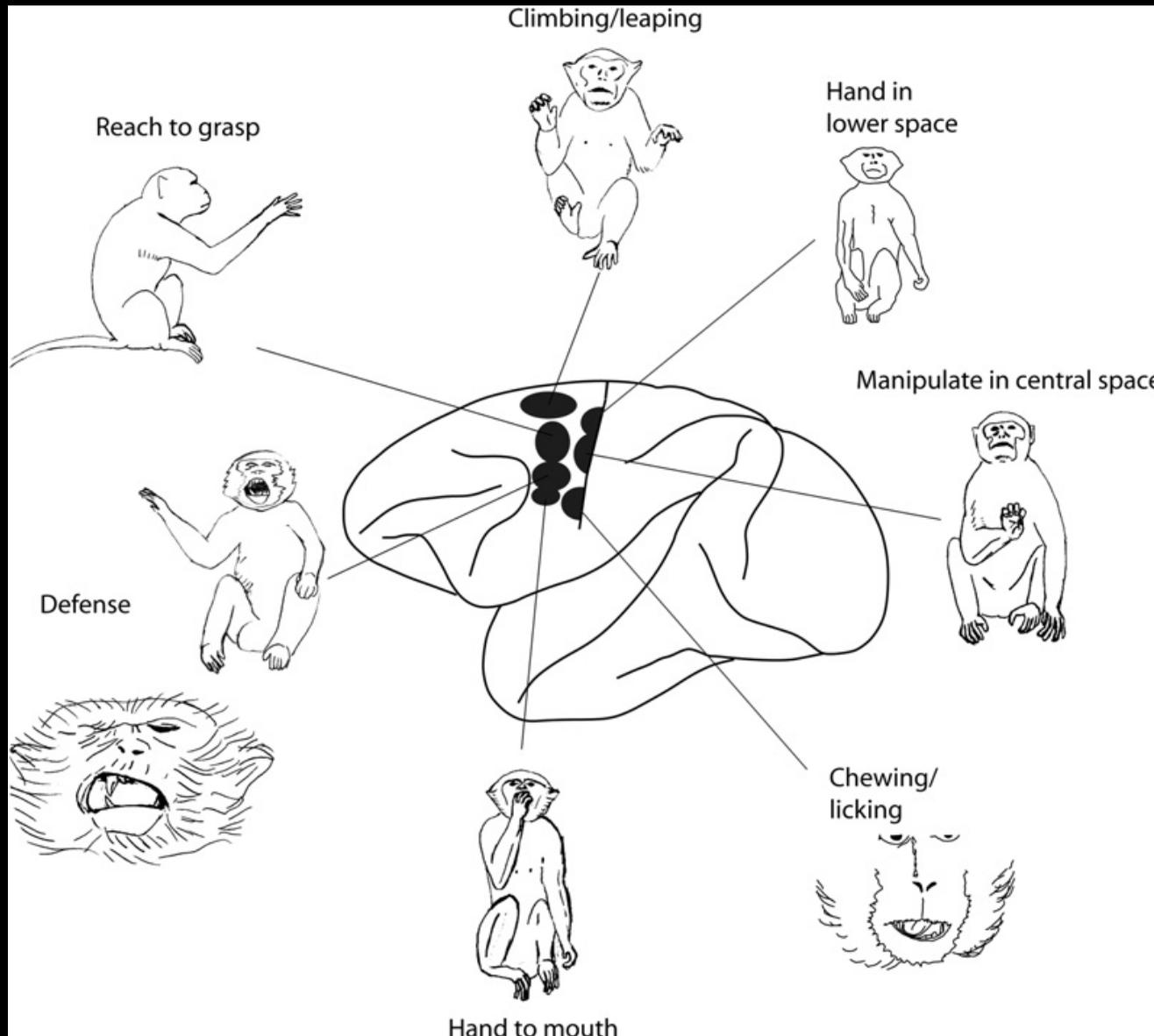
Integrated Motor Systems

Michael S. Beauchamp, Ph.D.
Department of Neurobiology and Anatomy
University of Texas Health Science Center at
Houston
Houston, TX

Michael.S.Beauchamp@uth.tmc.edu



Action Zones



Aflalo & Graziano,
Neuron, 2007

It's the one
you use
the most!
RIGHT!
DEPENDABLE
you know
works!



VOTE
RIGHT!

LEFT!
It's closer!
NEAR!
Conve
EA
CLOSE!
Try it!
EASY
LEFT!



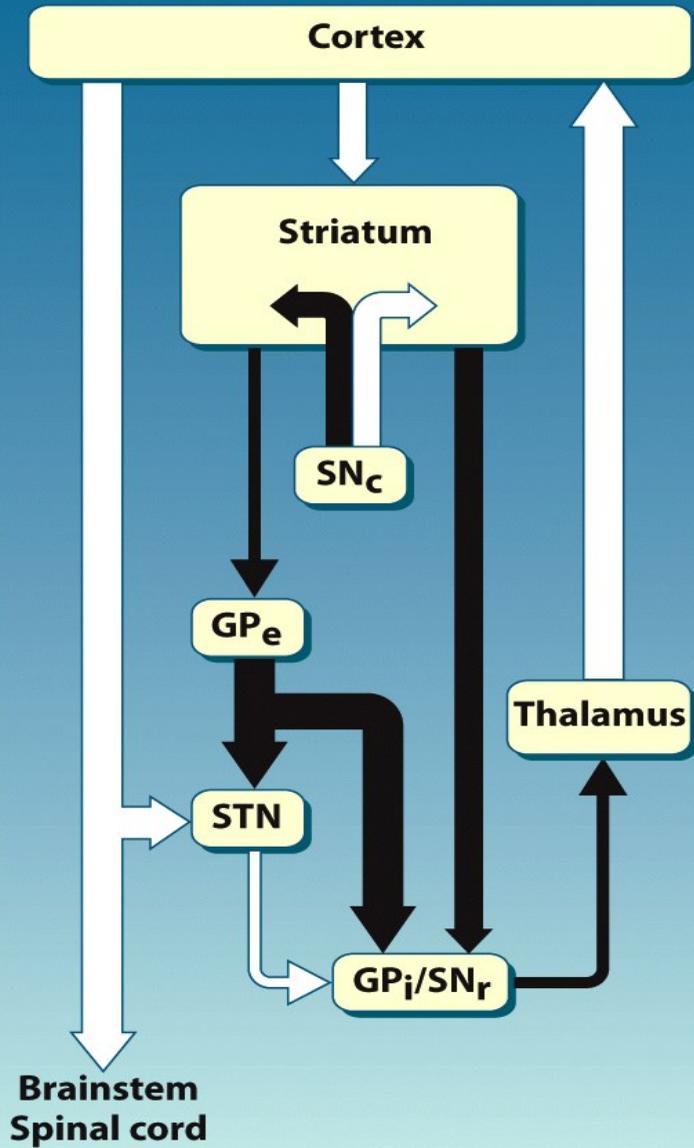
VOTE
LEFT!



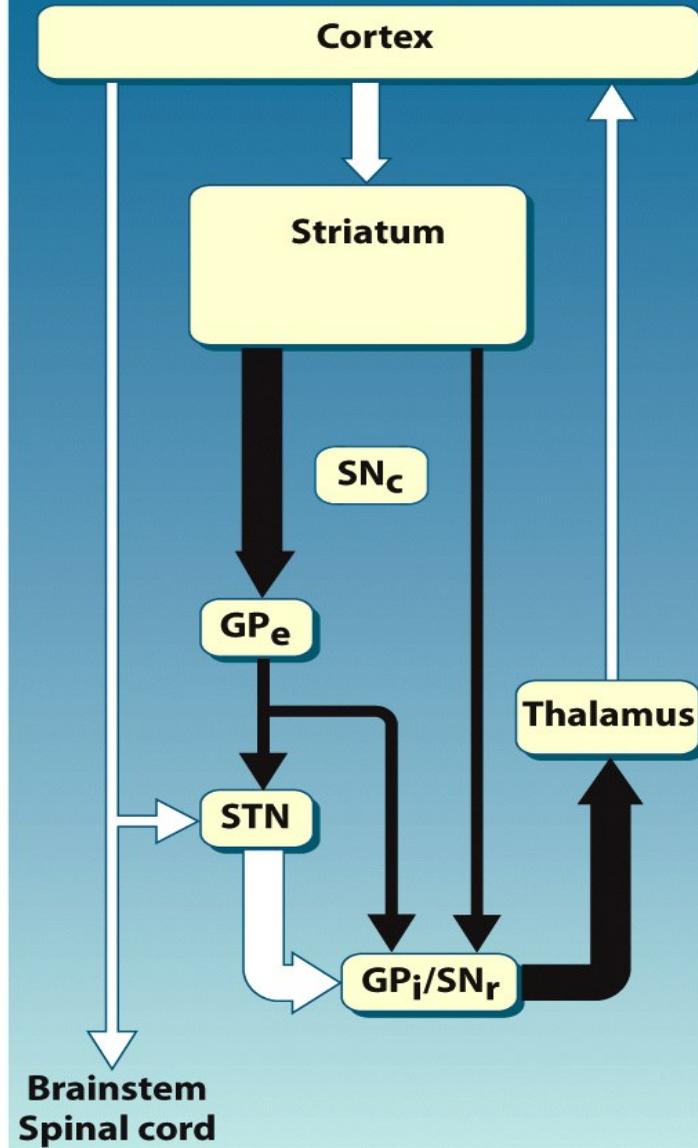
Disorders of Basal Ganglia

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

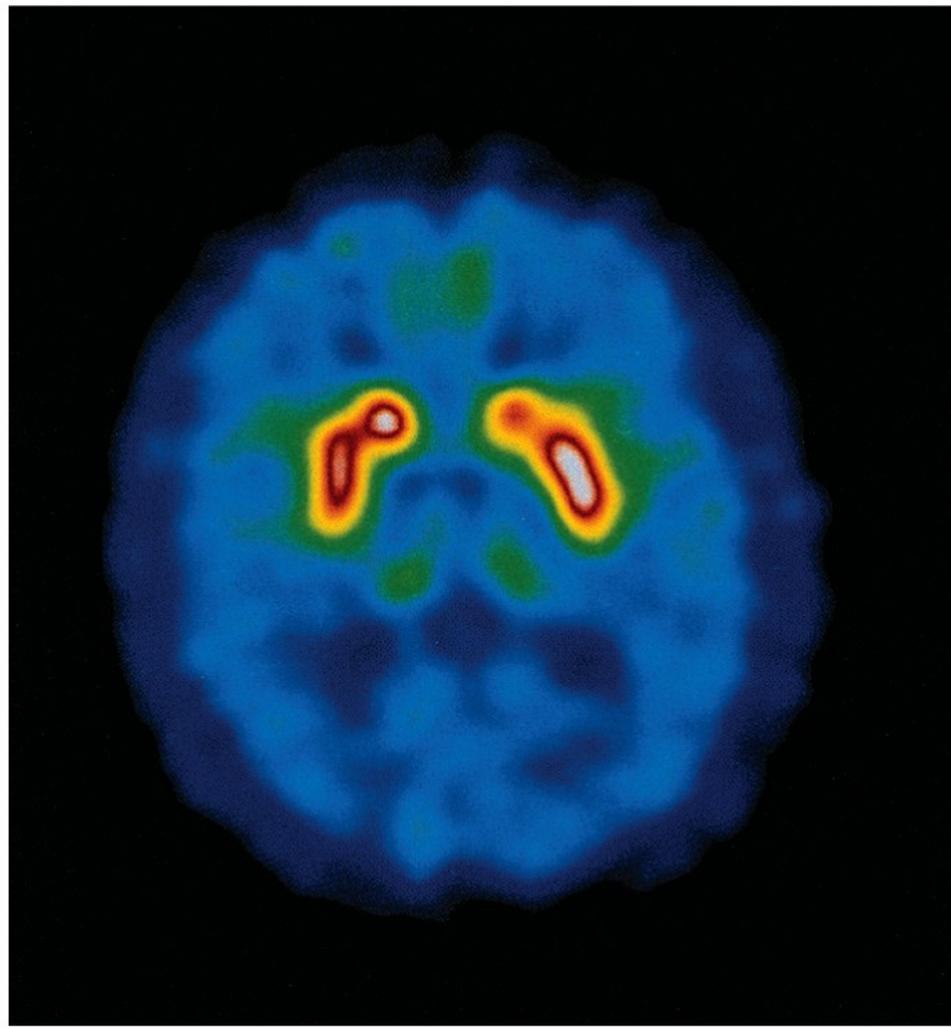
Huntington's disease



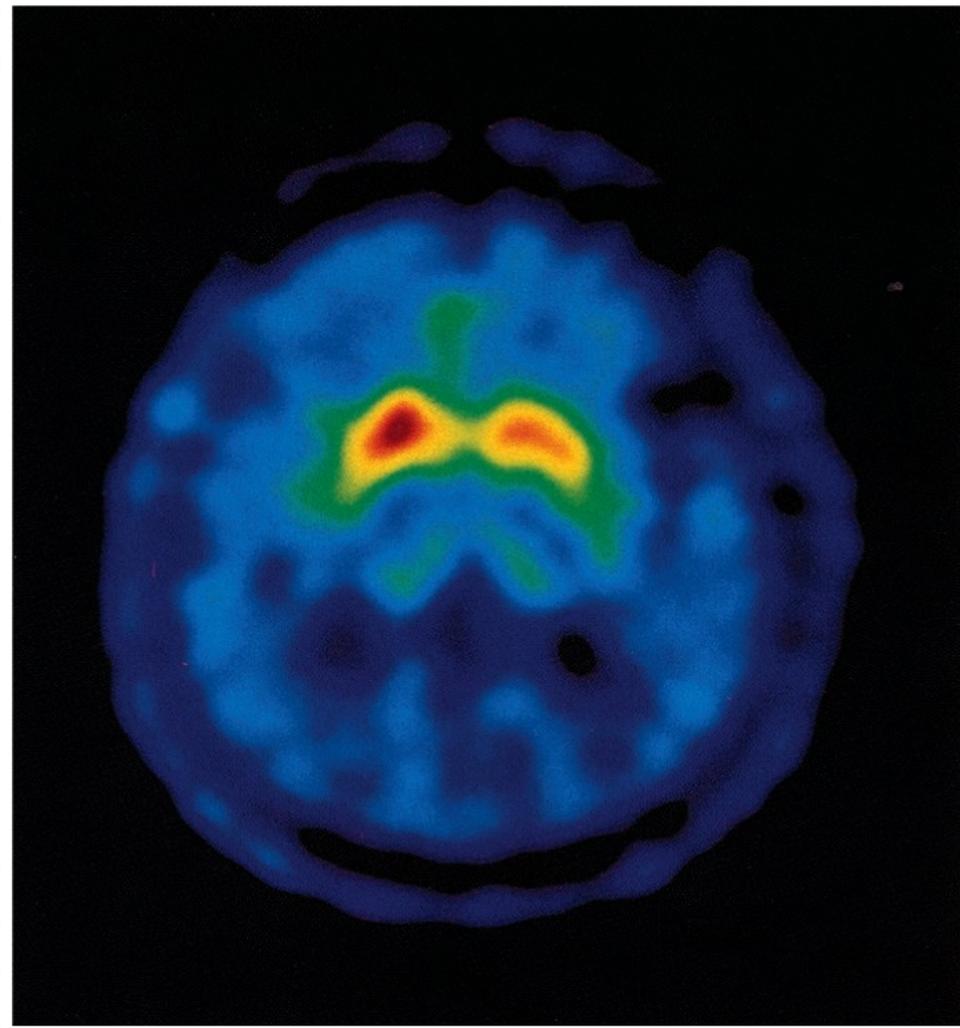
Parkinson's disease

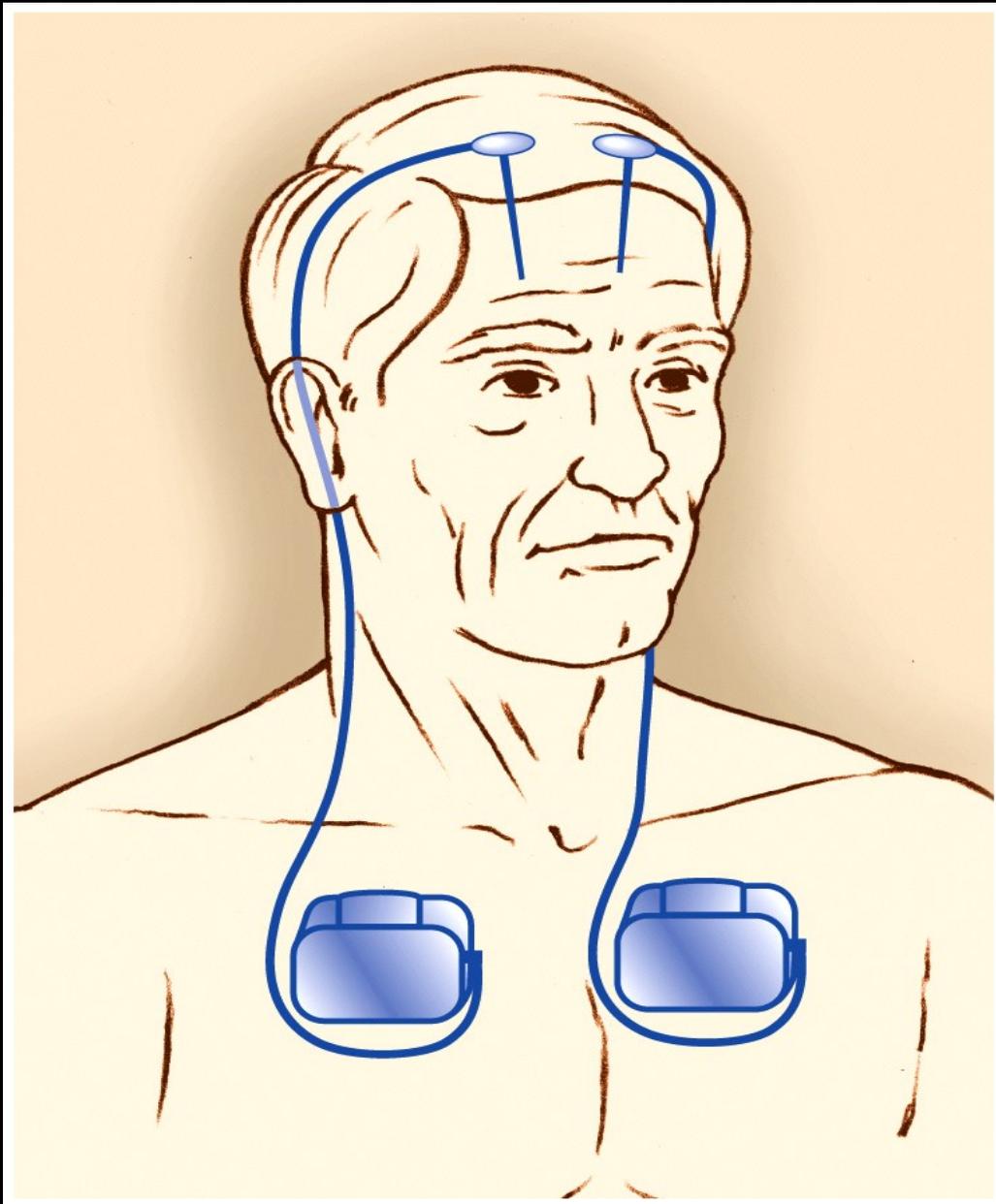


(a) Healthy subject



(b) Parkinsonian subject





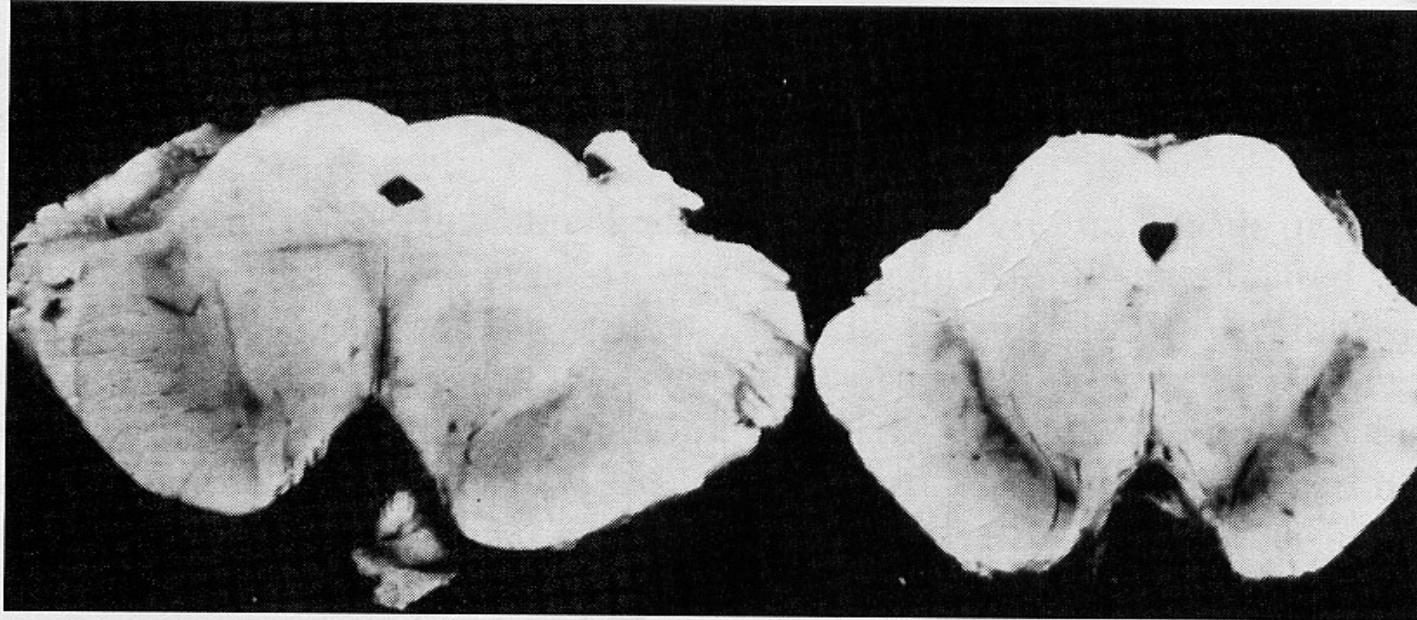
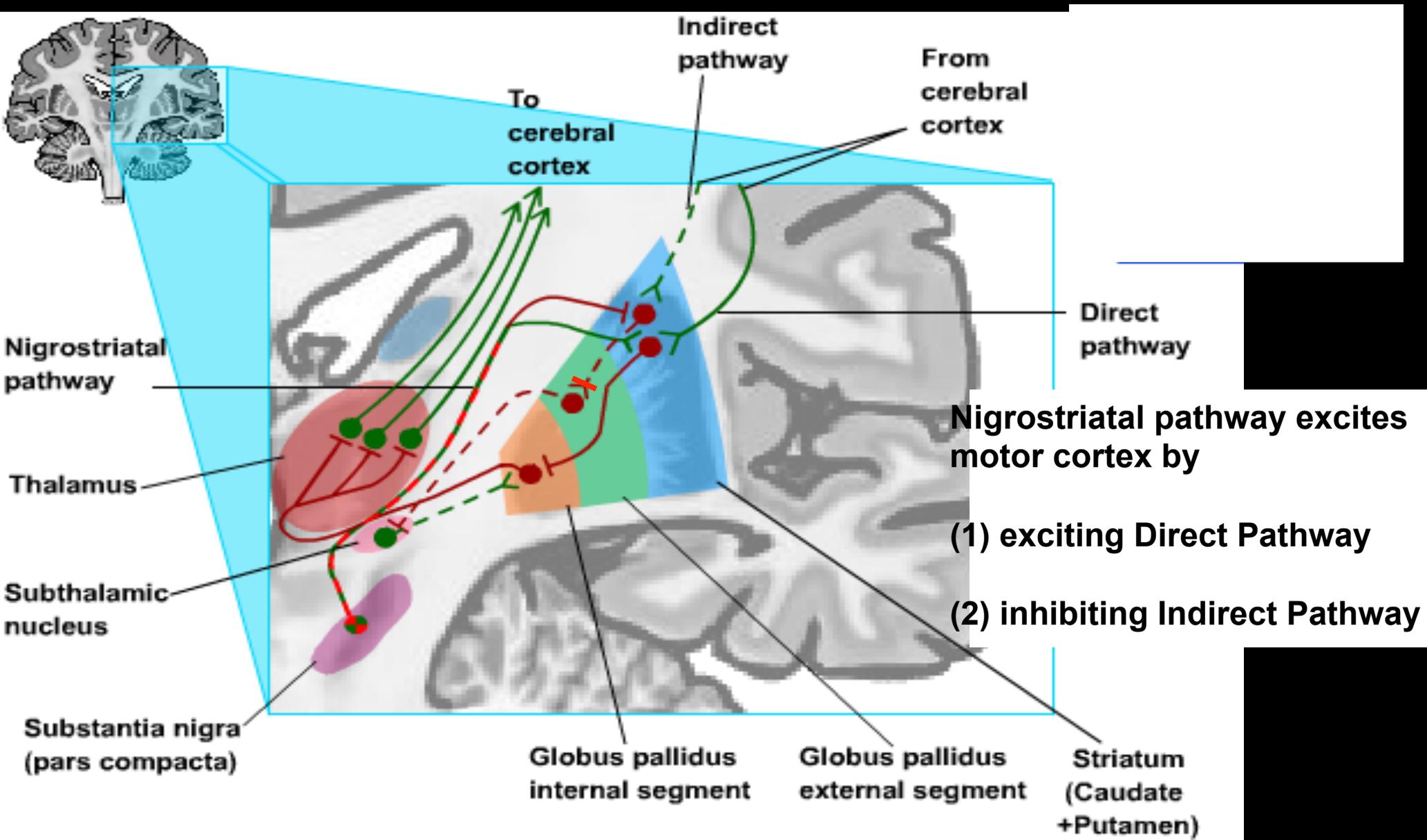
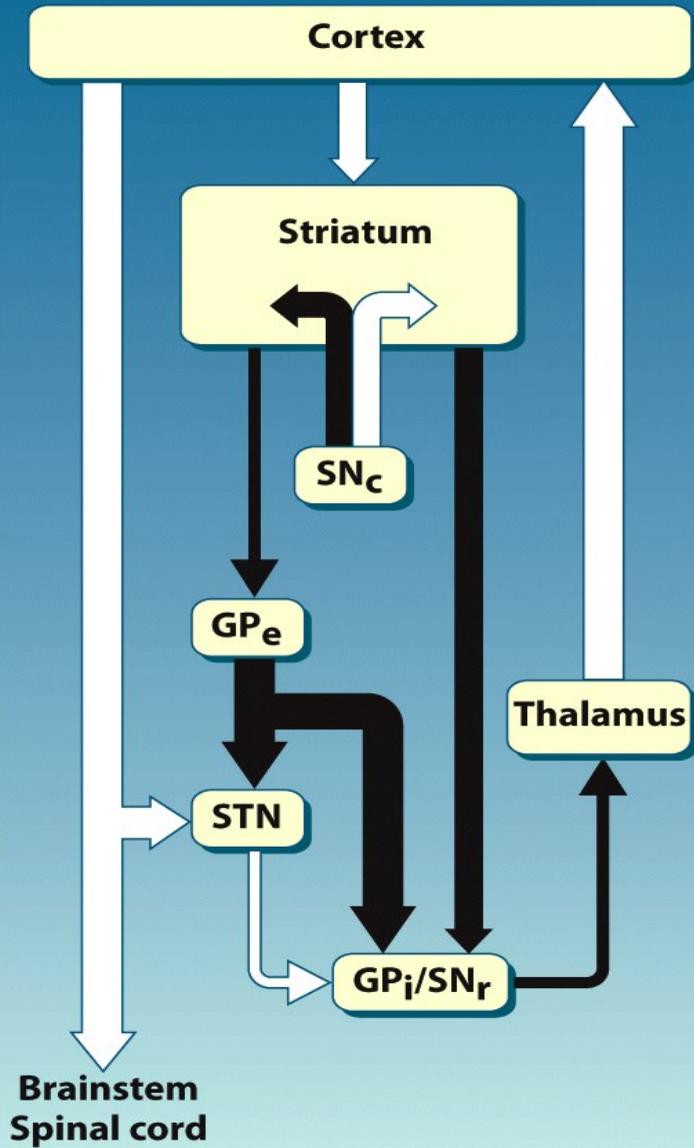


Figure 8.13 Parkinson's disease pathology

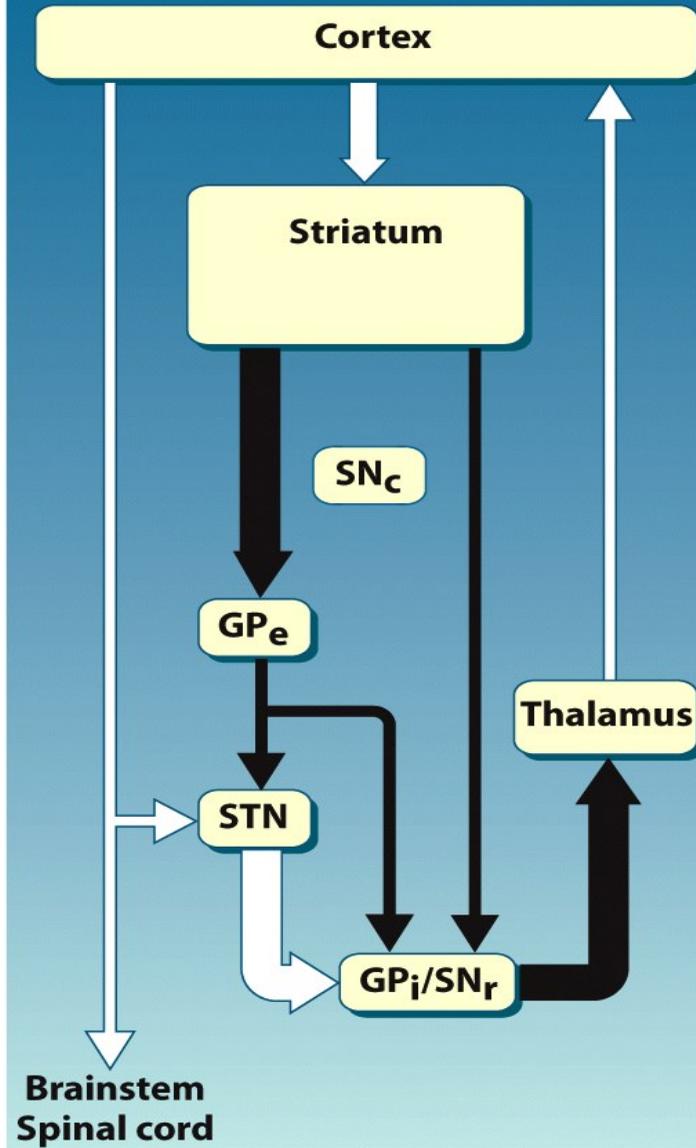
Dopaminergic Input from Substantia Nigra



