# Motor Systems: Lecture 1


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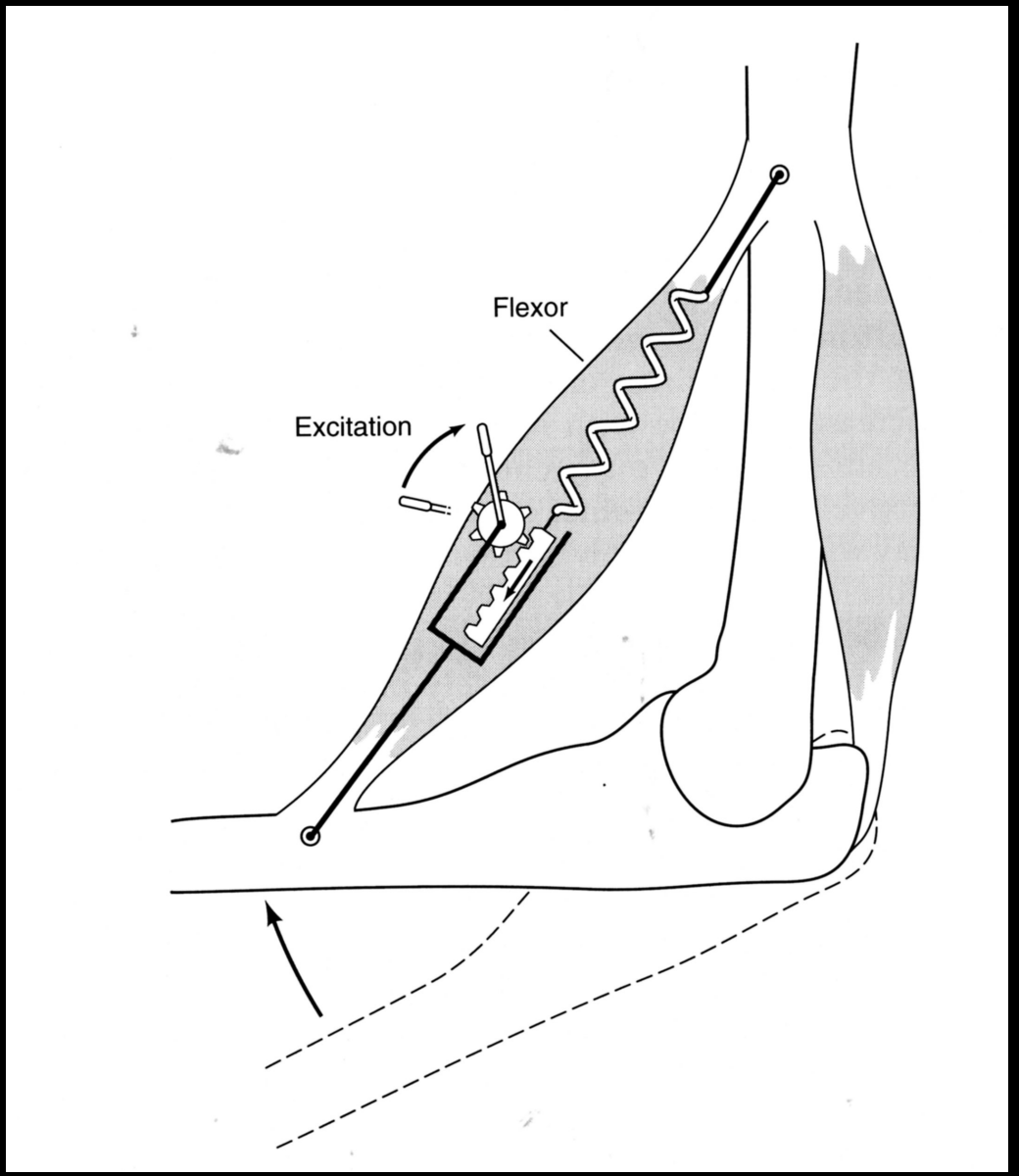
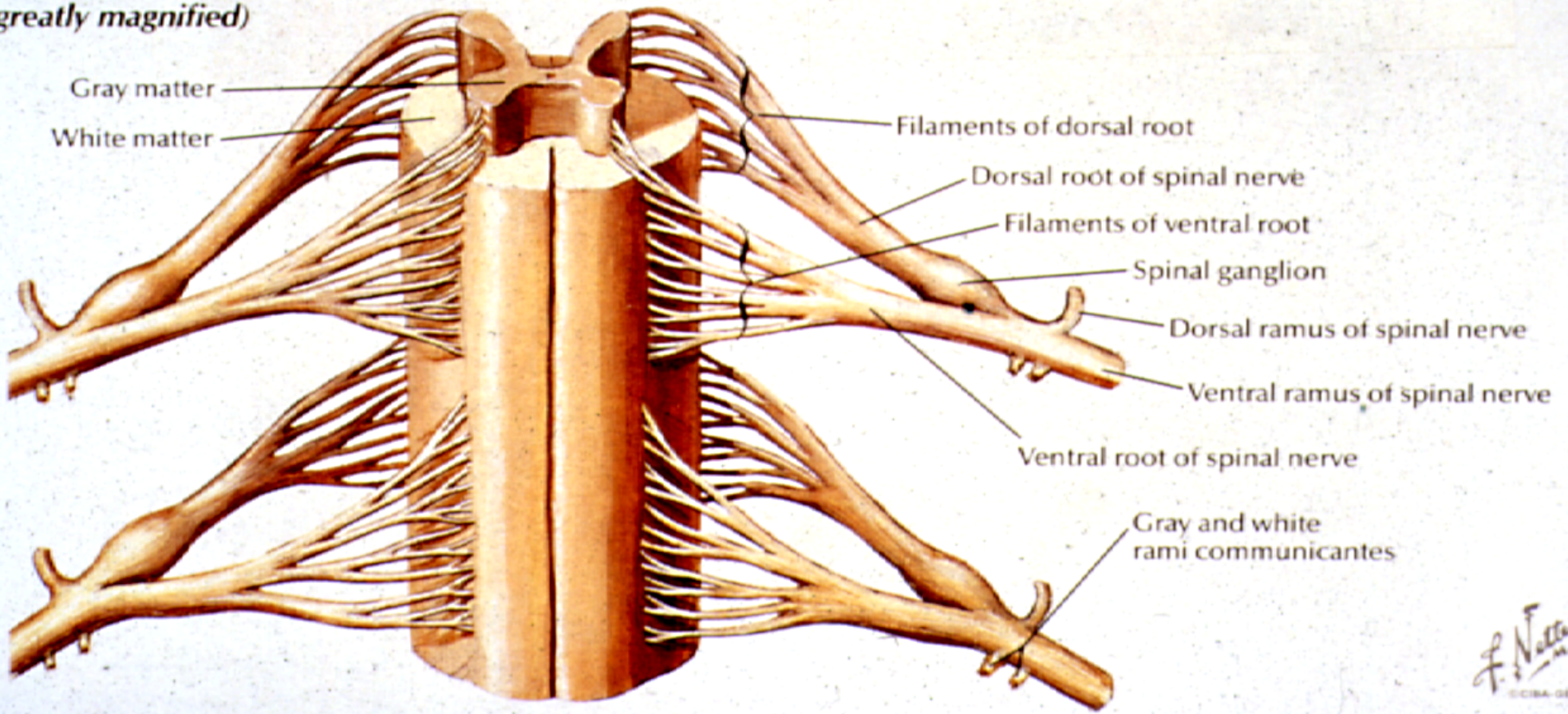
# Muscles, what are they good for?

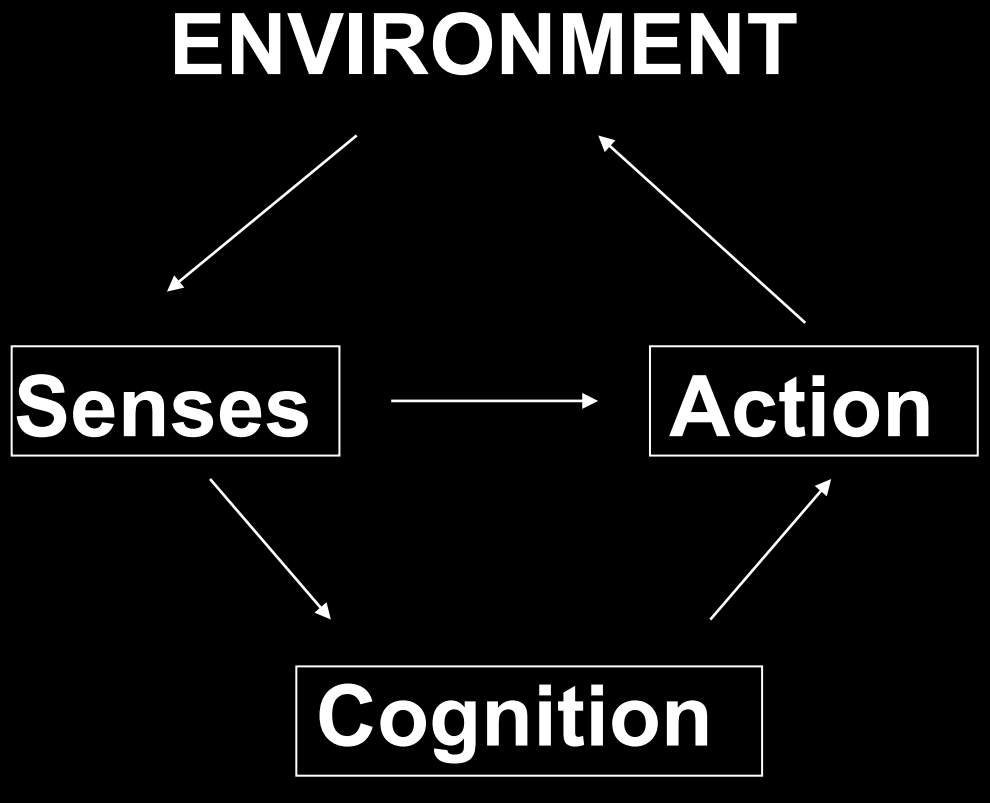
# Body as machine

**Membranes removed: anterior view**
***(greatly magnified)***



# MOTOR CONTROL



# Necessary Components of Proper Motor Control

- Volition
-

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- Volition
- Coordination of signals to many muscle groups
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- Sensory feedback
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- Sensory feedback
- Compensation for body and muscles
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- Volition
- Coordination of signals to many muscle groups
- Proprioception
- Postural adjustments
- Sensory feedback
- Compensation for body and muscles
- Unconscious processing
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# Necessary Components of Proper Motor Control

