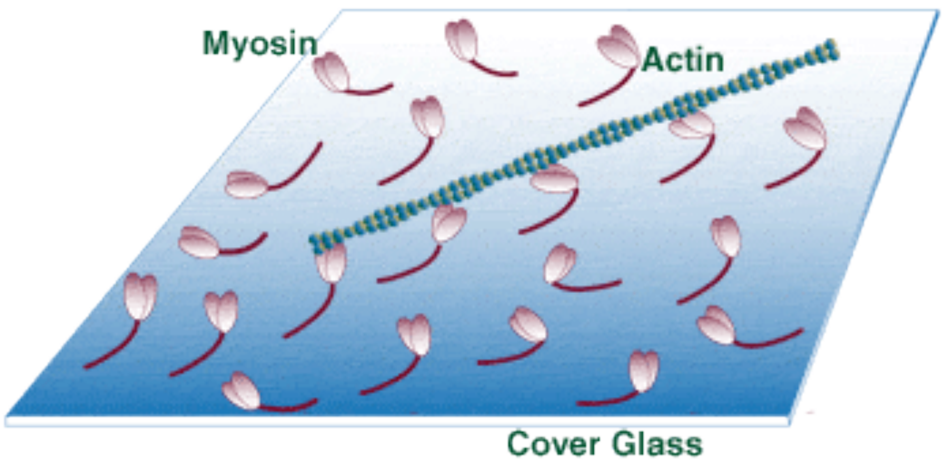
9.01 Introduction to Neuroscience
Fall 2007

Movement I

Sebastian Seung

Actin/myosin is a molecular motor

- *In vitro* motility assay



Courtesy of David Warshaw. Used with permission.

See the animation at:

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

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Three-step schematic of actin and myosin filaments in motion.
See Figure 13.14 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

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.
See Figure 13.4 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

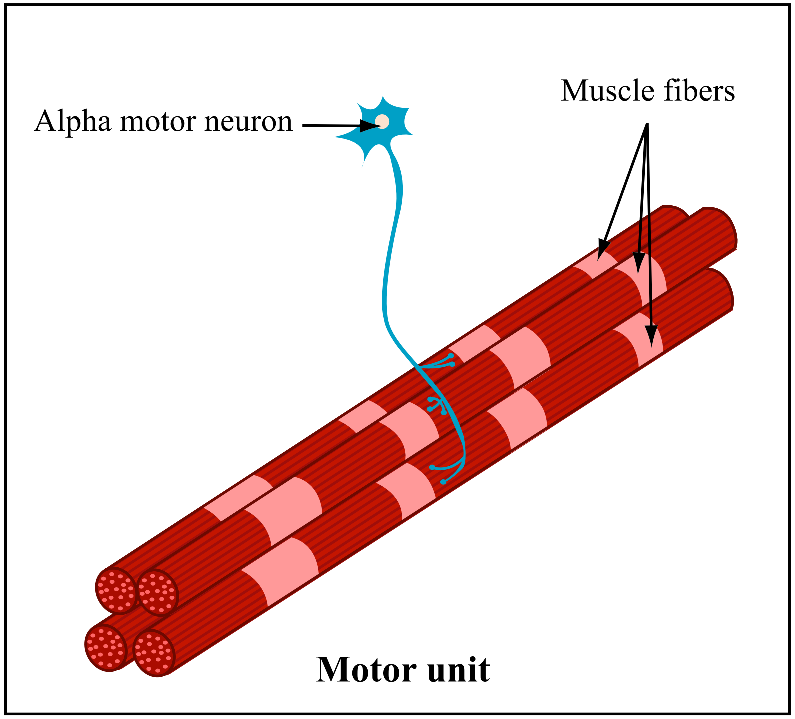
Axial-distal and flexor-extensor are "mapped" in the ventral horn

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.



