Motor Control: Lecture 2

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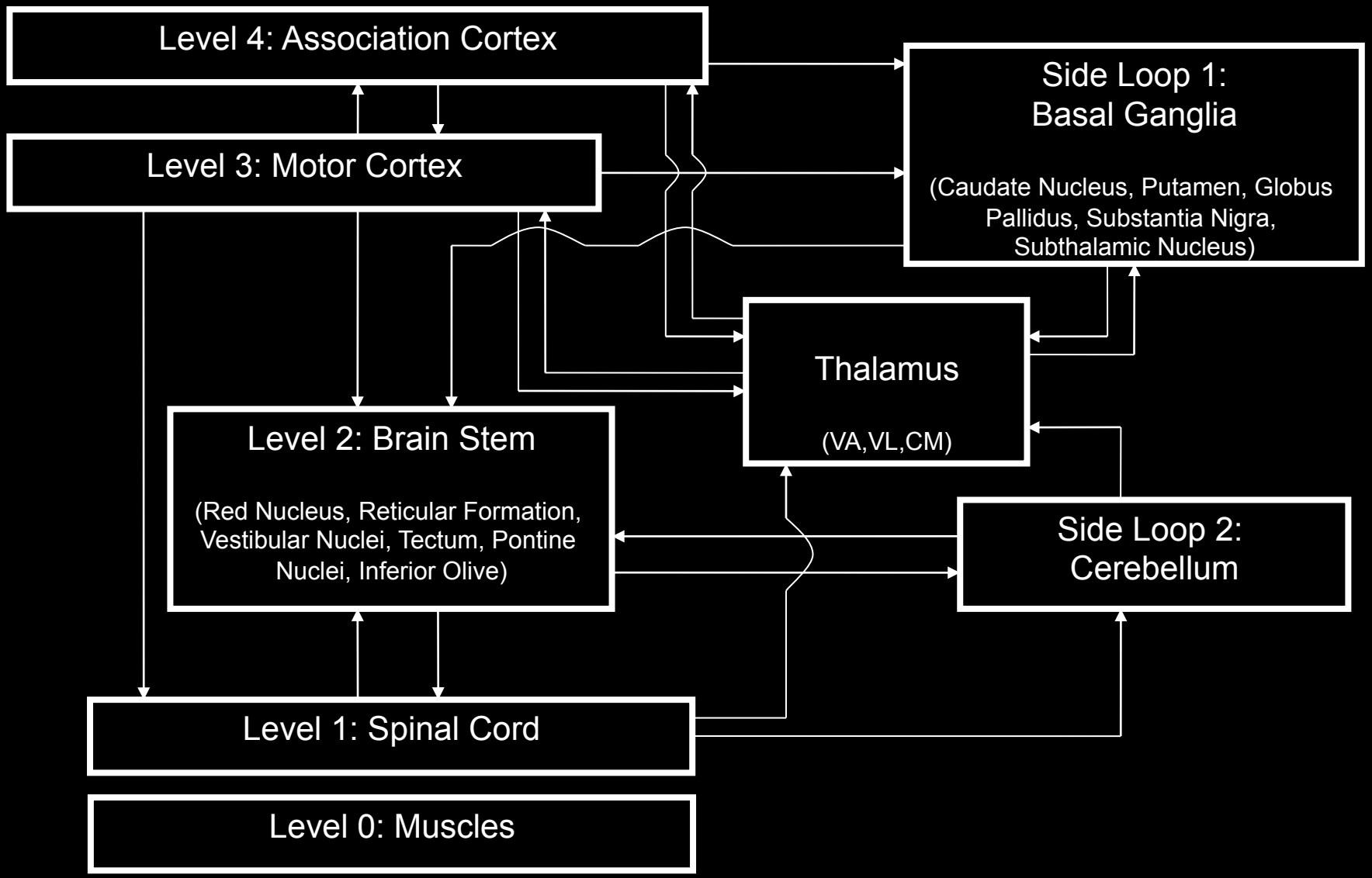
Hierarchical Organization and Functional Segregation of Central Motor Structures



Reflexes

- Most reflexes are "involuntary" in the sense that they occur without the person willing them to do so, but all of them can be brought under "voluntary" control

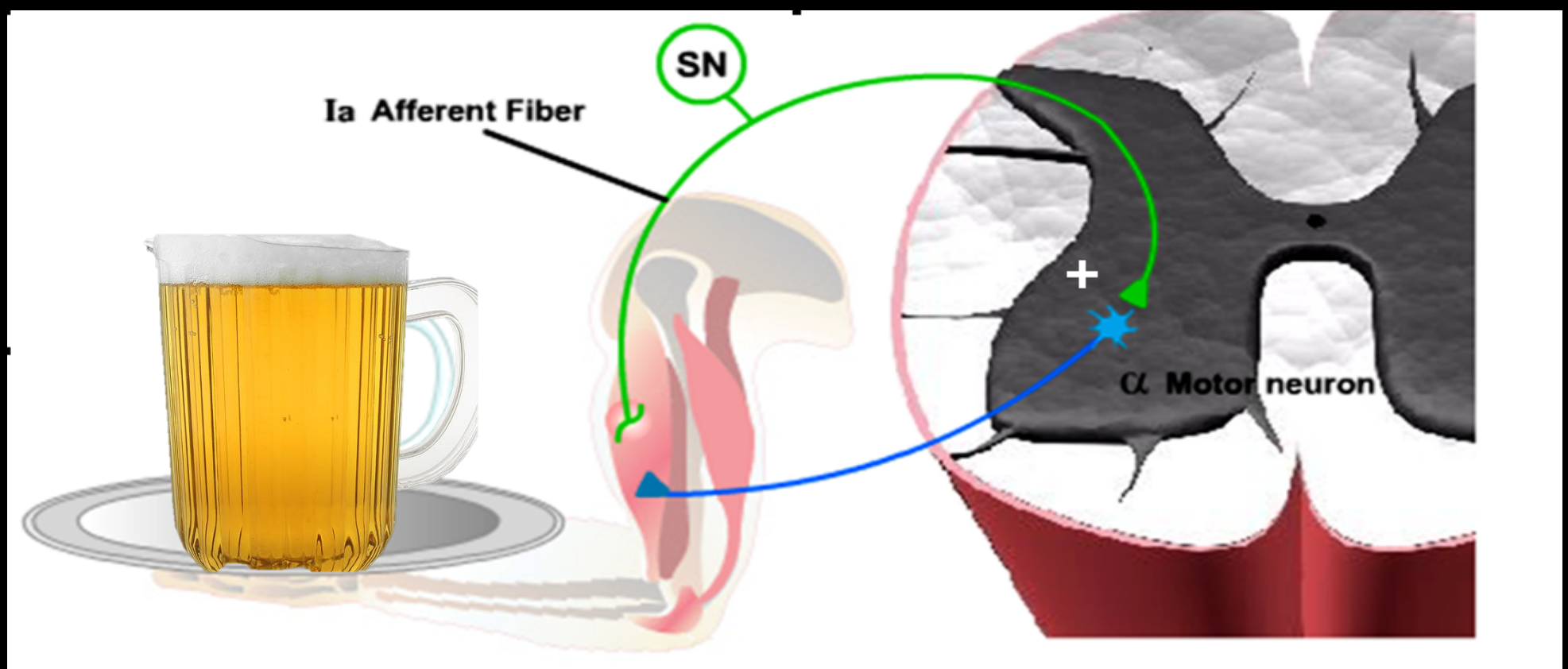
Spinal Reflexes

Myotatic reflex

[myo- + G. *tasis*, a stretching]
a.k.a. stretch reflex

Muscle spindles (Ia)
+ alpha motor neurons

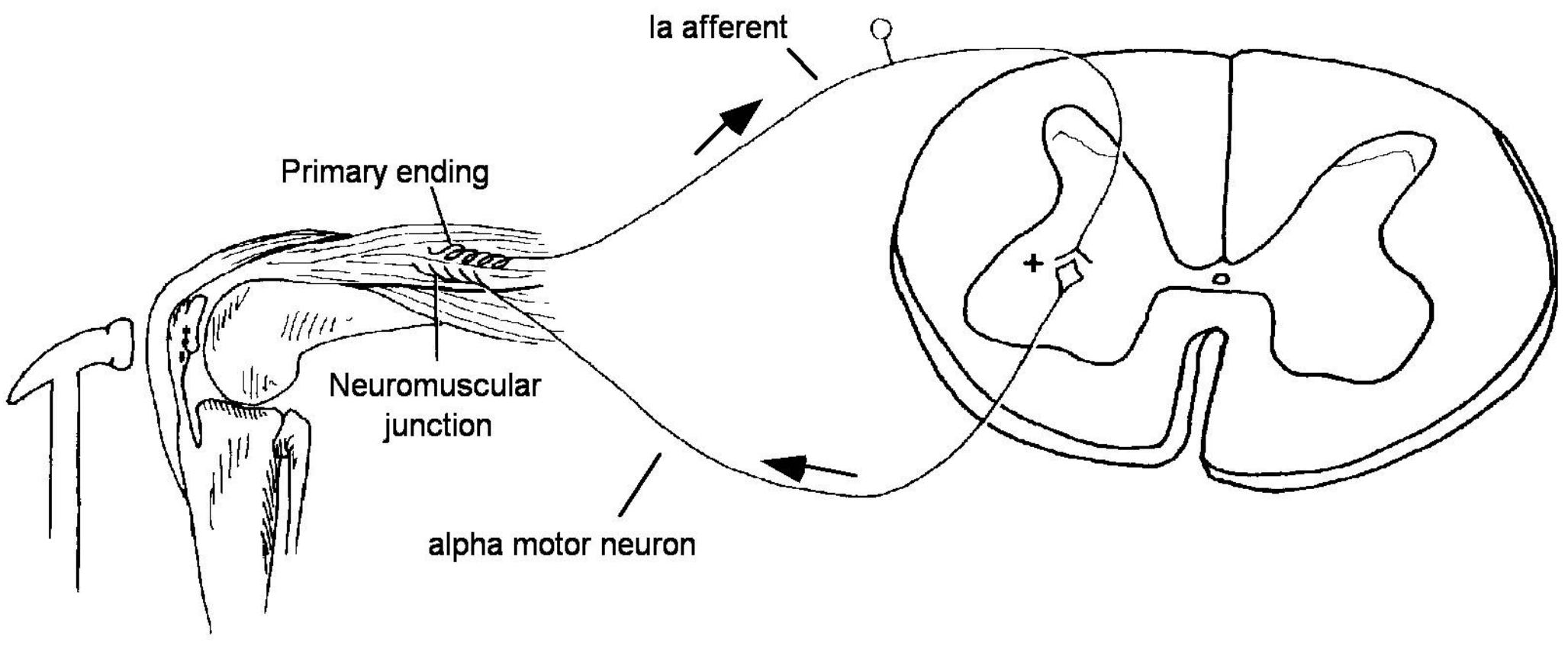
Myotatic reflex



Myotatic Reflex Important for Posture Maintenance

Continuous feedback from muscle spindles allows automatic postural maintenance and adjustments