- Volition
- Coordination of signals to many muscle groups
- Proprioception
- Postural adjustments
- Sensory feedback
- Compensation for body and muscles
- Unconscious processing
- Adaptability

# Motor control requires sensory input

**The case of Ian Waterman**

- **Lost all somatosensory and proprioceptive input**
- **Initially unable to make any coordinated movement**
- **After years of practice he trained himself to make movement under visual guidance**
- **Requires total concentration to move and even maintain posture**
- **Collapses to ground when lights unexpectedly go out**

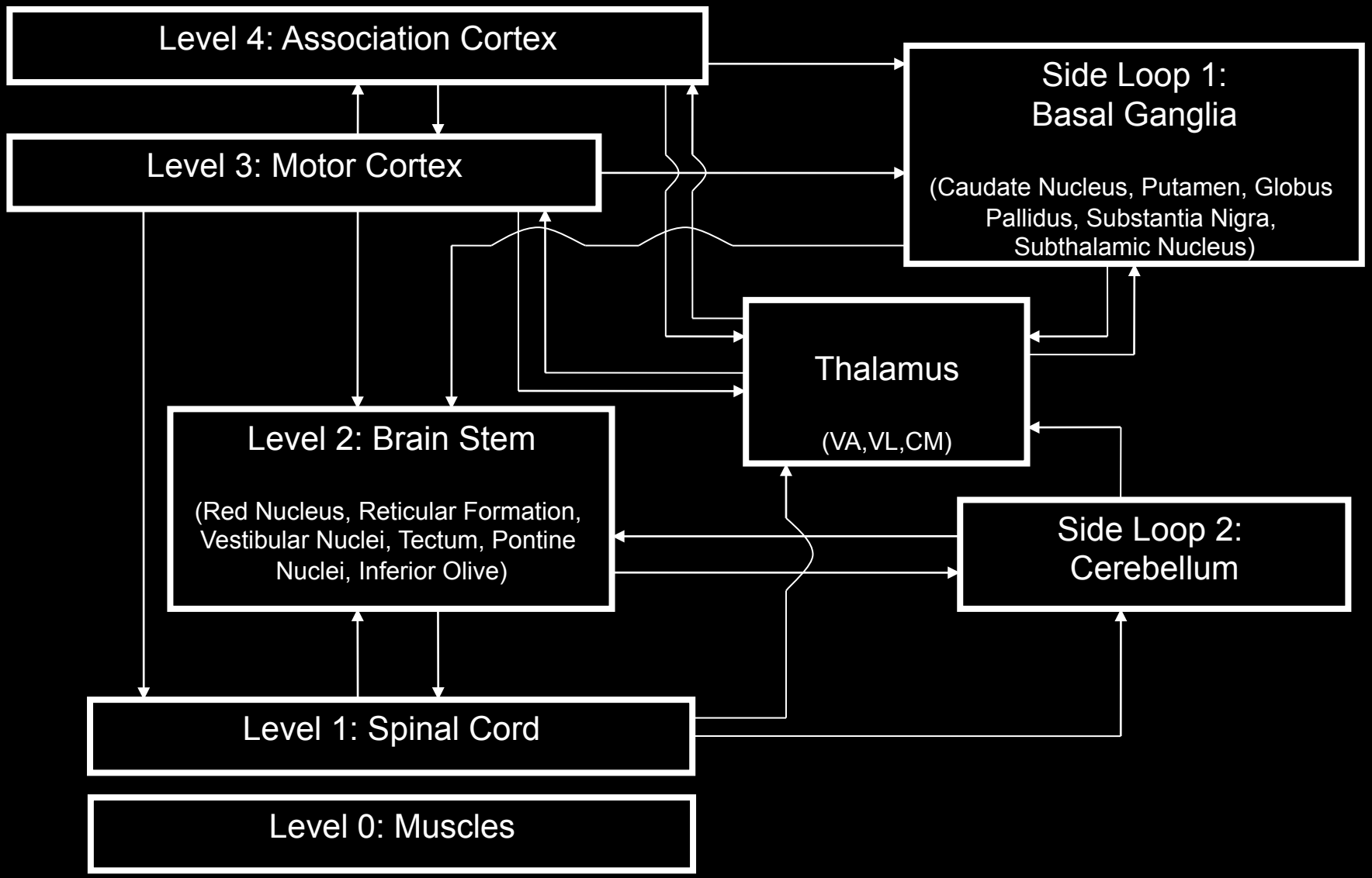
Jonathan Cole, *Pride and a Daily Marathon,* MIT Press, 1995.

# The Man Who Lost His Body

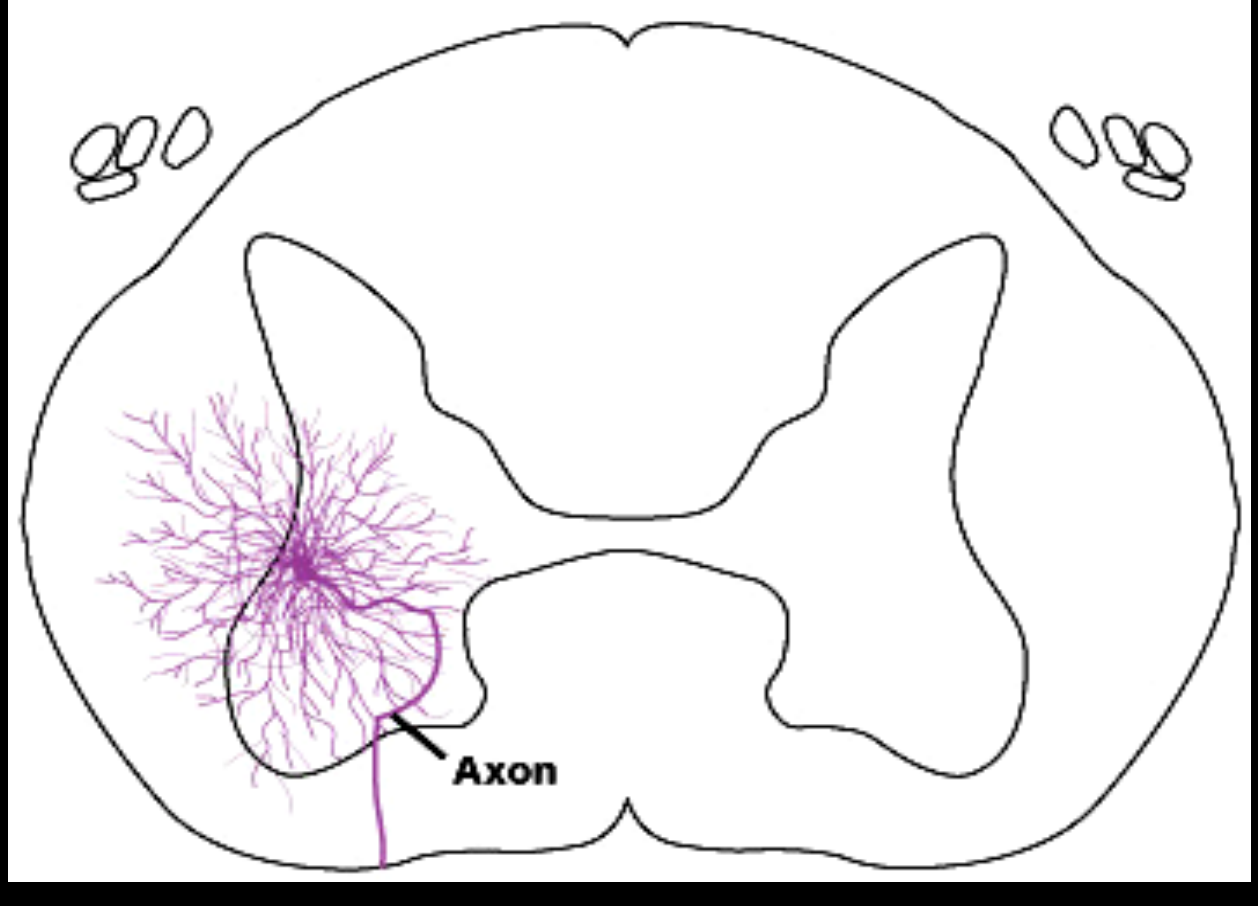
**Ian Waterman, age 19**

- **Lost all somatosensory and proprioceptive input**
- **Initially unable to make any coordinated movement**
- **After years of practice he trained himself to make movement under visual guidance**
- **Requires total concentration to move and even maintain posture**
- **Collapses to ground when lights unexpectedly go out**

# Hierarchical Organization and Functional Segregation of Central Motor Structures



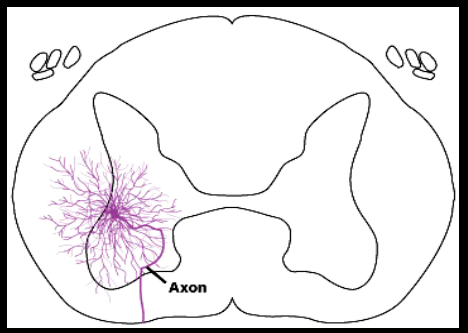
# Alpha motor neuron



# Alpha Motor Neurons

- aka Lower Motor Neurons
- Innervate skeletal muscle and cause muscle contractions
  - Isometric contraction (equal size)
  - Isotonic contraction (equal force)
- Release acetylcholine at the neuromuscular junction