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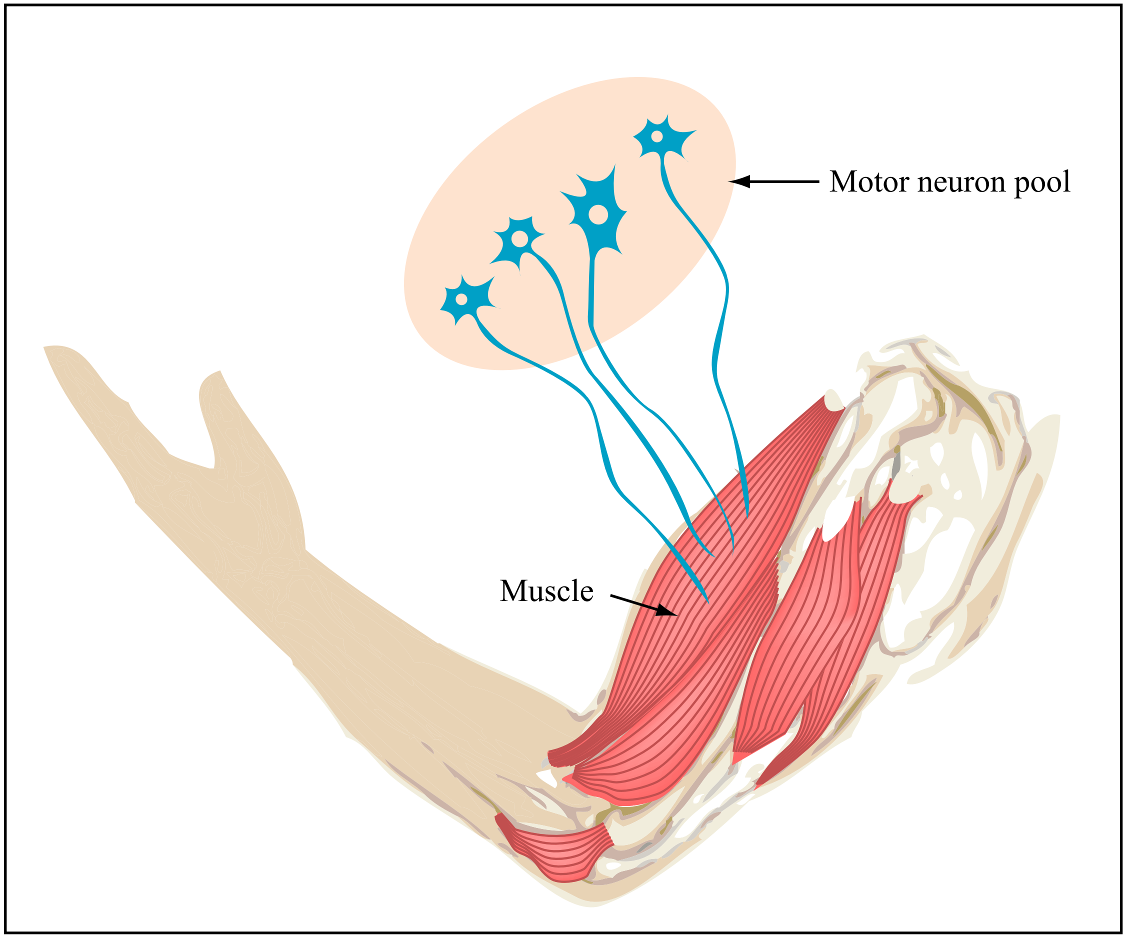
Motor neuron pool

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



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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 Ia axons

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See Figure 13.15 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 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

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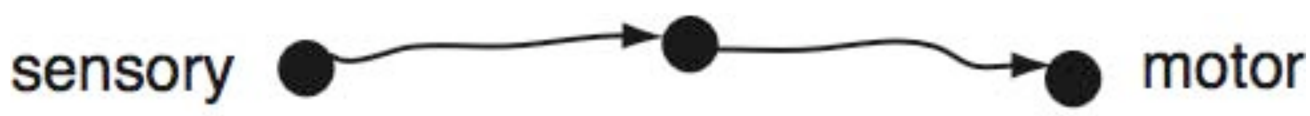
Diagram showing the sequence of neural connections that causes knee jerk when the quadriceps tendon below kneecap is struck. See Figure 13.5 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

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

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Three-step sequence diagram showing extrafusal and intrafusal fibers. See Figure 13.18 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Gamma motor neurons regulate muscle spindle length

The Golgi tendon organs sense muscle tension

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Diagram showing structure of Golgi tendon organ.
See Figure 13.20 in Bear, Mark F., Barry W. Connors,
and Michael A. Paradiso. *Neuroscience: Exploring the Brain*.
3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

The flexor reflex is poly-synaptic

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Diagram showing the sequence of neural connections
from stepping on a tack to contracting leg flexor muscles.
See Figure 13.24 in Bear, Mark F., Barry W. Connors, and
Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed.
Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Reciprocal inhibition of flexors and extensors

