

# Motor Systems: Motor Cortex

Michael S. Beauchamp, Ph.D.

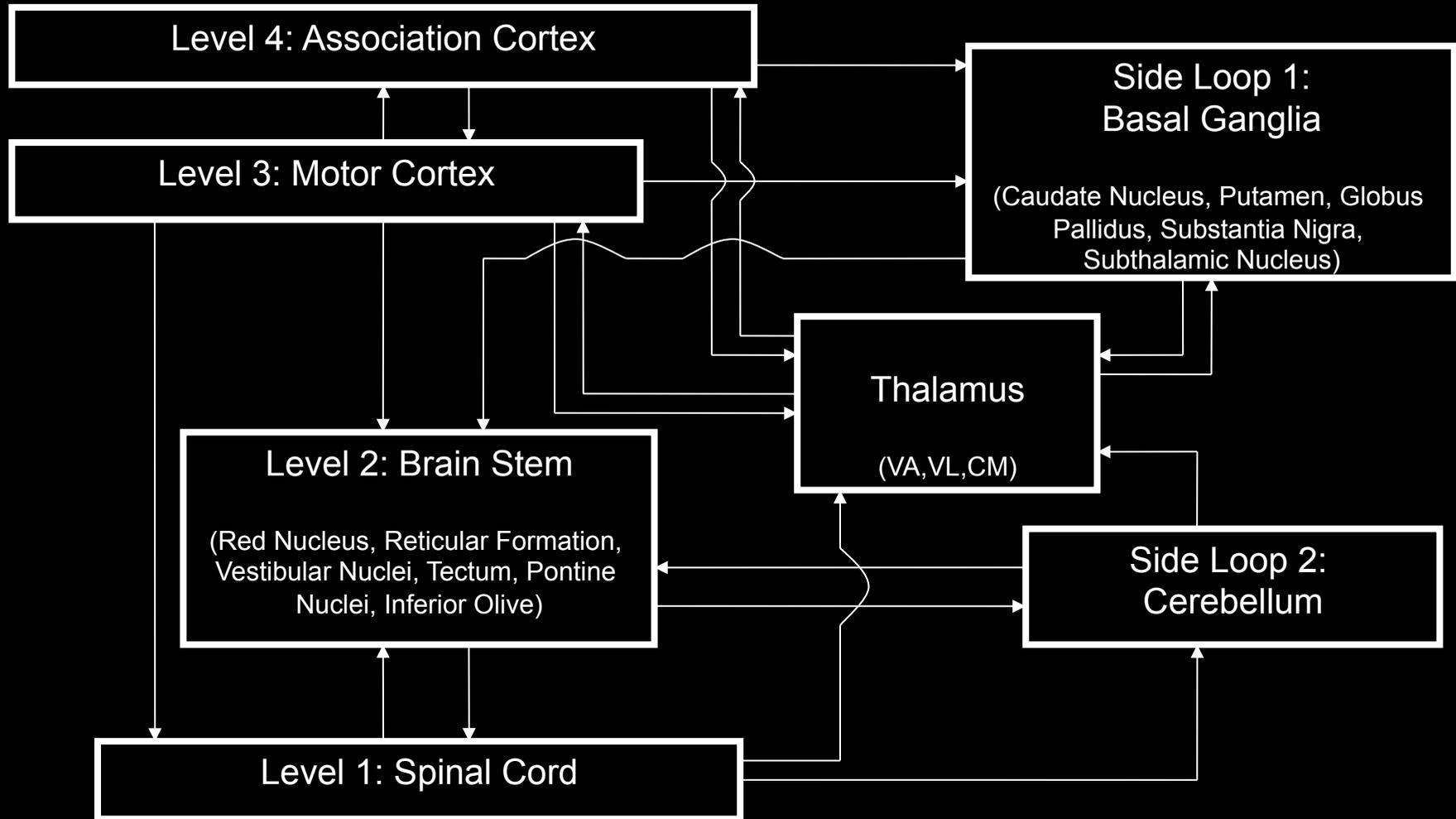
Department of Neurobiology and Anatomy

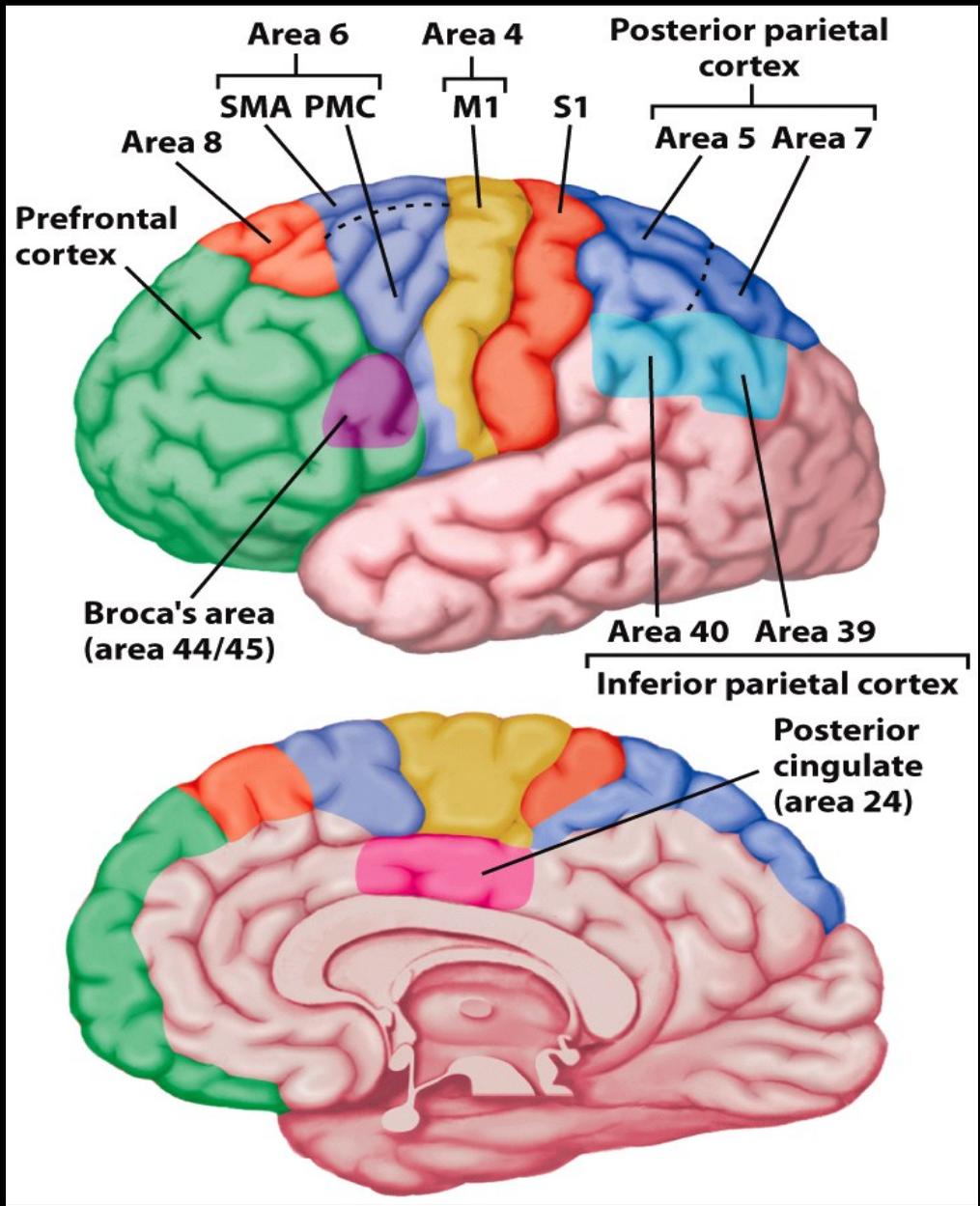
University of Texas Health Science Center at  
Houston

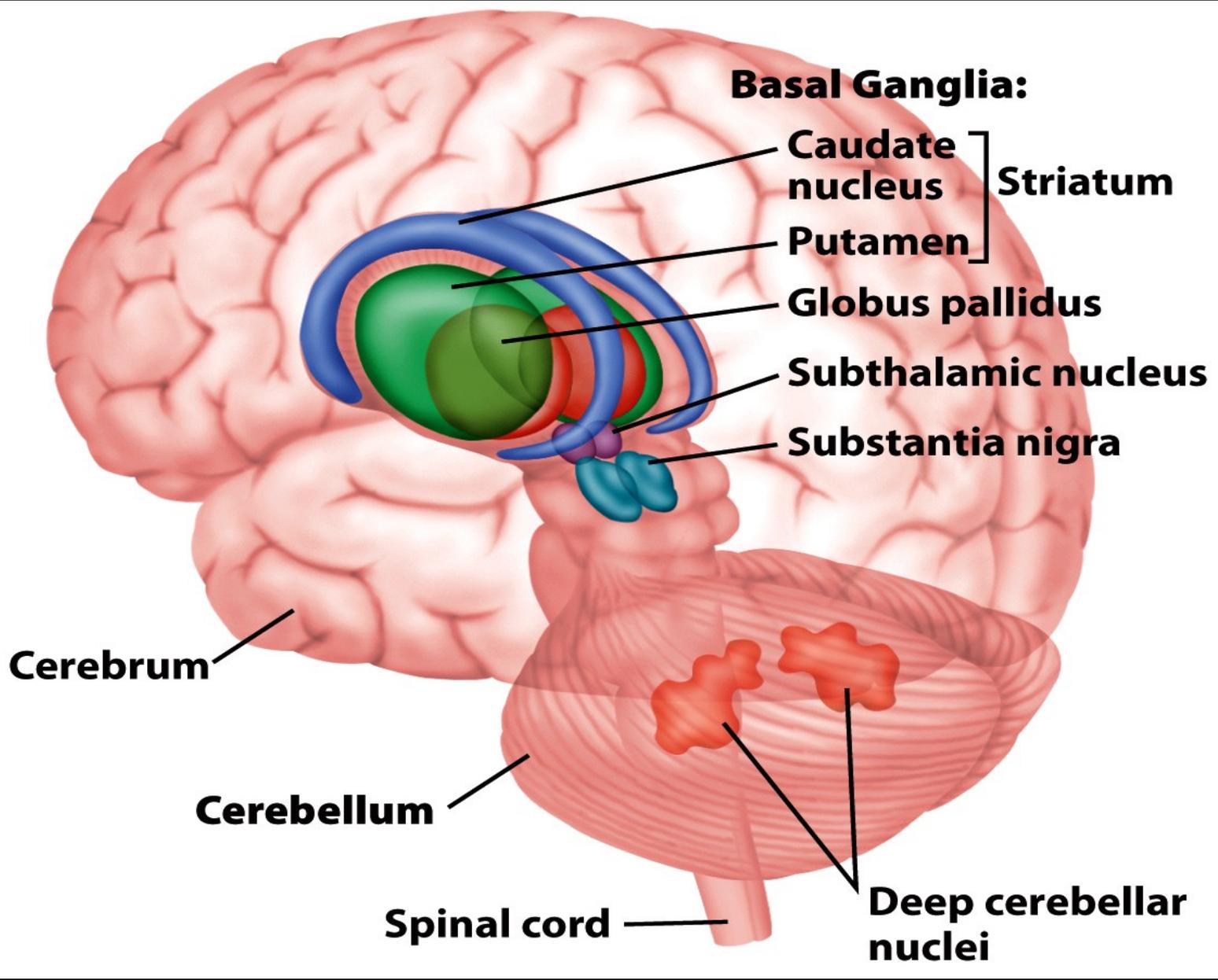
Houston, TX

**[Michael.S.Beauchamp@uth.tmc.edu](mailto:Michael.S.Beauchamp@uth.tmc.edu)**

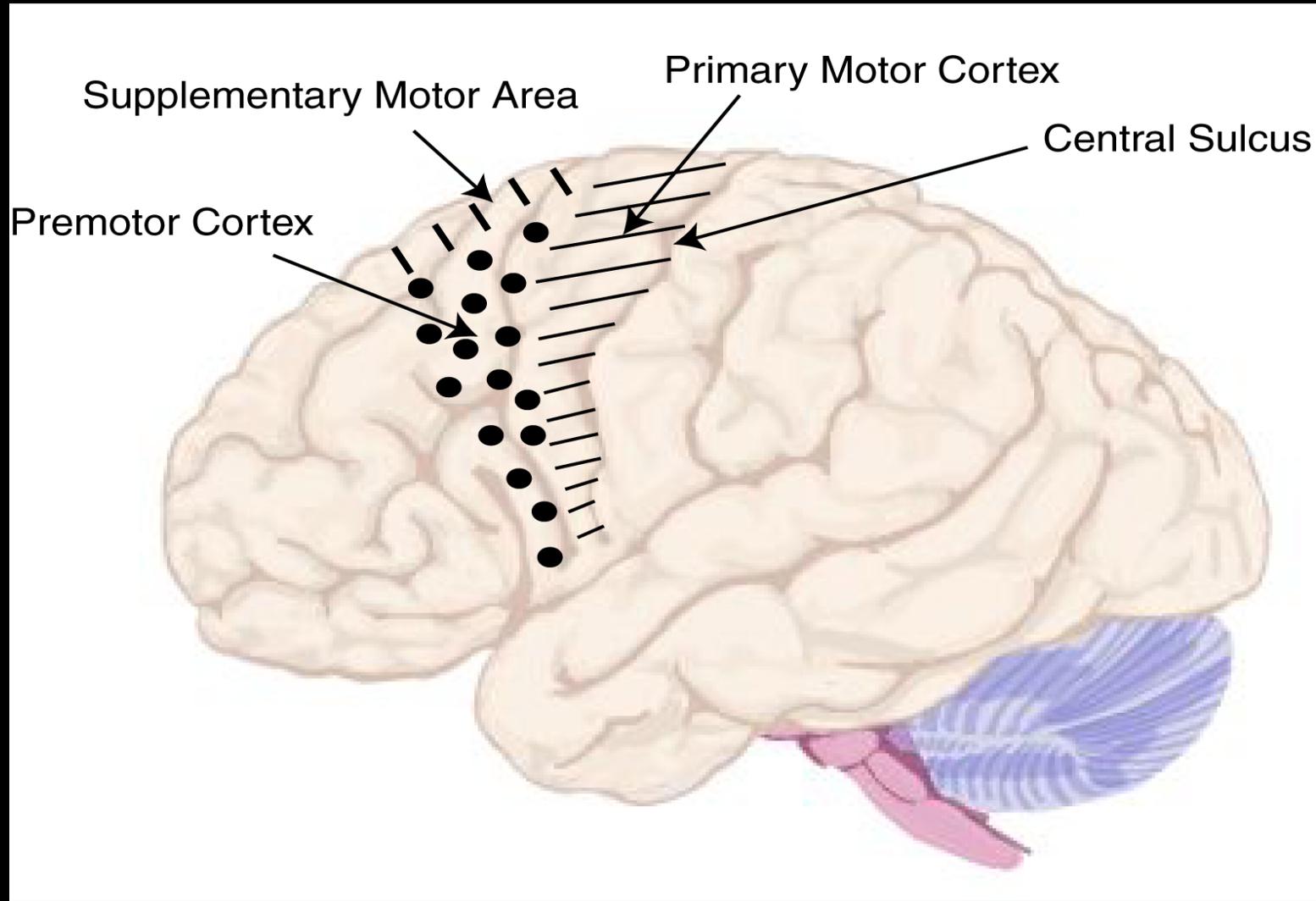
# Hierarchical Organization and Functional Segregation of Central Motor Structures



