PHSL2101 – PHSL2121 – PHSL2501   Dr Richard Vickery

Neurophysiology 6 – Reflexes and motor system

Objectives

- Draw the neural circuits for the myotatic, Golgi tendon organ, and withdrawal reflexes.
- Distinguish the function and general course of the pyramidal and extrapyramidal motor pathways.
- Describe the roles of the higher motor areas, and the topographic organization of motor cortex.
- List the sequence of events in a movement, from initial planning through to execution.

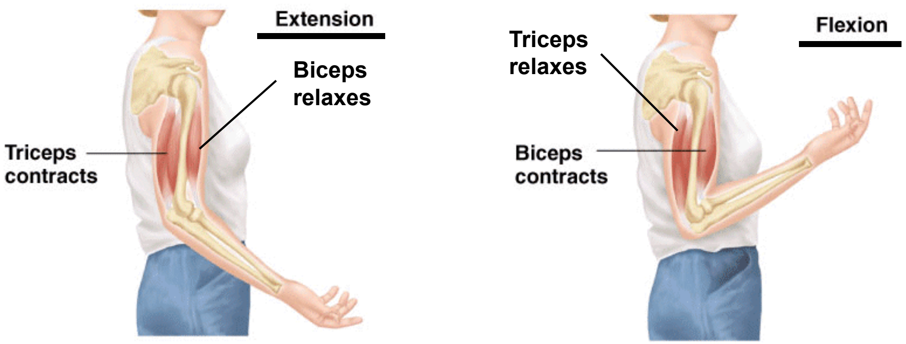
Reflexes

A reflex is:
- rapidly executed
- automatic
- stereotyped

A reflex may be:
- graded in strength
- subject to conscious modulation

A reflex arc has the following elements:
- sensory receptor (responds to stimulus)
- afferent neuron
- integration centre
- efferent neuron
- effector organ (produces response)

Antagonist muscles operate on the same joint in opposite directions



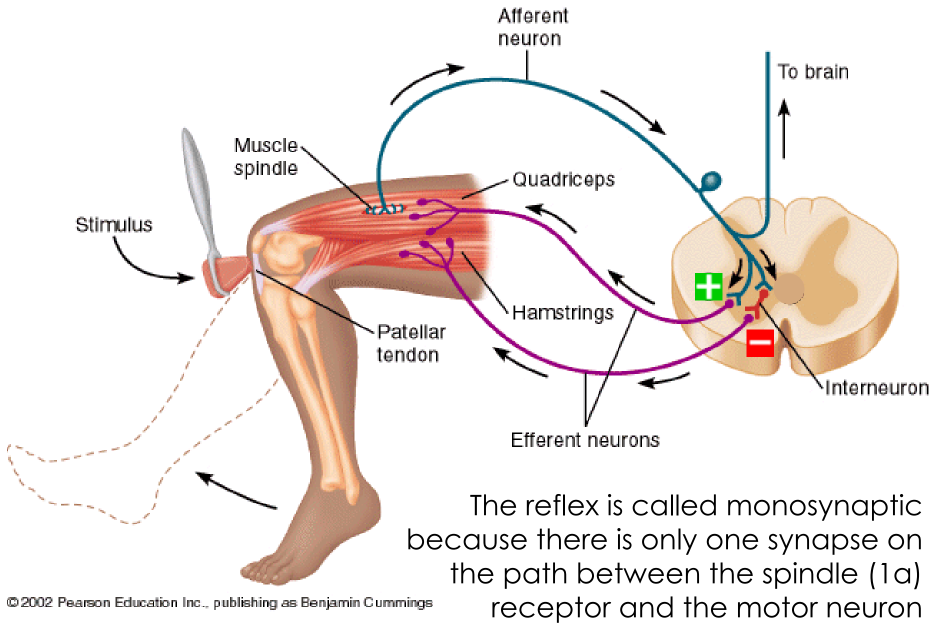
Triceps is the extensor muscle, which makes the arm straighten at the elbow