See Figure 13.23 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

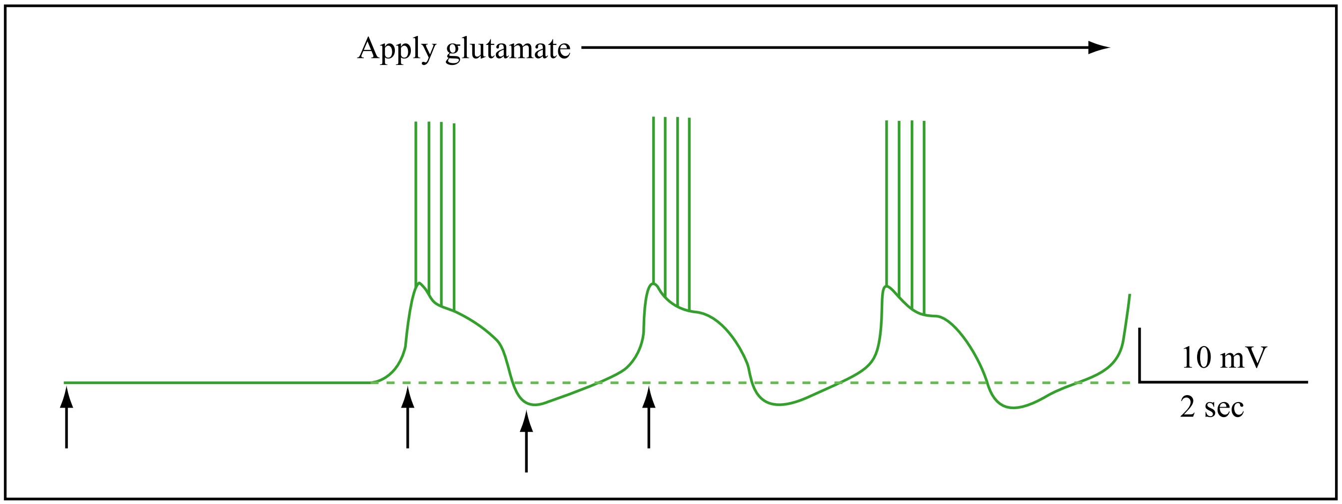
Rhythmic behaviors

- 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



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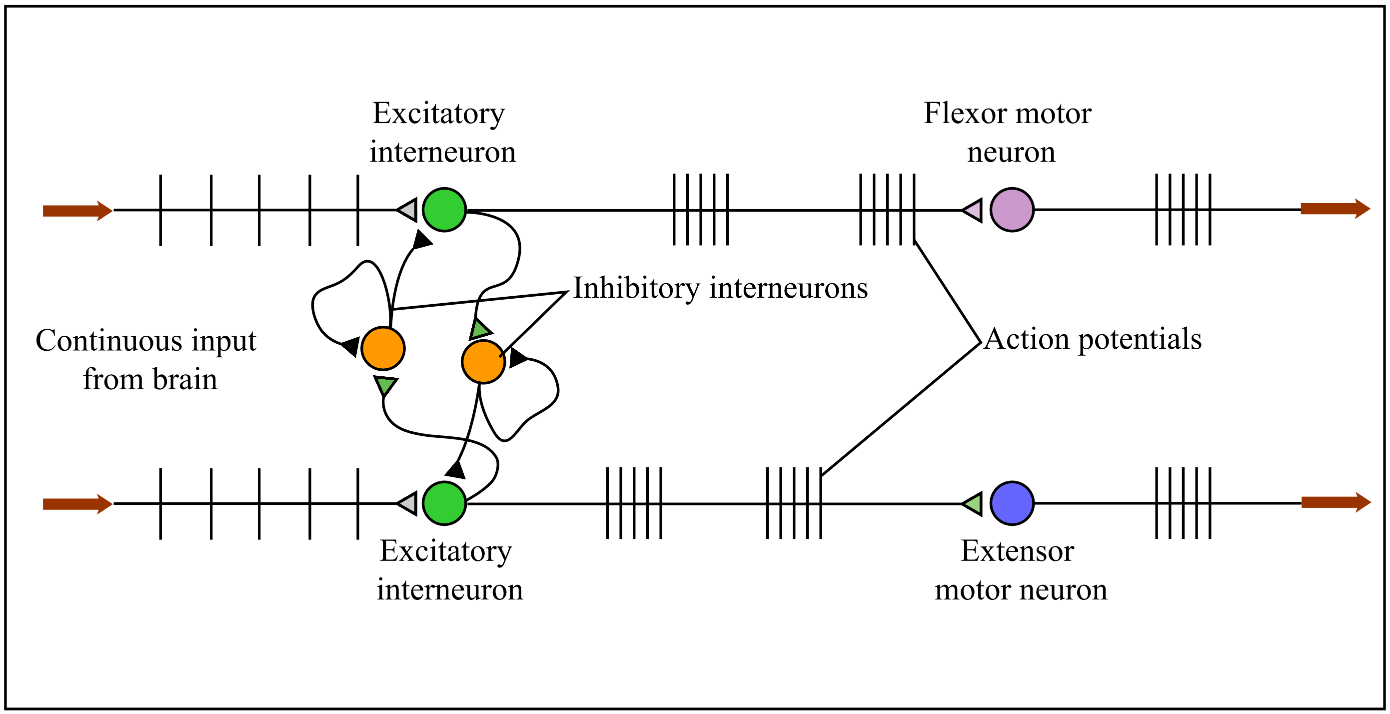
- Constant input generates oscillatory output.

Mutual inhibition coordinates oscillations



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