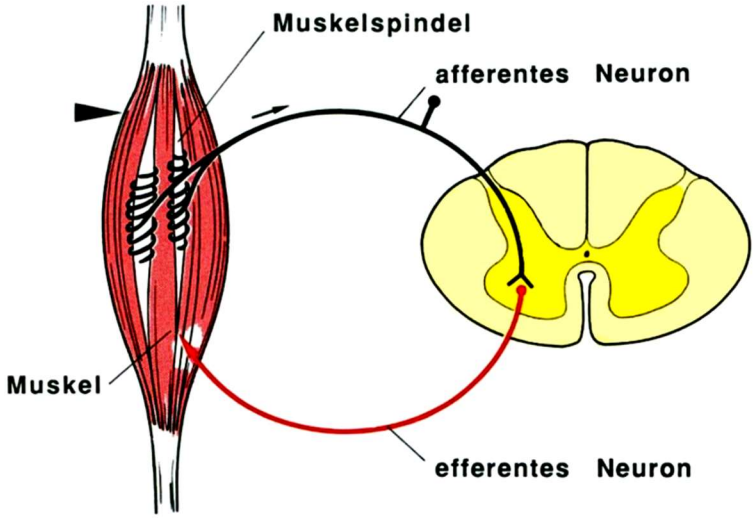
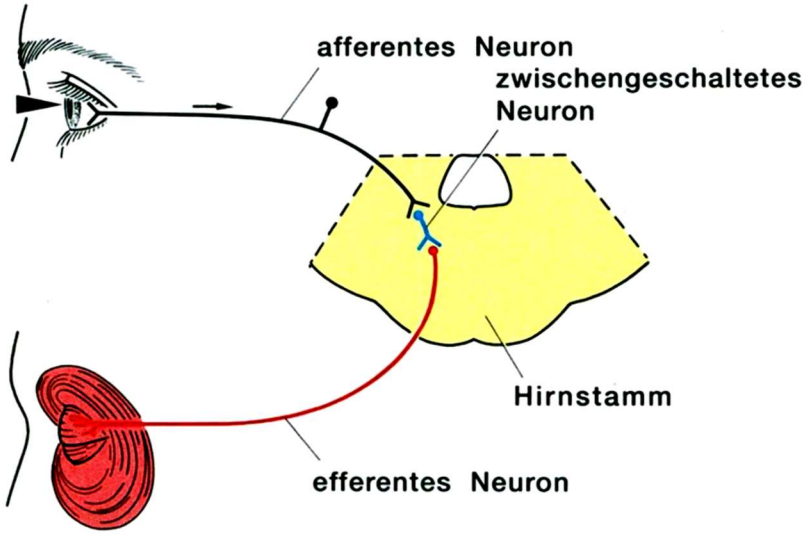
Motor System

Reflex Motor Control

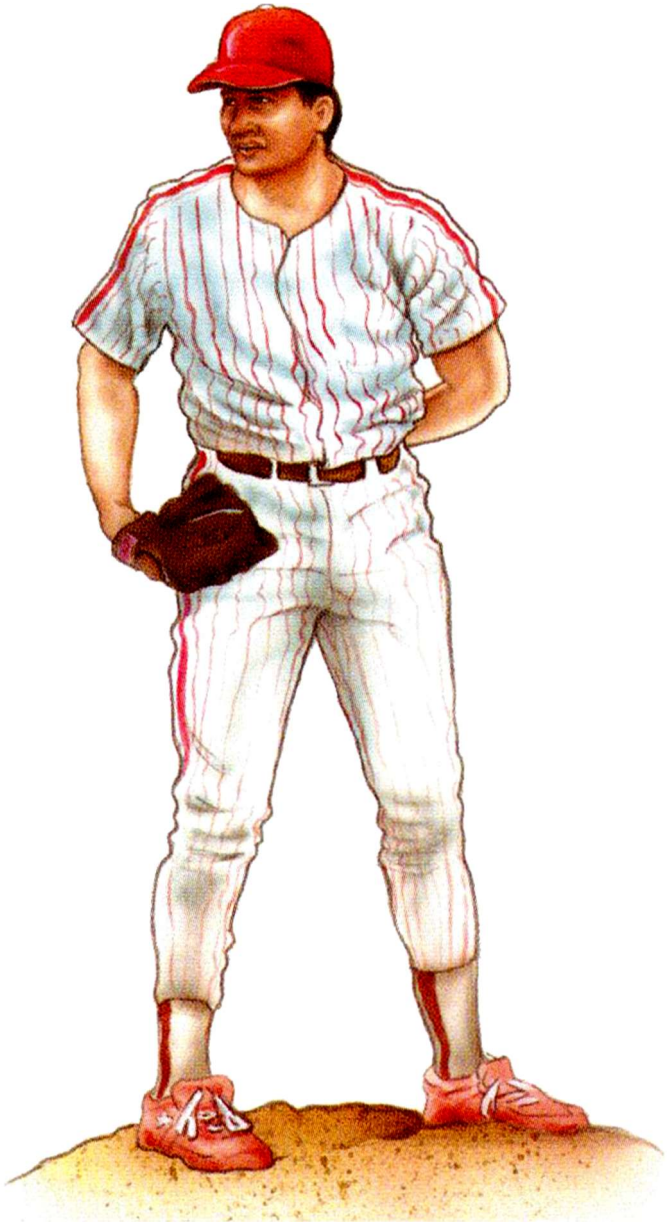


(↑) Monosynaptic Reflex

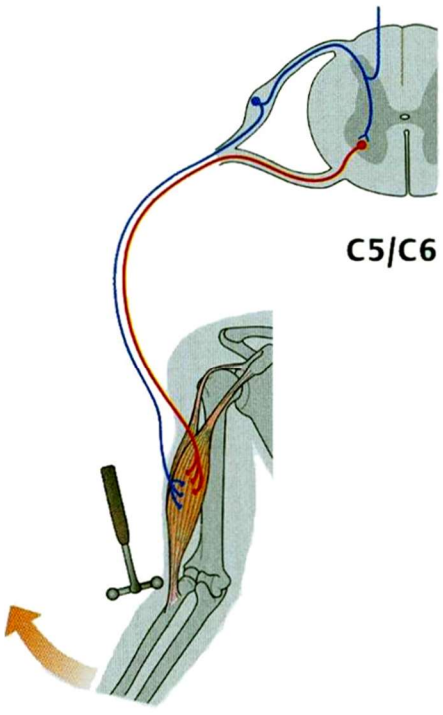
(↓) Polysynaptic Reflex



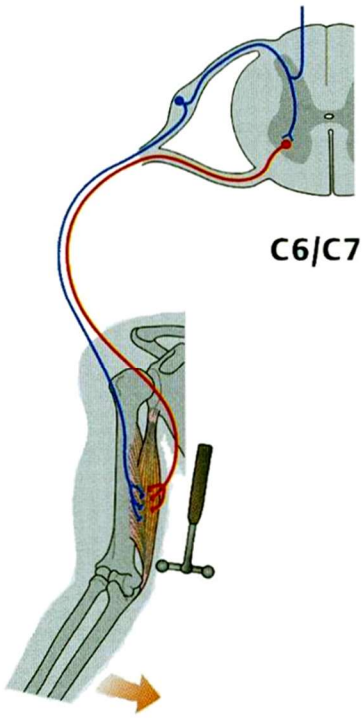
Voluntary Motor Control



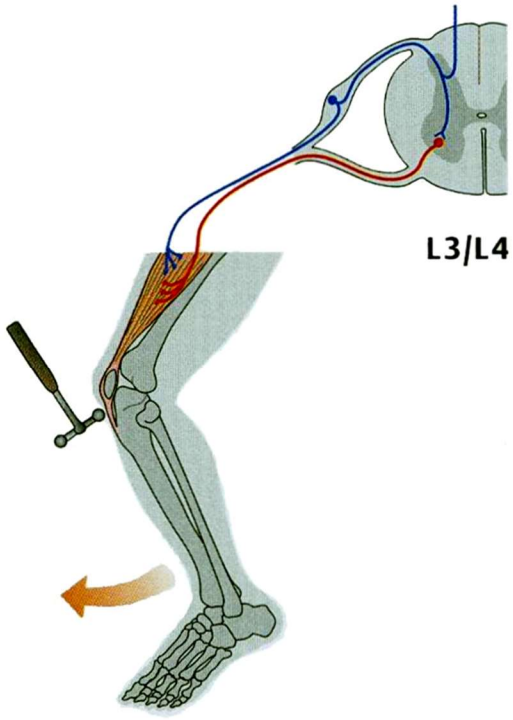
Clinically Important Monosynaptic Reflexes



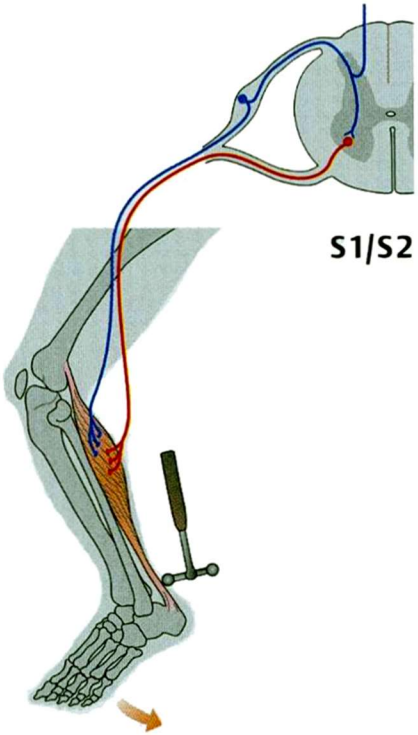
Biceps Jerk



Triceps Jerk

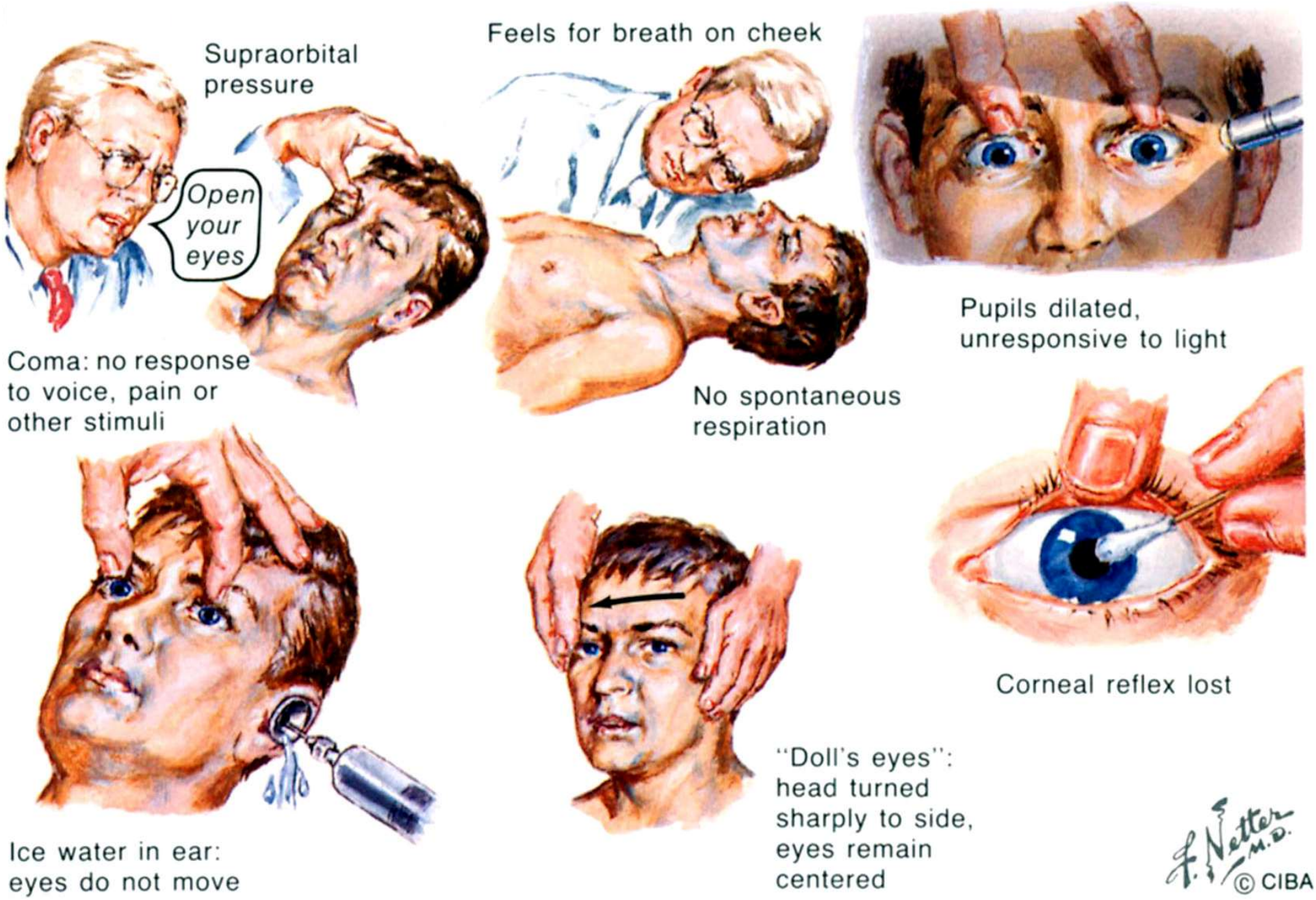


Knee Jerk



Ankle Jerk

Polysynaptic Brain Stem Reflexes – Diagnosis of Brain Death



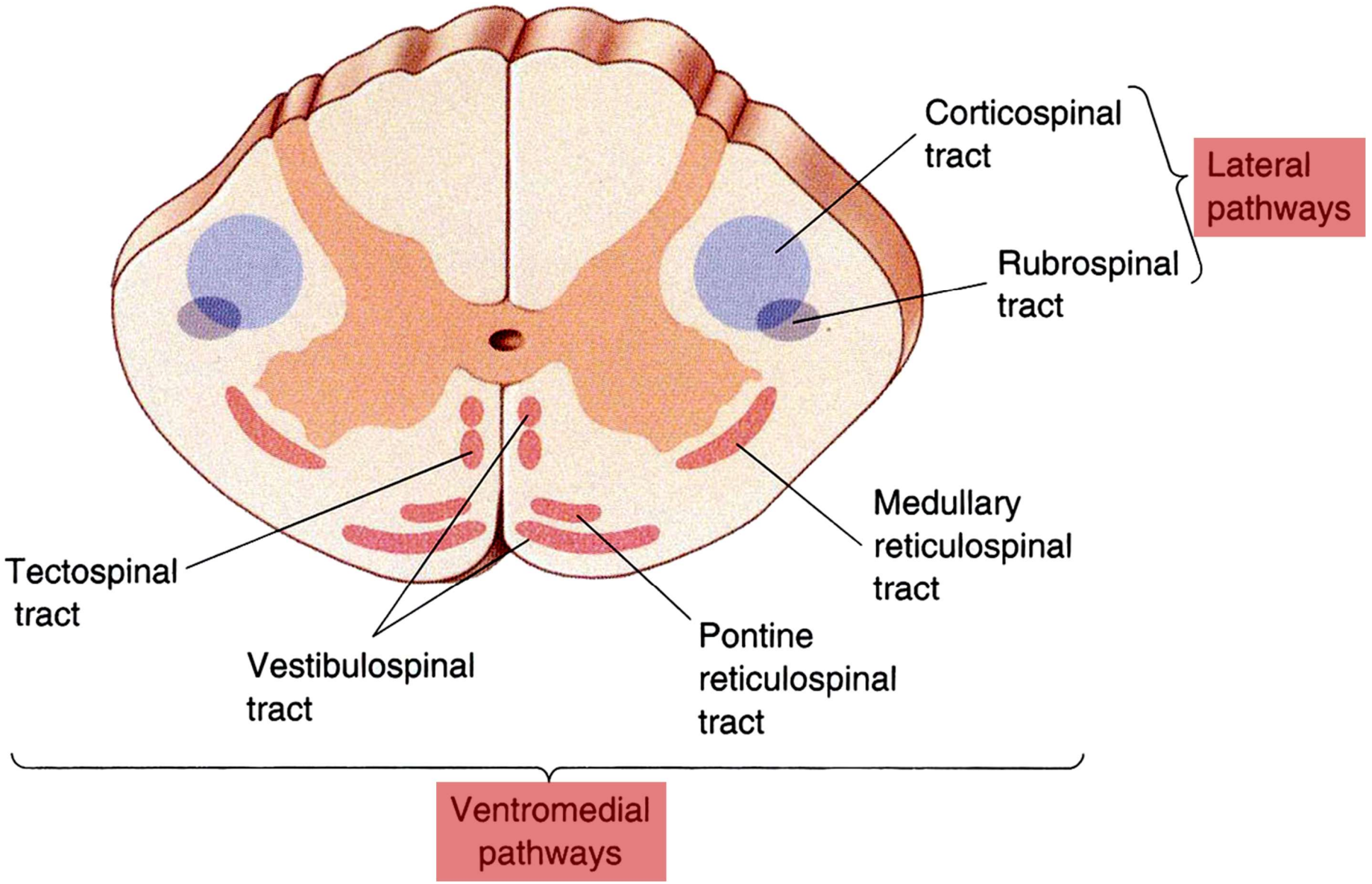
Voluntary Motor Control – Hierarchical Organization

LEVEL	FUNCTION	STRUCTURES
High	Strategy	Association Areas of Neocortex
Middle	Tactics	Motor Cortex, Cerebellum, Basal Ganglia
Low	Execution	Brain Stem, Spinal Cord

Proper Functioning Relies Heavily on Sensory Information →

"Sensorimotor System"

Descending Tracts of the Spinal Cord



Descending Tracts of the Spinal Cord

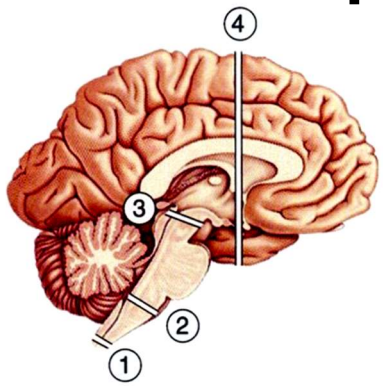
Lateral Pathways:

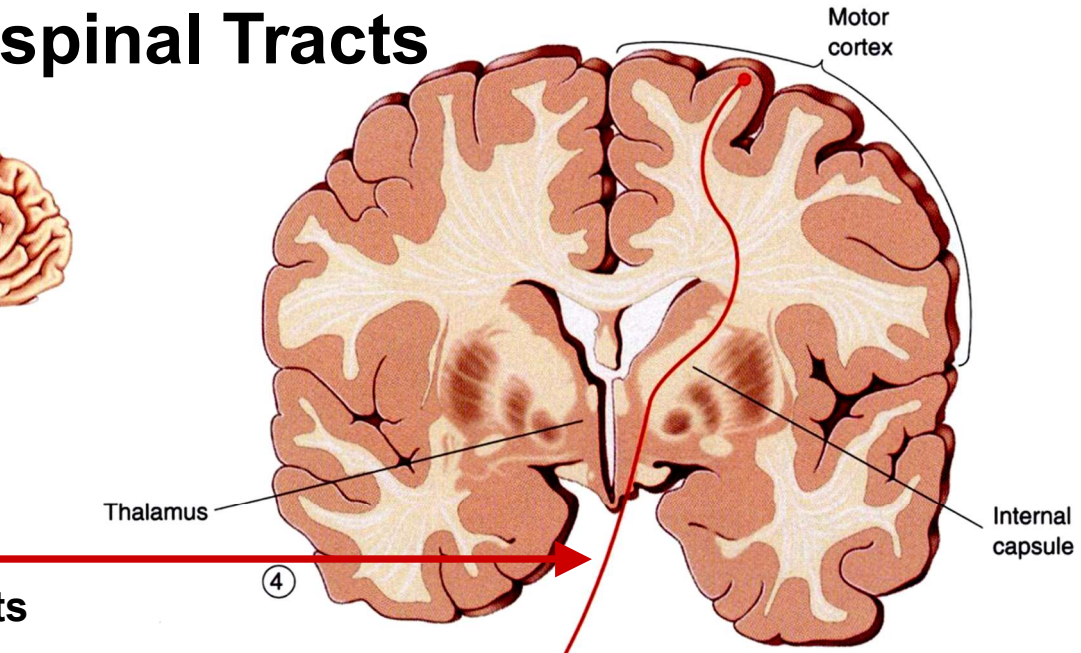
- ***Corticospinal Tract, Rubrospinal Tract***
- **Direct Cortical Control → Muscles of the Distal Extremities (e.g., for Grasping Movements)**
- **Phylogenetically Younger**

