MCB/Neuro 80 - Neurobiology of Behavior

Today's Topic:

MOTOR SYSTEMS - 2

Lecture 18

Optional reading: Purves et al., Neuroscience 6th pages 381-383, 387-391, 395-398, 401

Lecture notes, review questions, office hour times available at:

https://canvas.harvard.edu/courses/59120

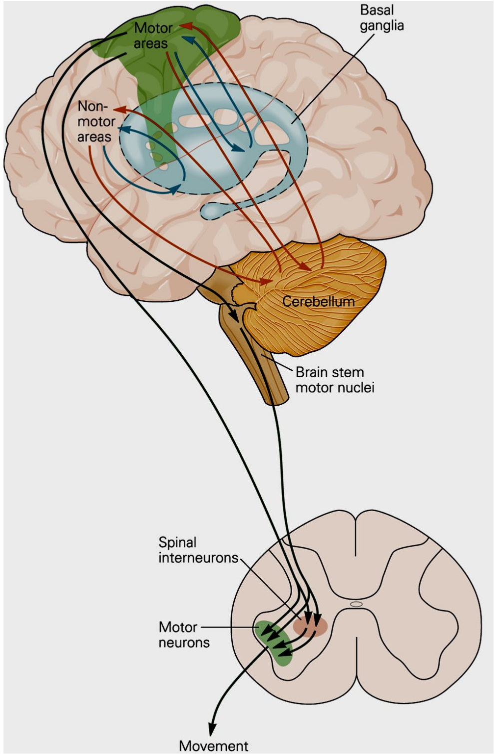

CLIMBING MT. POTENTIAL
(IN PRACTICE)
Response
Sensory/motor diseases
Upper Motor
Spinal Circuits
Neuronal processing
Cognition
Structural changes and aging
Long term synaptic plasticity
Memory systems
Stimulus (sensing information)
Information Coding
Other Senses
Visual system:
• Sensory transduction
• Visual circuits
• Cortical visual processing

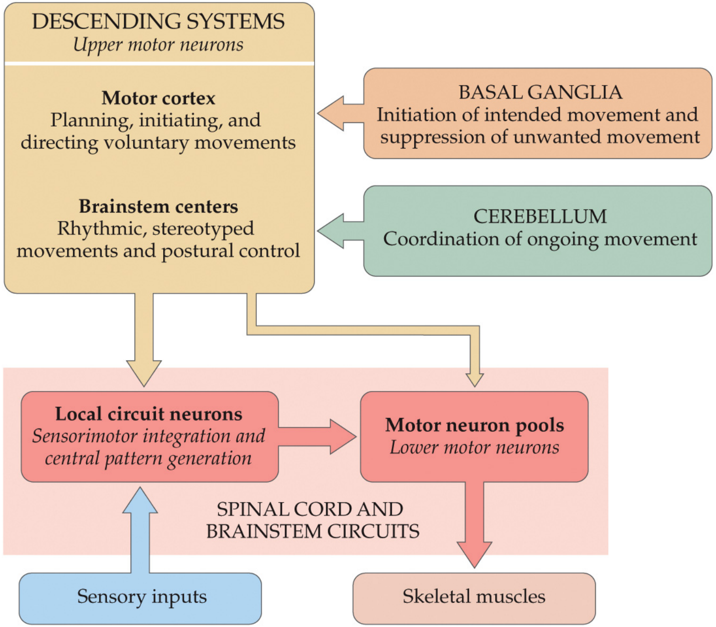
Motor system gives rise to all behavior

"We have a brain for one reason and one reason only – and that's to produce adaptable and complex movements"

(Daniel Wolpert, neuroscientist)

Overall organization





NEUROSCIENCE 6e, Figure 16.1

Voluntary control of movement

Conscious processes are not necessary for the moment to moment control of movement

Movements appear “effortless” as long as there is a steady stream of sensory information (vision, somatic sensation, vestibular) - take walking for example (you slow down with eyes closed).

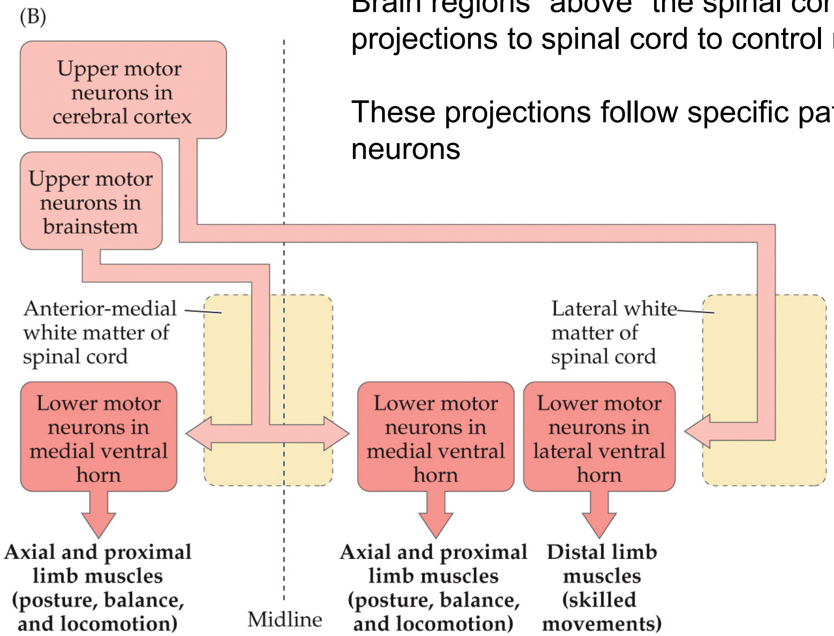
Successively higher levels of the motor hierarchy specify increasingly more complex aspects of a motor task

Reflexive (“lowest”) then rhythmic then voluntary (“highest”)- but even more complicated: learned movements become reflexive with practice!