Biceps is the flexor muscle, which makes the arm bend at the elbow

Reflexes need to regulate both muscles to produce movement

from Sherwood, Human Physiology

Myotatic reflex with reciprocal inhibition



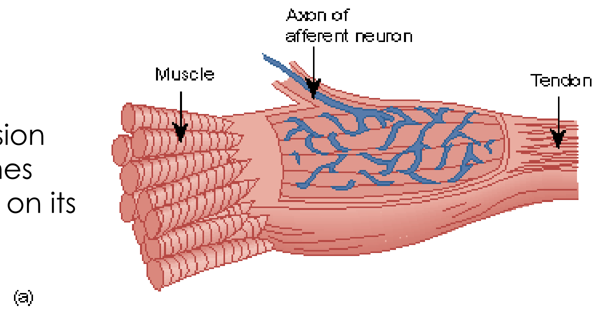
The reflex is called monosynaptic because there is only one synapse on the path between the spindle (1a) receptor and the motor neuron

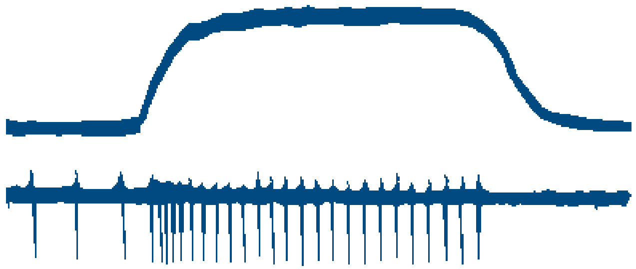
from Germann & Stanfield, Principles of Human Physiology

Reflexes

Golgi tendon organ

- in series with the extrafusal muscle
- signals muscle tension
- afferent is sometimes called "1b" based on its diameter.

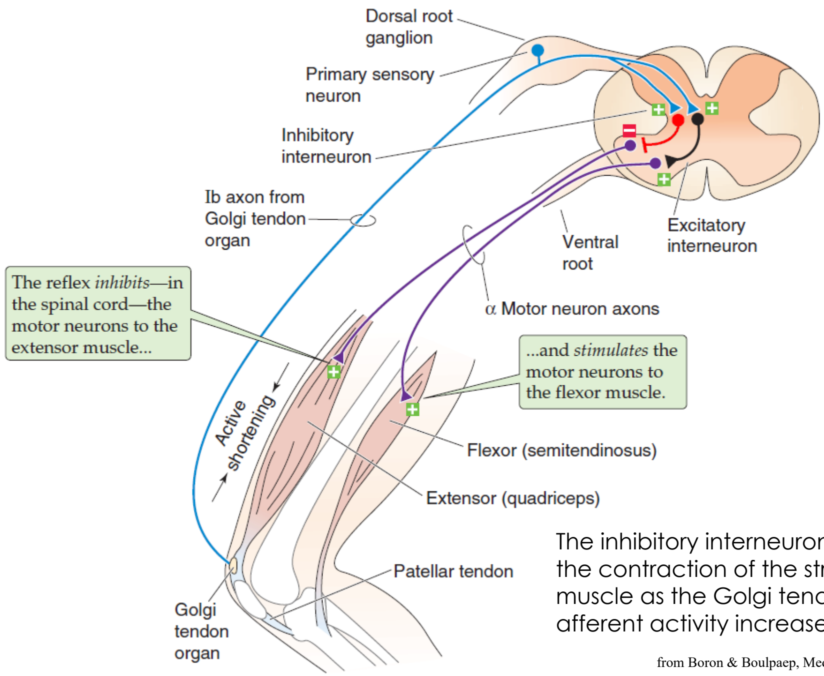




from Pocock & Richards, Human Physiology

Reflexes

Golgi tendon organ reflex

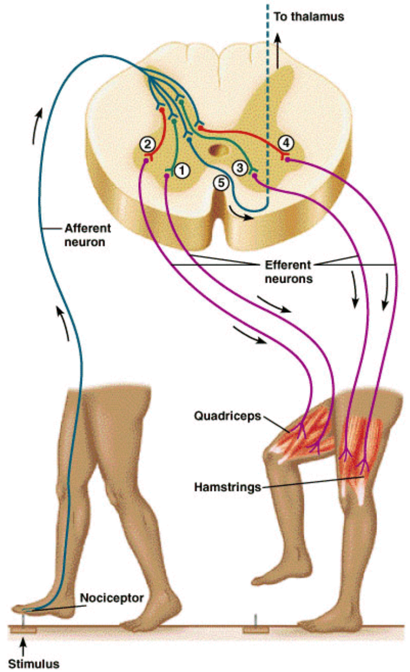


The inhibitory interneuron reduces the contraction of the stretched muscle as the Golgi tendon afferent activity increases

from Boron & Boulpaep, Medical Physiology

Reflexes

Withdrawal reflex, with crossed extensor reflex



This reflex is also called the *flexion* reflex or the *pain reflex*. This pathway uses interneurons for both the inhibitory and excitatory portions and causes extensive activity.