Ventromedial Pathways:

- ***Tectospinal Tract, Vestibulospinal Tract, Reticulospinal Tract***
- **Brain Stem Control → Muscles of the Trunk (e.g., for Posture and Locomotion)**
- **Phylogenetically Older**

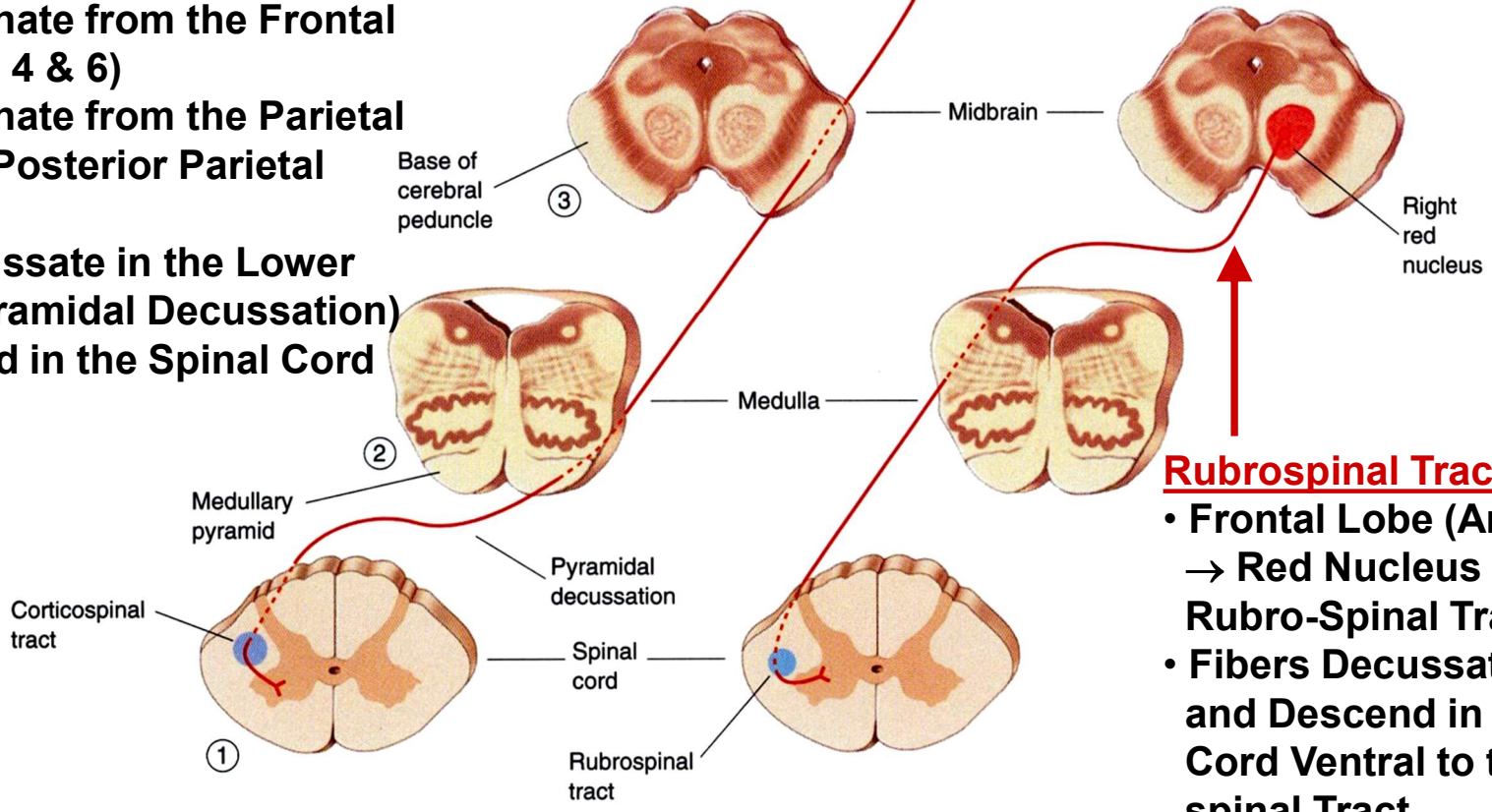
Cortico- and Rubrospinal Tracts





Corticospinal Tract

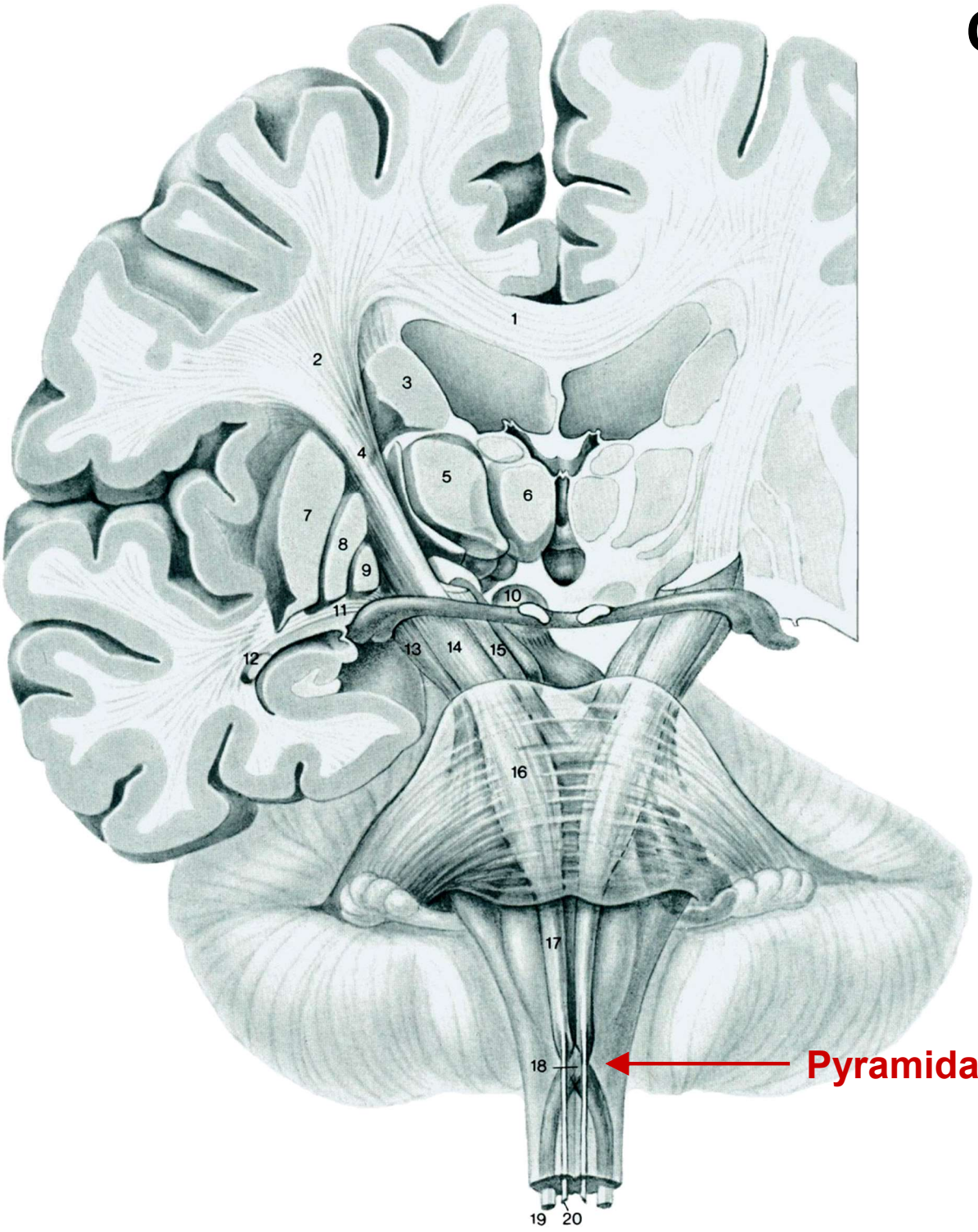
- One of the Largest Axonal Tracts of the CNS (~ 1 Million Axons !)
- ~ 50% Originate from the Frontal Lobe (Areas 4 & 6)
- ~ 50% Originate from the Parietal Lobe (S1 & Posterior Parietal Cortex)
- Fibers Decussate in the Lower Medulla (Pyramidal Decussation) and Descend in the Spinal Cord



Rubrospinal Tract

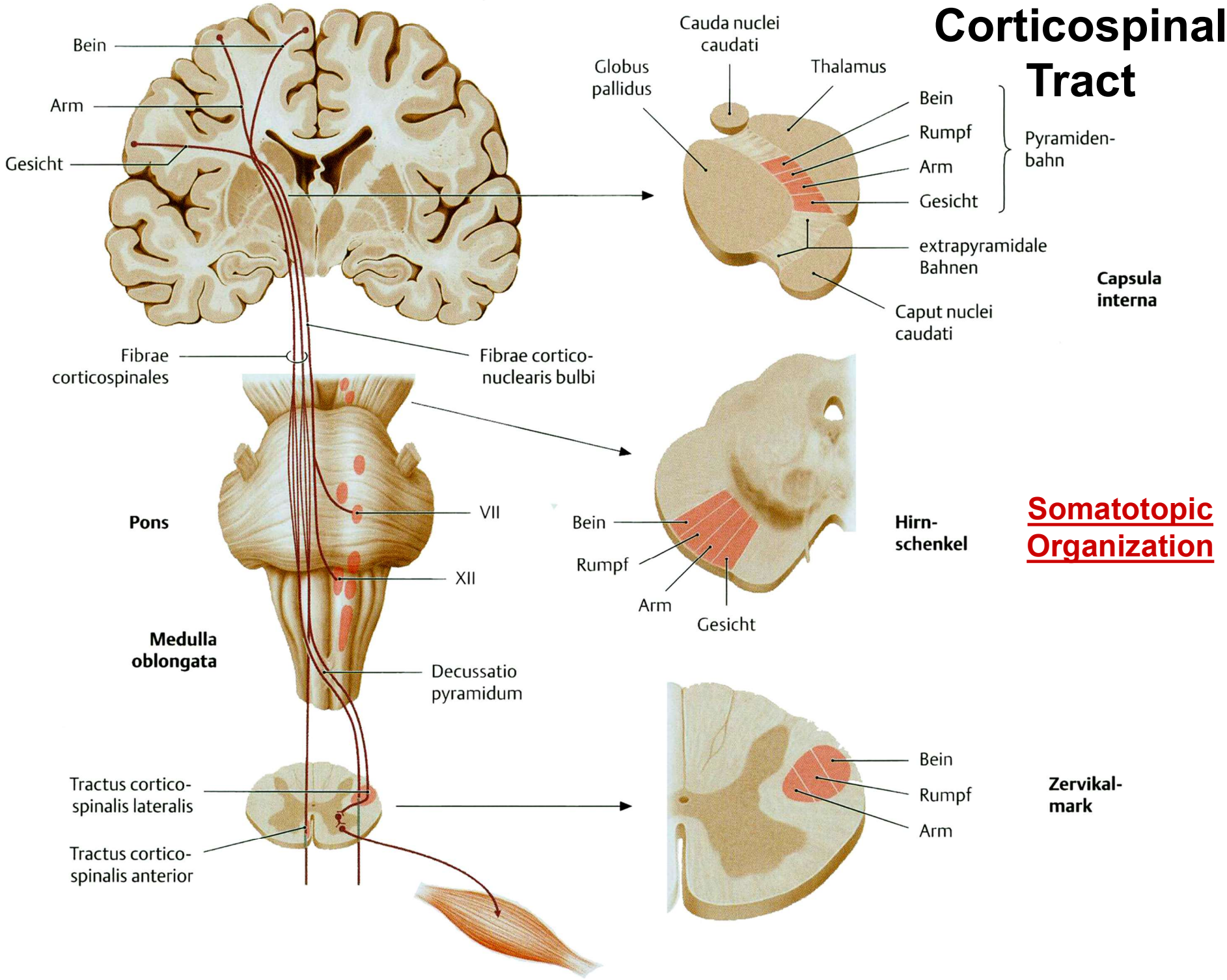
- Frontal Lobe (Areas 4 & 6) → Red Nucleus ("Cortico-Rubro-Spinal Tract")
- Fibers Decussate in the Pons and Descend in the Spinal Cord Ventral to the Cortico-spinal Tract

Corticospinal Tract



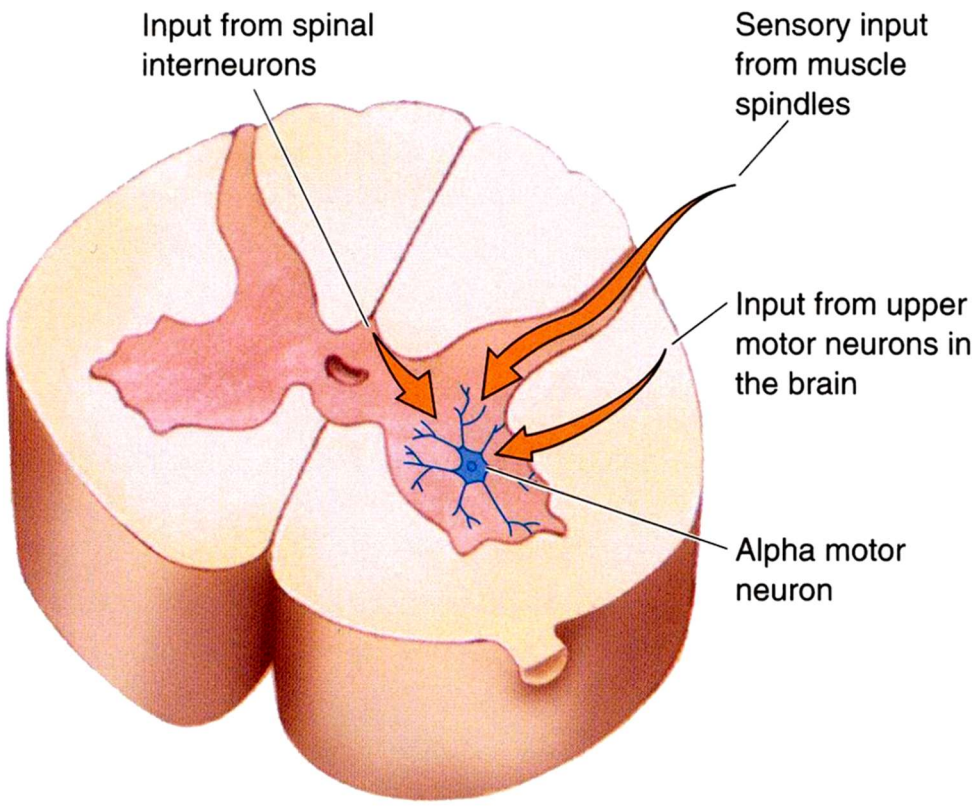
Pyramidal Decussation

Corticospinal Tract

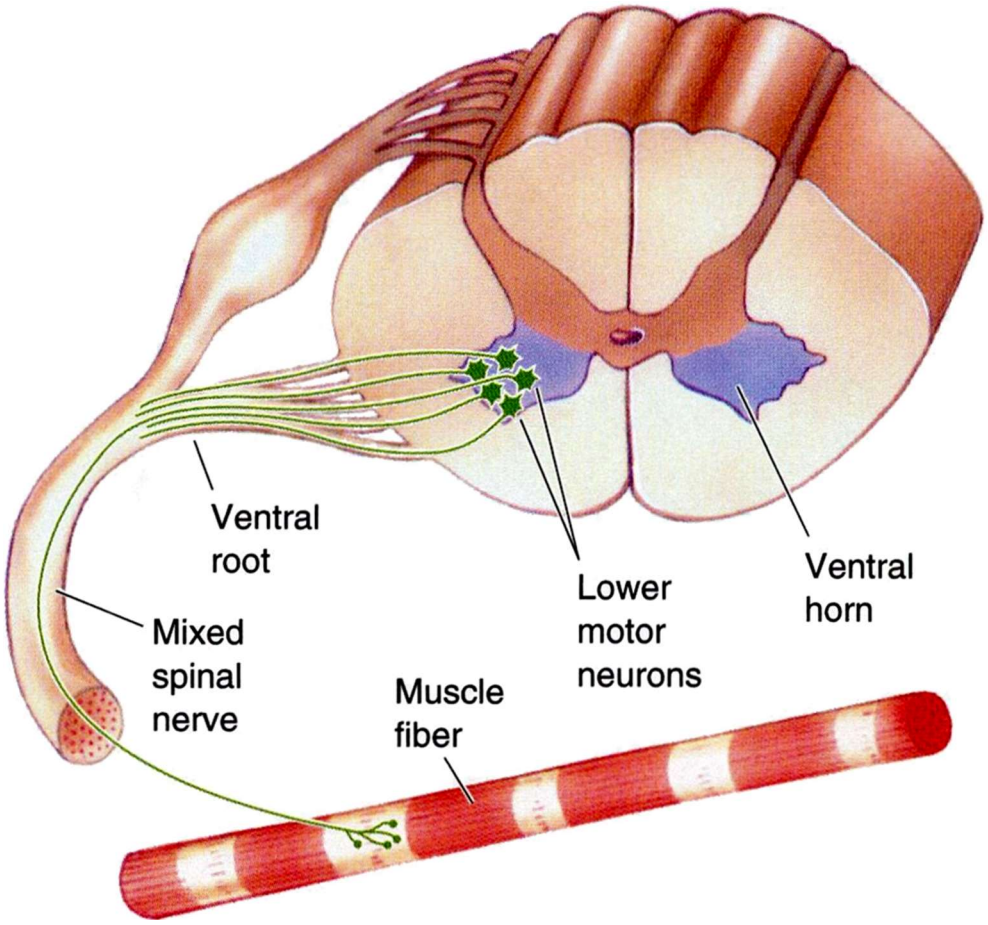


Somatotopic Organization

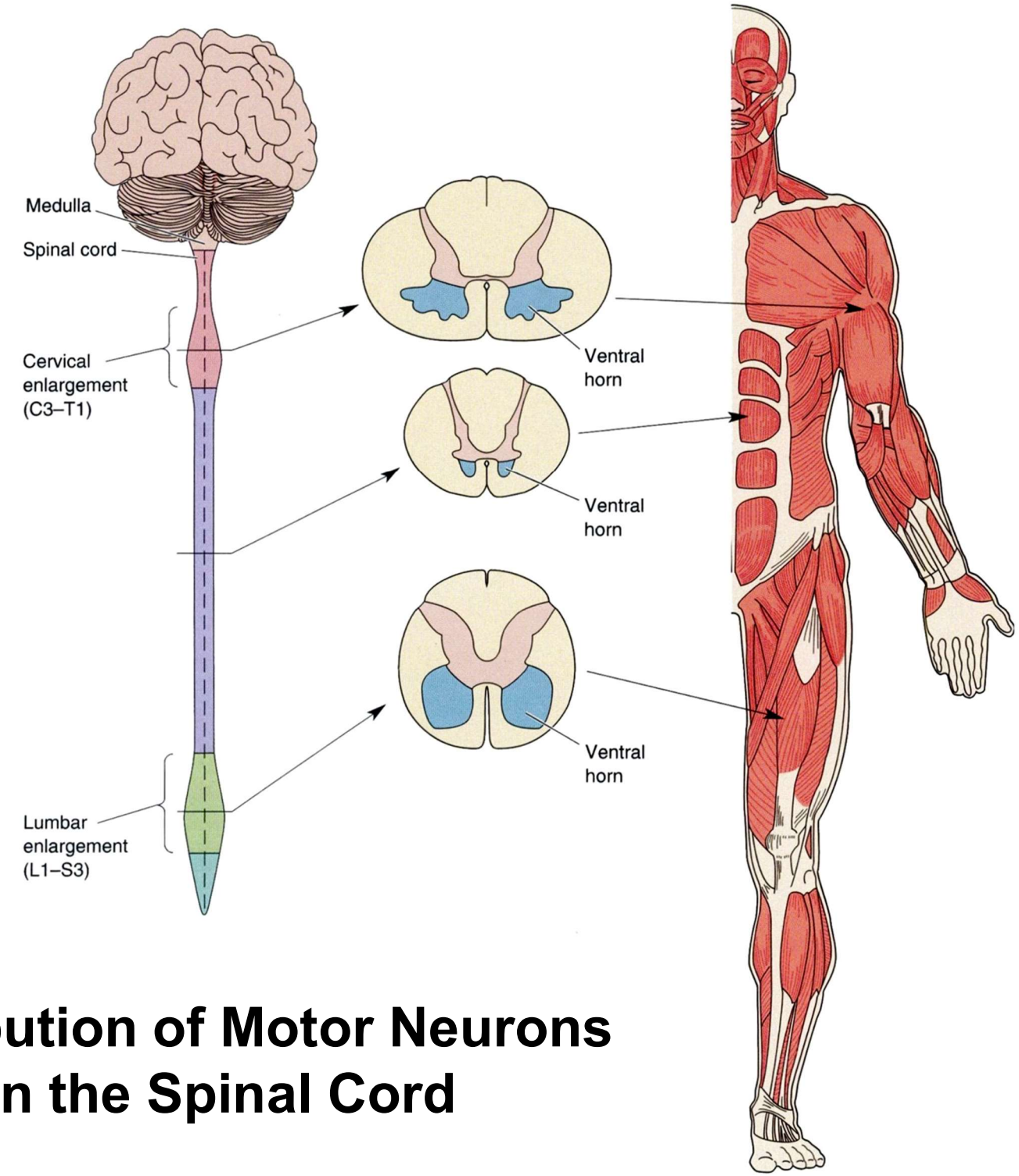
Muscle Innervation by Spinal Cord Motor Neurons