# Motor Unit

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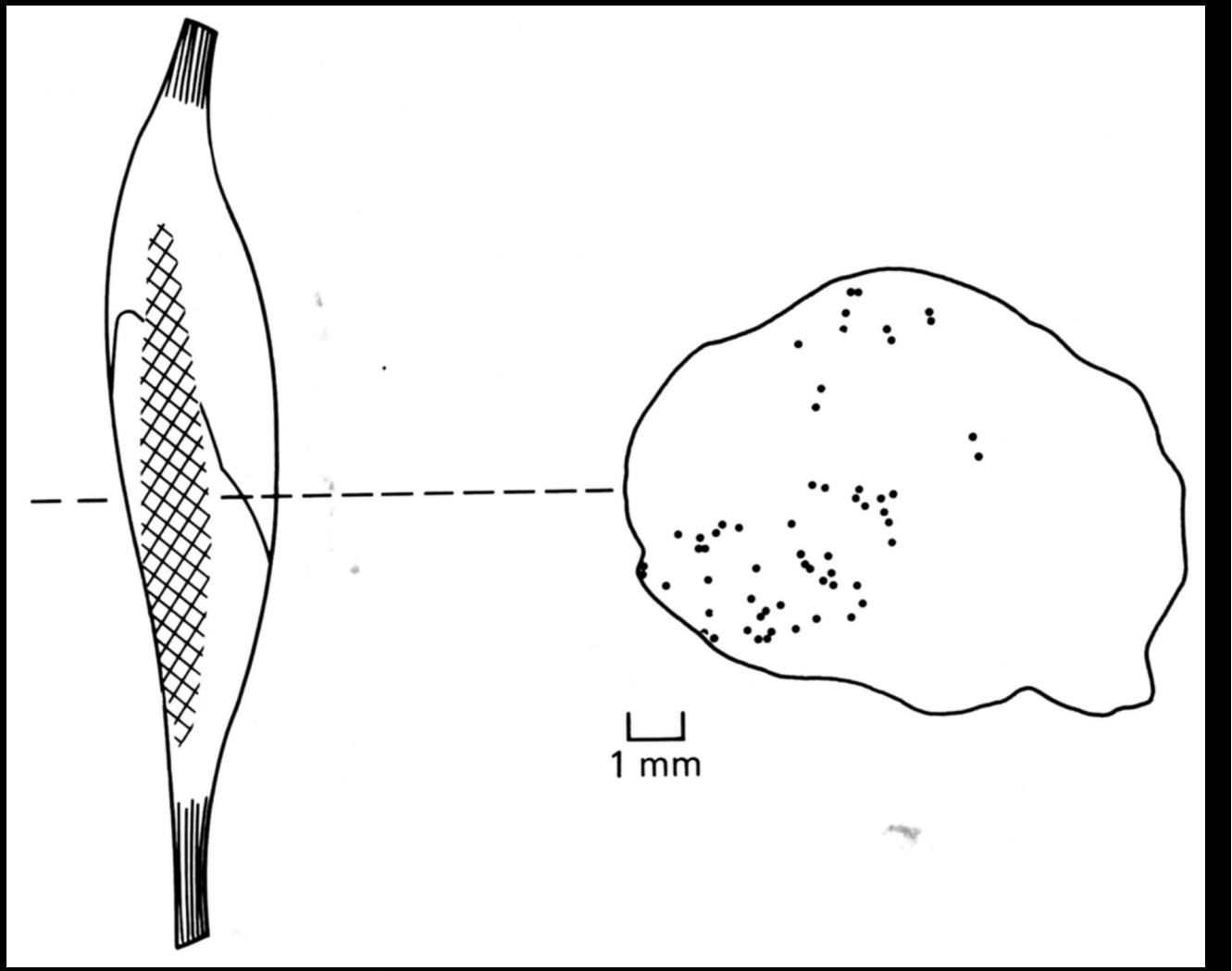


## Motor Neuron Pool (Motor Nucleus)

The group of motor neurons that innervate an individual muscle

# Motor Neuron Pool

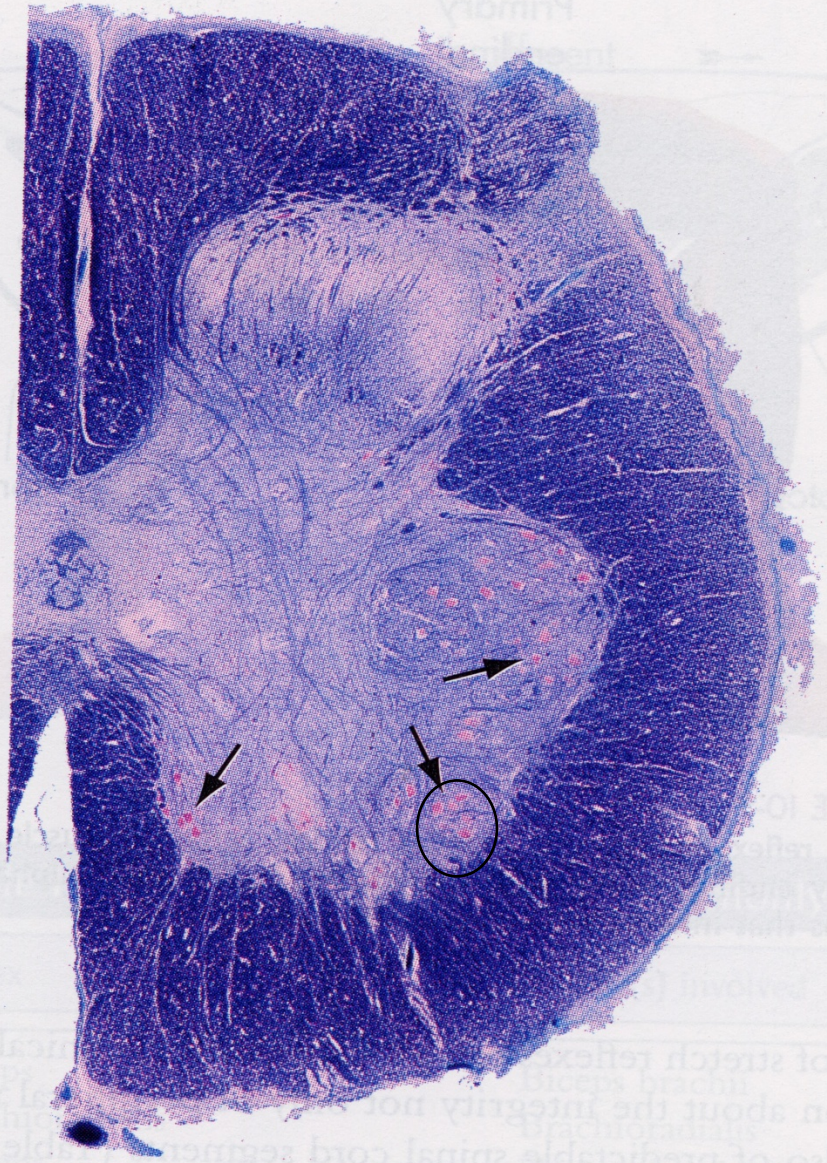


FIGURE 10-8
Clusters of motor neurons in the anterior horn at S4.

From J. Nolte (2002) *The Human Brain, 5th Edition*

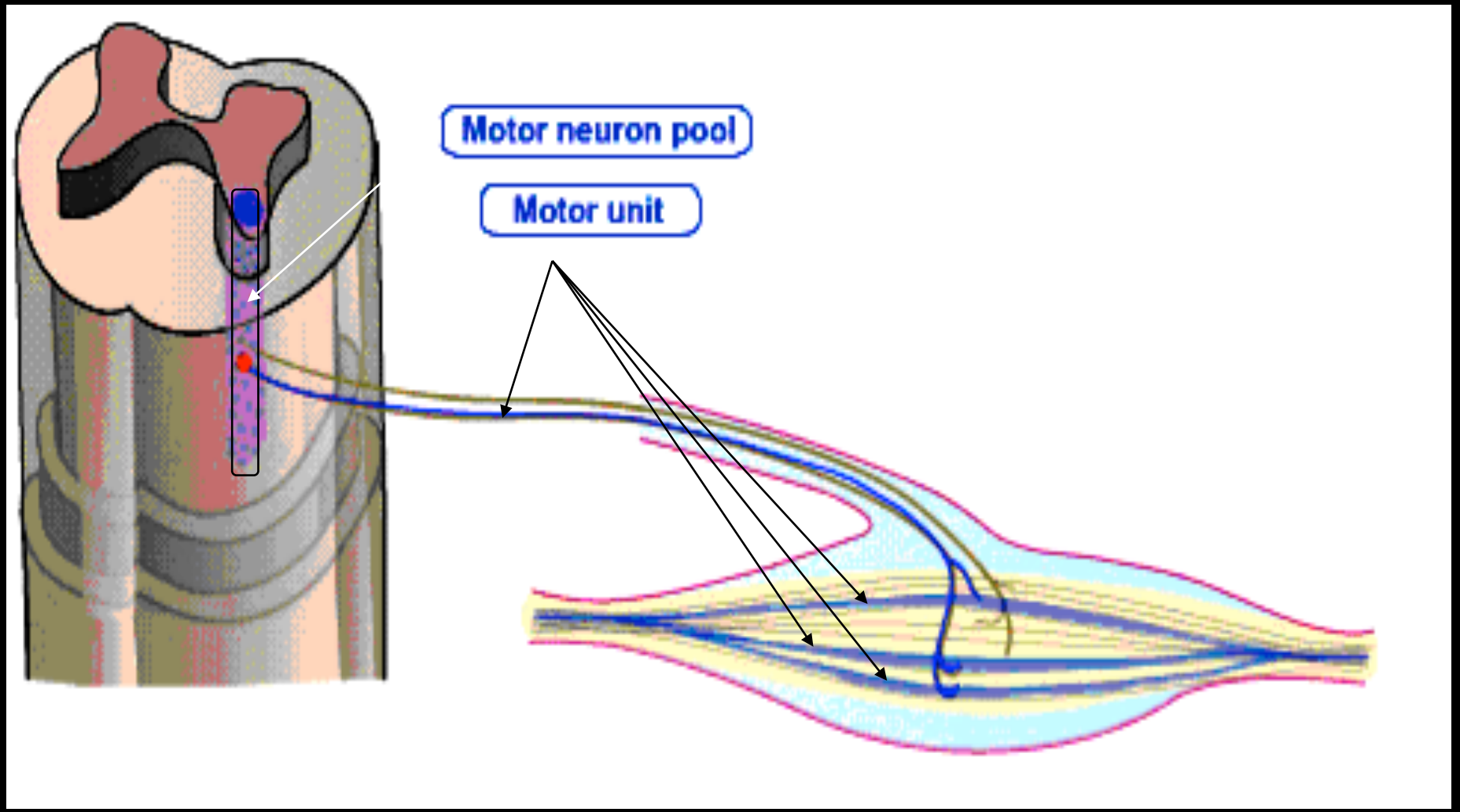
## Motor Neuron Pool (Motor Nucleus)