“Knee-jerk” Response



From J. Nolte (1993) *The Human Brain, 3rd Edition*

Clinical correlate

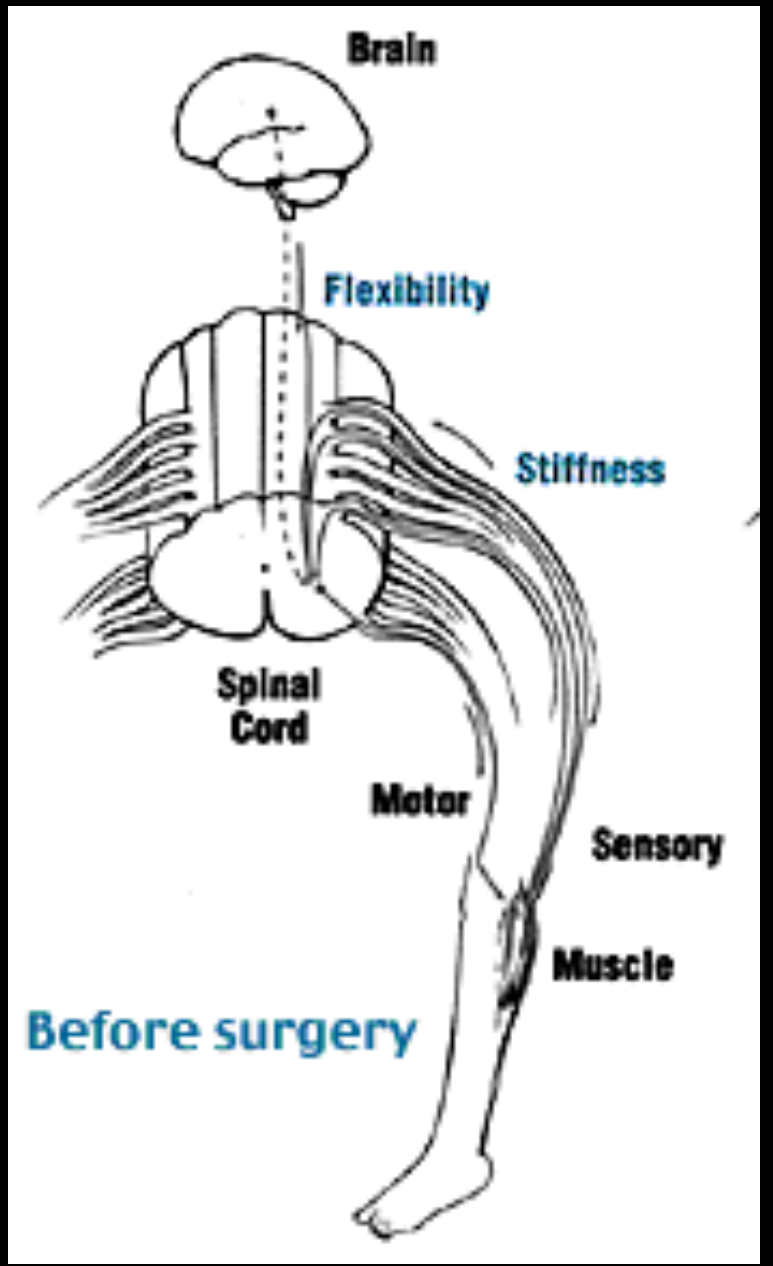
Cerebral Palsy

“palsy” = movement problem

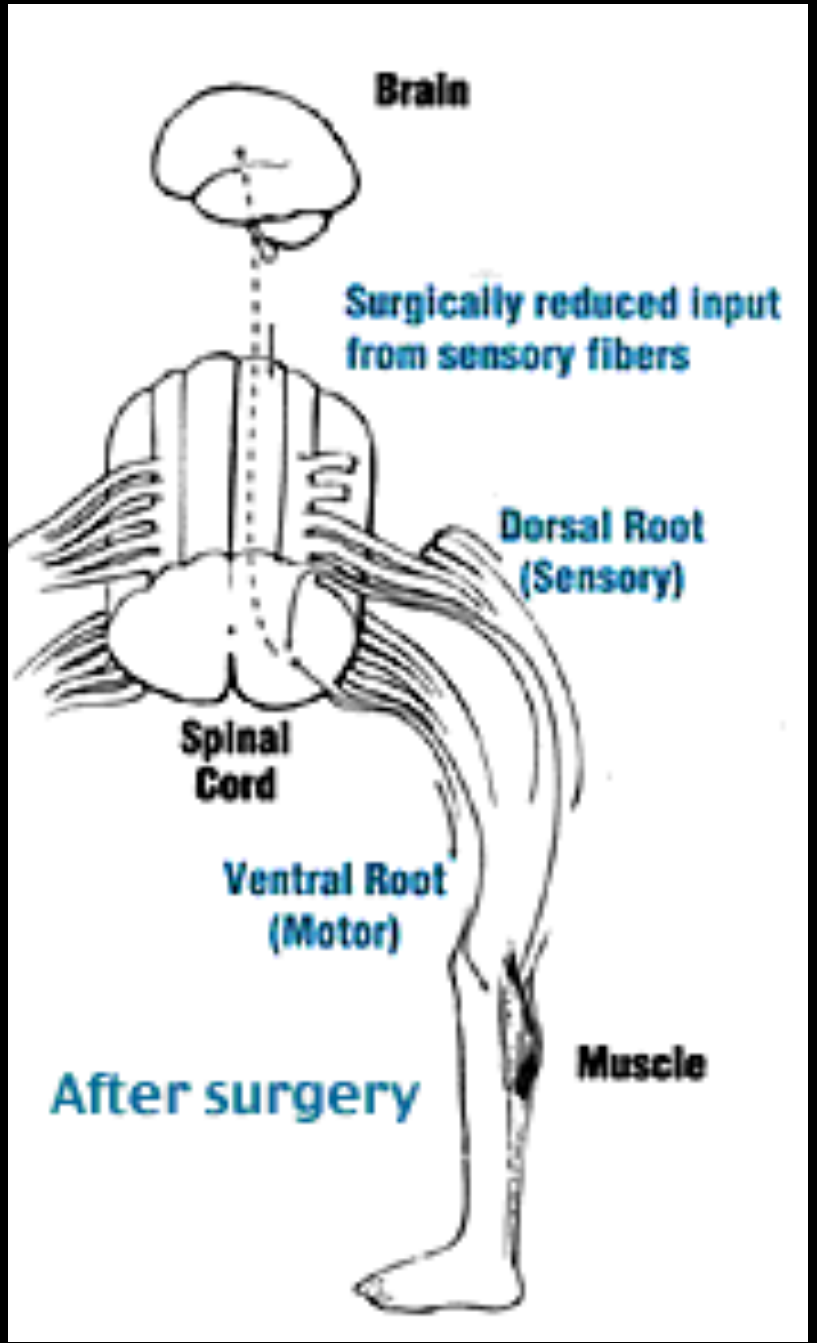
Common issue: spasticity

resistance of the muscle to passive lengthening in its most relaxed state.

Dorsal rhizotomy



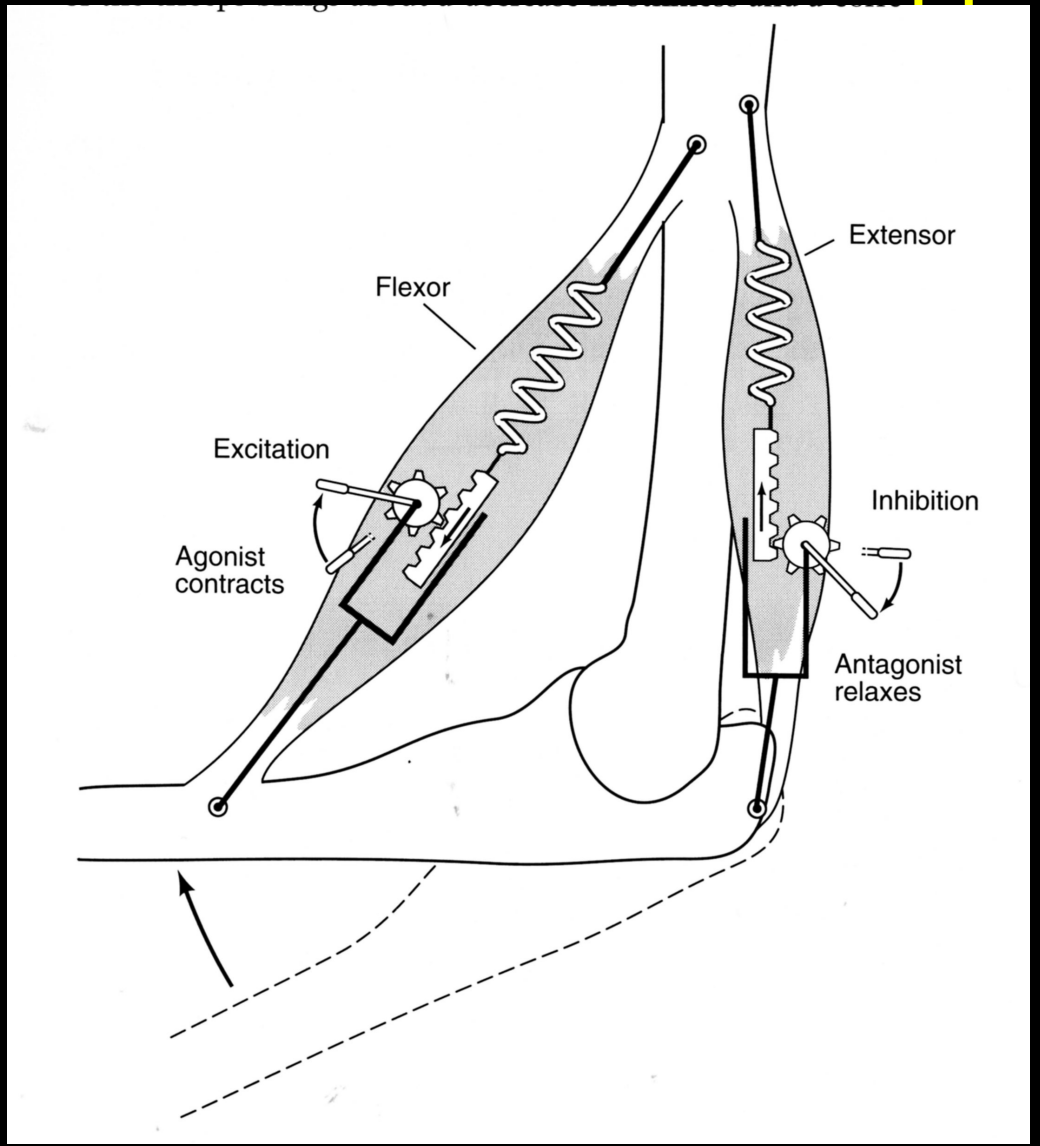
Dorsal rhizotomy



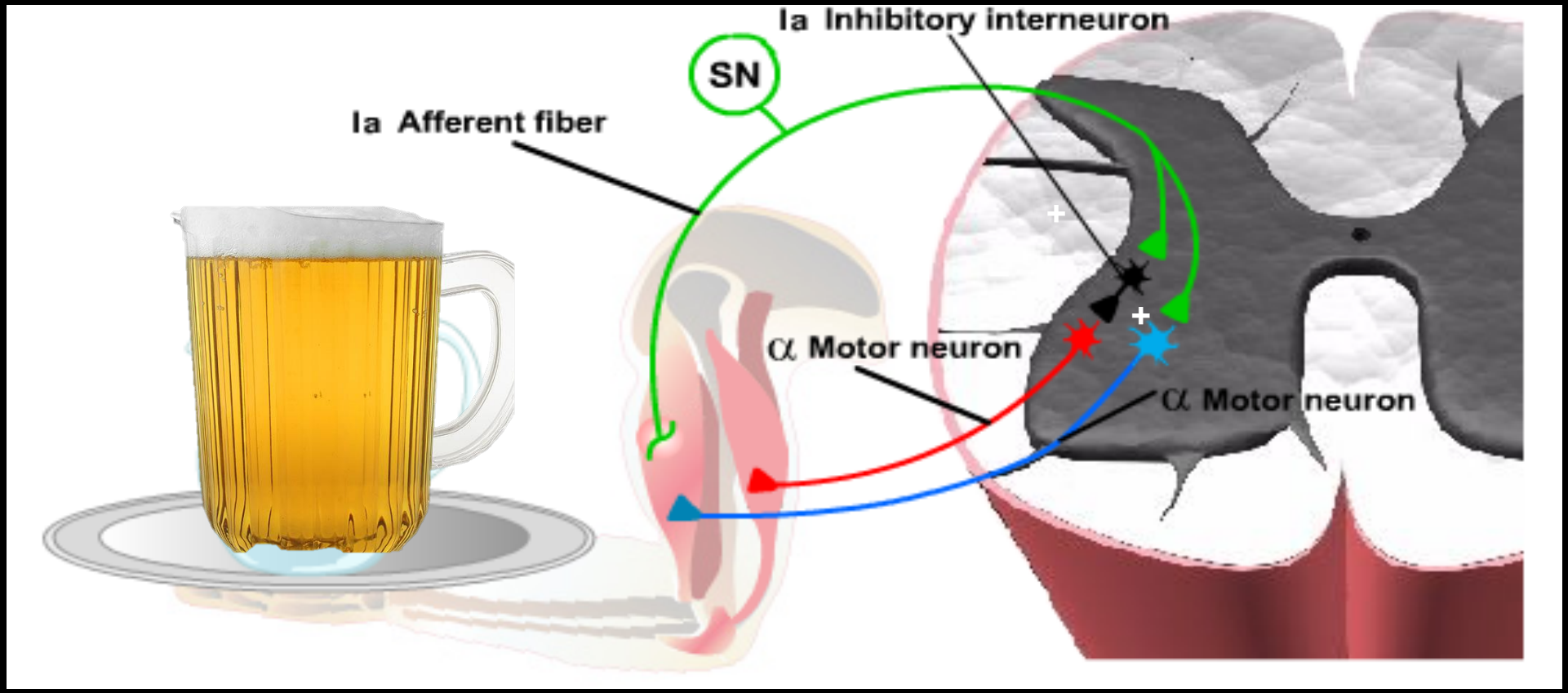
Reciprocal reflexes

Reciprocal inhibition in the stretch reflex

Flexor and extensor in opposition



Reciprocal inhibition in the stretch reflex



Spinal Reflexes

Myotatic reflex

Muscle spindles (Ia)

