Cortical Control of Movement

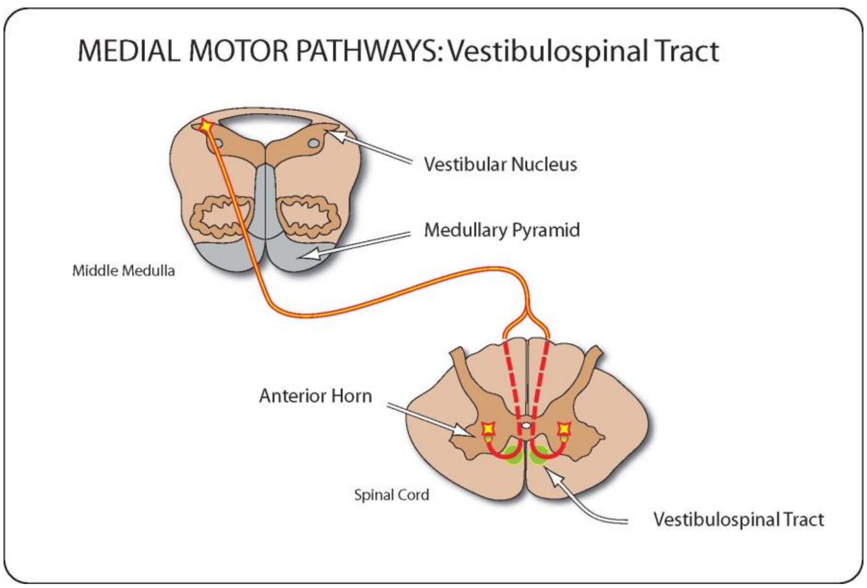
Brainstem and Cortical Control of Motor Neurons

Medial Motor Pathways

The medial motor pathways originate from the cerebral cortex and brainstem and mediate voluntary and involuntary control of the head and trunk; especially in the control of posture. The medial motor pathways include the

- Vestibulospinal tract
- Tectospinal tract
- Reticulospinal tracts

Signals from the vestibular apparatus, including the semicircular canals, are involved in the control of head movement and posture as well as in the control of eye movement. The basic organization of the vestibulospinal tract, which is involved in the control of head movement and posture, is shown in Figure 12.8.



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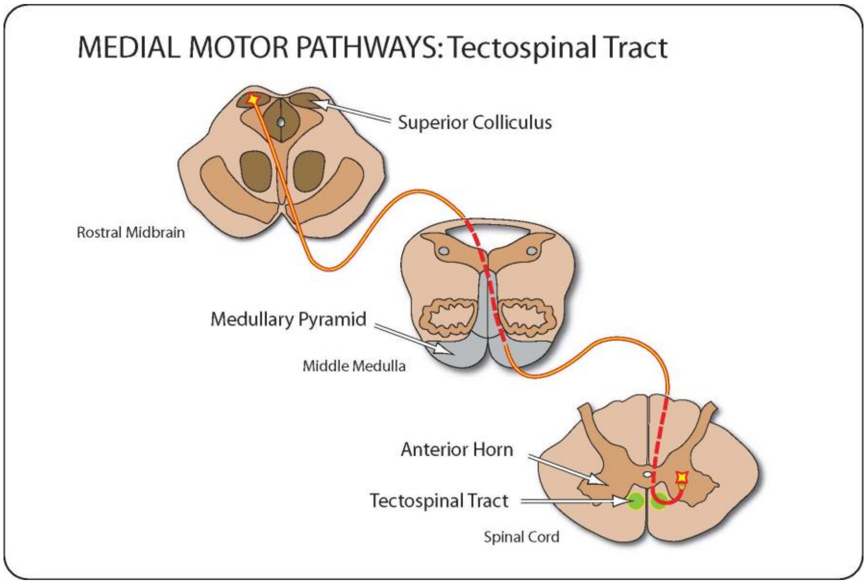
- Axons of neurons in the vestibular nuclei descend through the brainstem.
- One component continues bilaterally down the spinal cord to activate cervical spinal circuits that control neck and back muscles.
- Another component continues ipsilaterally down the spinal cord to activate lumbar spinal circuits that control the legs. Here motor neurons controlling extensor muscles are commonly excited.

Signals from the retina and the visual cortex are involved in the control of head movement eye movement as well as vision. Each superior colliculus receives signals both from the retina and from the visual cortex, and sends signals to the spinal cord. (The superior colliculus is sometimes referred to as the optic tectum, and thus the connection between the superior colliculus and the spinal cord is called the tectospinal tract.) The basic organization of the tectospinal tract, which is involved in the control of head movement, is shown in Figure 12.9.