The group of motor neurons that innervate an individual muscle

## Motor Unit

An individual motor neuron and all the muscle fibers that it innervates

# Motor Neuron Pool vs. Motor Unit



## Motor Neuron Pool (Motor Nucleus)

The group of motor neurons that innervate an individual muscle

## Motor Unit

An individual motor neuron and all the muscle fibers that it innervates

## Innervation Ratio

The number of muscle fibers innervated by a single motor neuron

# Control of muscle force I

**Type of Muscle:**

**Slow twitch - Type I**

**Fast twitch - Type II**

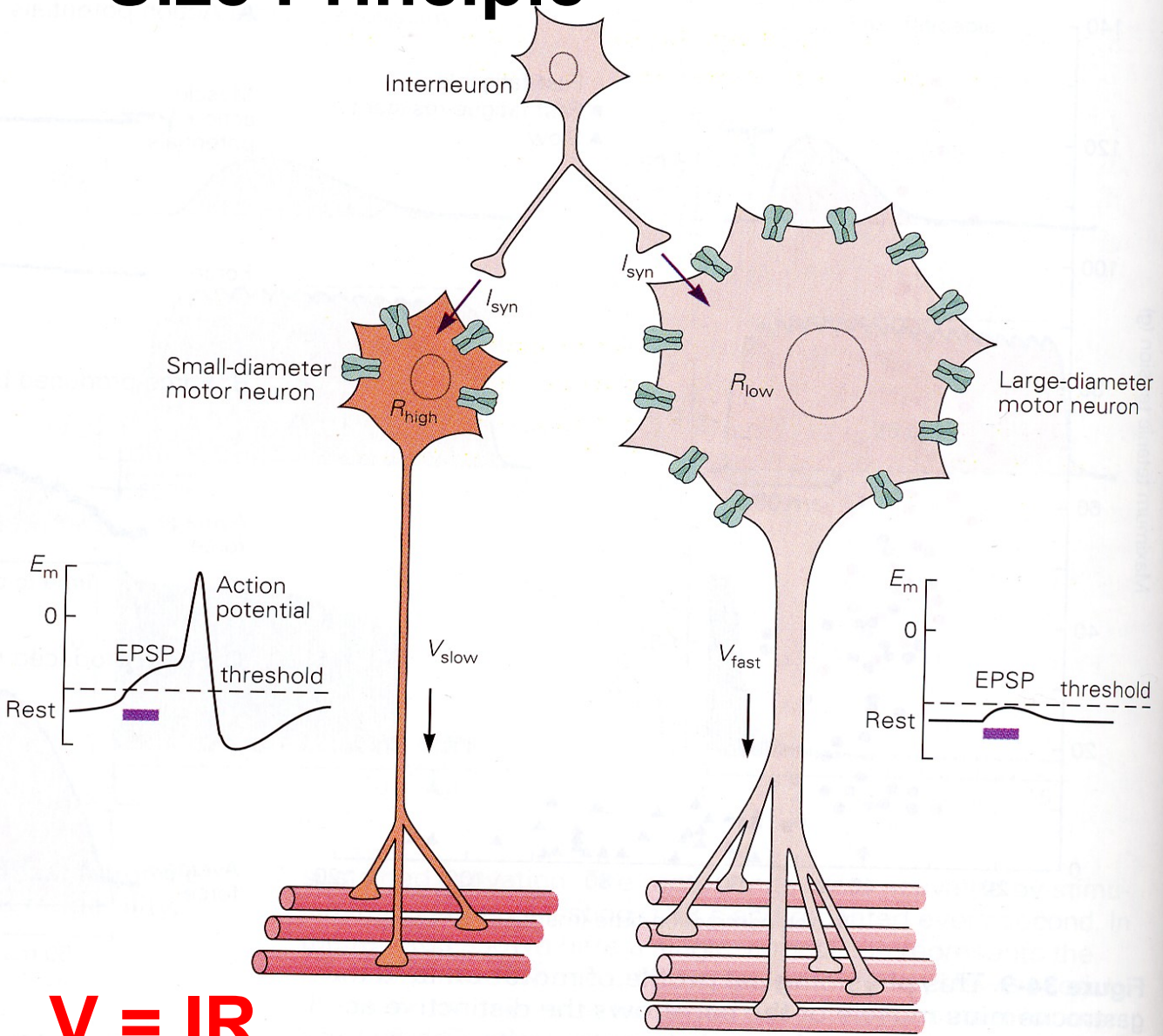
**Determined by innervation!**

# Control of muscle force II

**Size Principle:** With increasing strength of input, motor neurons are recruited from smallest to largest

**Rate Code:** Increases in rate of action potentials of motor neuron cause increases in muscle force

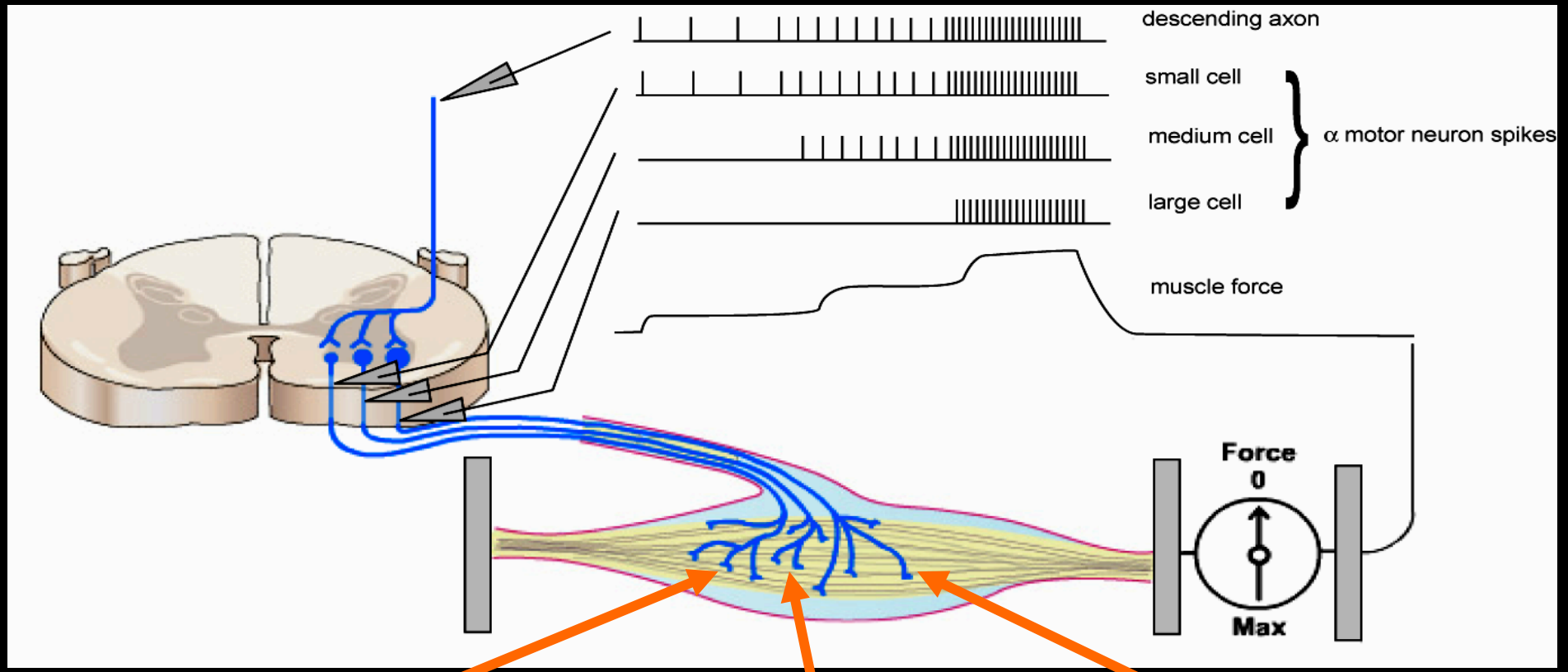
# Size Principle




**V = IR**

From G. E. Loeb & C. Ghez (2000), in *Principles of Neural Science, 4th Edition* (Kandel, Schwartz, & Jessel, Eds.)

# Size Principle




Small motor neurons innervate slow-twitch muscle fibers

Medium motor neurons innervate fast-twitch, fatigue-resistant muscle fibers

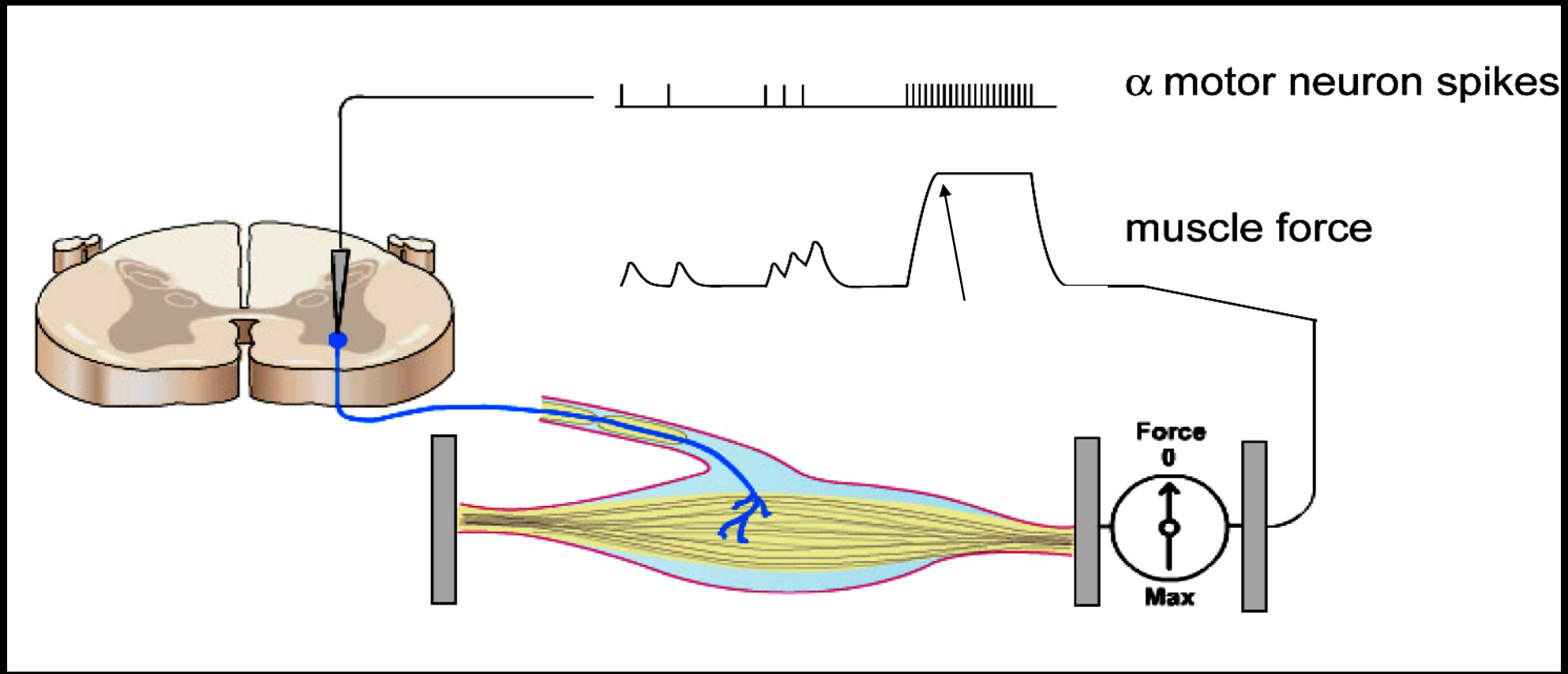
Large motor neurons innervate fast-twitch, fatigable muscle fibers