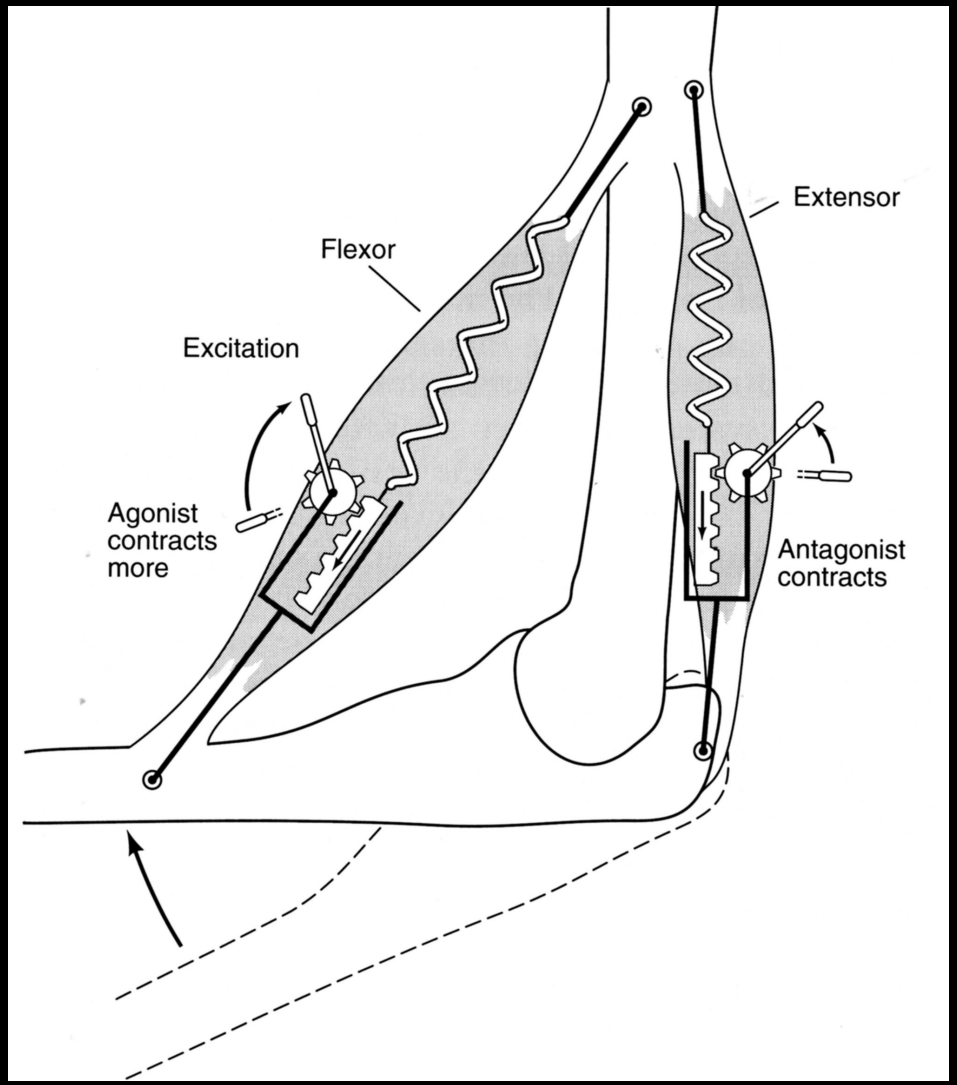
\+ alpha motor neurons

Autogenic inhibition

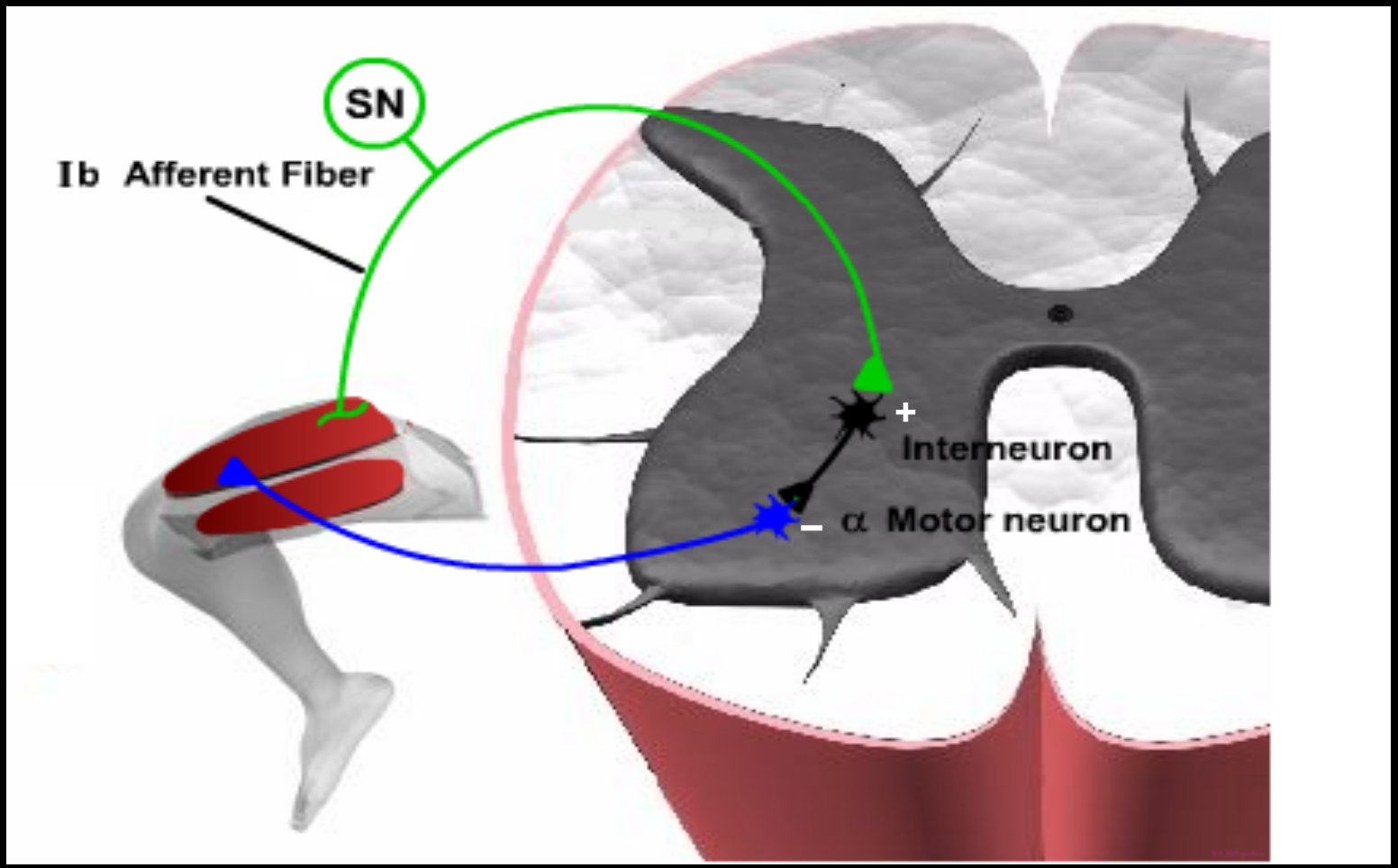
Golgi tendon organs (Ib)