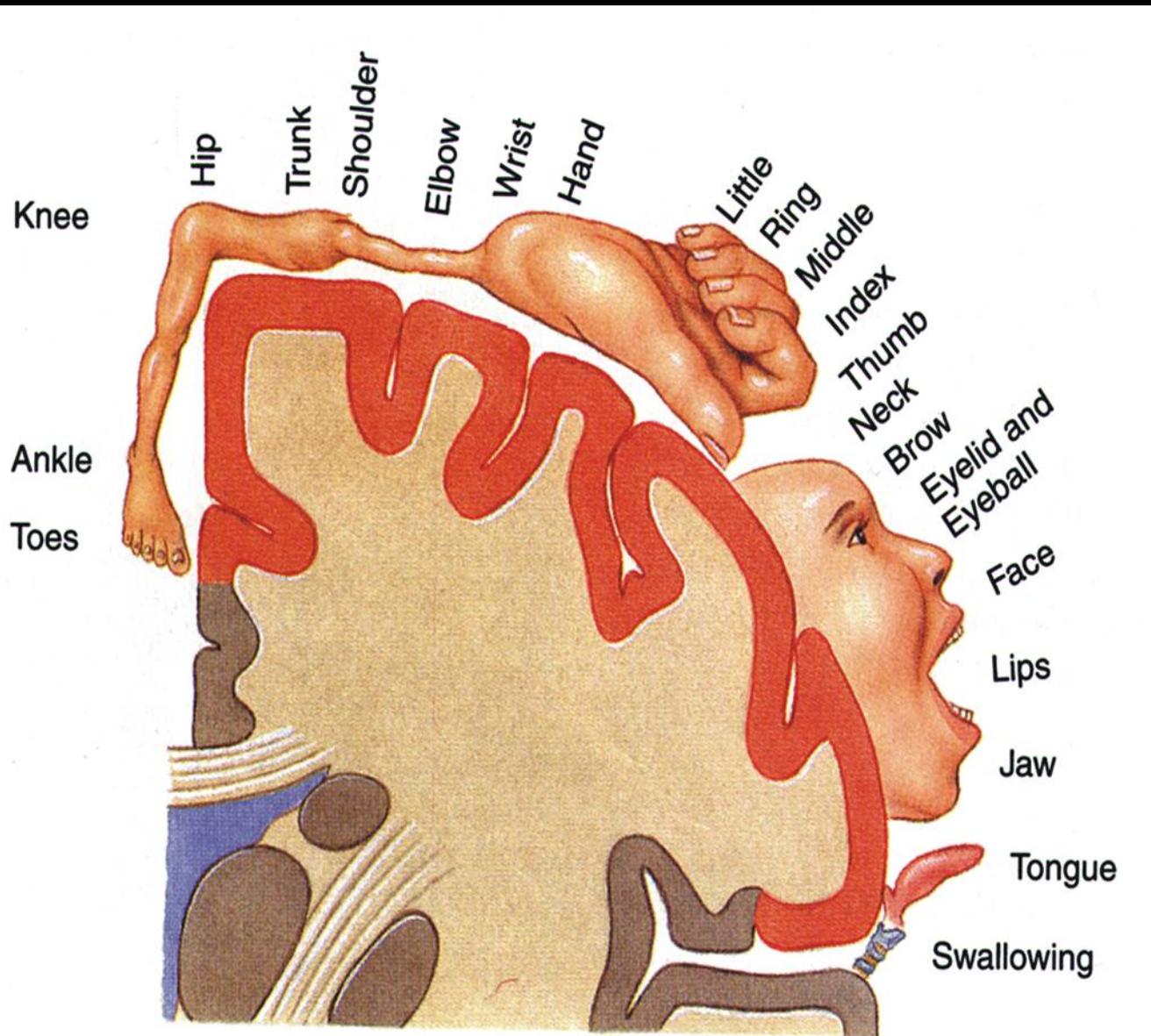




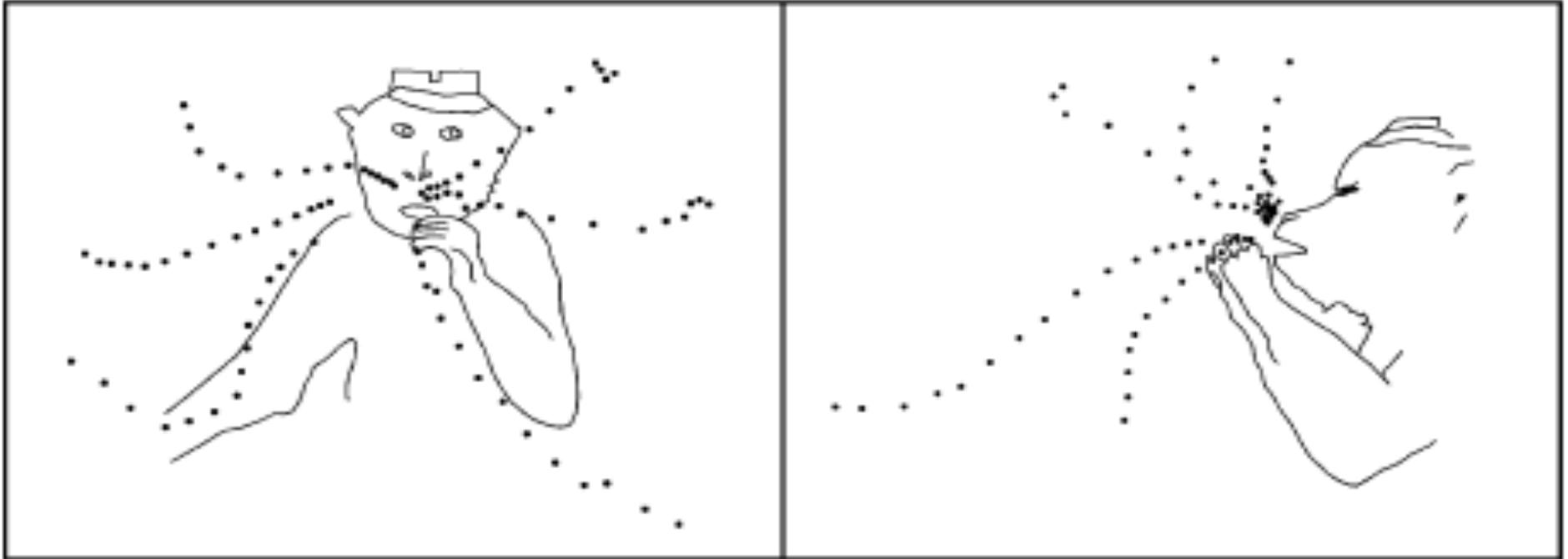
# Motor Cortex



# Motor Homunculus

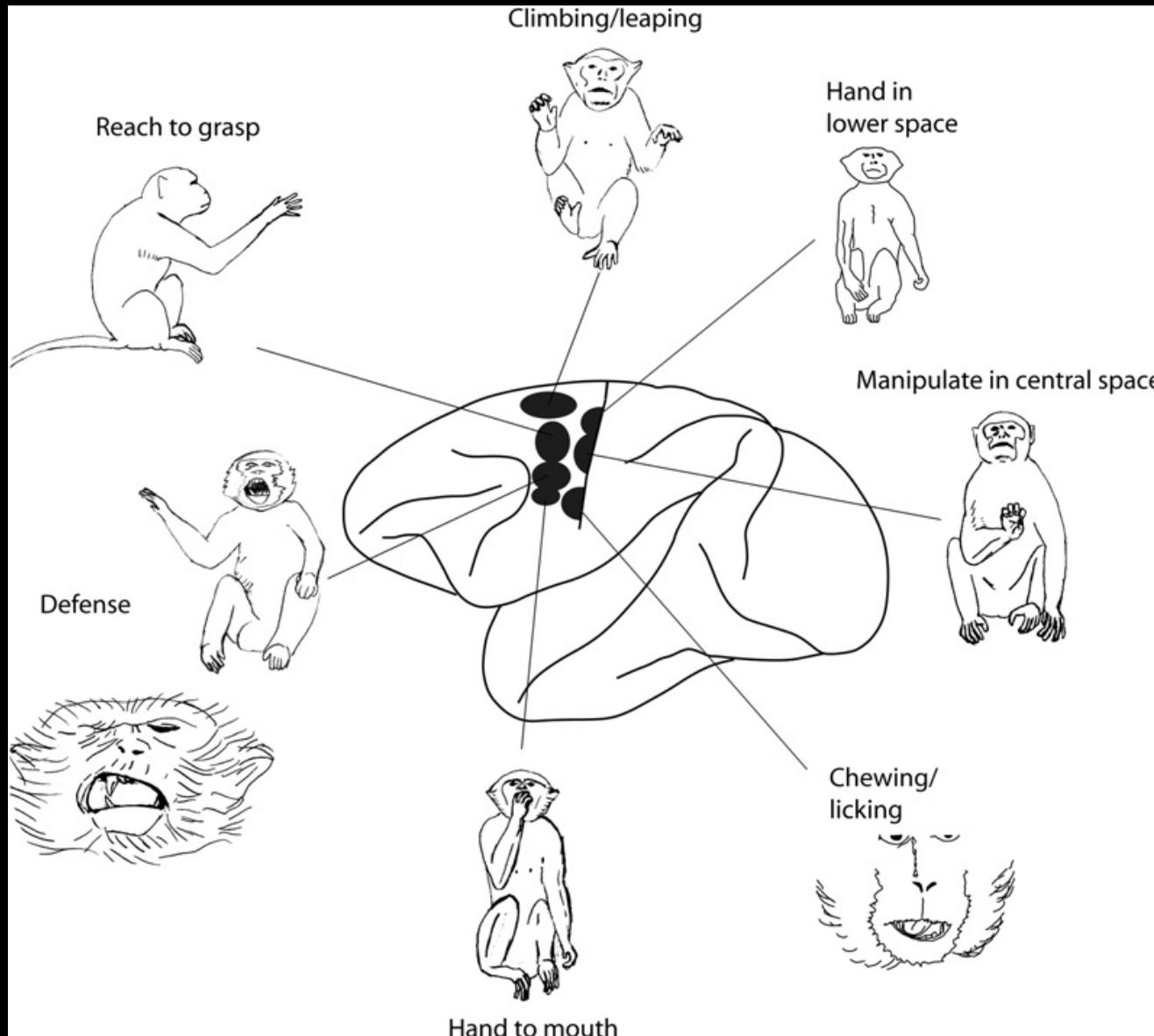


Long stimulation (e.g., 500 msec) of motor cortex elicits stereotyped postures



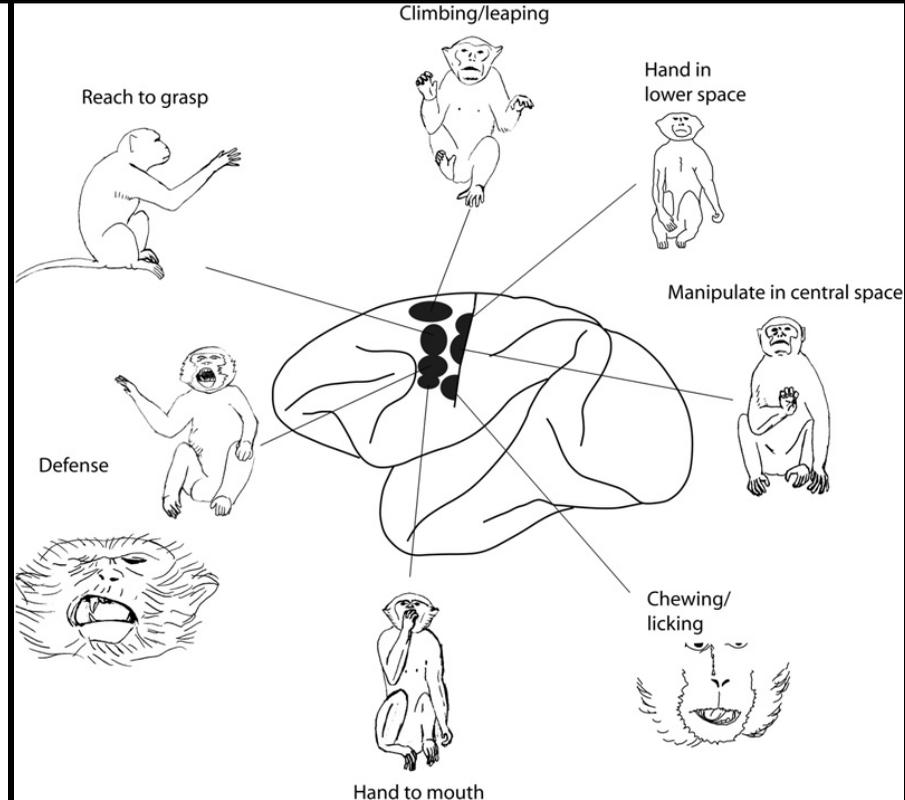
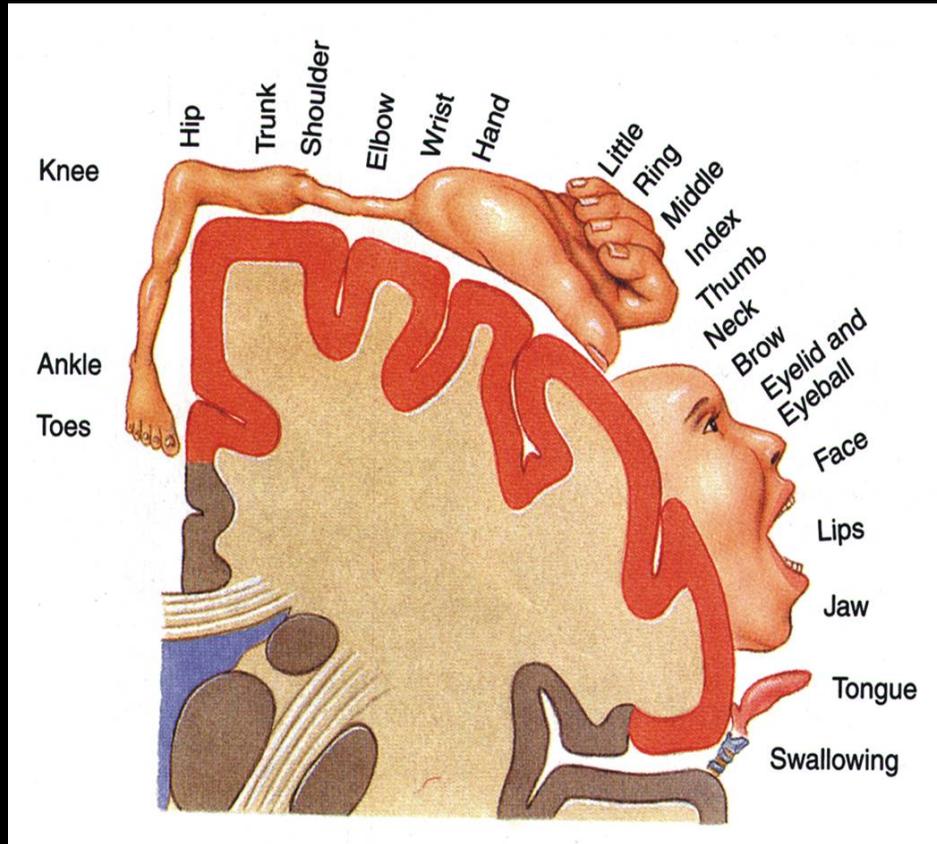
Graziano et al.,  
*Neuron*, 2002 34:841-51.