# Control of muscle force

**Size Principle (recruitment):** With increasing strength of input, motor neurons are recruited from smallest to largest

**Rate Code:** Increases in rate of action potentials of motor neuron cause increases in muscle force

# Rate Code



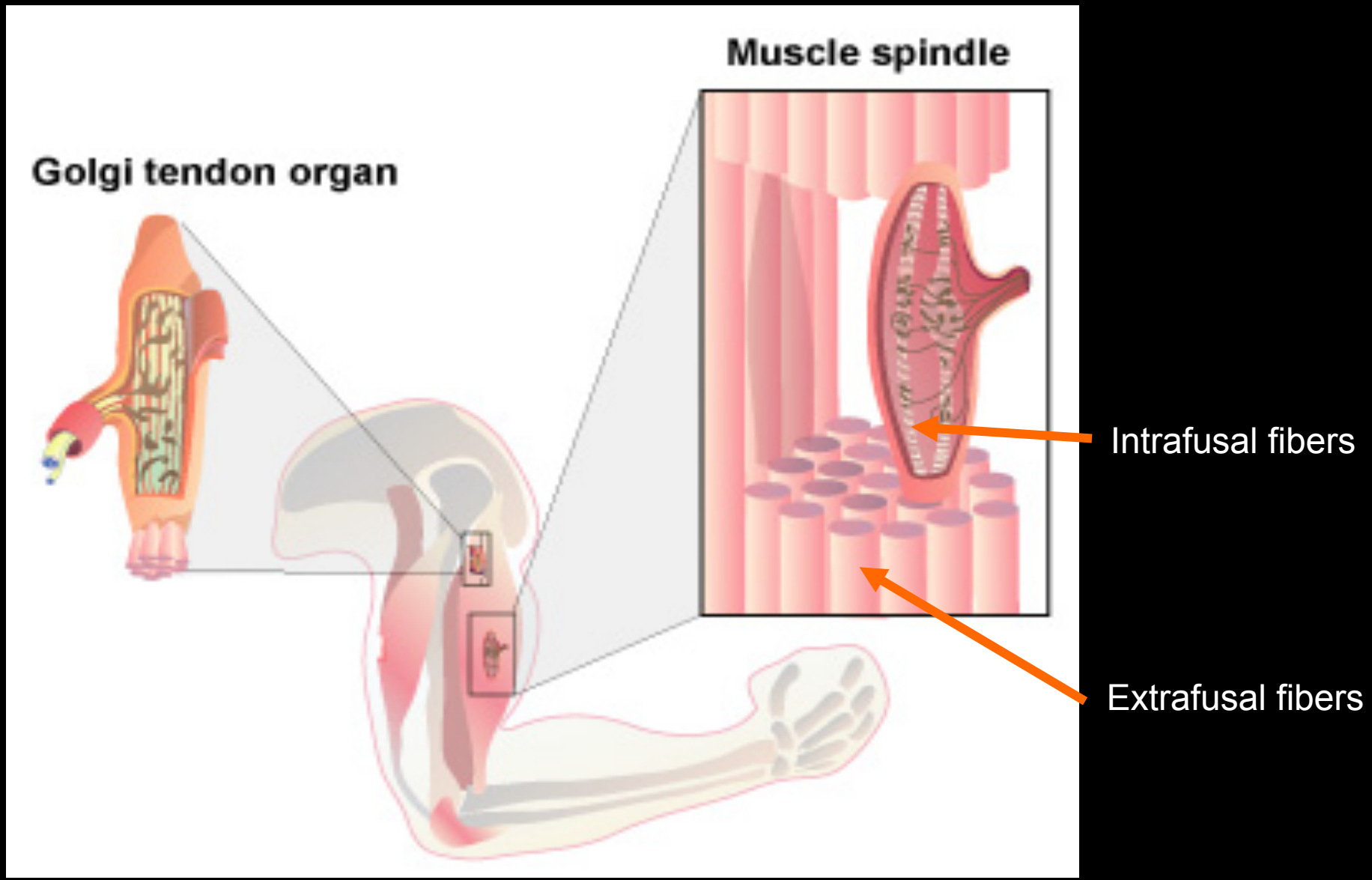
# Proprioception

Specialized receptors provide information about muscle:

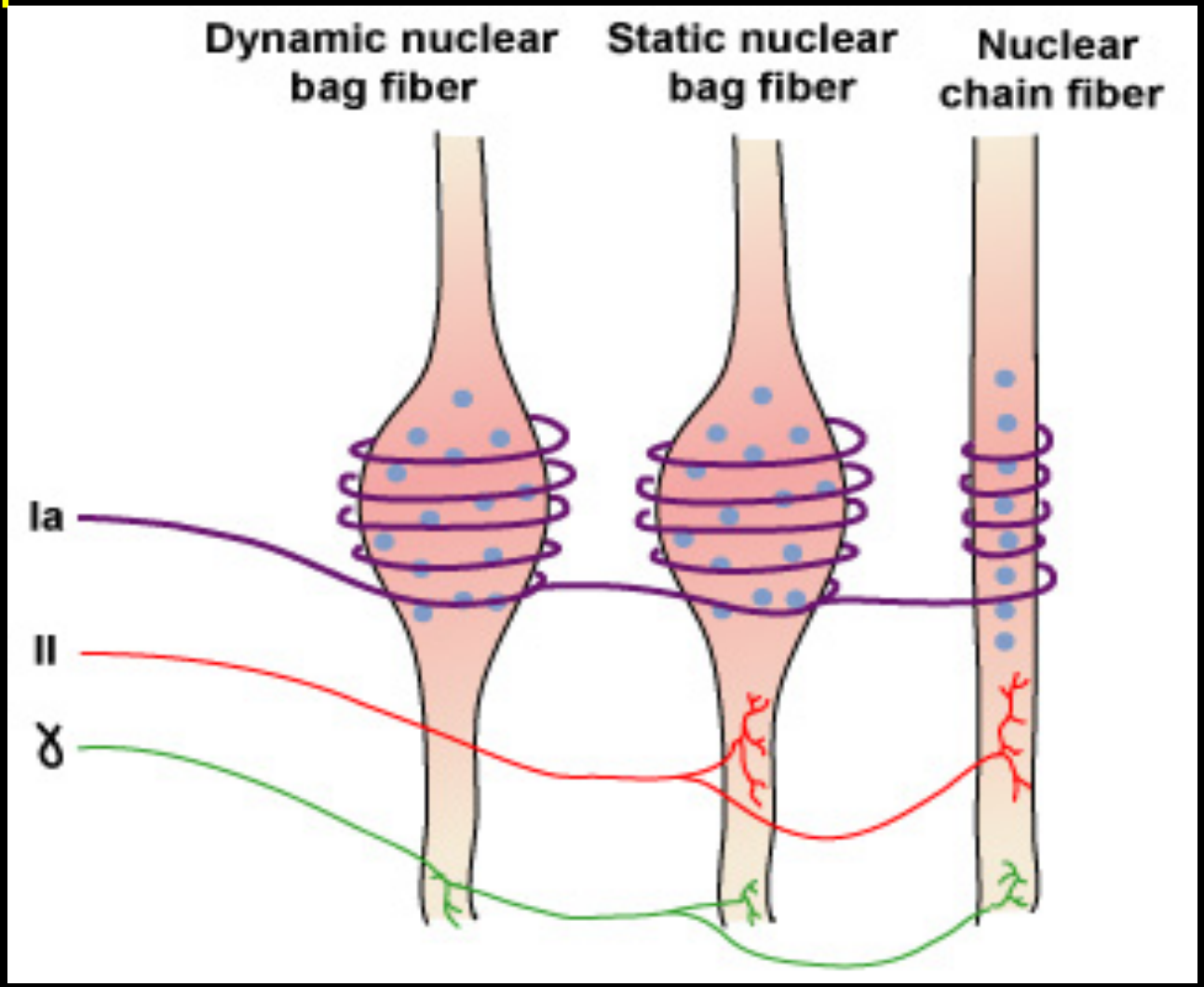
- length
- velocity (change in length)
- load (force)