\- alpha motor neurons

Flexor and extensor: co-contraction



Autogenic Inhibition

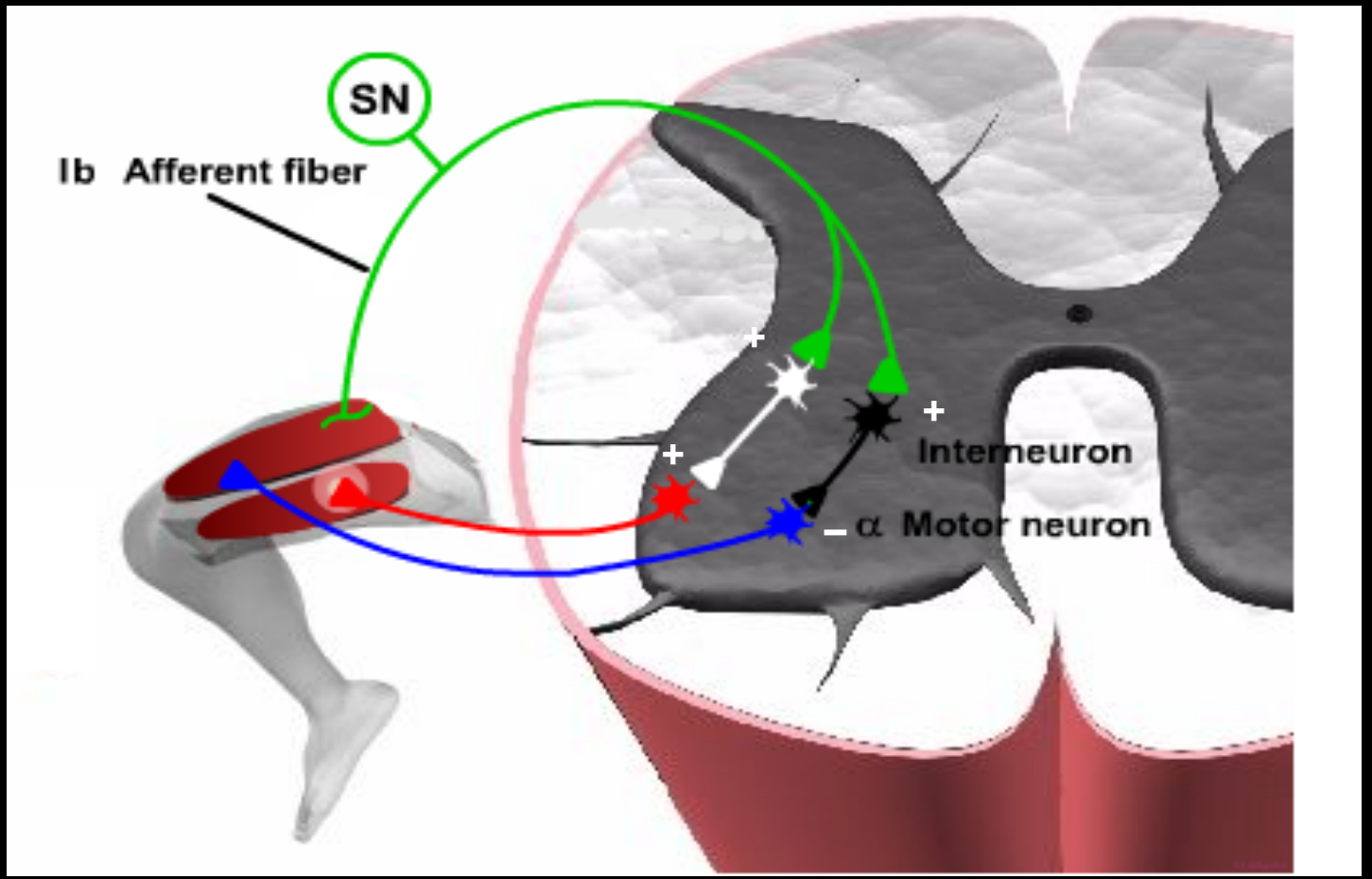


Reciprocal reflexes

Reciprocal inhibition in the stretch reflex

Reciprocal excitation in the autogenic inhibition reflex

Reciprocal excitation in the autogenic inhibition reflex

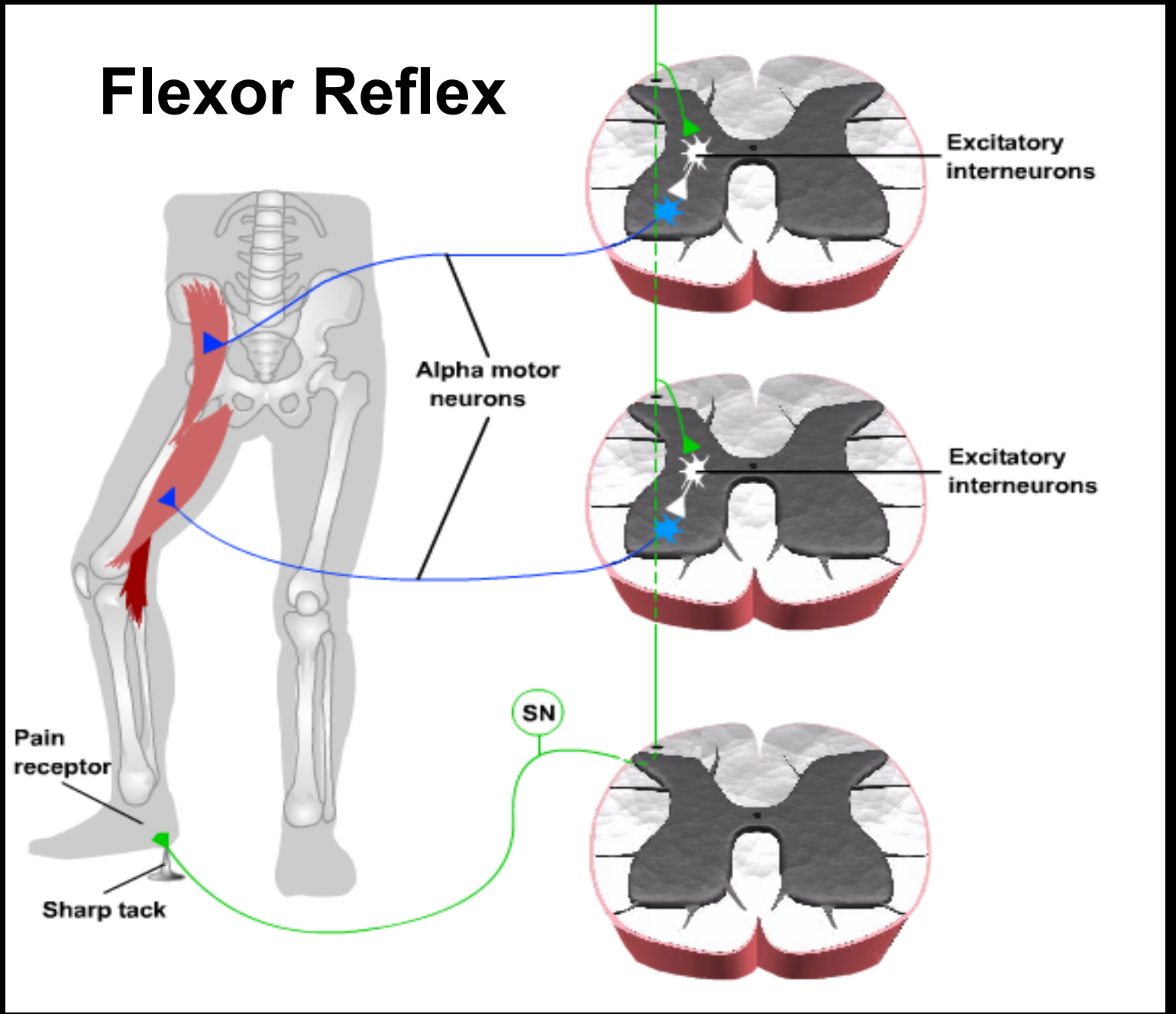


Flexor and crossed extension reflexes

Flexor reflex

Cutaneous and nociceptive receptors (II, III, and IV)
+ alpha motor neurons

Flexor Reflex



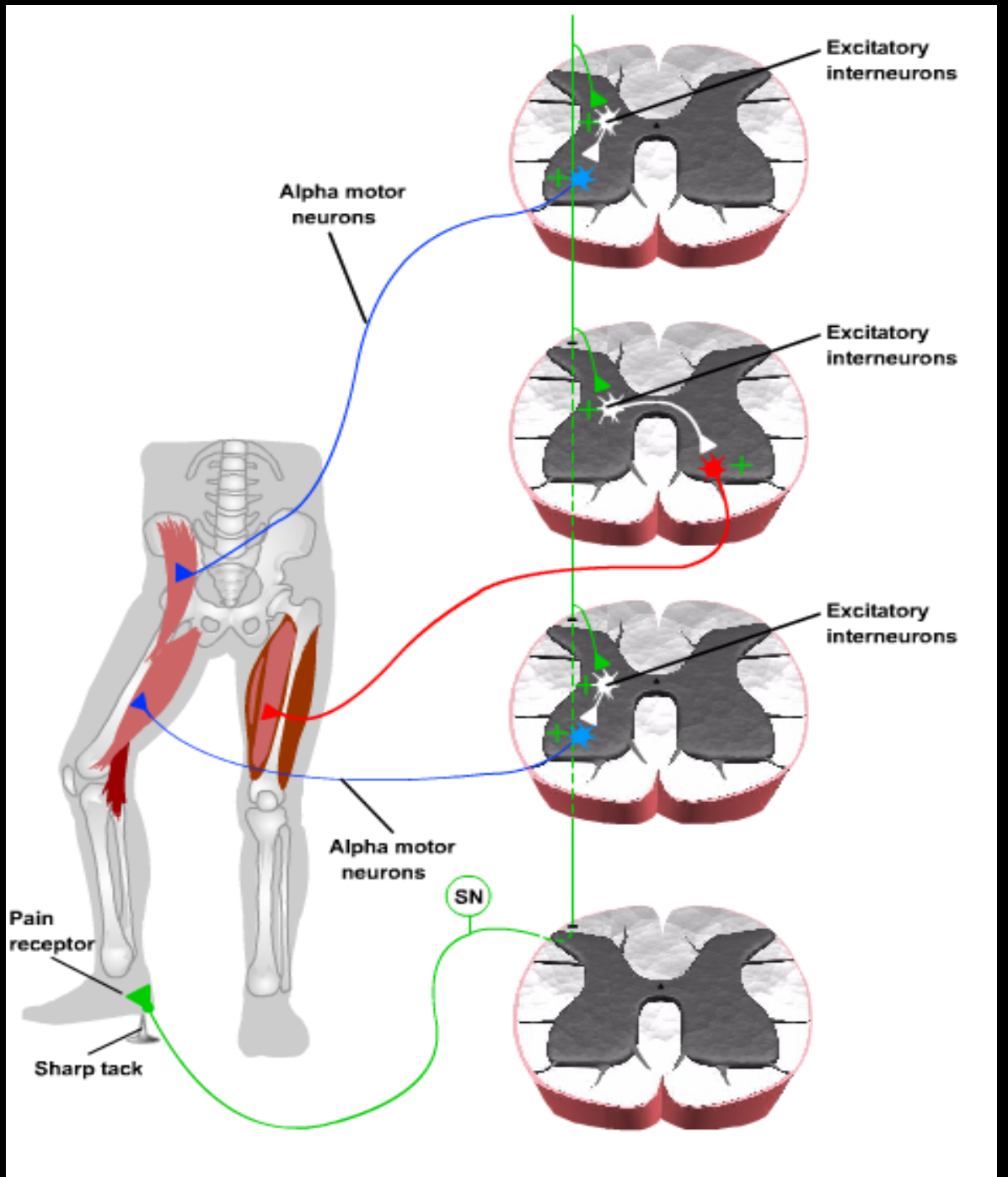
Flexor and crossed extension reflexes

Flexor reflex
Cutaneous and nociceptive receptors (II, III, and IV)
+ alpha motor neurons