# Action Zones

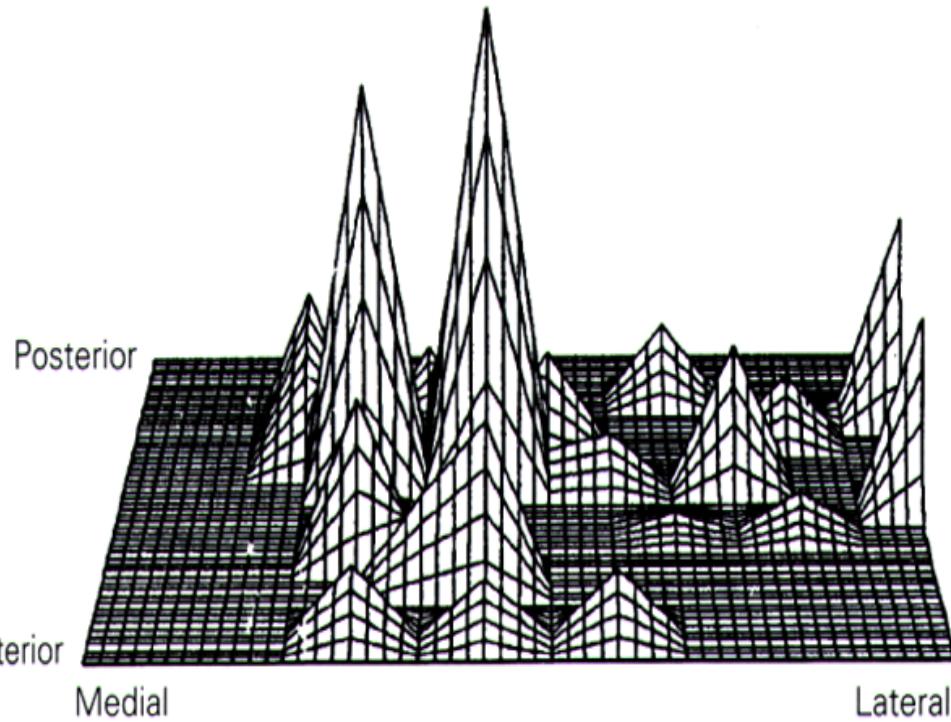


Aflalo & Graziano,  
*Neuron*, 2007

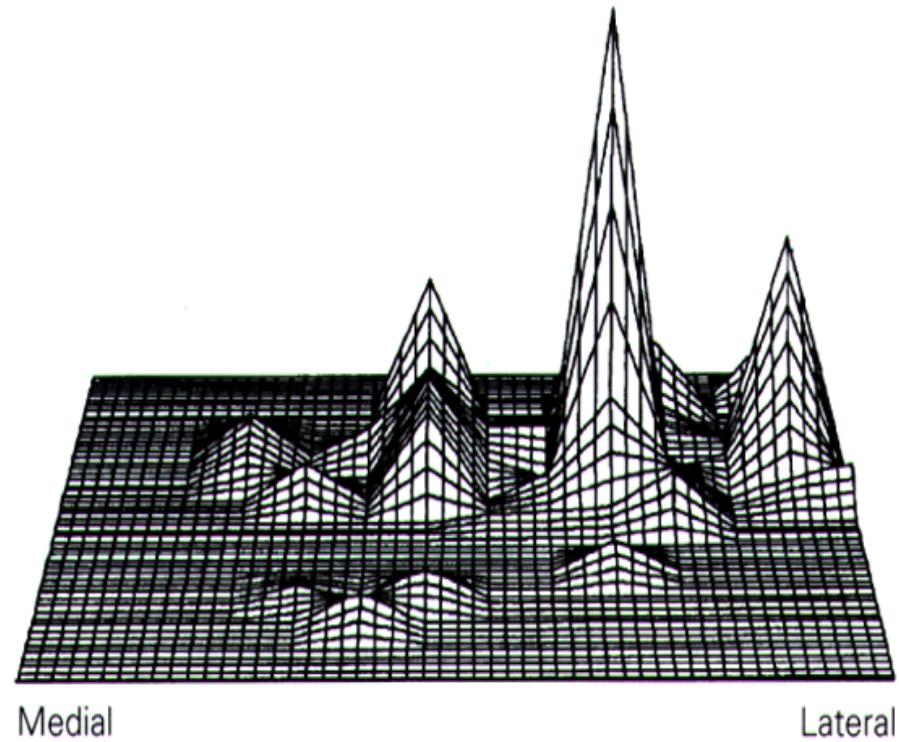
# Motor Homunculus vs. Action Zones



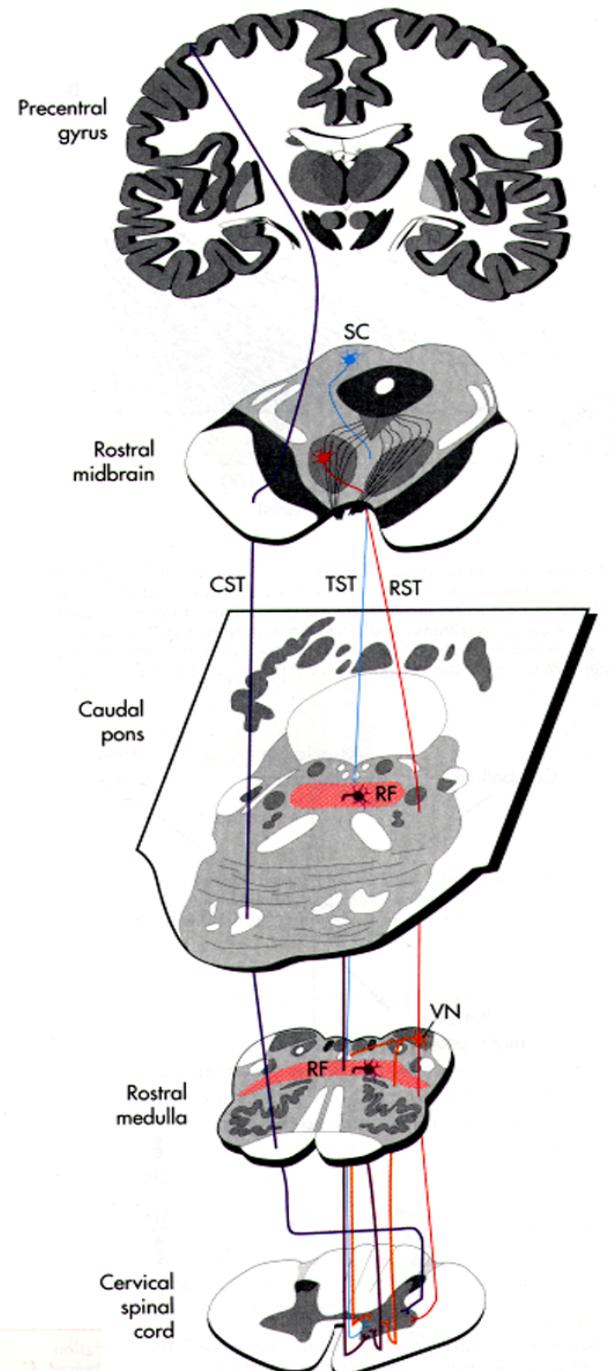
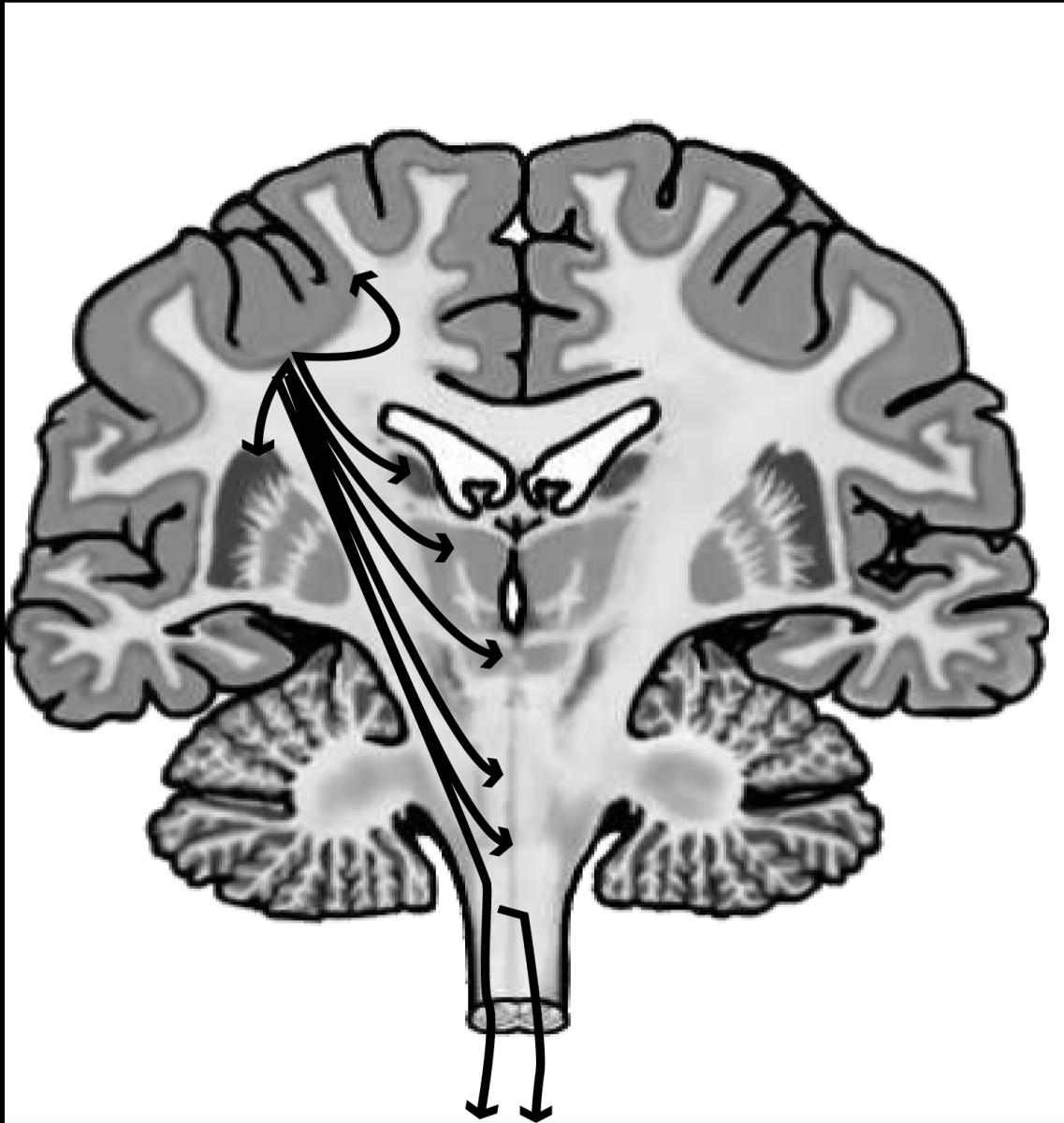
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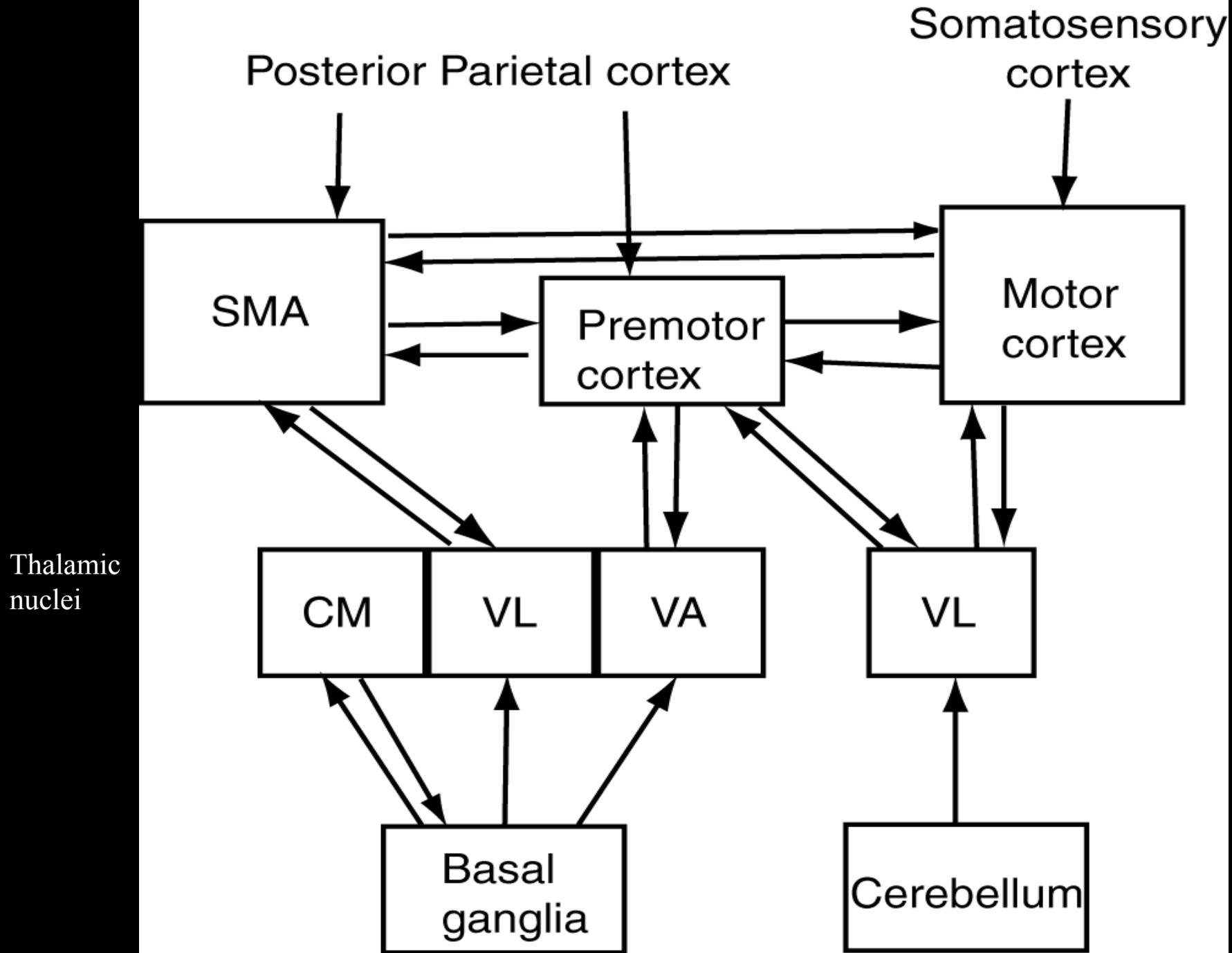


ECR



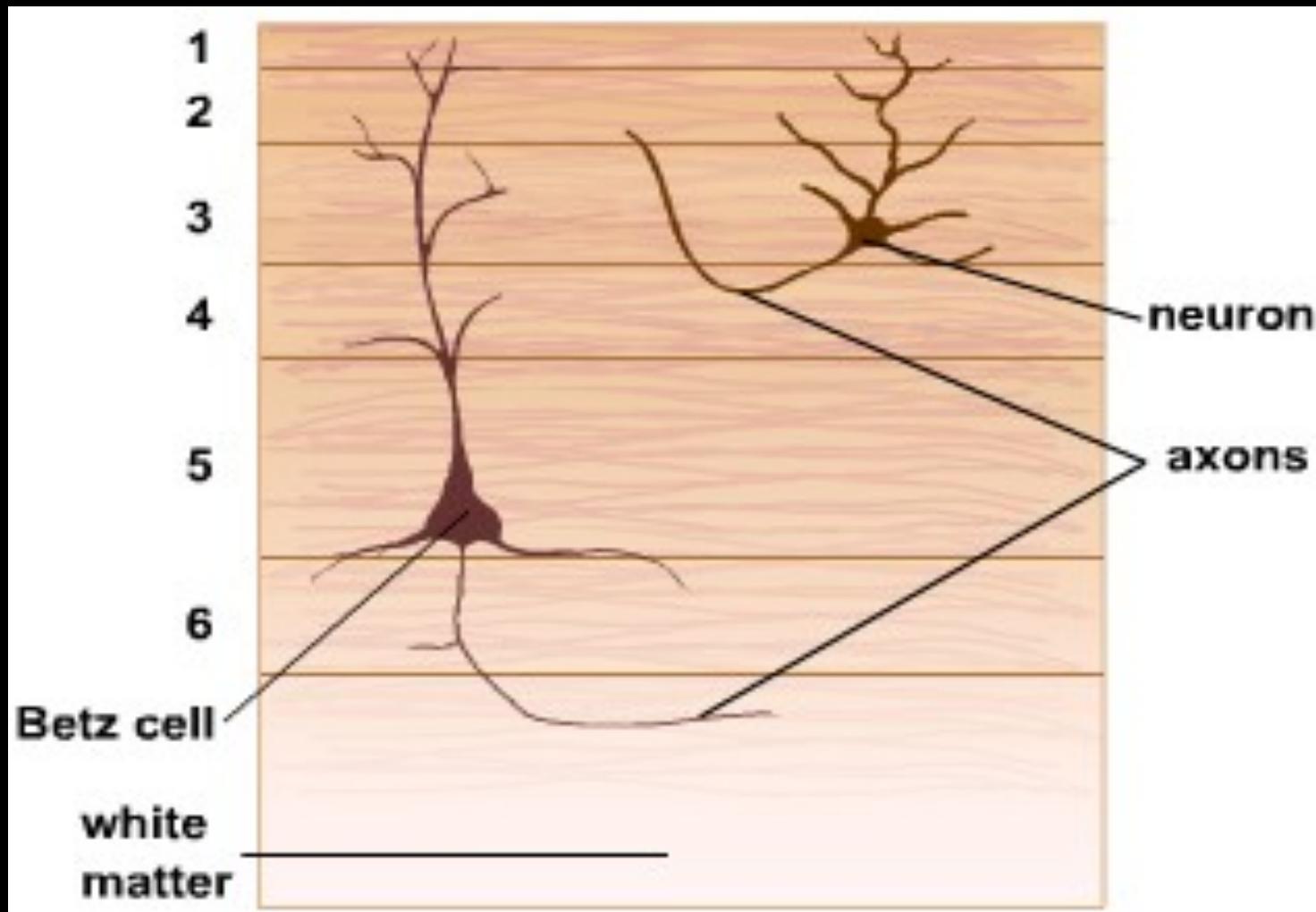
From J. Krakauer & C. Ghez (2000), in *Principles of Neural Science, 4<sup>th</sup> Edition* (Kandel, Schwartz, & Jessel, Eds.)