"Slaves of Many Masters"

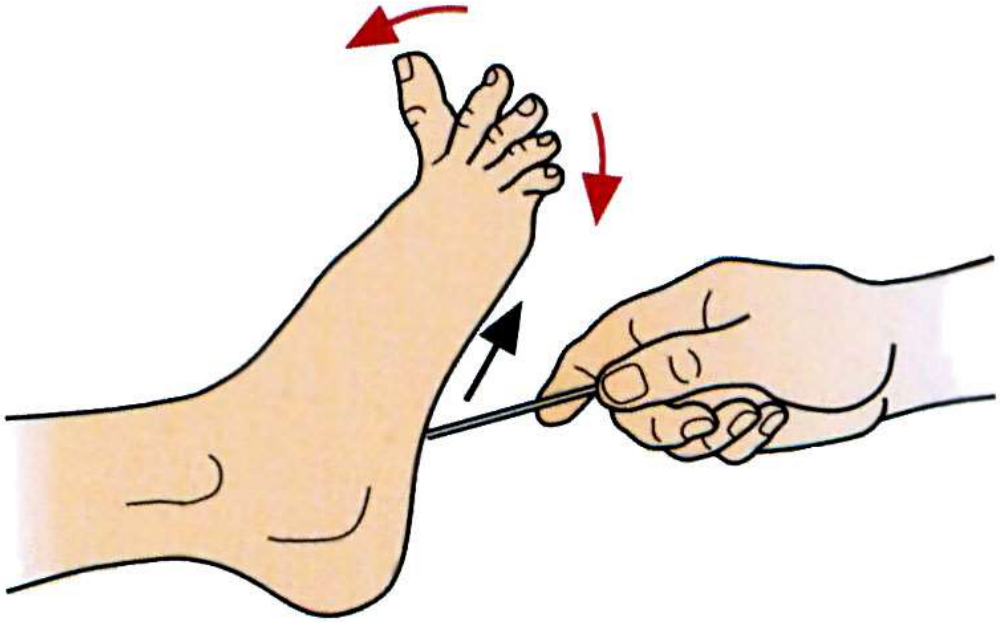


Motor Neuron Axons Bundle Together to Form <u>Ventral Roots</u>



Distribution of Motor Neurons in the Spinal Cord

Babinski Sign



Sharply Scratch the Sole of the Foot From the Heel toward the Toes

Normal (Physiological) Response (Negative Babinski Sign):
All Toes Curl Downward

Pathological Response (Positive Babinski Sign):
Big Toe Moves Upward, Other Toes Fan Outward
Indication of Corticospinal Tract Damage

Cave: Positive Babinski Sign is Normal for Infants up to 1 – 2 Years
(Until Descending Motor Tracts Are Fully Myelinated)

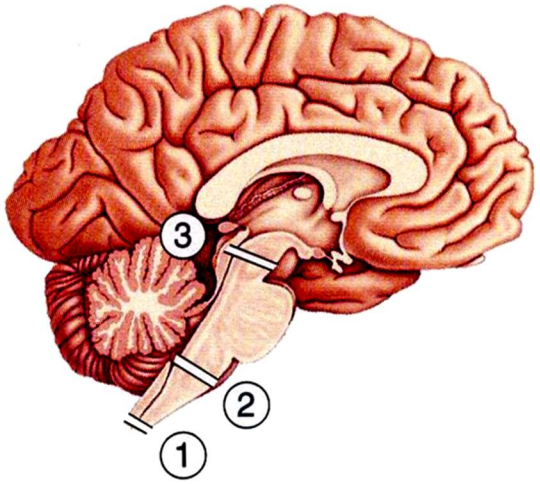
Positive Babinski Sign in an Infant (Normal !)

English Subtitles
by Courtesy of Dr. Derek Ott

Positive Babinski Sign in an Adult (Pathological !)

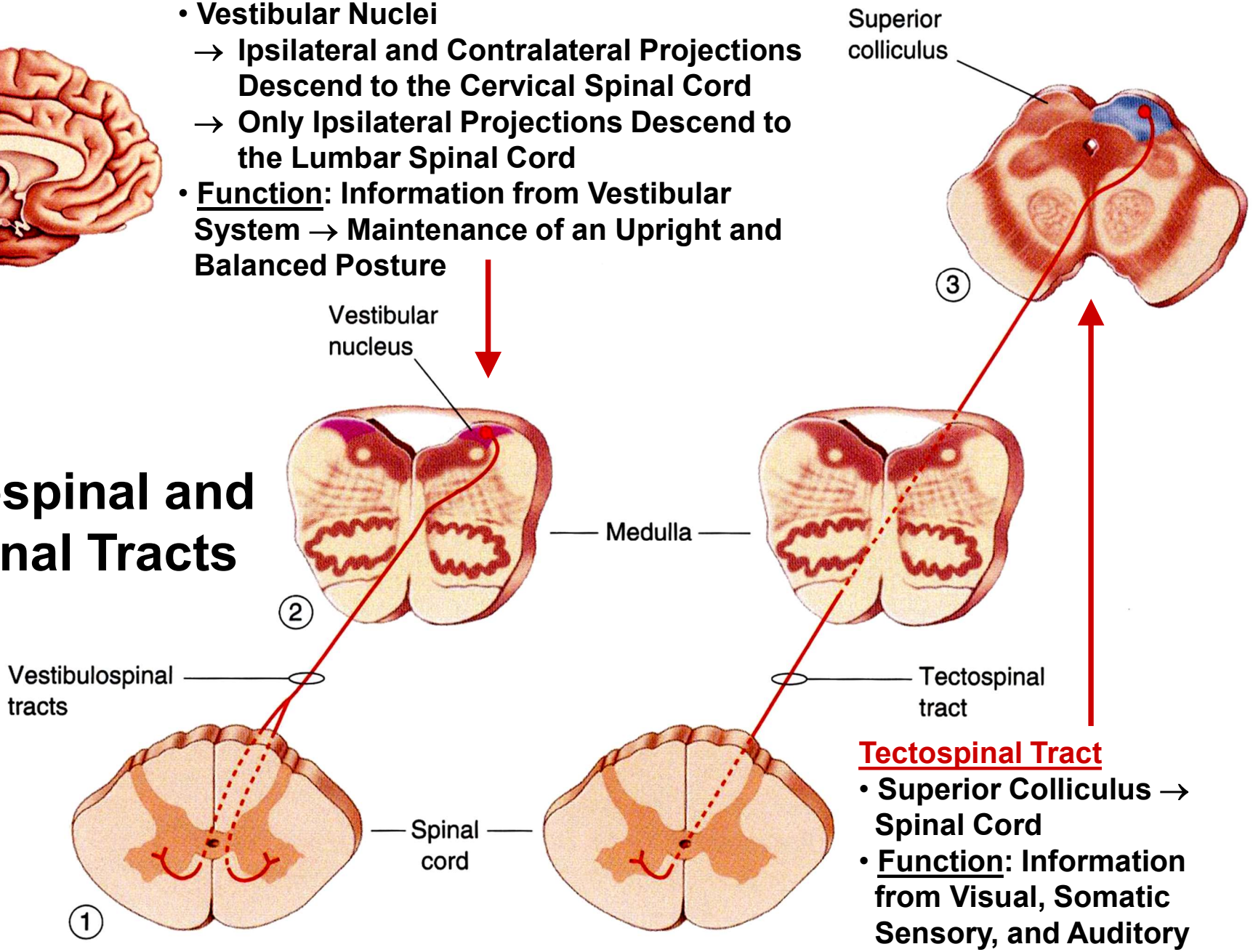
English Subtitles
by Courtesy of Dr. Derek Ott

Vestibulospinal and Tectospinal Tracts



Vestibulospinal Tract

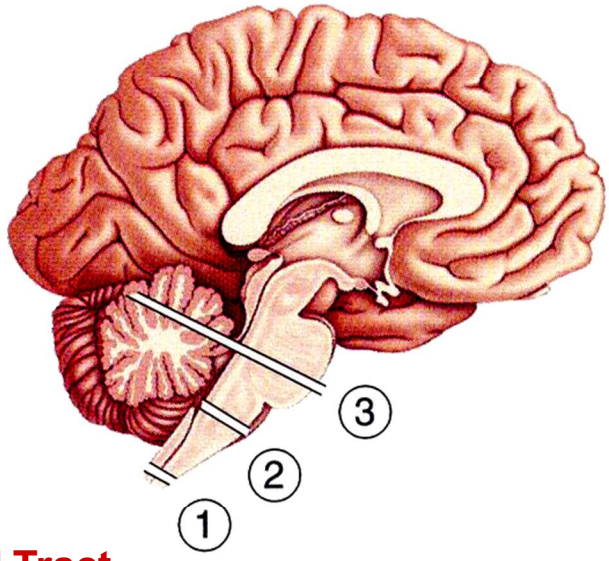
- Vestibular Nuclei
  - → Ipsilateral and Contralateral Projections Descend to the Cervical Spinal Cord
  - → Only Ipsilateral Projections Descend to the Lumbar Spinal Cord
- Function: Information from Vestibular System → Maintenance of an Upright and Balanced Posture

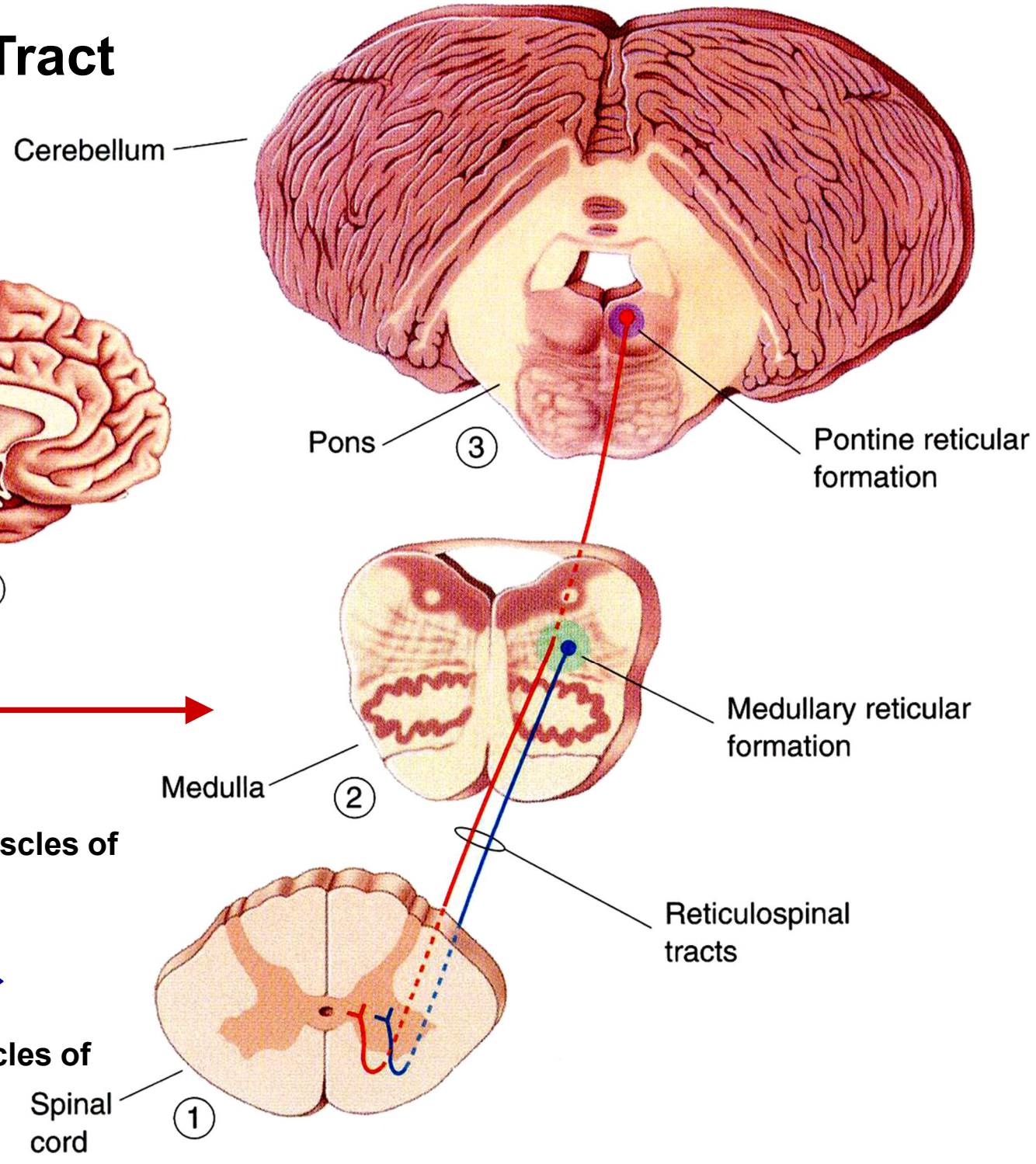


Tectospinal Tract

- Superior Colliculus → Spinal Cord
- Function: Information from Visual, Somatic Sensory, and Auditory Systems → Maintenance of an Upright and Balanced Posture

Reticulospinal Tract



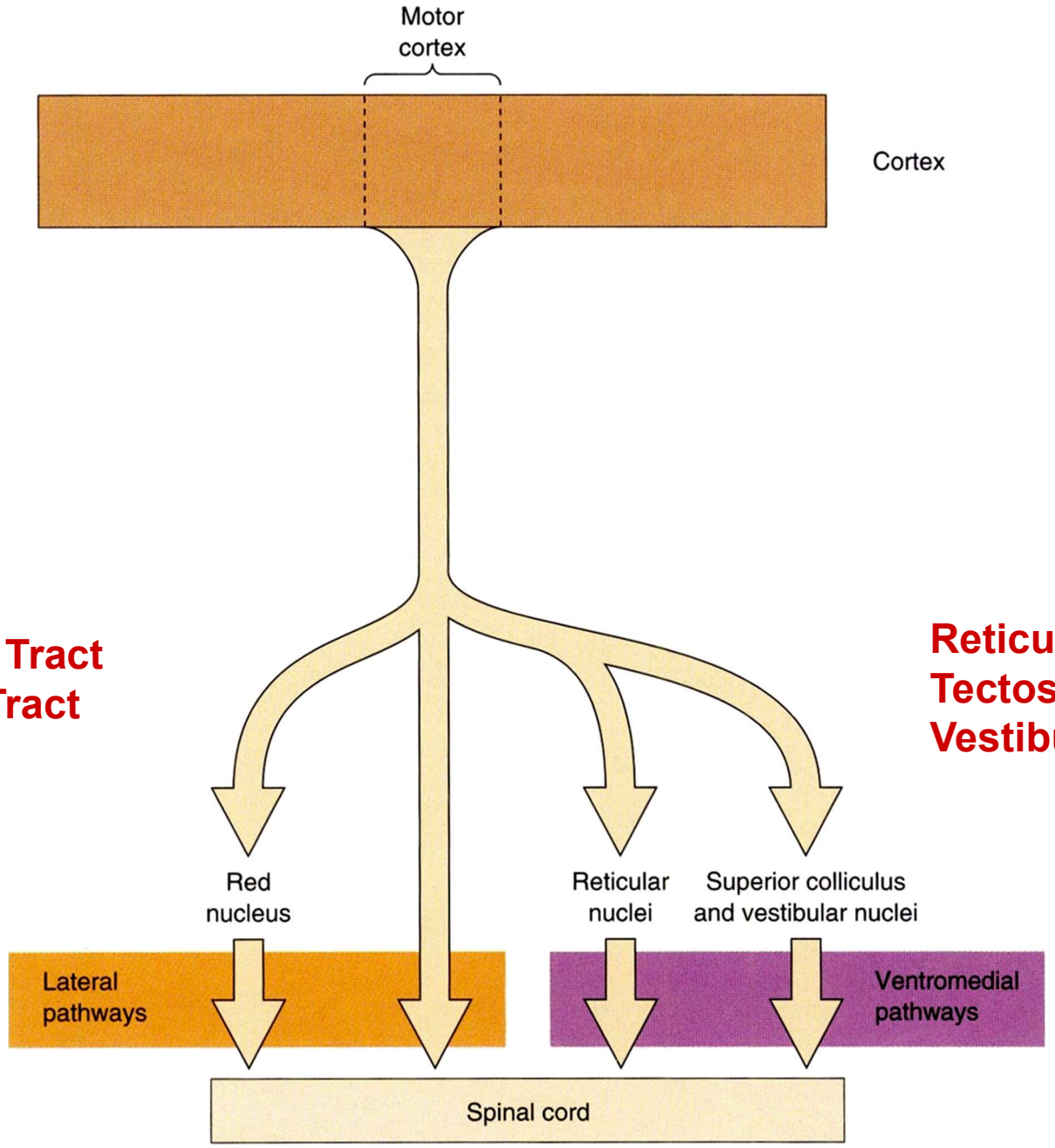


Reticulospinal Tract

- **Pontine Reticular Formation →**
  Medial Reticulospinal Tract
- **Function: Activates Extensor Muscles of the Lower Limbs (Positive Antigravity Effect)**
- **Medullary Reticular Formation →**
  Lateral Reticulospinal Tract
- **Function: Inhibits Extensor Muscles of the Lower Limbs (Negative Antigravity Effect)**