# Receptors Involved in Proprioception

- Muscle Spindles
- Golgi Tendon Organ


Muscle spindle
Golgi tendon organ
Intrafusal fibers
Extrafusal fibers

# Muscle Spindles are made of intrafusal muscle fibers



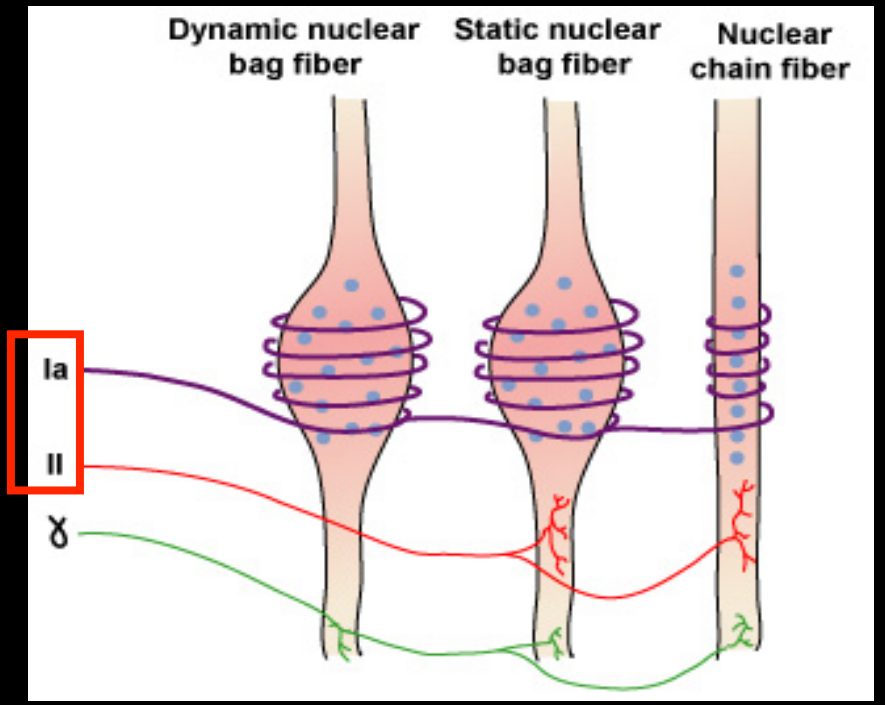

Typical muscle spindle = 1 dynamic nuclear bag fiber
1 static nuclear bag fiber
~ 5 nuclear chain fibers

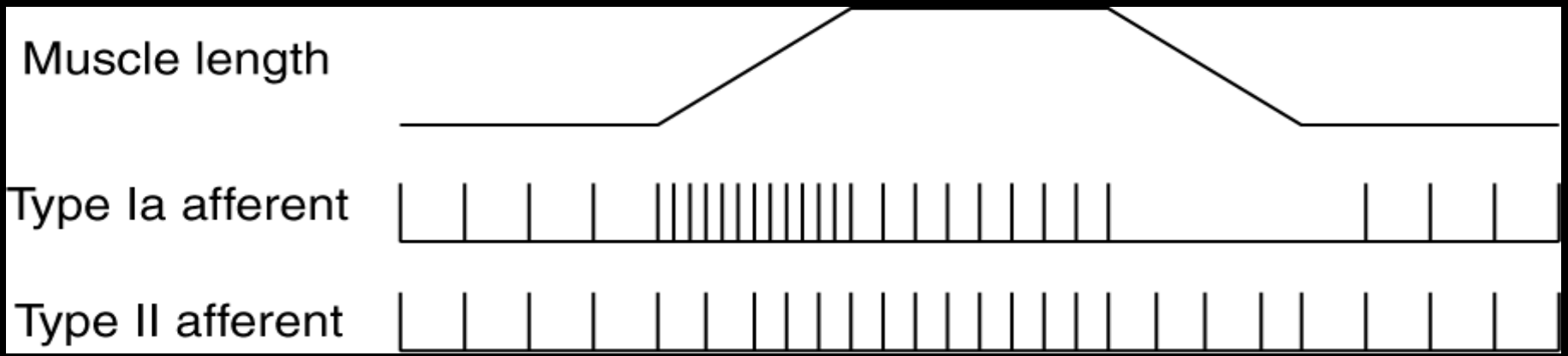
# Sensory Fibers Involved in Proprioception

**Muscle Spindles**

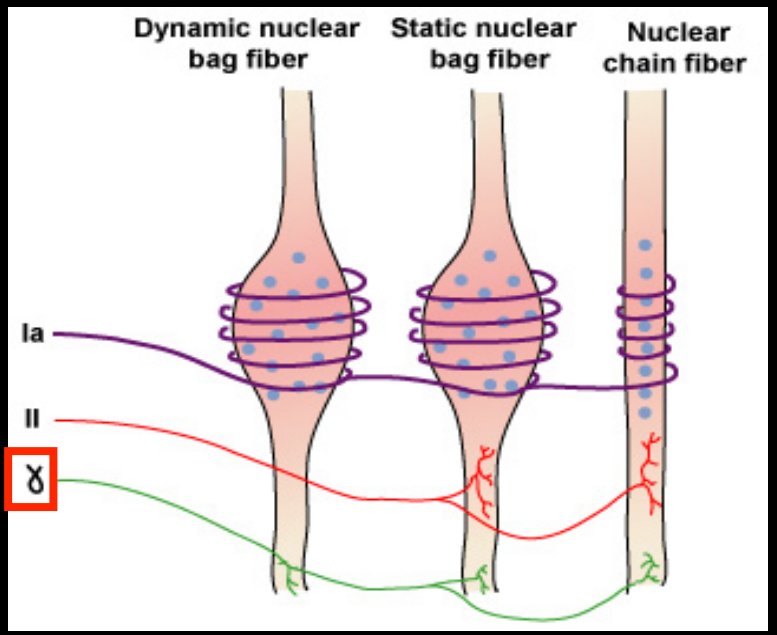
- **Group Ia (primary): velocity and length**
- **Group II (secondary): length**

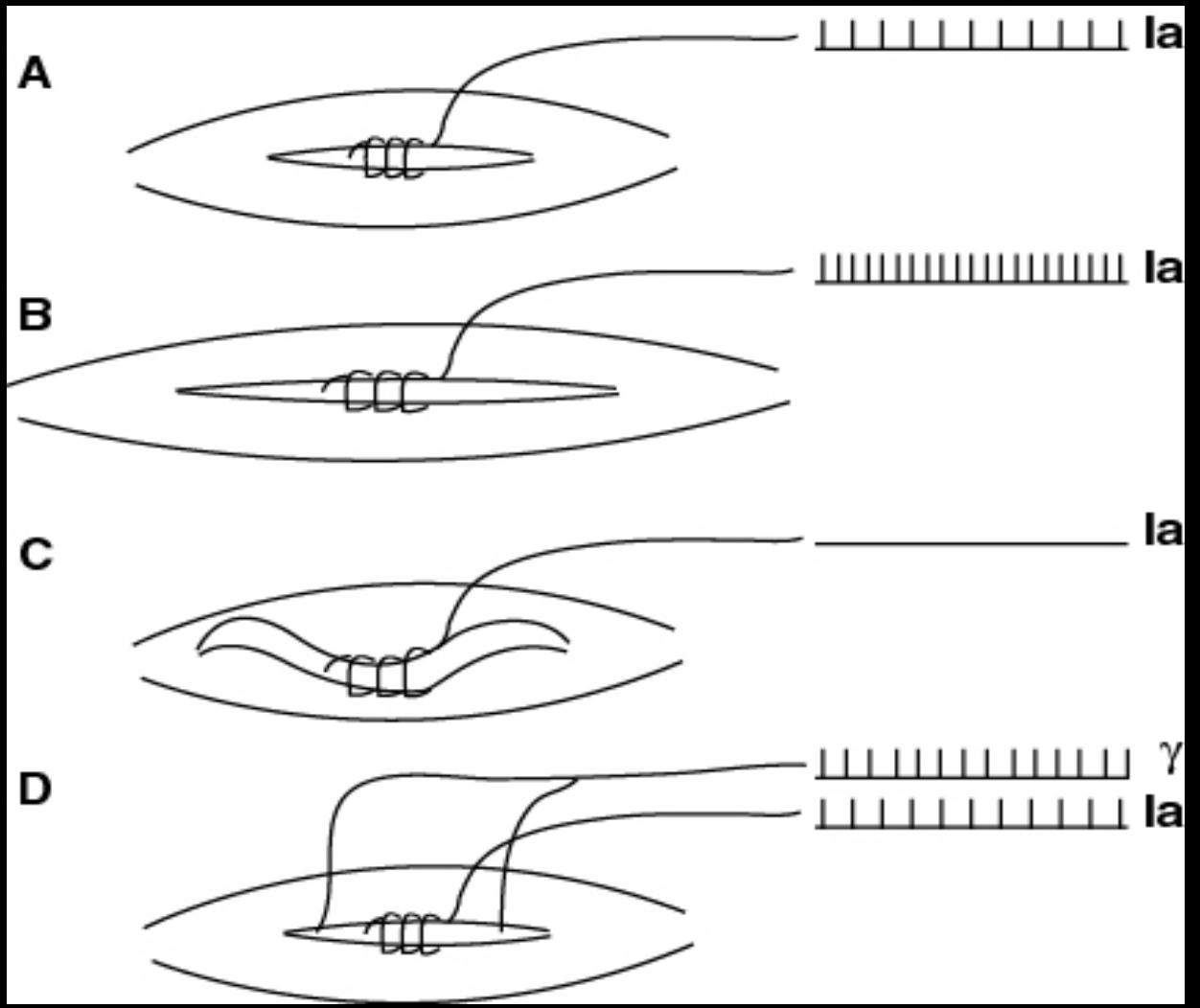
# Type Ia afferents signal velocity and length, Type II afferents signal length only