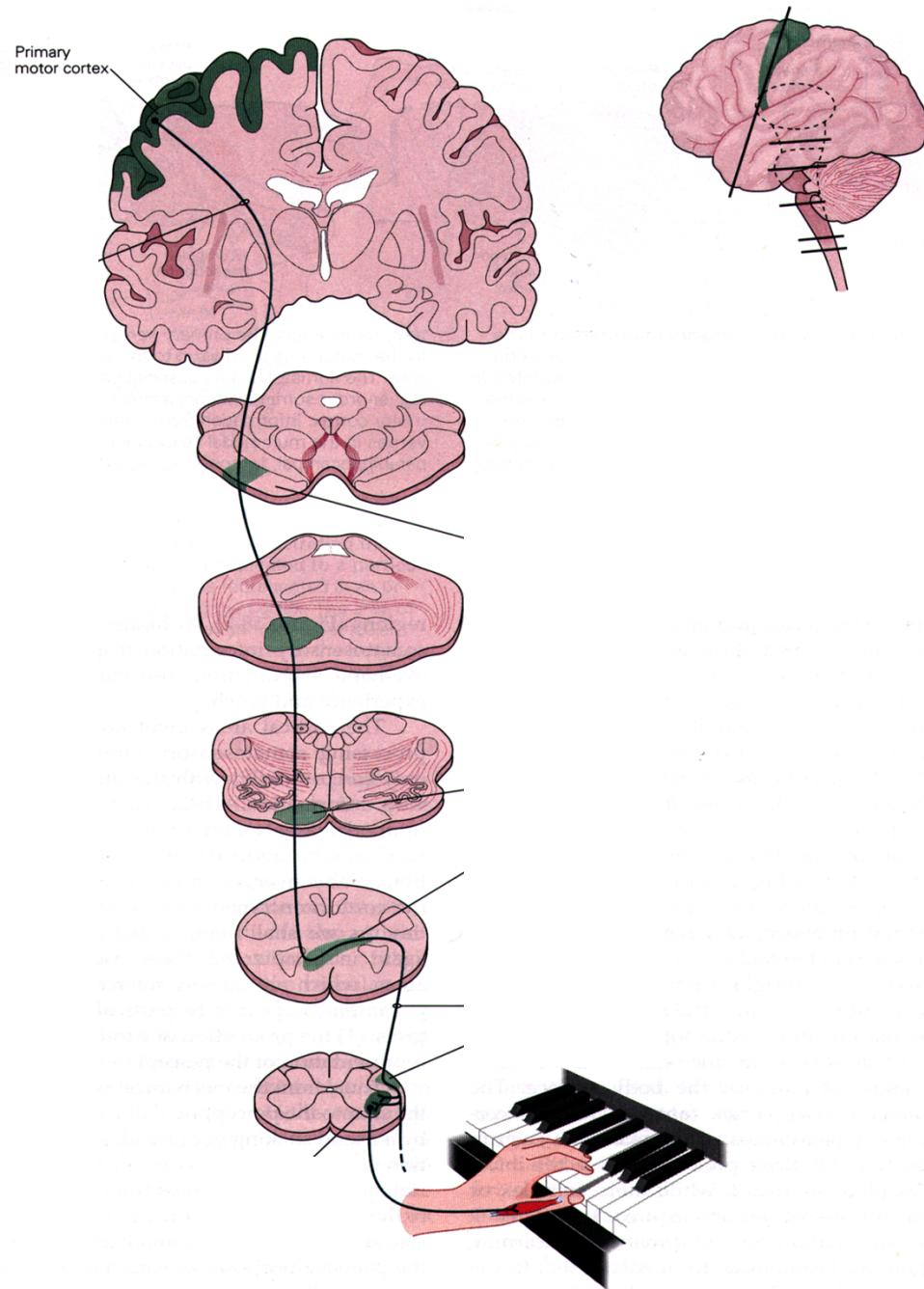


# Betz Cell in Layer V of Motor Cortex





# Primary motor cortex



From D. G. Amaral (2000), in *Principles of Neural Science, 4th Edition* (Kandel, Schwartz, & Jessel, Eds.)

# Origins of the Corticospinal Tract

Primary Motor Cortex (~30%)

Supplementary Motor Cortex

Premotor Cortex

} (~30%)

Primary Somatosensory Cortex

Secondary Somatosensory Cortex

} (~30%)

Posterior Parietal Cortex (~10%)

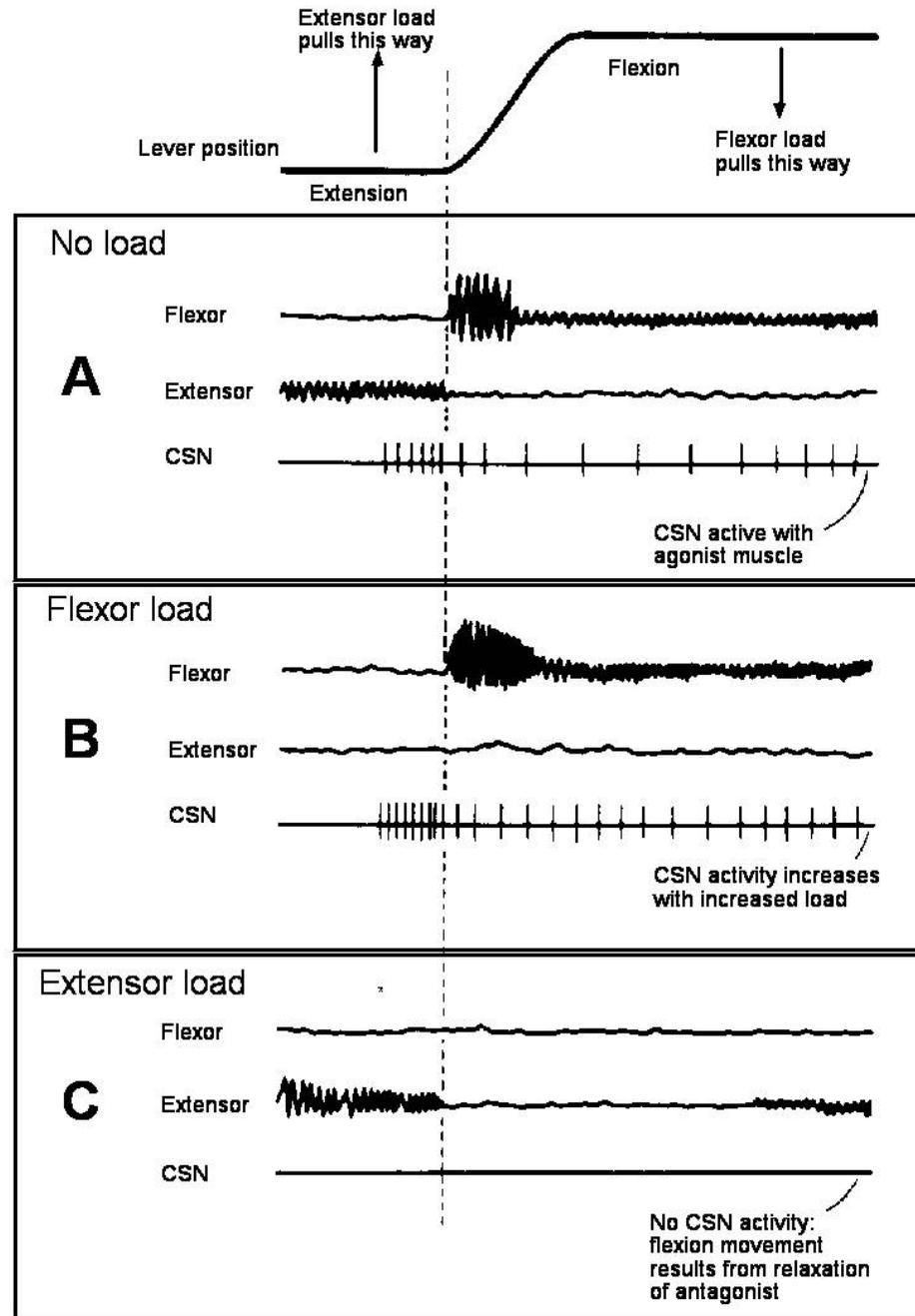
Other minor origins

# Primary Motor Cortex (M1)

Neurons fire *before* the contraction of muscle

Neurons encode *force* of contraction

# Primary Motor Cortex neurons encode the force of movements



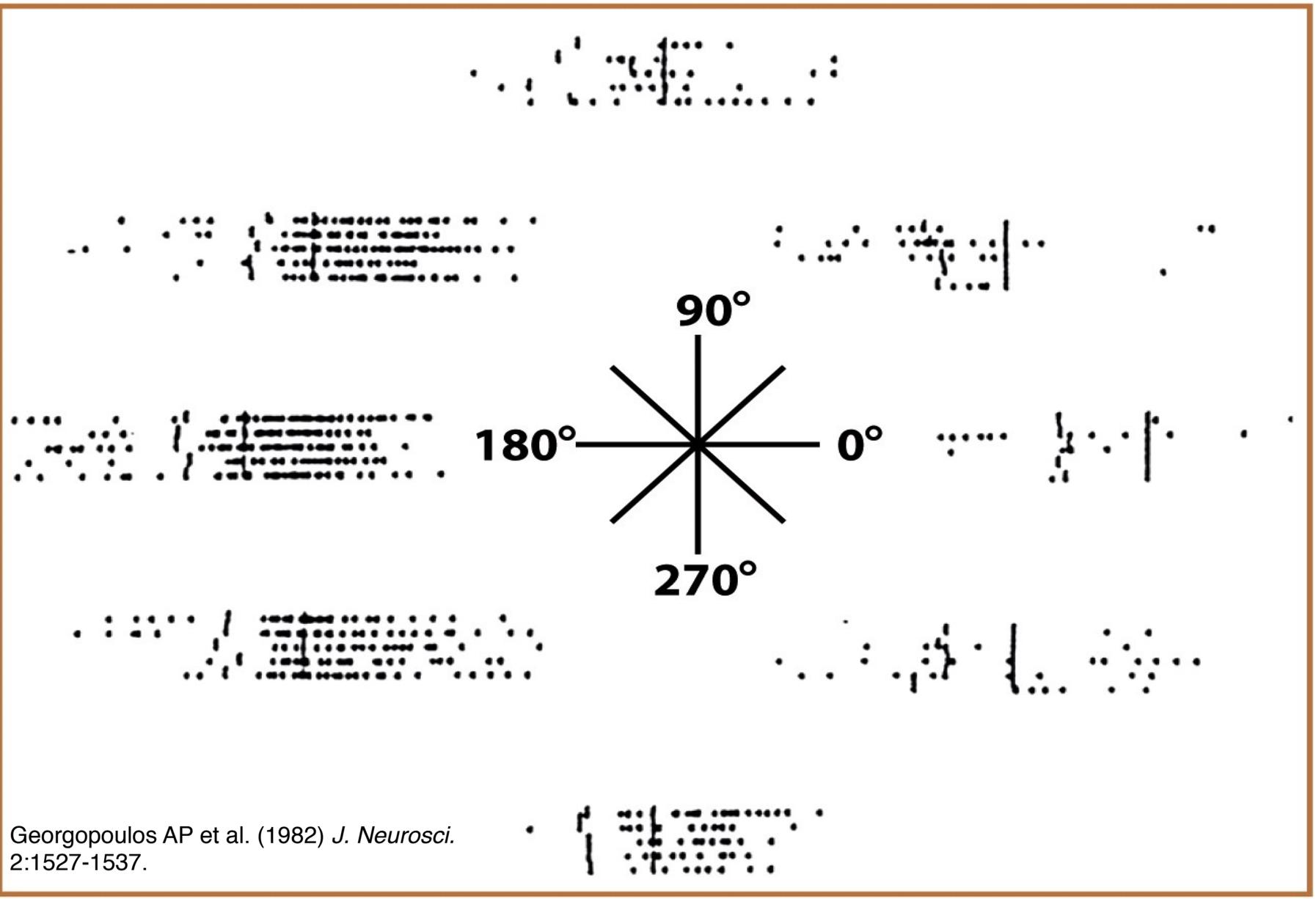
# Primary Motor Cortex (M1)