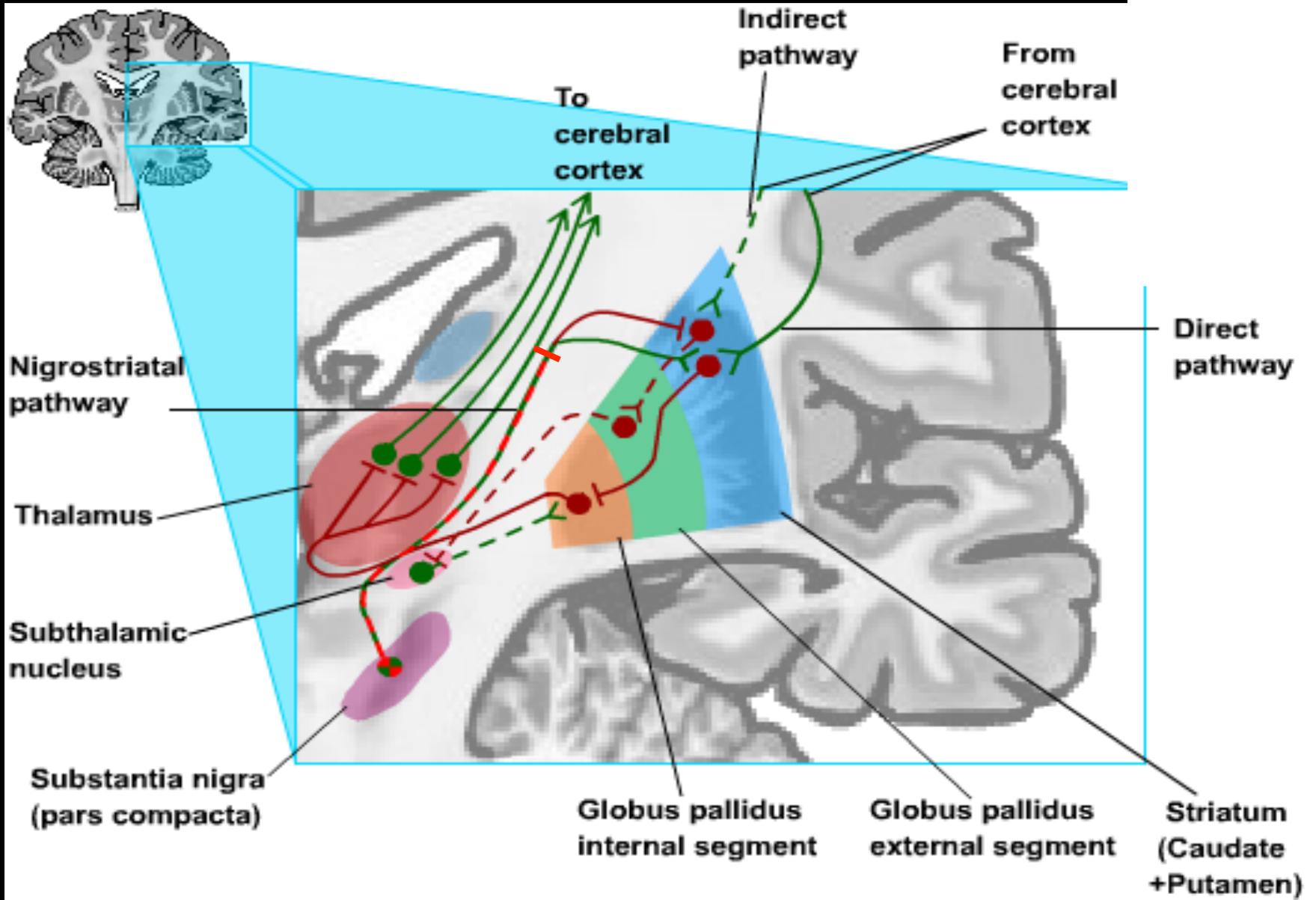
Huntington's disease



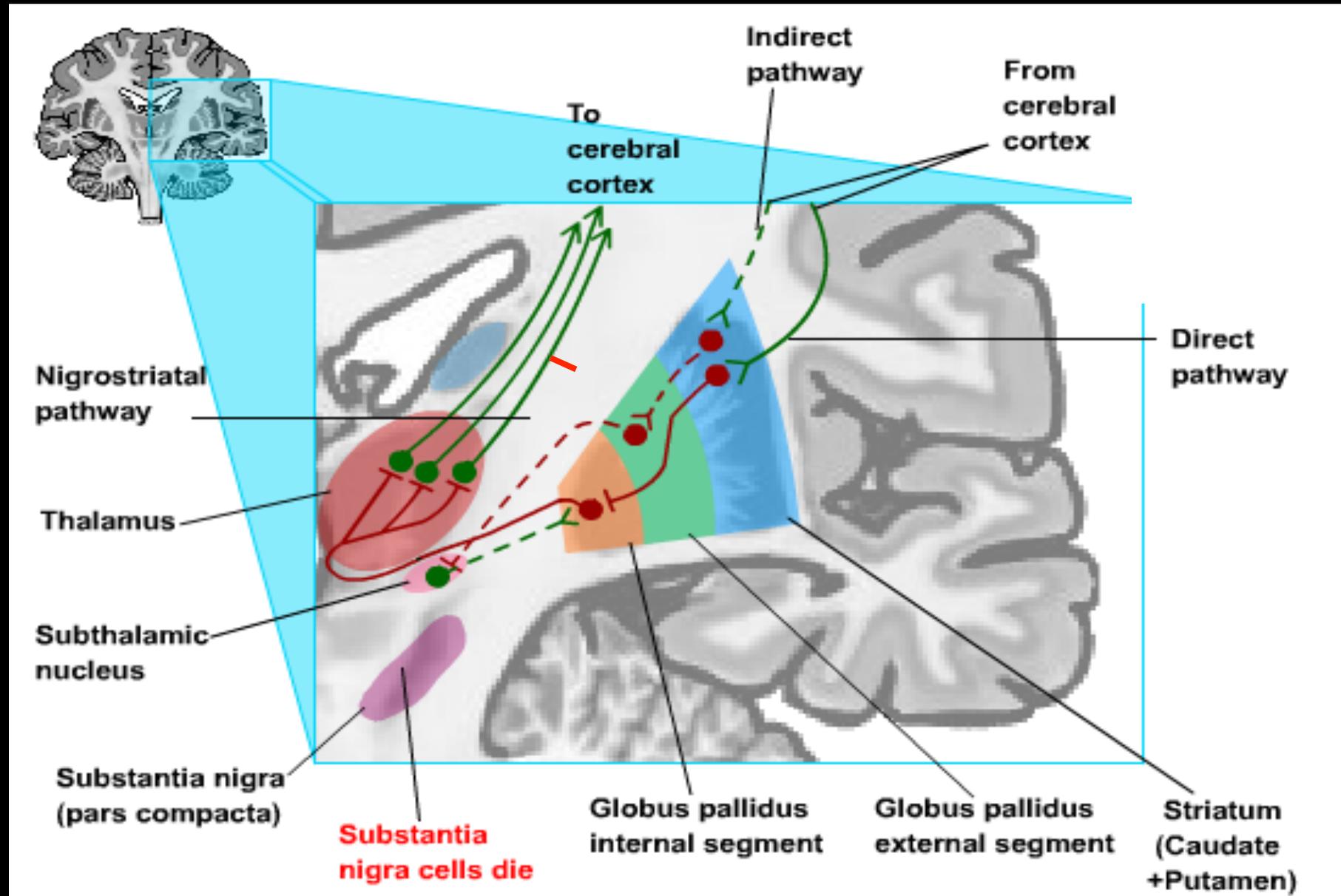
Parkinson's disease



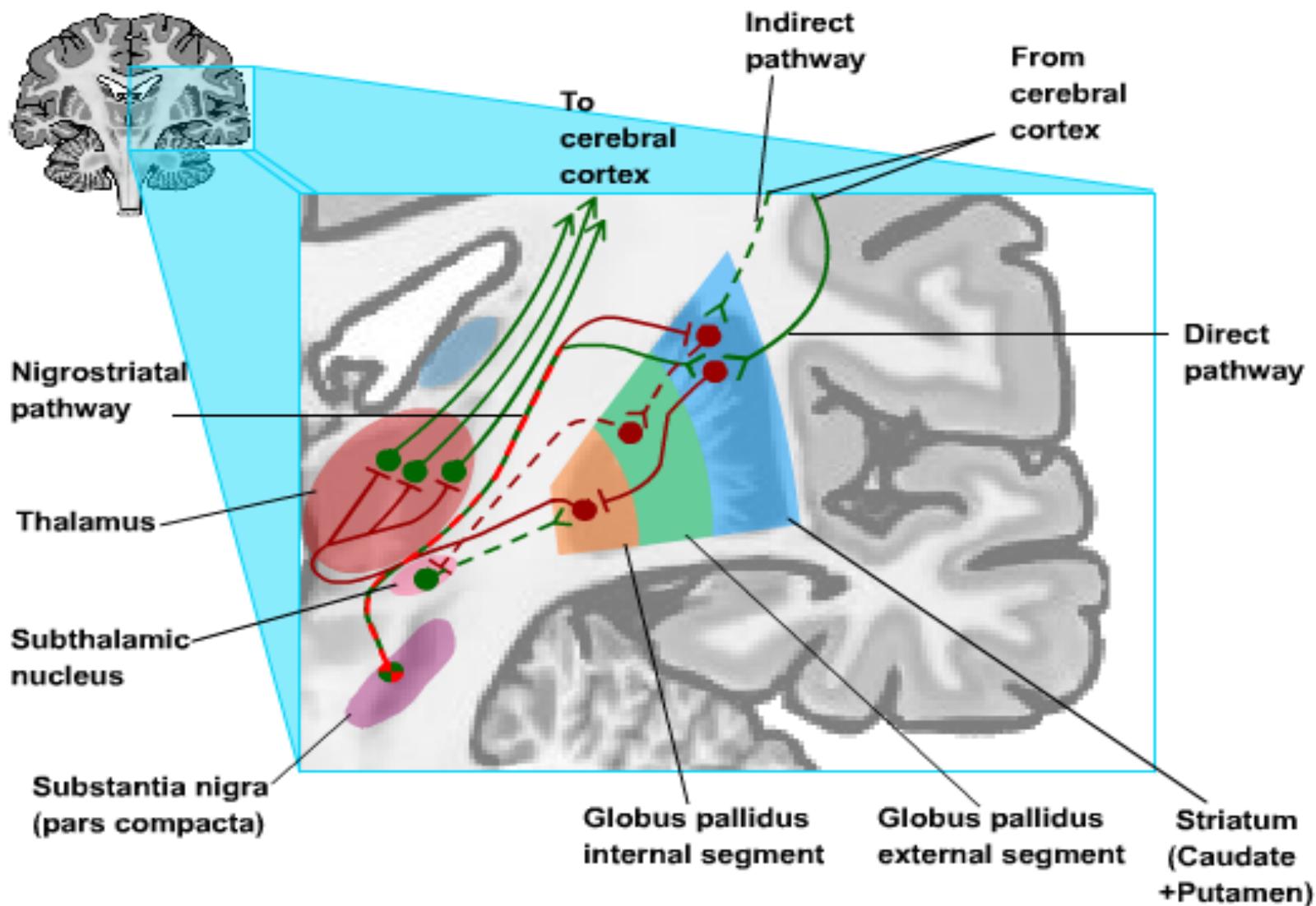
Parkinson's Disease



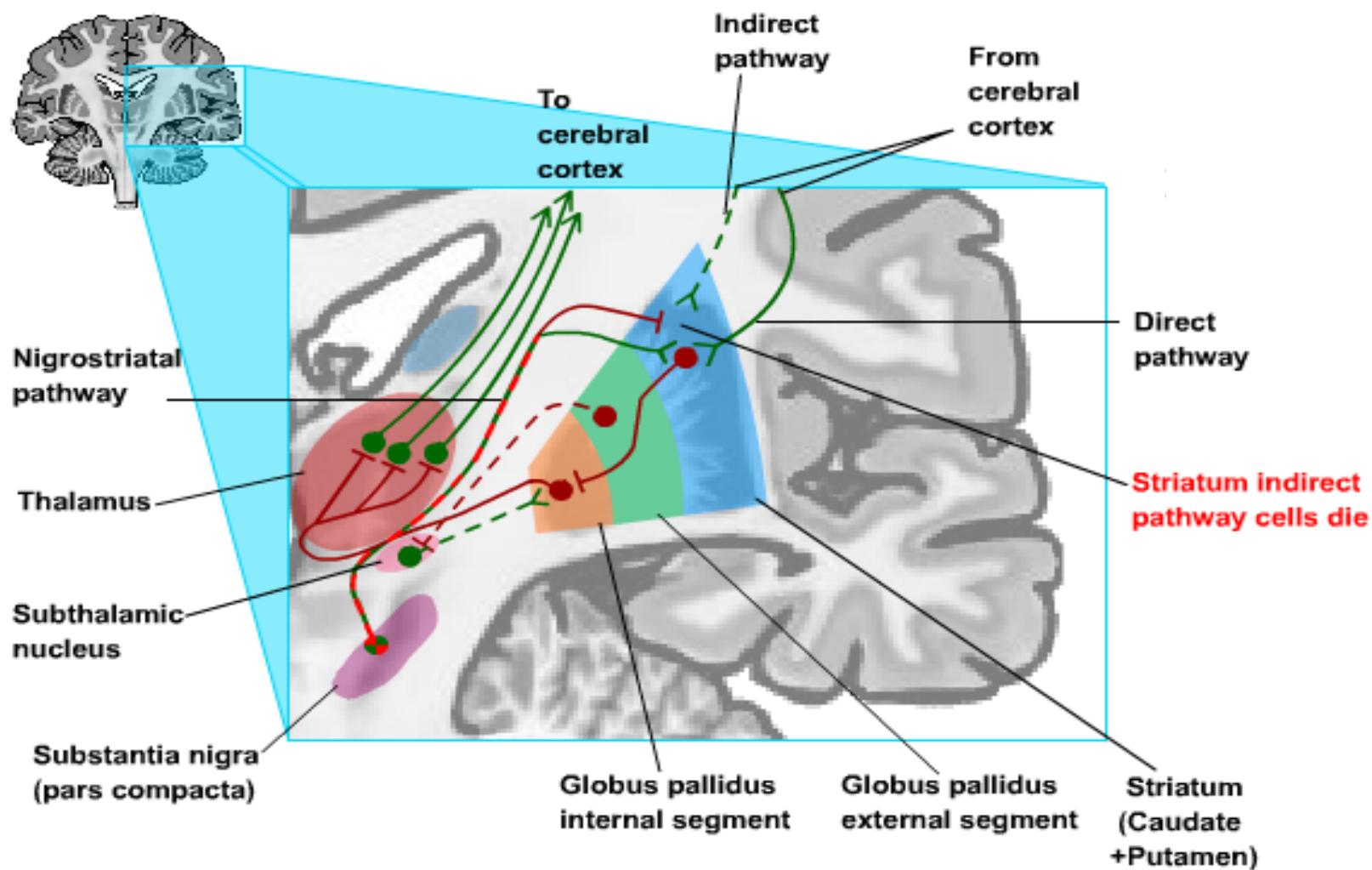
Parkinson's Disease

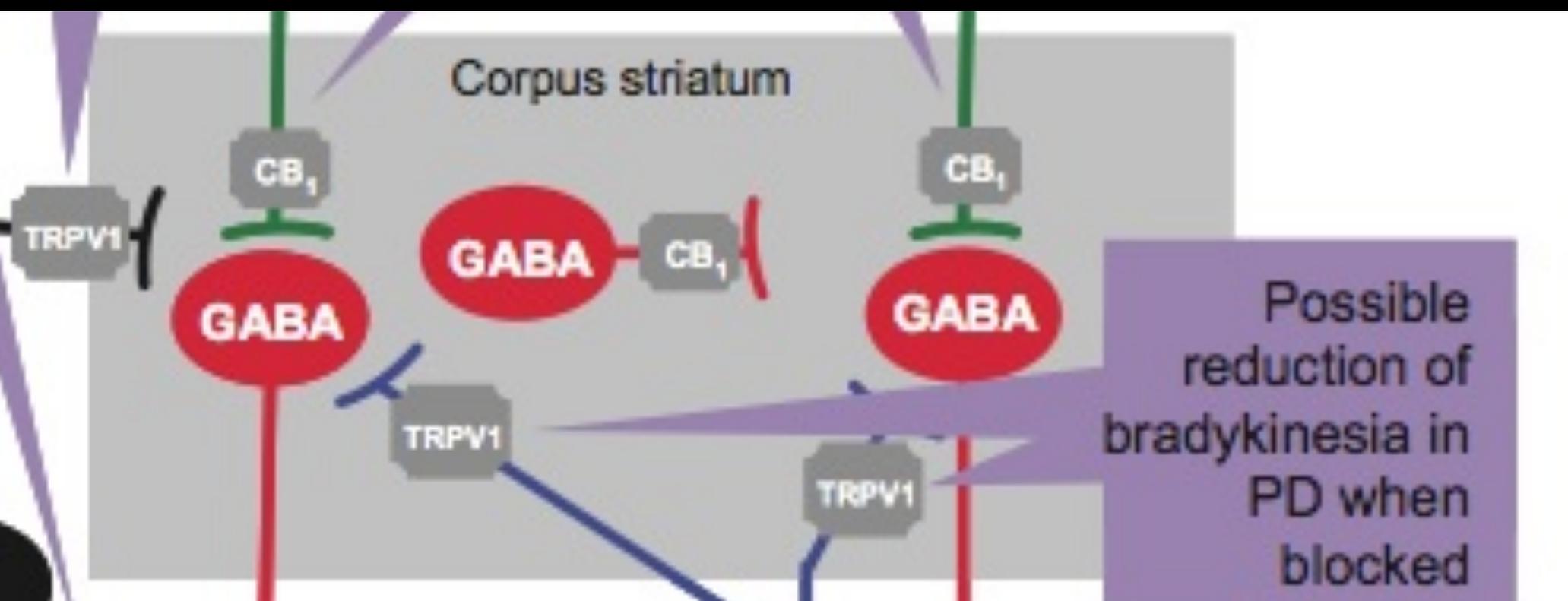


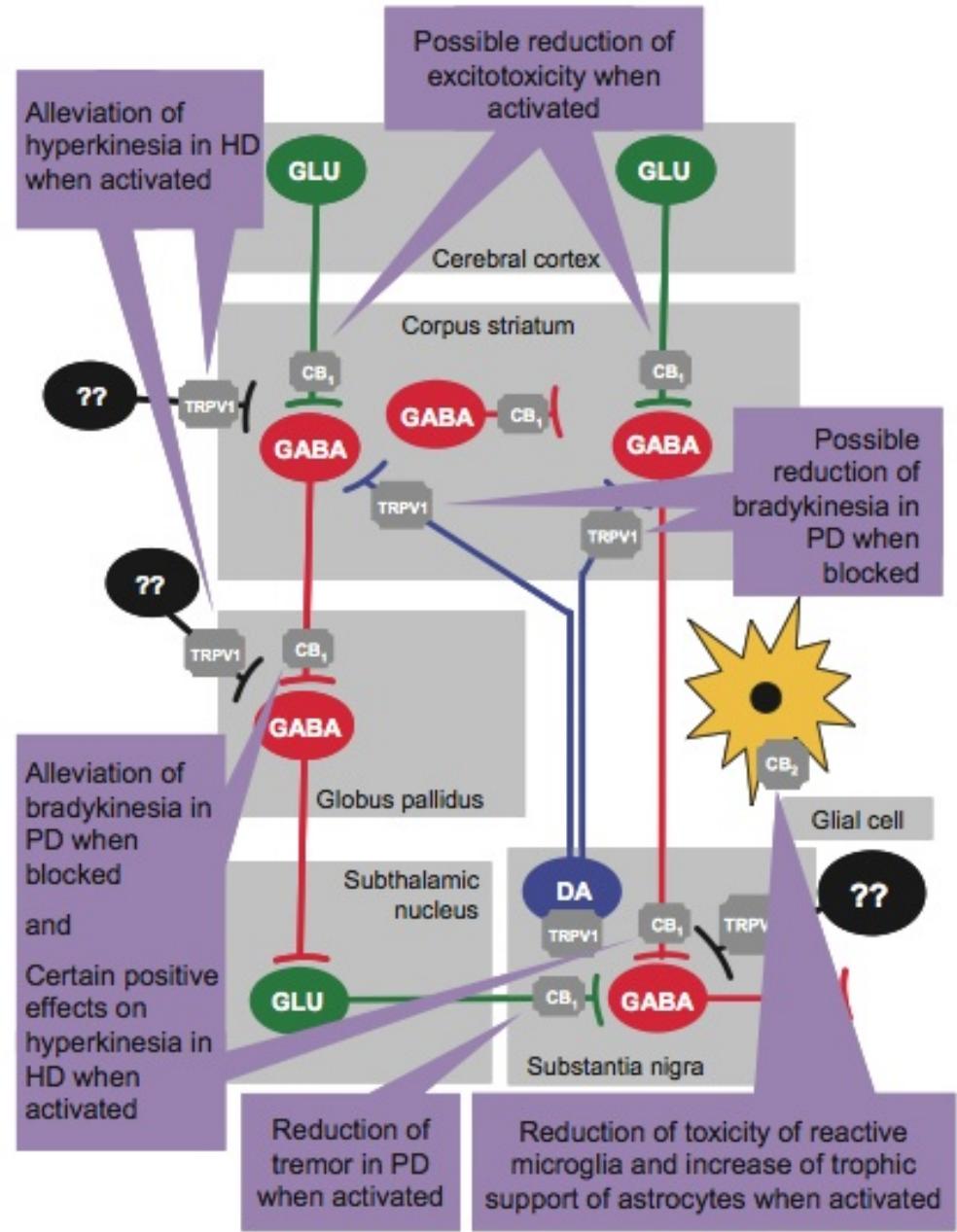
Huntington's Disease



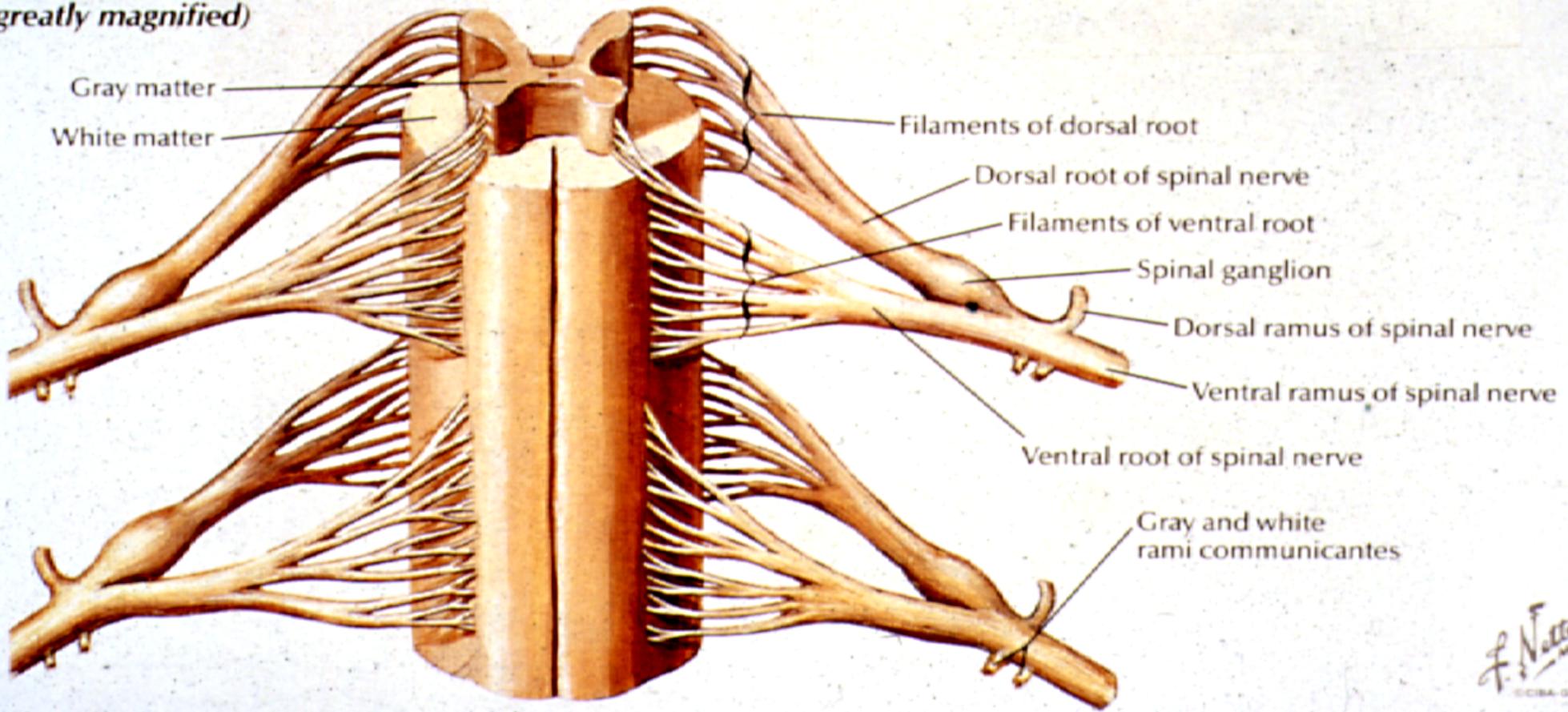
Huntington's Disease





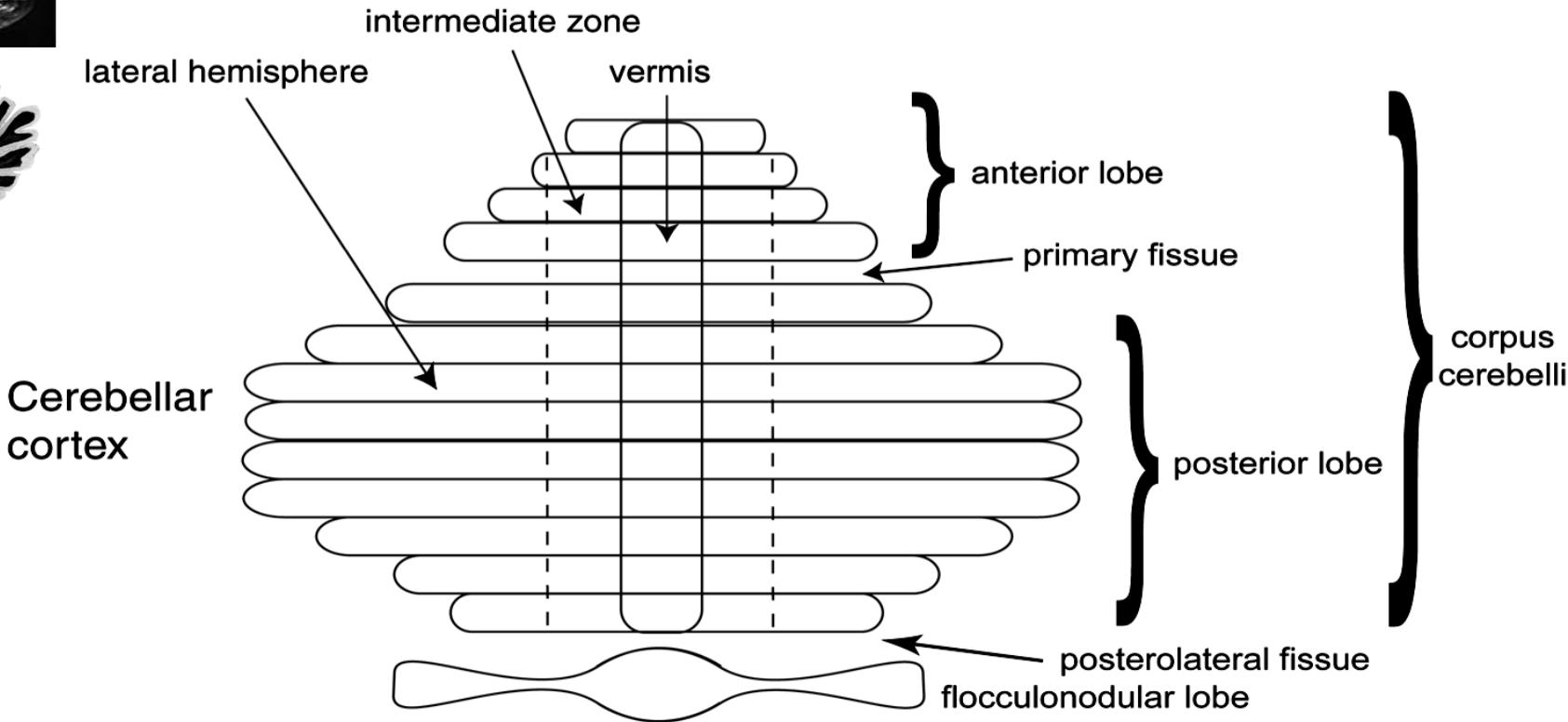


Membranes removed: anterior view
(greatly magnified)