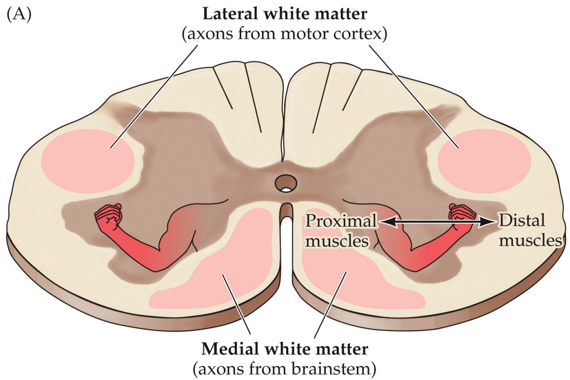
Descending control of movement

Brain regions “above” the spinal cord (brainstem, cortex) send projections to spinal cord to control motor neuron activity

These projections follow specific pathways, and target specific neurons

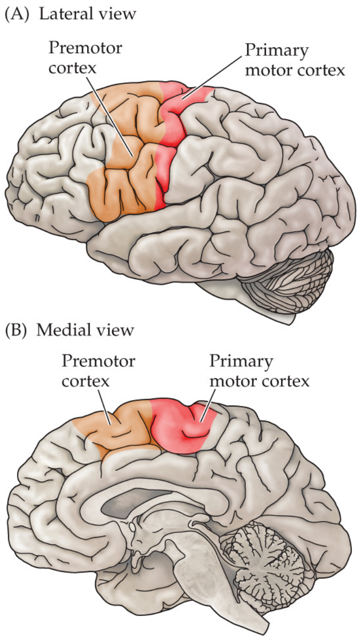


NEUROSCIENCE 6e, Figure 17.1 (Part 2)

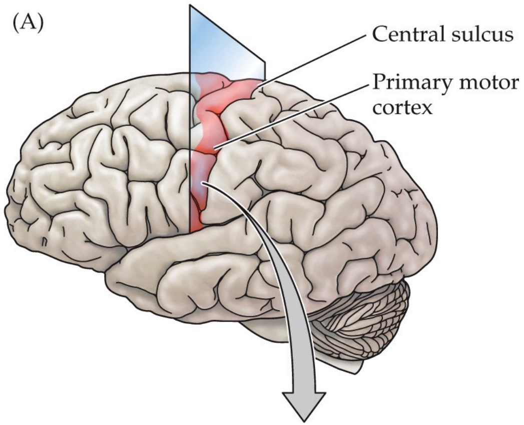


NEUROSCIENCE 6e, Figure 17.1 (Part 1)

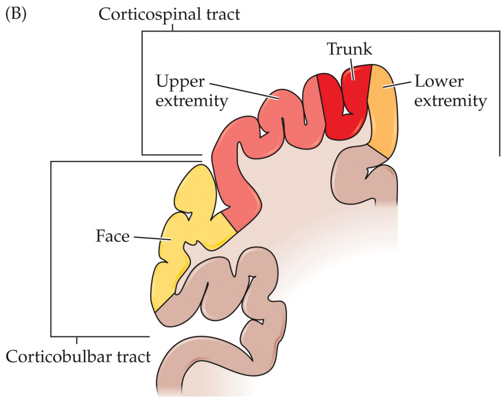
Primary motor cortex



NEUROSCIENCE 6e, Figure 17.2



NEUROSCIENCE 6e, Figure 17.5 (Part 1)



NEUROSCIENCE 6e, Figure 17.5 (Part 2)

You can stimulate neurons locally in the motor cortex, and produce movement.

As you change the stimulus site gradually, you seem to activate muscle groups in a systematic manner – for example, proximal (shoulder/trunk) to distal (elbow/hand) muscle groups. This is analogous to the sensory "homunculus".

Original experiments as early as in 1937!

SOMATIC MOTOR AND SENSORY REPRESENTATION IN THE CEREBRAL CORTEX OF MAN AS STUDIED BY ELECTRICAL STIMULATION.[1]

BY WILDER PENFIELD AND EDWIN BOLDREY (MONTREAL).

1937

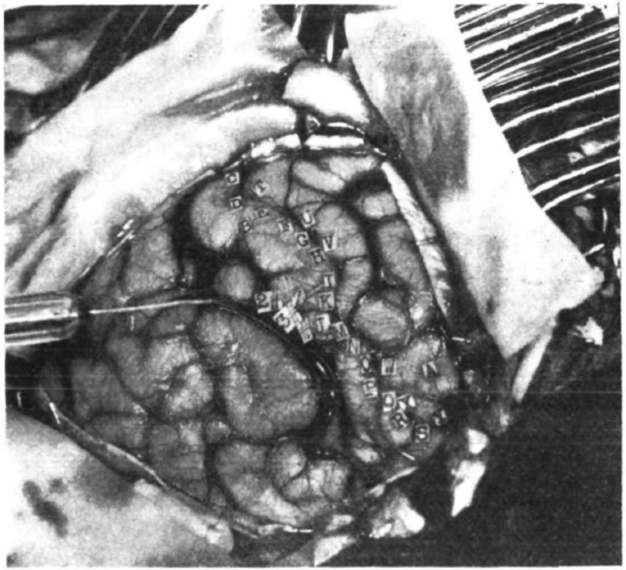


FIG. 4.—Cerebral cortex in Case 110 photographed during operation. The tickets of reference indicate responses which are described in text. *See* fig. 24 for diagram of same case.