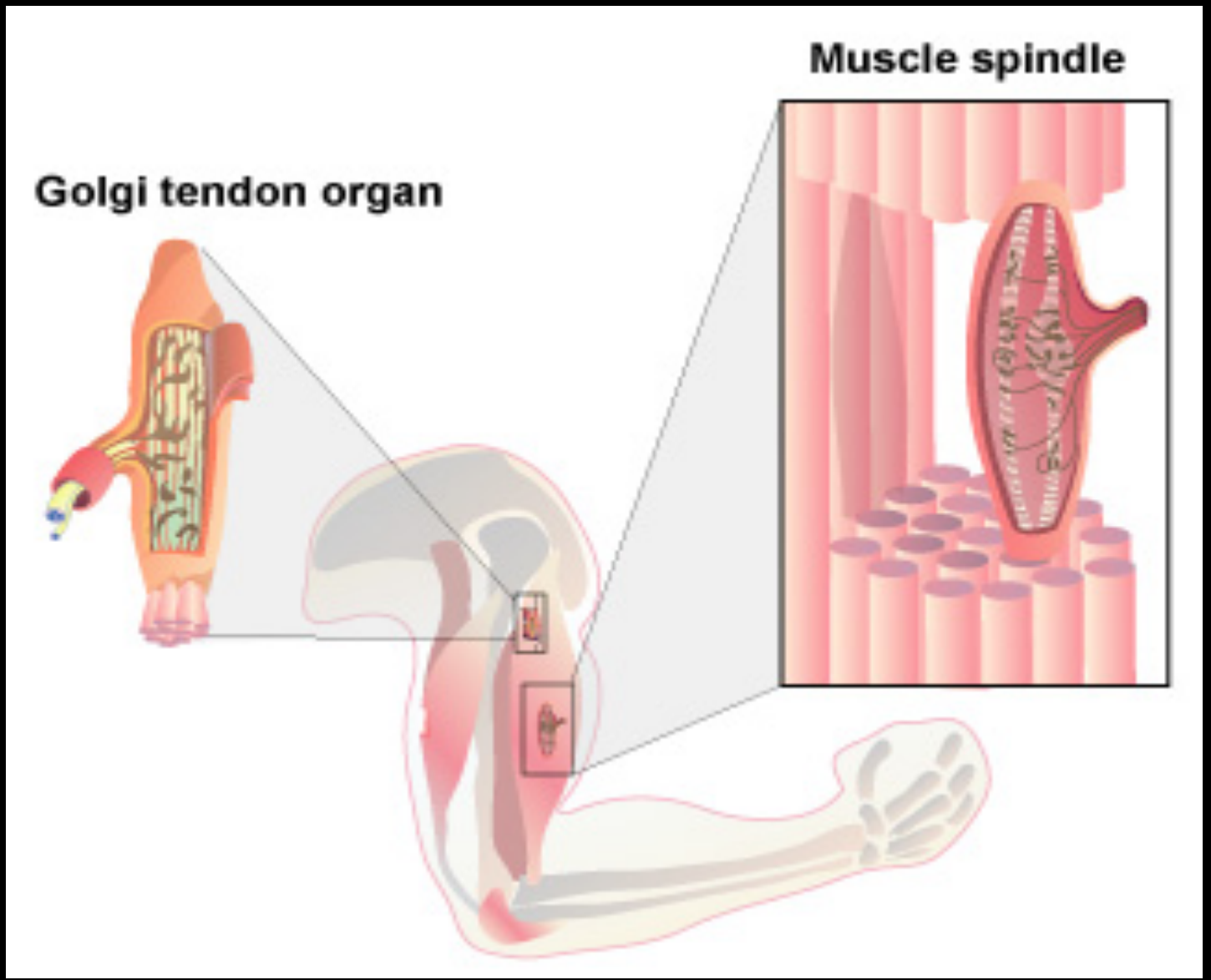
# Gamma motor neurons maintain sensitivity of muscle spindle