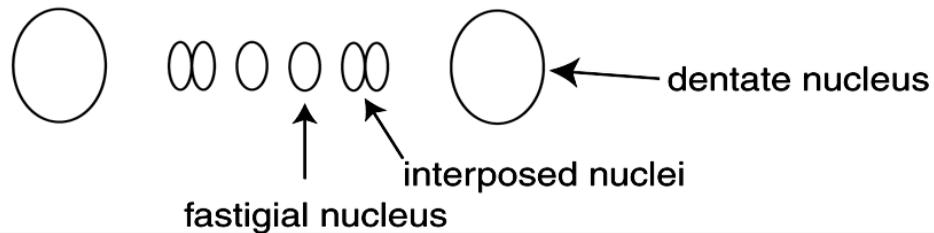


F. Netter
M.D.
© CIBA GEIGY

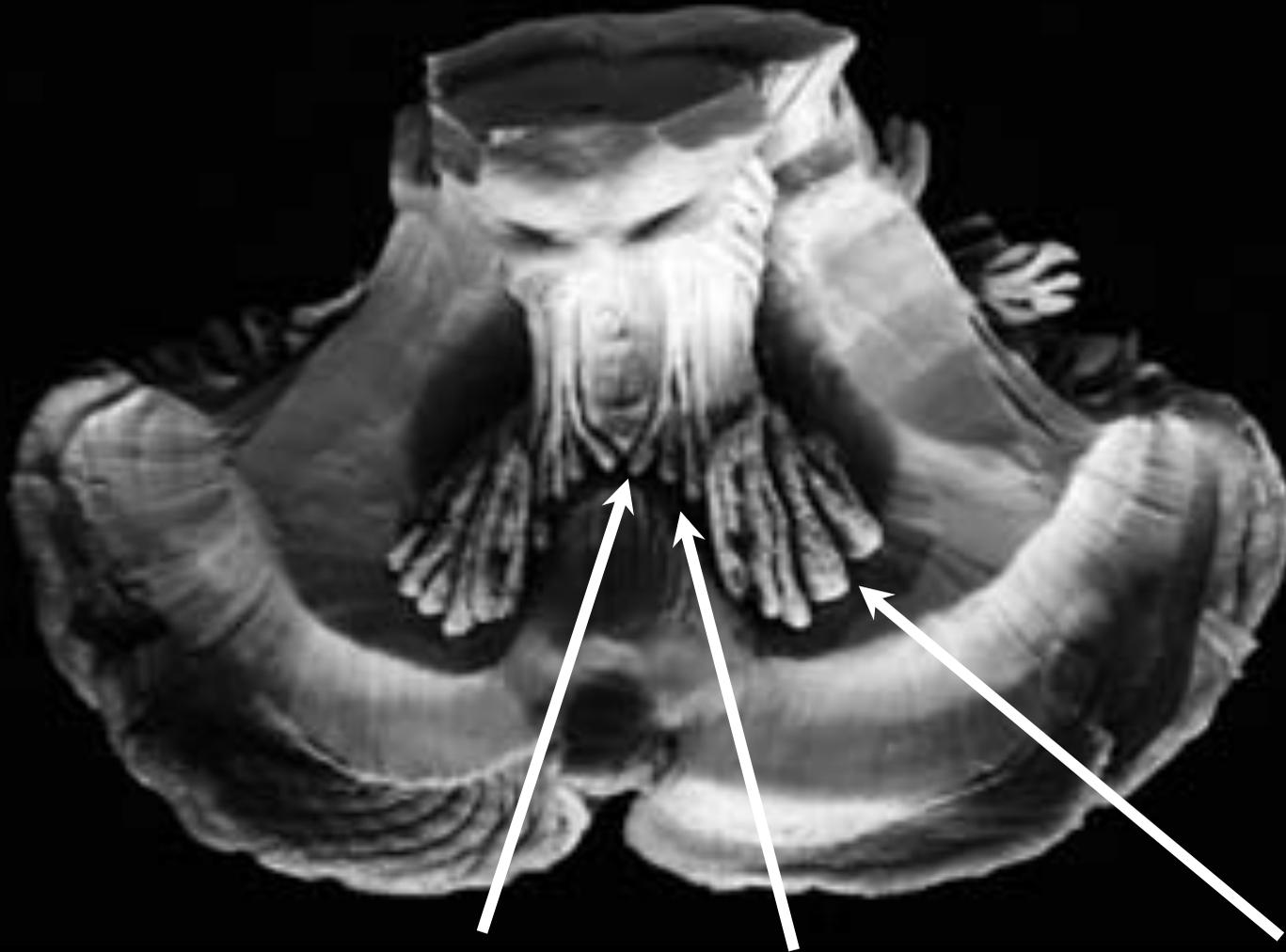
Gross Anatomical Organization of Cerebellum



Cerebellar deep nuclei



Deep Cerebellar Nuclei



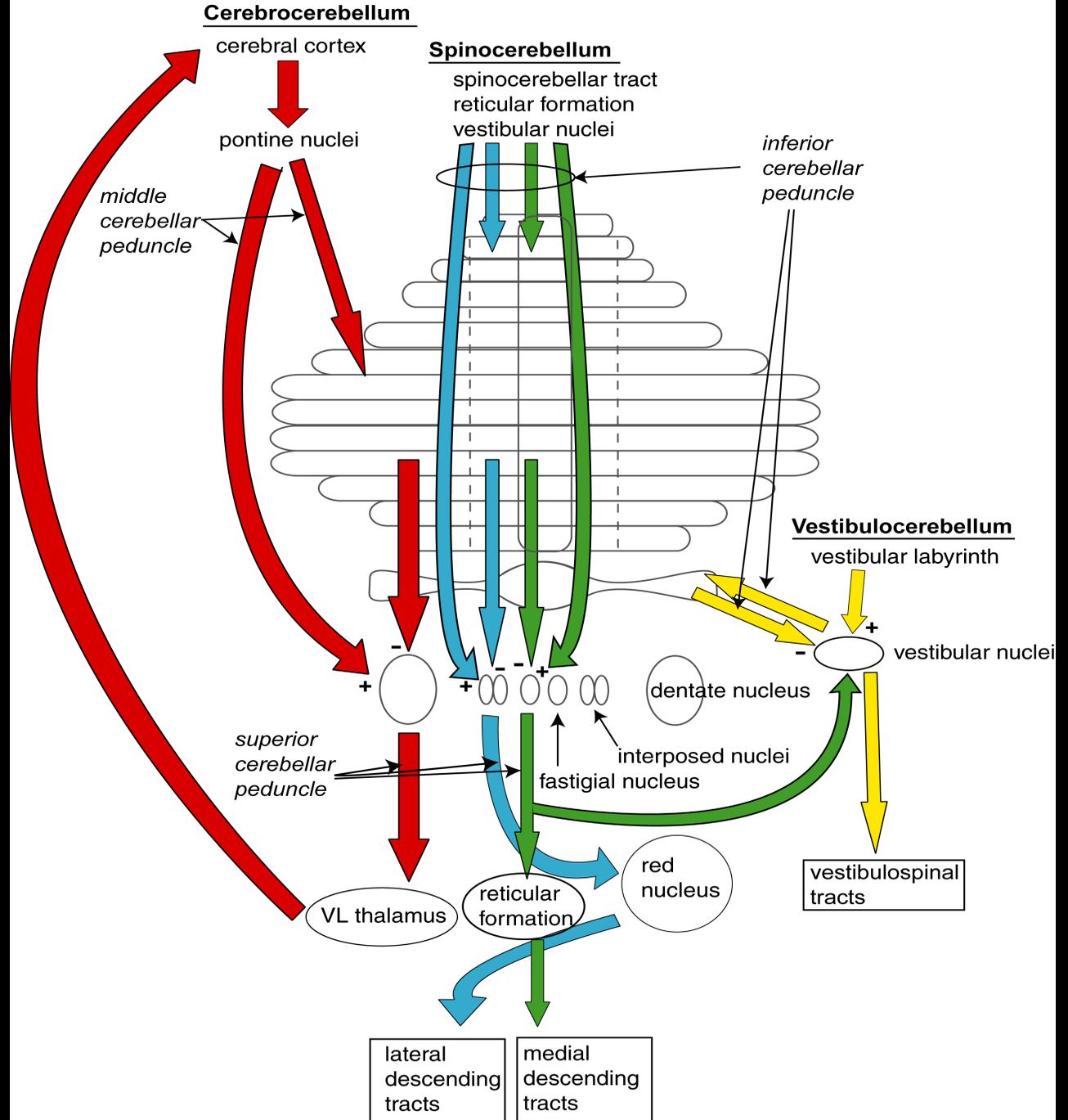
Fastigial

Interposed

Dentate

Also
Lateral
Vestibular

Cerebellar Afferents and Efferents



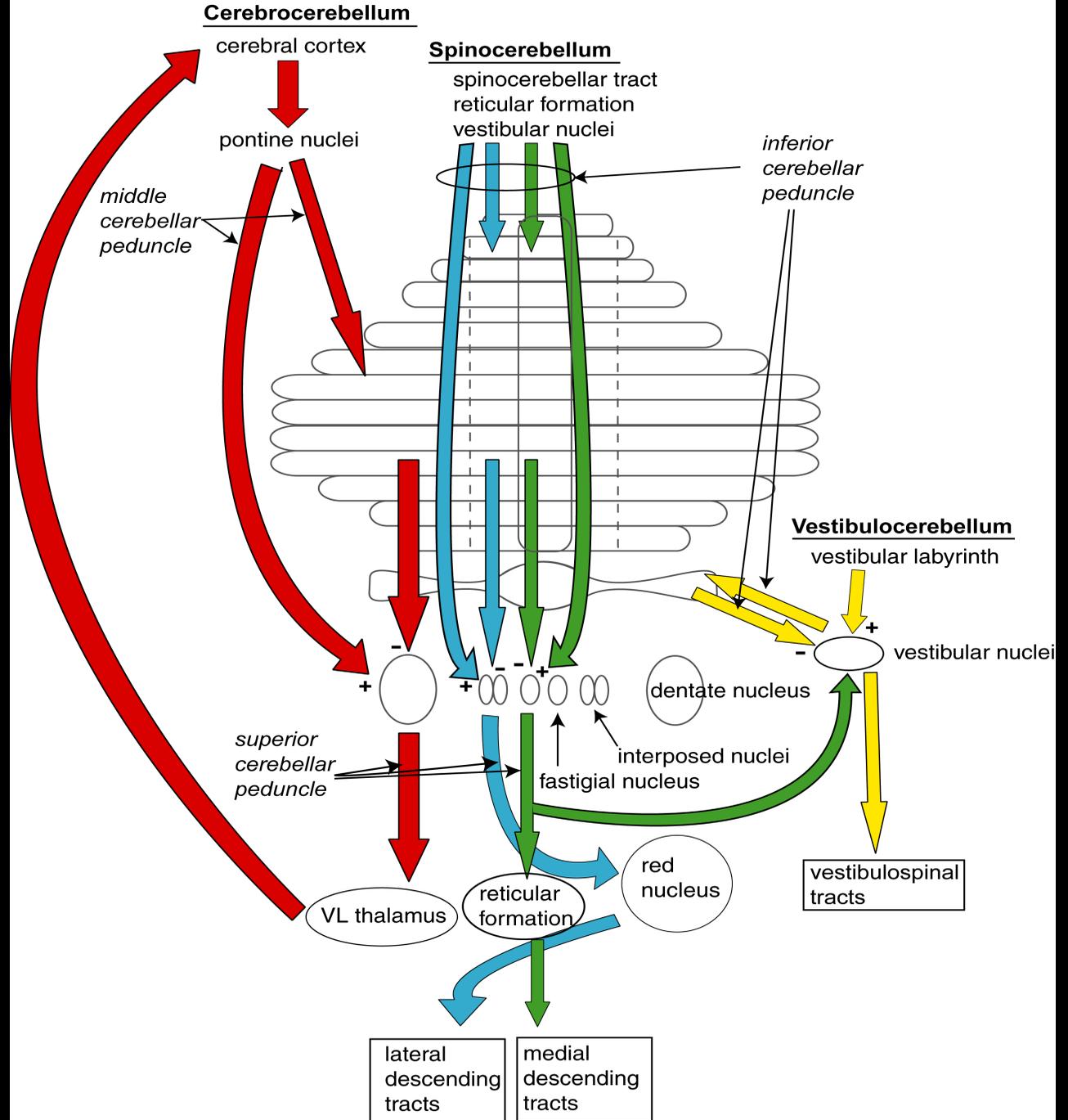
Deep Cerebellar Nuclei



Fastigial Nucleus

- inhibitory input from cerebellar cortex: vermis
- excitatory input: vestibular, proximal somatosensory, auditory, visual
- projects to vestibular nuclei, reticular formation

Cerebellar Afferents and Efferents



Deep Cerebellar Nuclei

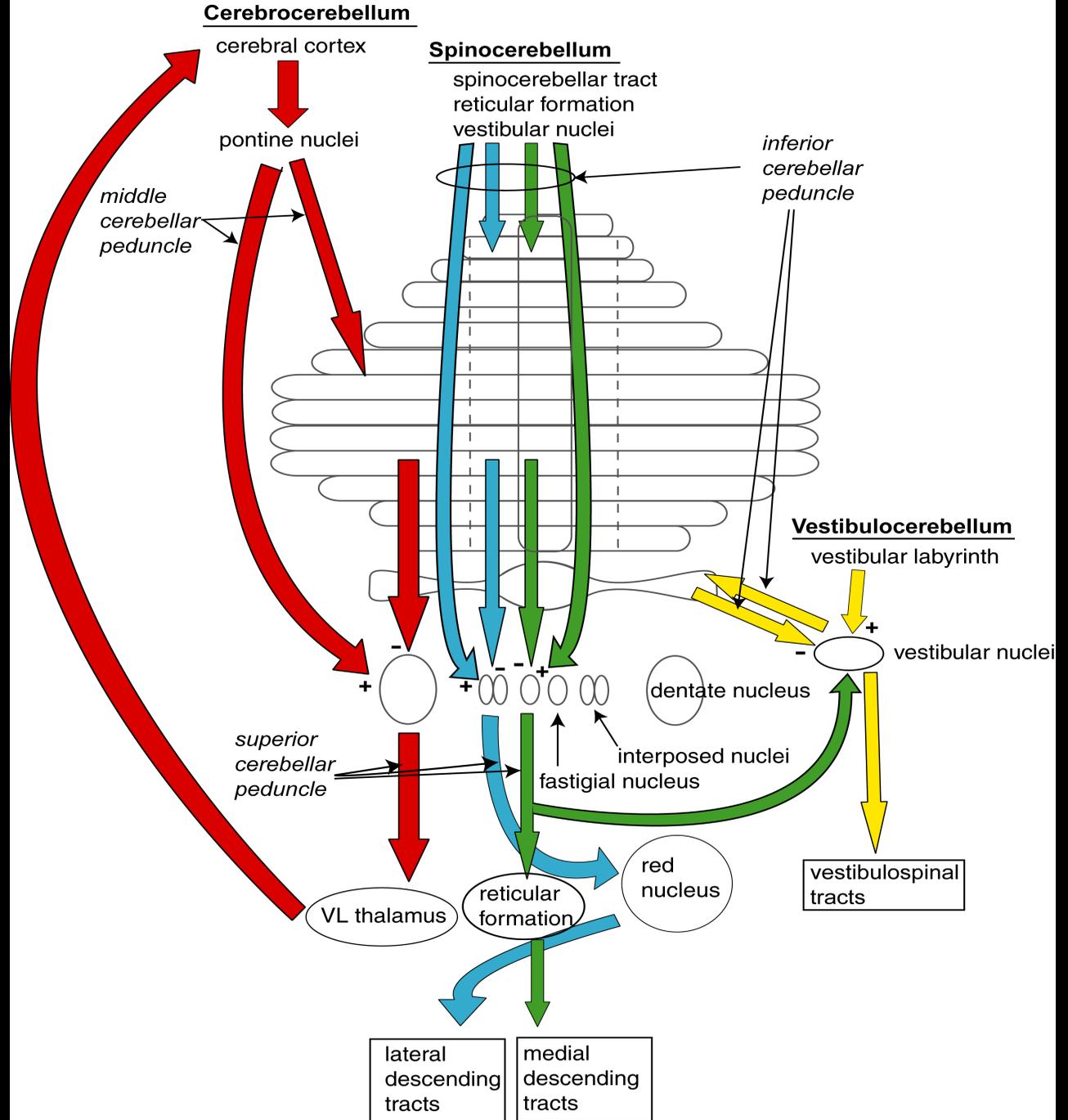
Fastigial Nucleus

- inhibitory input from cerebellar cortex : vermis
- excitatory input: vestibular, proximal somatosensory, auditory, visual
- projects to vestibular nuclei, reticular formation

Interposed

- inhibitory input from cerebellar cortex : intermediate zone
- excitatory input : spinal, proximal somatosensory, auditory, visual
- projects to contralateral red nucleus

Cerebellar Afferents and Efferents



Deep Cerebellar Nuclei

Fastigial Nucleus

- inhibitory input from cerebellar cortex : vermis
- excitatory input: vestibular, proximal somatosensory, auditory, visual
- projects to vestibular nuclei, reticular formation

Interposed

- inhibitory input from cerebellar cortex : intermediate zone
- excitatory input : spinal, proximal somatosensory, auditory, visual
- projects to contralateral red nucleus

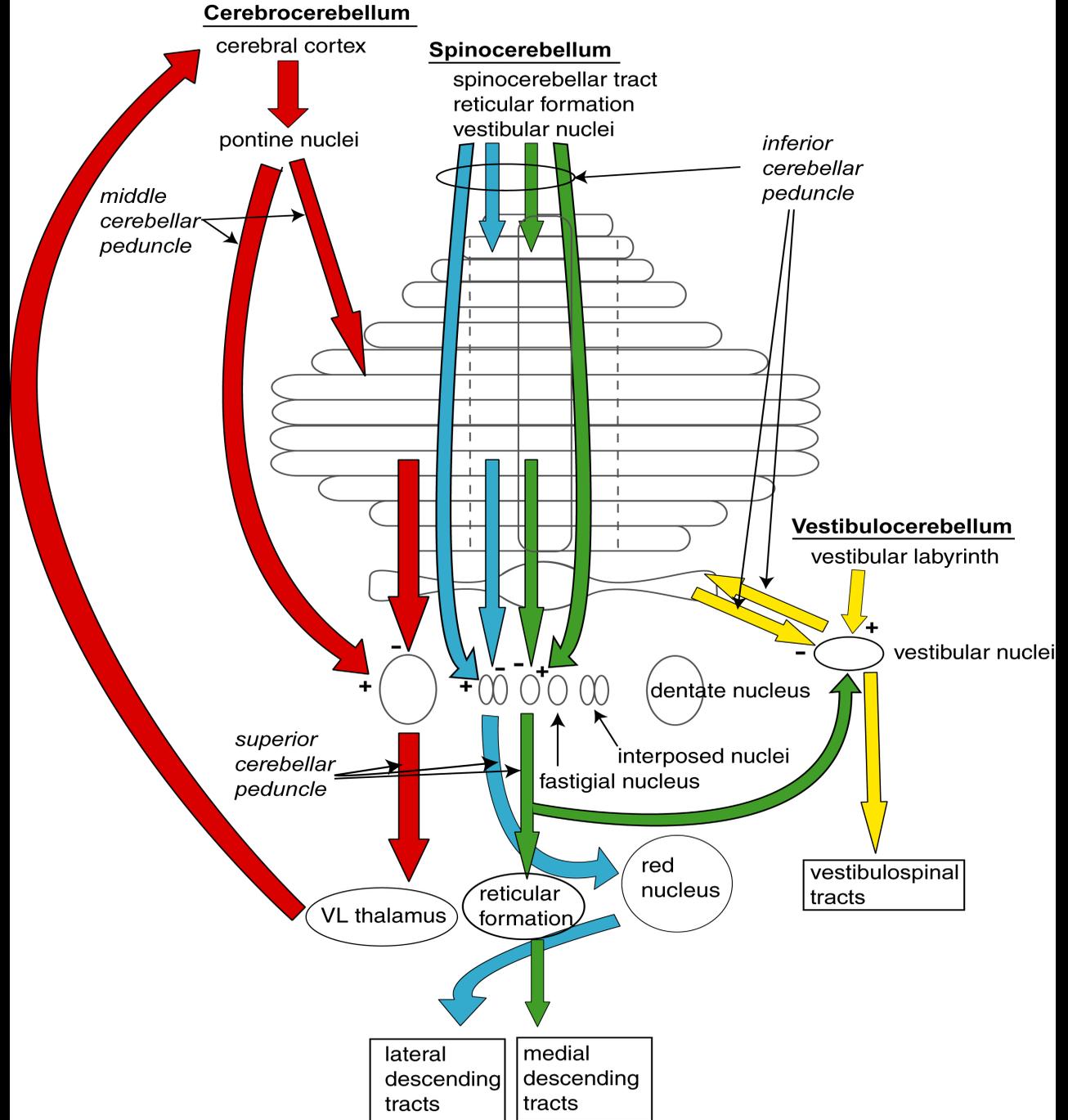
Dentate

- inhibitory input from cerebellar cortex : lateral hemisphere
- excitatory input: cortex via pontine nuclei
- projects to contralateral red nucleus, thalamus (VL)



DeArmond Fig. 81

Cerebellar Afferents and Efferents



Deep Cerebellar Nuclei

Fastigial Nucleus

- inhibitory input from cerebellar cortex : vermis
- excitatory input: vestibular, proximal somatosensory, auditory, visual
- projects to vestibular nuclei, reticular formation

Interposed

- inhibitory input from cerebellar cortex : intermediate zone
- excitatory input : spinal, proximal somatosensory, auditory, visual
- projects to contralateral red nucleus

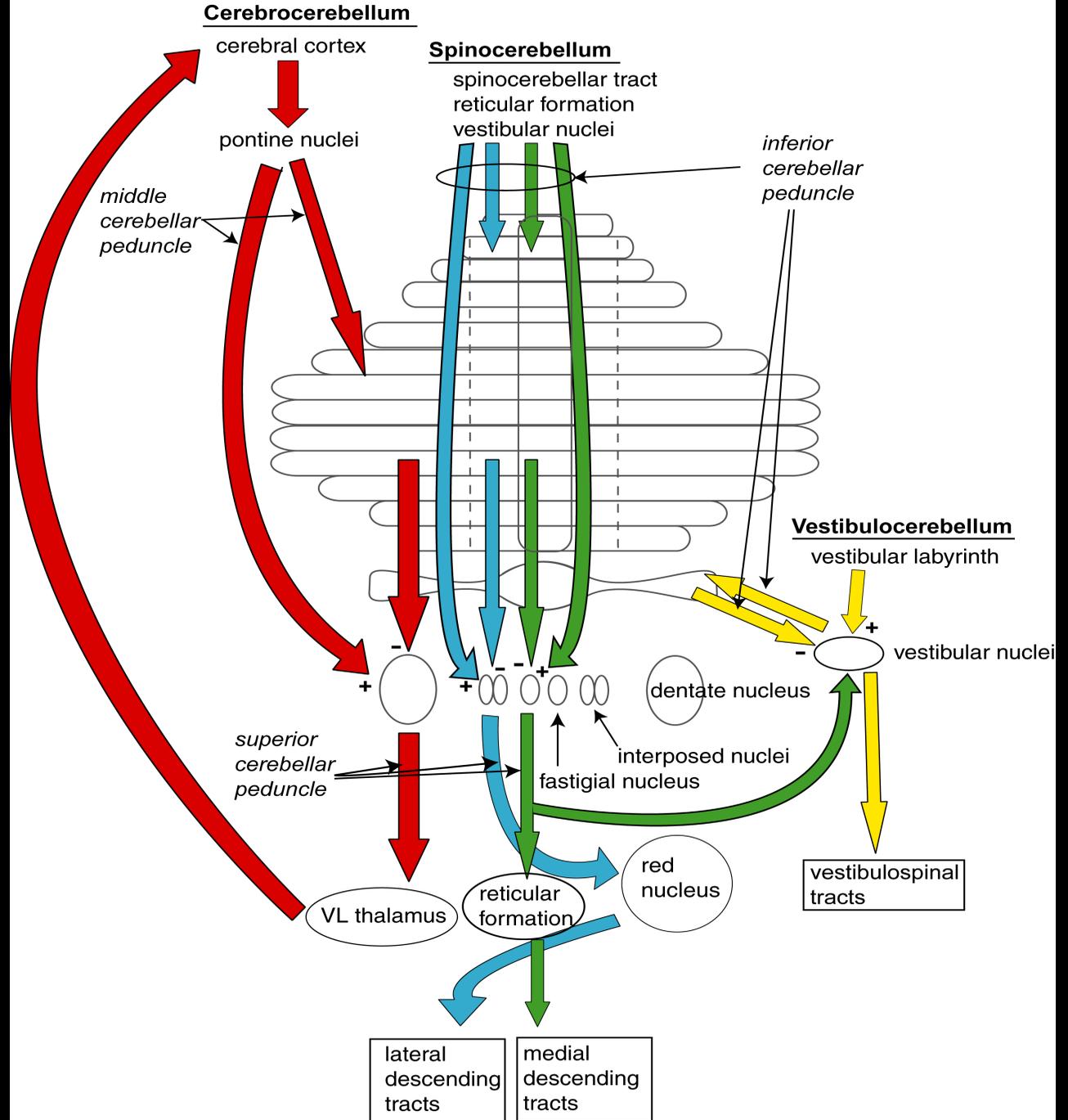
Dentate

- inhibitory input from cerebellar cortex : lateral hemisphere
- excitatory input: cortex via pontine nuclei
- projects to contralateral red nucleus, thalamus (VL)

Vestibular

- inhibitory input from cerebellar cortex : flocculonodular lobe
- excitatory input: vestibular labyrinth
- projects to motor nuclei

Cerebellar Afferents and Efferents



Cerebellar Peduncles

Input and output tracts of cerebellum

Inferior Cerebellar Peduncle (restiform body)

Primarily afferent fibers from medulla

Middle Cerebellar Peduncle (brachium pontis)

Primarily afferent fibers from pons

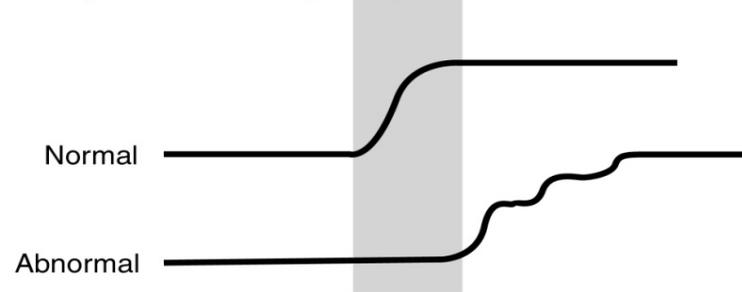
Superior Cerebellar Peduncle (brachium conjunctivum)

Primarily efferent fibers from the cerebellar nuclei

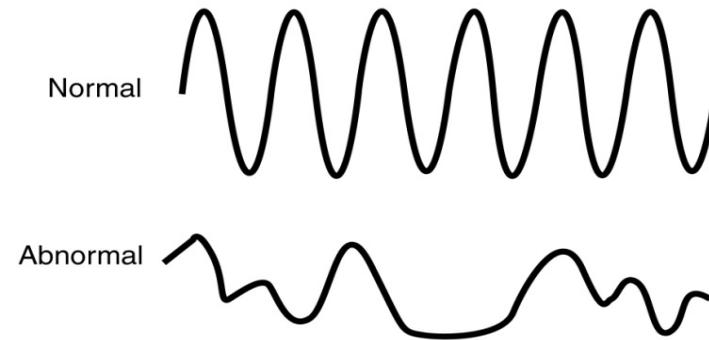
Cerebellum controls the IPSILATERAL side of the body