Neurons fire *before* the contraction of muscle

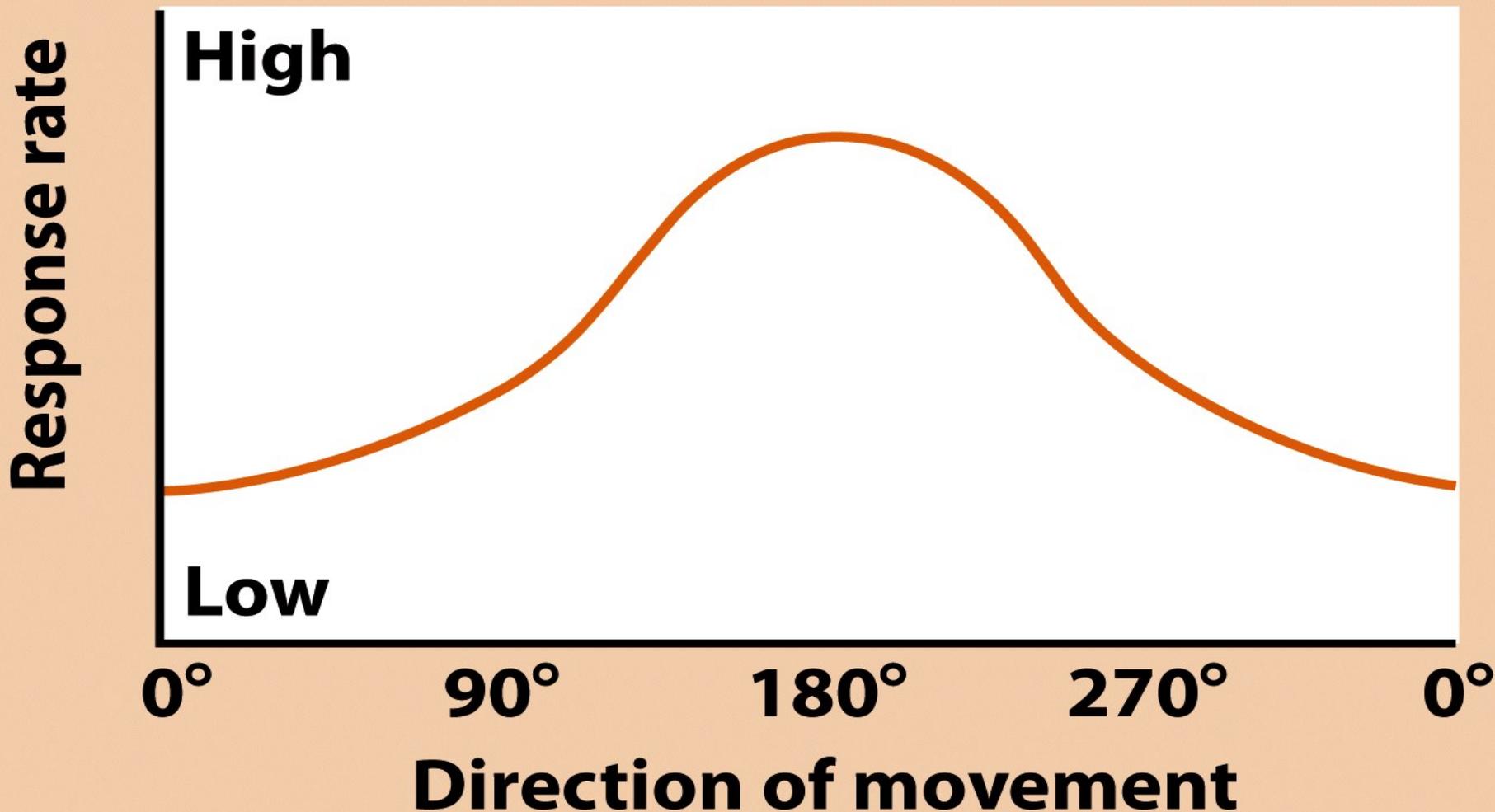
Neurons encode *force* of contraction

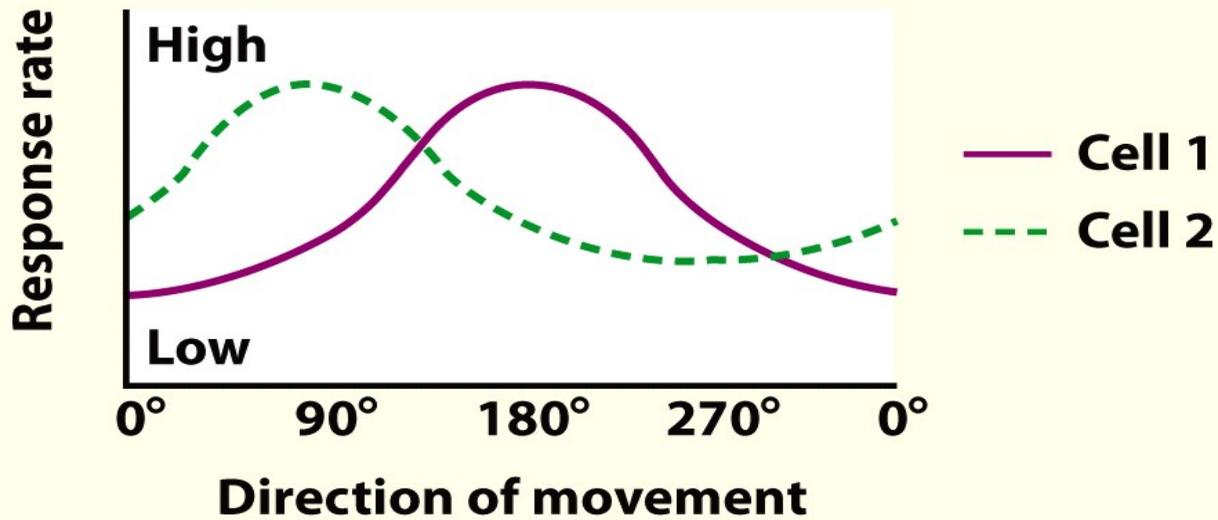
Neurons encode *direction* of movement

# Direction Tuning of Primary Motor Cortex Neurons



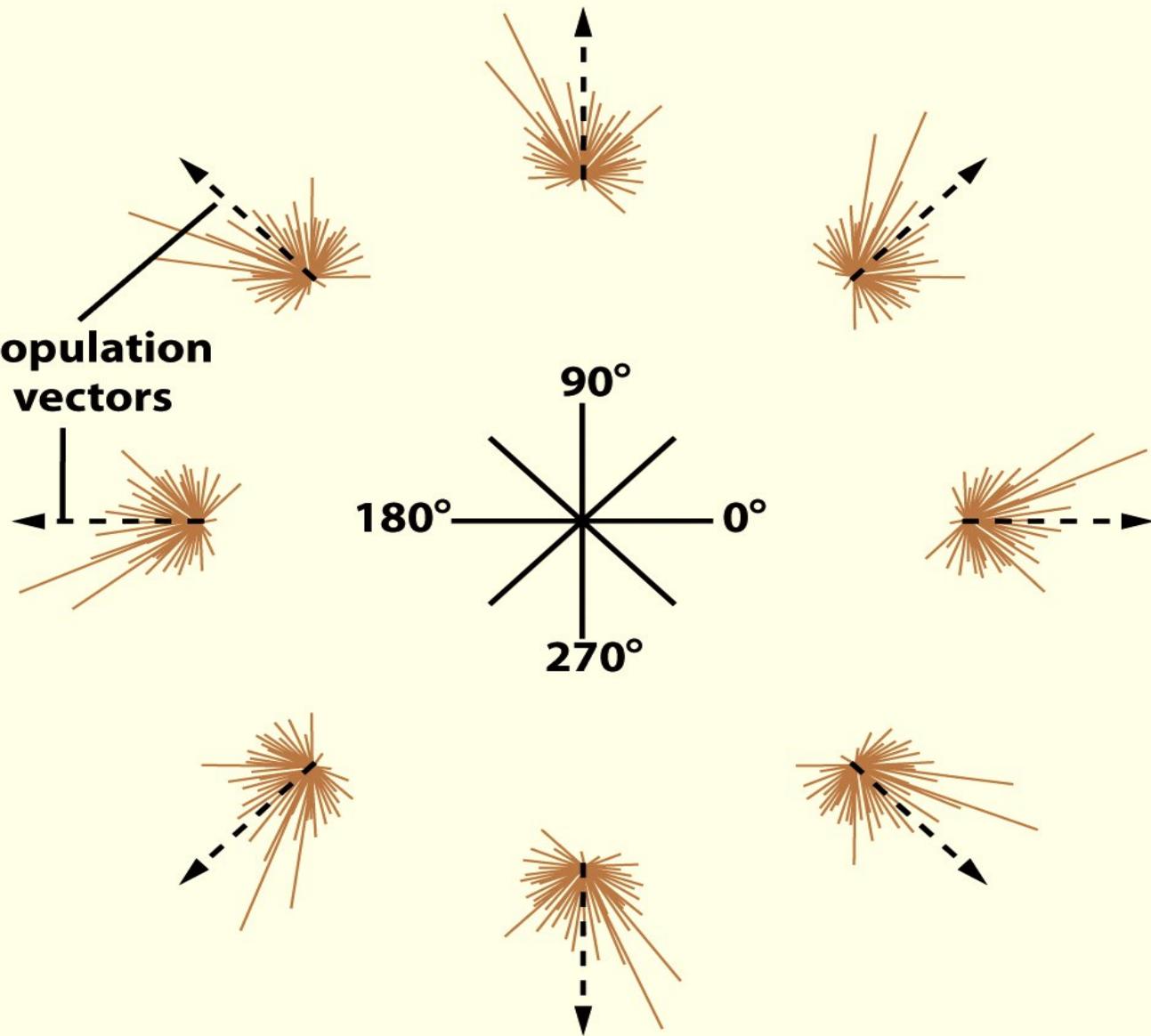
## Tuning curve



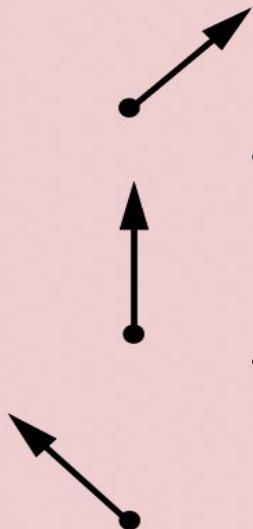


Movement direction	Direction vector for cell 1	+	Direction vector for cell 2	=	Population vector for cells 1 and 2
Left (180°)		+		=	
Up (90°)		+		=	