Descending Spinal Tracts – Summary

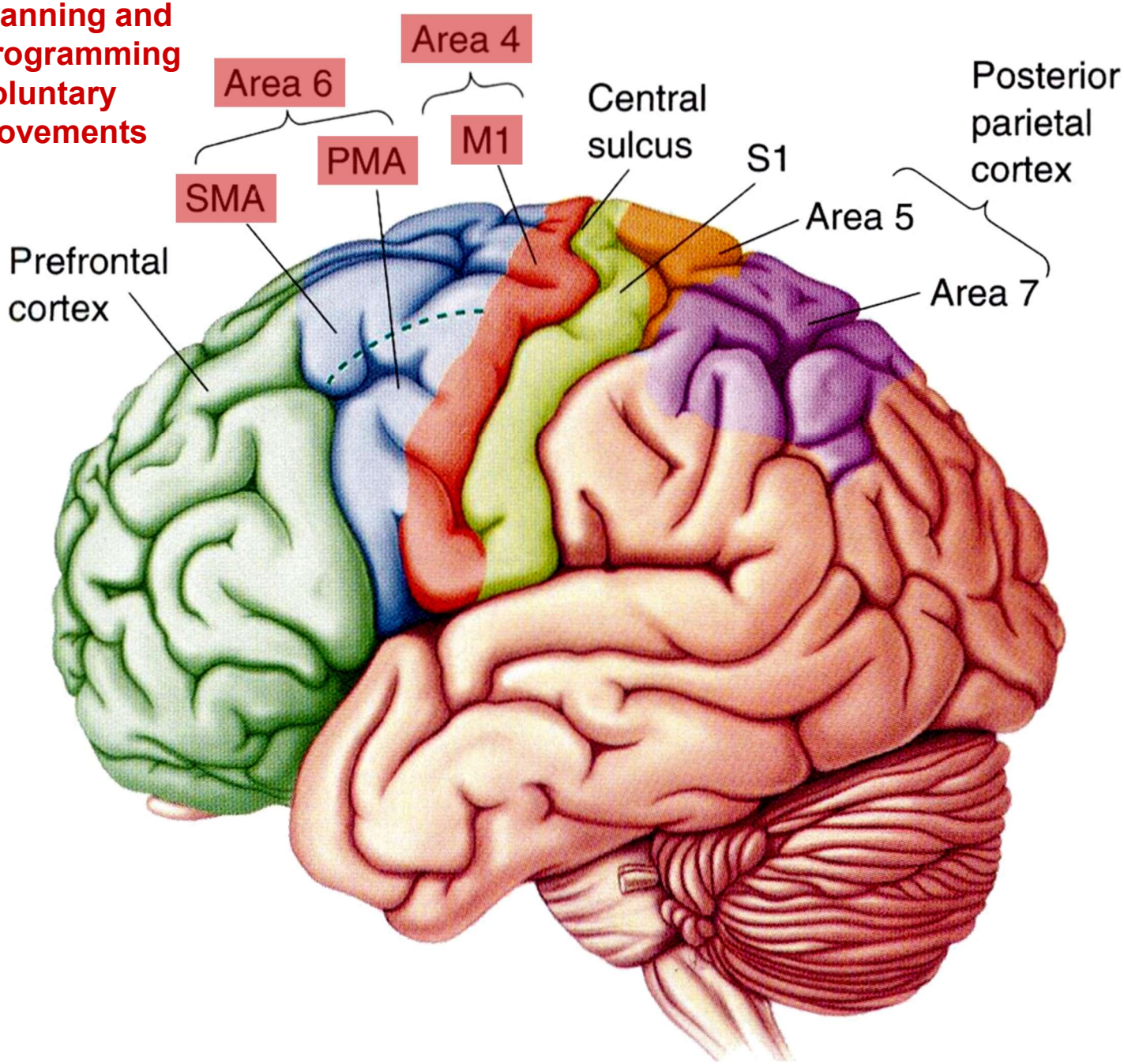
Corticospinal Tract
Rubrospinal Tract



Reticulospinal Tract
Tectospinal Tract
Vestibulospinal Tract

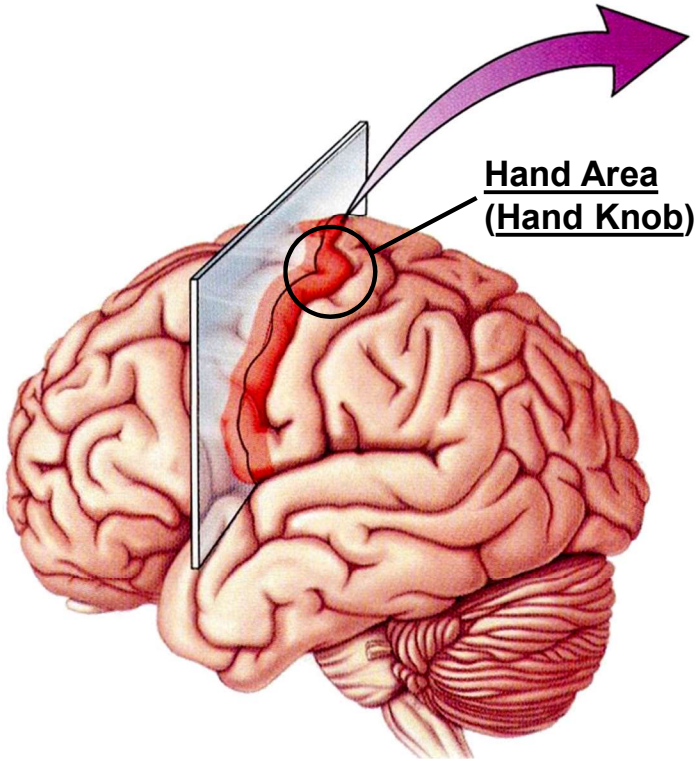
Planning and Directing Voluntary Movements – Part 1

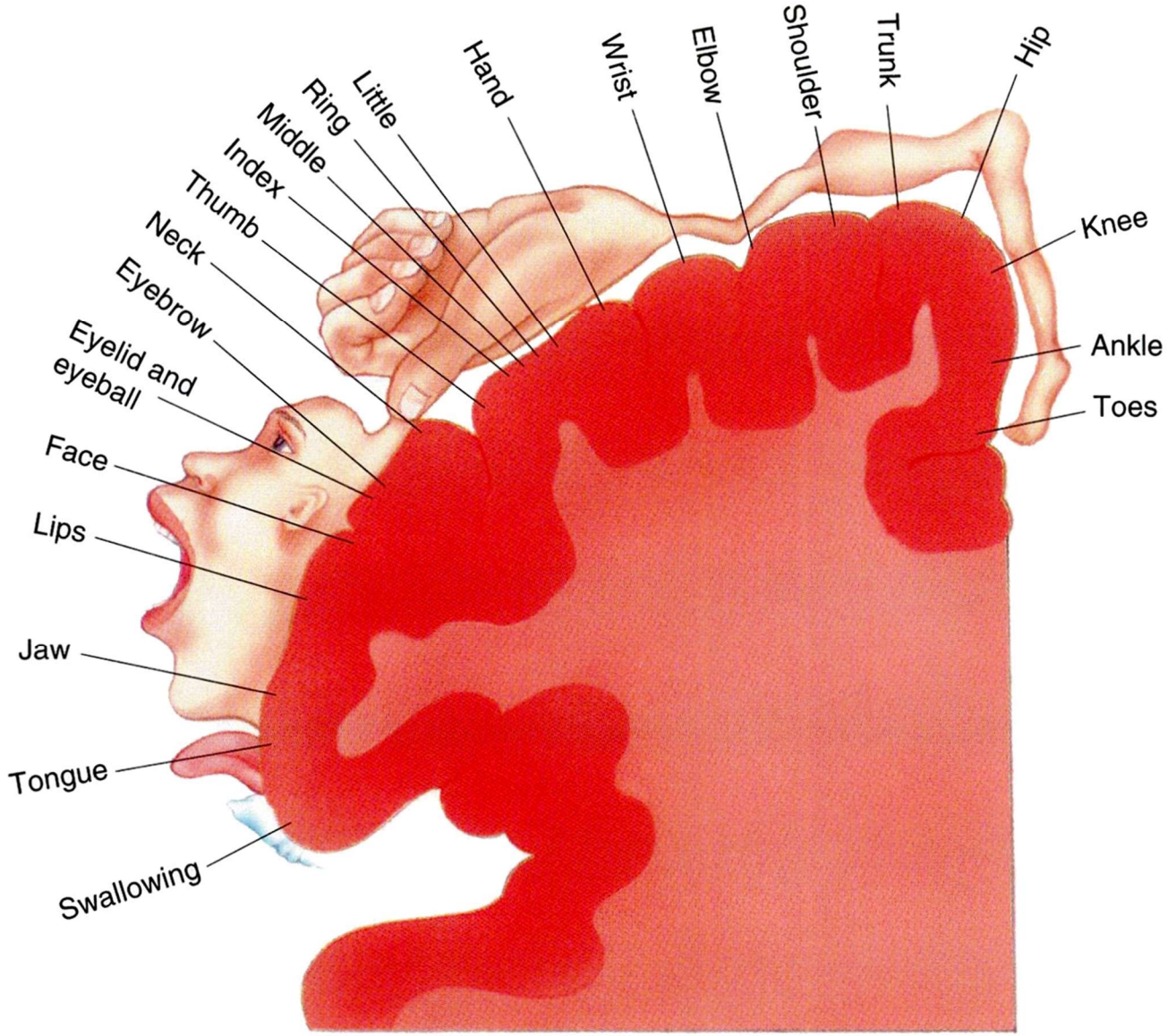
Planning and Programming Voluntary Movements



Primary Motor Cortex – Somatotopic Map

Motor Homunculus

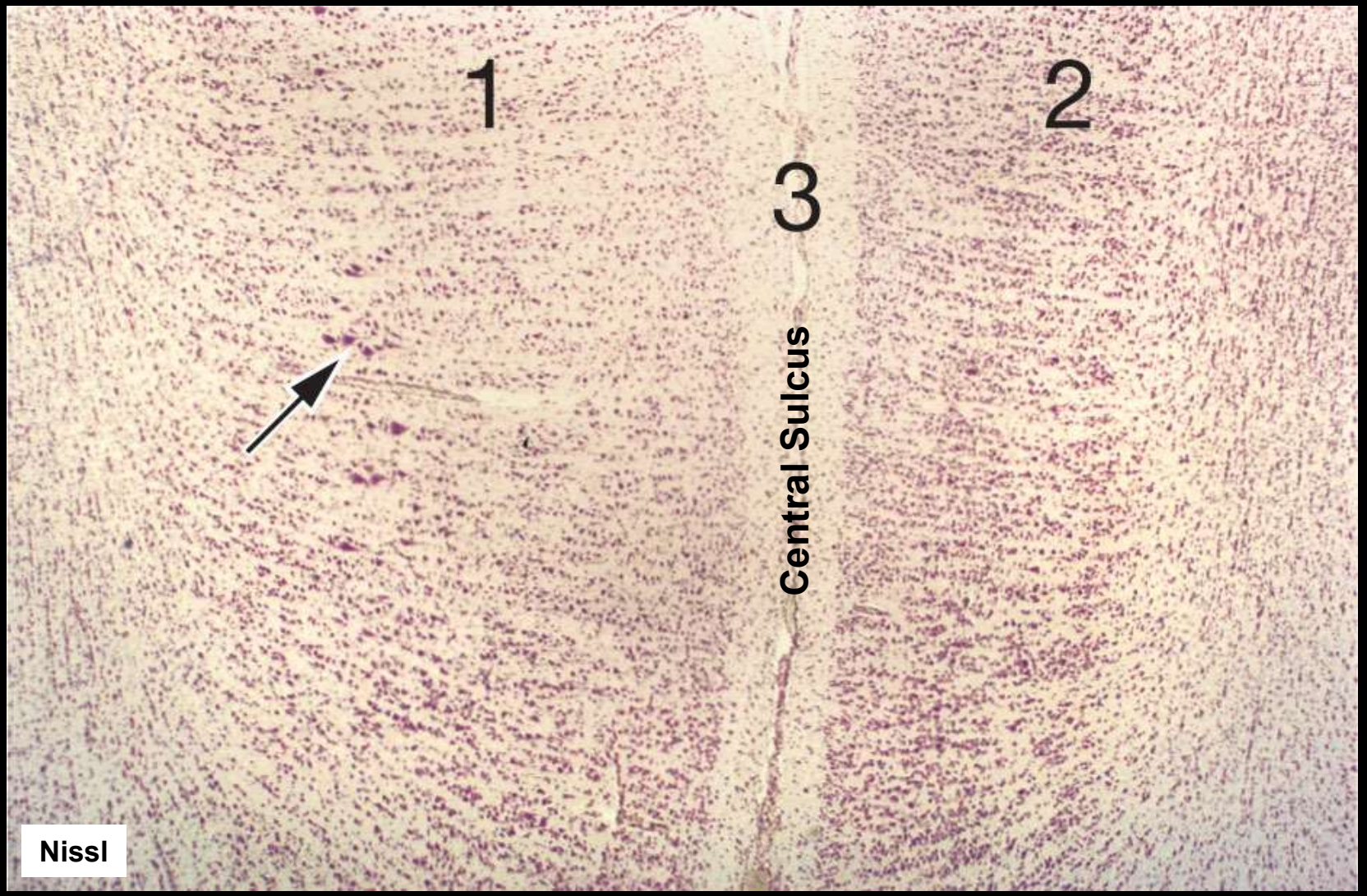




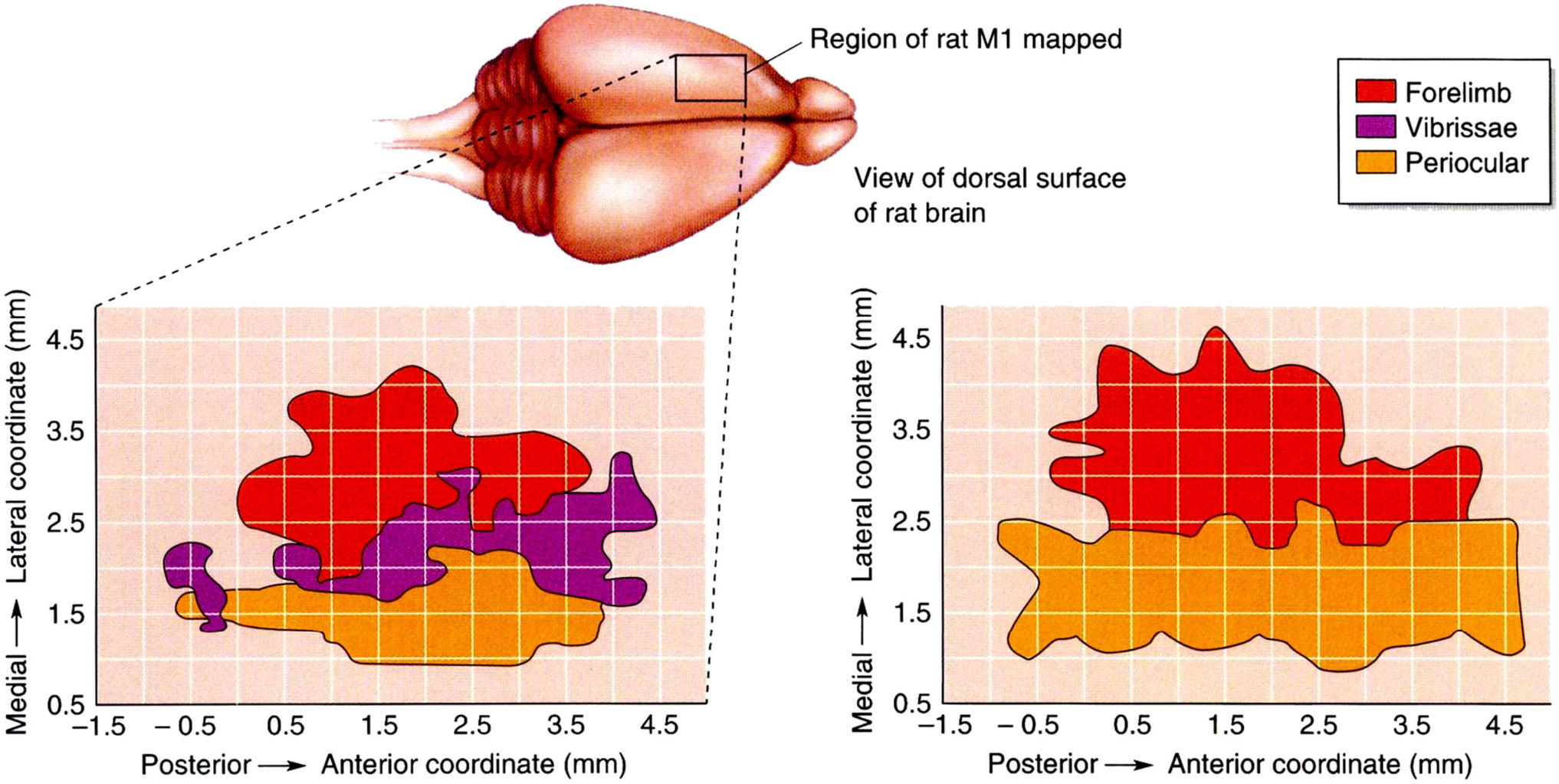
Primary Motor Cortex – Histology

Area 4

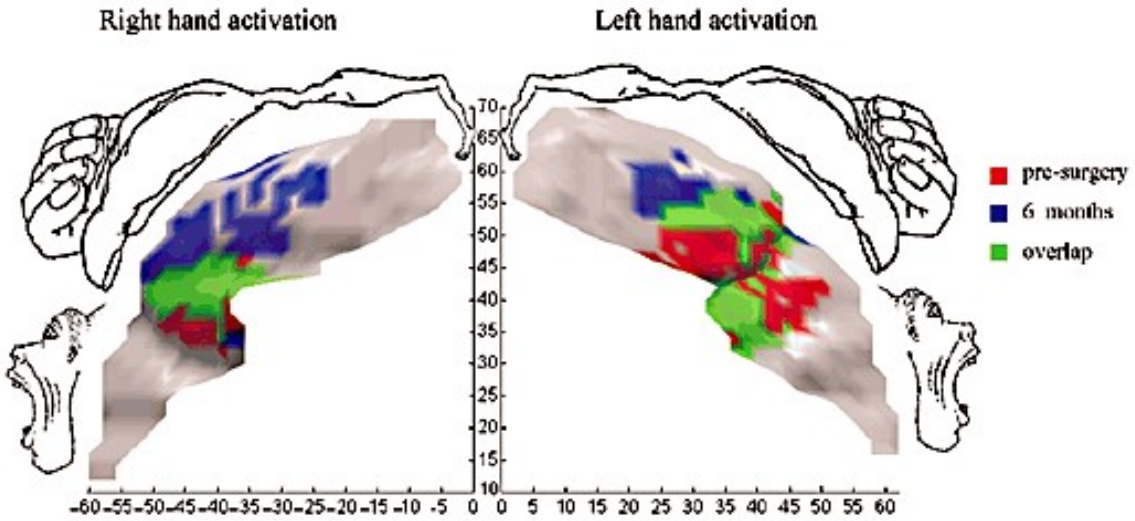
Giant Pyramidal Cells (Betz Cells)
in Layer V (Only in Area 4):
First Neurons of the Corticospinal Tract

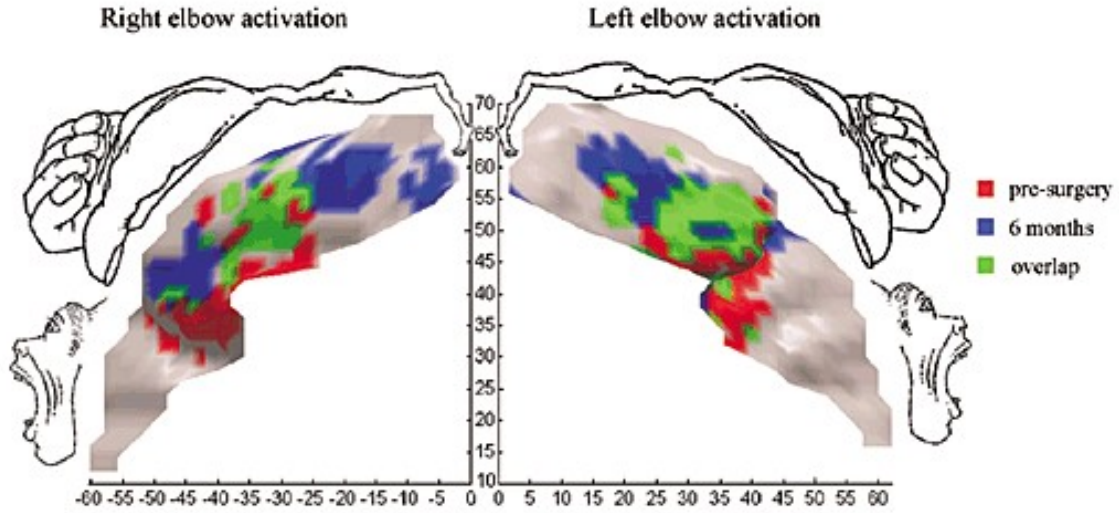


Primary Motor Cortex – Plasticity (Rat)



Primary Motor Cortex – Plasticity (Homo)





Patient C.D.