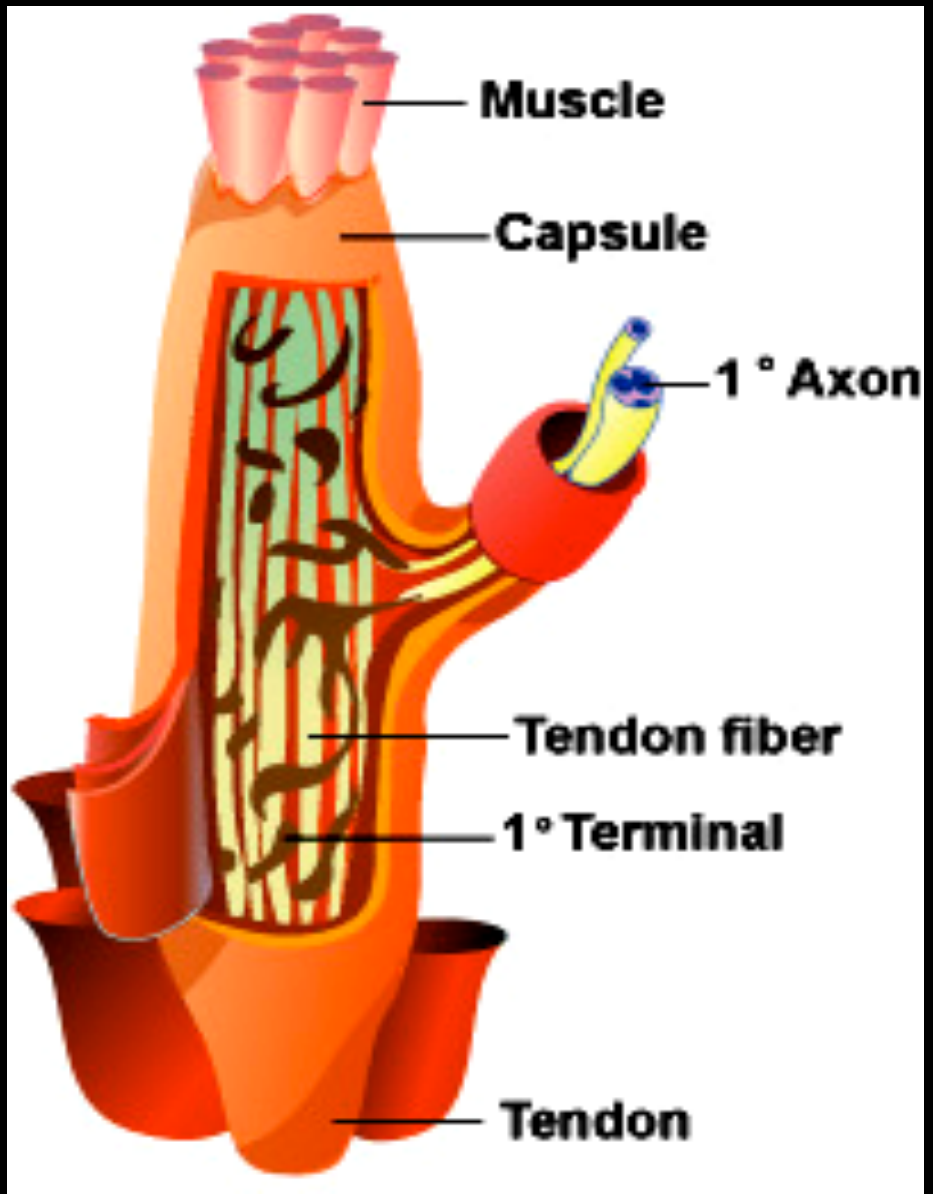



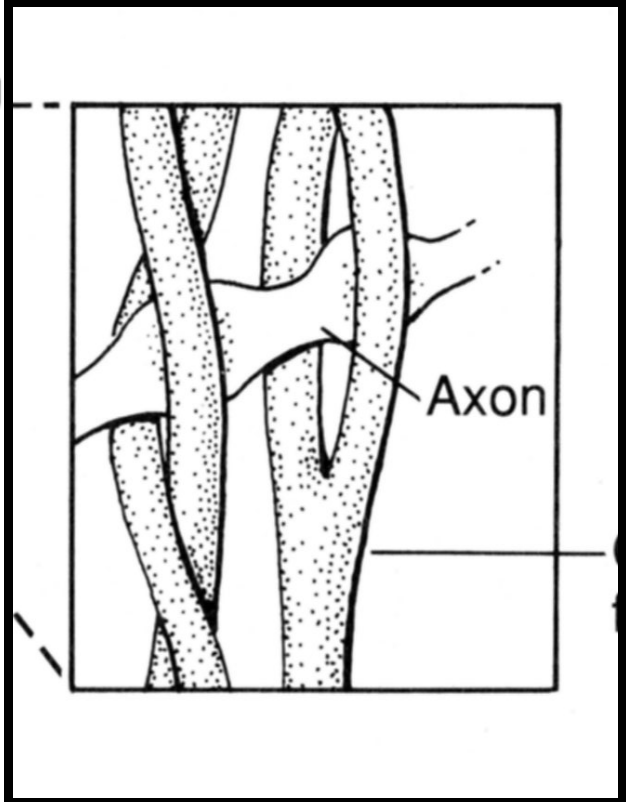
# Receptors Involved in Proprioception

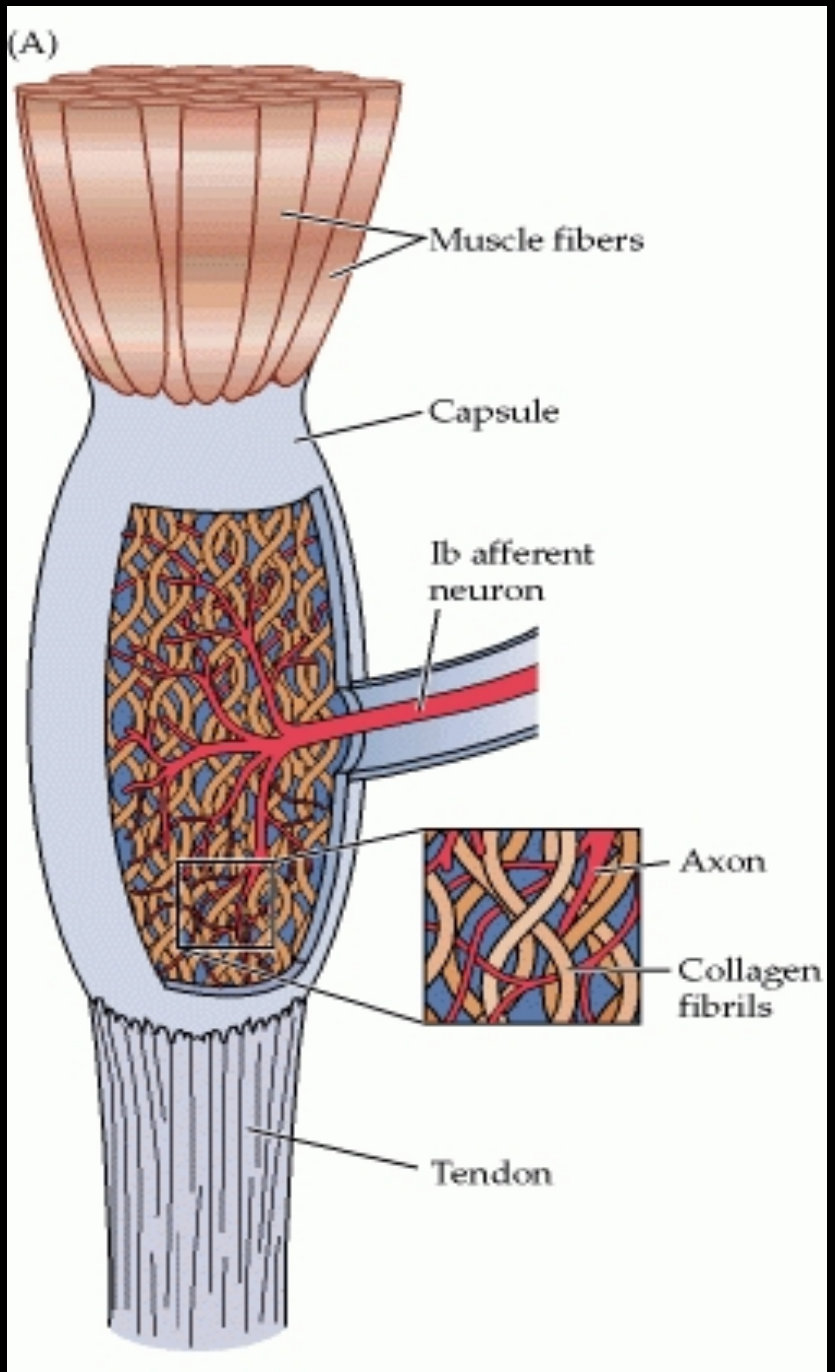
- Muscle Spindles
- Golgi Tendon Organs

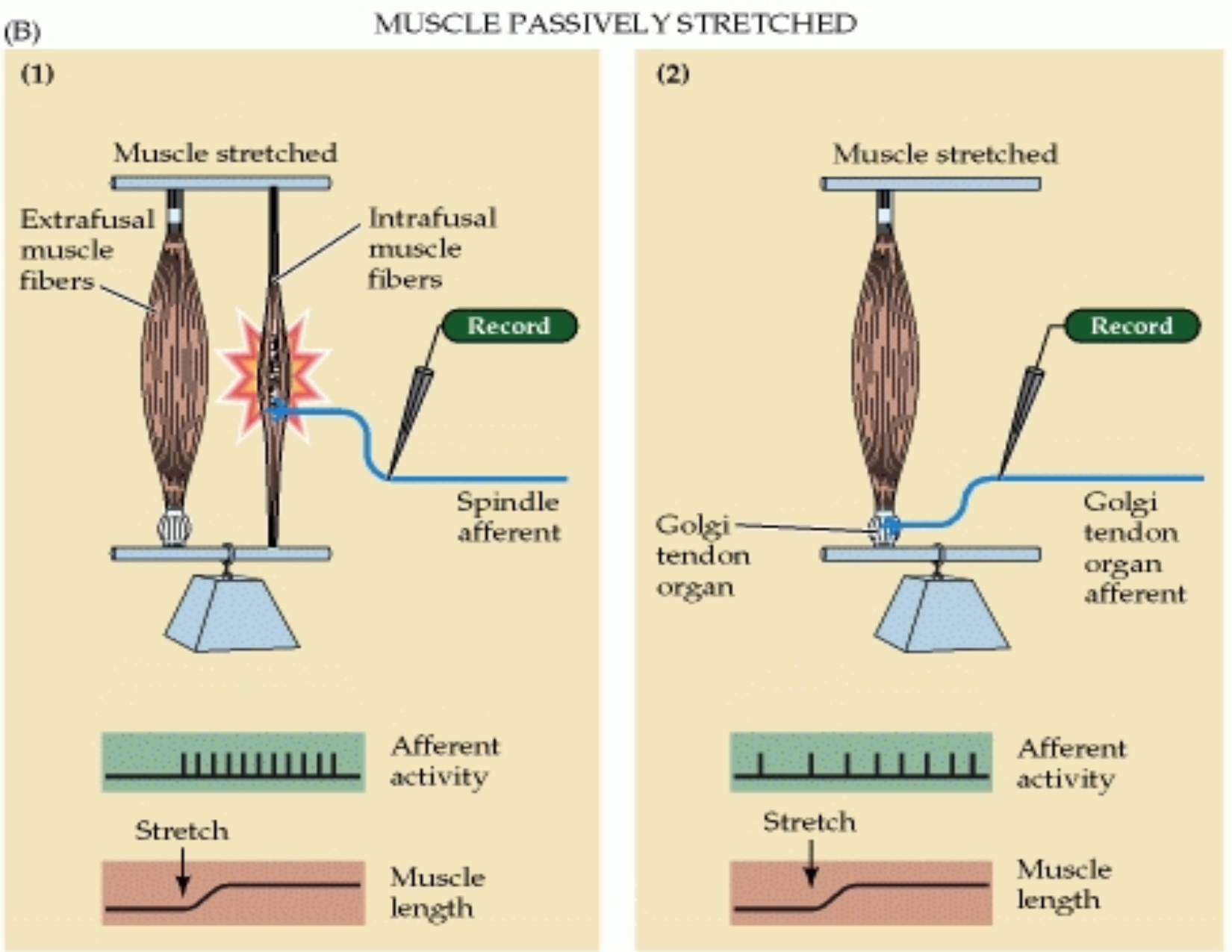

Muscle spindle
Golgi tendon organ

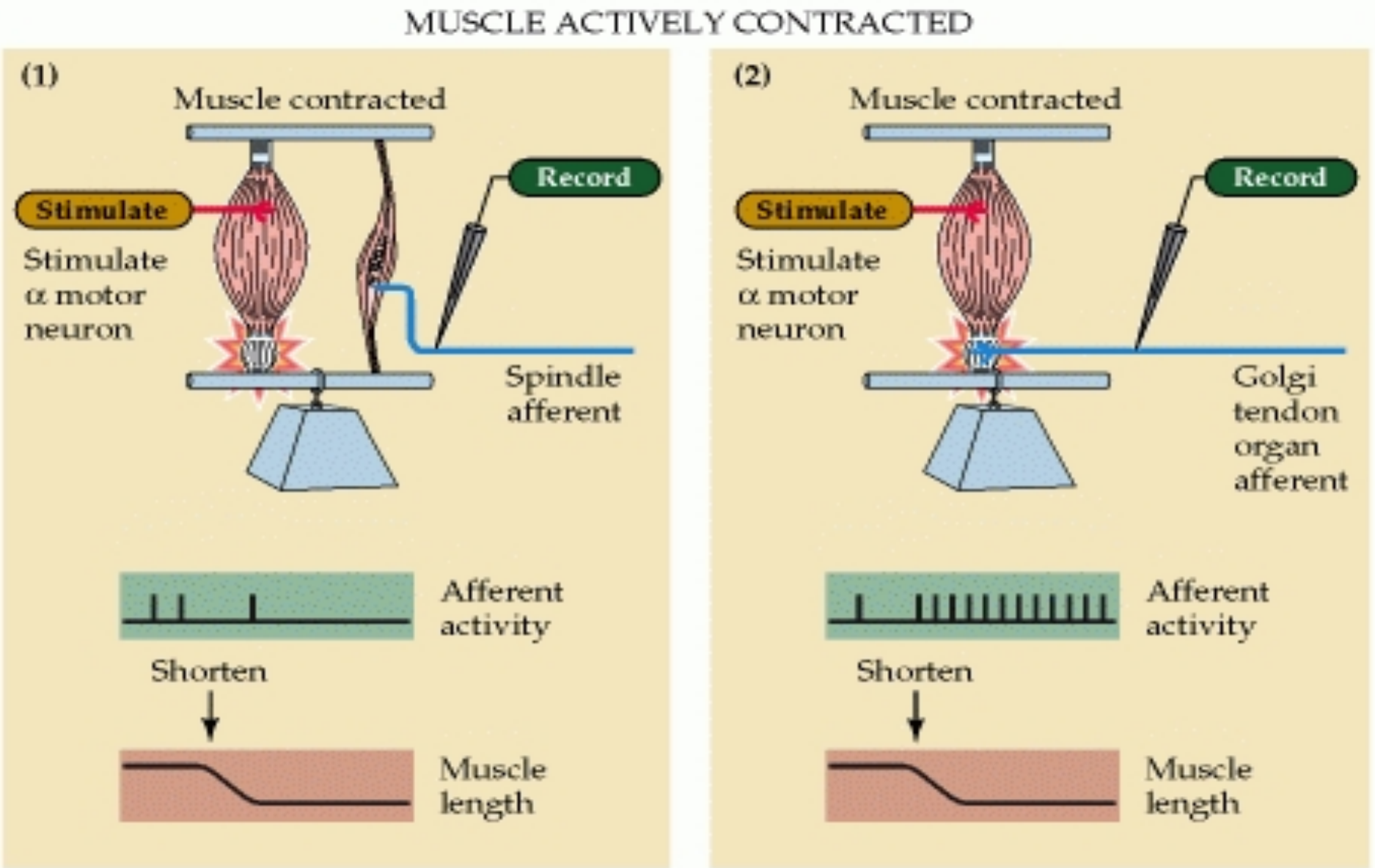
# Golgi Tendon Organ




(A)
Muscle fibers
Capsule
Ib afferent neuron
Axon
Collagen fibrils
Tendon


(B)
MUSCLE PASSIVELY STRETCHED
(1)
Muscle stretched
Extrafusal muscle fibers
Intrafusal muscle fibers
Record
Spindle afferent
Afferent activity
Stretch
Muscle length
(2)
Muscle stretched
Record
Golgi tendon organ
Golgi tendon organ afferent
Afferent activity
Stretch
Muscle length


MUSCLE ACTIVELY CONTRACTED
(1)
Muscle contracted
Record
Stimulate
Stimulate α motor neuron
Spindle afferent
Afferent activity
Shorten
Muscle length
(2)
Muscle contracted
Record
Stimulate
Stimulate α motor neuron
Golgi tendon organ afferent
Afferent activity
Shorten
Muscle length

# Sensory Fibers Involved in Proprioception

**Muscle Spindles**

- **Group Ia (primary): velocity and length**
- **Group II (secondary): length**

**Golgi Tendon Organs**

- **Group Ib: Tension or force**

# Questions

**When is the muscle spindle afferent activated, during muscle stretch or during muscle contraction?**

# Questions

**When is the gamma MN activated, during muscle stretch or muscle contraction?**

# Questions

**When is the Golgi tendon organ afferent activated, during**
**muscle stretch or muscle contraction?**

# Questions

**Activation of the gamma MN causes muscle contraction: true or false?**

# Next Lecture: Spinal Reflexes

## Myotatic reflex

Muscle spindles (Ia)
+ alpha motor neurons

## Autogenic inhibition

Golgi tendon organs (Ib)
- alpha motor neurons