Cerebellum Produces Movement Disorders

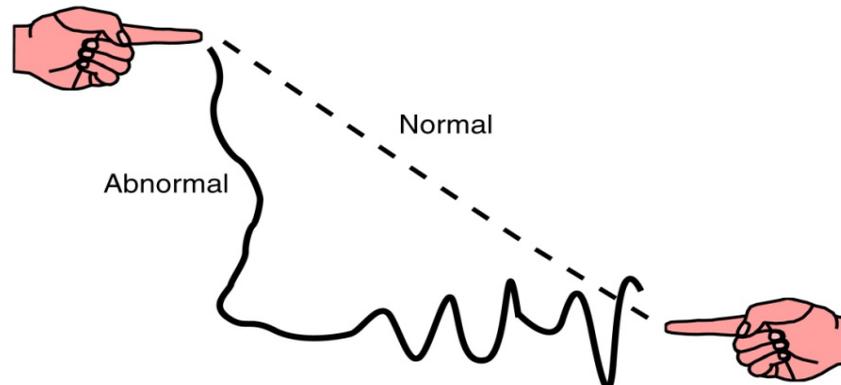
Delay in initiating responses



Dysdiadochokinesia



Decomposition of movement / intention tremor

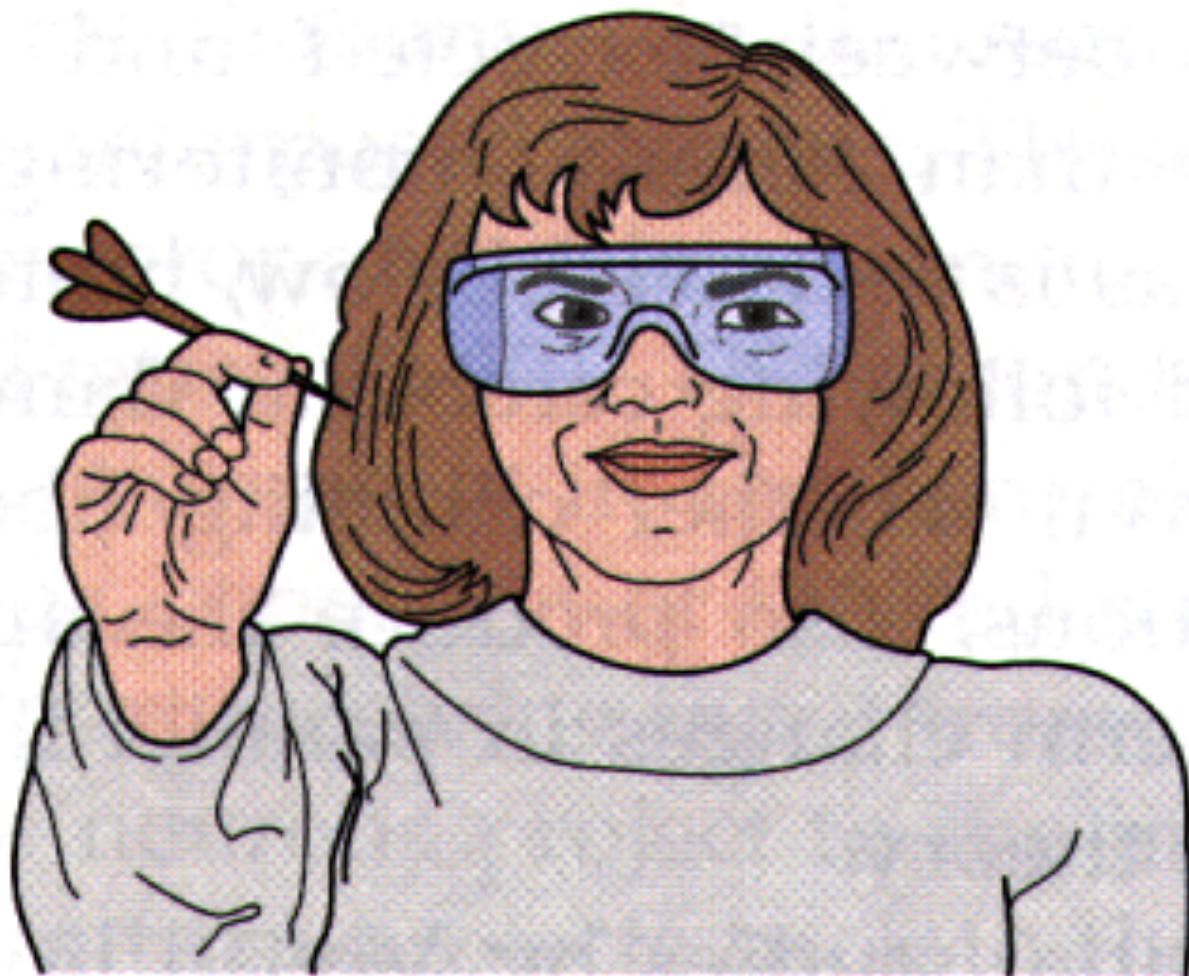


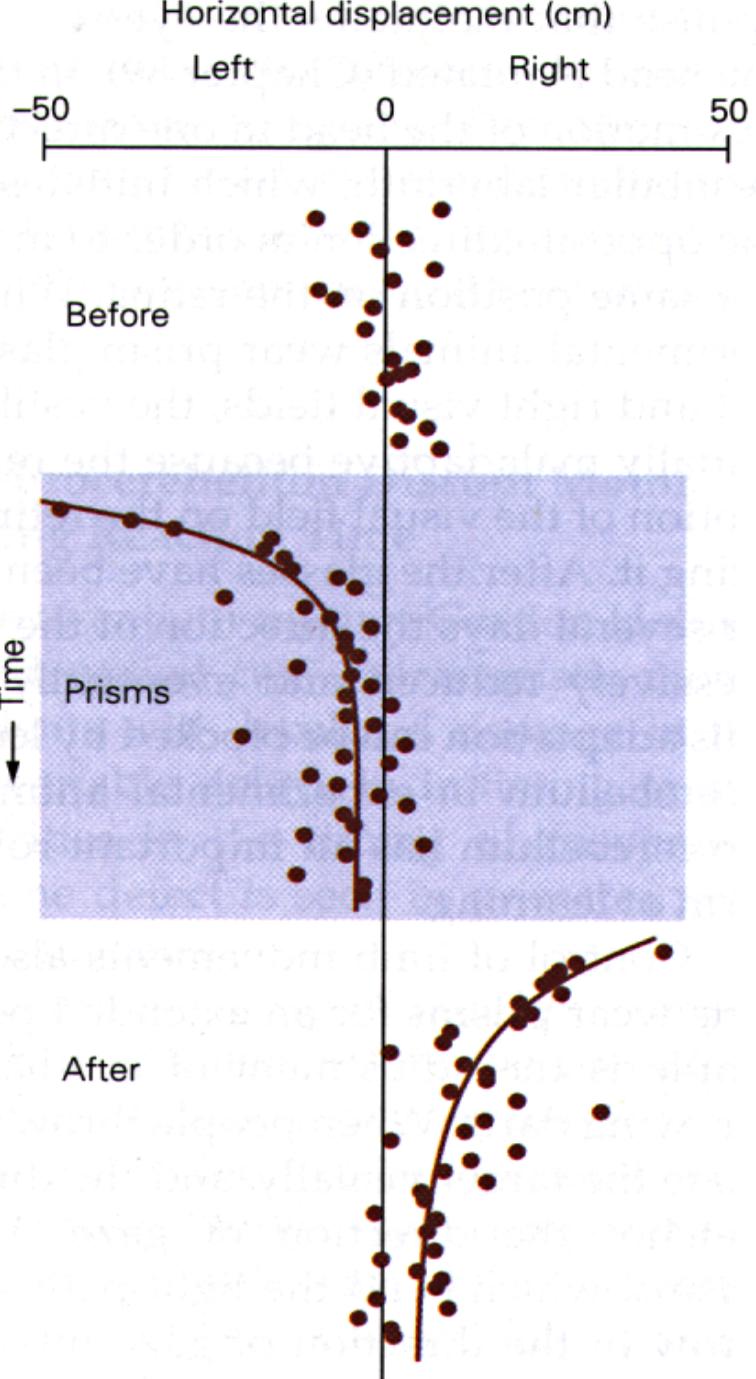
Cerebellum and Motor Learning

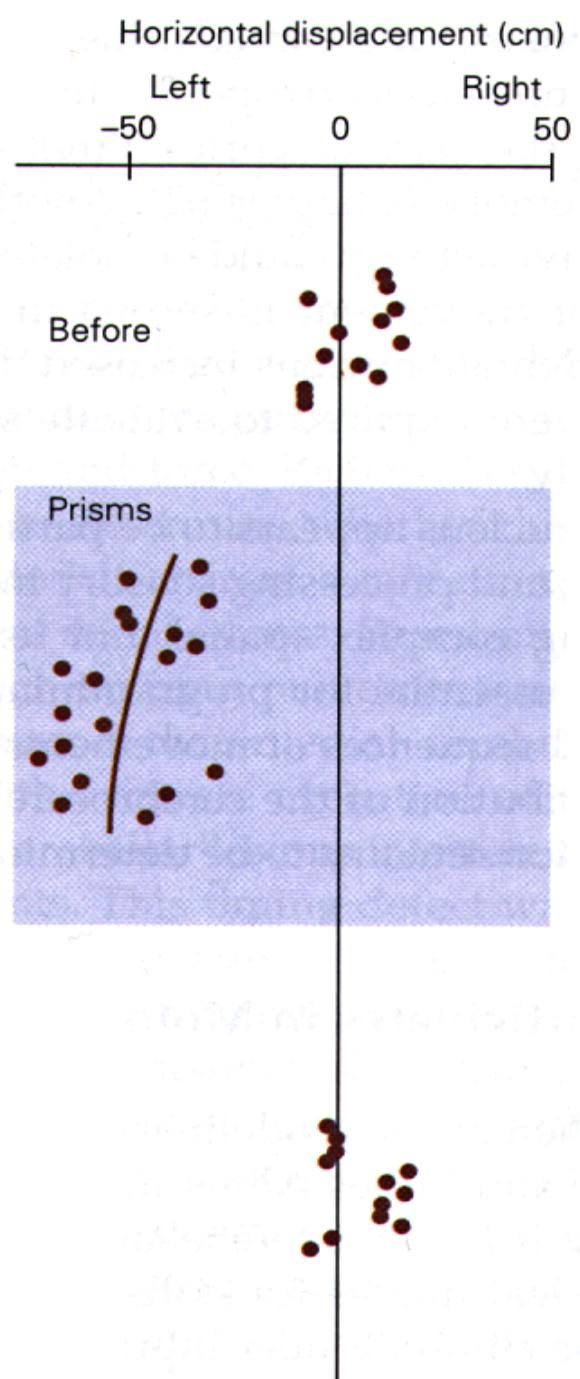
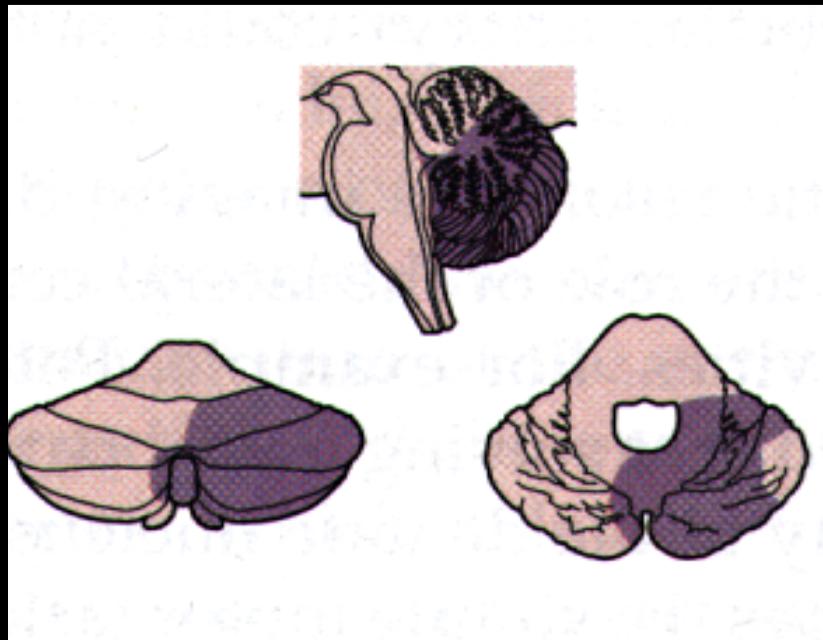
Vestibulo-ocular reflex

Coordination of movements

Pavlovian Classical Conditioning





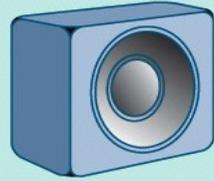


Cerebellum and Motor Learning

Vestibulo-ocular reflex

Coordination of movements

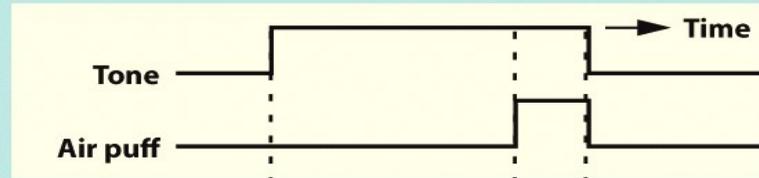
Pavlovian Classical Conditioning



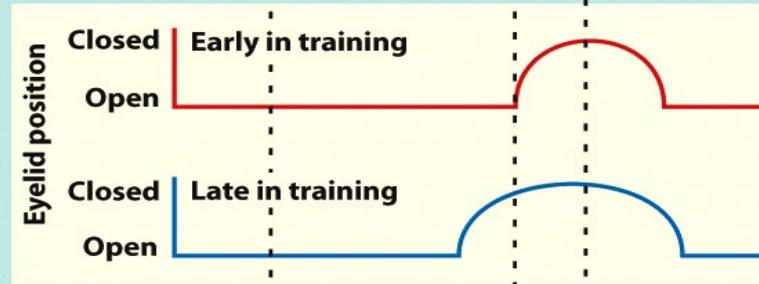
Loudspeaker



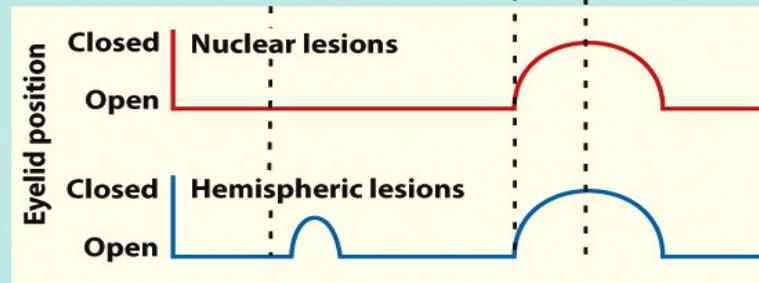
(a) Stimulus



(b) Acquisition of eyeblink conditioning



(c) Lesion effects on eyeblink conditioning

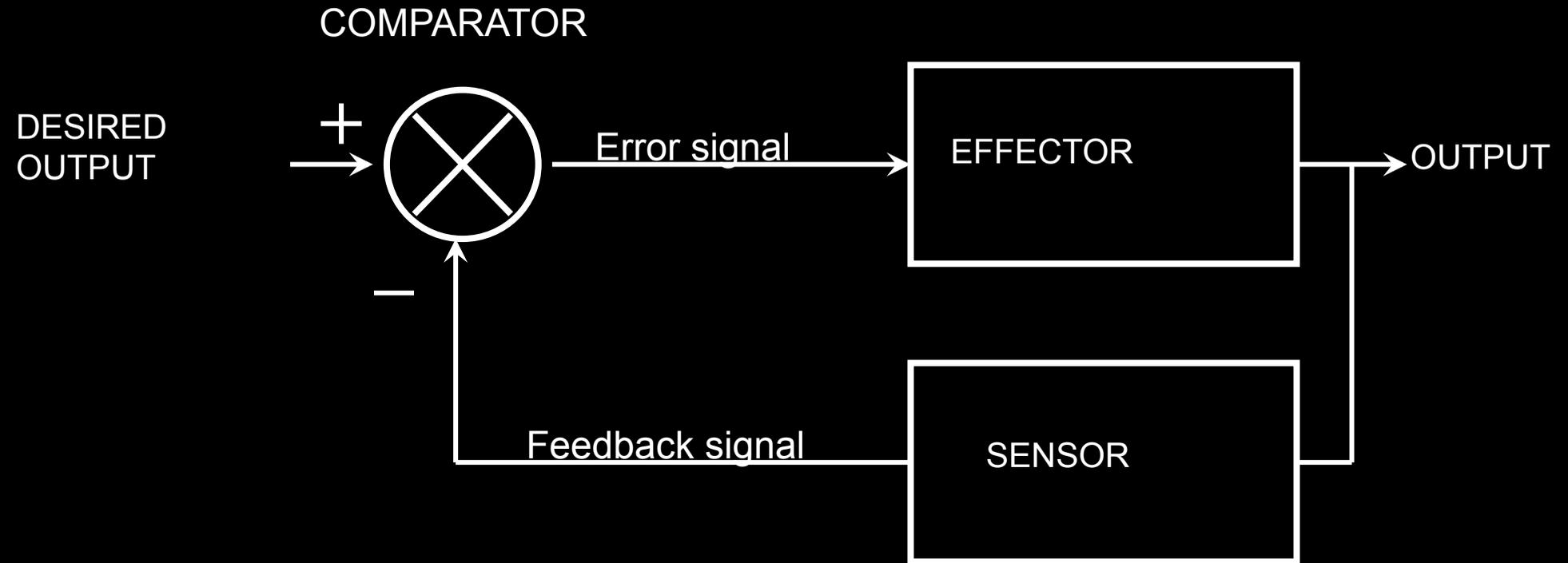


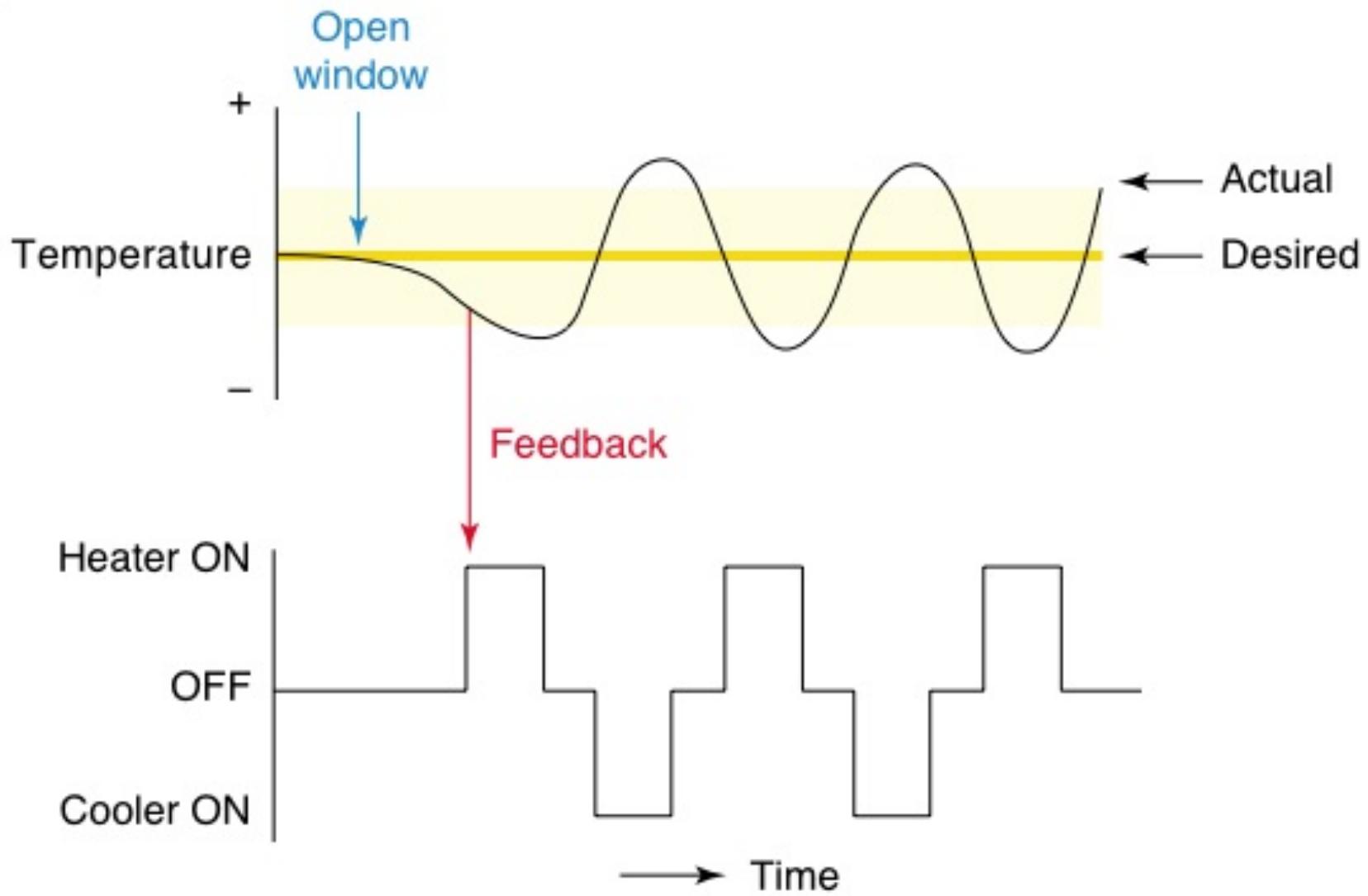
Cerebellum as a Control System

Feedback Controller for Slow movements (e.g., posture)

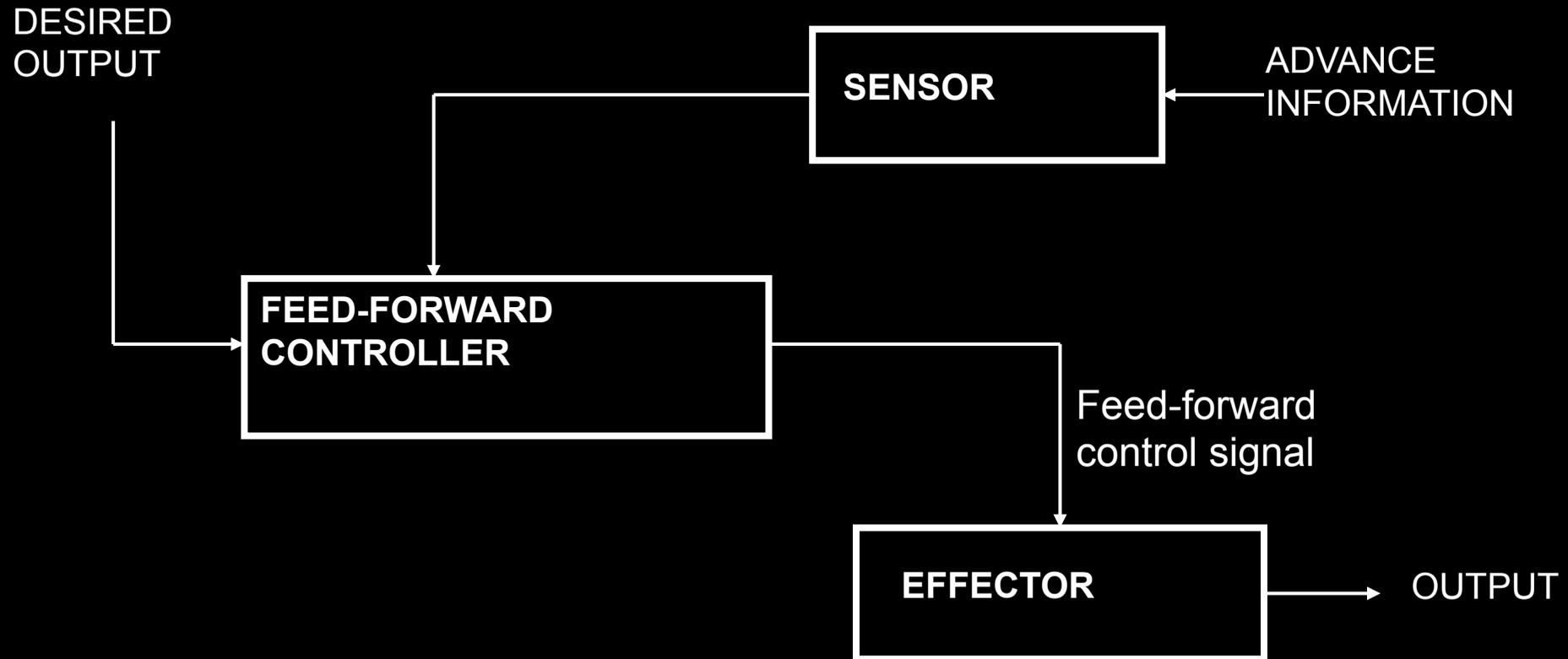
Feedforward Controller for Fast movements (e.g., most voluntary movements)

Feedback control system

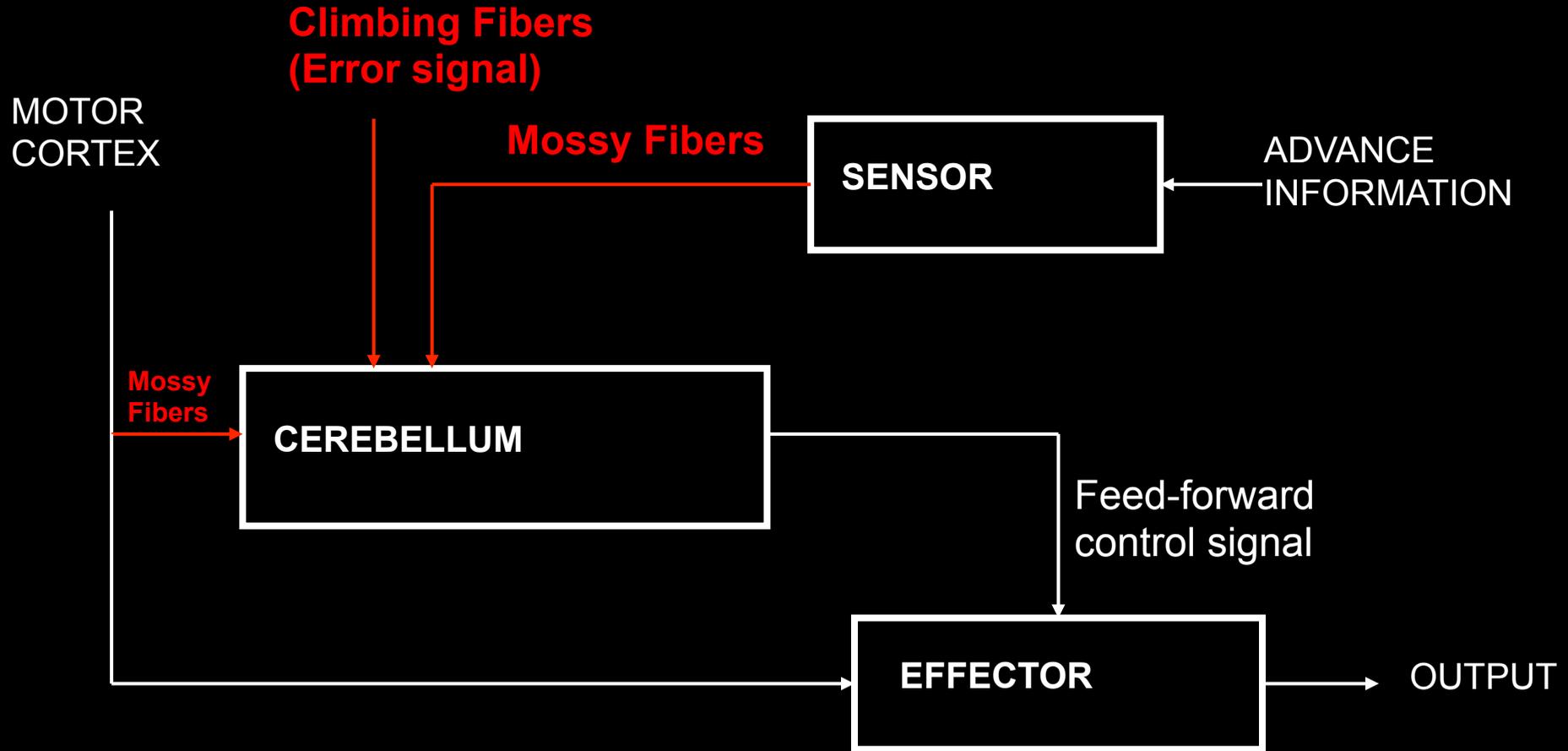




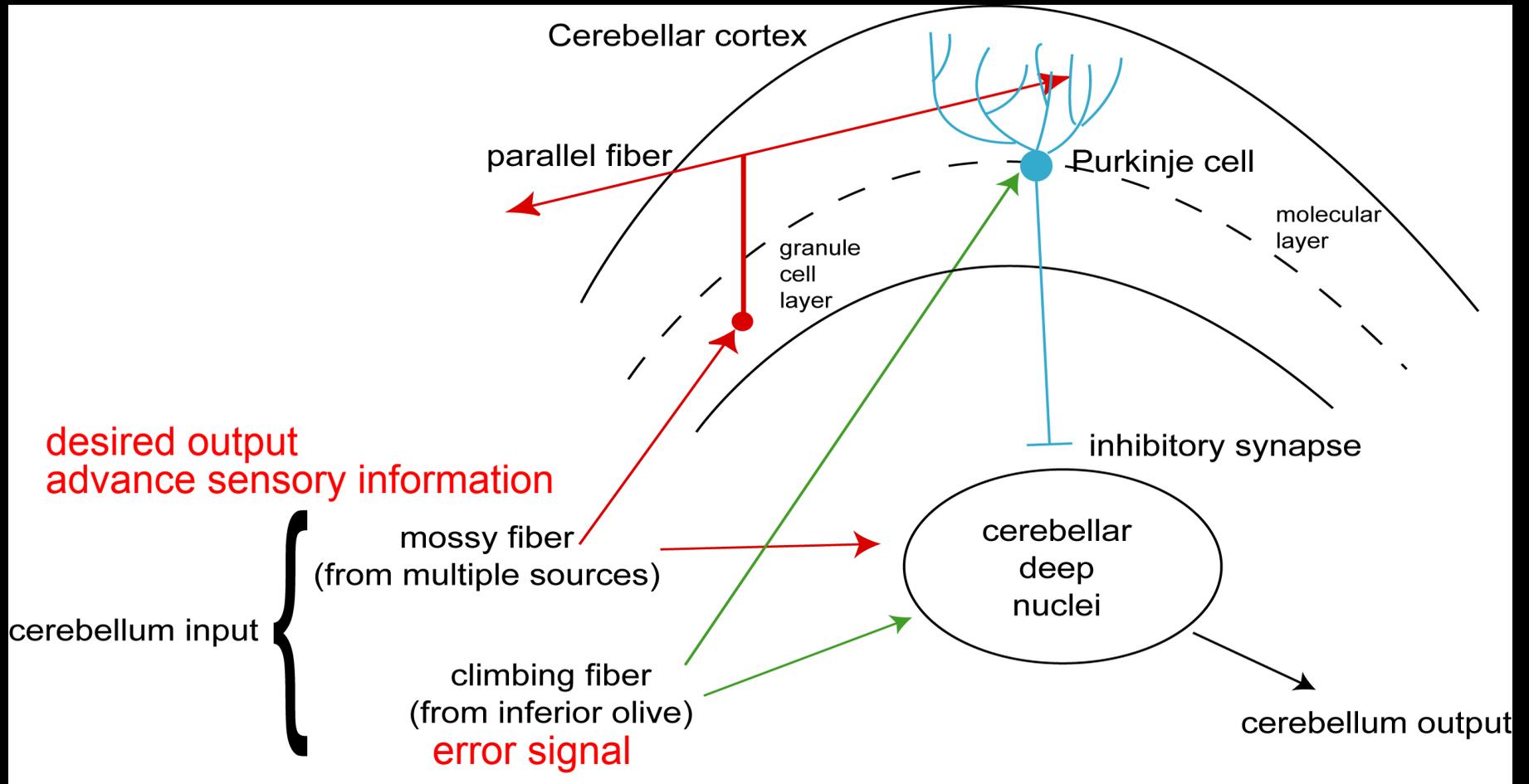
Feedforward control system



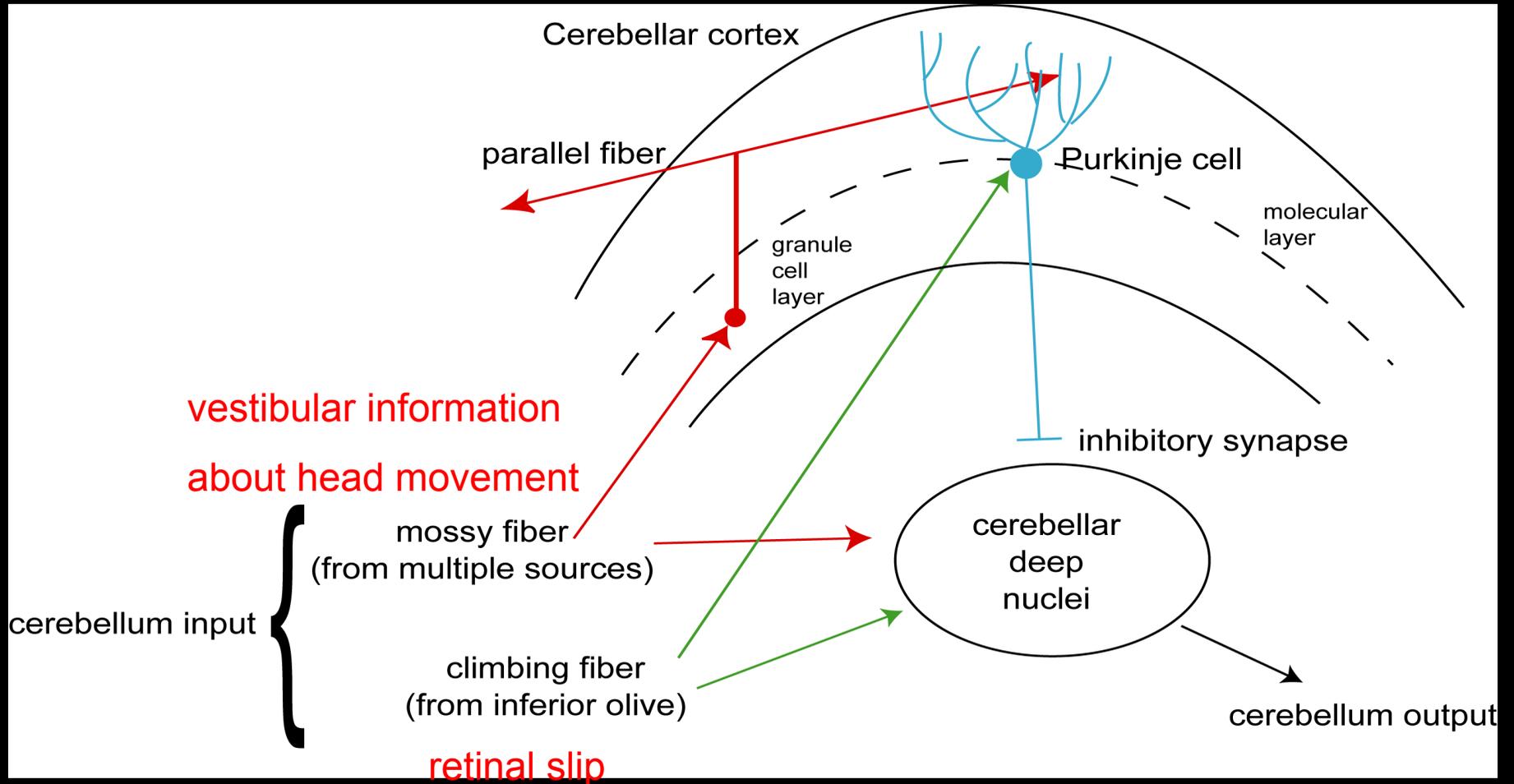
Cerebellum as a feedforward control system