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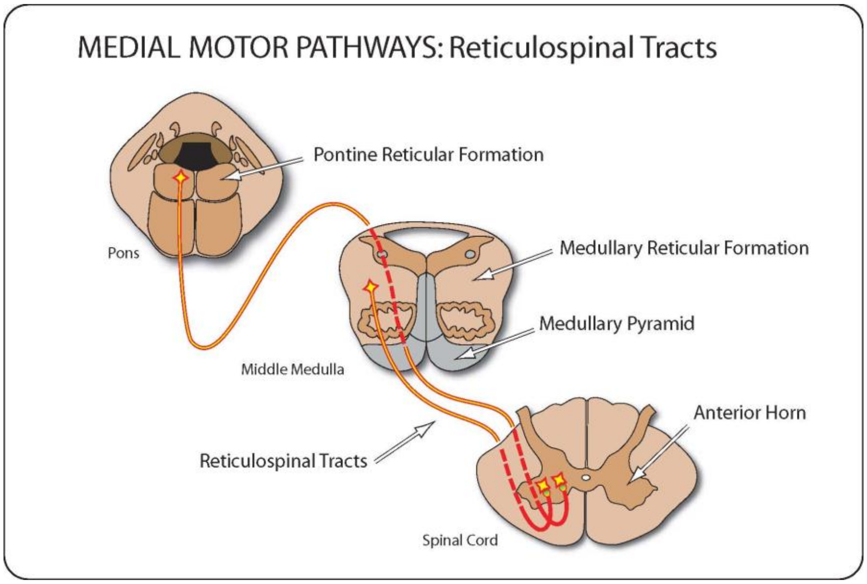
- Axons of neurons in the superior colliculus descend through the brainstem.
- The axons continue contralaterally down the spinal cord to activate cervical spinal circuits that control head and neck muscles. The head is moved so that the target of interest is imaged on the fovea.

Most of the time, the activity of neurons in the anterior horn of the spinal cord maintains (rather than changes) the length and tension of muscles. Recall that a primary function of the circuitry for the stretch reflex is to maintain muscle length and tension. The sensitivity of these circuits is controlled in part by the reticulospinal tracts. As shown in Figure 12.10, one reticulospinal tract originates in the pons and another originates in the medulla.



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- Axons of neurons in the reticular formation of the pons descend through the brainstem ipsilaterally to synapse on neurons in the ventral horn. Reflex control of extensor muscles of the lower limbs is facilitated.
- Axons of neurons in the reticular formation of the medulla descend through the brainstem ipsilaterally to synapse on neurons in the ventral horn. Reflex control of extensor muscles of the lower limbs is suppressed.

Lateral Motor Pathways

The lateral motor pathways originate from the cerebral cortex or midbrain and mediate voluntary control of distal extremities, especially digits, and mimetic movements of the face and tongue. The lateral motor pathways include the

- Lateral Corticospinal tract
- Rubrospinal tract

The lateral corticospinal tract is the most important of the lateral motor pathways and is shown in Figure 12.11. The corticospinal tract originates from pyramidal cells (neurons) in the motor cortex.