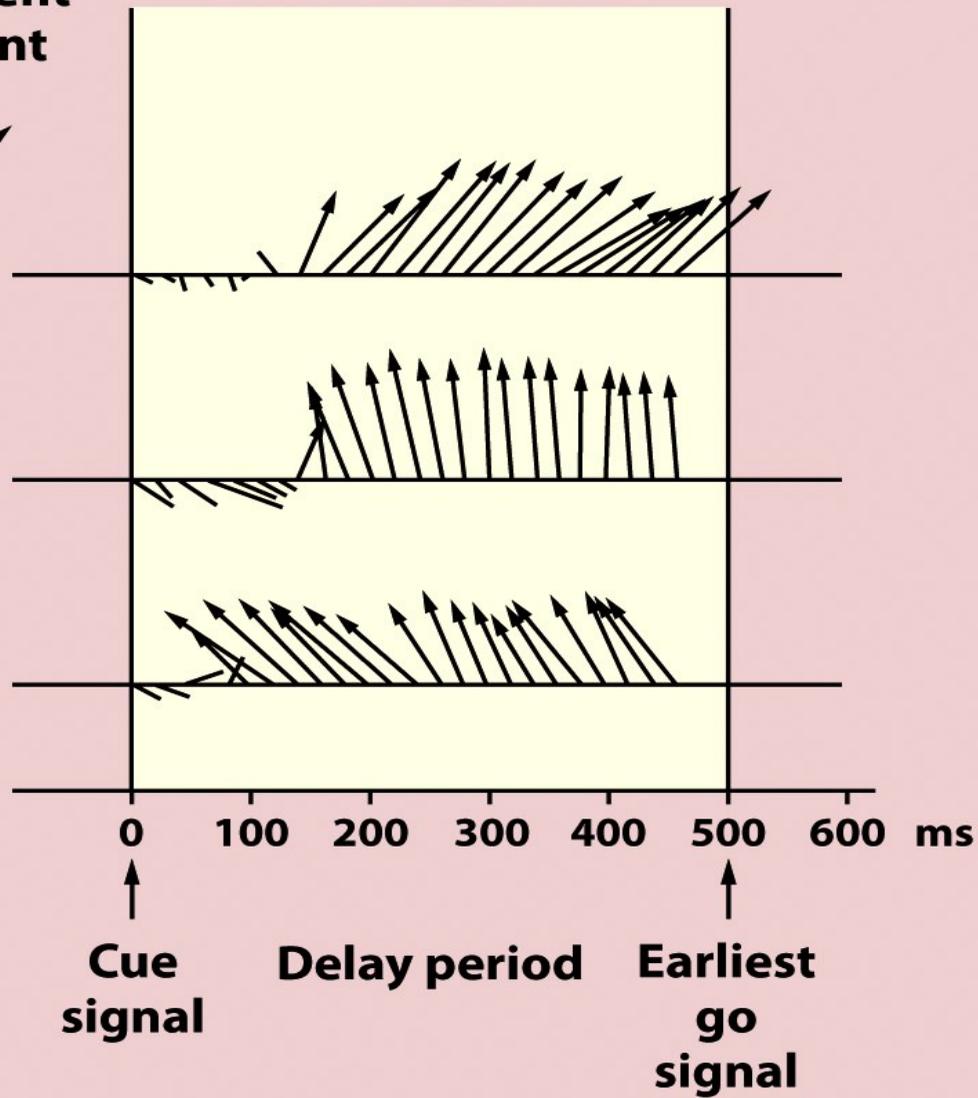
**Population  
vectors**



**Direction of  
subsequent  
movement**



**Population vector**



# Primary Motor Cortex (M1)

Neurons fire *before* the contraction of muscle

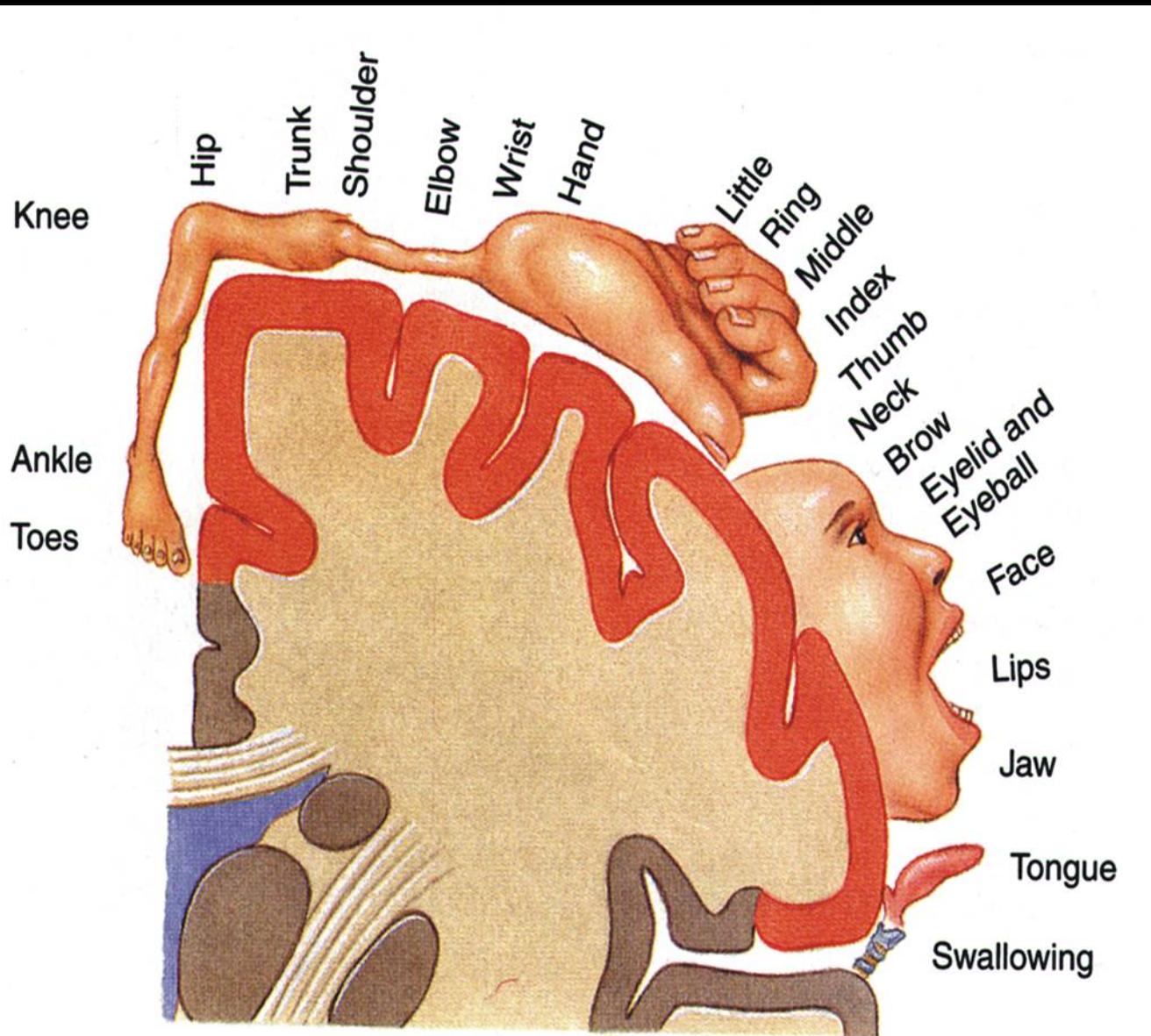
Neurons encode *force* of contraction

Neurons encode *direction* of movement

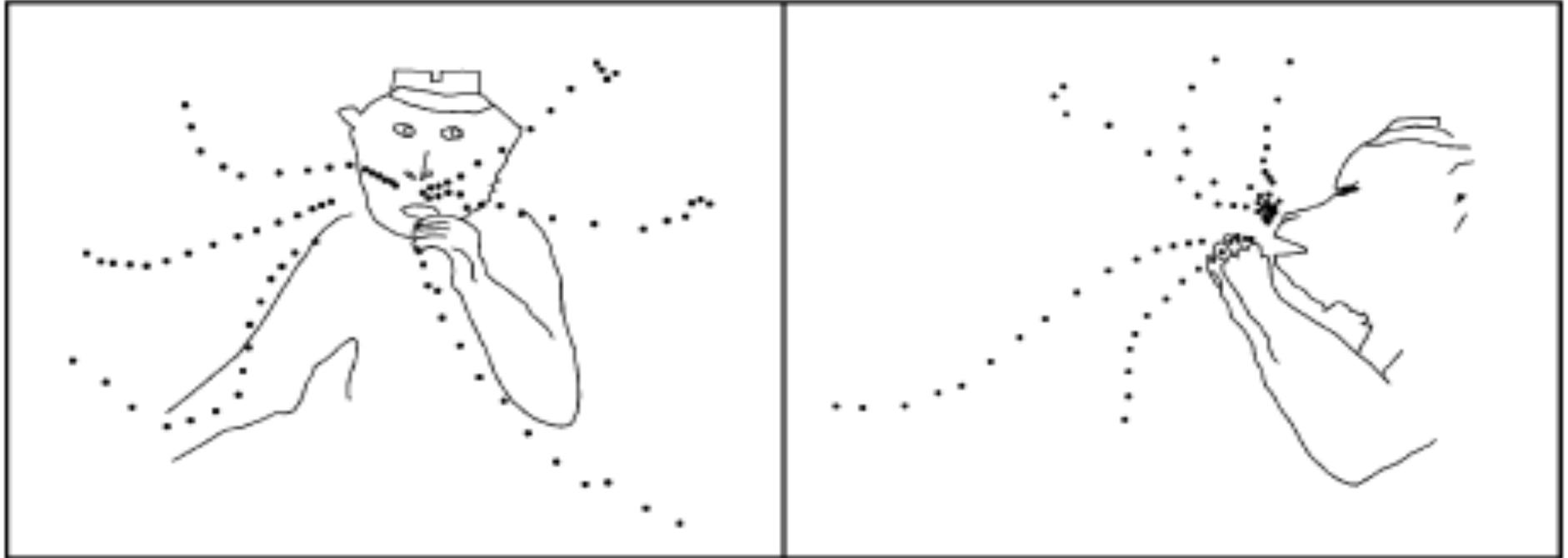
Neurons encode *extent* of movement

Neurons encode *speed* of movement

# Motor Homunculus

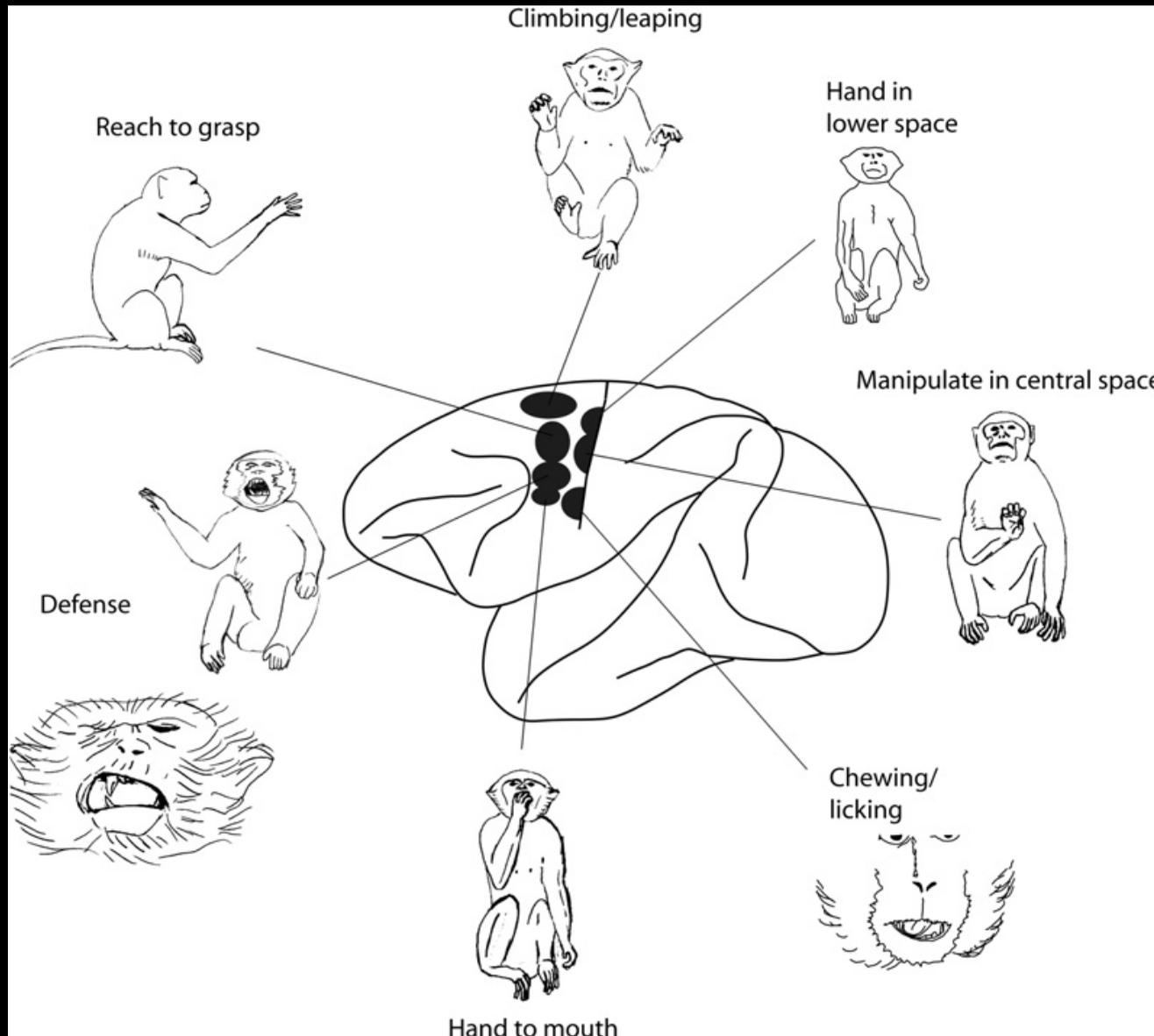


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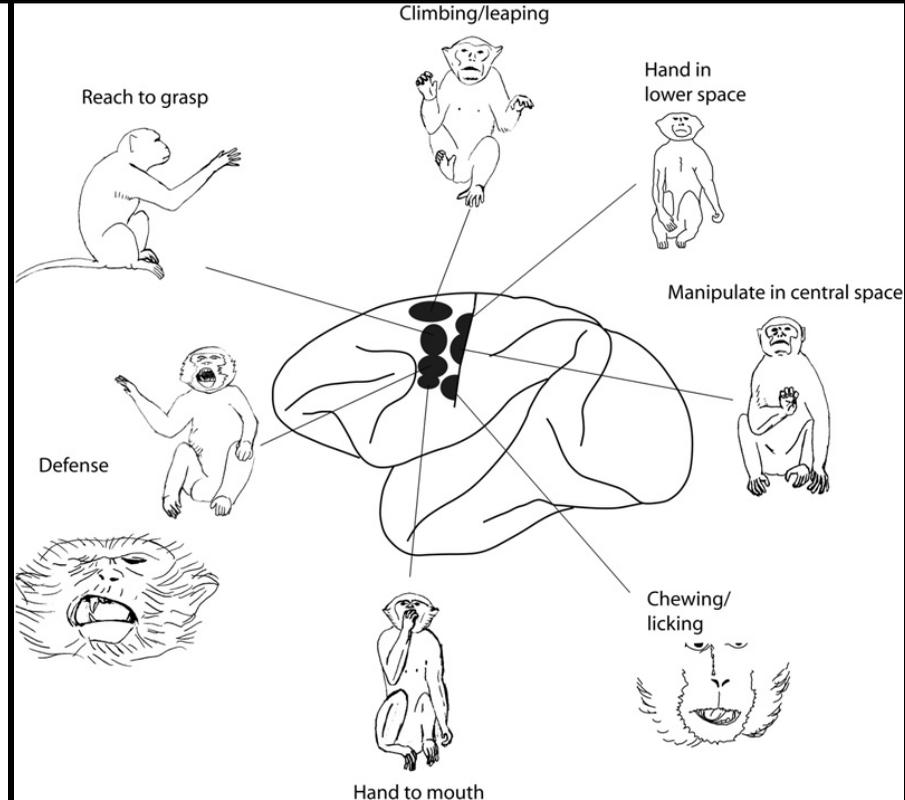
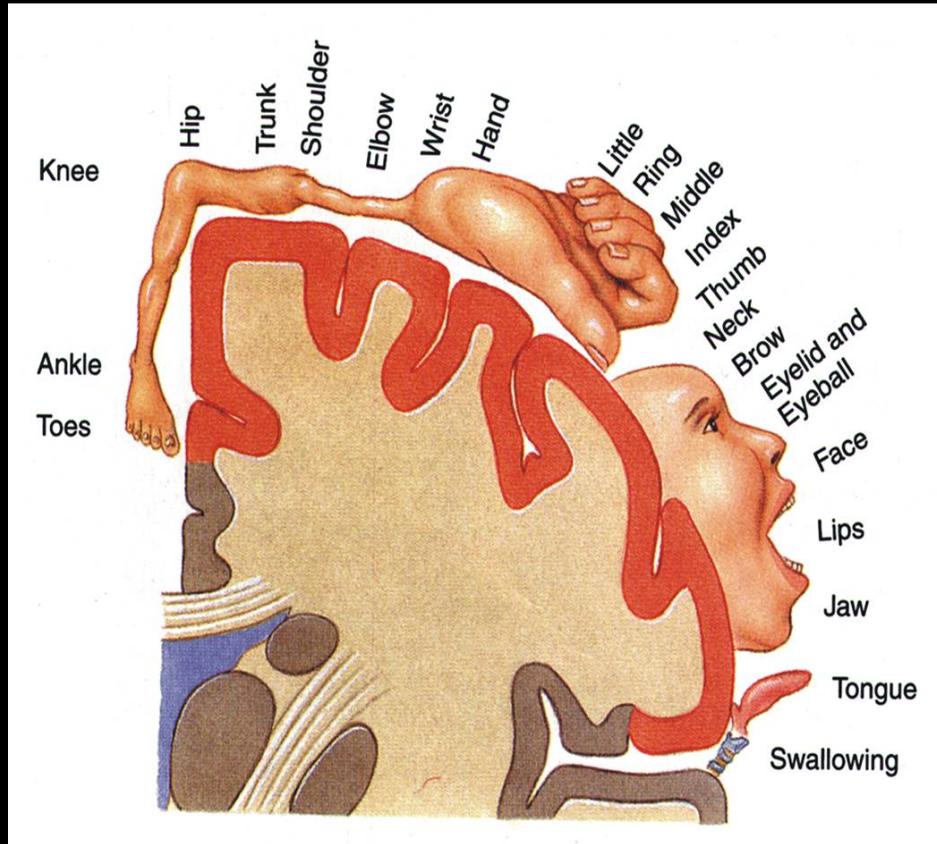
Graziano et al.,  
*Neuron*, 2002 34:841-51.

# Action Zones

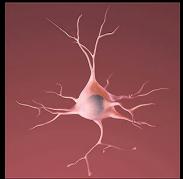
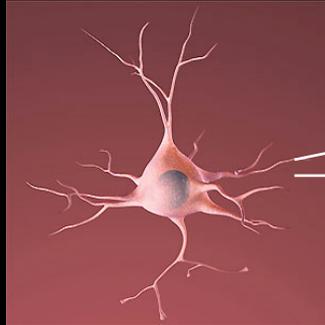