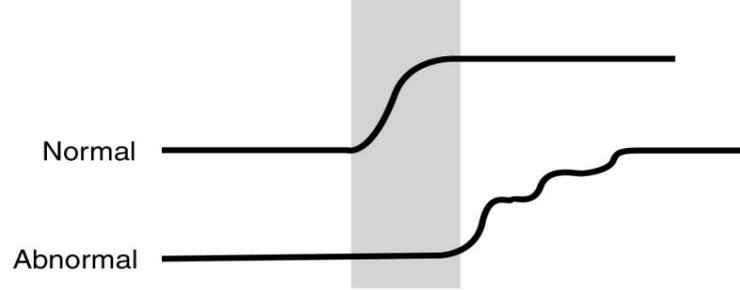
Internal Circuitry of Cerebellum



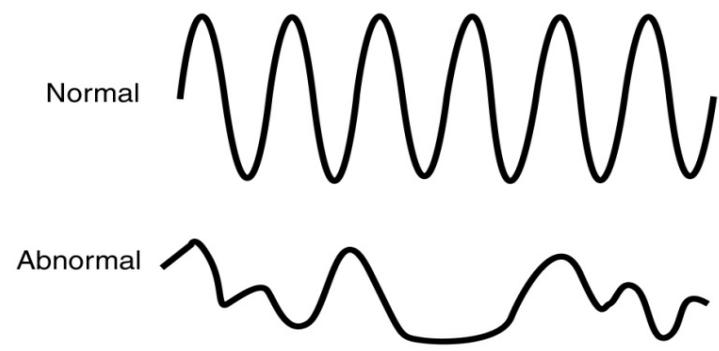
VOR and feedforward control



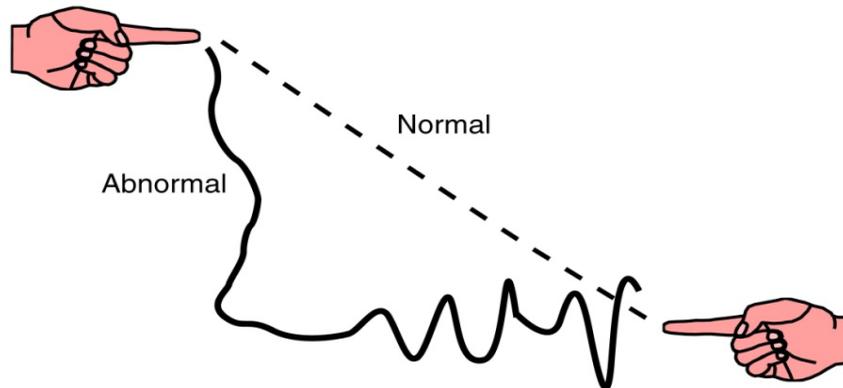
Delay in initiating responses



Dysdiadochokinesia

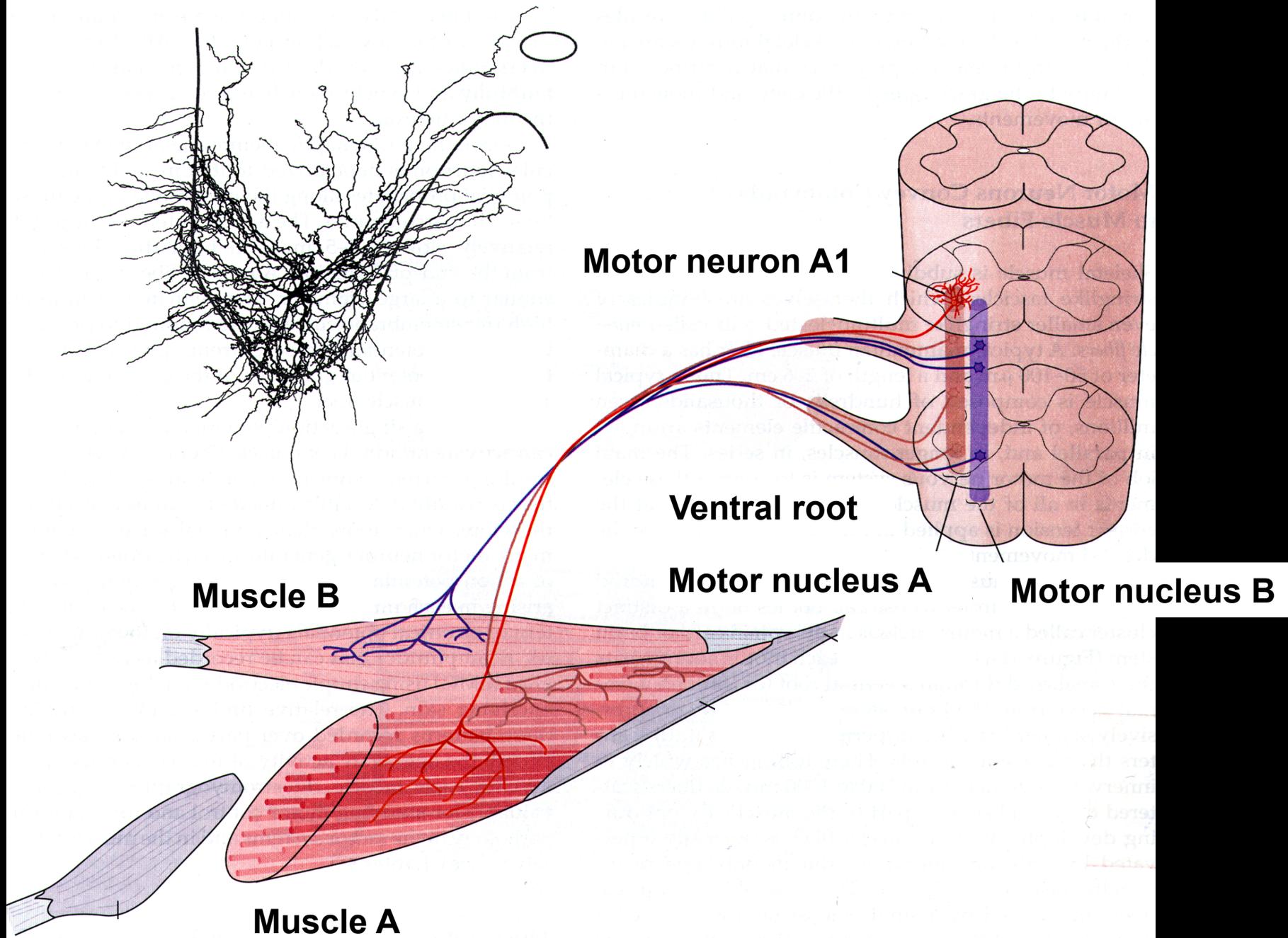


Decomposition of movement / intention tremor



Lower Motor Neuron Syndrome

- Effects limited to small groups of muscles
- Muscle atrophy
- Weakness
- Fasciculation/fibrillation
- Decrease in muscle tone (hypotonia)
- Absent reflexes (hyporeflexia)



Lower Motor Neuron Syndrome

- Effects limited to small groups of muscles
- Muscle atrophy
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- Fasciculation/fibrillation
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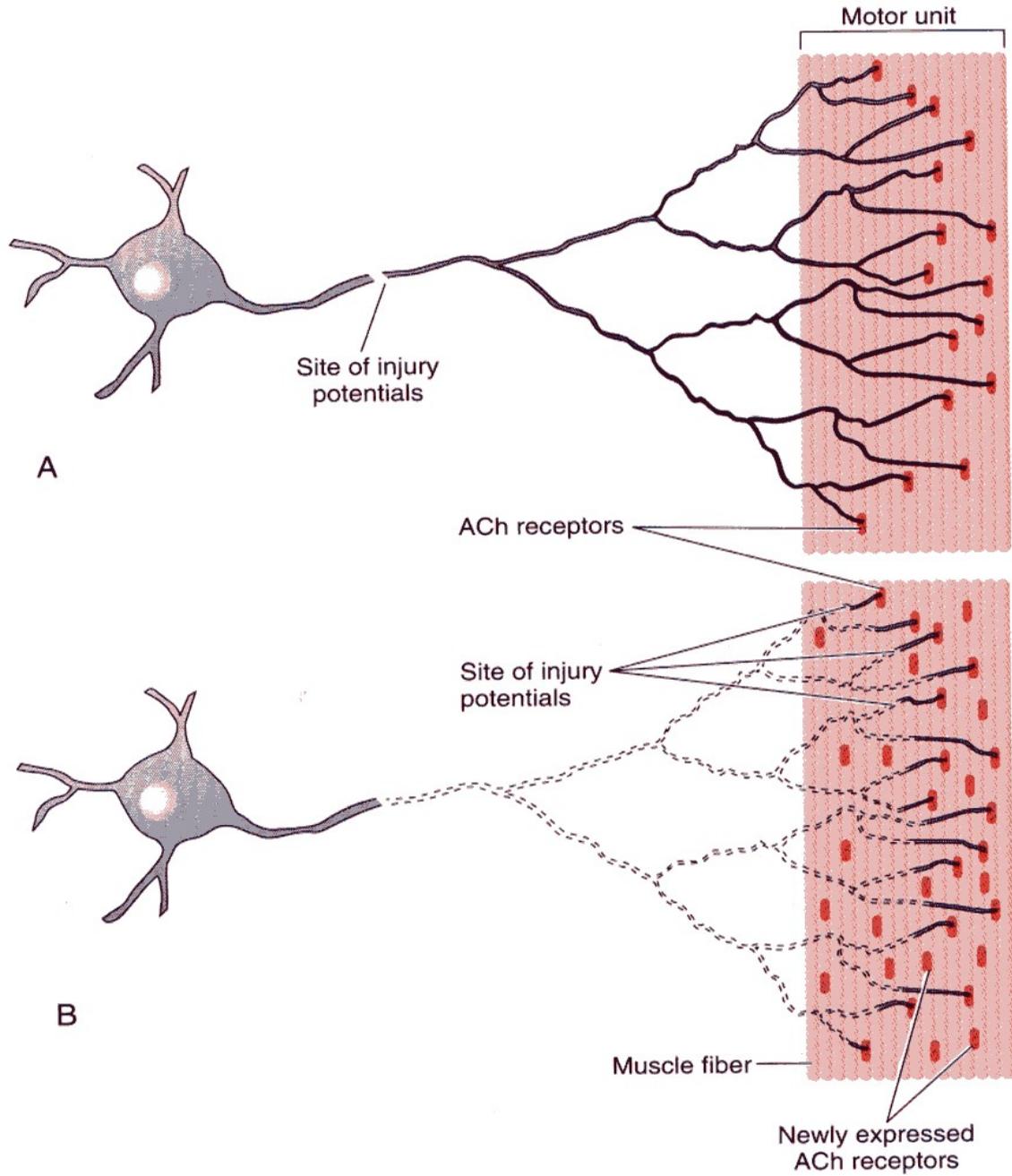


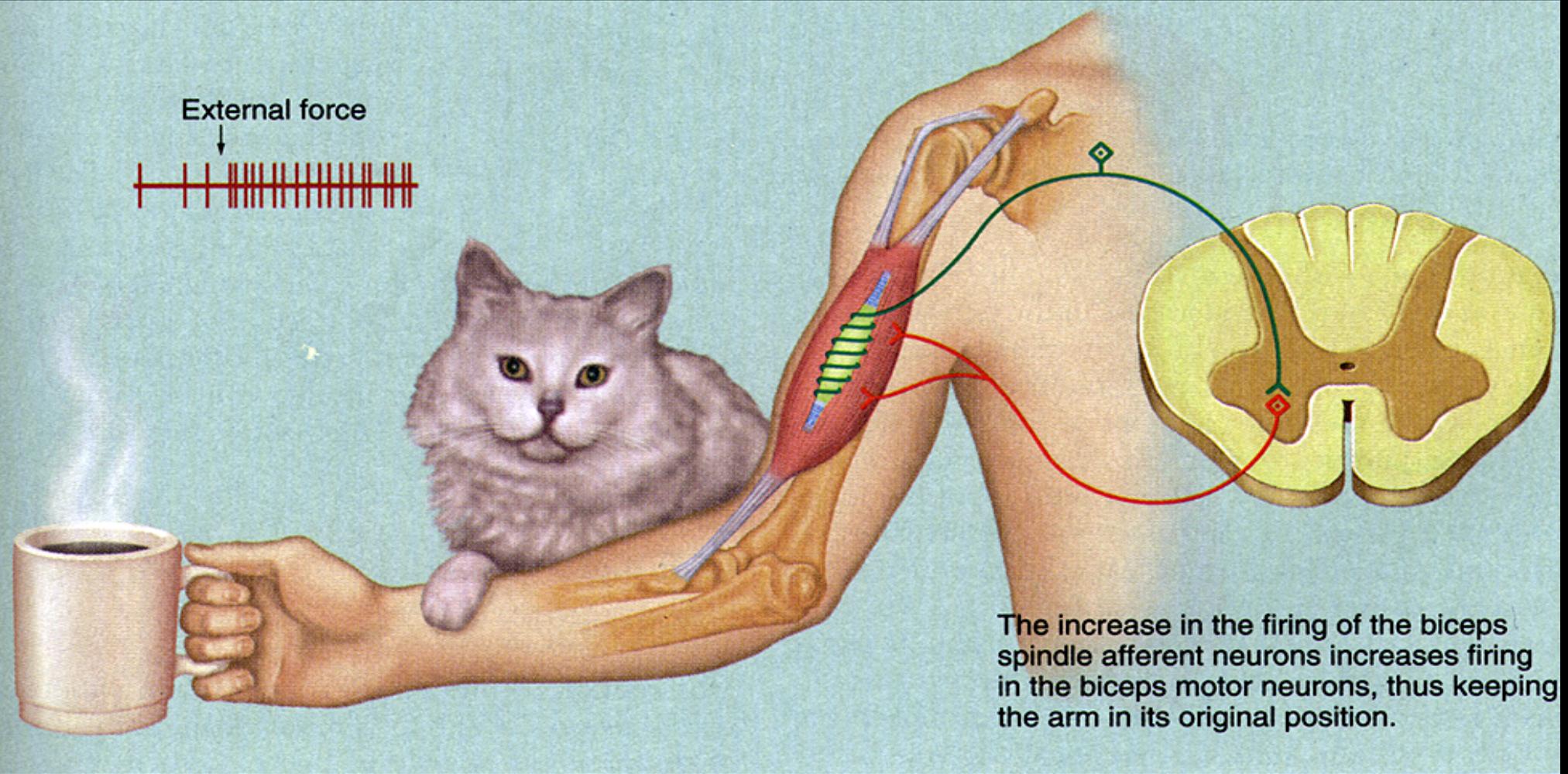
Figure 6.13 Effects of muscle denervation

Lower Motor Neuron Syndrome

- Effects limited to small groups of muscles
- Muscle atrophy
- Weakness
- Fasciculation/fibrillation
- Decrease in muscle tone (hypotonia)
- Absent reflexes (hyporeflexia)

Lower Motor Neuron Syndrome

- Effects limited to small groups of muscles
- Muscle atrophy
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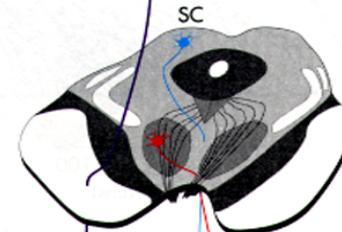
Descending Spinal Pathways

(from Nolte, p. 438)

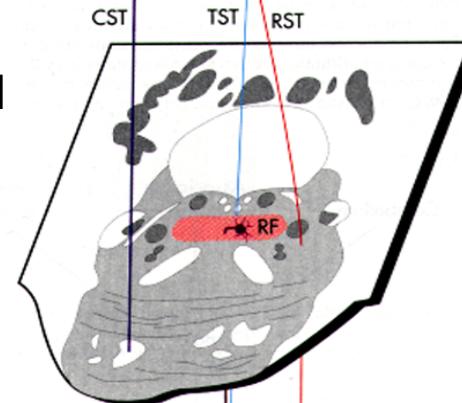
Precentral gyrus



Rostral midbrain



Caudal pons



Rostral medulla



Cervical spinal cord



Upper Motor Neurons

Upper Motor Neuron Syndrome

- Effects extend to large groups of muscles
- Atrophy is rare
- Weakness (paresis, not plegia)
- No fasciculation/fibrillation
- Increase in muscle tone (hypertonia)
- Hyperreflexia
- Clonus
- Initial contralateral flaccid paralysis
- Spasticity
- Babinski sign

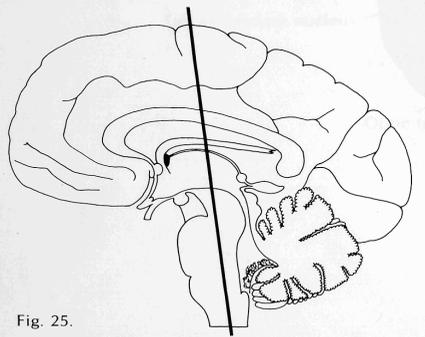
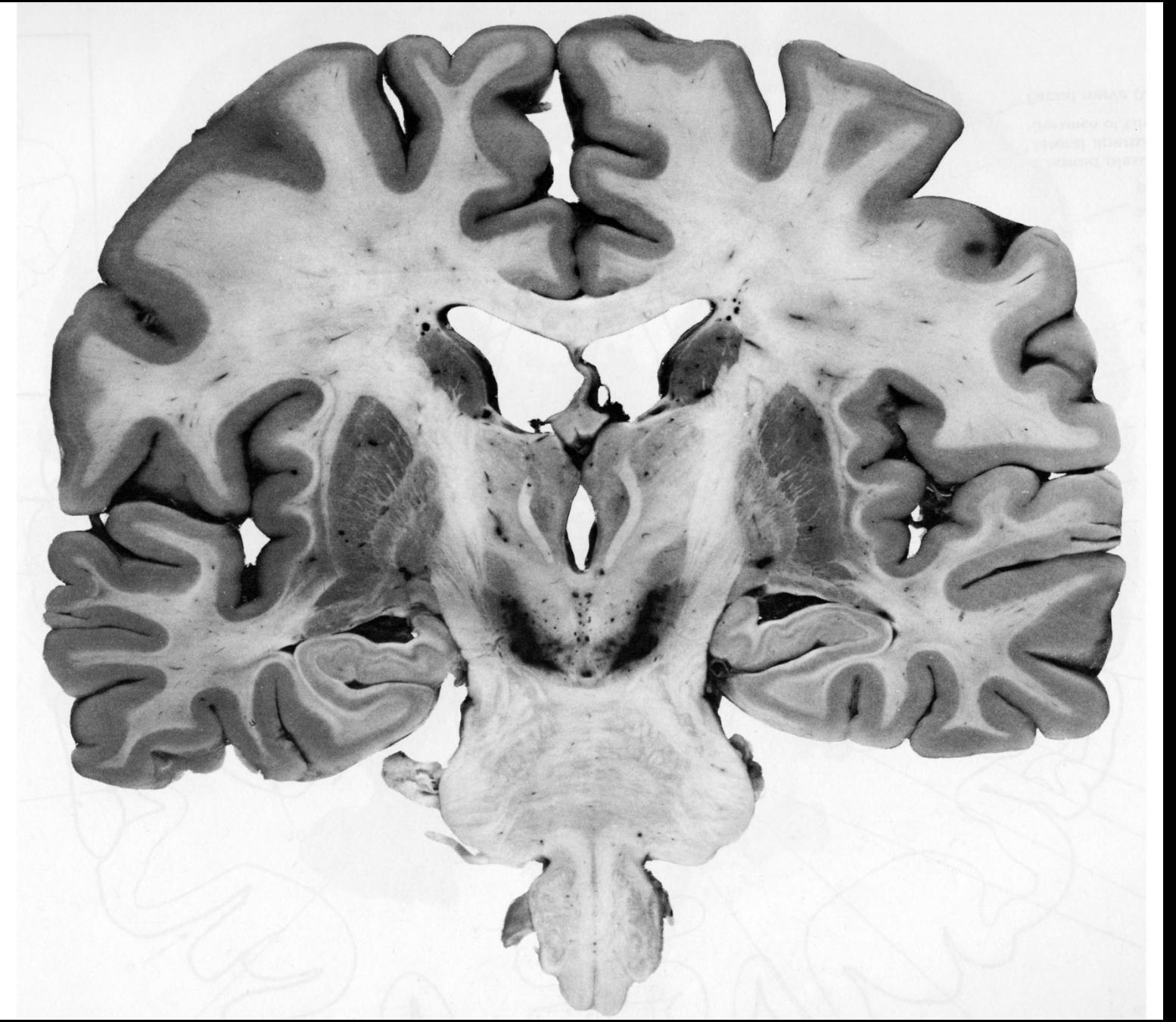
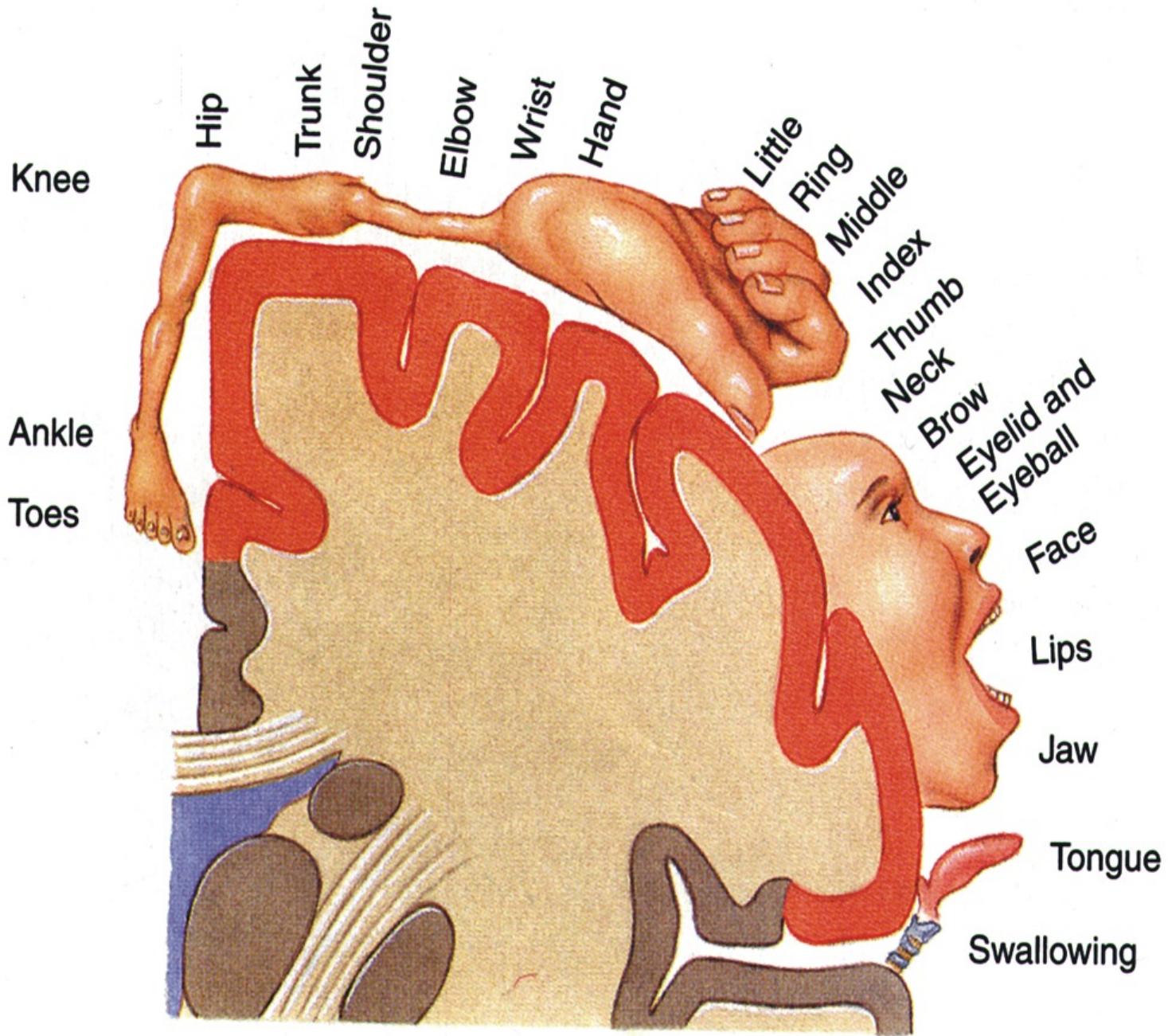


Fig. 25.