from Germann & Stanfield, Principles of Human Physiology

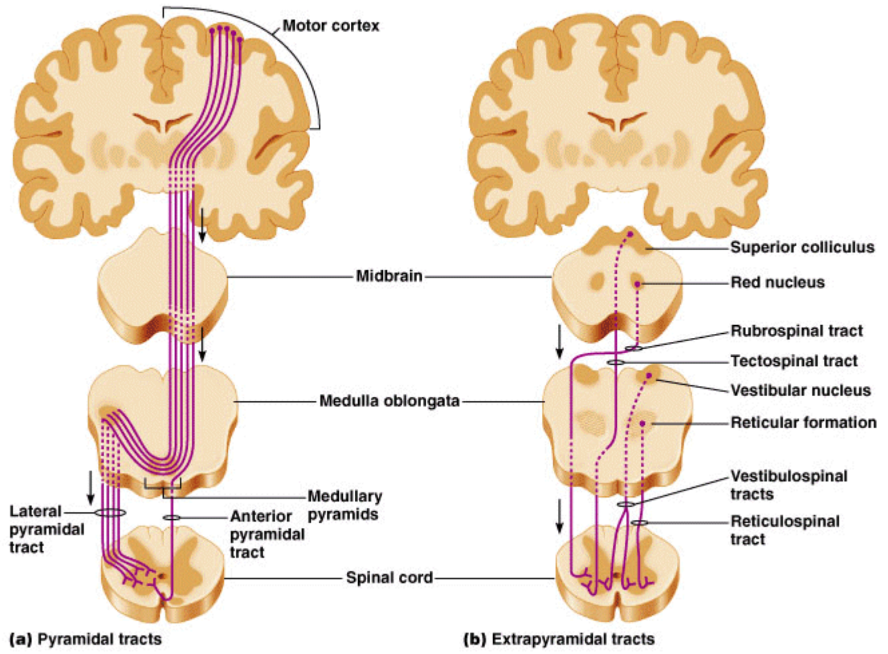
Reflexes

Reflexes

- All reflexes are driven by sensory inputs. Motor reflexes are usually driven by proprioceptors, pain receptors, or the vestibular system.
- To be effective, a motor reflex needs to act on all the antagonist muscles around a joint: causing contraction of one and relaxation in the other.
- Reflexes can operate in a tonic (ongoing) manner: the main role of the myotatic reflex is to hold a limb in stable position - not to make a knee jerk.
- Motor control involves descending inputs harnessing reflex responses to achieve the desired response.
- Motor reflexes happen automatically, but are still consciously detectable. This is because the original afferent activity that activated the reflex still goes to cortex, and also because the reflex movement may cause a burst of afferent activity.

Motor pathways

Central Pathways for Motor Information



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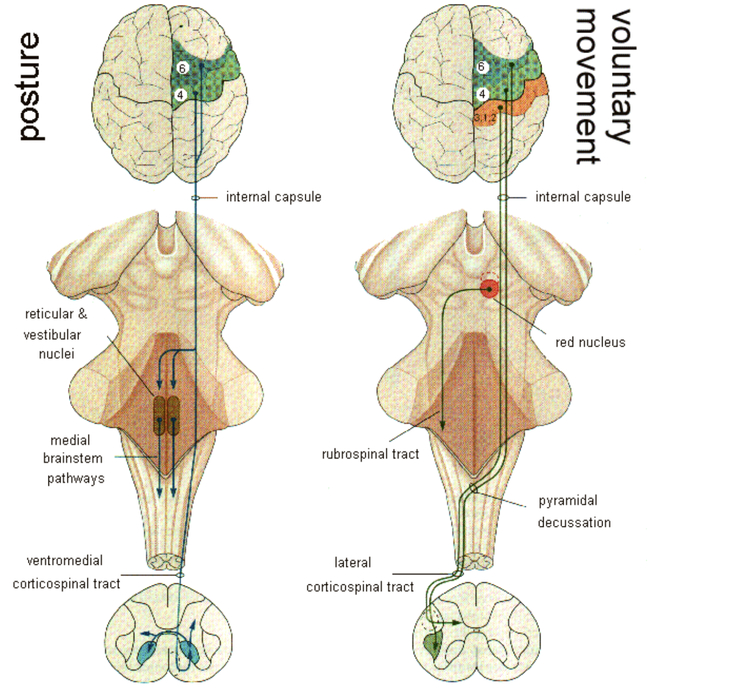
Motor pathways