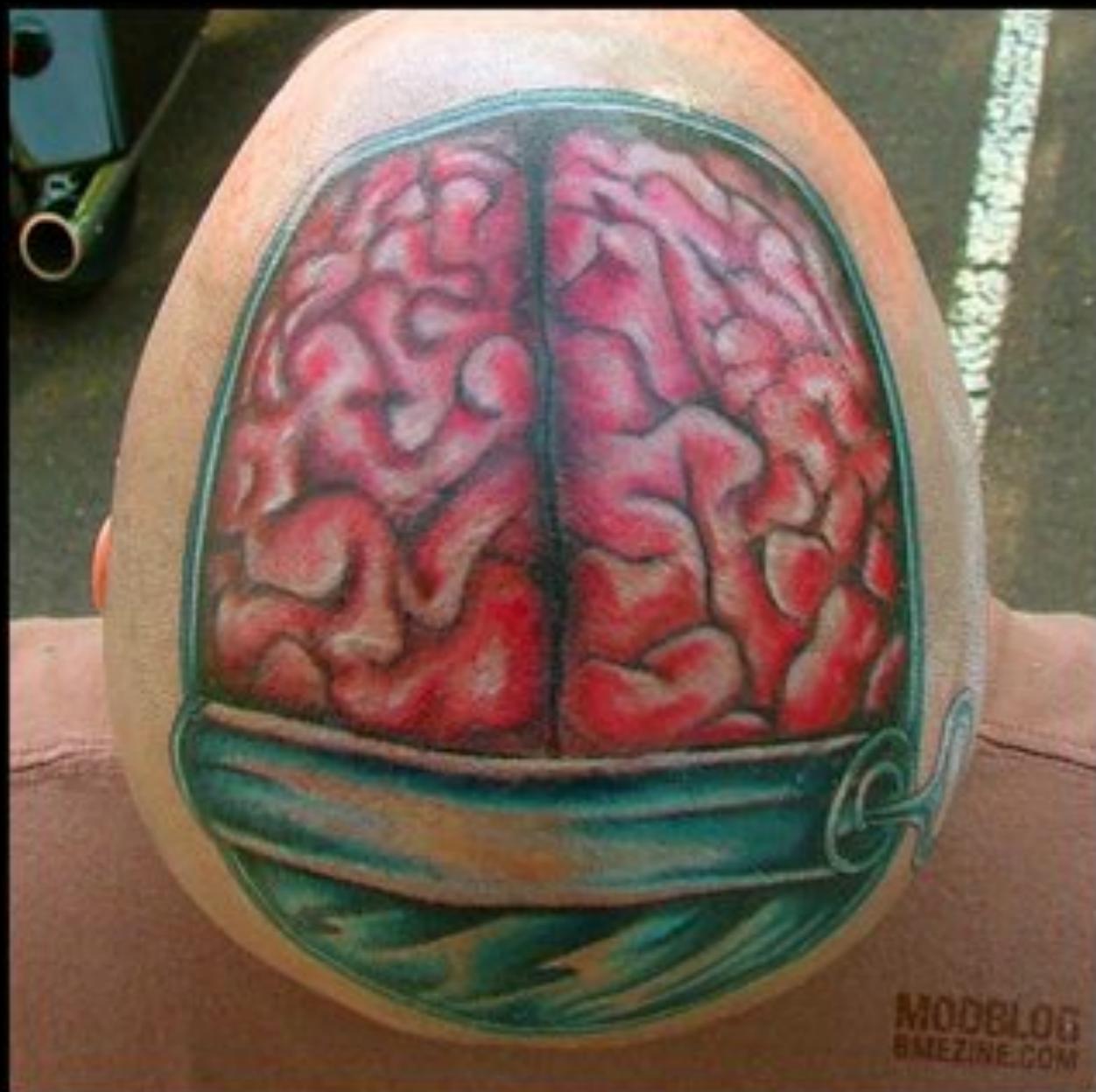
Aflalo & Graziano,  
*Neuron*, 2007

# Motor Homunculus vs. Action Zones



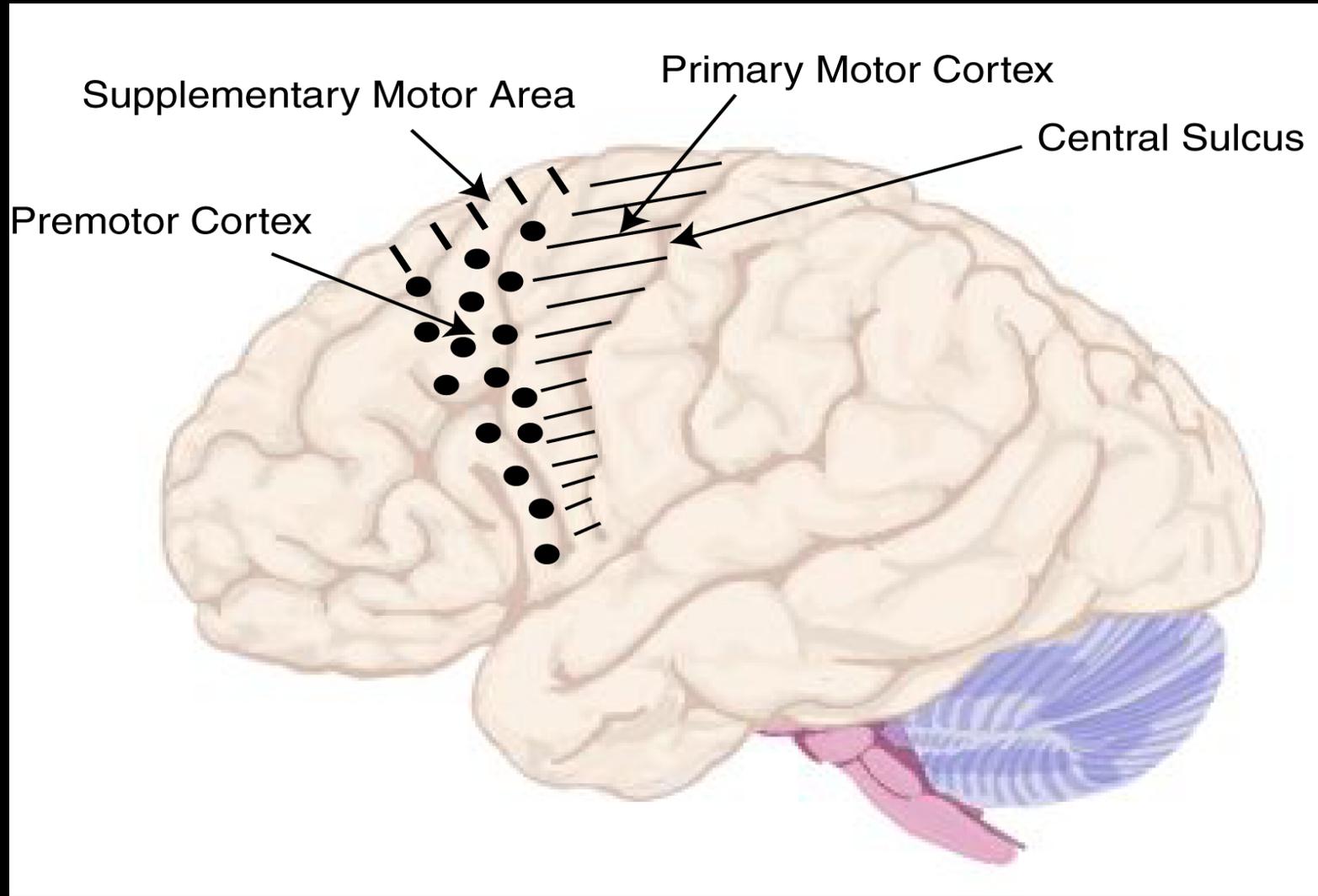
# Divergence and Convergence

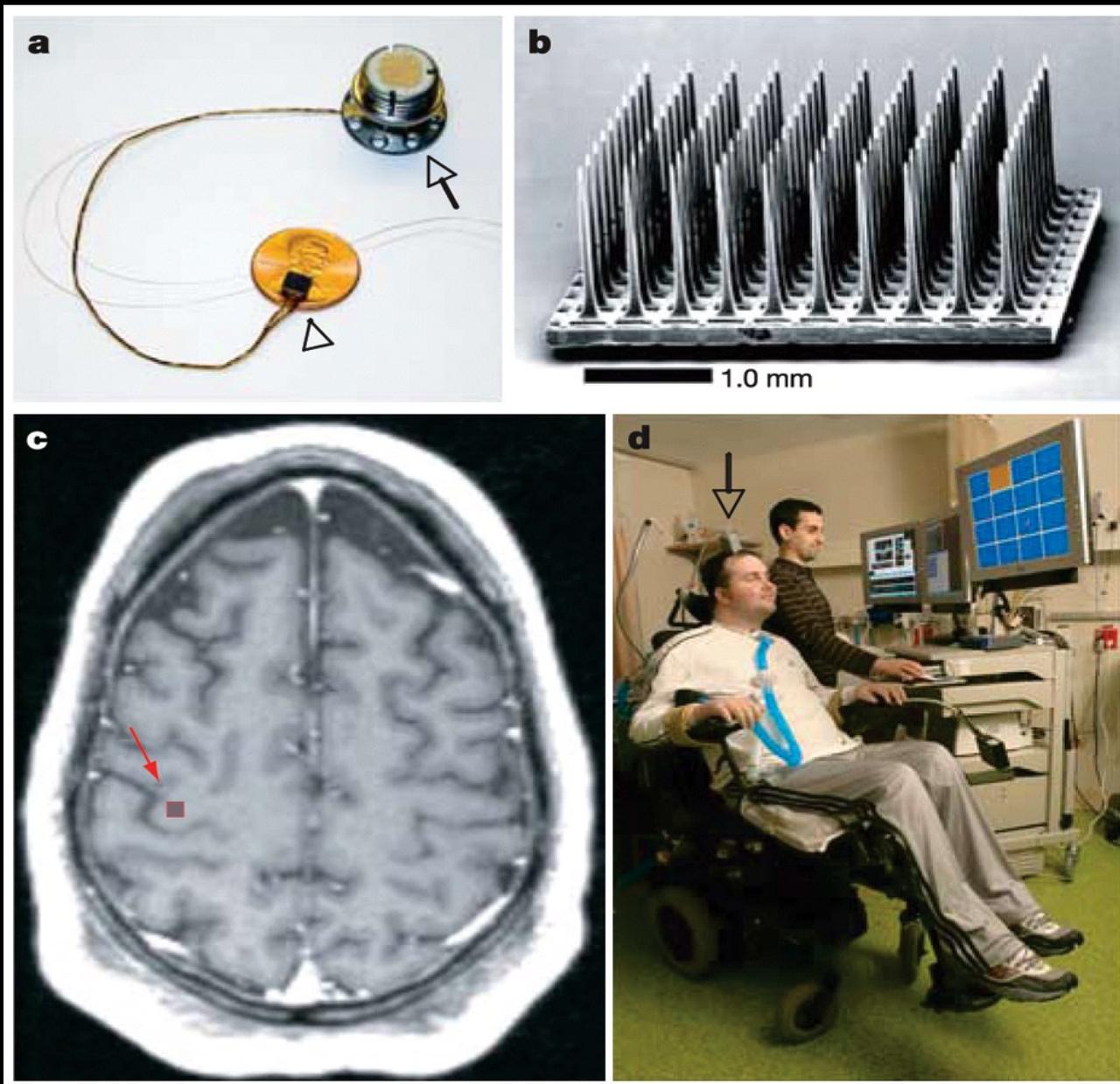




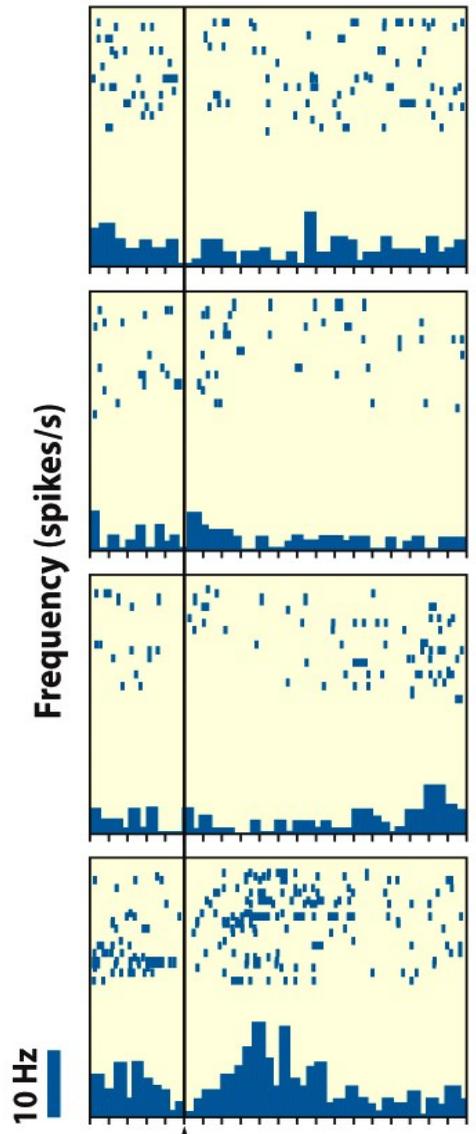
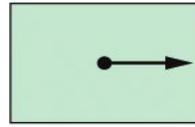
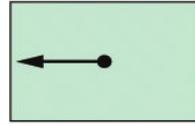
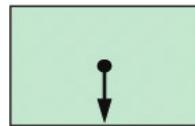
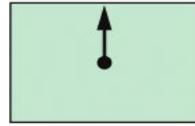
MOBBLOG  
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# Motor Cortex





**Target Direction:**



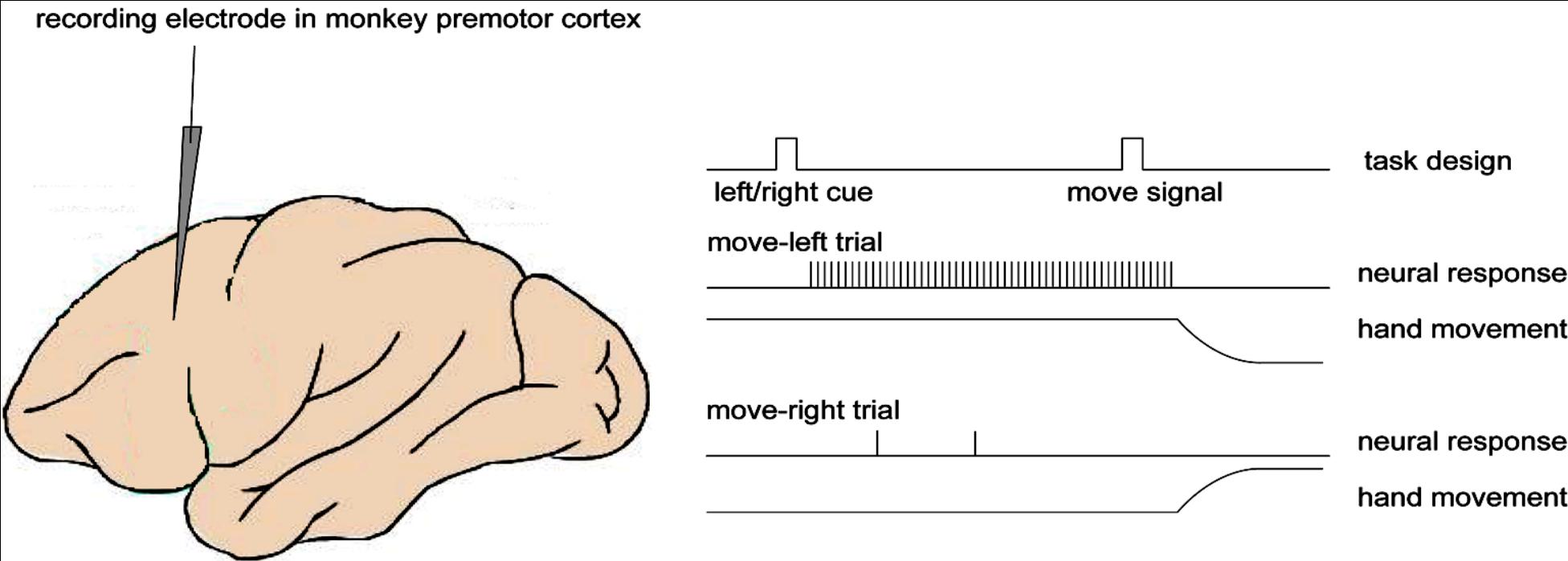
**Onset of cue for M.N. to imagine movement**



# Premotor Cortex

Preparation for movement (“Motor set”)

# Premotor cortex is involved in preparation for movement

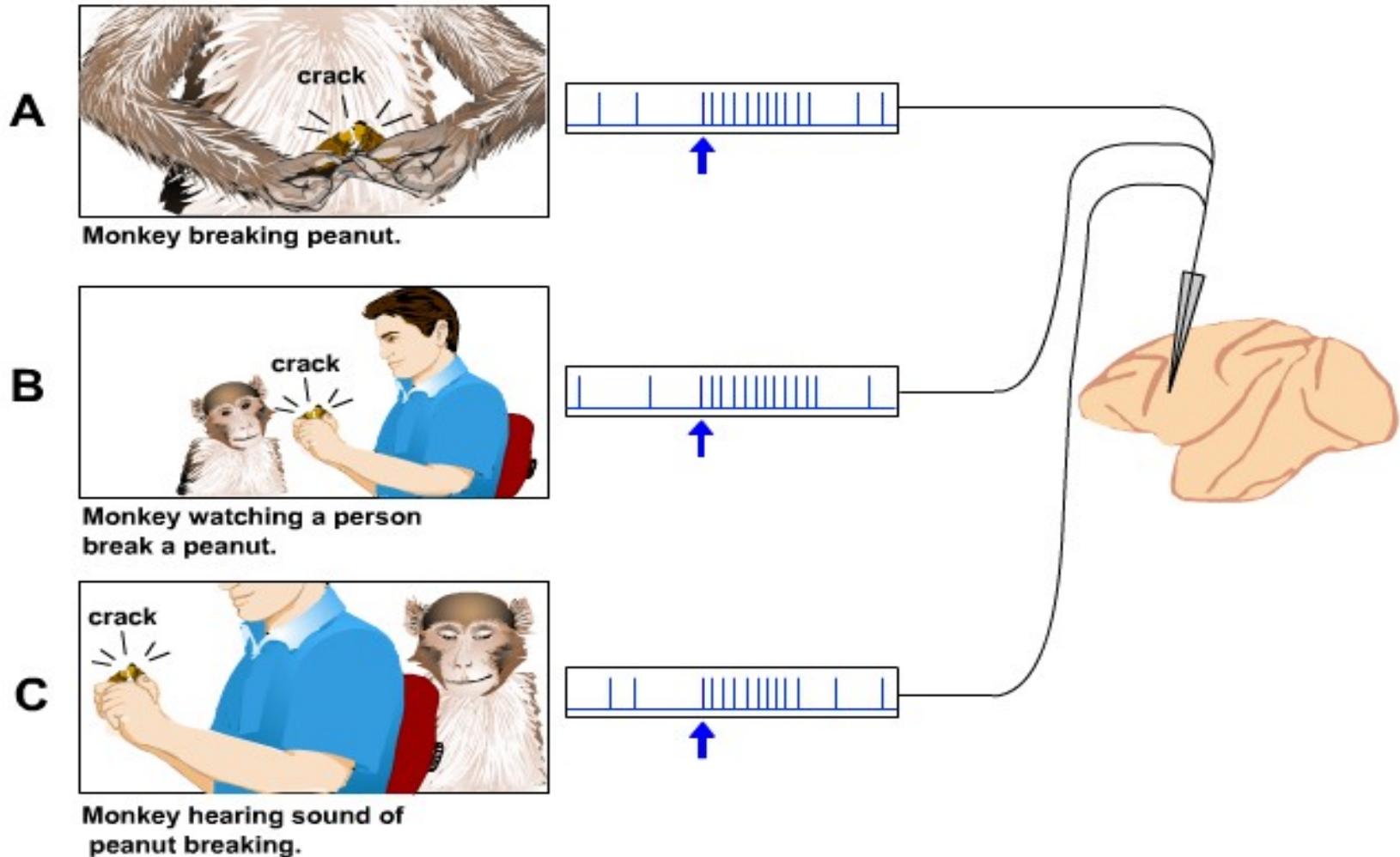


# Premotor Cortex

**Preparation for movement (“Motor set”)**

**Sensory aspects associated with motor acts**

# Premotor Cortex “Mirror” Neuron



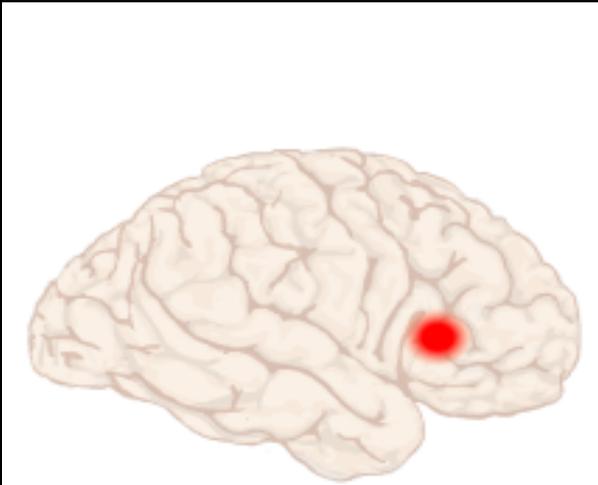
# Premotor Cortex

**Preparation for movement (“Motor set”)**

**Sensory aspects associated with motor acts**

**Behavioral context**

# Premotor cortex encodes behavioral context



# Premotor Cortex

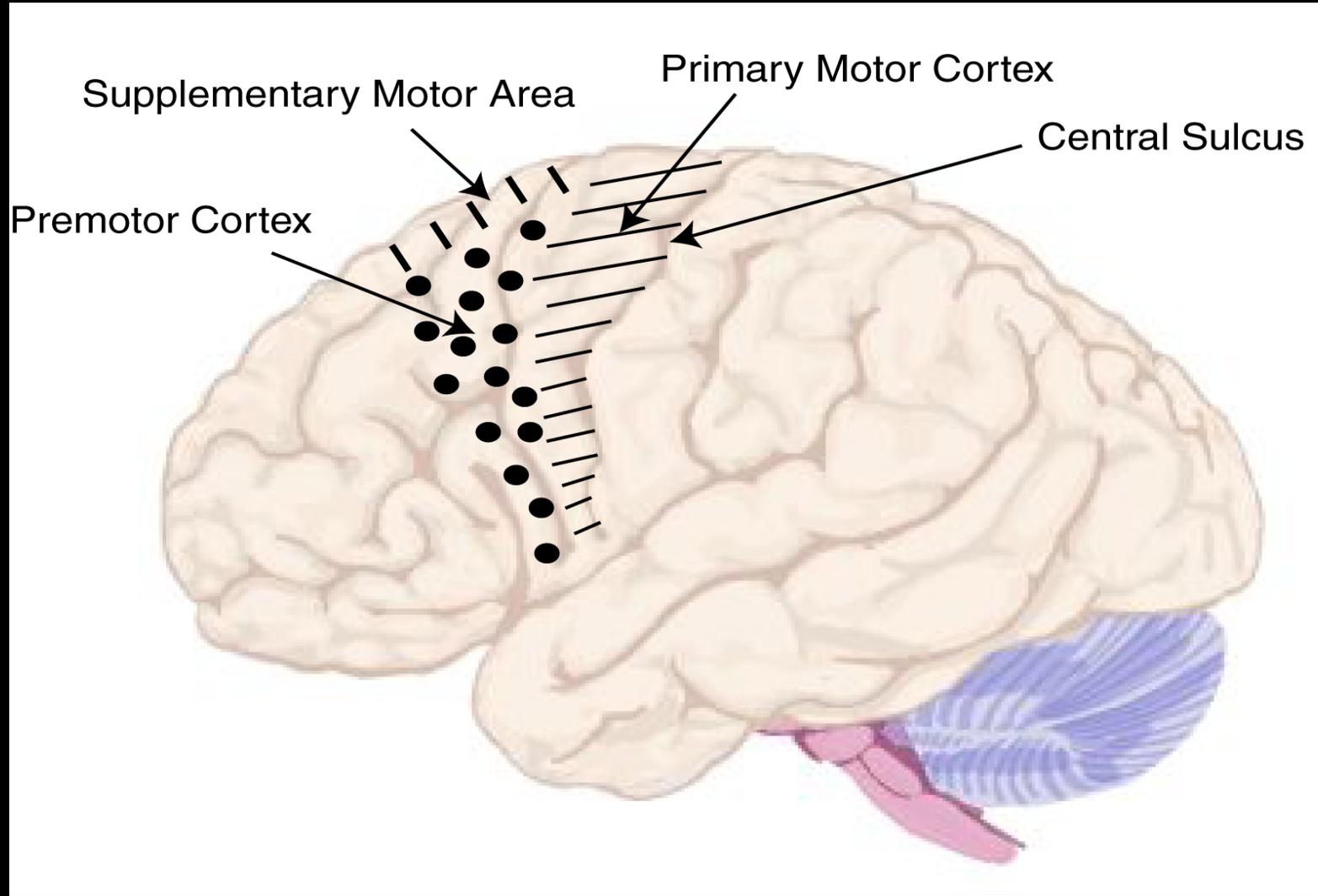
**Preparation for movement (“Motor set”)**

**Sensory aspects associated with motor acts**

**Behavioral context**

**Signals correct and incorrect actions**

# Motor Cortex



# **Supplementary Motor Area**

**Programming complex sequences of movements**

**Coordination of bilateral movements**

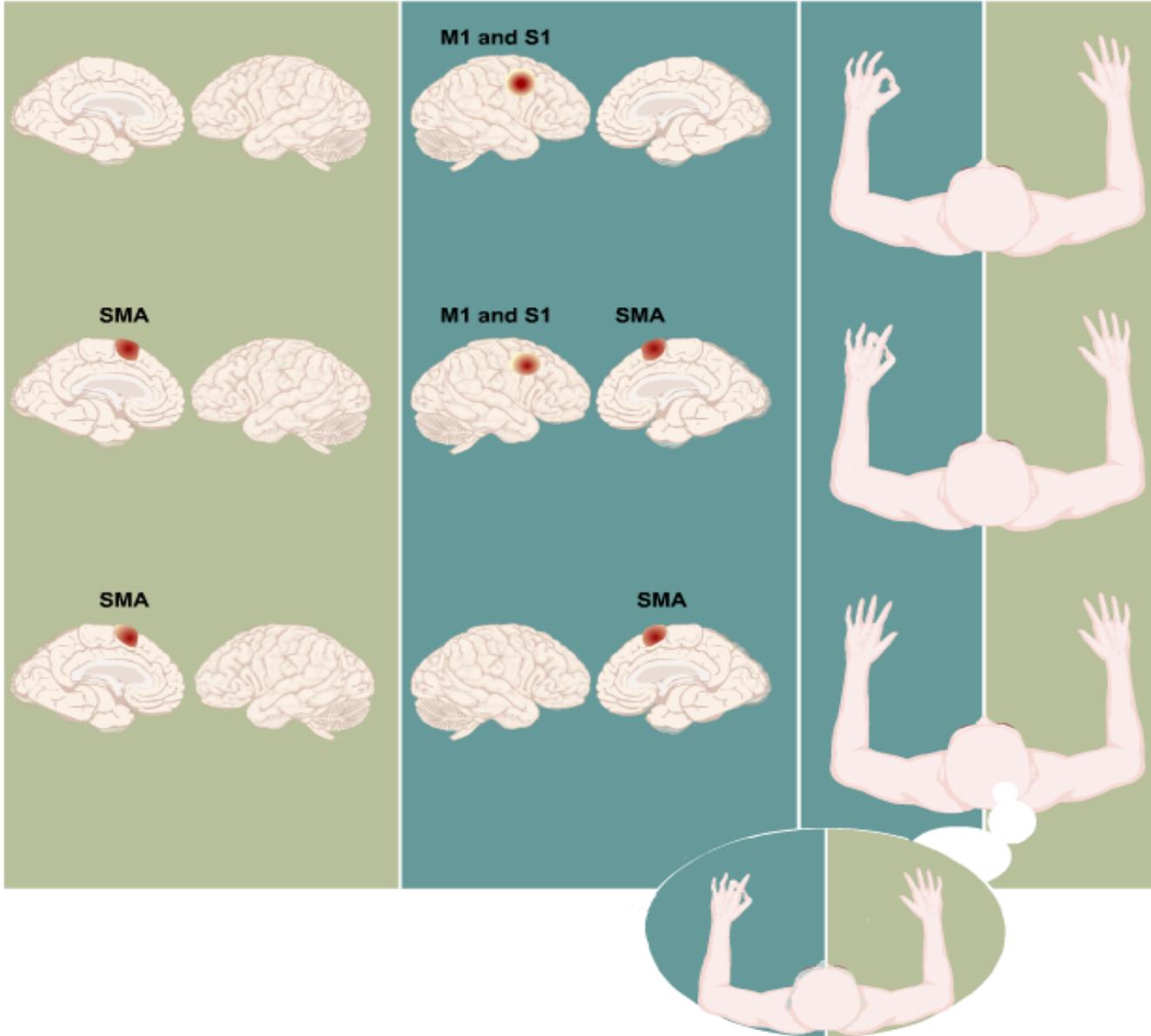
**Transformation of kinematic to dynamic information**

