The Sensorimotor System: Cortex
Hierarchical Organization
- association cortex at the highest level, muscles at the lowest
- signals flow between levels over multiple paths

Motor output is guided by sensory input

Learning changes the nature and locus of sensorimotor control (e.g., conscious to automatic)
Association cortex is at the top of the sensorimotor hierarchy.

There are two major areas of sensorimotor association cortex:
• posterior parietal
• dorsolateral prefrontal

Each is composed of several different areas with different functions.
Before a movement can be initiated, need to know:
• current position of body parts; and
• location of external objects of interest

The PPAC receives input from the **dorsal streams** of the somatosensory, auditory and visual systems and thus plays an important role in integrating these two types of information.
Electrical stimulation of the PPAC causes patients to experience the **intent** to perform a particular action.

Damage to PPAC:
- apraxia (left): inability to make a requested movement (i.e., cannot form intent)
- contralateral neglect (right): inability to respond to stimuli contralateral to the lesion

Outputs to dorsolateral prefrontal association cortex, secondary motor cortex, and frontal eye field.
Dorsolateral Prefrontal Association Cortex

The DLPFAC receives inputs from, and projects to, the PPAC.

Given an intent to move, the DLPFAC, with other frontal lobe inputs including the ventrolateral PFC (which is the termination site of the ventral streams), anticipates the consequences of various movements and forms a plan of action.

Outputs to secondary motor cortex, primary motor cortex, and frontal eye field.
Inputs from association cortex (mainly DLPFAC)

Three major areas (each subdivided): premotor, supplementary and cingulate

The secondary motor cortex converts general plans of action into **specific sets of instructions**
- active during imagining or planning of movements

Outputs to primary motor cortex
Located in the precentral gyrus of the frontal lobe (in front of the central fissure)

Major point of convergence of cortical sensorimotor signals. Major, but not only, point of departure of signals from cortex.

Controls the **execution** of movement
The motor cortex is organized in a somatotopic manner; that is, according to a body map.

Most of primary motor cortex is dedicated to controlling body parts that are capable of intricate movements, such as the hands and face.

Each site receives feedback (from primary somatosensory cortex) from receptors in the muscles and the joints that the site influences.
Activation of the homunculus at a given site with natural-duration stimulation elicits complex, species-typical movements involving that body part.

Neurons direct movement of a body part to a target location regardless of starting position. This implies that signals from a given cortical area must contact multiple muscles to allow for this range of motion.

Small lesions often have minimal effects. Large lesions may disrupt a patient’s ability to move one body part independently of others.
Many neurons in sensorimotor cortex (up to 50% in some areas) are active not only when performing a specific action, but are also active when a person imagines or watches the same action.

The body does not move when mirror neurons fire because the overall level of activity is lower than needed.

A possible neural basis of learning by imitation
Cerebellum and Basal Ganglia

Interact at many levels of the sensorimotor hierarchy

Coordinate and modulate

May permit maintenance of visually-guided responses despite cortical damage
Cerebellum

10% of brain mass, but more than 50% of its neurons

Informed of motor commands by inputs from primary motor cortex, and from brainstem motor nuclei

Informed of actual motor performance by feedback from somatosensory and vestibular systems

Involved in coordination, precision and timing of execution commands from primary motor cortex. Also involved in motor learning
Basal Ganglia 1

A collection of interconnected, midline, nuclei located lateral to the thalamus

Includes the striatum (caudate and putamen), globus pallidus (external and internal), subthalamic nucleus and substantia nigra

http://cti.itc.virginia.edu/~psyc220/kalat/JK246.fig8.15.basal_ganglia.jpg
Two major functional pathways through basal ganglia, direct and indirect/hyper-direct, with opposite net effects on thalamic targets. Proper function: balance

Direct: excitation
   Facilitates motor (or cognitive) programs in the secondary motor cortex that are adaptive for the present task

Indirect/hyper-direct: inhibition
   Inhibits the execution of competing motor programs.
**Basal Ganglia 3: Parkinson’s Disease**

**Parkinson’s disease** is characterized by slowness or absence of movement (bradykinesia or akinesia), rigidity, and a **resting tremor** (hands, fingers).

Cause: the loss of the **dopaminergic neurons** in the **substantia nigra**

Direct pathway striatal neurons have D1 dopamine receptors, which cause depolarization, whereas indirect pathway striatal neurons have D2 dopamine receptors, which cause hyperpolarization. Thus, the nigrostriatal pathway has the net effect of exciting secondary motor cortex by two routes. In Parkinson’s disease, balance is tipped in favor of the indirect inhibitory pathway.
The symptoms of Huntington’s disease are in many respects the opposite of the symptoms of Parkinson’s disease. Huntington’s disease is characterized by choreiform movements: involuntary, jerky movement of the body, especially of the extremities and face.

Huntington’s disease results from the selective loss of striatal neurons in the indirect pathway. Thus, the balance between the direct and indirect pathways becomes tipped in favor of the direct pathway. Without their normal inhibitory inputs, thalamic neurons can fire randomly and inappropriately, causing the secondary motor cortex to execute motor programs with no control by the patient.