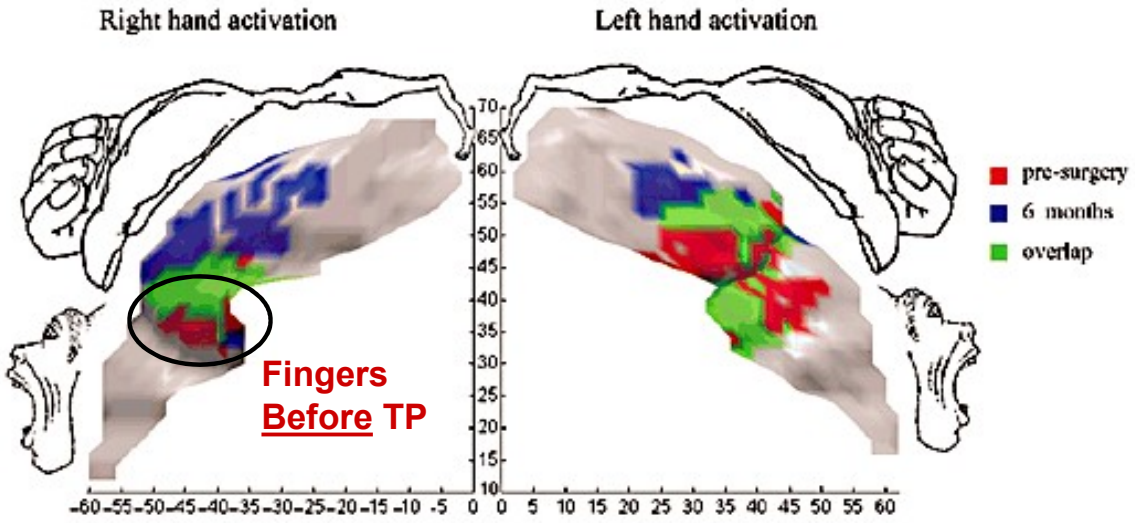
- **1996: Traumatic Amputation of Both Hands**
- **2000: Bilateral Hand Transplantation**

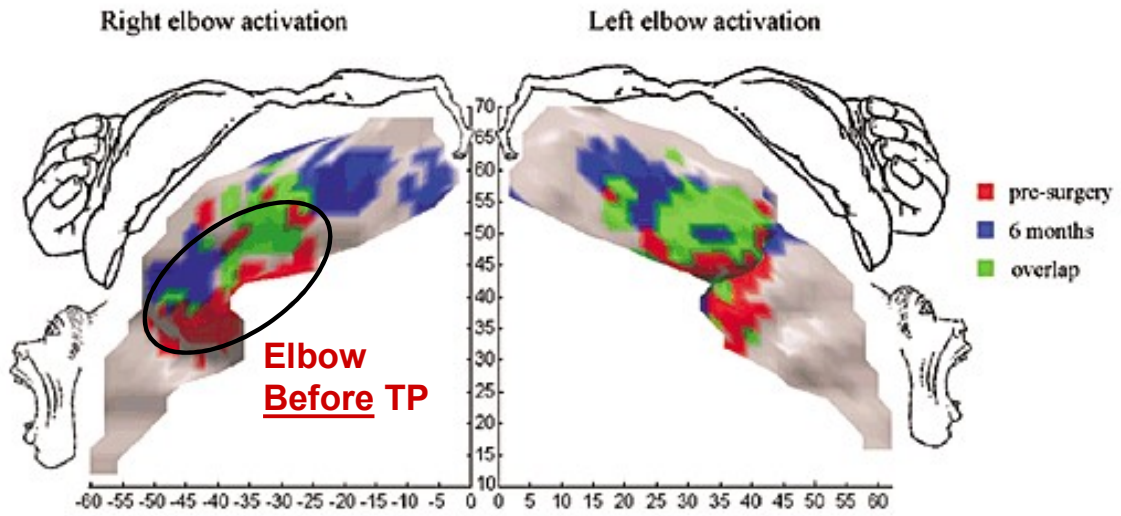
Functional MRI Scan during Flexion and Extension of:

- **Right Fingers II – V**
- **Left Fingers II – V**
- **Right Elbow**
- **Left Elbow**

Giraux et al.
Nature Neuroscience 2001

Primary Motor Cortex – Plasticity (Homo)





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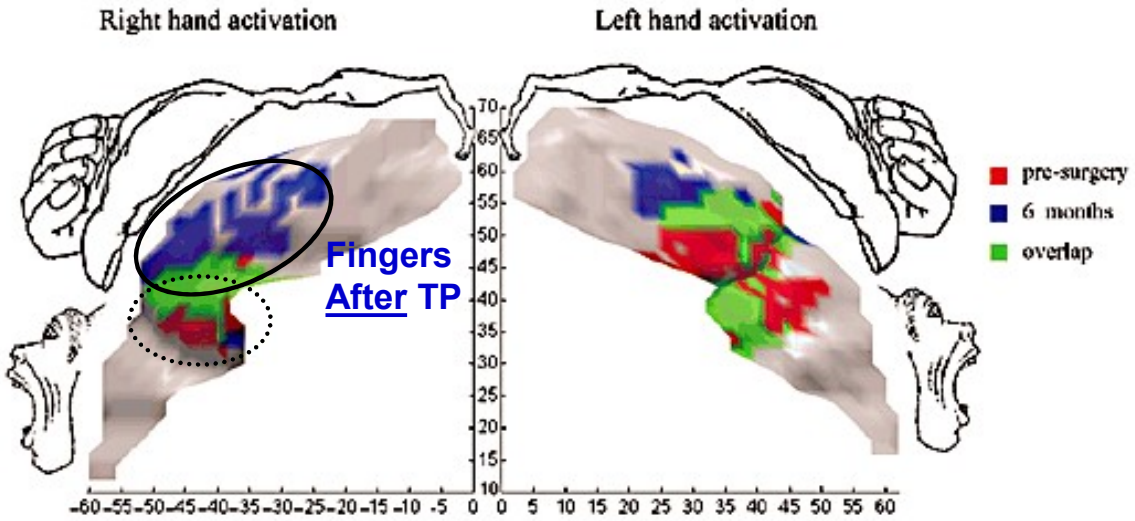
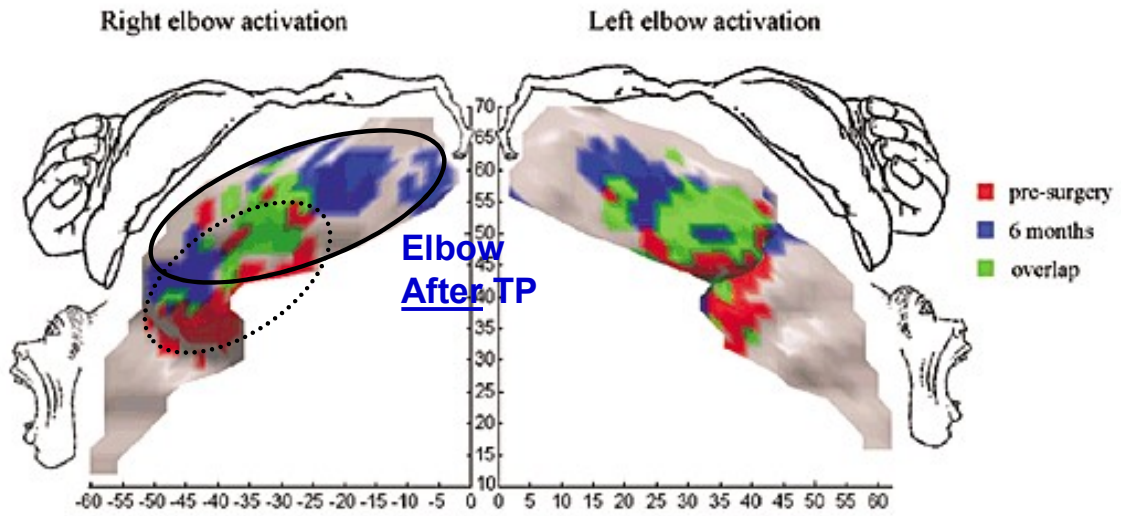
Before Transplantation (TP) (Red)

Giraux et al.
Nature Neuroscience 2001

Primary Motor Cortex – Plasticity (Homo)





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Functional MRI Scan during Flexion and Extension of:

- **Right Fingers II – V**
- **Left Fingers II – V**
- **Right Elbow**
- **Left Elbow**

Before Transplantation (TP) (Red)

6 Months After Transplantation (TP) (Blue)

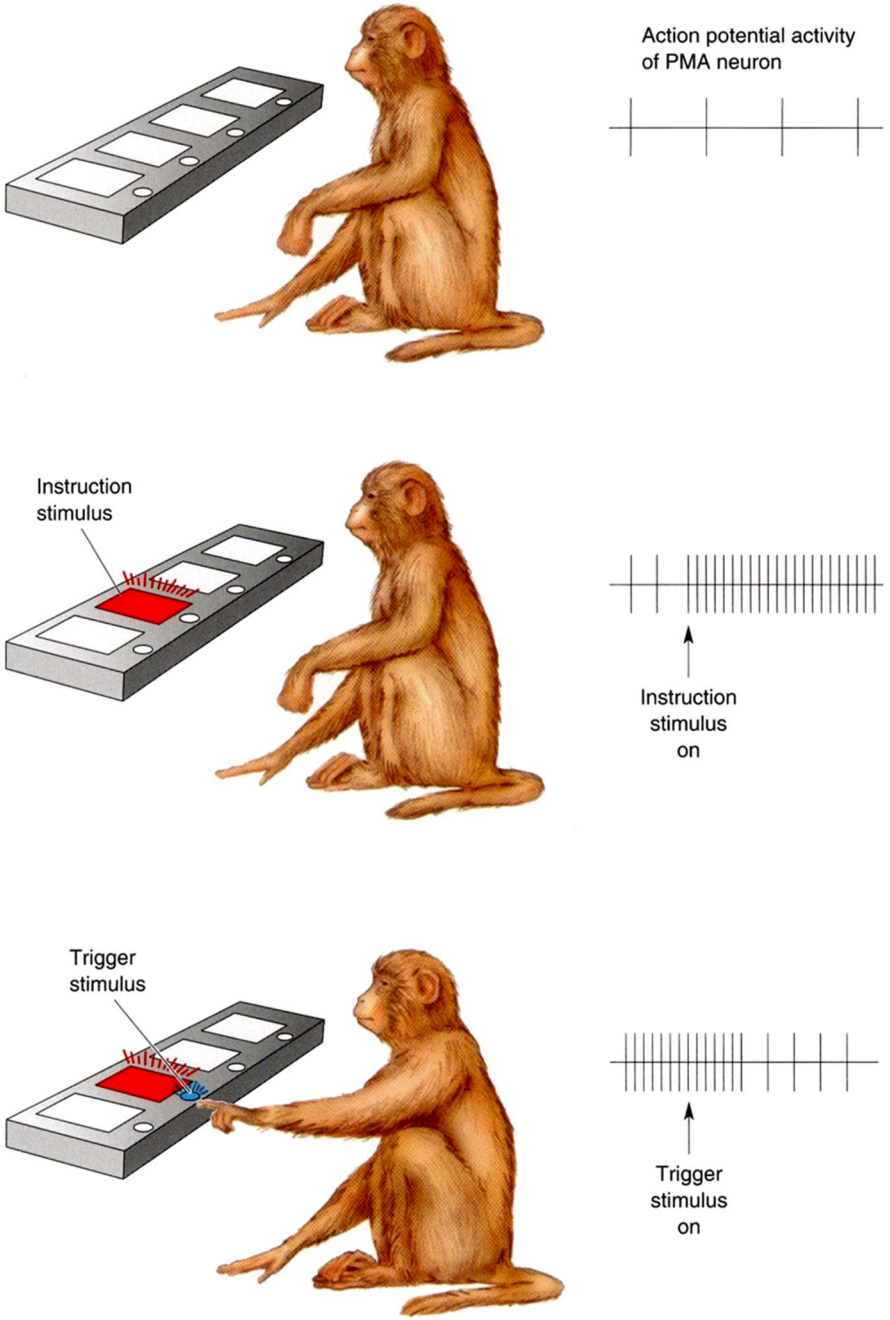
Giraux et al.
Nature Neuroscience 2001

Premotor Cortex – Movement Planning

"Ready"

"Set"

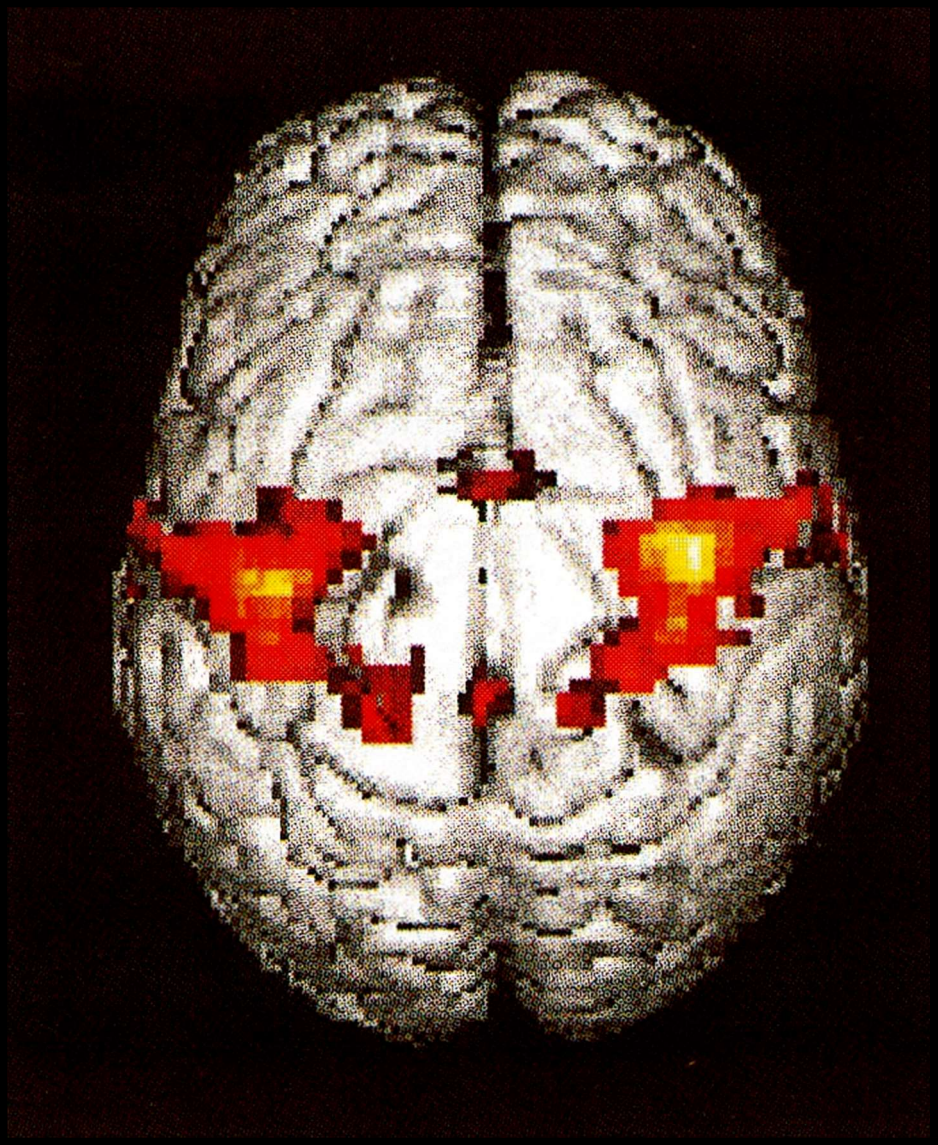
"Go"



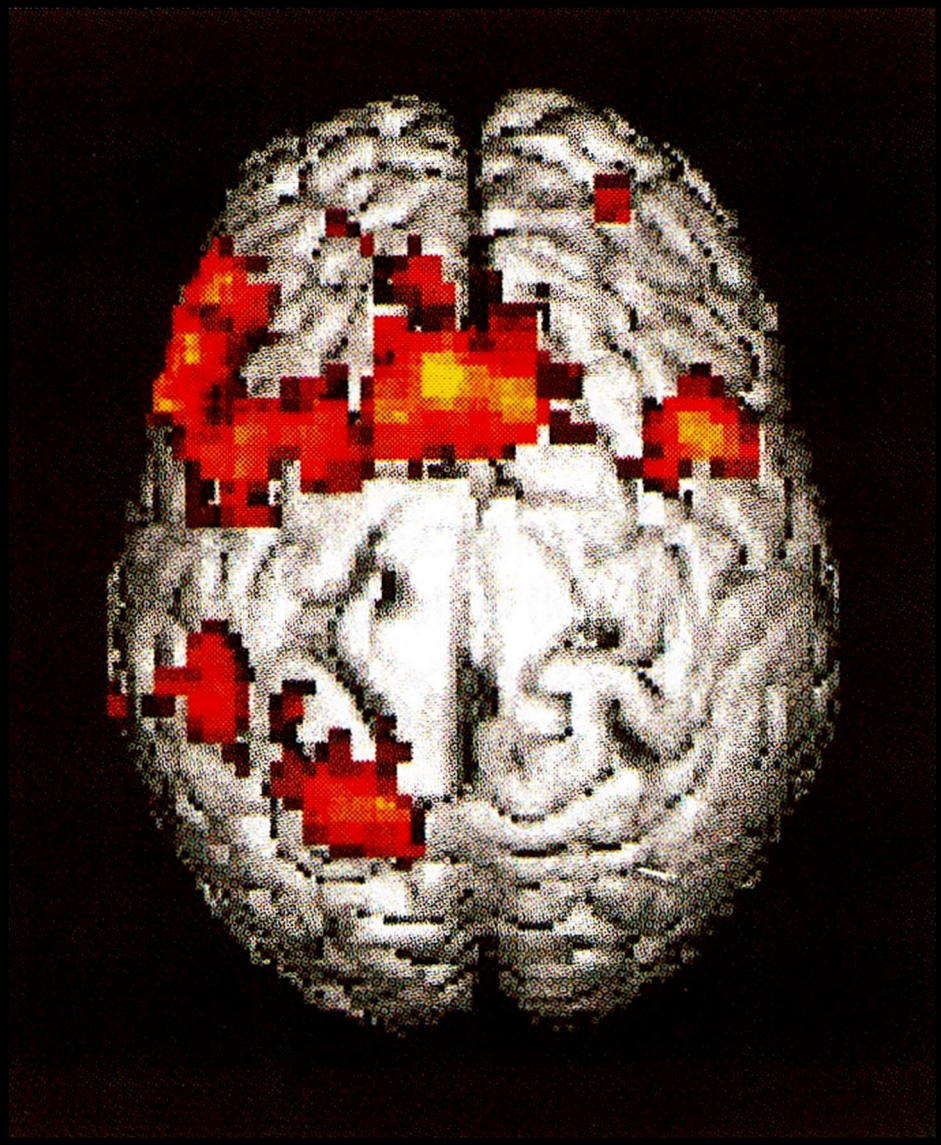
Discharge Pattern of a Neuron in the Premotor Area (PMA)

Imagination and Execution of Finger Movements

Execution vs. Imagination:
- **Frontal Cortex: Areas 4, 6**
- **Parietal Cortex: Areas 1-3, 40, 43**