Stimulation during surgeries for epilepsy or other conditions.

Stimulating electrode placed on the surface and electrical current passed

Visual observation of movement or ask patient (who is awake!) what they felt

Stimulation produces sensation and/or movement

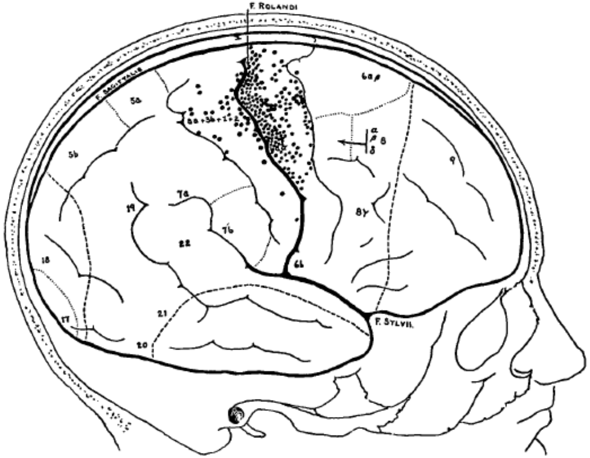


FIG. 14.—Movement of hand, arm and shoulder.

FIG. 15.—Sensation of hand, arm and shoulder.

Stimulation in **pre**central areas (in front of the central sulcus) produced movements (but also sensations – see right)

Stimulation in **post**central areas (behind the central sulcus) produced sensations

A map in the primary motor cortex

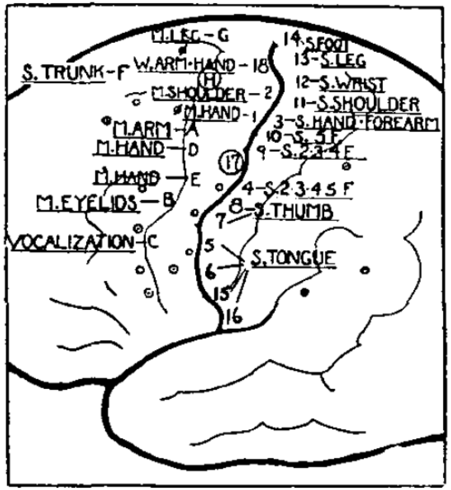


Fig. 22.

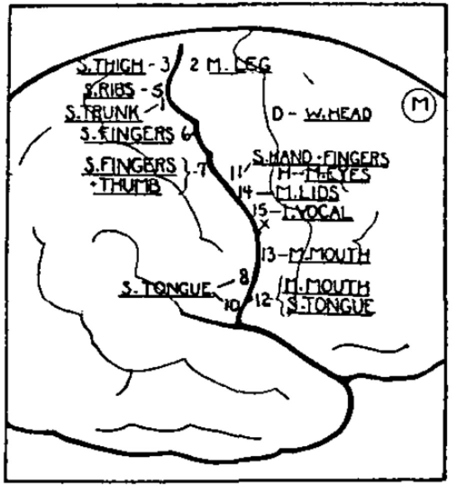
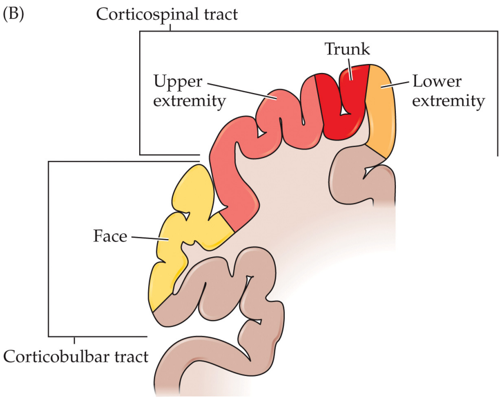


Fig. 23.

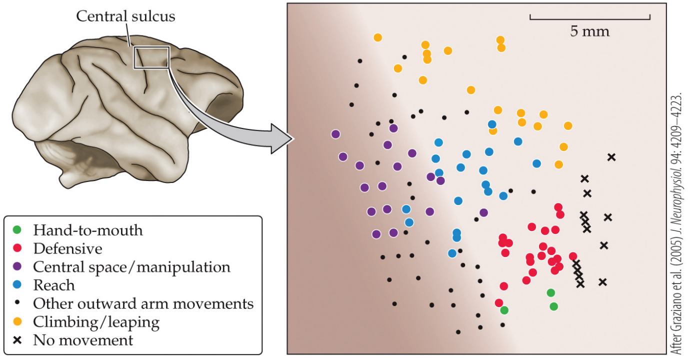


NEUROSCIENCE 6e, Figure 17.5 (Part 2)

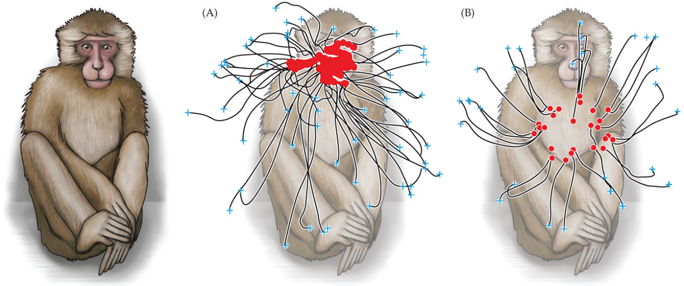
Coordinated movements elicited by motor cortex stimulation

We now realize that the motor "homunculus" is much more complicated. Stimulation of specific sites in motor cortex usually lead to coordinated movements across multiple joints.