Reciprocal inhibition in the flexor reflex

Crossed extension reflex

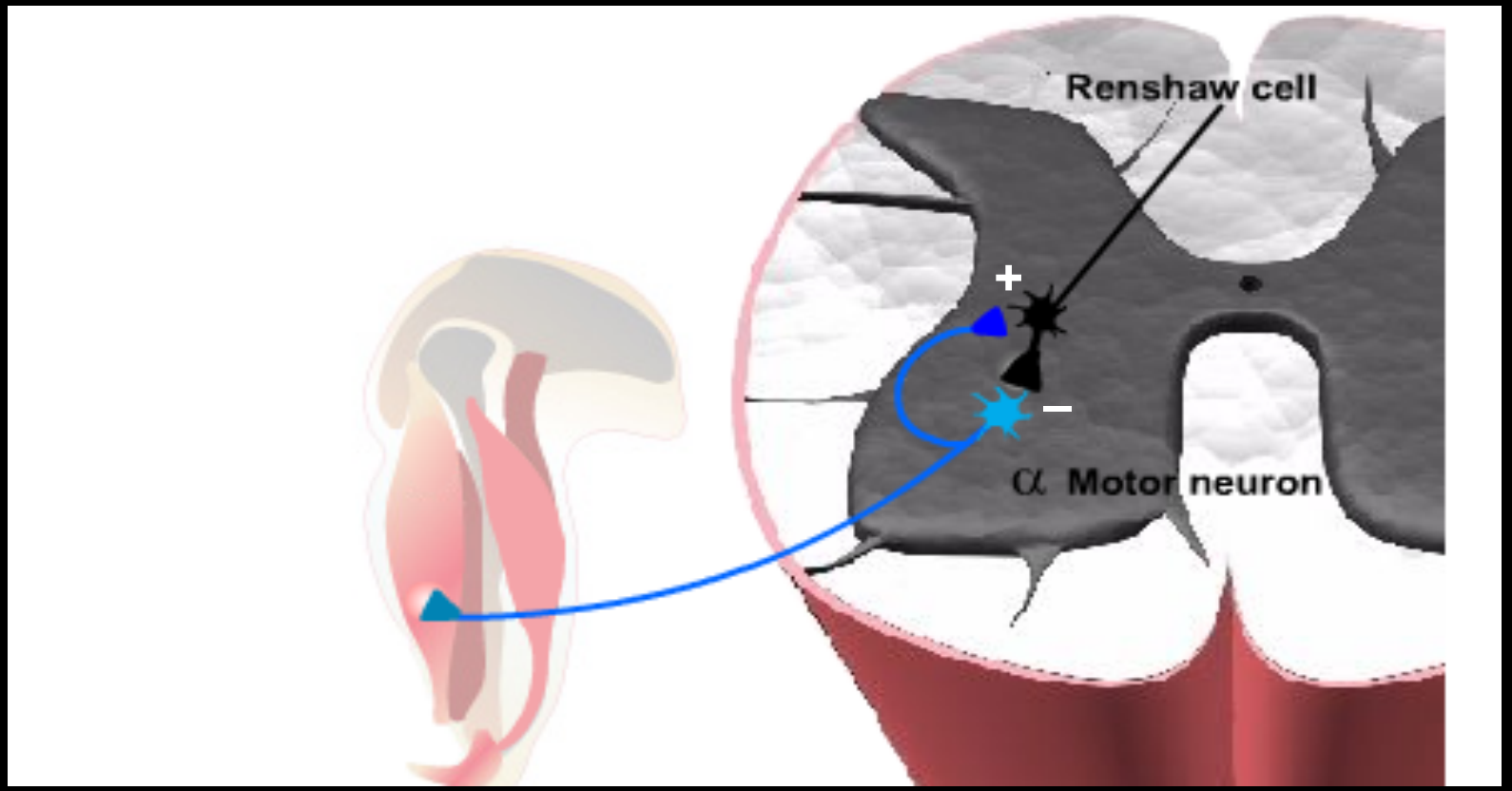
Crossed extension reflex



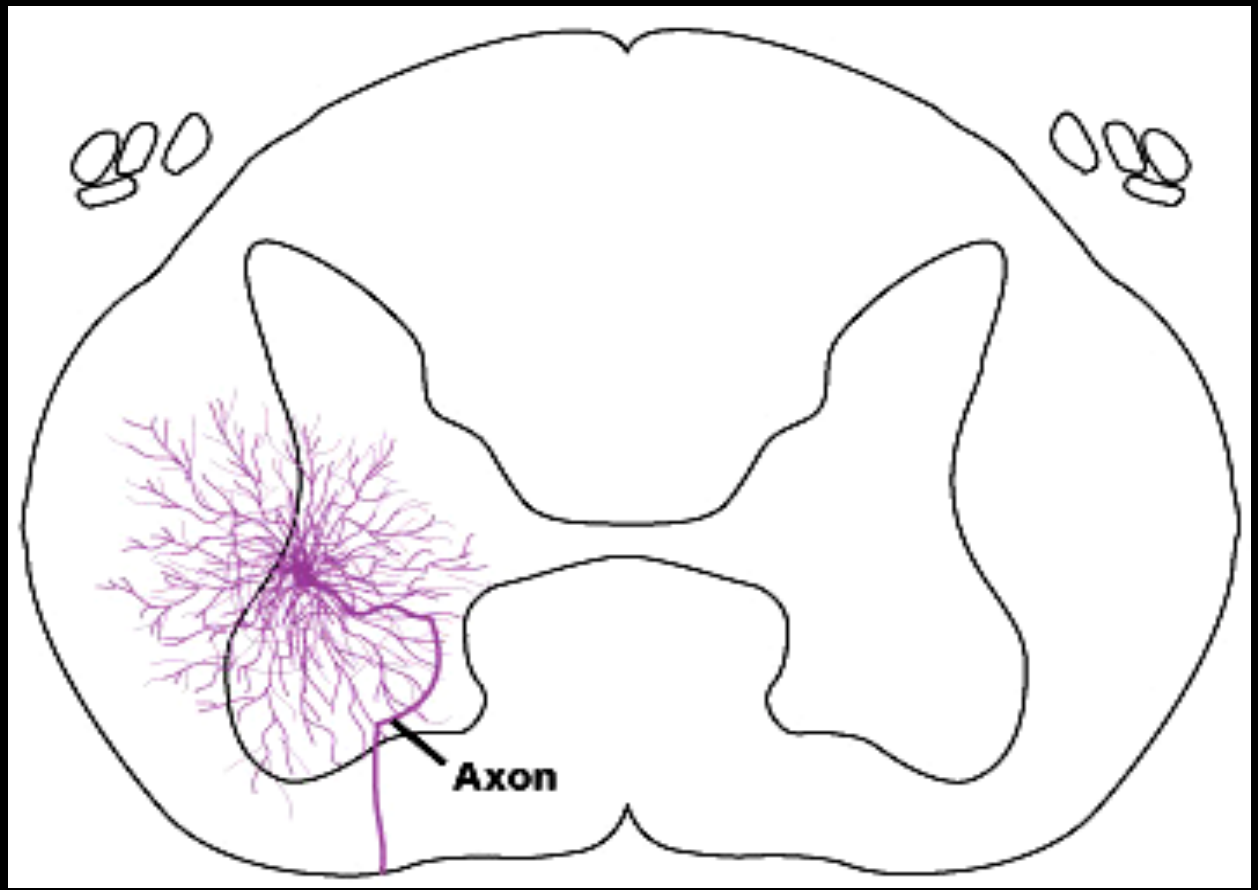
Recurrent inhibition of motor neurons

Renshaw Cell

Renshaw cell



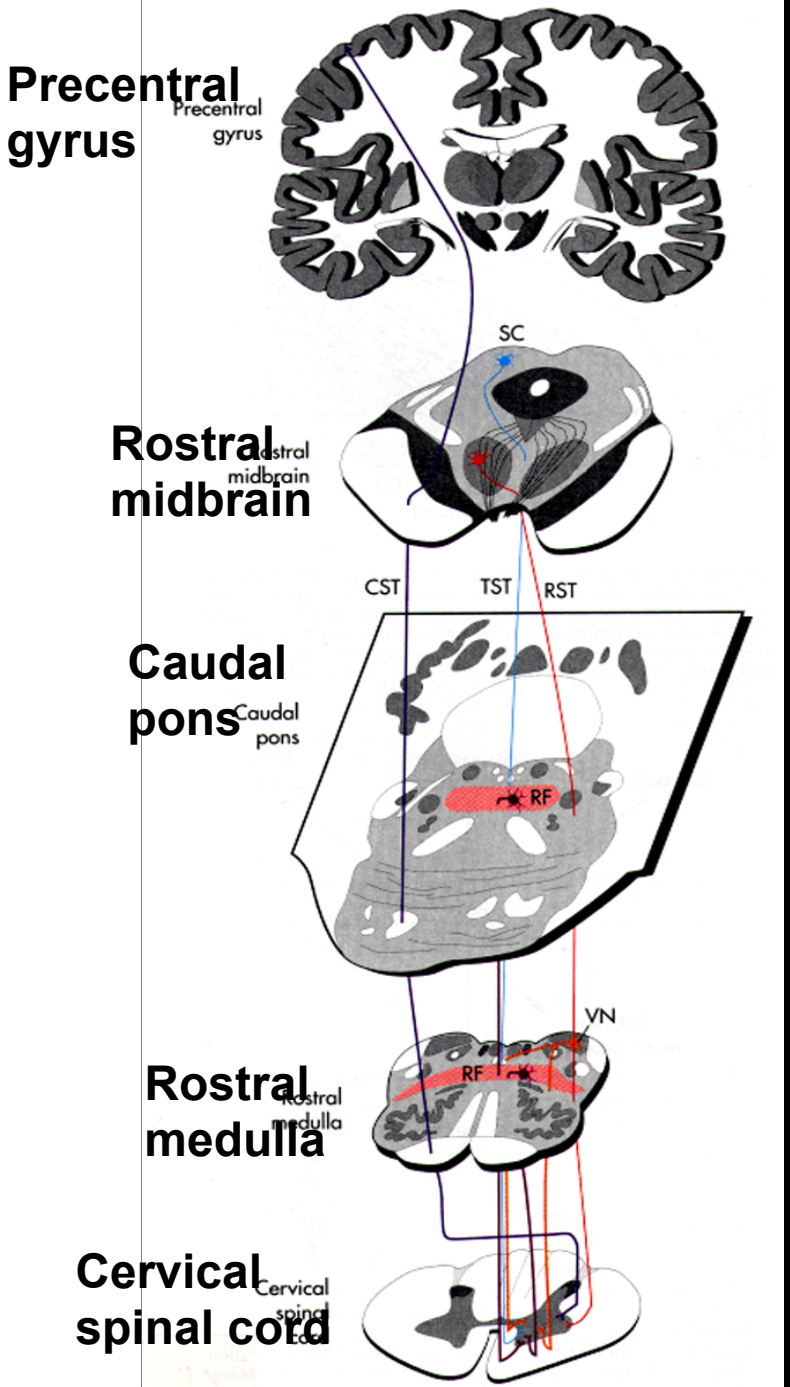
Alpha motor neuron



Clinically, often called Lower Motor Neurons

Descending Spinal Pathways

Upper Motor Neurons



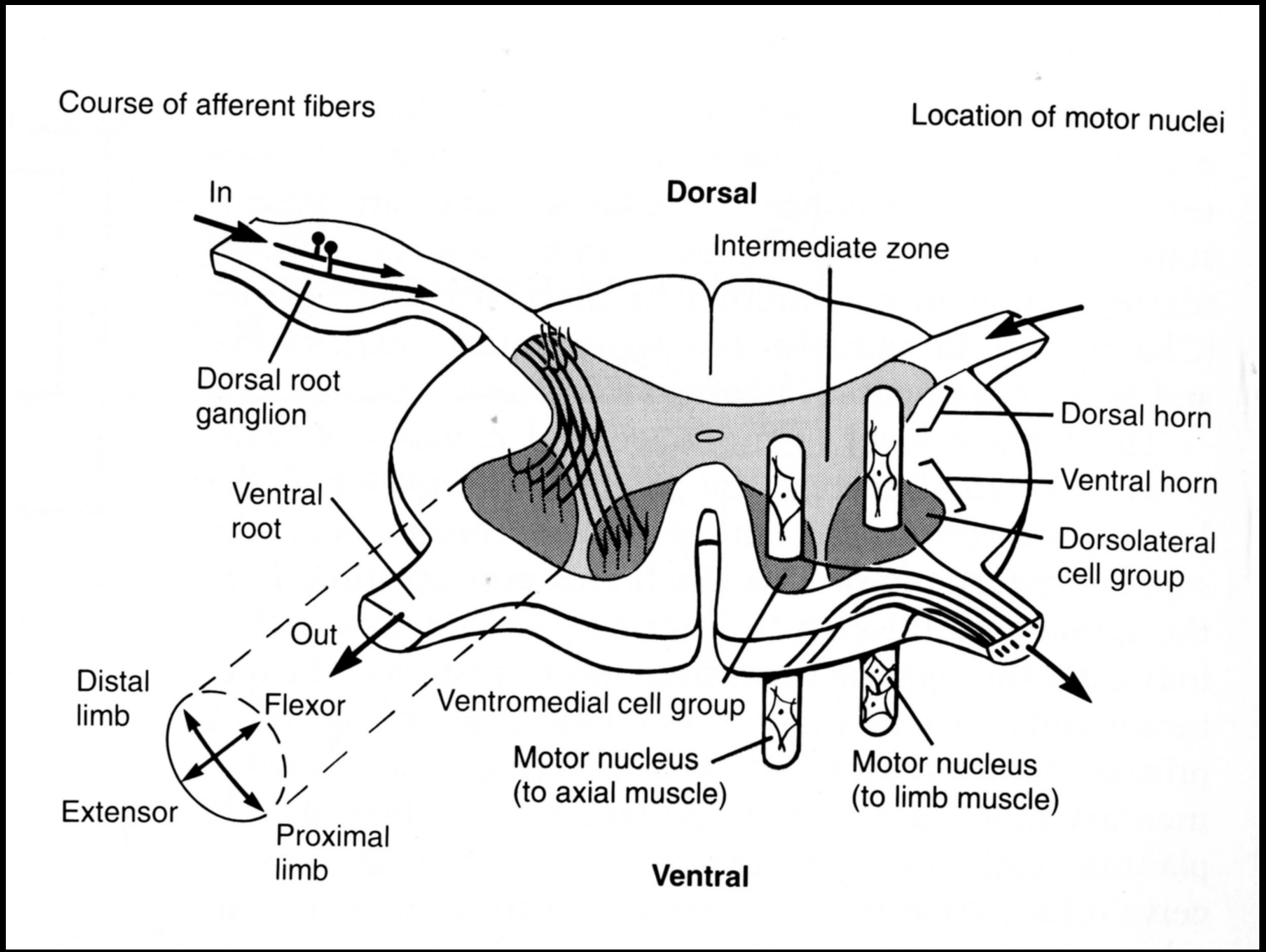
Anatomy and Physiology of Descending Spinal Pathways

Brain structures influence spinal motor neurons and spinal circuits through descending pathways