Two classes of motor pathway



from Bear, Paradiso & Connors, Neuroscience: exploring the brain

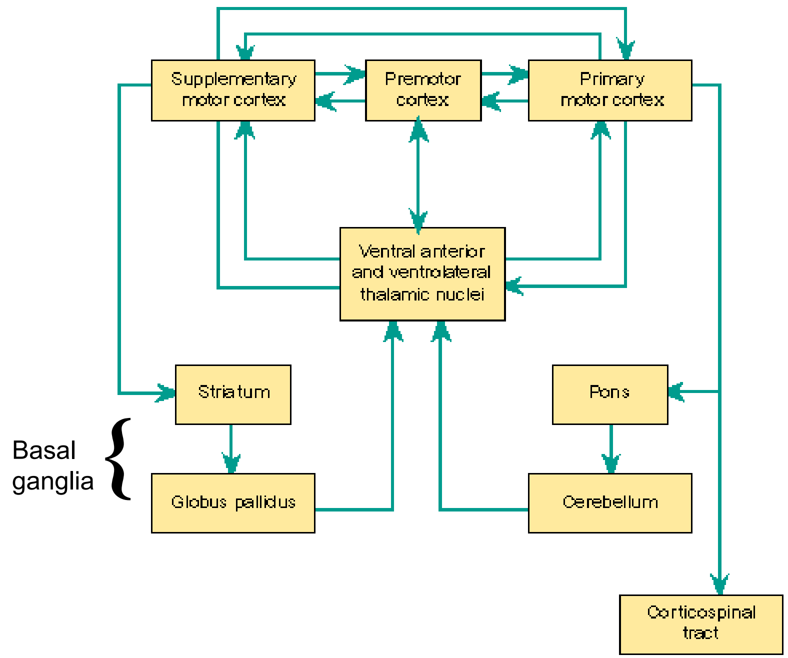
Motor pathways

Motor pathways

- Descending control of the spinal motor neurons comes from the motor cortex, and from brain stem motor nuclei.
- The corticospinal and the corticobulbar (motor control of face) make up the pyramidal tract. About 2/3 of these fibres originate in motor cortex. Some of these axons synapse onto brainstem nuclei that give rise to the extrapyramidal tracts.
- About 90% of corticospinal axons decussate and control the contralateral limbs via the lateral corticospinal tract. The remaining 10% form the ventromedial corticospinal tract, remain ipsilateral and control posture.
- Spinal neurons of limbs and digits can be controlled directly by corticospinal neurons travelling via the lateral corticospinal tract. There are ~ 10^6 corticospinal axons.
- Postural movements are driven via the brain stem nuclei and the ventromedial corticospinal tract, that innervates interneurons in spinal cord and activates motor neurons on both sides of the body.