Therefore, only a loose topographic organization



NEUROSCIENCE 6e, Box 17A

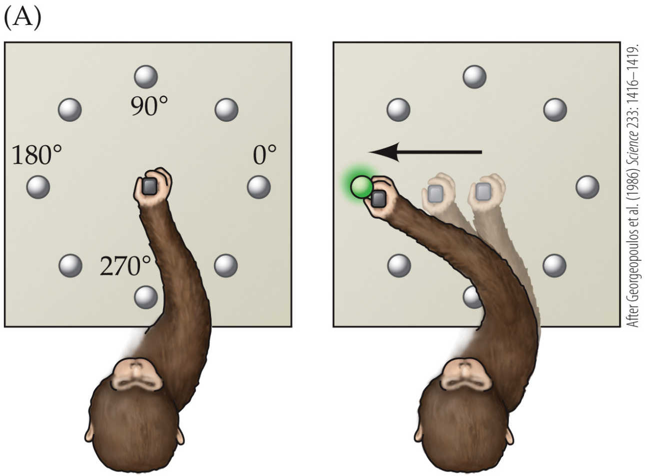


After Graziano et al. (2005) J. Neurophysiol. 94: 4209–4223.

NEUROSCIENCE 6e, Figure 17.7

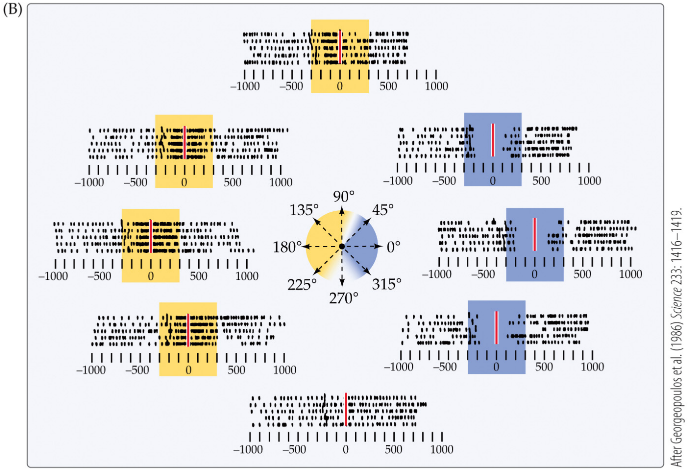
Neural coding of movement parameters

Monkey is asked to move the joystick in one of 8 directions (green light signals which direction)



NEUROSCIENCE 6e, Figure 17.8 (Part 1)

Neural activity (spikes) recorded in motor cortex as the monkey makes the movement

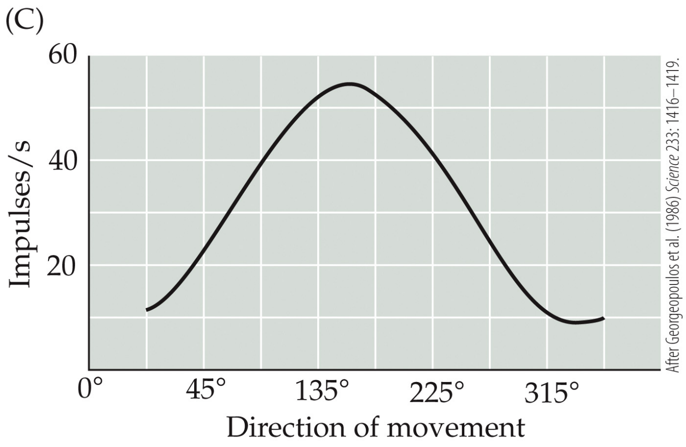


NEUROSCIENCE 6e, Figure 17.8 (Part 2)

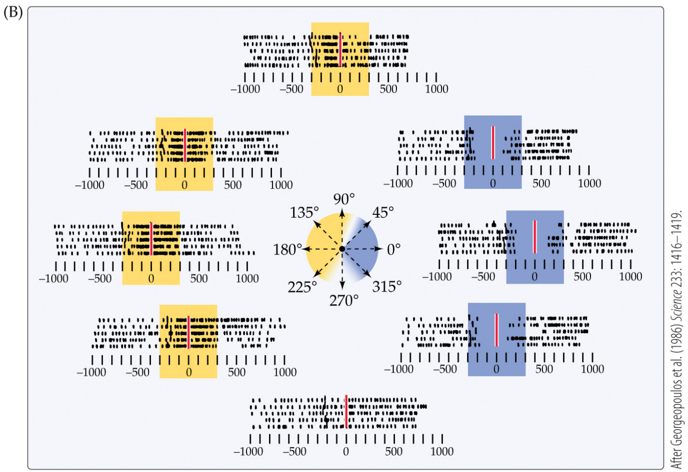
Neural coding of movement parameters

Neurons in motor cortex are tuned to different parameters of movement, including direction, velocity, joint angle etc.

Many neurons are active for any given movement, and they "code" for that movement as a population.

