9.01 Introduction to Neuroscience
Fall 2007

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Movement I

Sebastian Seung
Actin/myosin is a molecular motor

- *In vitro* motility assay

See the animation at: [http://physiology.med.uvm.edu/warshaw/TechspgInVitro.html](http://physiology.med.uvm.edu/warshaw/TechspgInVitro.html)

David Warshaw
Skeletal muscle

- A muscle is a bundle of fibers.
- A fiber is a bundle of myofibrils.
- Myofibrils are composed of segments called sarcomeres.
- Sarcomeres are composed of actin and myosin filaments.
Myosin heads walk along actin filaments.
Steps in a muscle “twitch”

- ACh depolarizes the NMJ
- Action potential generated in muscle fiber.
- Release of calcium leads to contraction.
- Reuptake of calcium causes relaxation.
Lower motor neurons

- ventral horn of spinal cord
- motor nuclei of brainstem
- send axons to muscles
  - spinal and cranial nerves
There is a map of the body along the length of the spinal cord.

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Diagram showing physical correspondence between particular points on the spinal cord and places in the body.
Axial-distal and flexor-extensor are "mapped" in the ventral horn.

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There are two types of lower motor neurons

• alpha motor neurons
  – directly control force generation

• gamma motor neurons
  – indirectly modulate force generation
An alpha motor neuron and its fibers are a “motor unit”

- An alpha motor neuron innervates multiple fibers.
- A fiber receives input from a single alpha motor neuron.

Figure by MIT OpenCourseWare. After Figure 13.6 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. Neuroscience: Exploring the Brain. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.
Motor neuron pool

• The set of alpha motor neurons that innervates a single muscle.

Figure by MIT OpenCourseWare. After Figure 13.6 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.
Muscle force is controlled in two ways

- Firing rate of motor units
- Recruitment of motor units
- Size principle
  - smallest motor units are recruited first
Reflex behavior

• Rapid, involuntary, stereotyped response to a specific stimulus.

• Examples
  – Knee-jerk reflex
  – Salivation
DRG cells bring sensory information to the spinal cord.

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Diagram showing connection by dorsal root ganglion cell from sensory receptors to the grey matter of spinal cord. See Figure 12.8 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. Neuroscience: Exploring the Brain. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.
Muscle spindles are special fibers wrapped in la axons.

Image removed due to copyright restrictions.
Muscle spindles sense changes in muscle length

• They are also called “stretch receptors,”
• They are examples of proprioceptors.
The knee-jerk reflex involves a mono-synaptic reflex arc.
The myotatic ("stretch") reflex

- muscle spindles
- Ia sensory axons
- alpha motor neurons
- muscle contraction
Reflex arc

- A synaptic chain of cause and effect

- The simplest structure-function theory of the nervous system.
Intrafusal fibers are innervated by gamma motor neurons.

Image removed due to copyright restrictions.
Gamma motor neurons regulate muscle spindle length

Image removed due to copyright restrictions.
The Golgi tendon organs sense muscle tension.

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Diagram showing structure of Golgi tendon organ.

The flexor reflex is polysynaptic.
Reciprocal inhibition of flexors and extensors
Rhythmic behaviors

• Swimming, walking, running, chewing,..

• Two questions:
  – Are they generated in the spinal cord, or do they require sensory input or control from the brain?
  – Are rhythms generated by single neurons, or by networks of neurons?
Central pattern generators

- Experiment: transection of spinal cord.
- Hindlimbs of cat can still generate walking-like movements.
Some spinal interneurons are intrinsic oscillators

- Constant input generates oscillatory output.

Figure by MIT OpenCourseWare. After Figure 13.26 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.
Mutual inhibition coordinates oscillations

Figure by MIT OpenCourseWare. After Figure 13.27 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.