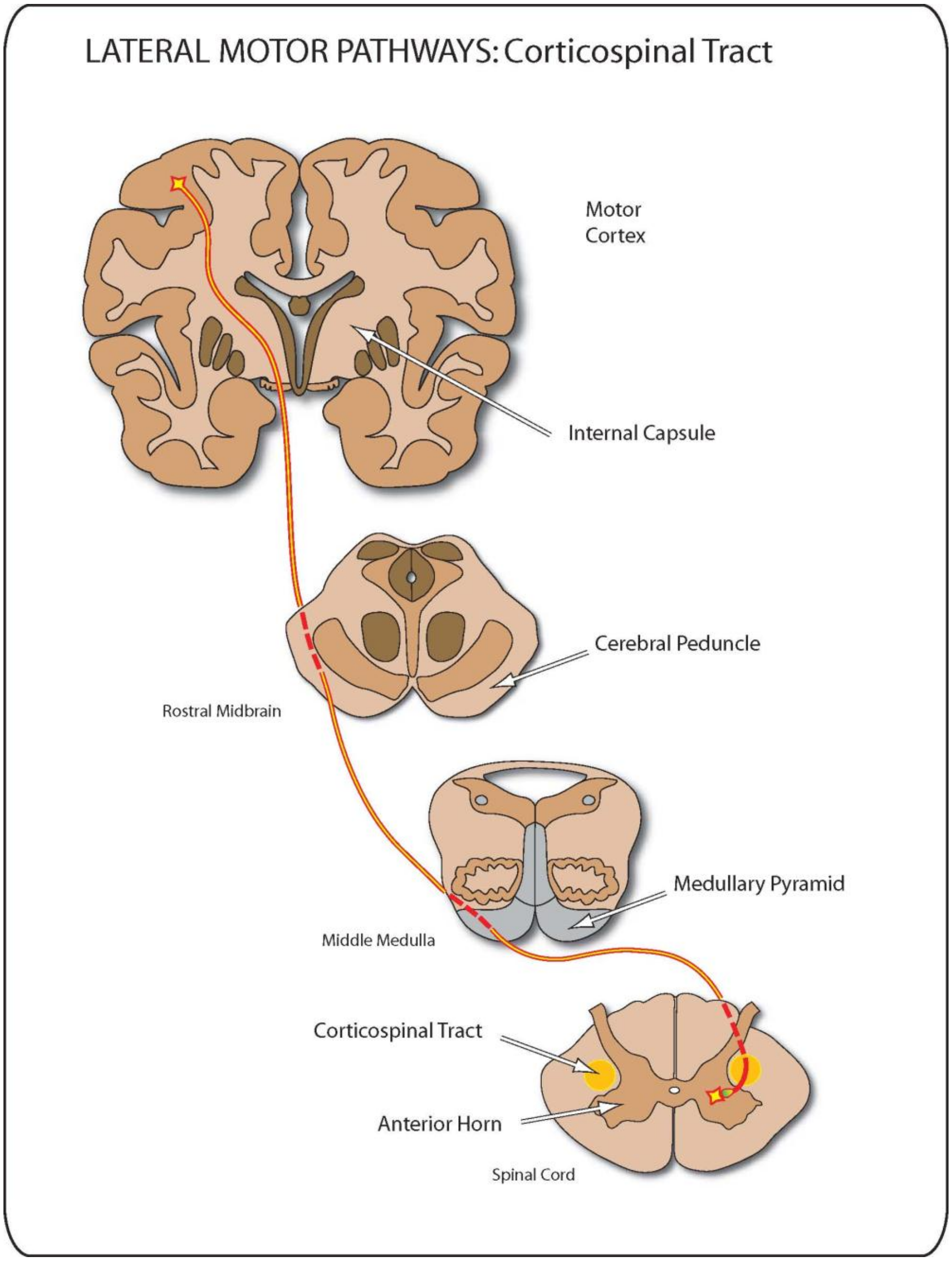


Figure 12.11 © 2007 David G. Ward, Ph.D.

- Axons of pyramidal cells (neurons) in the motor cortex descend ipsilaterally through the internal capsule, the base of the cerebral peduncle and into the medullary pyramid.
- At the junction of the medulla and spinal cord the axons cross over and descend contralaterally through the corticospinal tract to synapse on motor neurons in the anterior horn of the spinal cord.

The rubrospinal tract is a smaller component of the lateral motor pathways and is shown in Figure 12.12. The rubrospinal tract originates in the red nucleus of the midbrain which in turn receives its major source of input from the motor cortex.