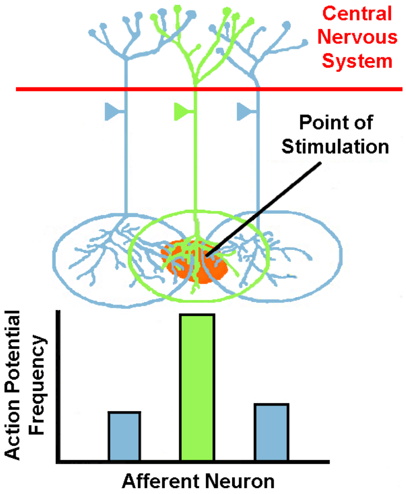


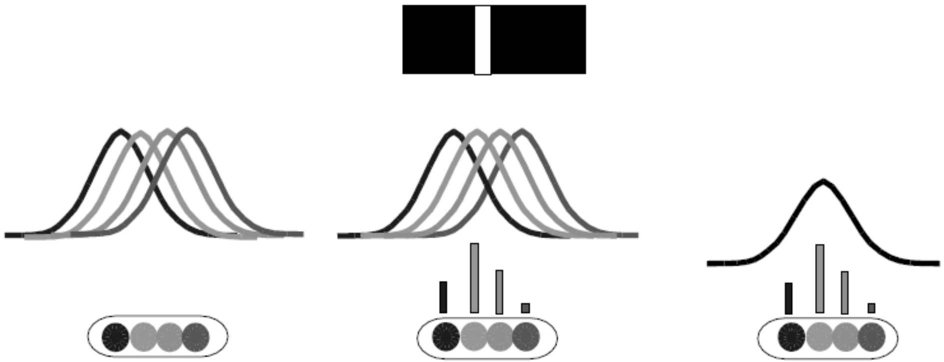
NEUROSCIENCE 6e, Figure 17.8 (Part 3)



NEUROSCIENCE 6e, Figure 17.8 (Part 2)

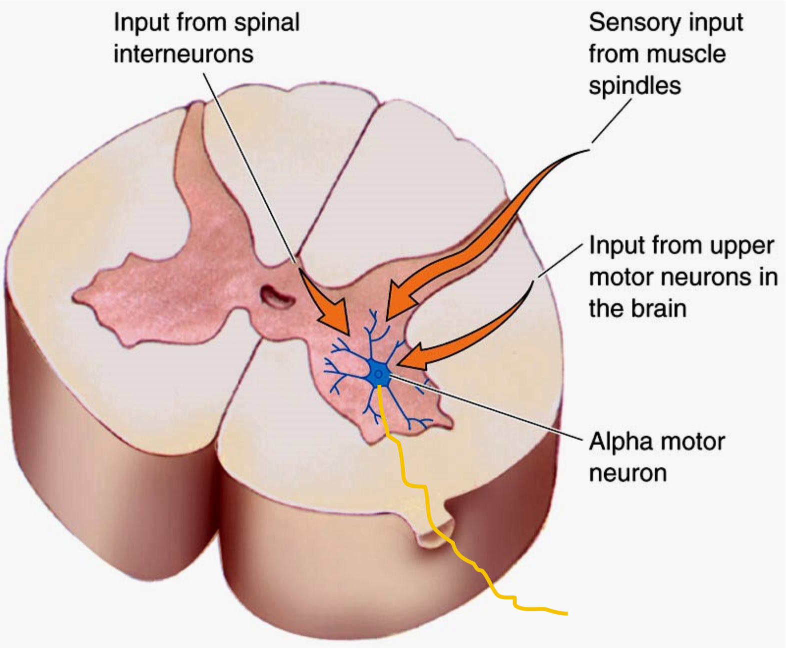
Recall from earlier: population coding in sensory systems





http://www.d.umn.edu/~jfitzake/Lectures/DMED/Sensory
Physiology/GeneralPrinciples/IntensityMechanisms.html

Recall from previous lecture: inputs to motor neurons



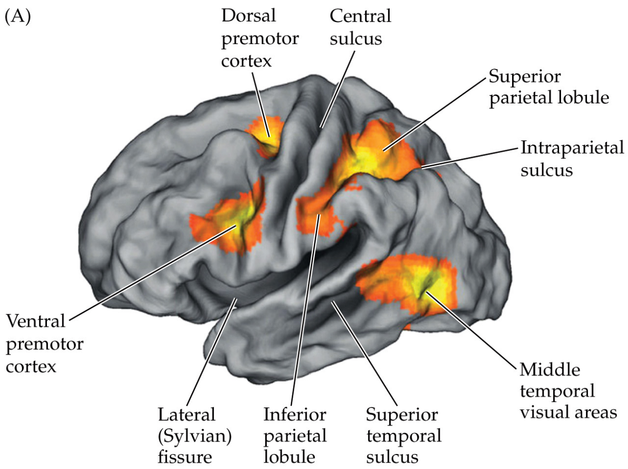
Three sources:

- Dorsal Root Ganglion cells (sensory)
- Upper motor neurons
- Spinal interneurons (excitatory and inhibitory)

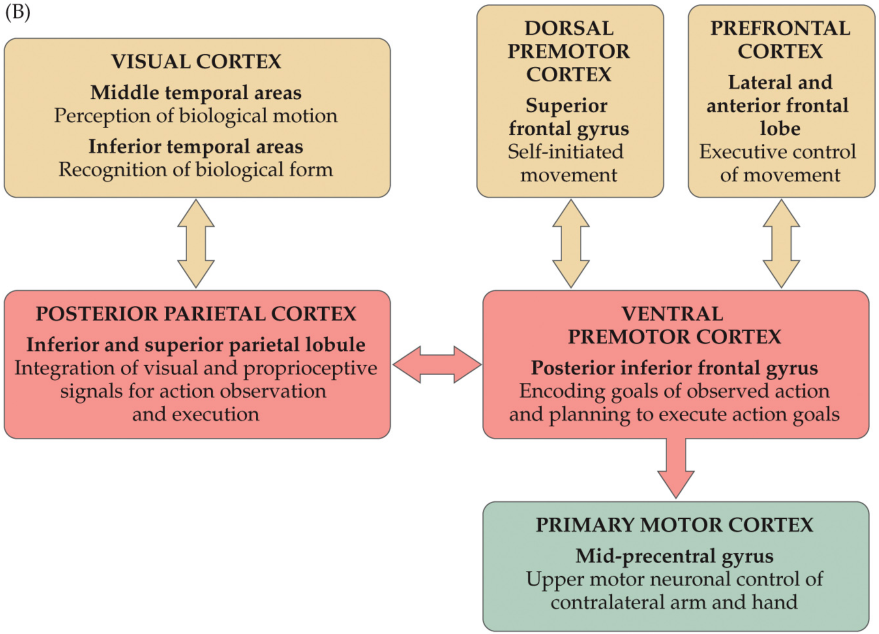
Planning to move: e.g. visually-guided reaching movement