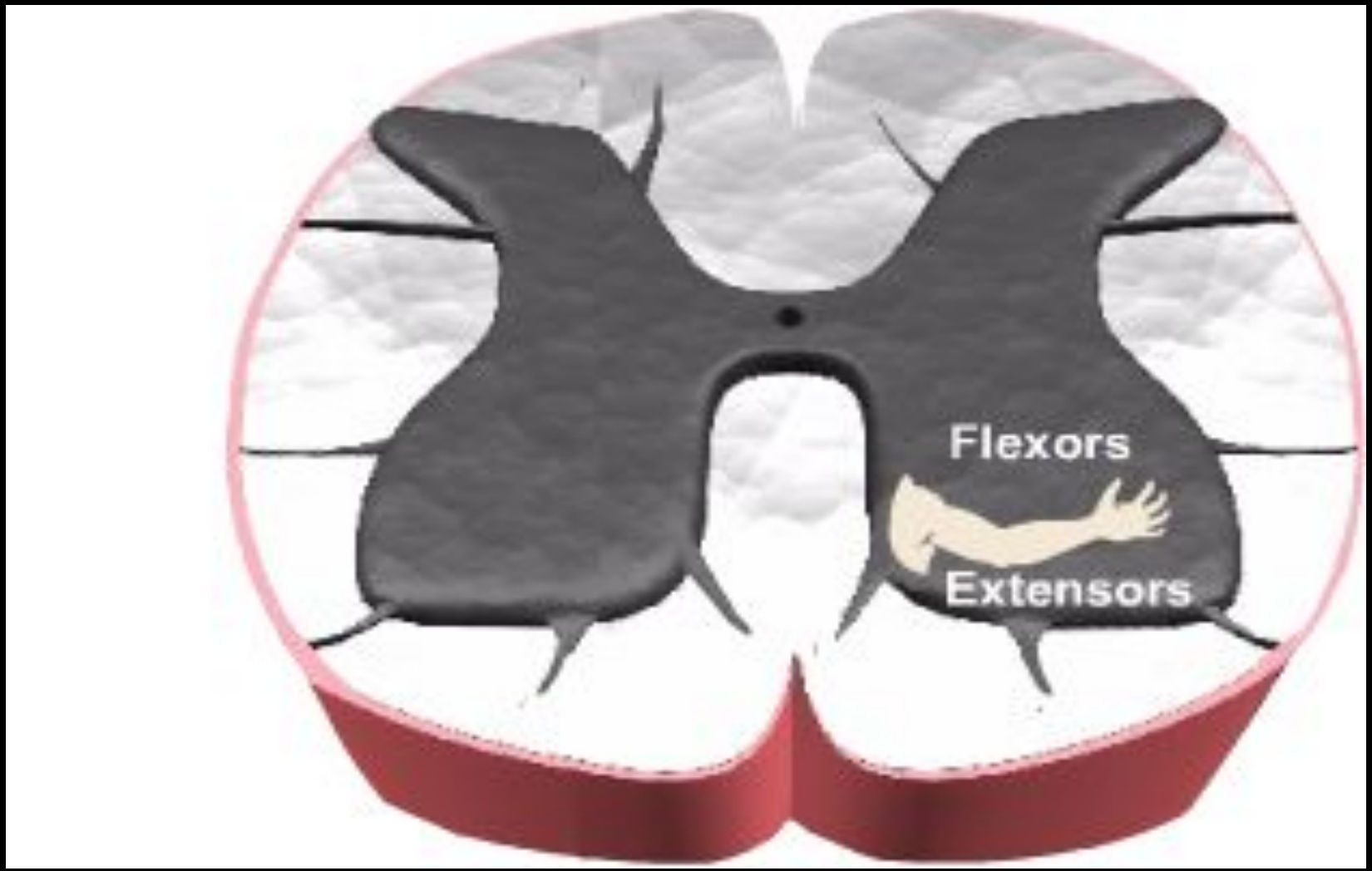
Flexor-extensor rule

Proximal-distal rule

Organization of spinal tracts



Flexor-Extensor Rule and Proximal-Distal Rule



Two Groups of Descending Pathways

Lateral pathways

control proximal and distal muscles

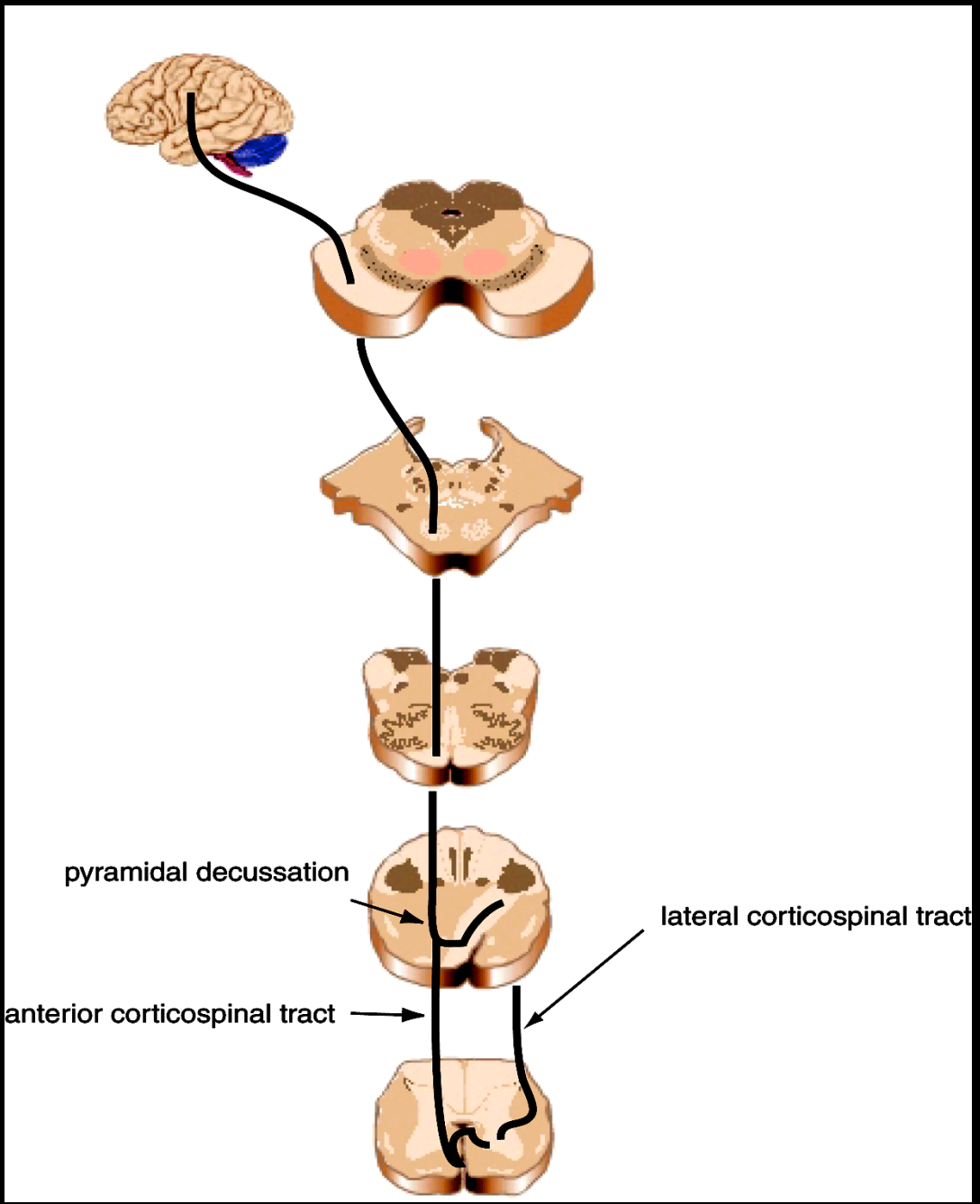
Lateral corticospinal
Rubrospinal

Medial pathways

control axial muscles

Vestibulospinal
Reticulospinal
Tectospinal
Anterior corticospinal

Corticospinal Tracts



Corticospinal tracts

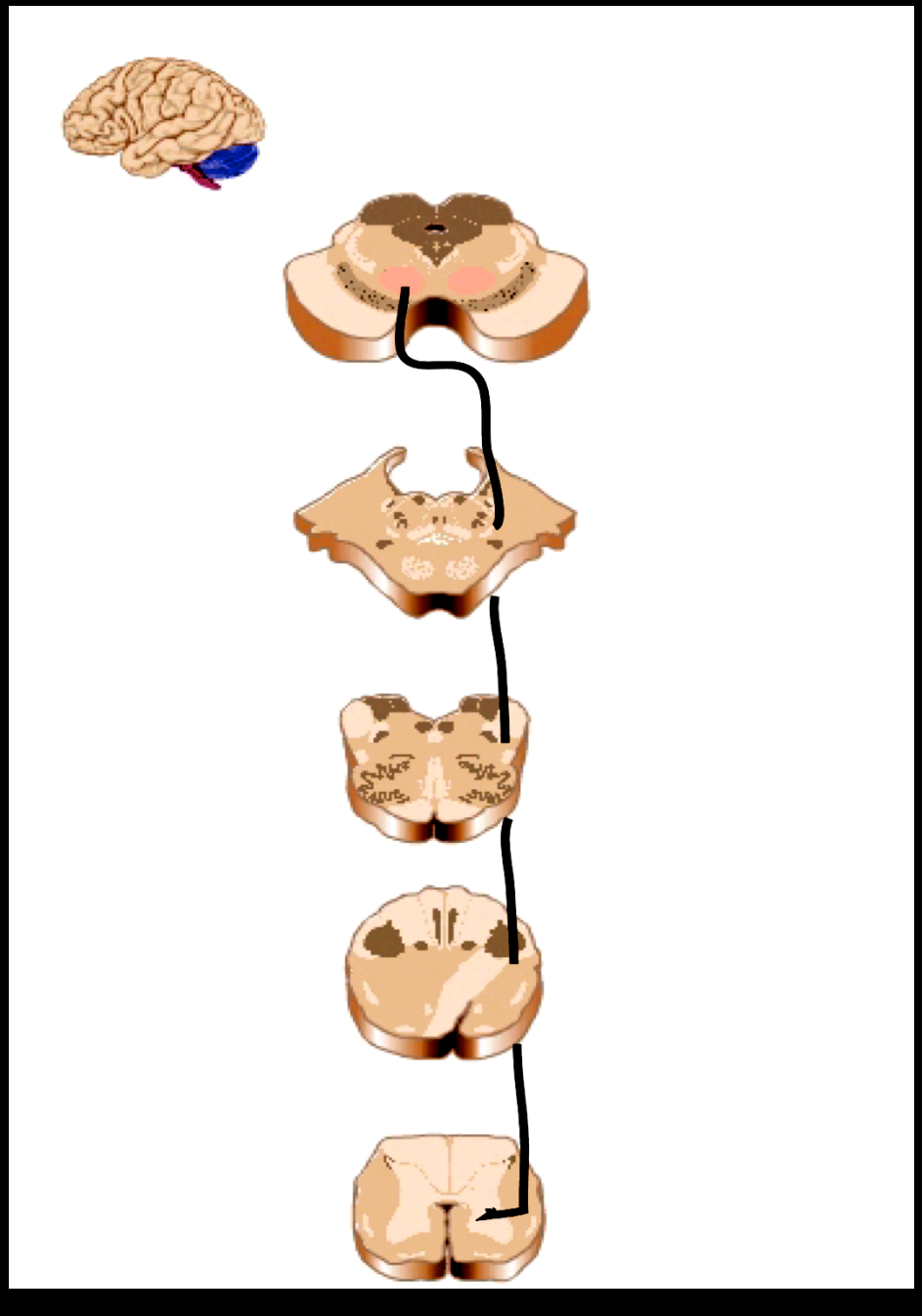
Control of distal musculature, esp. fine control of extremities

Control of axial muscles

Corticospinal and corticobulbar tracts constitute the major *voluntary* drive to the brain stem and spinal motor systems

Lesions produce initial paralysis, with eventual recovery of function (except fine control of distal musculature)

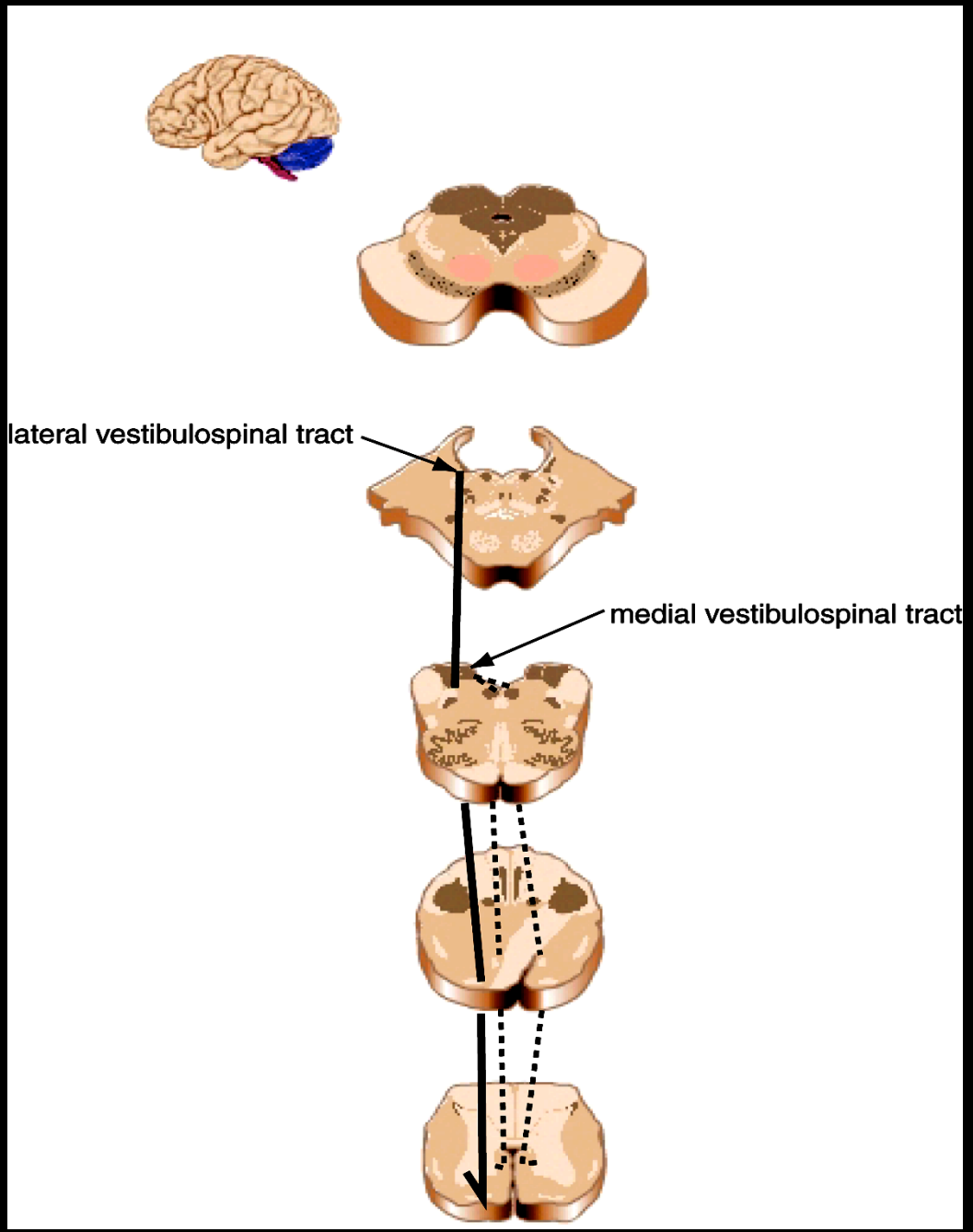
Rubrospinal Tract



Rubrospinal tract

- Alternate route to corticospinal tract
- Receives input from cerebellum and cerebral cortex
- Encodes movement *velocity*
- Excitation of flexors and inhibition of extensors
- Relatively small in humans

Vestibulospinal Tracts



Vestibulospinal tracts

Mediate postural adjustments and head movements

Control balance

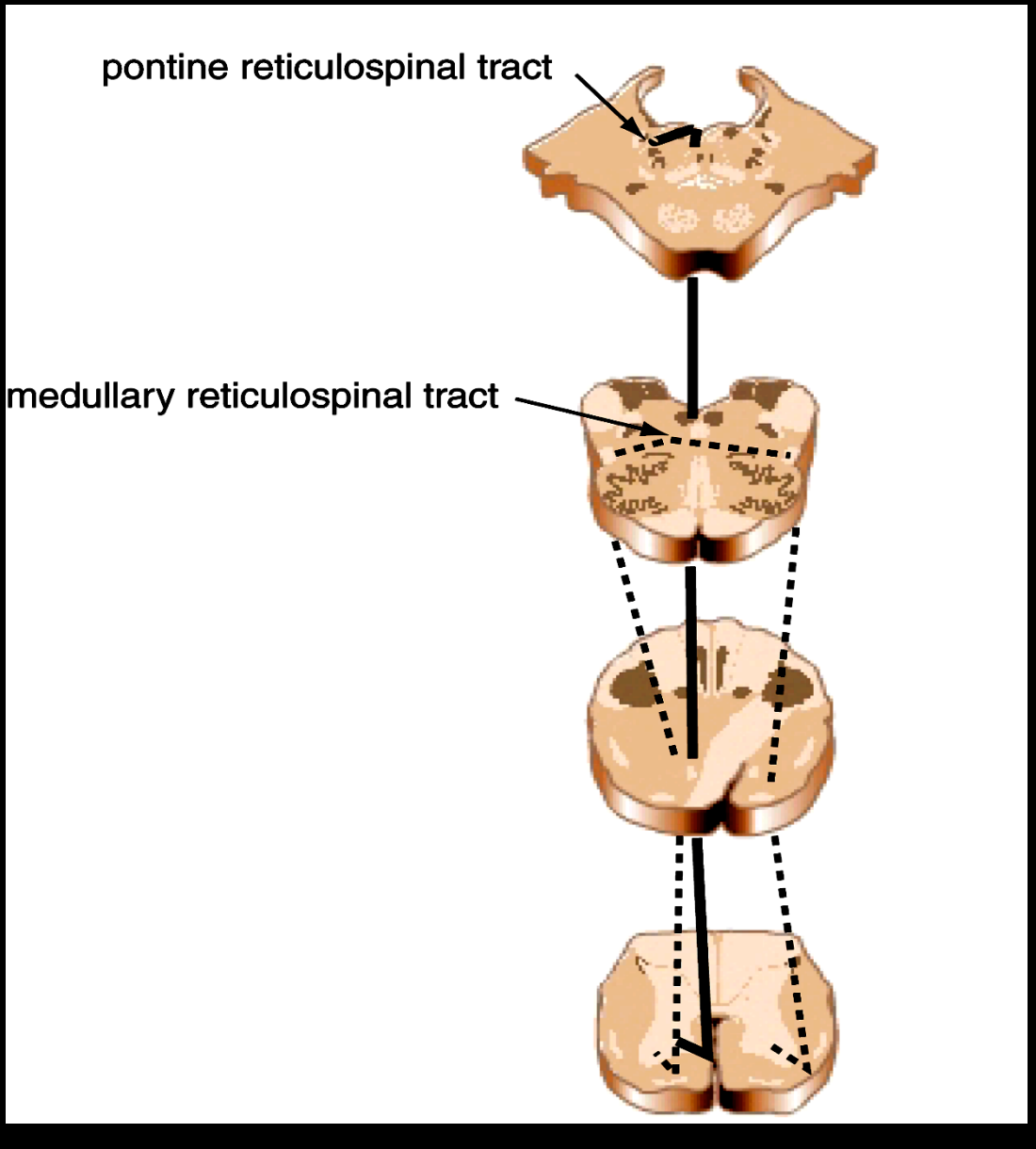
Lateral vestibulospinal tract

- Excites antigravity muscles
- Controls postural changes to compensate for tilts and movements of body