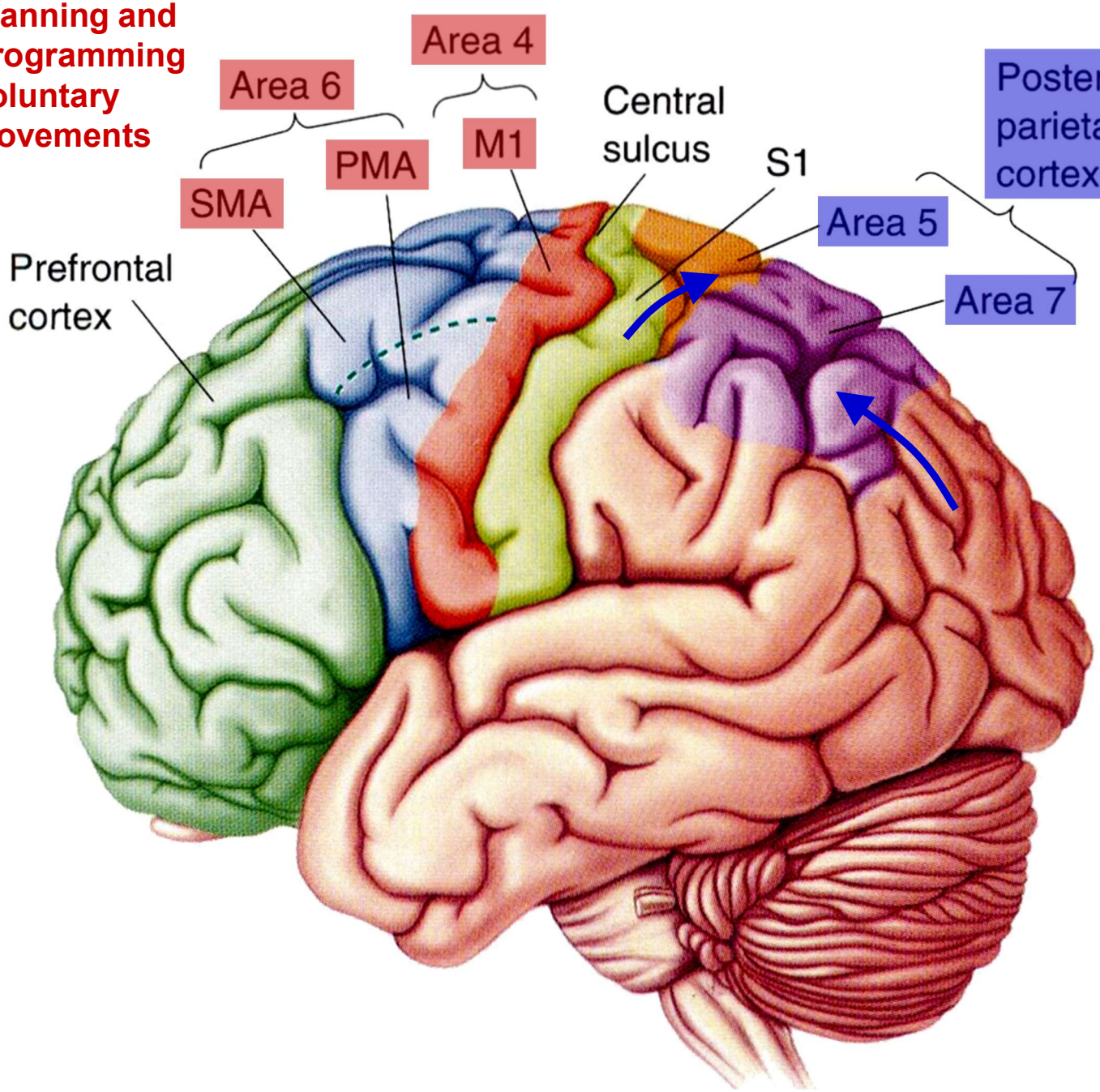


Imagination vs. Execution:
- **Frontal Cortex: Areas 6, 44, 9, 46, 10, 11**
- **Parietal Cortex: Areas 7, 40**



Planning and Directing Voluntary Movements – Part 2

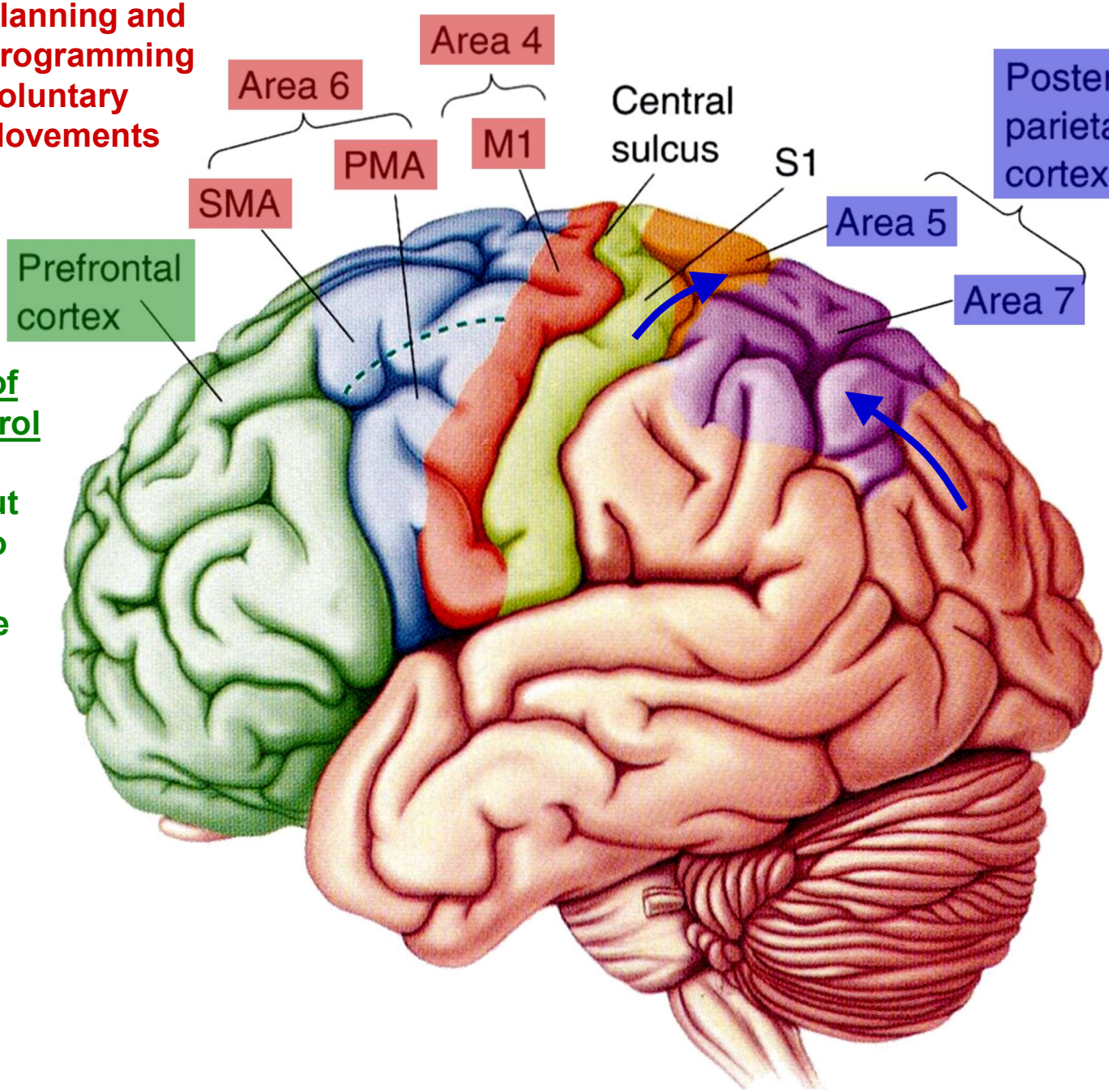
Planning and Programming Voluntary Movements



Exteroceptive, Proprioceptive, and Visual Inputs → Information about the Current Position of the Body in Space

Planning and Directing Voluntary Movements – Part 3

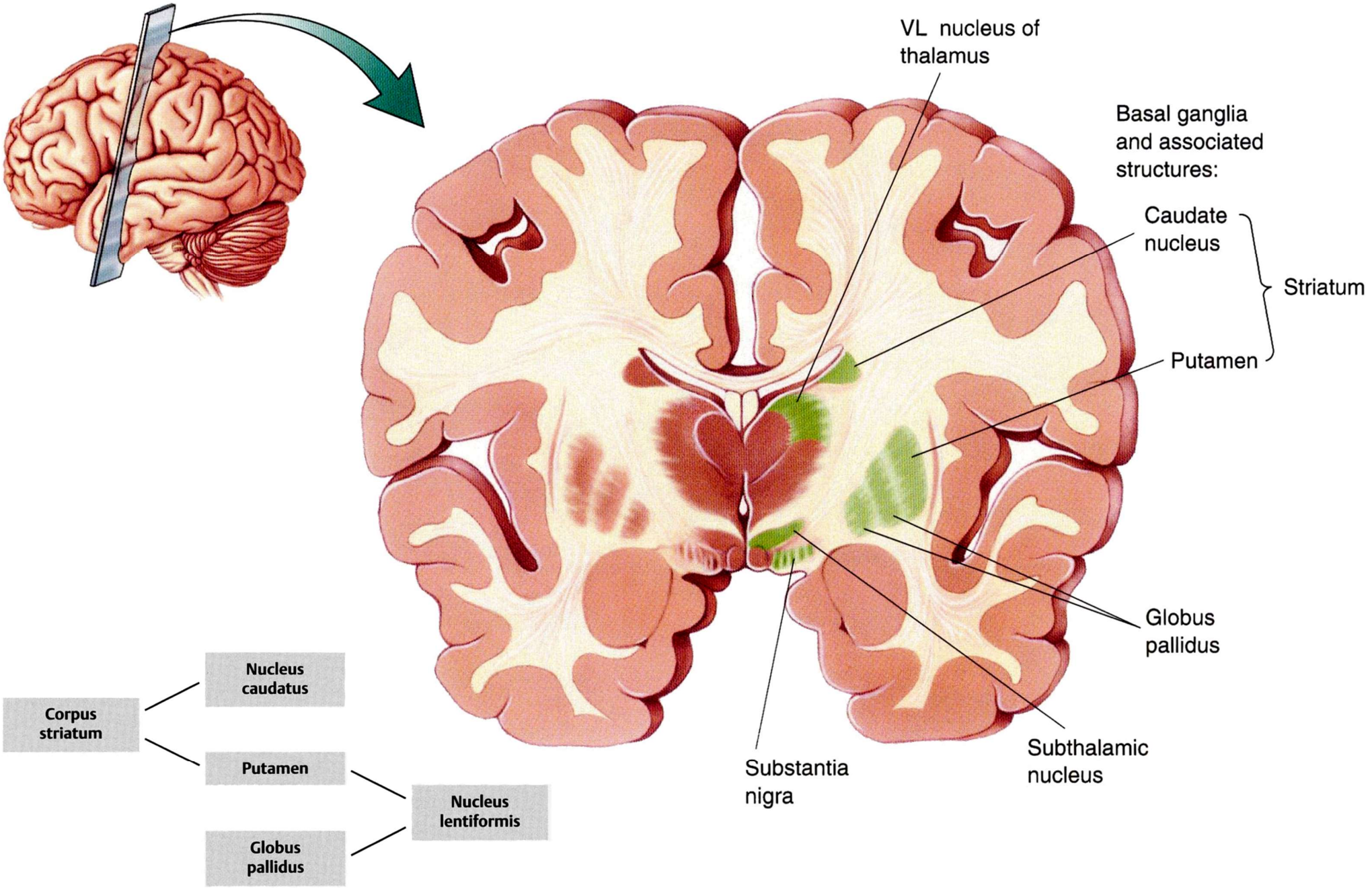
Planning and Programming Voluntary Movements



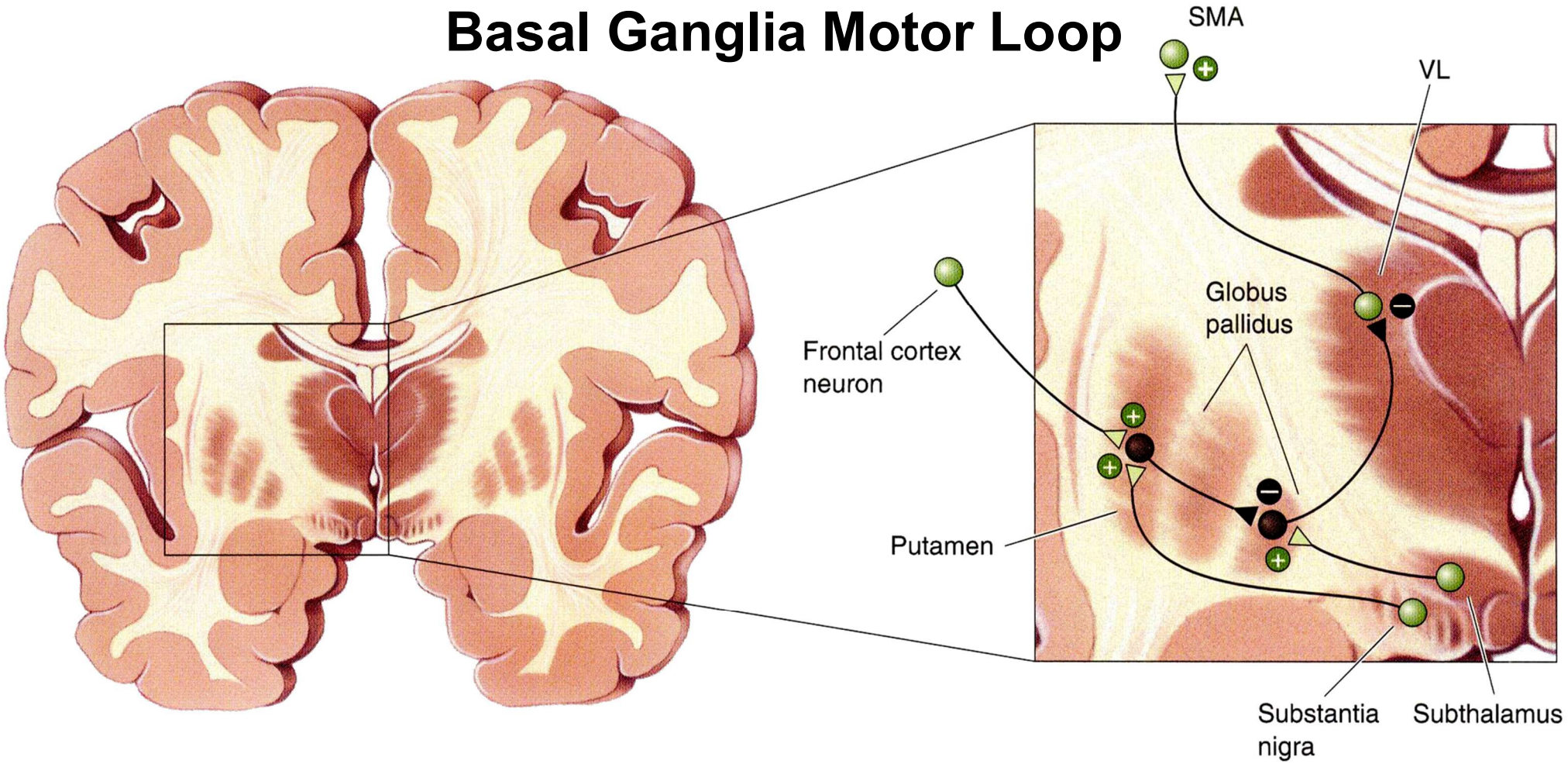
Highest Level of the Motor Control Hierarchy: Decisions about what Actions to Take and their Likely Outcome

Exteroceptive, Proprioceptive, and Visual Inputs → Information about the Current Position of the Body in Space

Basal Ganglia



Basal Ganglia Motor Loop



Connectivity: Cortex $\xrightarrow{+}$ Striatum $\xrightarrow{-}$ Pallidum $\xrightarrow{-}$ VLo $\xrightarrow{+}$ Cortex

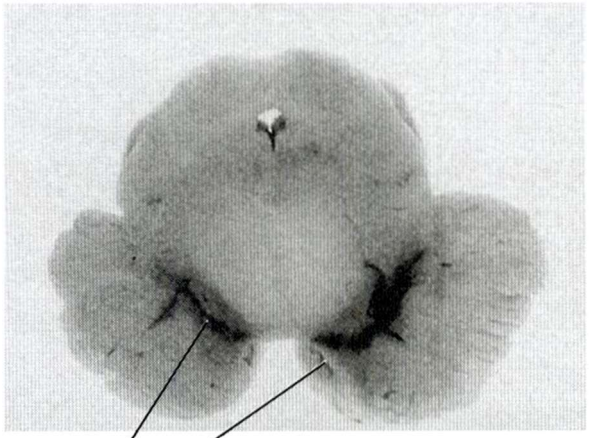
Motor Rest: ϟϟ $\xrightarrow{-}$ Ø

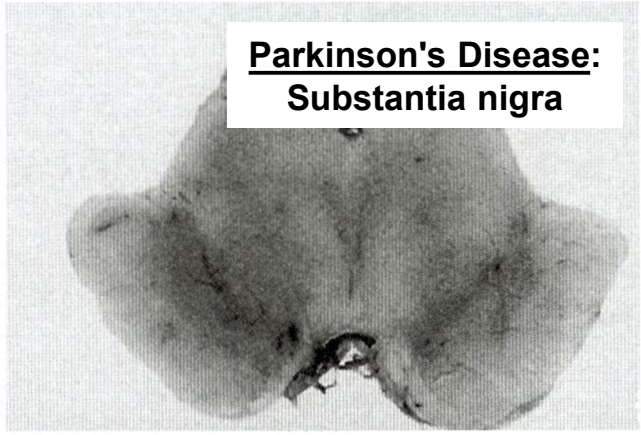
Motor Activity: ϟϟ $\xrightarrow{+}$ ϟϟ $\xrightarrow{-}$ Ø ϟϟ $\xrightarrow{+}$ ϟϟ

Disinhibition !