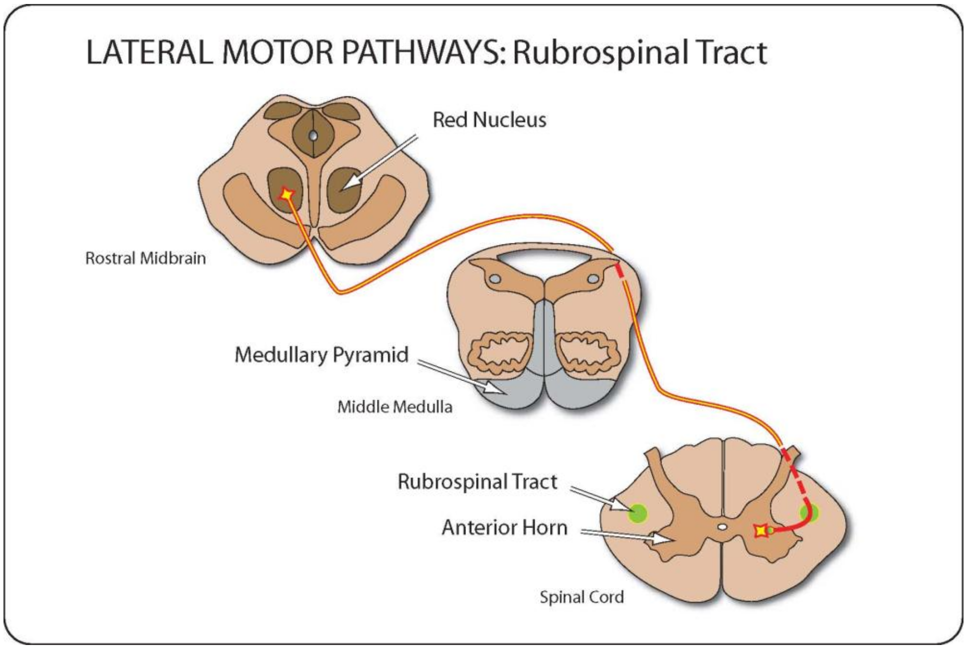
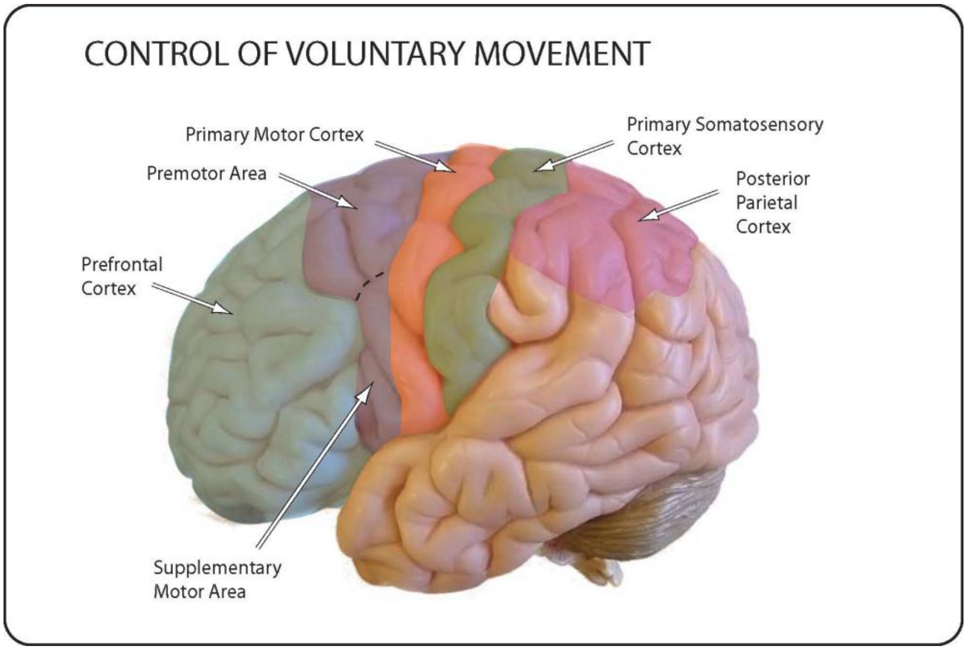


Figure 12.12 © 2007 David G. Ward, Ph.D.

- Axons of neurons in the red nucleus cross over in the pons and descend contralaterally into the medulla.
- The axons run parallel with those of the corticospinal tract to synapse on motor neurons in the anterior horn of the spinal cord.

Cortical control of Voluntary Movement

Much of the cerebral cortex is involved in control of voluntary movement. Critical regions of the cerebral cortex are shown in Figure 12.13. As we saw in Chapter 9, the primary somatosensory cortex is located posterior to the central sulcus in the postcentral gyrus. We now see that the primary motor cortex is located anterior to the central sulcus in the precentral gyrus.



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Both the premotor area and the supplementary motor area are located anterior to the primary motor cortex.