Planning to move: e.g. visually-guided reaching movement

Multiple brain areas coordinate to carry out intentional movements occurring in response to the environment



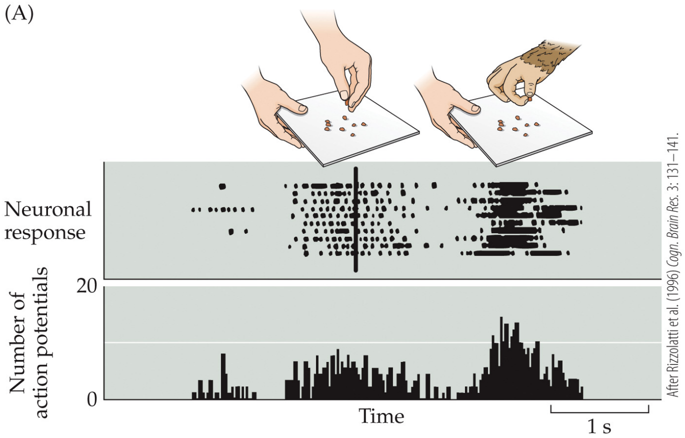
NEUROSCIENCE 6e, Figure 17.11 (Part 1)



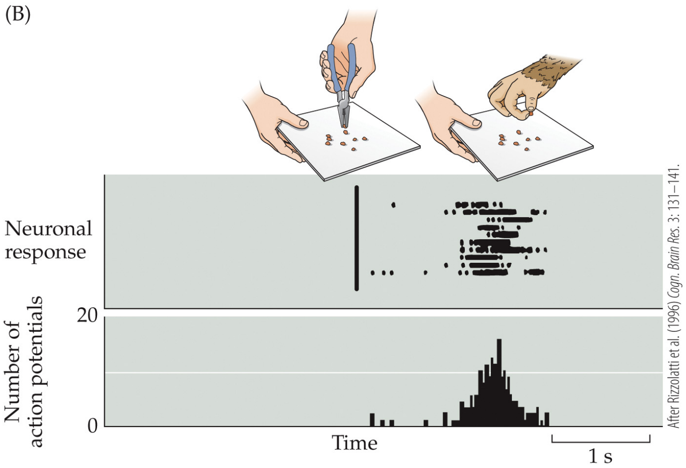
NEUROSCIENCE 6e, Figure 17.11 (Part 2)

Mirror neurons

Neurons in some parts of the primate brain respond to movements by others that mimic the monkey's own movement!

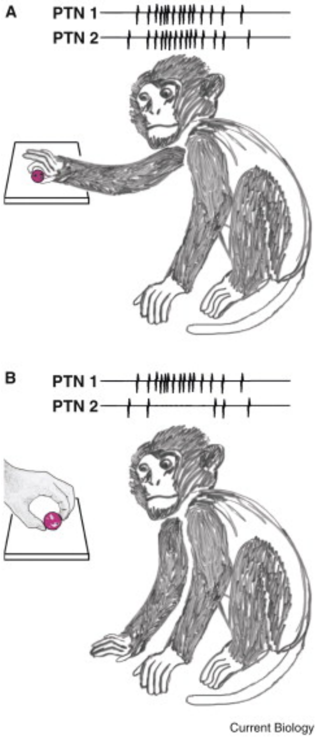


NEUROSCIENCE 6e, Figure 17.10 (Part 1)



NEUROSCIENCE 6e, Figure 17.10 (Part 2)

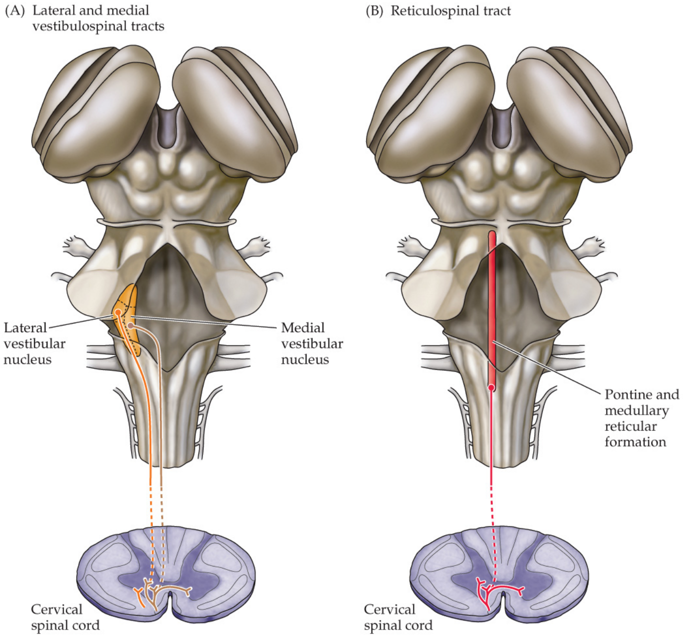
Mirror neurons



PTN: Pyramidal Tract Neuron (in primary motor cortex) project to brain stem and spinal cord to activate movement