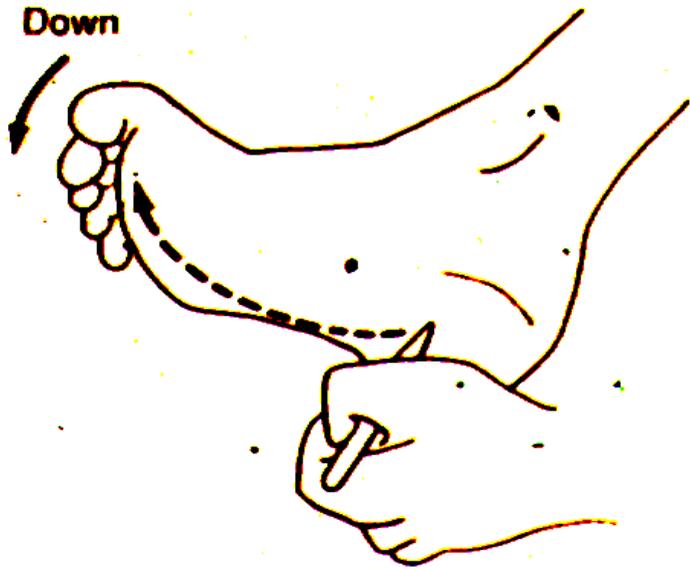
DeArmond Fig. 25



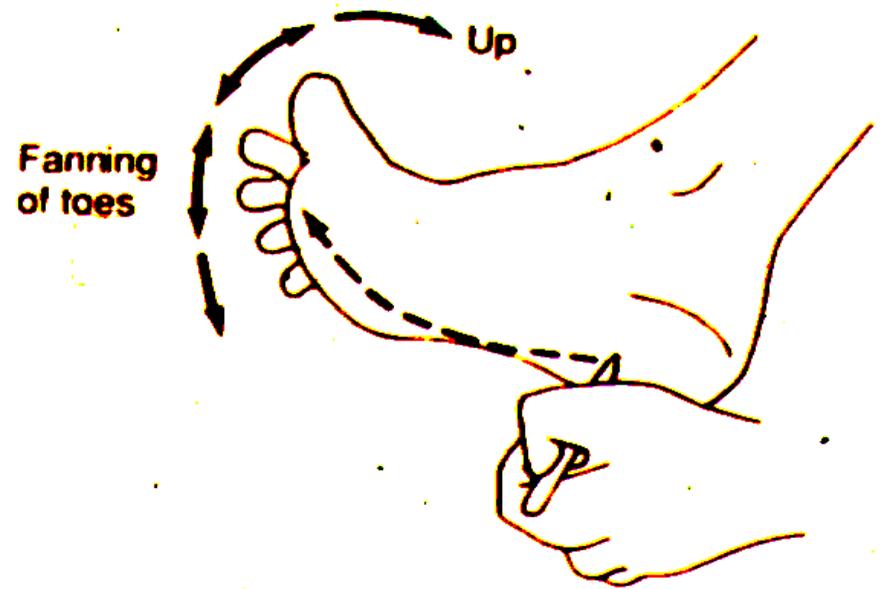
Upper Motor Neuron Syndrome

- Effects extend to large groups of muscles
- Atrophy is rare
- Moderate weakness (paresis, not plegia)
- No fasciculation/fibrillation
- Increase in muscle tone (hypertonia)
- Hyperreflexia
- Clonus
- Initial contralateral flaccid paralysis
(eventual recovery of some movement)
- Spasticity (“clasp-knife reflex”)
- Babinski sign

Normal plantar response



**Extensor plantar response
(Babinski sign)**



Lesions of Higher Motor Cortical Areas (premotor, supplementary)

- Impairments in motor planning and strategies
- Unable to perform complex motor tasks (apraxia)

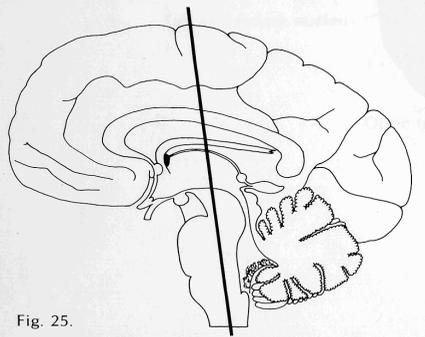
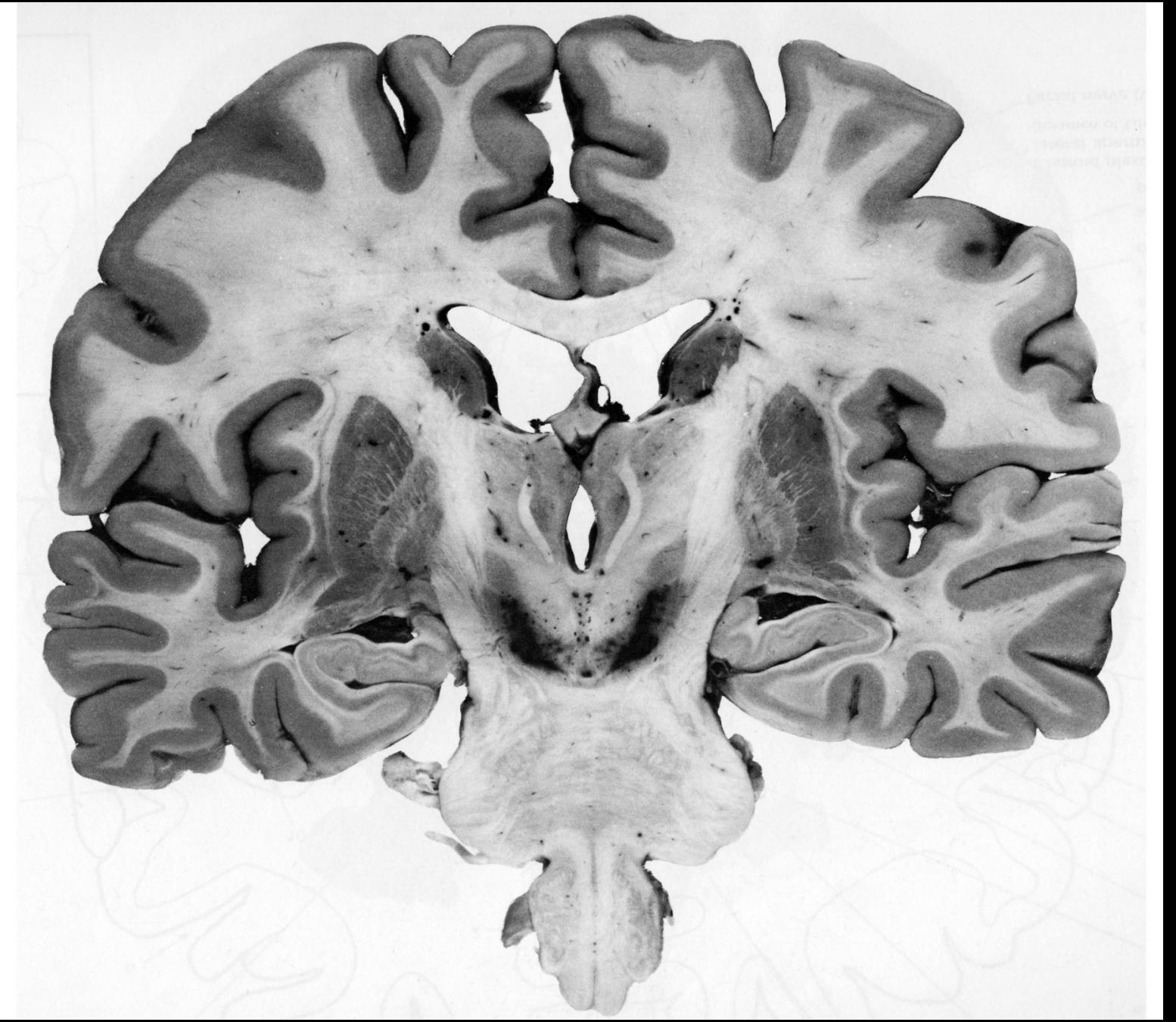


Fig. 25.



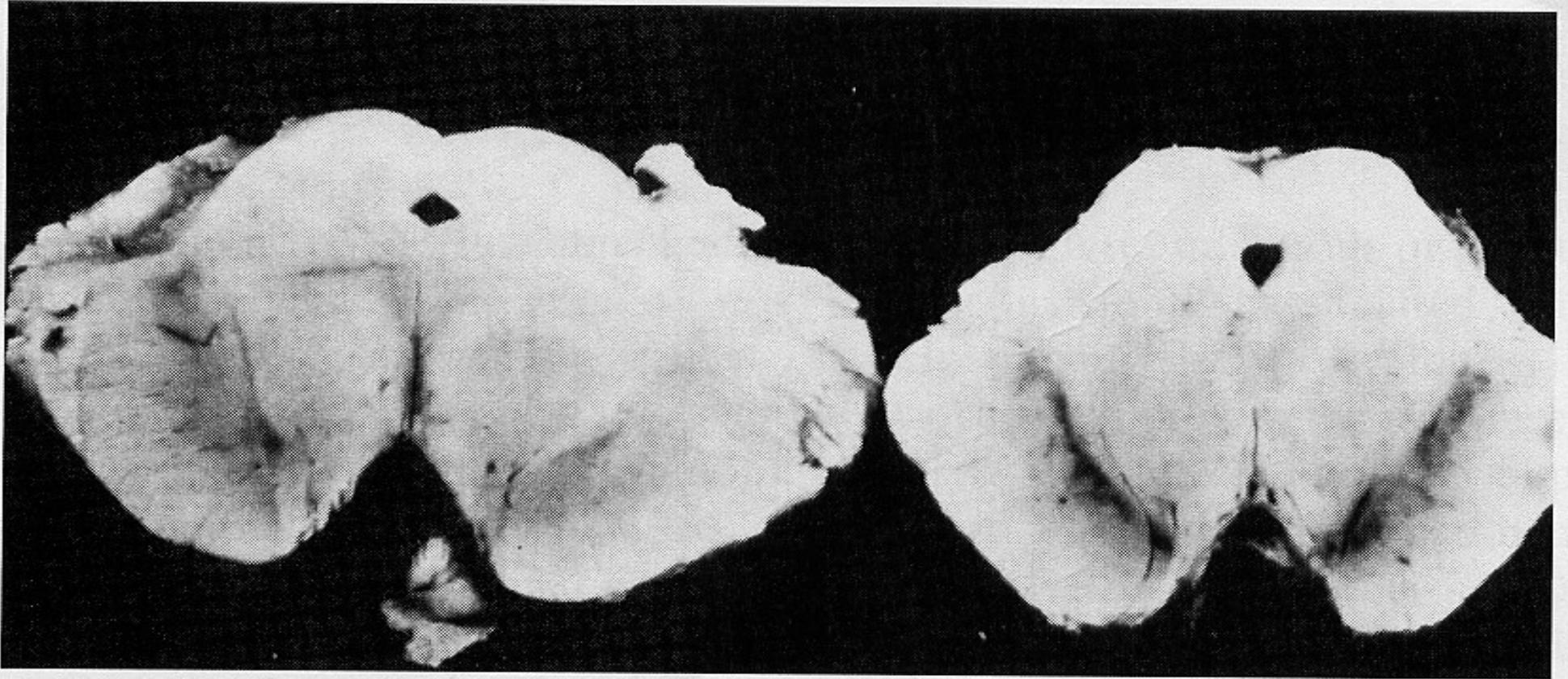
DeArmond Fig. 25

Disorders of the Basal Ganglia

Dyskinesia: abnormal involuntary movements:

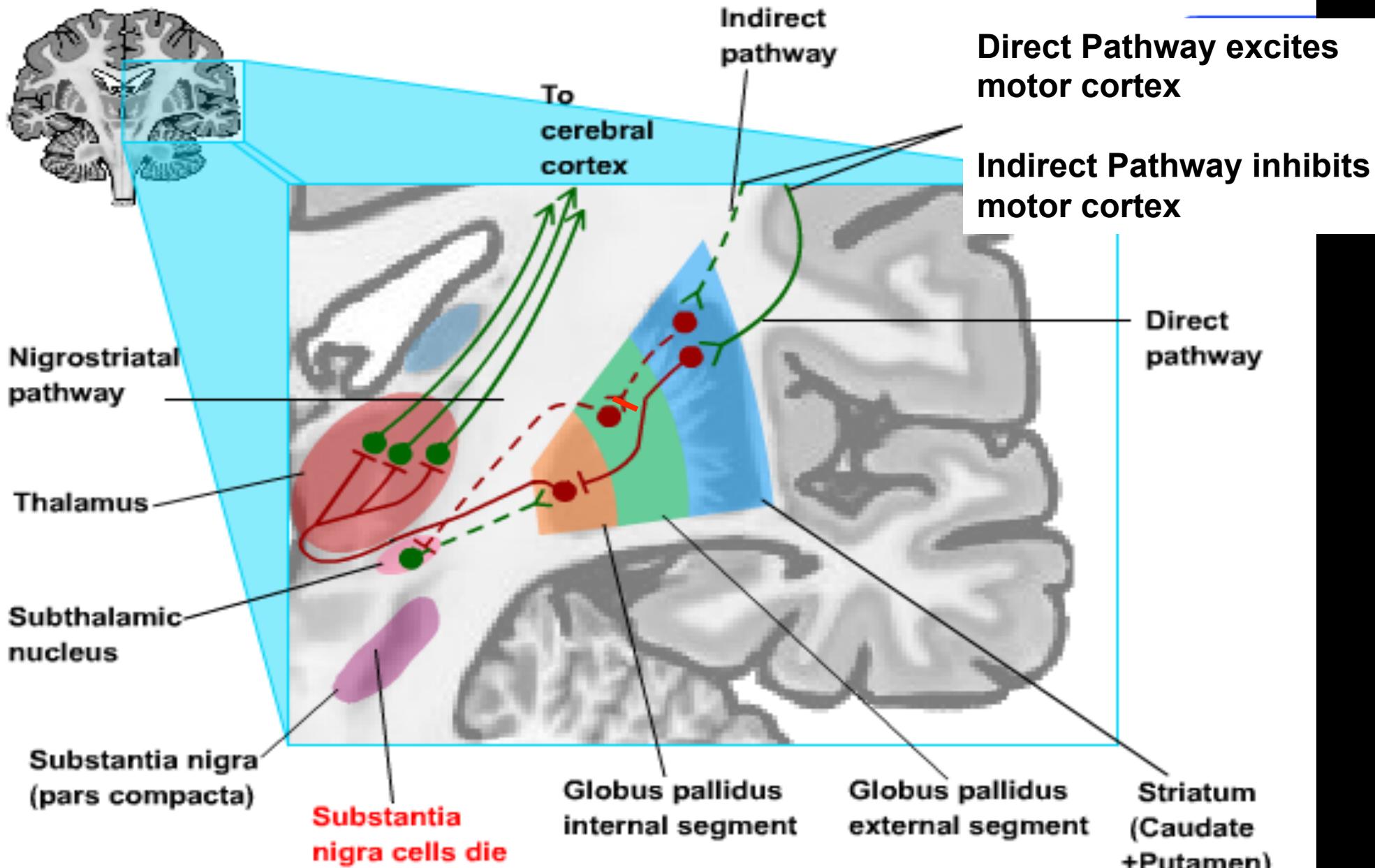
- Resting tremor (“pill-rolling tremor”)
 - Athetosis (slow, writhing movements of extremities)
 - Chorea (jerky, random movements of limbs and face)
 - Ballismus (violent, large movements of proximal limbs)
 - Tardive dyskinesia
-
- Akinesia: abnormal involuntary posture
 - Rigidity (resistance to passive movement; “lead-pipe rigidity, cog-wheel rigidity”)
 - Dystonia (abnormal postures from contraction of agonist & antagonist muscles)
 - Bradykinesia

Parkinson's Disease

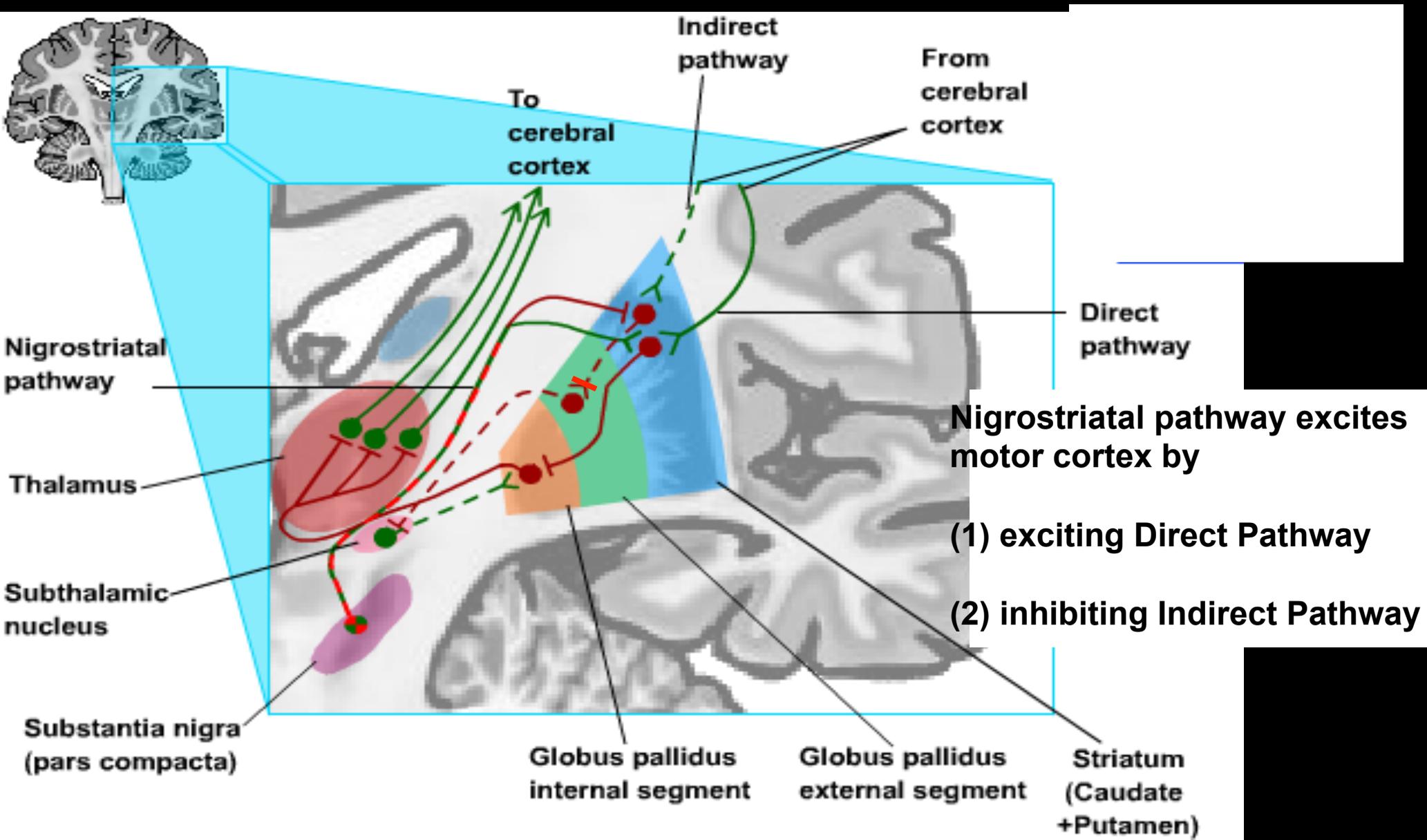


From Kingsley RE (2000) *Concise Text of Neuroscience, 2nd Ed.*

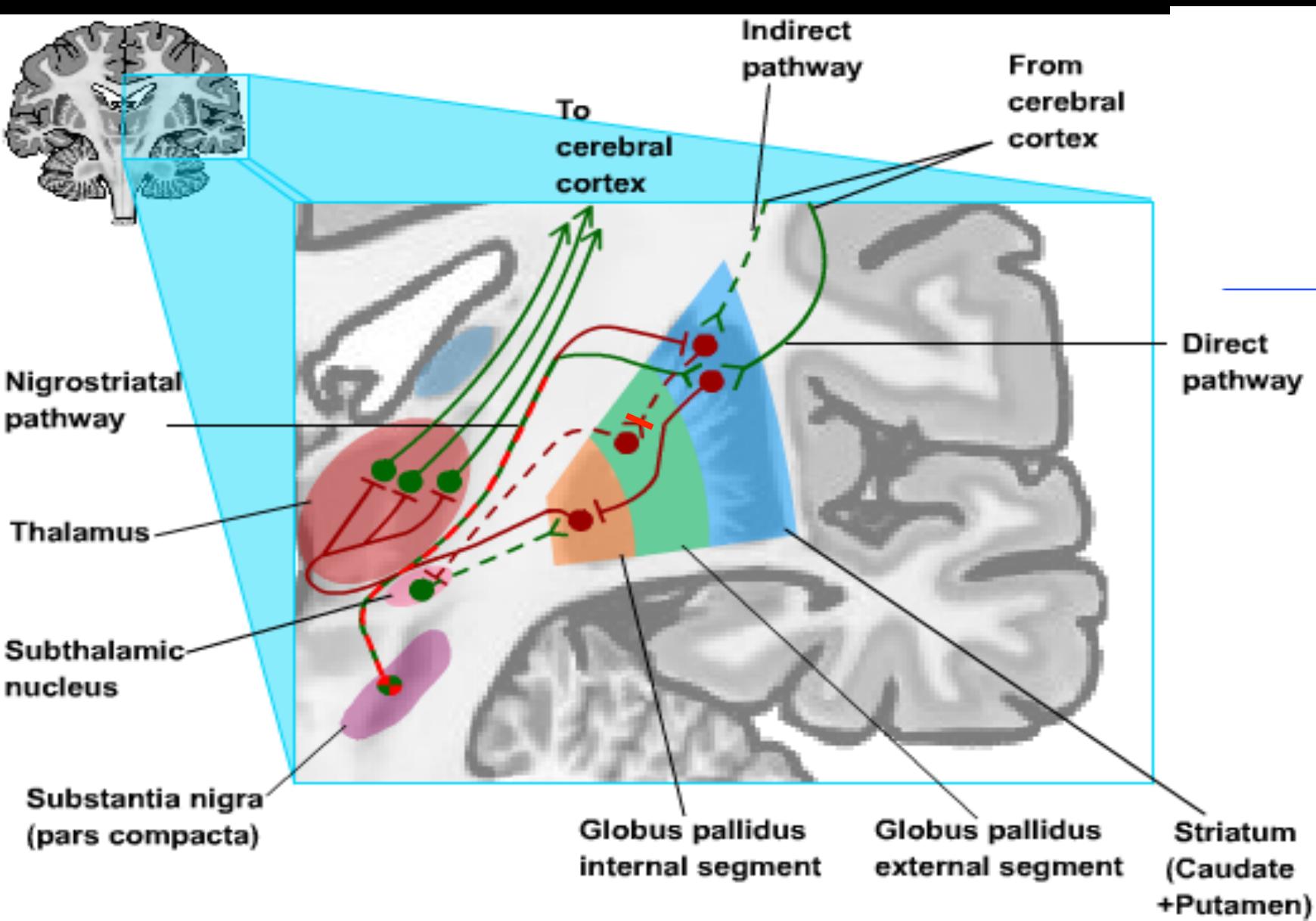
Direct and Indirect Pathways



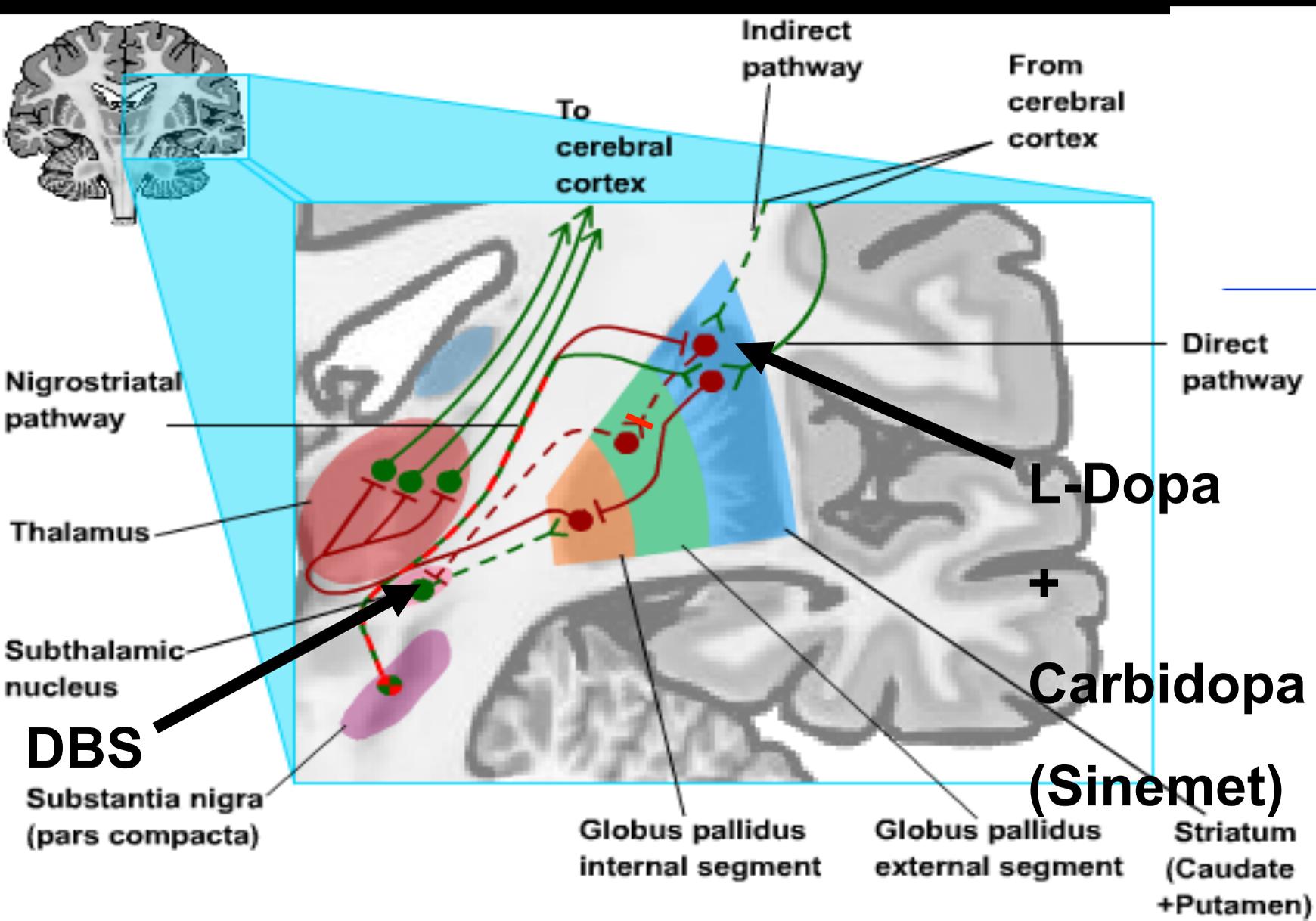
Dopaminergic Input from Substantia Nigra



Parkinson's Disease



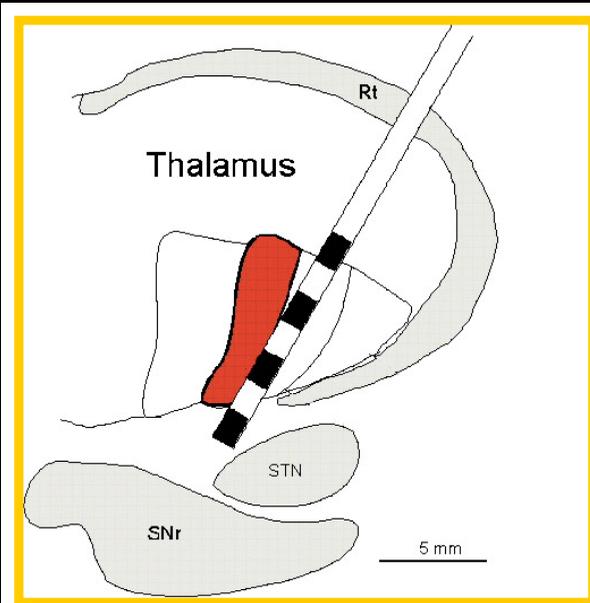
Parkinson's Disease Treatments



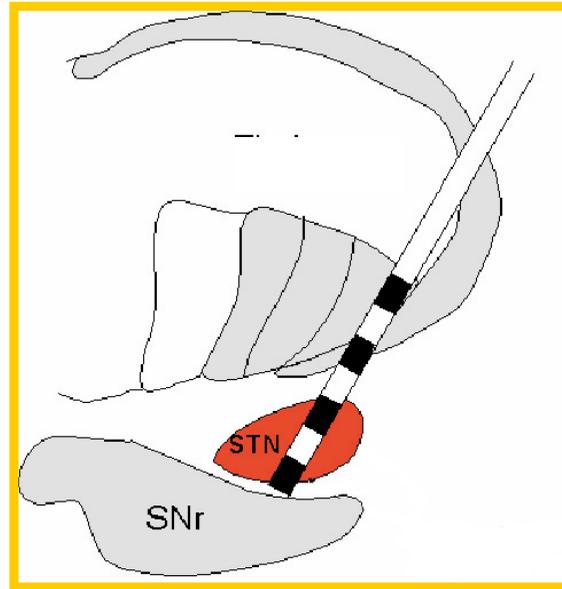
Deep brain stimulation for movement disorders

- Mechanics:
- Pre-implantation MRI
- Sterotaxy (frameless or not)
- Recording to ensure correct placement
- Post-surgery: Programming: pulse width, rate, amplitude

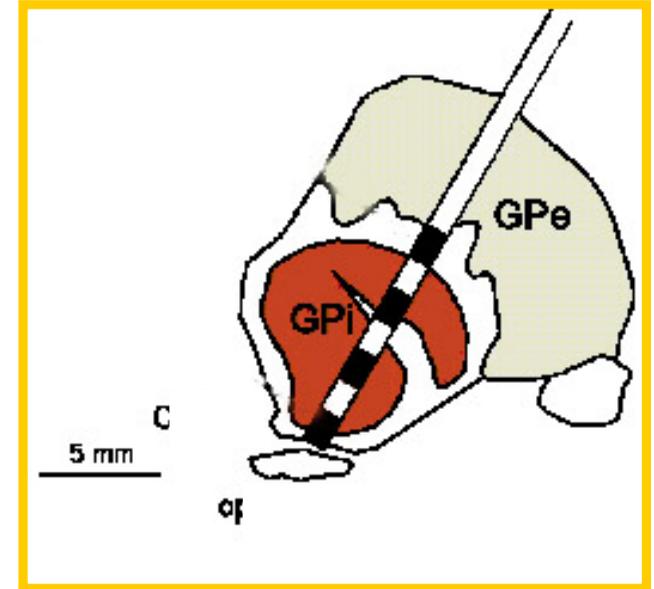
DBS targets



Vim Thalamus:
Essential tremor &
other tremor disorders

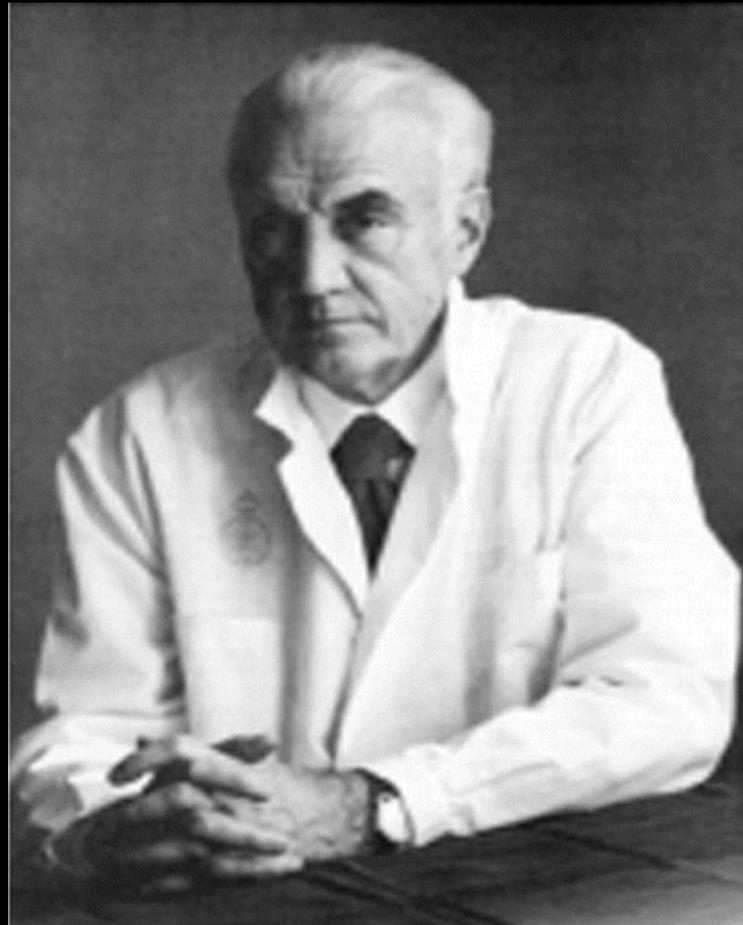


Subthalamic nucleus:
Parkinson's disease



Globus pallidus:
Parkinson's disease &
dystonia

Lars Leksell



“I was born under the sign of the ‘archer’ and look forward to sharpshoot into the brain.”