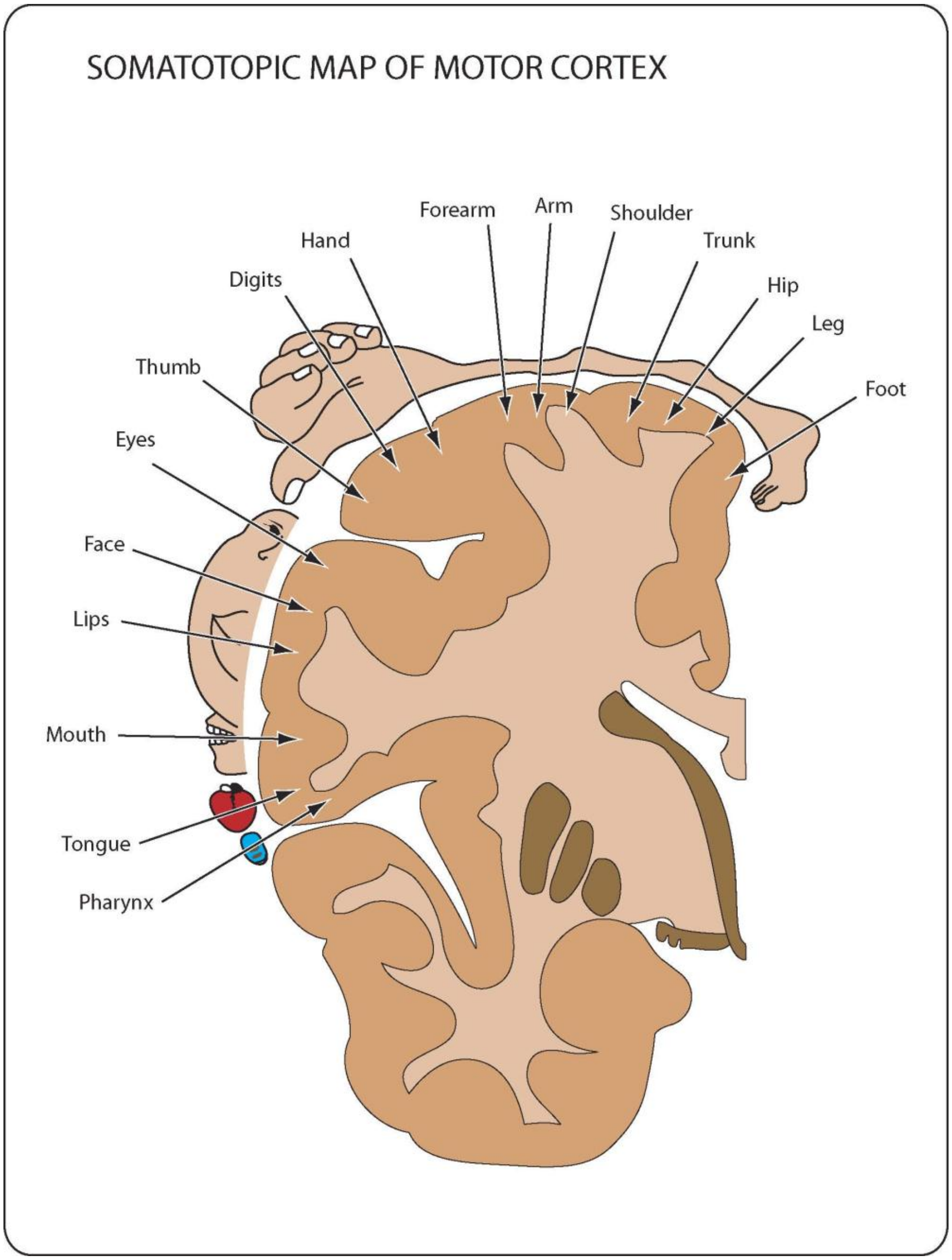
- The supplementary motor area is somatotopically organized and controls distal muscles.
- Axons of neurons in the supplementary motor area synapse directly on motor neurons in the brainstem and spinal cord and form part of the lateral corticospinal tract.
- The premotor area is somatotopically organized and controls proximal muscle.
- Axons of neurons in the premotor area synapse on neurons in the pons and medulla that give rise to the reticulospinal tracts.

Other cortical areas are also critically involved in control of voluntary movement.

- The posterior parietal cortex is involved in control of body image and perception of spatial relations.
- The prefrontal cortex is involved in abstract thought, decision making and anticipating the consequences of action.
- Both the posterior parietal cortex and the prefrontal cortex send axons that synapse on neurons of the supplementary motor area and the premotor area.
- The posterior parietal cortex and the prefrontal cortex may be the junctions where signals encoding *what* actions are desired are converted into signals that specify *how* the actions will be carried out.

Furthermore, the primary motor cortex is organized somatotopically, as shown in Figure 12.14, much like the somatosensory cortex.