Higher motor areas

Organization of higher motor areas



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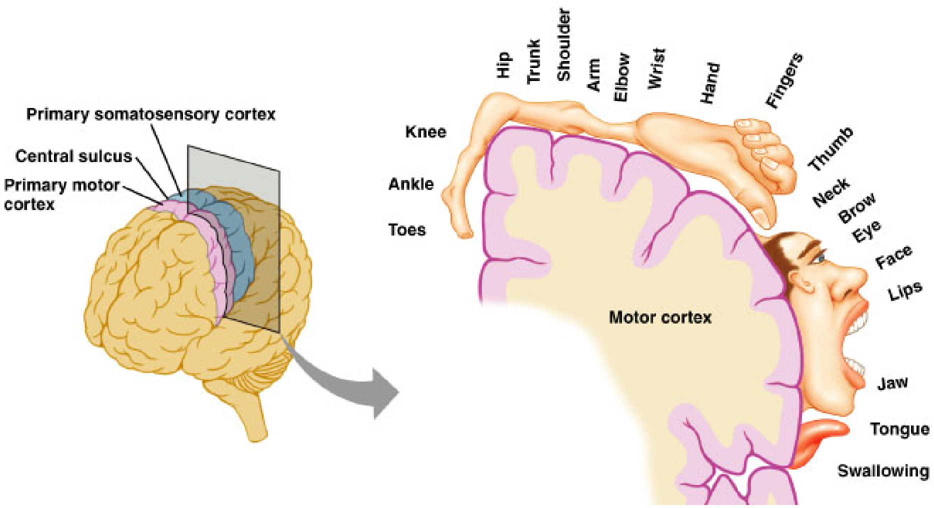
Topographic organization of primary motor cortex



This map is basically just like the one for somatosensory cortex.

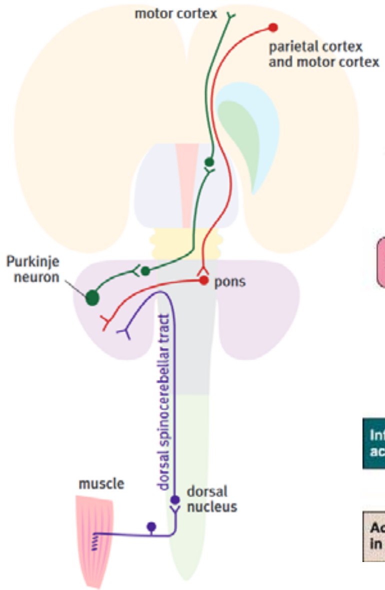
from Germann & Stanfield, Principles of Human Physiology

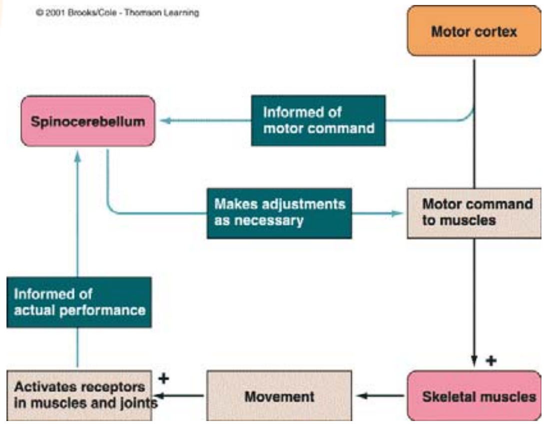
Primary Motor Cortex

Plays an important role in:
- direct output to lower motor neurons
- output to brainstem motor nuclei to exert indirect control of lower motor neurons
- integration of information from other motor areas

Lesions may cause:
- paralysis or weakness, on the opposite side of the body, and restricted by topographic organization
- hyperreflexia and hypertonia, which together constitute spasticity