Medial vestibulospinal tract

- Innervates neck muscles to stabilize head position
- Coordinates head and eye movements

Reticulospinal Tracts



Reticulospinal tracts

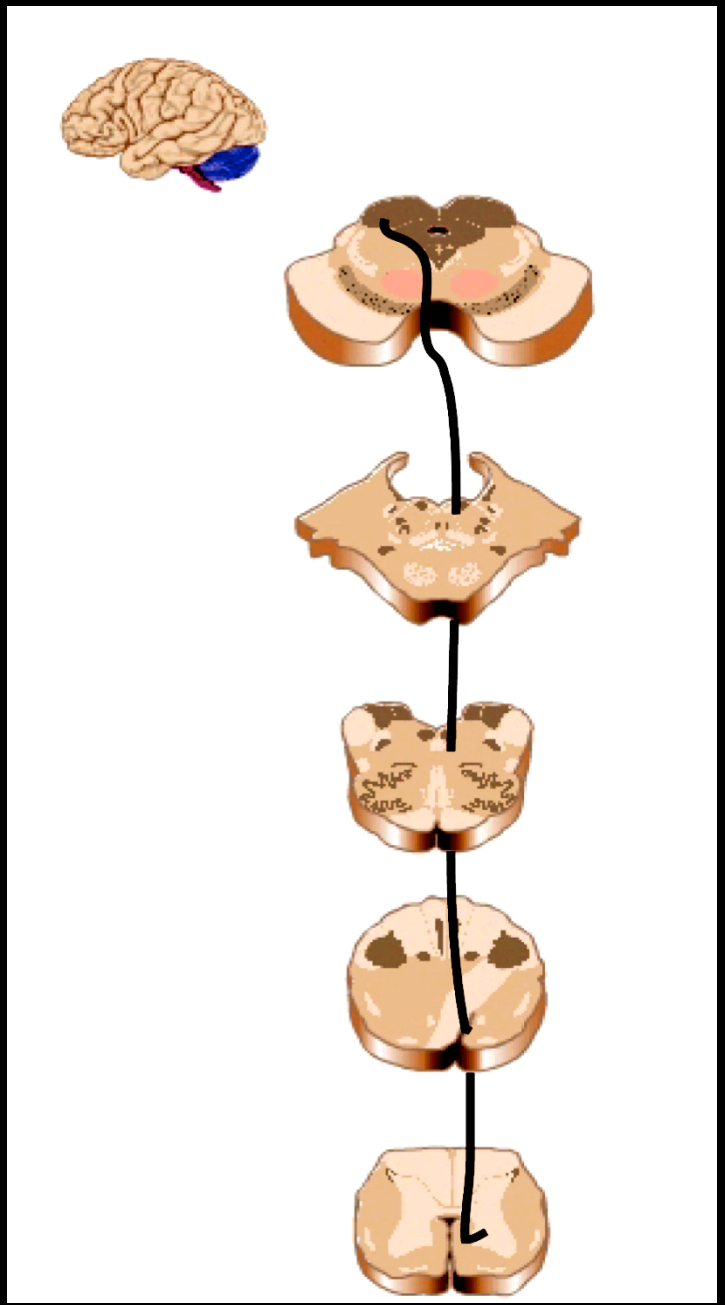
Major alternate route (to the corticospinal tract) to spinal motor neurons

Regulate sensitivity to flexor reflexes, such that only noxious stimuli elicit them

Reticular formation contains circuitry for complex movements, including complex postures, orienting, and stretching

Integration of sensory input to guide motor output

Tectospinal Tract



Tectospinal tract

Originates in Superior Colliculus

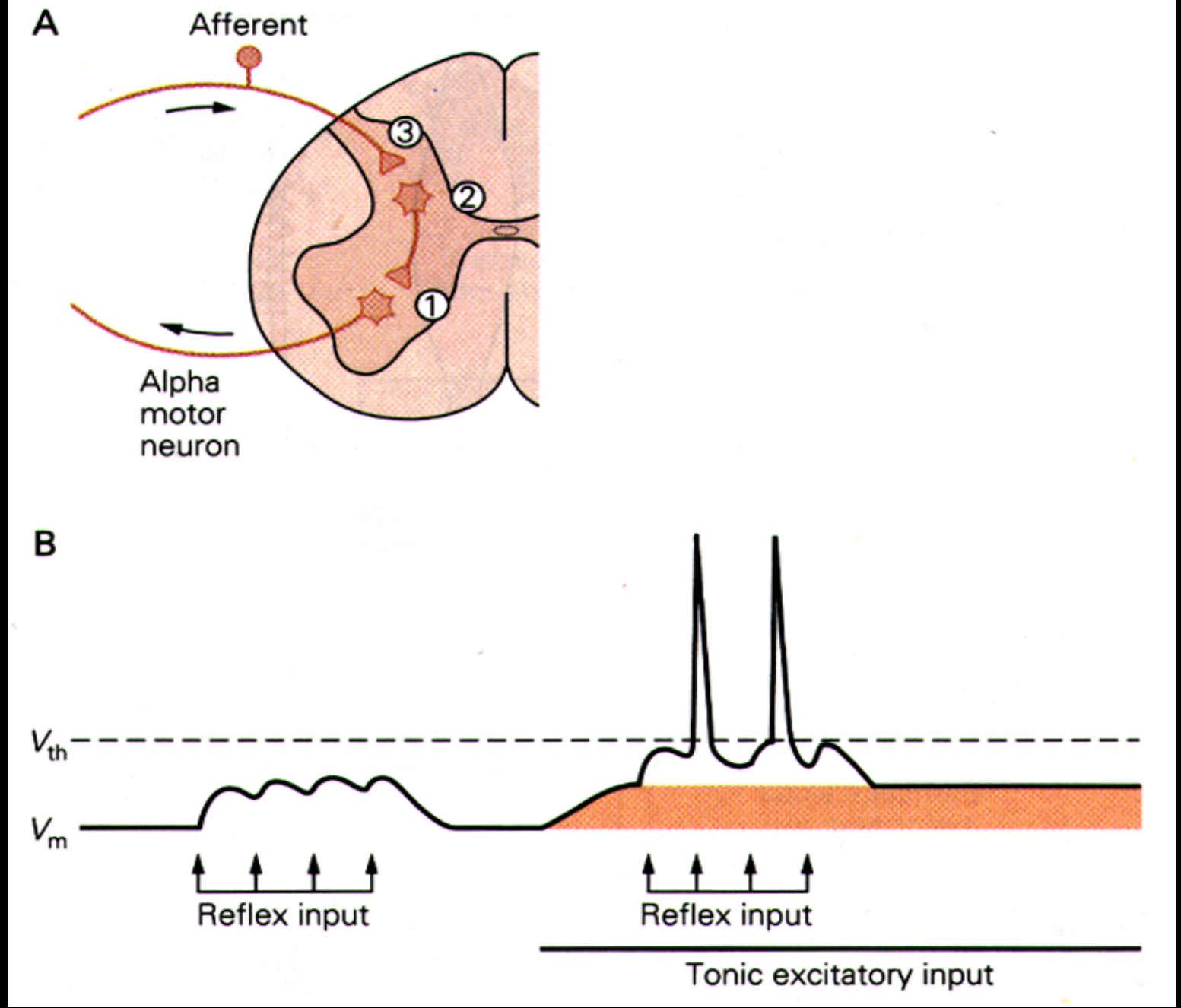
Innervates neck and proximal muscles

Presumably involved in reflex orienting to visual stimuli

Relatively minor in humans

Influence of descending pathways on spinal mechanisms

- voluntary movement
- reflex modulation



From K. Pearson & J. Gordon (2000), in *Principles of Neural Science, 4th Edition* (Kandel, Schwartz, & Jessel, Eds.)