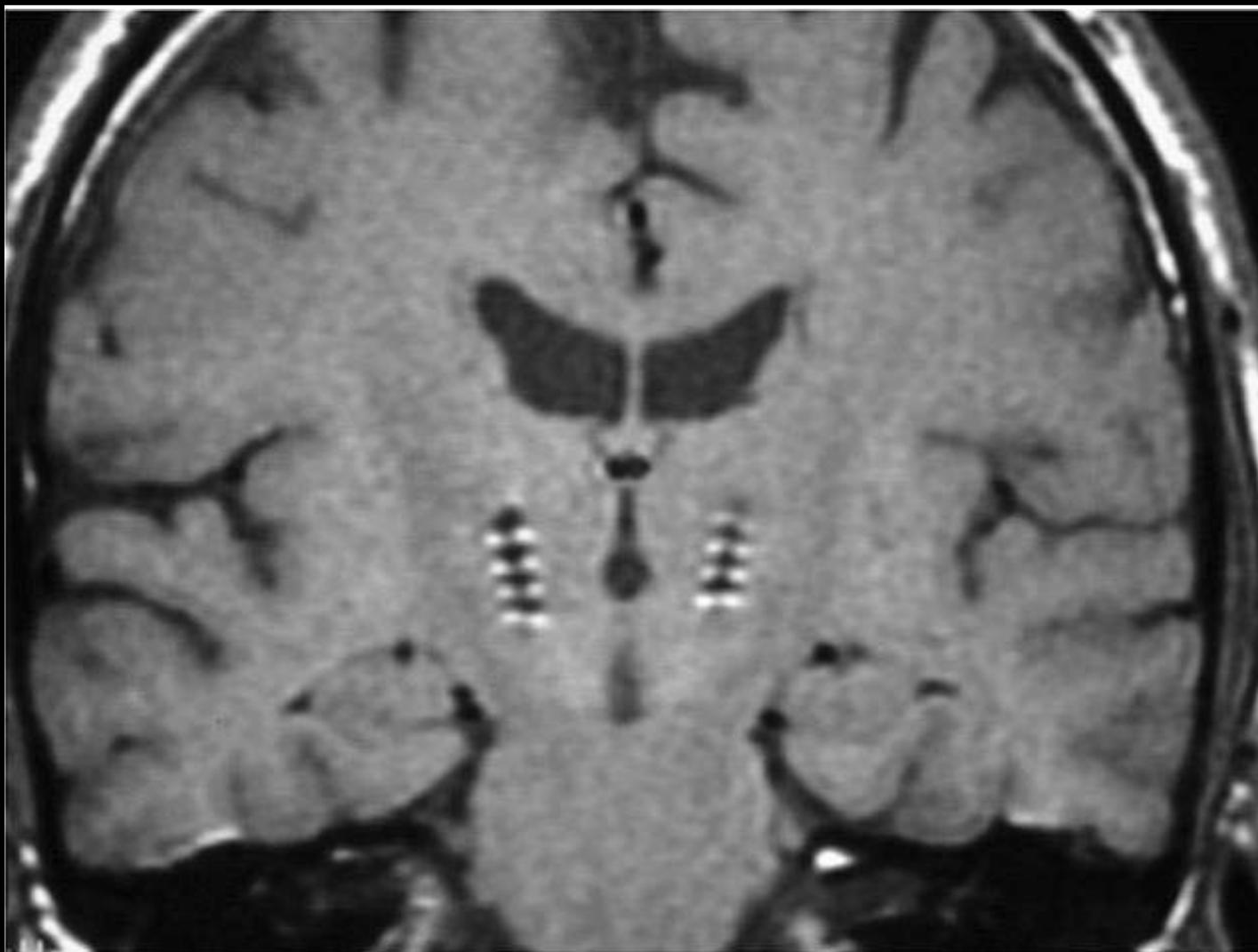
Surgical Technique: Targeting

- Sophisticated imaging and software enables precise targeting for optimal outcomes and minimal risk
- Microelectrode recording (MER) offers additional levels of verification of lead location

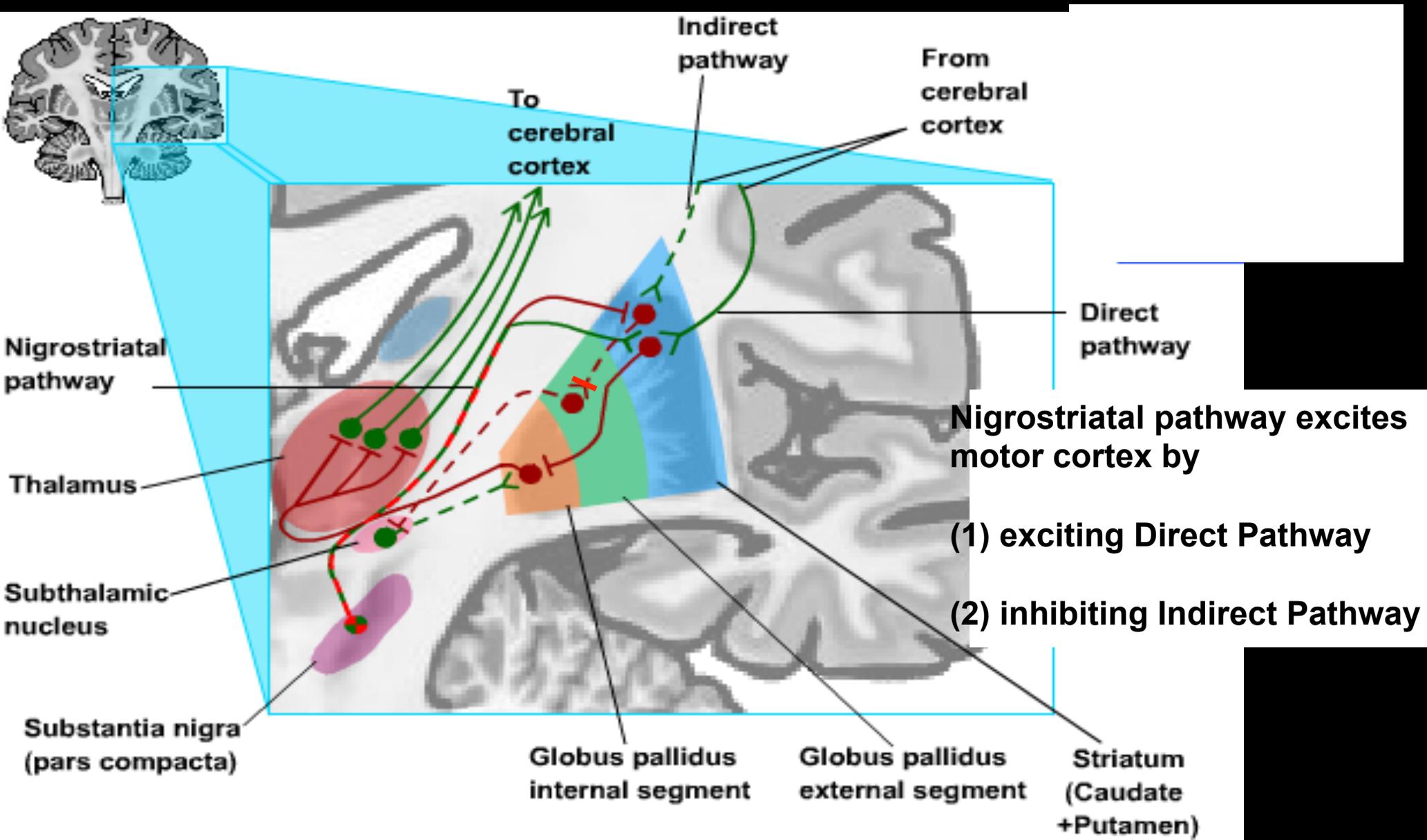


- Complications:
 - Stroke/ hemorrhage (2%)
 - Infection (4%)
 - Hardware complications – leads breaking, electrode malfunction, stimulator failure, battery failure

MRI of electrode placement



Dopaminergic Input from Substantia Nigra



Deep brain stimulation for movement disorders

- Post-surgery: Programming: pulse width, rate (135 – 185 Hz), amplitude
- Don't really understand how it works

DBS and ...

“No neuron is safe from a neurosurgeon”

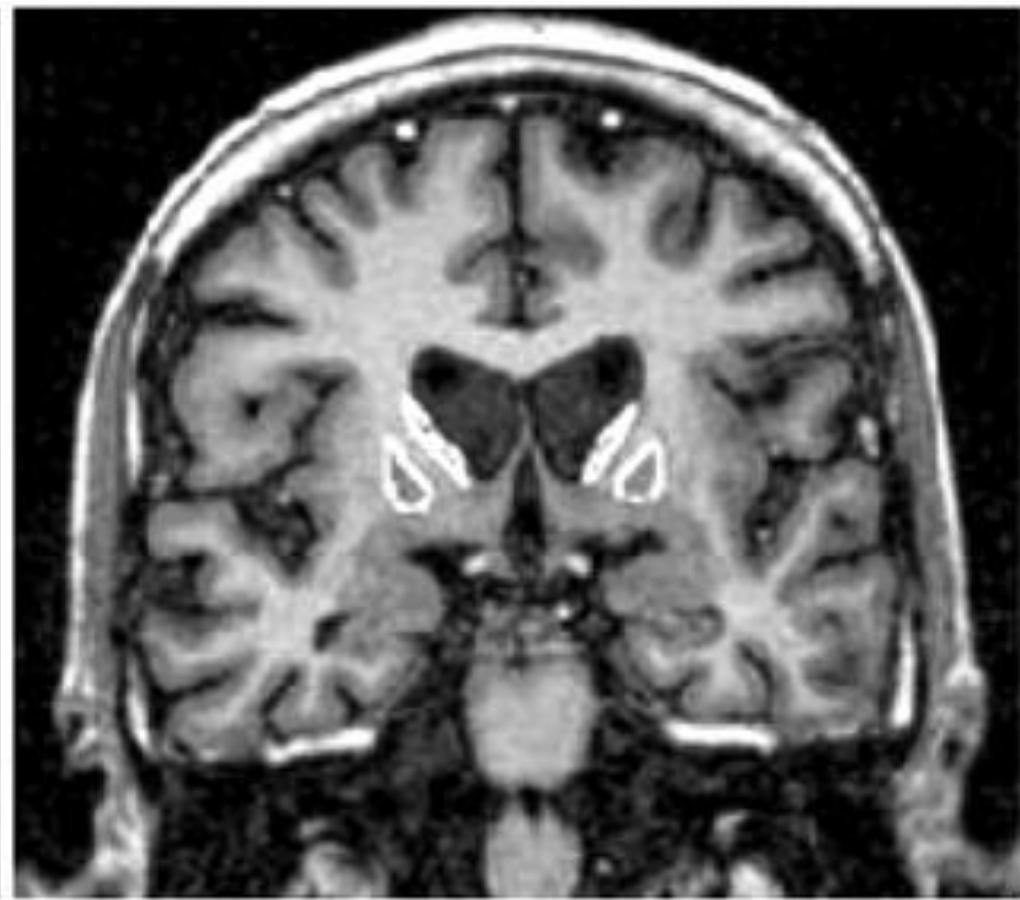
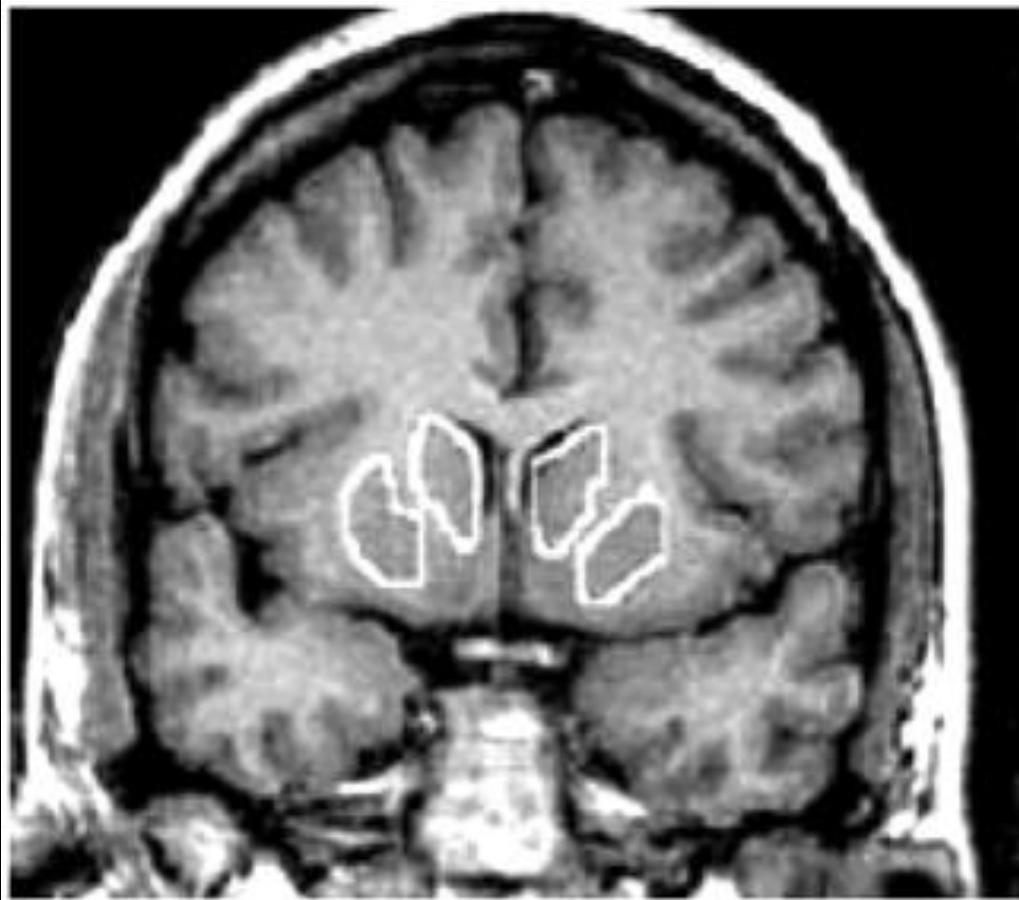
– Andres Lozano, MD,PhD at the 62nd Annual Meeting of the AAN

Huntington's Disease

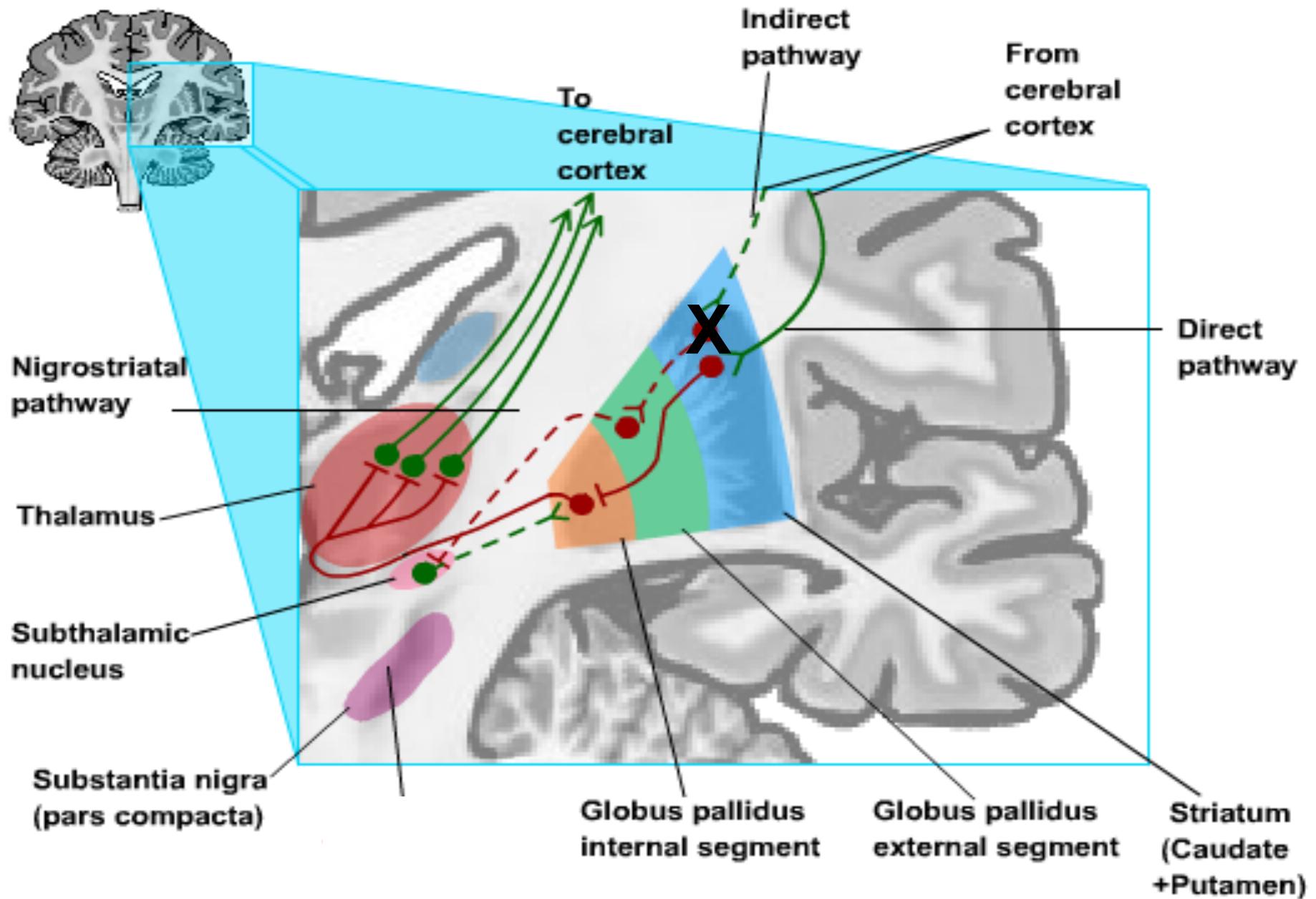
- Genetic disorder caused by an abnormally large number of repeats of nucleotide sequence CAG on chromosome 4
- Autosomal dominant mutation (50% chance of offspring inheriting the mutation and developing the disease)
- Mutation of *huntingtin* gene, causing destruction of indirect pathways neurons of striatum
- Characterized by continuous, choreiform movements of body (esp. hands and face)
- Dementia in advanced cases (reflecting loss of cognitive functions of basal ganglia as well as neocortical degeneration)
- No cure, treatment or prophylaxis