Some of these PTNs are suppressed during observation of mirror movement, so may balance the increase in the activity of other PTNs (to prevent actual arm movement)

Other upper motor neurons



NEUROSCIENCE 6e, Figure 17.12

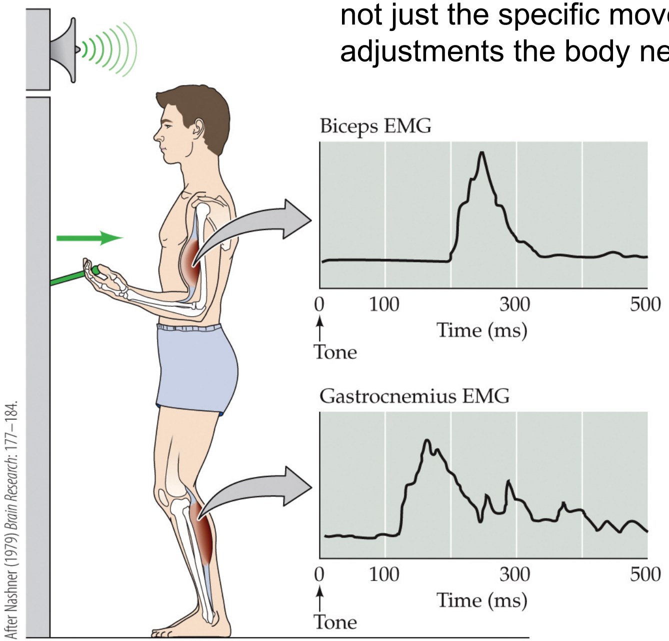
The brain stem has regions (nuclei) that project to spinal cord to control certain movements

Vestibular nucleus: big role in responding to changes in body movement that affects the vestibular system (unexpected fall etc) – then sends information to neck and other muscles to stabilize eyes, head and trunk.

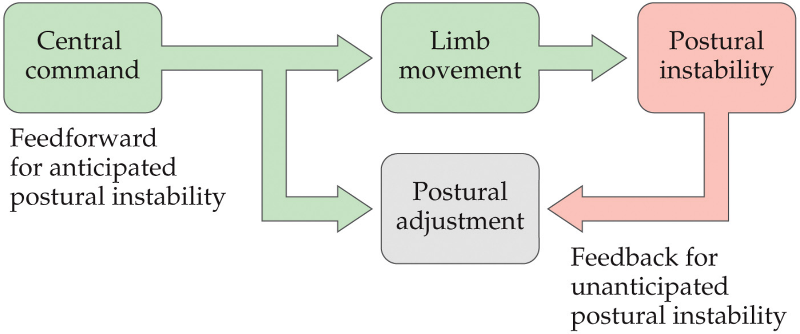
Reticular formation: diverse function, playing a role in coordinating many reflex-like and learned movements. Interestingly, this can happen in a feedback manner (ie, after some perturbation occurs) as well as in a feedforward manner (ie, anticipating a movment)

Movement planning and “predictive” adjustment

Input from cortex and areas above spinal cord can coordinate not just the specific movement to be made, but also other adjustments the body needs to make (for example, posture)

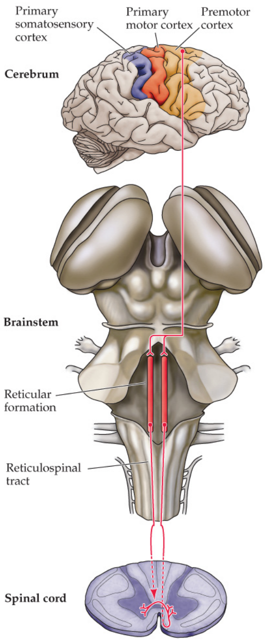


NEUROSCIENCE 6e, Figure 17.14



NEUROSCIENCE 6e, Figure 17.15

Reticular formation is involved in postural control



NEUROSCIENCE 6e, Figure 17.16

The effect of the impending movement on the body (stability, posture etc) is anticipated, and the reticular formation sends information to other muscles to prepare for the impending movement

Learning Objectives

Explain how all observable behavior is the result of the coordinated activity of muscles.

Differentiate the behavioral output of activating a lower motor neuron versus an upper motor neuron in primary motor cortex and other “higher” areas.

Motor cortex organization – loose topography.

How neurons in cortical areas code for movement parameters – population coding.

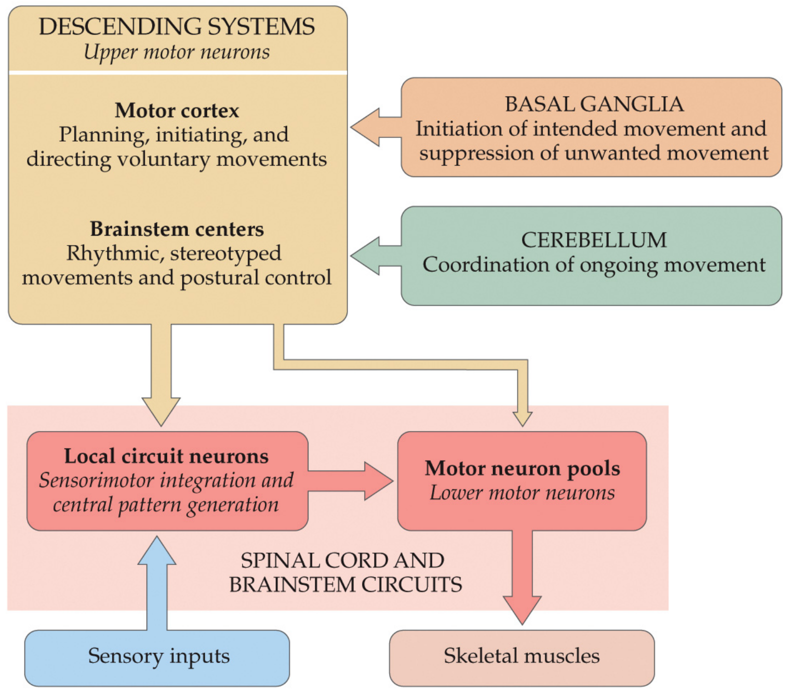
Brainstem nuclei controlling movement – postural adjustment.