"Go"

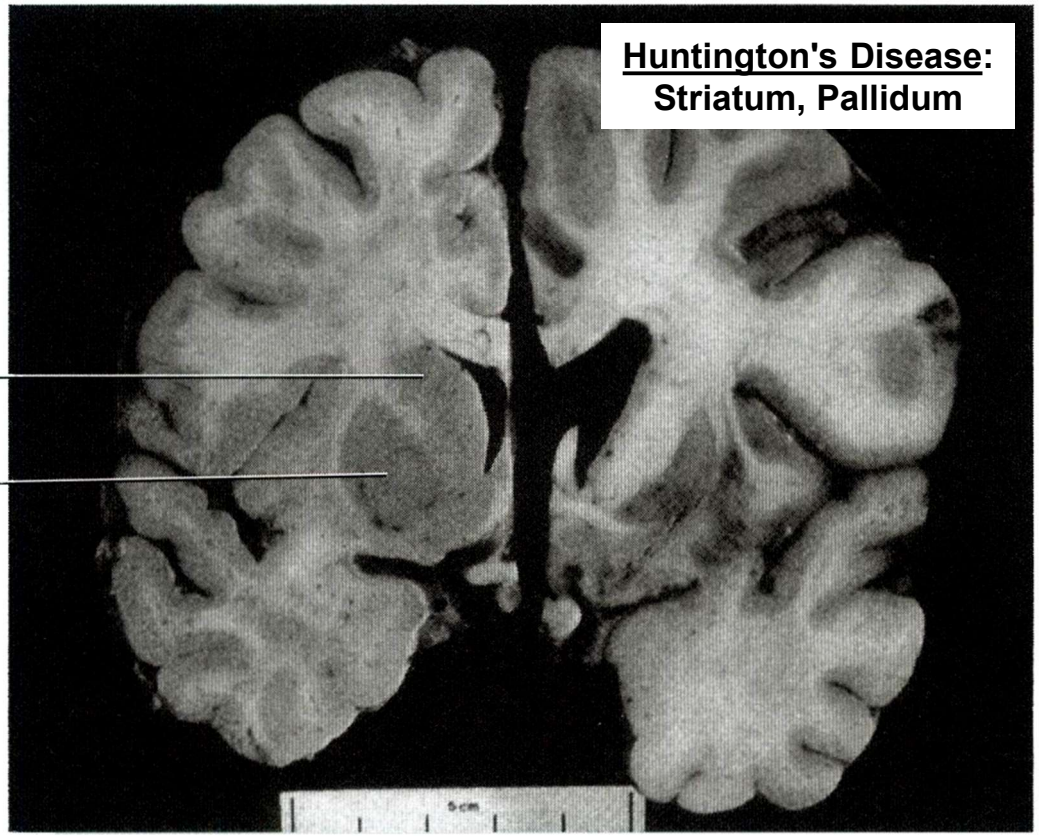
Parkinson's Disease – Huntington's Disease





Parkinson's Disease:
Substantia nigra

Substantia nigra

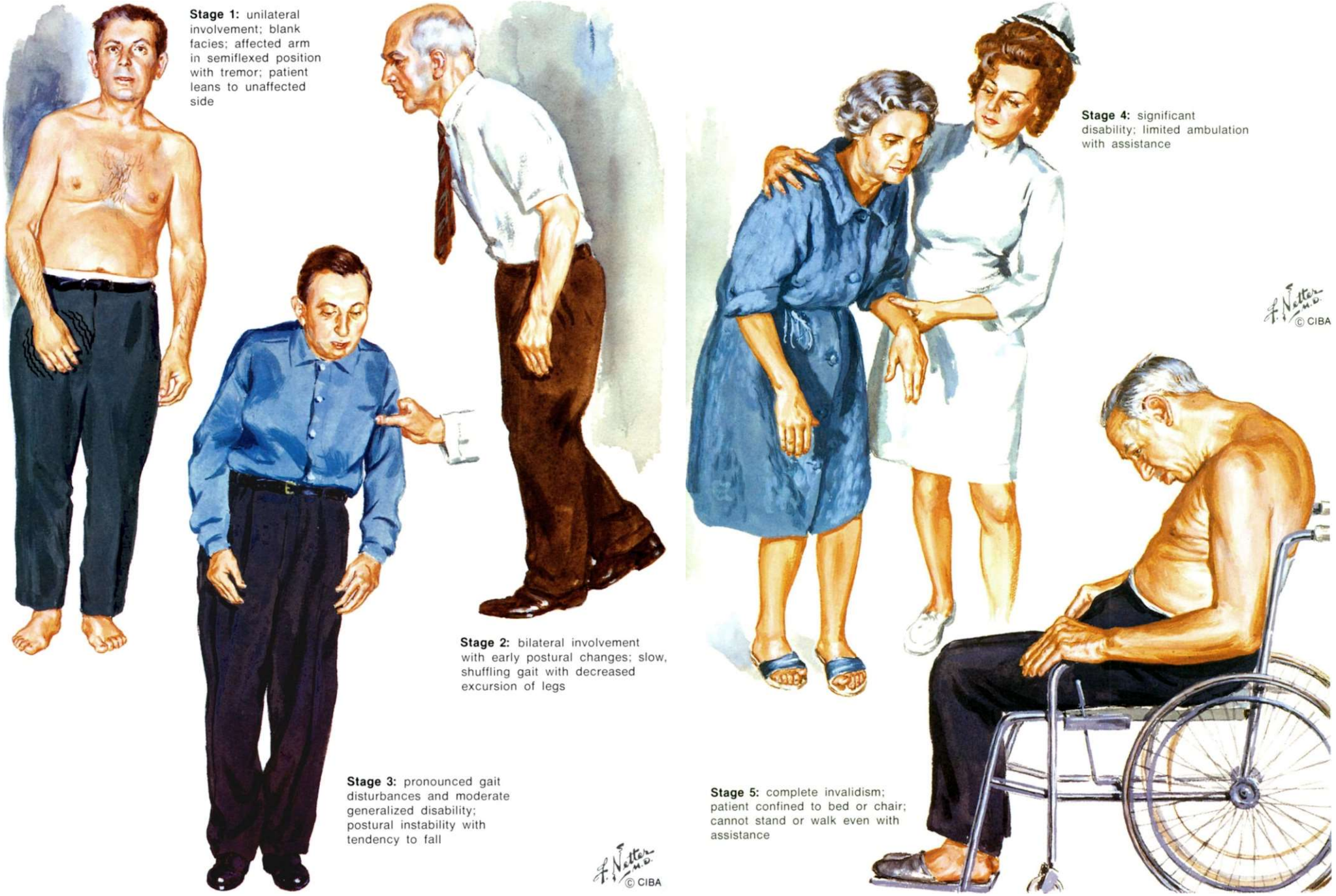


Huntington's Disease:
Striatum, Pallidum

Caudate nucleus

Putamen

Parkinson's Disease



Stage 1: unilateral involvement; blank facies; affected arm in semiflexed position with tremor; patient leans to unaffected side

Stage 2: bilateral involvement with early postural changes; slow, shuffling gait with decreased excursion of legs

Stage 3: pronounced gait disturbances and moderate generalized disability; postural instability with tendency to fall

Stage 4: significant disability; limited ambulation with assistance

Stage 5: complete invalidism; patient confined to bed or chair; cannot stand or walk even with assistance

Parkinson's Disease – Resting Tremor 1

English Subtitles
by Courtesy of Dr. Derek Ott

Parkinson's Disease – Resting Tremor 2

English Subtitles
by Courtesy of Dr. Derek Ott

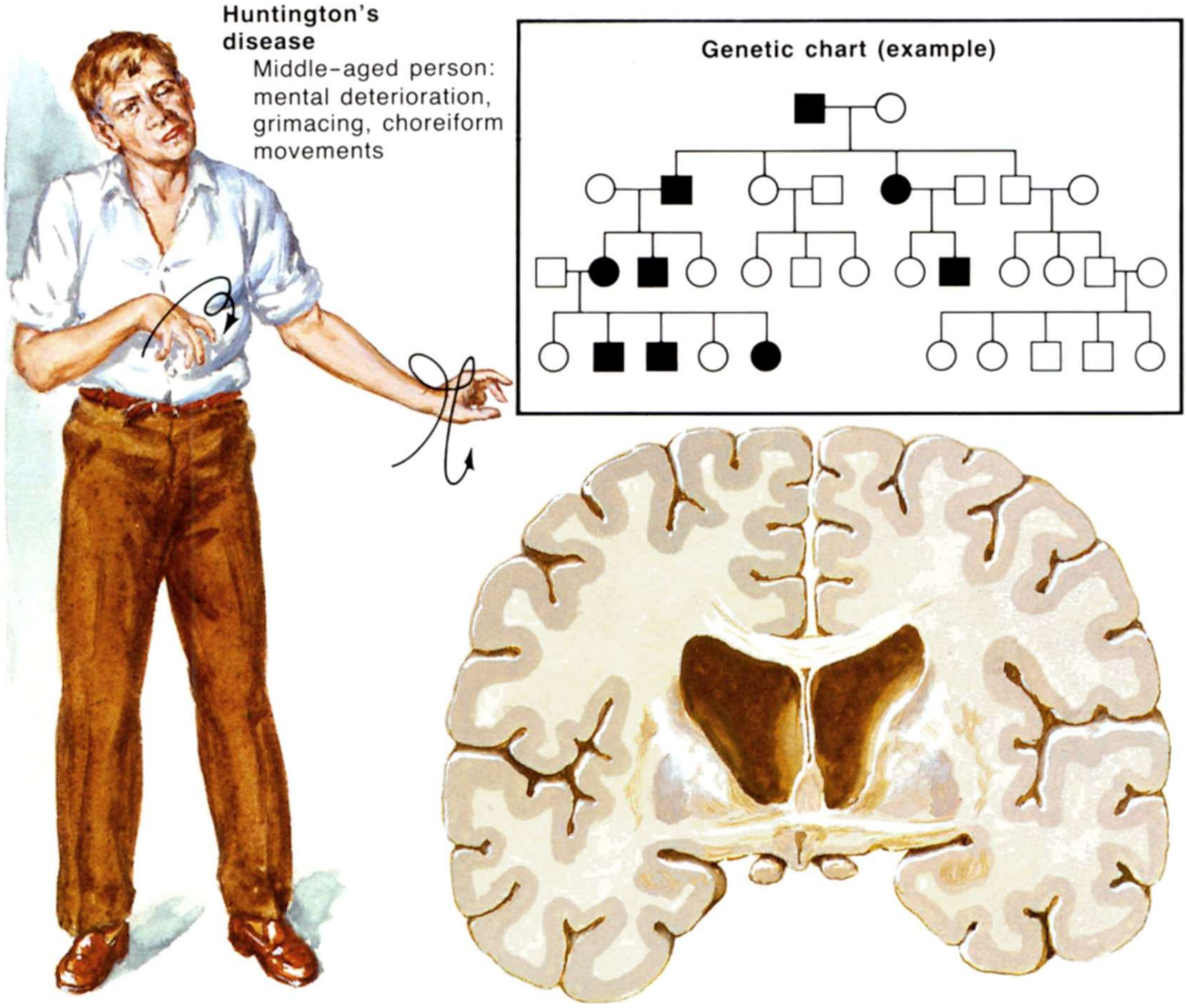
Parkinson's Disease – Resting Tremor 3

English Subtitles
by Courtesy of Dr. Derek Ott

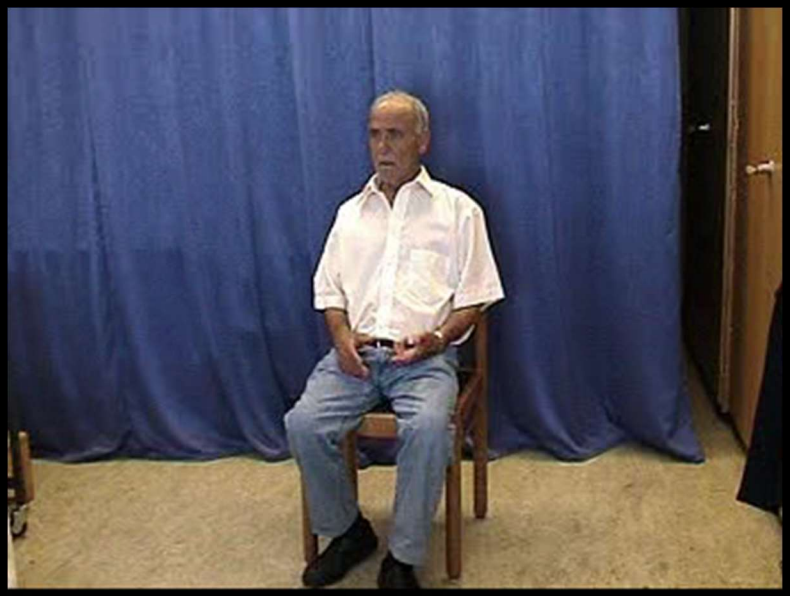
Parkinson's Disease – Posture and Tremor

English Subtitles
by Courtesy of Dr. Derek Ott

Huntington's Disease

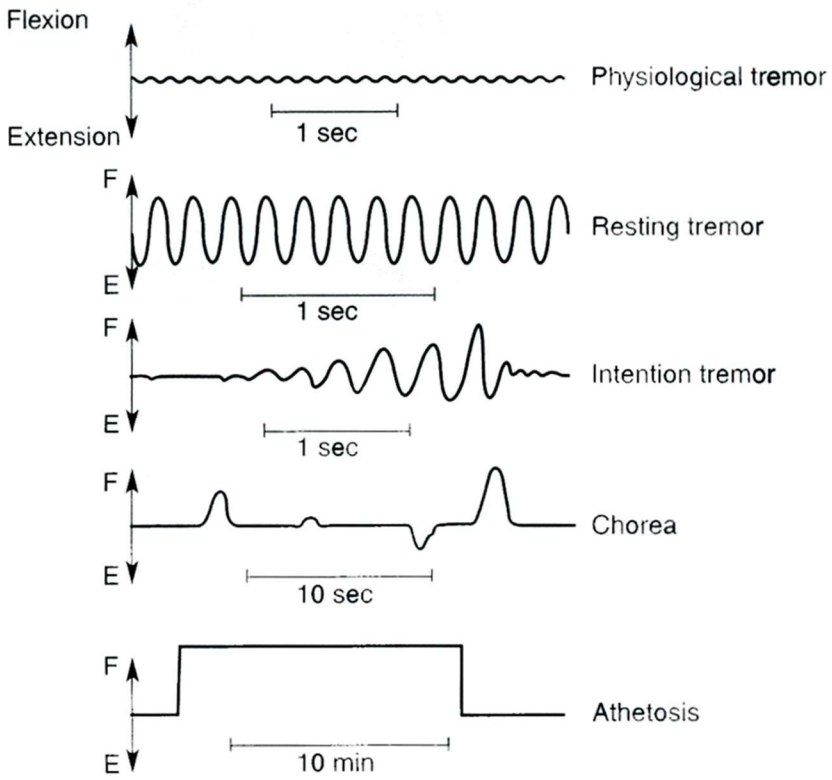


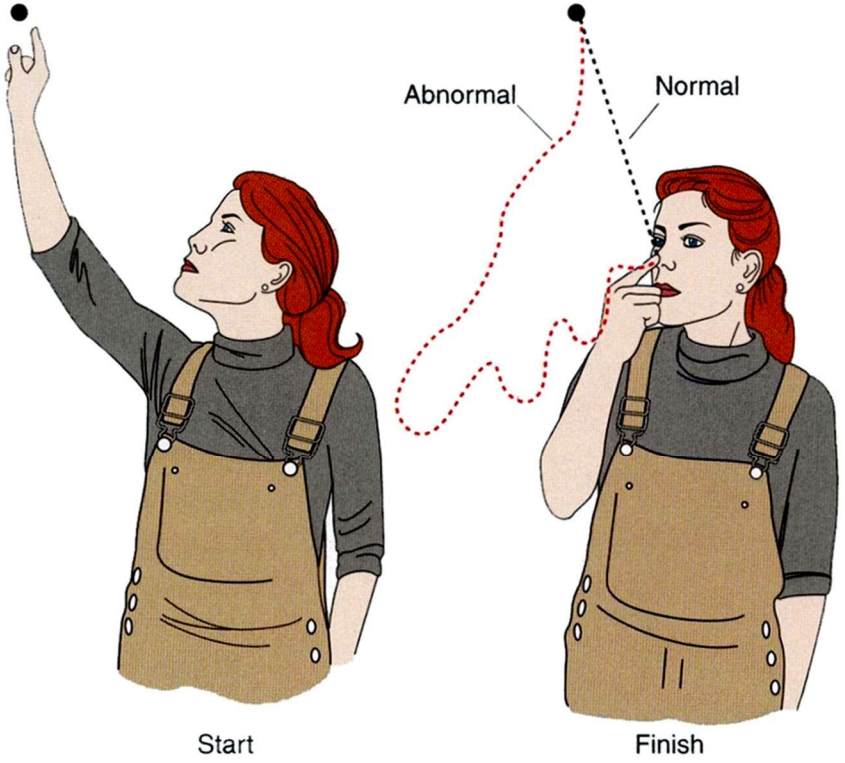
Huntington's Disease – Chorea

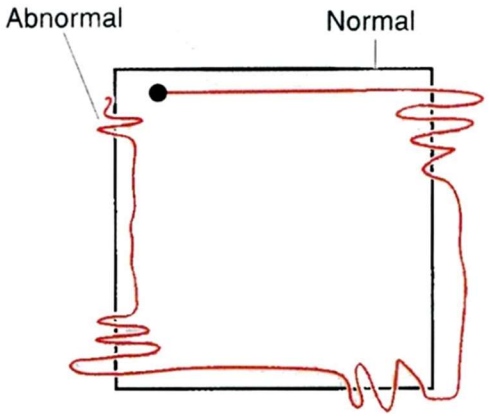


English Subtitles
by Courtesy of Dr. Derek Ott

Tremor


Flexion
Extension
Physiological tremor
1 sec
F
E
Resting tremor
1 sec
Intention tremor
1 sec
Chorea
10 sec
Athetosis
10 min


Abnormal
Normal
Start
Finish


Abnormal
Normal

Postural Tremor

English Subtitles
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Postural Tremor and Intention Tremor

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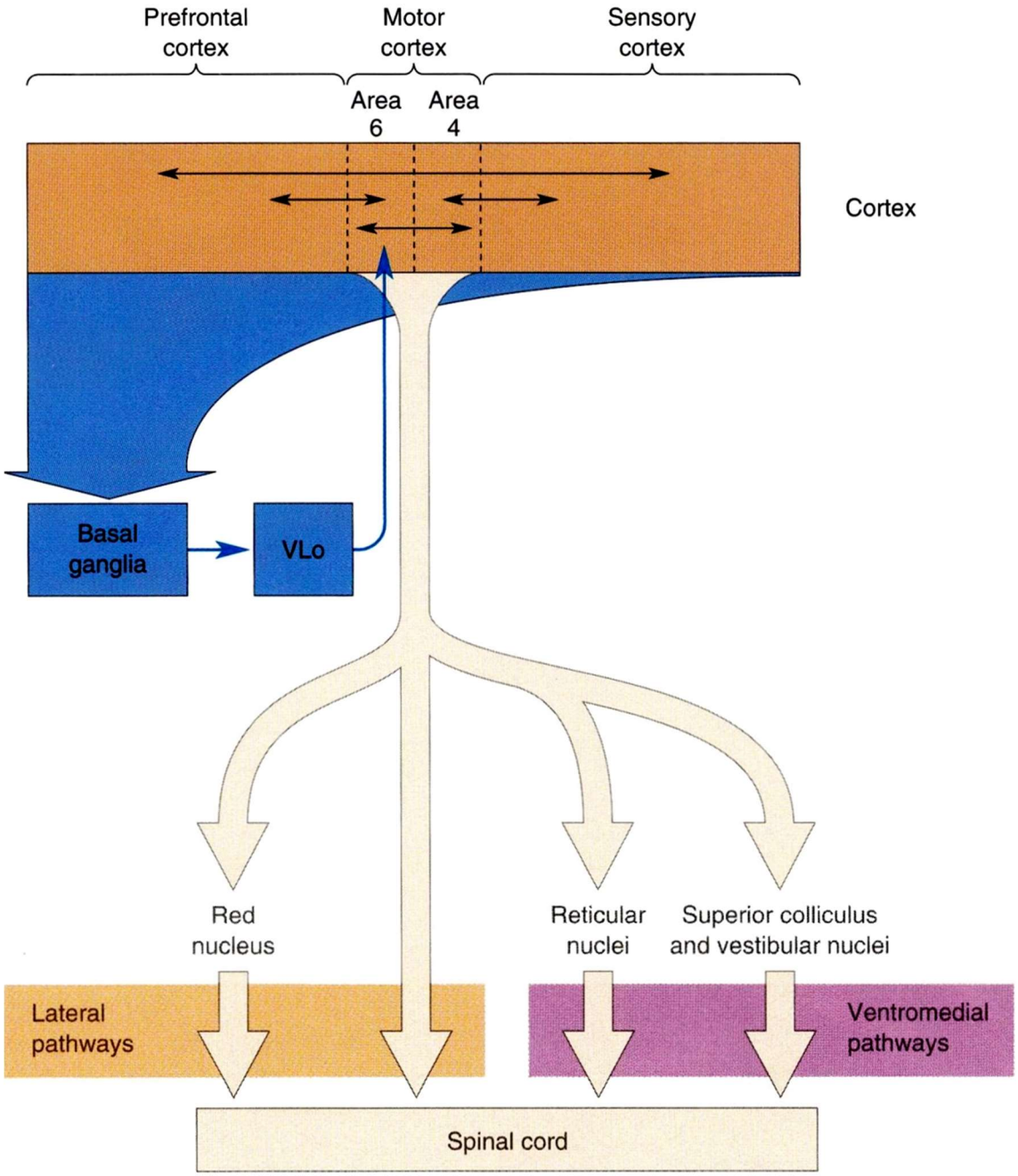
by Courtesy of Dr. Derek Ott