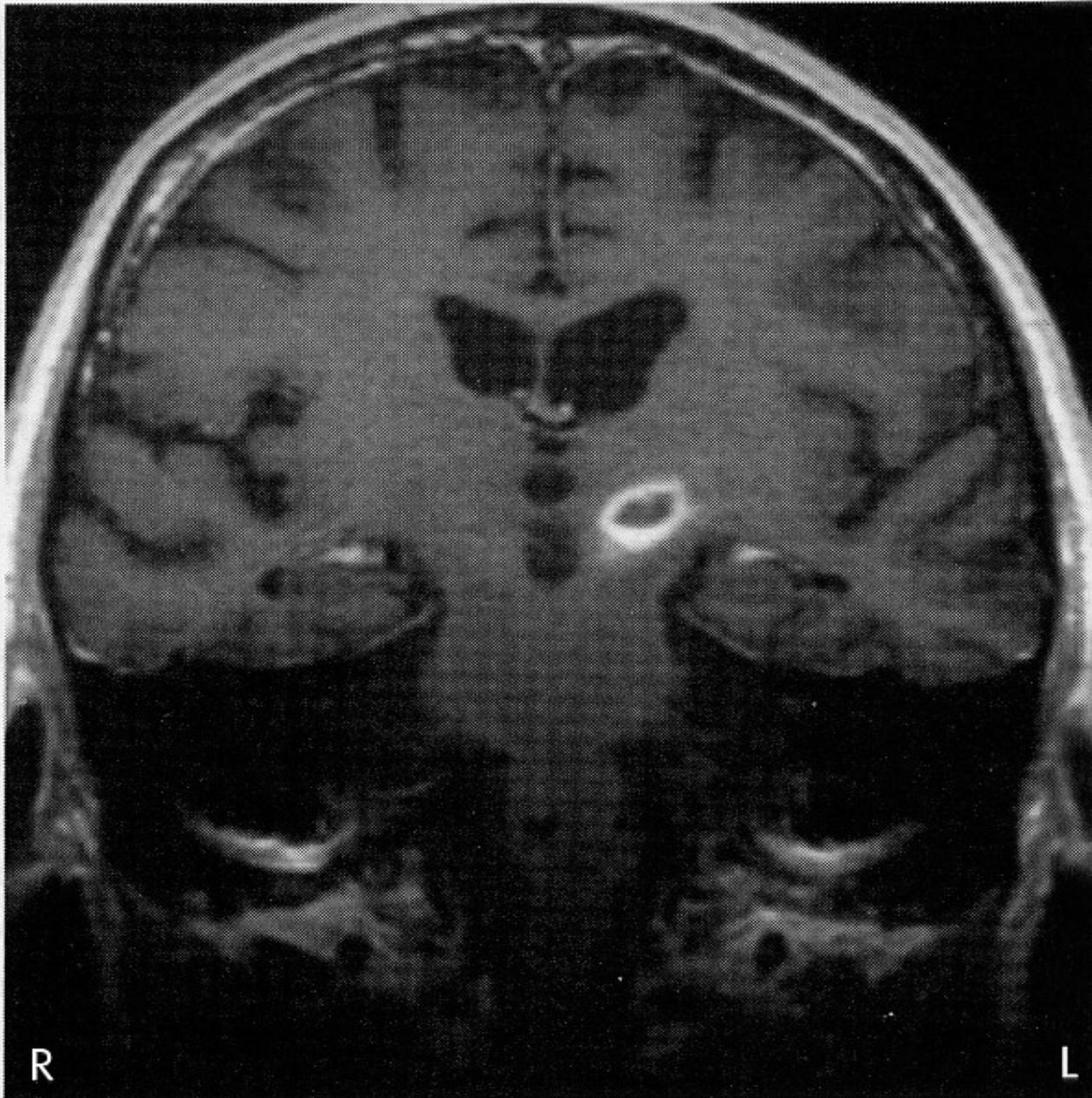


Huntington's Disease



Huntington's Disease

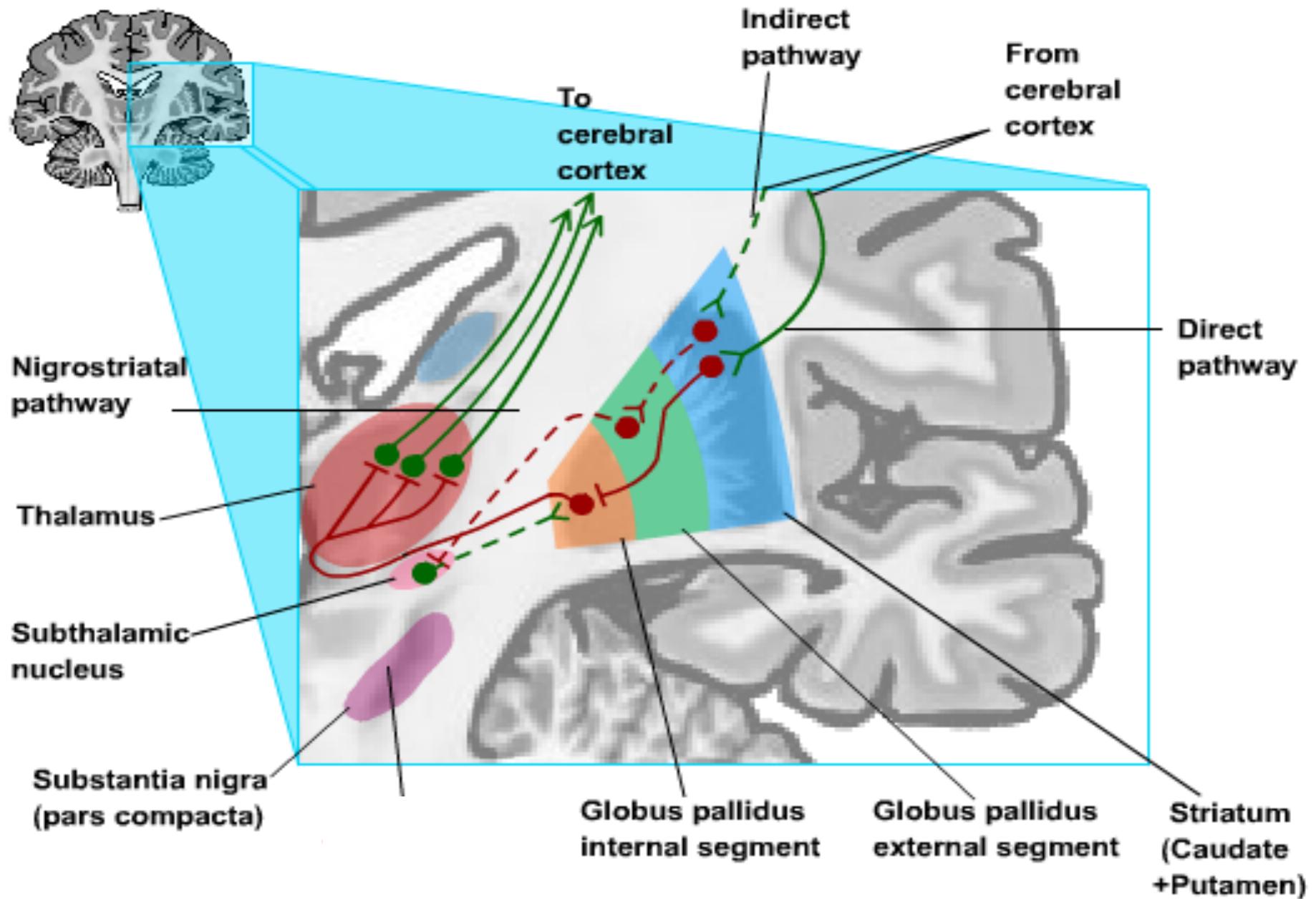


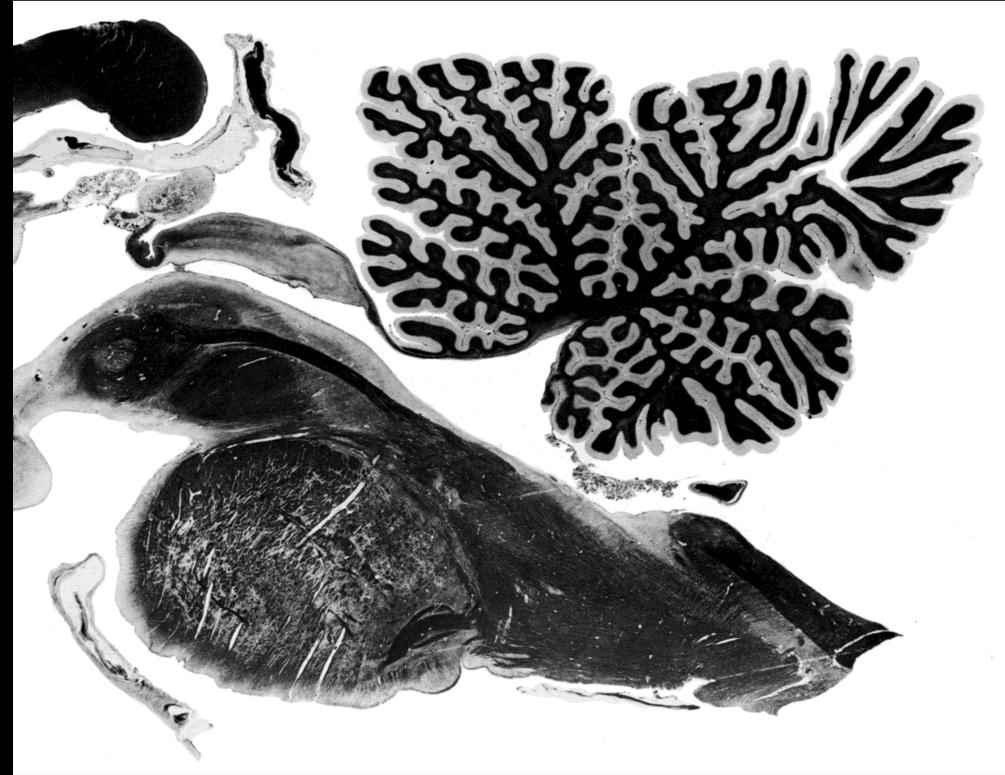


Lesion of the
subthalamic nucleus
produces
hemiballismus

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

Hemiballismus



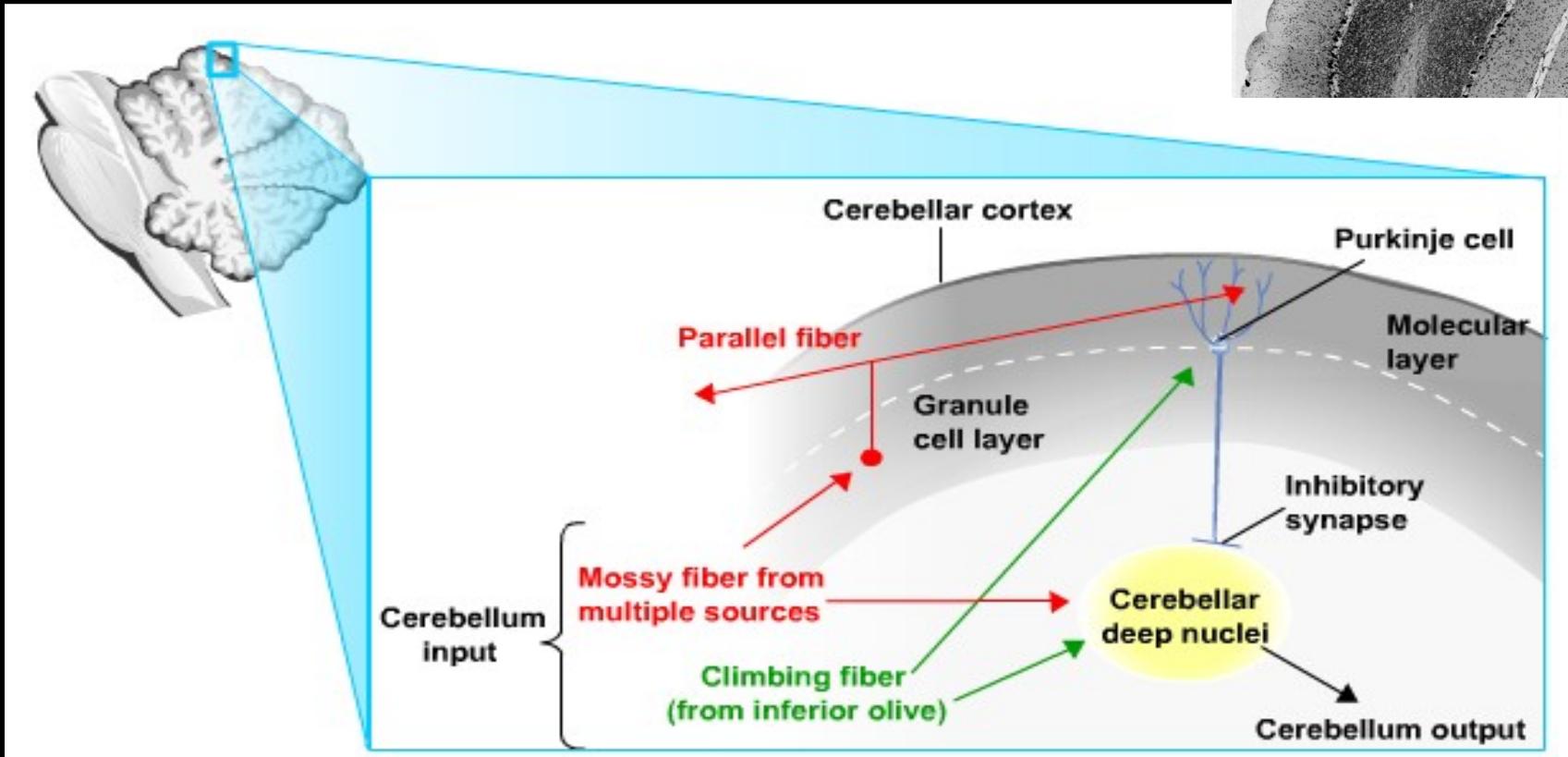
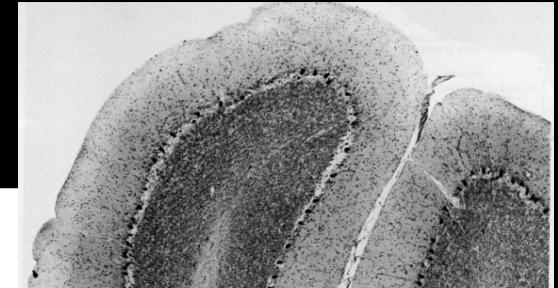


Disorders of the Cerebellum

- Ataxia
 - Disturbance of posture or gait
 - Decomposition of movement
- Dysmetria
- Dysdiadochokinesia
- Scanning speech
- Hypotonia
 - Pendular reflexes
- Tremor (intention tremor)
- Nystagmus
- Delay in initiating movements
- Subtle cognitive deficits

Cerebellum as a feedforward control system

Internal Circuitry of Cerebellum

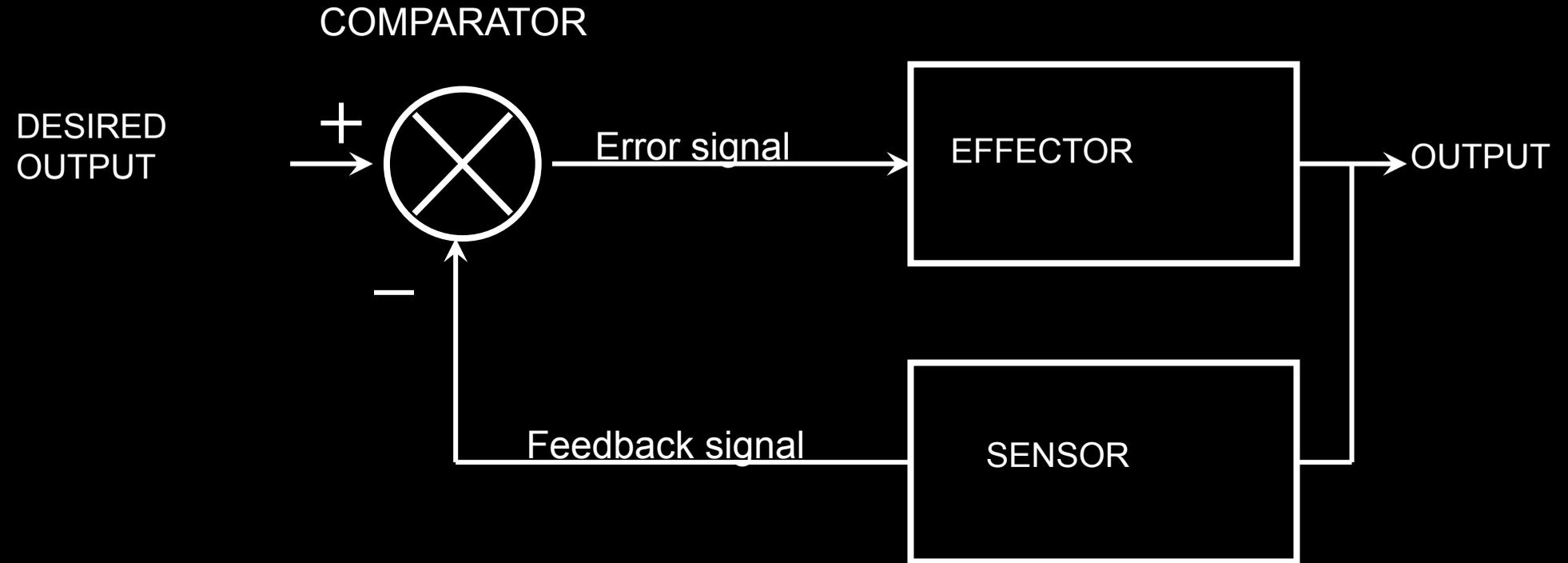


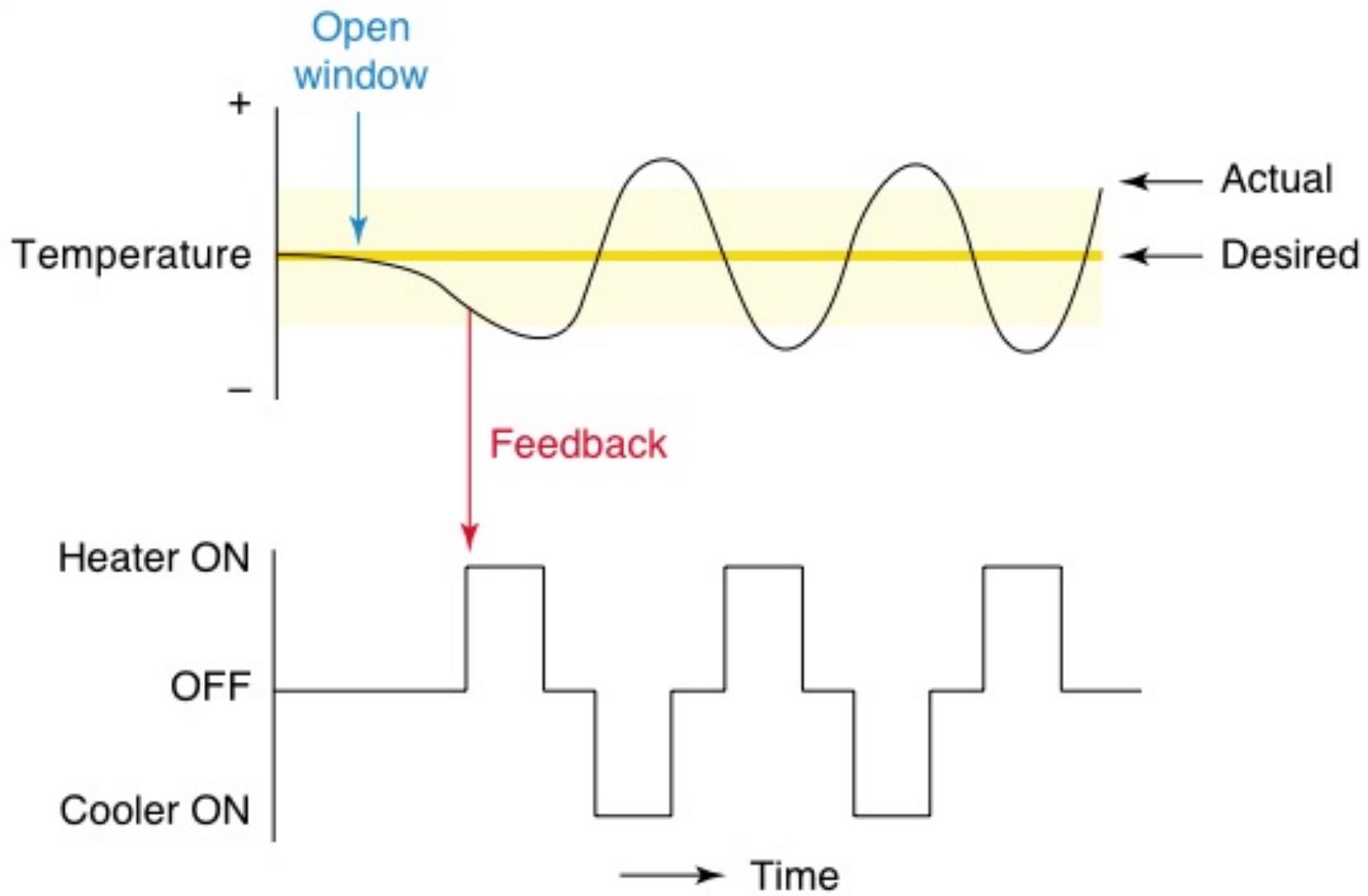
Cerebellum as a Control System

Feedback Controller for Slow movements (e.g., posture)

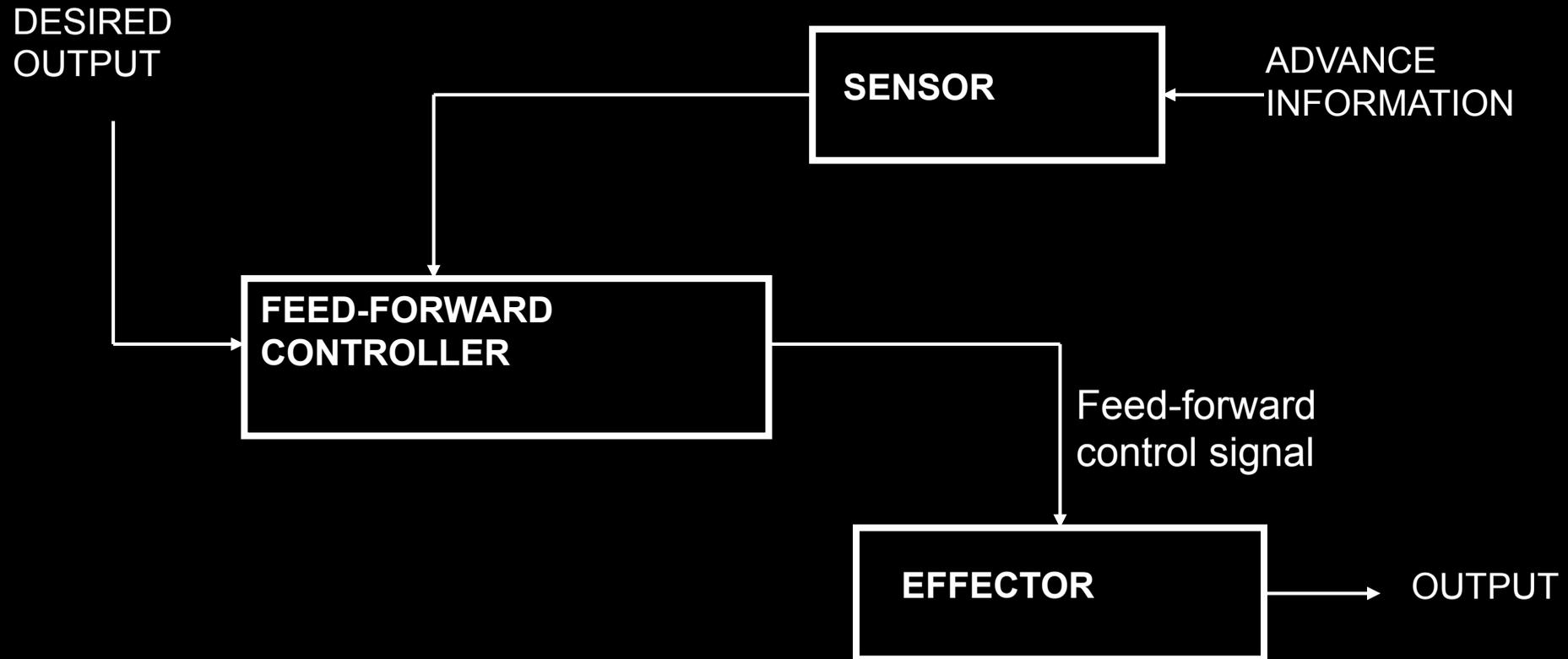
Feedforward Controller for Fast movements (e.g., most voluntary movements)

Feedback control system

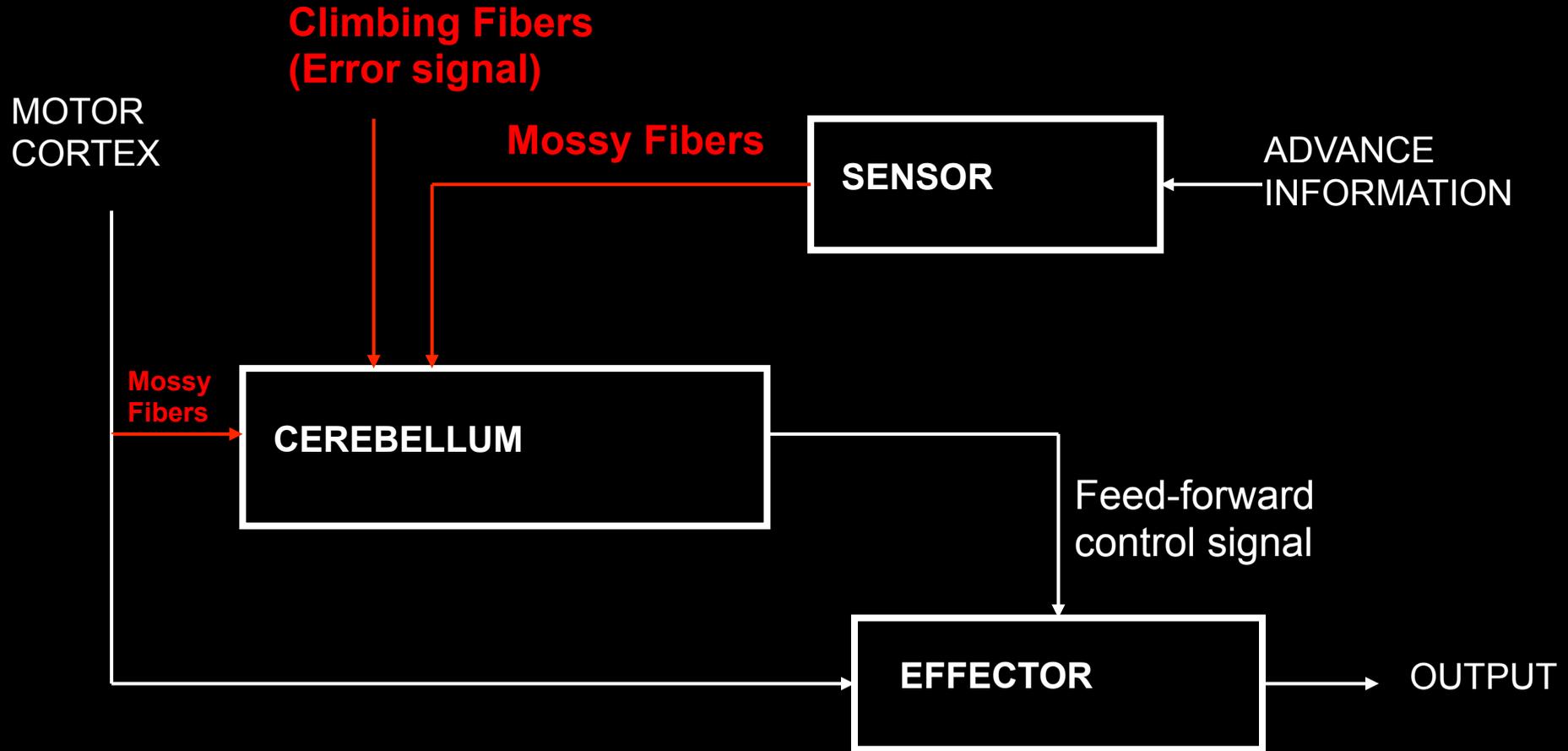




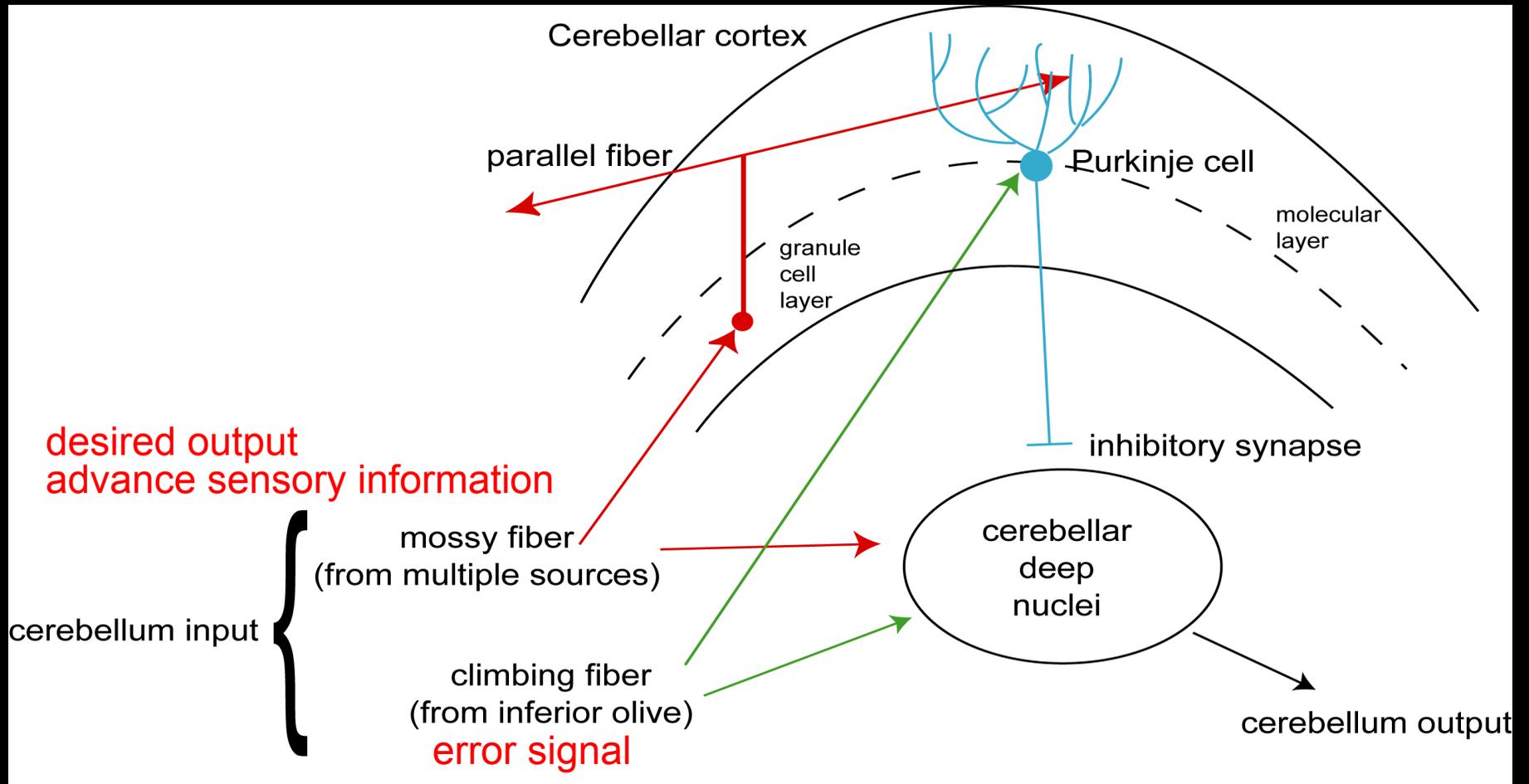
Feedforward control system



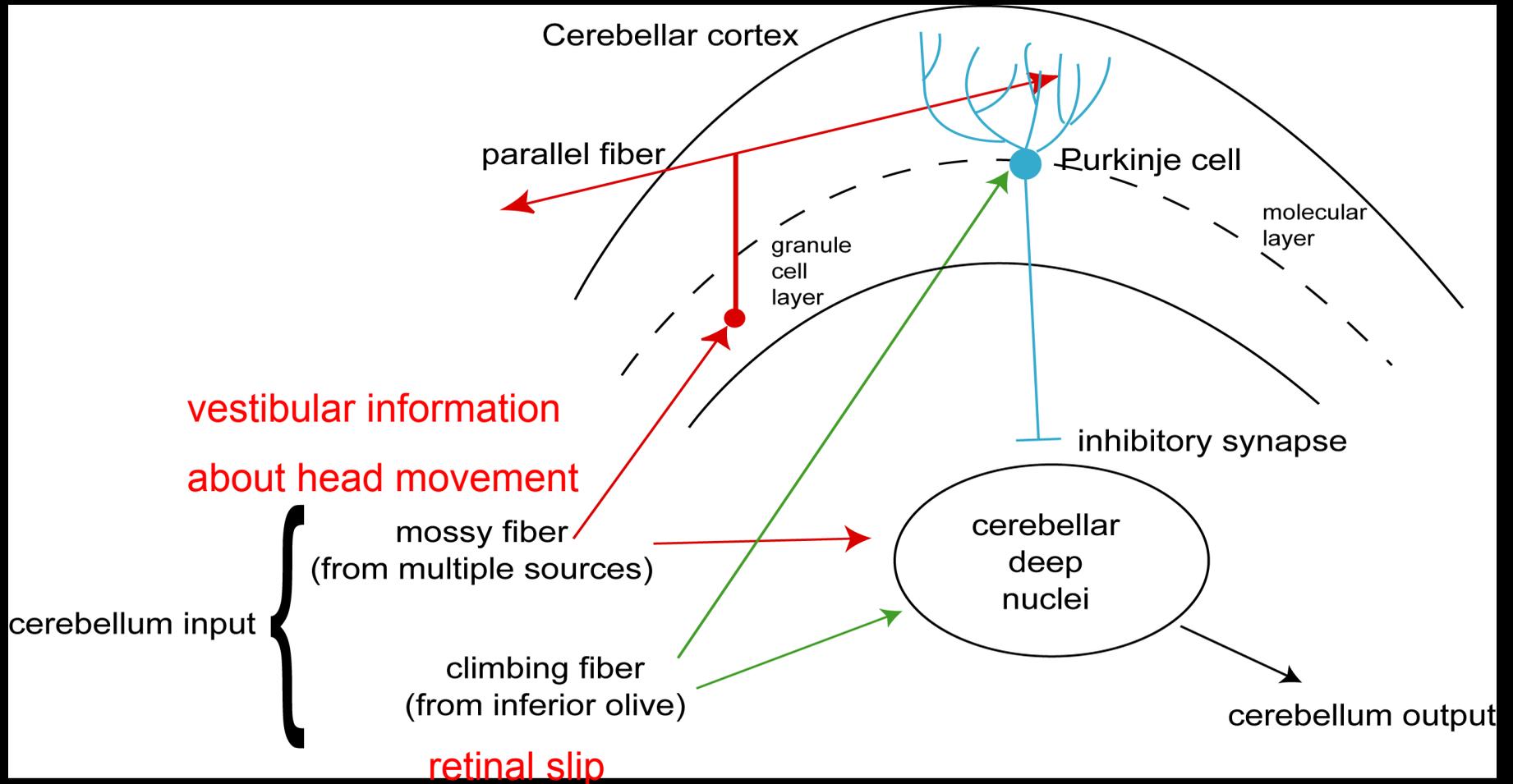
Cerebellum as a feedforward control system



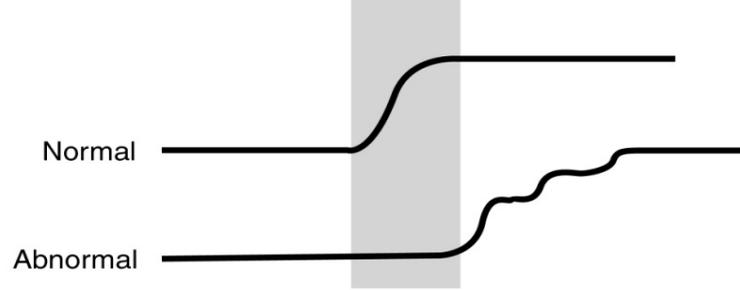
Internal Circuitry of Cerebellum



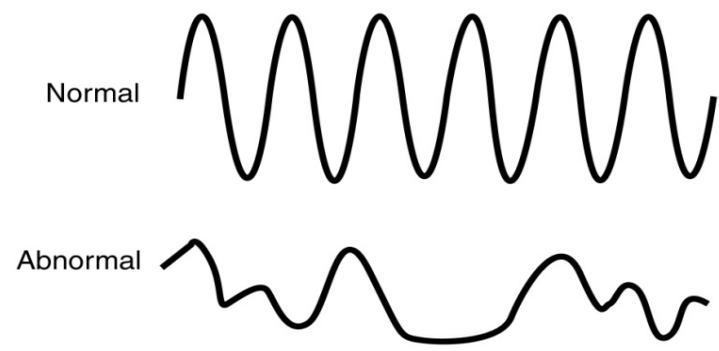
VOR and feedforward control



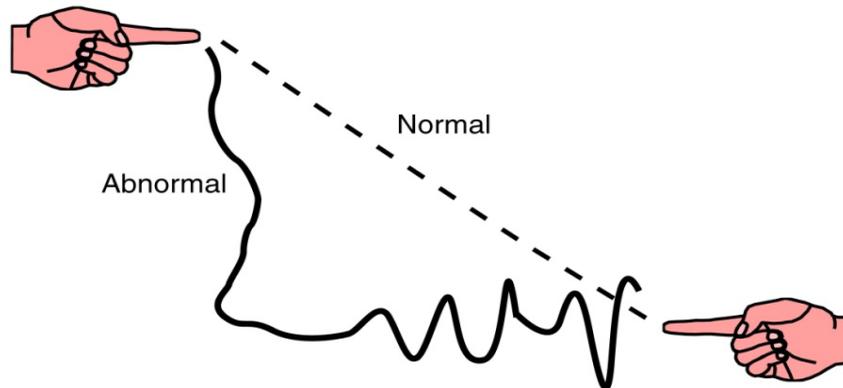
Delay in initiating responses



Dysdiadochokinesia



Decomposition of movement / intention tremor



Necessary Components of Proper Motor Control

- Volition
- Coordination of Signals to many muscle groups
- Proprioception
- Postural adjustments
- Sensory feedback
- Compensation for body and muscles
- Unconscious processing
- Adaptability