Lecture 22 (and 23) -Motor Systems 2

Pre-class notes for November 20, 2019
Reading: *Neuroscience ed. 6* by Purves et al., pages 392-397, 407-413, 427

Primary motor cortex - Contains upper motor neurons, which control contralateral body parts. Stimulation of specific sites in motor cortex usually leads to coordinated movements across multiple joints. Large neurons in layer 5 send their axons down the spine to synapse onto lower motor neurons and interneurons in the spinal cord.

Provides commands to initiate voluntary movement and control complex movement. Primary motor cortex is topographically organized. The motor cortex, in coordination with other areas of the brain integrates information from multiple sensory systems and sends depending axons to the motor control regions of the brainstem, to spinal cord interneurons, and to lower motor neurons themselves.



NEUROSCIENCE 6e, Figure 16.1

Neurons in motor cortex are tuned to different parameters of movement, including direction, velocity, joint angle etc. There is some evidence that stimulation of specific sites in motor cortex can lead to coordinated movements across multiple joints

Premotor cortex - Contains neurons that help plan more complicated actions. Also contains *mirror neurons,* which are active not only when planning/performing complicated actions, but also when watching the same types of actions.

Basal ganglia - A group of nuclei lying deep in the subcortical white matter of the frontal lobes that organize motor behavior. The major components are the striatum (caudate and putamen), substantial nigra, globus pallidus external segment (GPe) and globus pallidus internal segment (GPi) which connects to nuclei in the thalamus and brain stem. The basal ganglia is essential for motor initiation and control, habit formation and reward-based learning. Contains 2 different pathways the *direct* and *indirect pathway*.

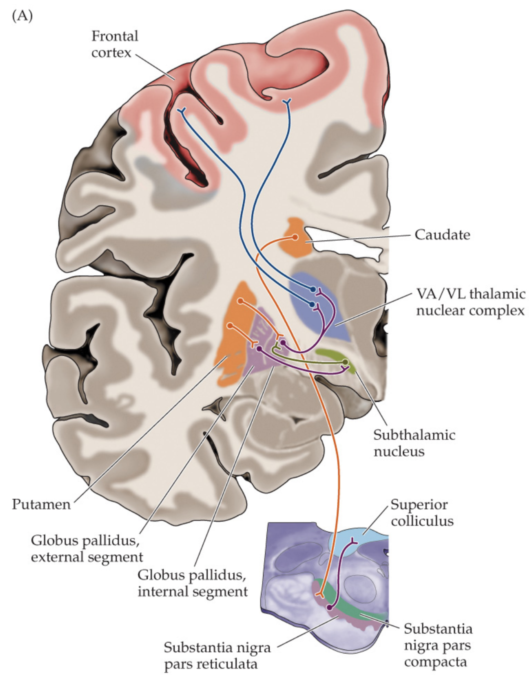
Direct pathway - a subset of projection neurons (medium spiny neurons) link the striatum directly to the basal ganglia output: GPi and the substantia nigra. Since both the striatum and globus pallidus are GABAergic, activating this pathway, provides less inhibition to the thalamus and brain stem.

Indirect pathway - a subset of medium spiny neurons in the striatum project to the GPe, which in turn projects to the GPi. Because there is a chain of inhibitory connections (disinhibition), activating this pathway provides more inhibition to the thalamus and brainstem.

Parkinson's disease - A neurodegenerative disease with symptoms that include shaking, rigidity, slowness and difficulty walking. Dopaminergic neurons which help activate the direct pathway degenerate, this leads to an increase in the GPi activity and causing more *inhibition* to the thalamus.

Huntington's disease - A genetic disease that is characterized by abnormal, hyperkinetic movements. Caused by the degeneration of medium spiny neurons in the striatum that specifically project to the GPe, resulting in the inactivation of the indirect pathway and decreased inhibition to the thalamus.

Cerebellum - structure located dorsal to the pons and medulla that plays an important role in motor coordination, motor learning and other cognitive functions. The cerebellum influences movements primarily by modifying the activity patterns of upper motor neurons. A primary function of the cerebellum is to detect the difference or "motor error" between an intended movement and the actual movement and thus modulate the upper motor neurons to reduce the error. These corrections can be made both during the movement and as a form of motor learning.



NEUROSCIENCE 6e, Figure 18.4 (Part 1)

Brain computer interface - uses brain signals to control either devices or muscles using bidirectional communication between the nervous system and a computer.

Learning Objectives: (By the end of Lecture 22 you should be able answer questions about the following)

1. Explain how all observable behavior is the result of the coordinated activity of muscles.
2. Differentiate the behavioral output of activating a lower motor neuron versus an upper motor neuron in primary motor cortex and other "higher" areas.
3. Describe the motor cortex organization – loose topography.
4. How neurons in cortical areas code for movement parameters – population coding.
5. Brainstem nuclei controlling movement – postural adjustment.