Basal Ganglia – Summary



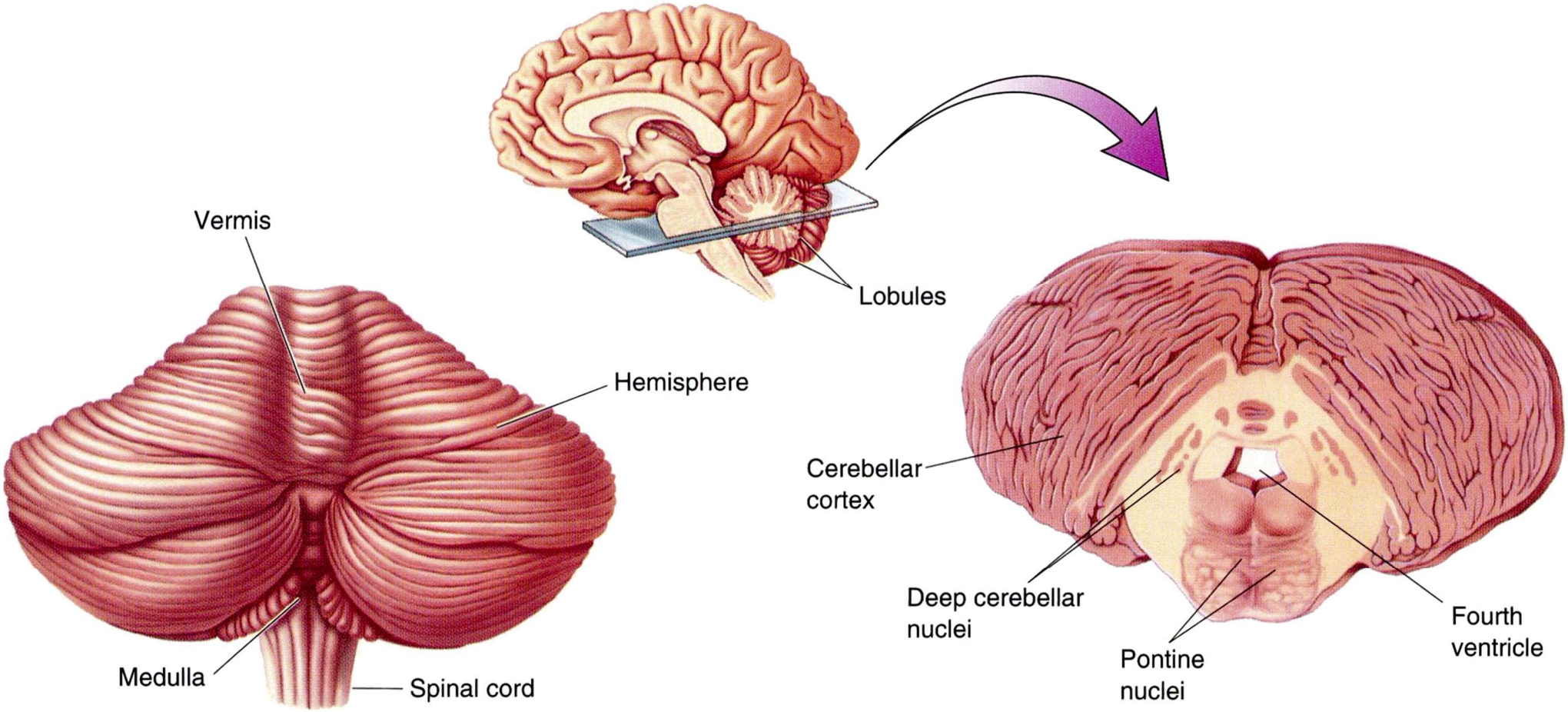
Cerebellum

Dorsal View:

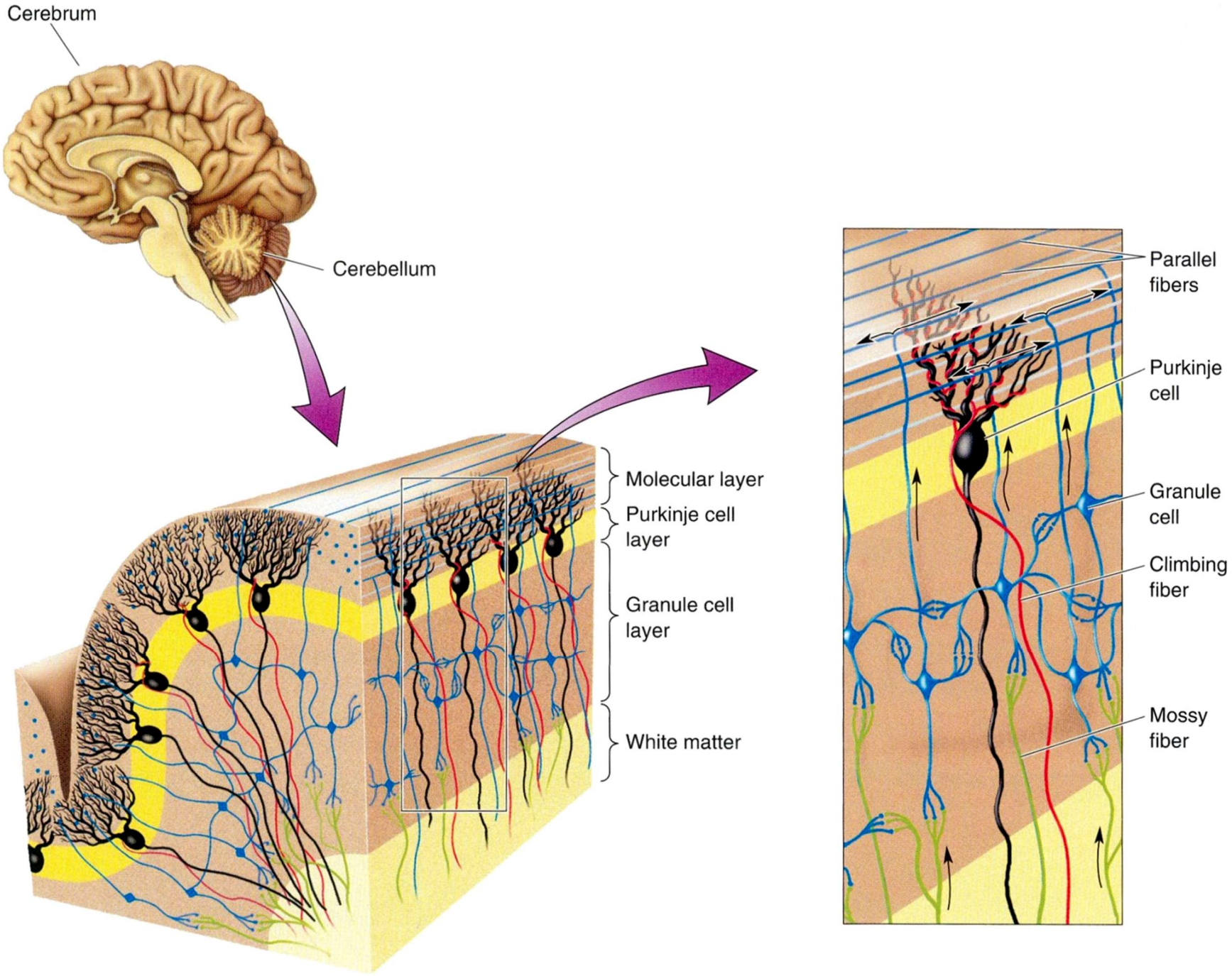
- **Midline Region (Vermis)**
- **2 Hemispheres**
- **Series of Shallow Ridges (Folia)**

Cross Section:

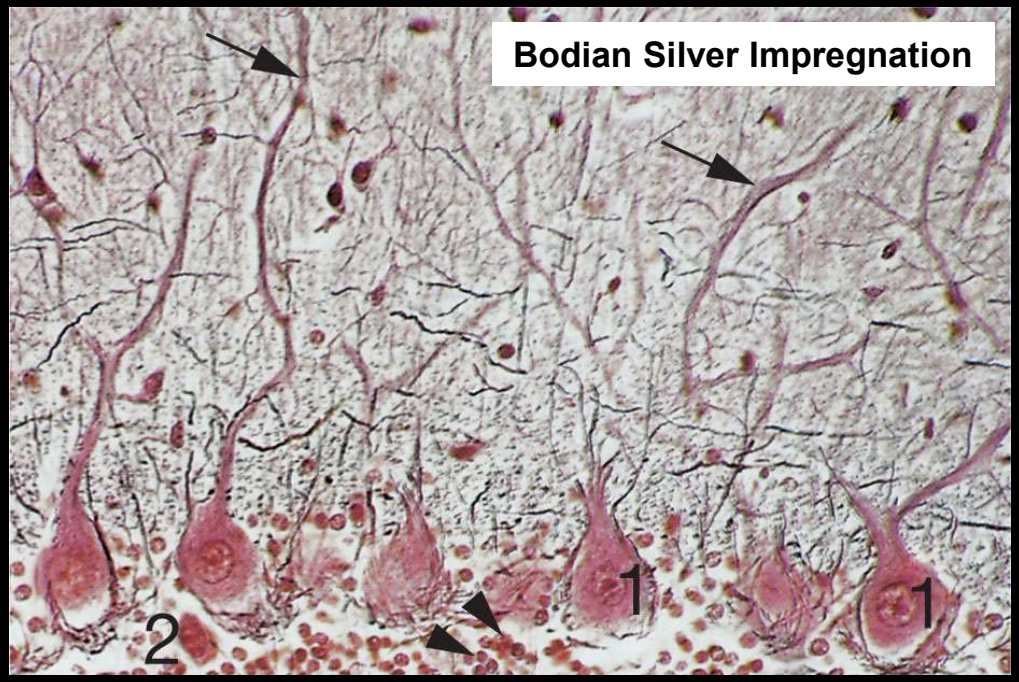
- **Cortex**
- **Deep Nuclei: Dentate Nucleus and others**



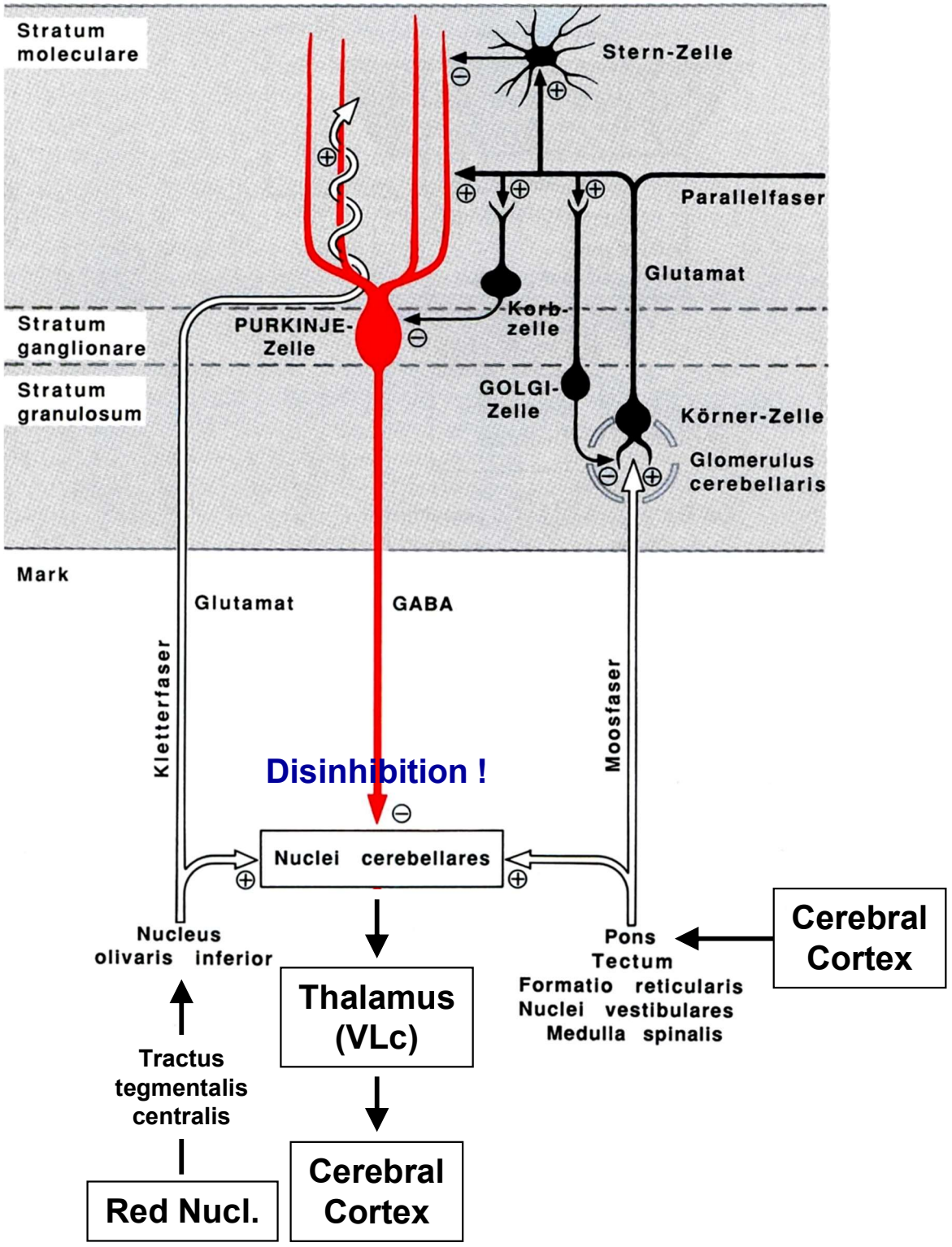
Cerebellar Cortex



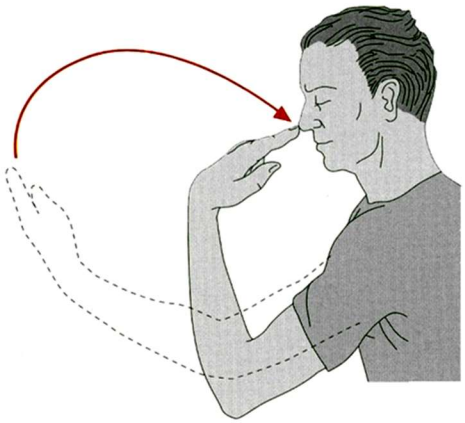
Cerebellar Cortex



Cerebellar Cortex

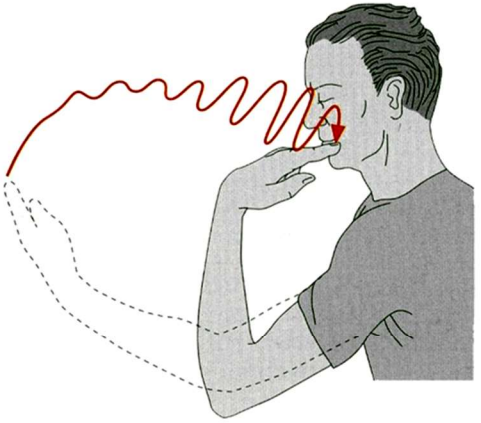


Cerebellar Signs and Symptoms



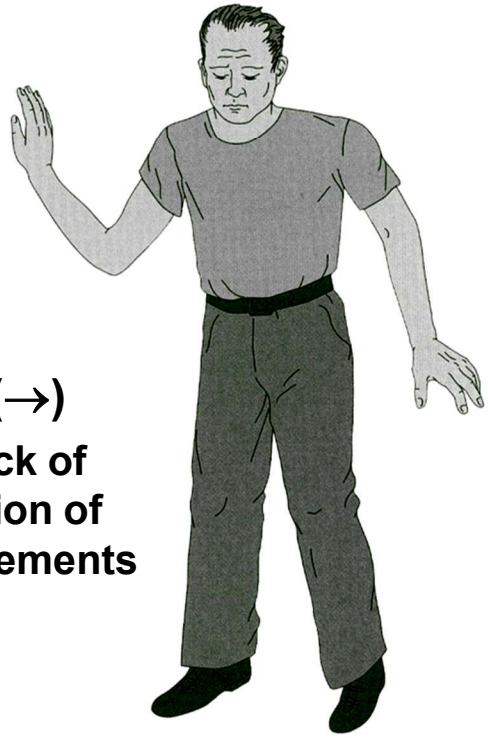
Dysdiadochokinesia

Inability to Perform Rapid, Alternating Movements



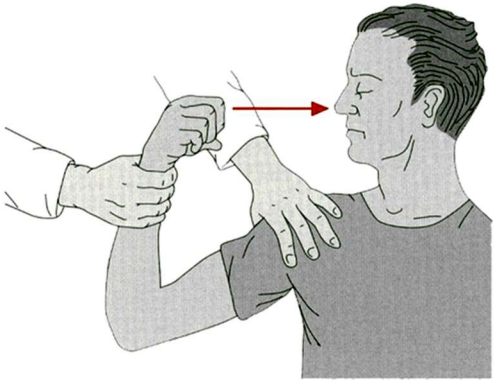
(←) Intention Tremor

Tremor Amplitude Increases as the Target is Reached



Ataxia (→)

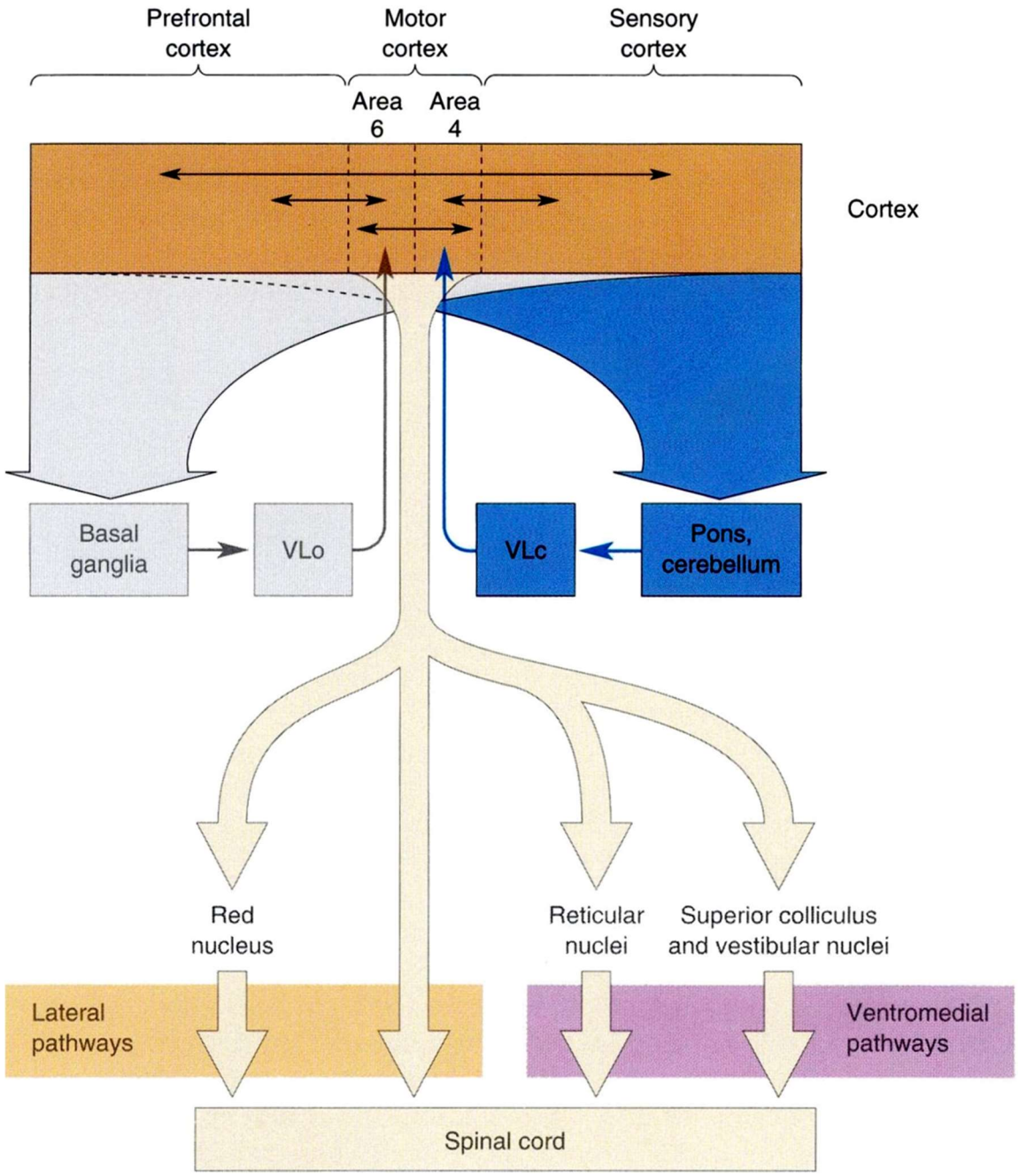
Gross Lack of Coordination of Muscle Movements



(←) Rebound

of the Limb when Arm is Moved against Resistance and Suddenly Released

Cerebellum – Summary




The Anatomy Lesson Is Over !
Thank You
For Your Attention !
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