Cerebellar Control Loop





from Watson, Kirkcaldie & Paxinos, The Brain

from Sherwood, Human Physiology

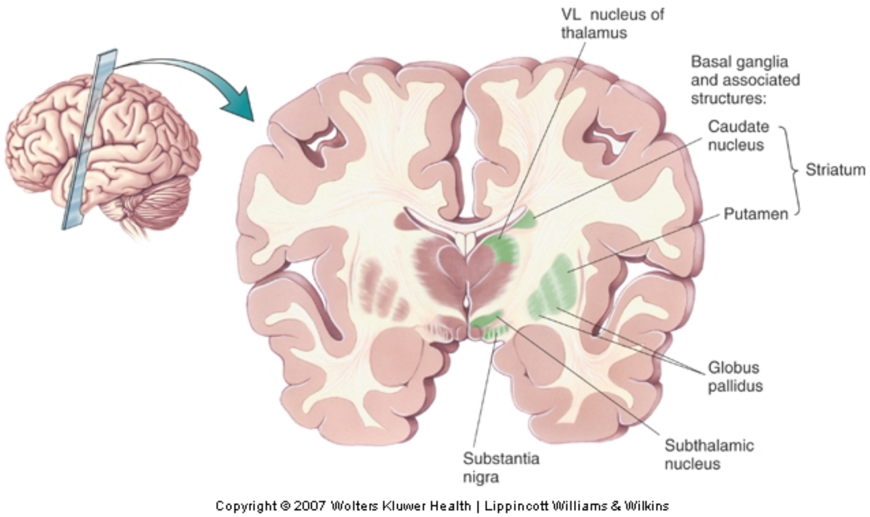
Cerebellum

Plays an important role in:
- control of posture and muscle tone
- correction and coordination during slow goal-directed movement and coordination of these movements with posture
- ensuring smooth execution of rapid goal-directed movement
- motor learning

Lesions may cause:
- intention tremor
- clumsiness and disconnected movements
- dizziness
- postural difficulties
- problems with speech

Higher motor areas

Location of the basal ganglia



from Bear, Paradiso & Connors, Neuroscience: exploring the brain

Higher motor areas

Function of basal ganglia

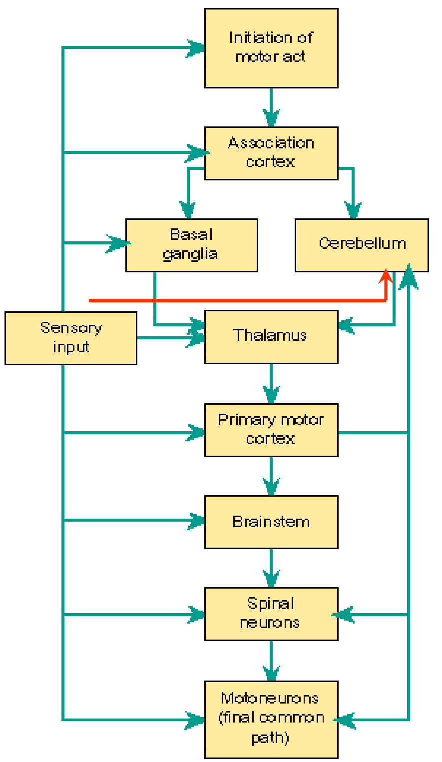
Play an important role in:
- planning of movements
- initiating movement

Lesions may cause:

Parkinson's-like symptoms: akinesia
- muscle rigidity
- resting tremor
- slowness or absence of movement

Huntington's chorea-like symptoms: dyskinesia
- loss of motor co-ordination
- spontaneous jerking and twitching movements

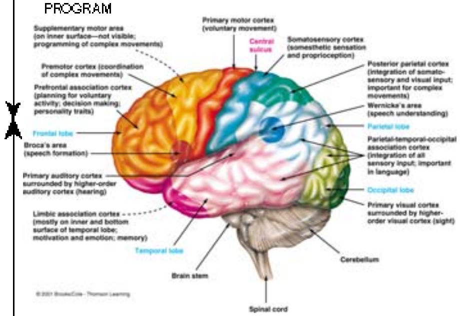
Integrating the motor system



PLAN

Integration to produce a simple action

PROGRAM



EXECUTION

from Pocock & Richards, Human Physiology

Integrating the motor system

Integrating the motor system

- Like the autonomic nervous system, there are a series of levels of control loops for the motor system.
- At the lowest level is reflex control, where peripheral receptors can produce limb movement.
- These reflexes can be integrated in the spinal cord to produce co-ordinated movements such as stepping, or the withdrawal reflex affecting four limbs.
- At the highest level, a movement is initiated by interactions between sensory input (possibilities), the limbic system (desires) and pre-frontal cortex (decision). The association areas of cortex have an integrated view of the environment and inform the plan of action.
- The basic plan of action needs to be translated into a motor program. This involves basal ganglia, cerebellum and the supplementary and pre-motor cortices.
- The primary motor cortex is given the “go” signal by basal ganglia, and then sends the motor program out to the motor neurons, directly, and via the brain stem nuclei.
- The motor neurons fire action potentials, depolarize muscle fibres at the neuromuscular junction, cause muscle contraction which ultimately carries out the desired action. - Simples!