Hierarchical Organization and Functional Segregation of Central Motor Structures

Level 4: Association Cortex

Level 3: Motor Cortex

Level 2: Brain Stem
(Red Nucleus, Reticular Formation, Vestibular Nuclei, Tectum, Pontine Nuclei, Inferior Olive)

Level 1: Spinal Cord

Level 0: Muscles

Side Loop 1: Basal Ganglia
(Caudate Nucleus, Putamen, Globus Pallidus, Substantia Nigra, Subthalamic Nucleus)

Thalamus
(VA, VL, CM)

Side Loop 2: Cerebellum
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

Primary ending

Neuromuscular junction

alpha motor neuron

la afferent

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

After surgery

- Brain
- Surgically reduced input from sensory fibers
- Dorsal Root (Sensory)
- Spinal Cord
- Ventral Root (Motor)
- Muscle
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

Pain receptor

Sharp tack

Excitatory interneurons

Alpha motor neurons

SN
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

- Course of afferent fibers
- Location of motor nuclei
- Dorsal root ganglion
- Dorsal horn
- Ventral horn
- Dorsolateral cell group
- Ventromedial cell group
- Motor nucleus (to axial muscle)
- Motor nucleus (to limb muscle)
- Flexor
- Proximal limb
- Extensor
- Distal limb
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

pyramidal decussation

anterior corticospinal tract

lateral corticospinal tract
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

- Pontine reticulospinal tract
- Medullary reticulospinal tract
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
Influence of descending pathways on spinal mechanisms

- voluntary movement
- reflex modulation
- gamma bias
  - alpha-gamma coactivation
Fig. 1 Pain-related BOLD responses and their reduction by placebo.

F. Eippert et al. Science 2009;326:404-404
Published by AAAS
Fig. 1 Pain-related BOLD responses and their reduction by placebo.

F. Eippert et al. Science 2009;326:404-404
Fig. 1 Pain-related BOLD responses and their reduction by placebo.

F Eippert et al. Science 2009;326:404-404
Published by AAAS
Hierarchical Organization and Functional Segregation of Central Motor Structures

Level 1: Spinal Cord

Level 2: Brain Stem
(Red Nucleus, Reticular Formation, Vestibular Nuclei, Tectum, Pontine Nuclei, Inferior Olive)

Level 3: Motor Cortex

Level 4: Association Cortex

Side Loop 1: Basal Ganglia
(Caudate Nucleus, Putamen, Globus Pallidus, Substantia Nigra, Subthalamic Nucleus)

Thalamus (VA, VL, CM)

Side Loop 2: Cerebellum