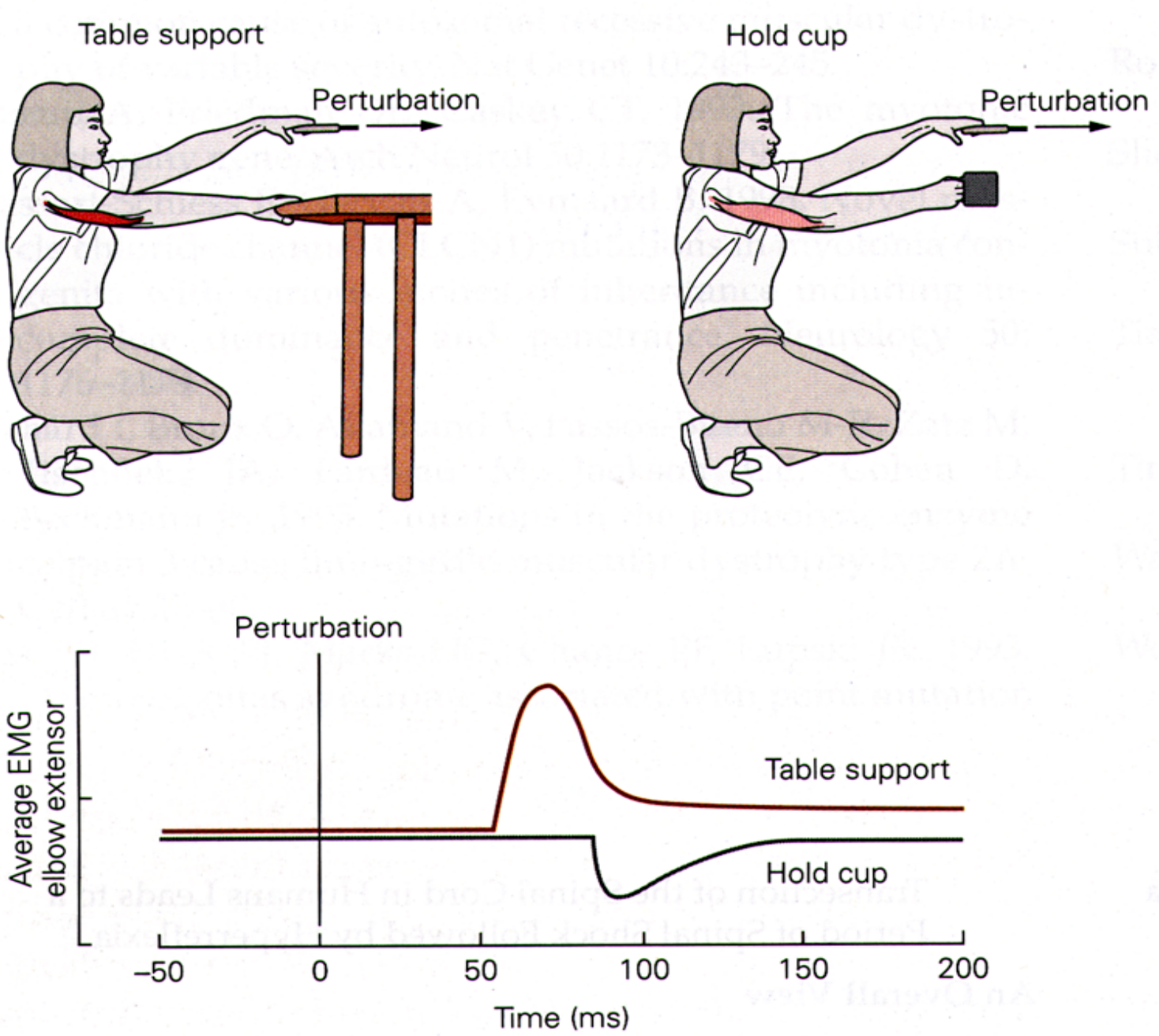
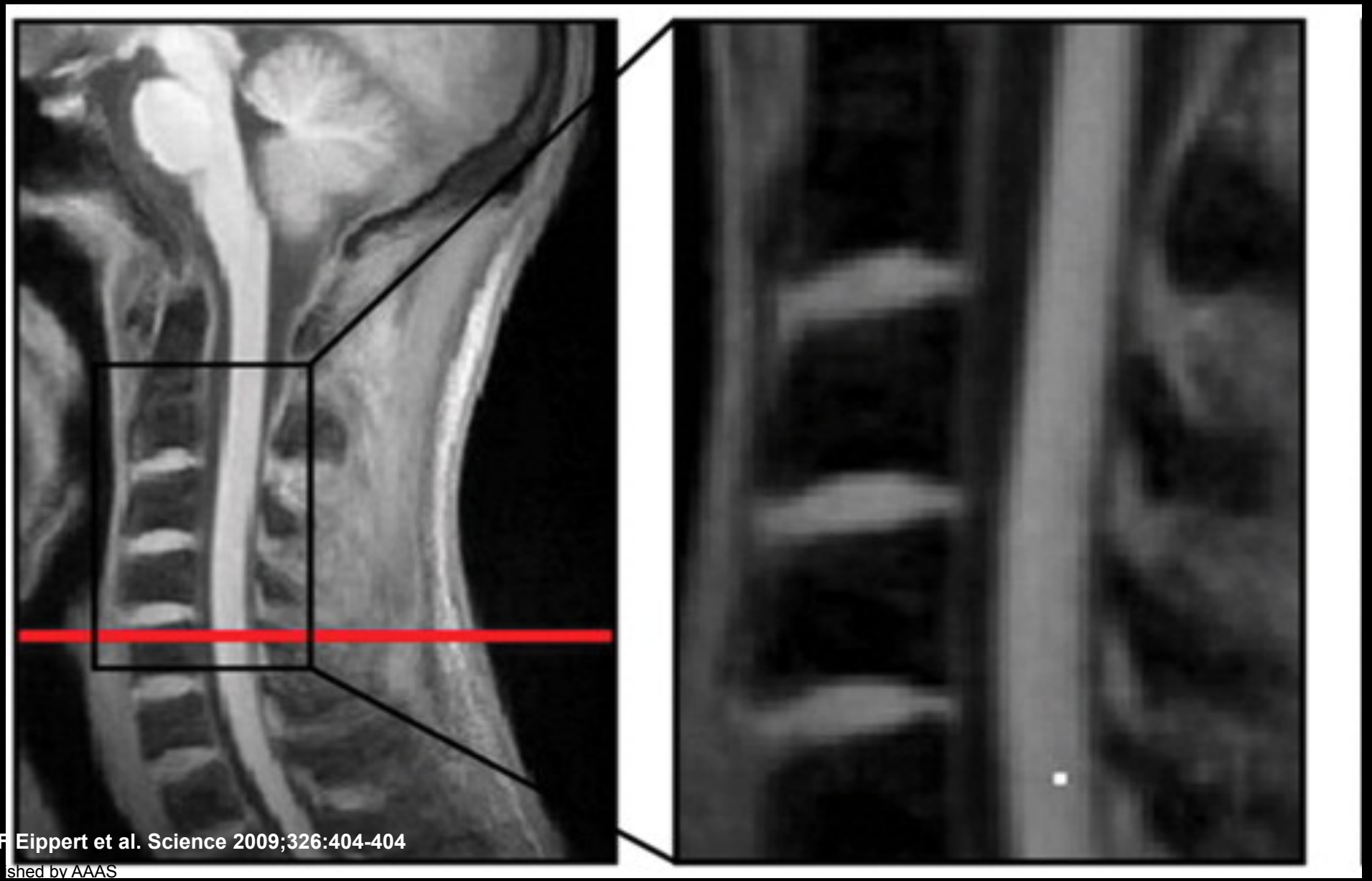


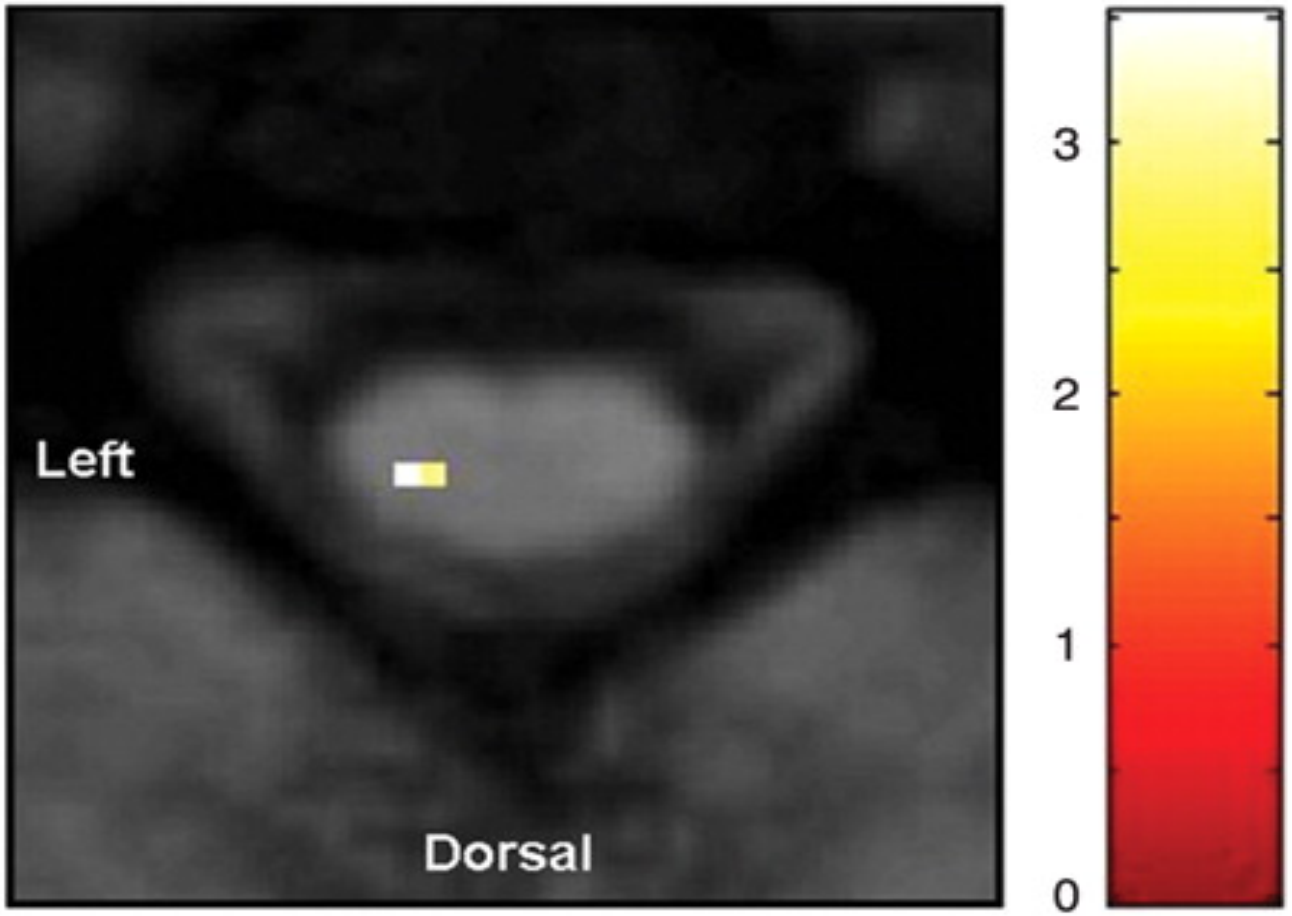
Table support
Perturbation
Hold cup
Perturbation
Perturbation
Average EMG
elbow extensor
Table support
Hold cup
–50
0
50
100
150
200
Time (ms)

Influence of descending pathways on spinal mechanisms

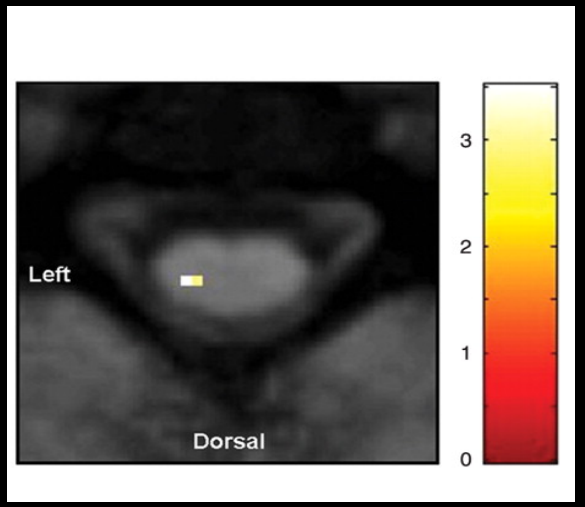
- voluntary movement
- reflex modulation
- gamma bias
  - alpha-gamma coactivation



F Eippert et al. Science 2009;326:404-404



F Eippert et al. Science 2009;326:404-404


Left
Dorsal
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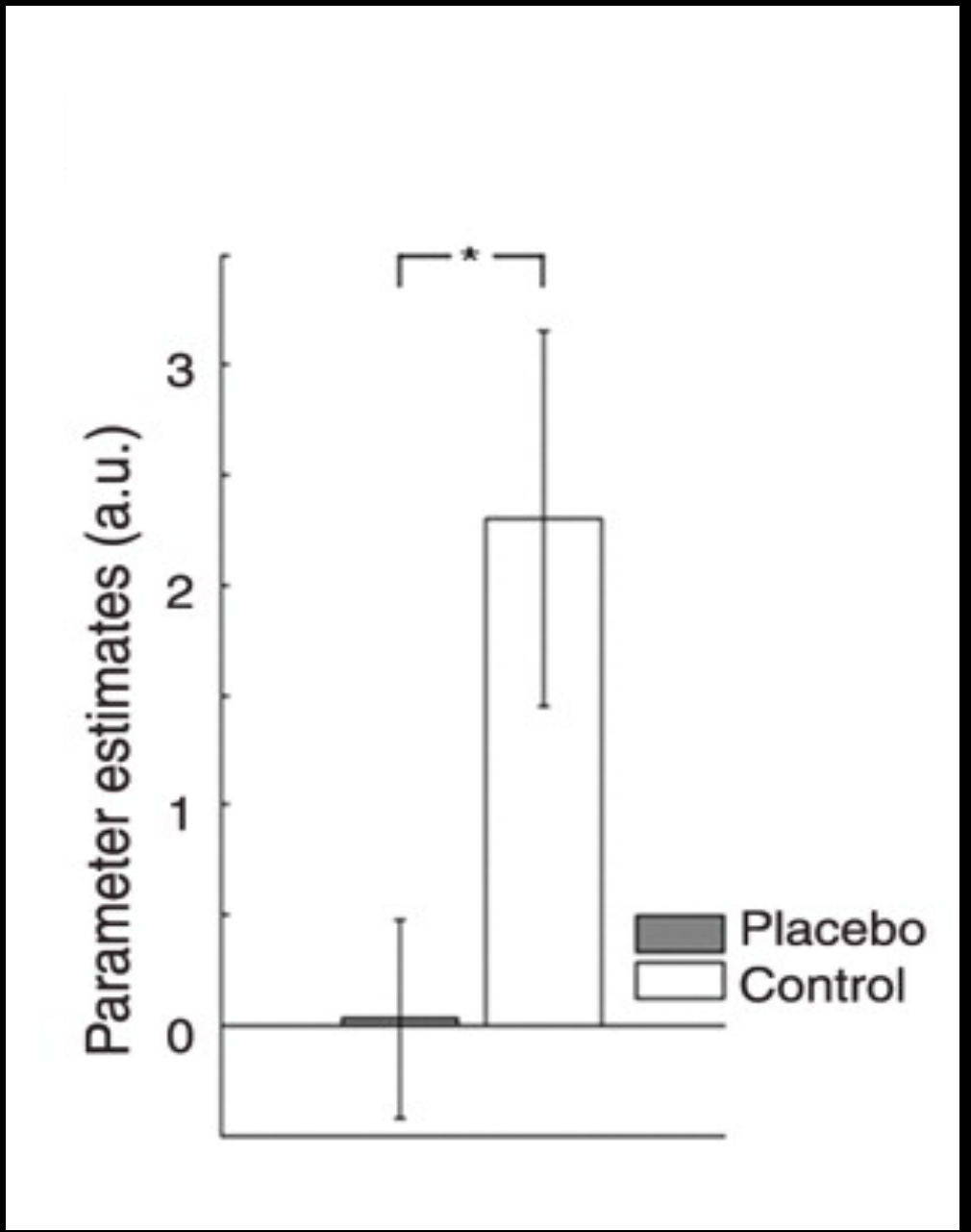
Parameter estimates (a.u.)
3
2
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0
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Placebo
Control

Hierarchical Organization and Functional Segregation of Central Motor Structures