Left hemisphere

Right hemisphere

Left hand

Right hand



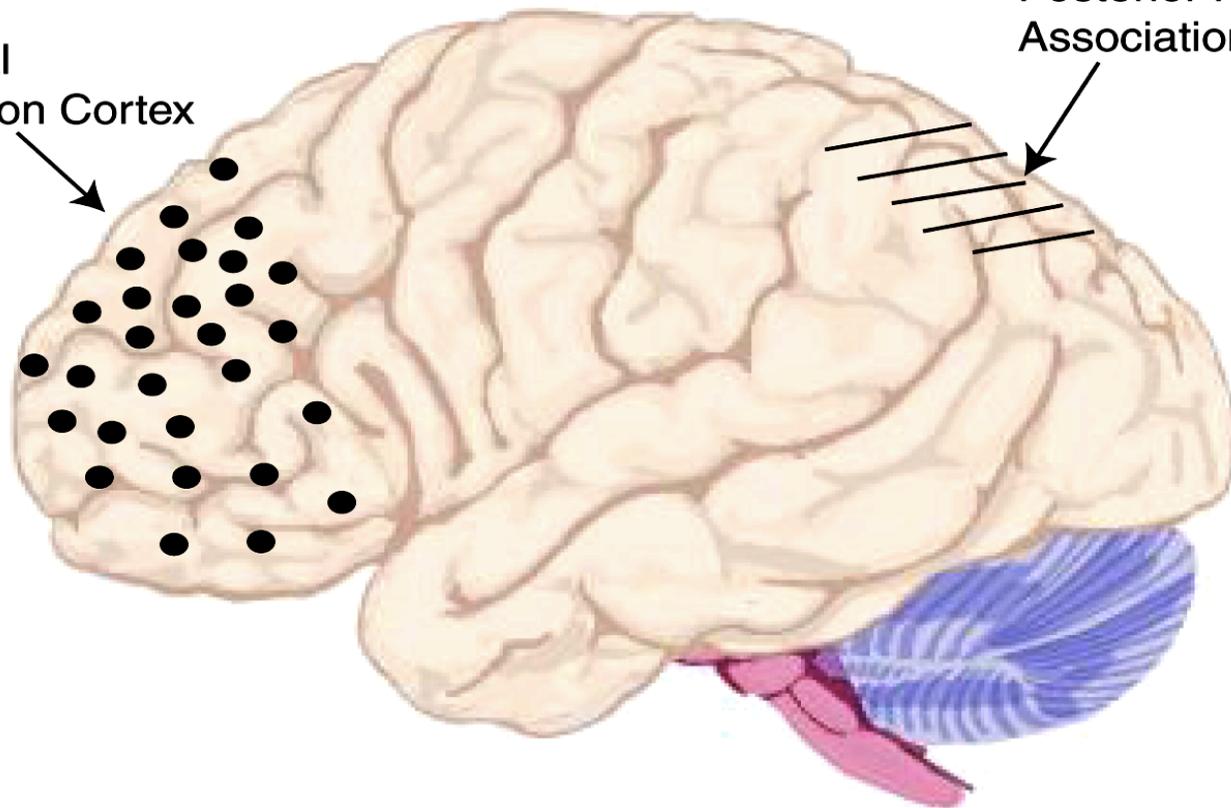
# **Supplementary Motor Area**

**Programming complex sequences of movements**

**Coordination of bilateral movements**

**Transformation of kinematic to dynamic information**

Prefrontal  
Association Cortex



Posterior Parietal  
Association Cortex

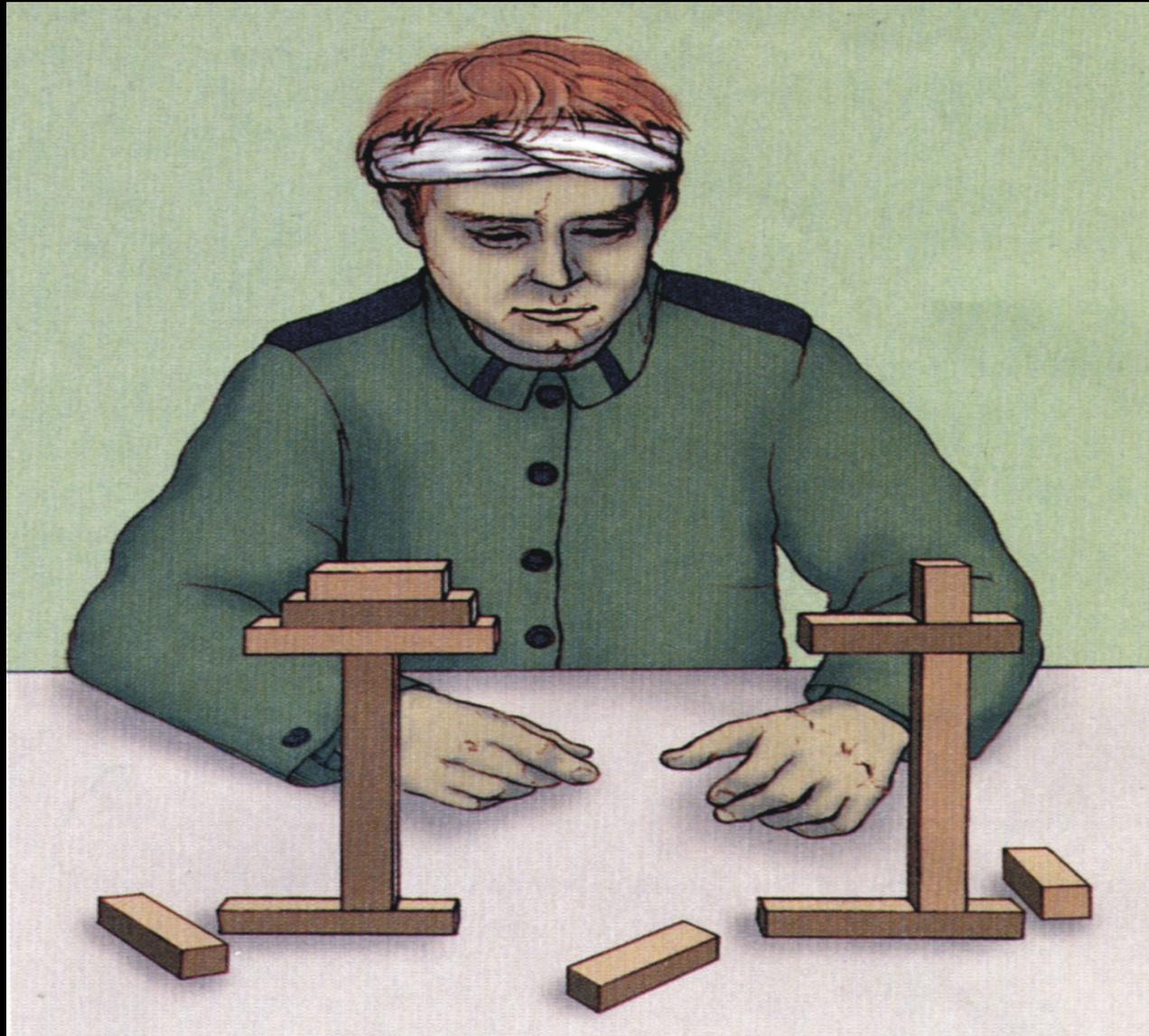
# Association Cortex

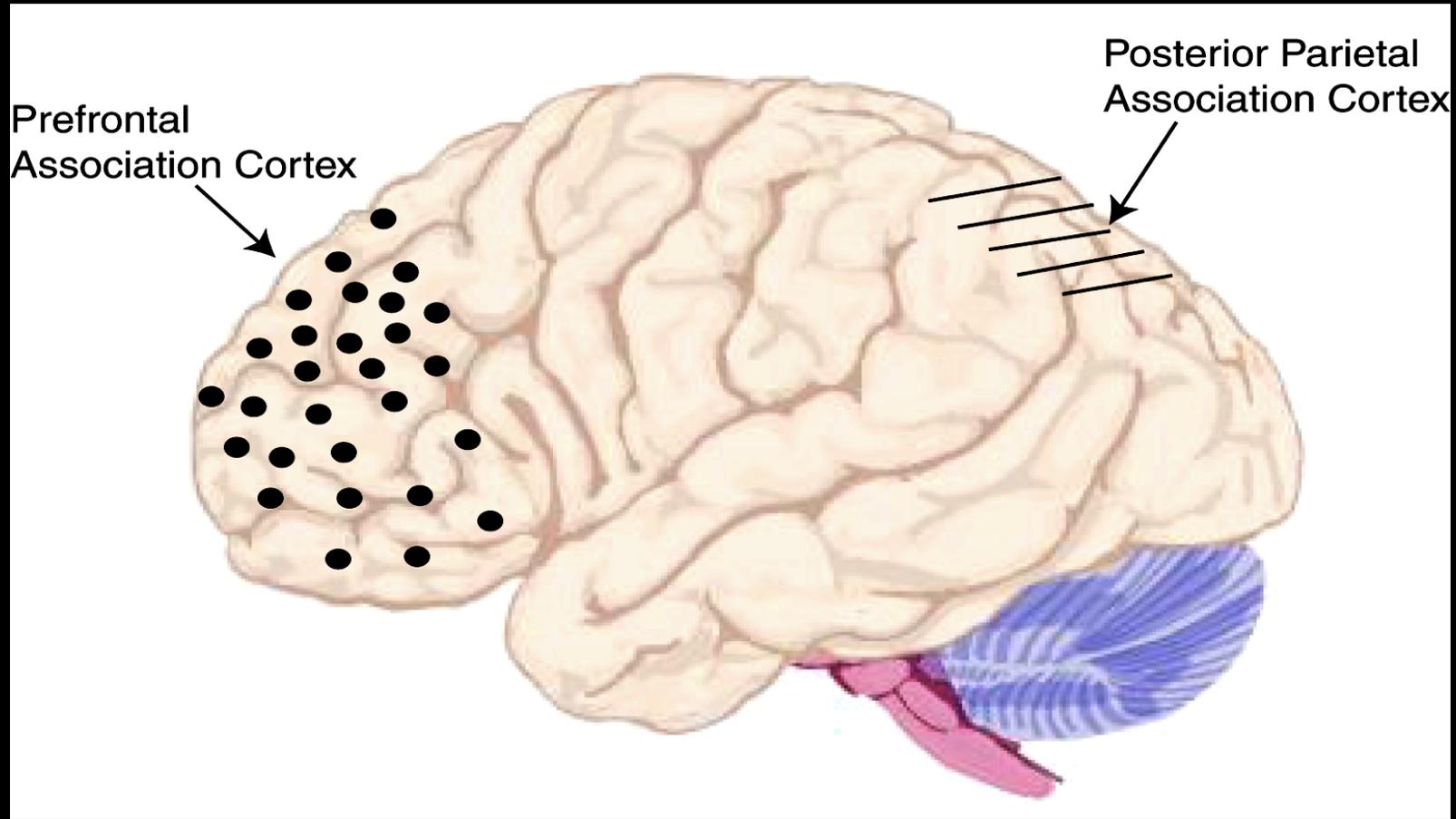
**4th hierarchical level**

**Goals, context, attention, spatial layout of environment**

**Posterior parietal cortex**

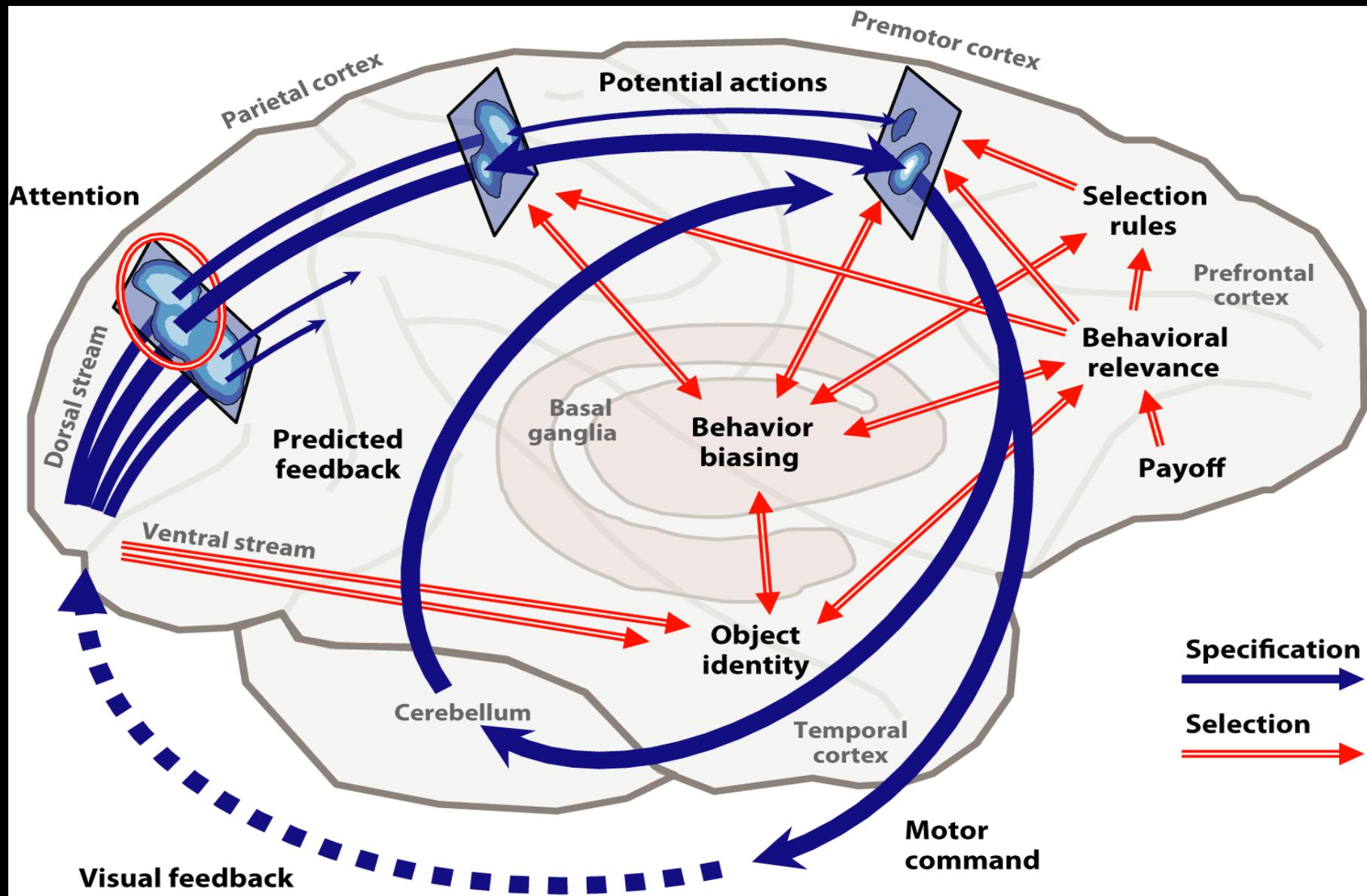
# Constructional Apraxia





Prefrontal Association Cortex

Posterior Parietal Association Cortex



# Hierarchical Organization and Functional Segregation of Central Motor Structures