- The primary motor cortex is somatotopically organized.
- Axons of neurons in the primary motor cortex synapse directly on motor neurons in the brainstem and spinal cord.
- Much of the lateral corticospinal tract originates in the primary motor cortex.
- When a command for a voluntary movement passes through the lateral corticospinal tract it coactivates alpha motor neurons and gamma motor neurons.



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The Basal Ganglia (Nuclei)

One of the functions of the basal nuclei appears to be the selection and initiation of willed movement. The organization of the basal nuclei and some of their critical connections is shown in Figure 12.15.

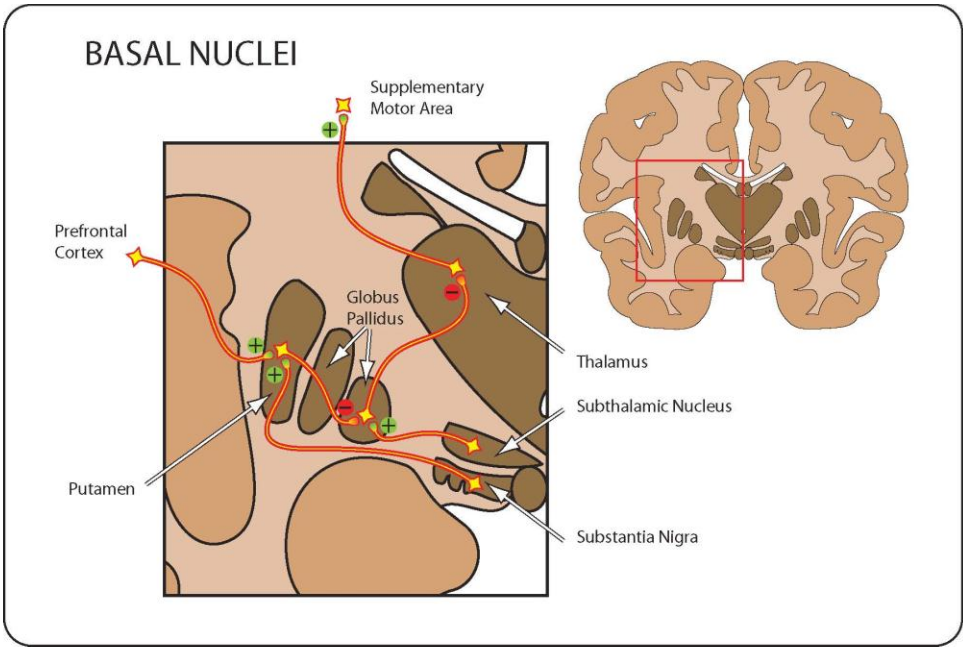

Figure 12.15 © 2007 David G. Ward, Ph.D.

- Neurons in the prefrontal cortex send excitatory signals to the putamen and caudate nucleus.
- The putamen also receives excitatory signals from the substantia nigra.
- Neurons in the putamen send inhibitory signals to the globus pallidus.
- The globus pallidus also receives excitatory signals from the subthalamic nucleus.
- The globus pallidus sends inhibitory signals to the thalamus (ventral lateral nucleus).
- The thalamus sends excitatory signals to the supplementary motor area.
- The signals from the thalamus to the supplementary motor cortex provide a"Go" signal to initiate movement.

Patients with Parkinson's disease exhibit slowness of movement, difficulty in initiating willed movements, increased muscle tone, and tremors. Loss of dopamine neurons in the substantia nigra, and subsequent loss of excitatory input to the caudate nucleus and putamen, seems to account for the disorders of movement in Parkinson's patients.

Patients with Huntington's disease exhibit excess movements, abnormal movements, impaired cognitive abilities, and a disorder of personality. Loss of neurons in the caudate nucleus, putamen, and globus pallidus, and subsequent loss of inhibitory input to the thalamus, seem to account for the disorders of movement in Huntington's patients.

The Cerebellum

The cerebellum appears to be critically involved with the detailed sequencing and timing of muscle contractions.

- The cerebellum contains more than 50% of the total number of neurons in the CNS.
- The cerebellum is critical for the proper execution of planned voluntary multi-joint movements.
- The cerebellum appears to provide information to the primary motor cortex about the direction, timing, and force of a movement.
- The cerebellum is important for motor learning. For some movements, information provided to the primary motor cortex is based entirely on predictions through experience about the outcome of the movement.

Patients with damage to the cerebellum exhibit uncoordinated and inaccurate movement. Joints are moved sequentially rather than simultaneously. Movements tend to wander and overshoot or undershoot their target.