HUBS 191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,
it is NOT a substitute for the lecture !

Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

HUBS 191

Jeff Erickson – Department of Physiology

Lecture 24
Neurophysiology 4: Motor Control

Example exam question

Areas of skin with large and widely-spaced receptive fields:

A. always yield very intense stimuli.
B. are associated with visceral sensation.
C. provide a low accuracy of signal localization.
D. are common in the fingers, hands, and lips.

Objectives and Study Guide

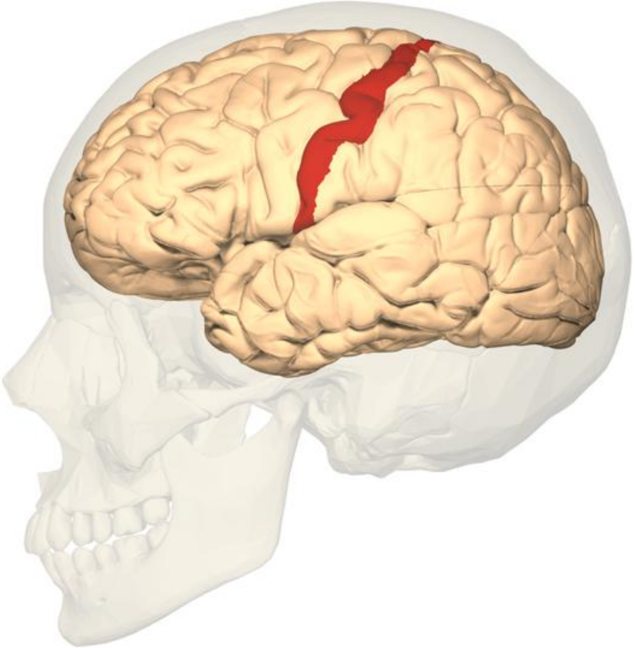
After this lecture you should be able to:

- Name the regions of the brain involved in planning, refining, and executing movement and briefly describe their function
- Describe the function of the neuromuscular junction
- Contrast voluntary and reflex responses

Related reading: Martini et al. Modules **12.12-12.14** (p. 498-502), **13.6** (p. 520-521), and **13.12** (p. 532)

Afferent vs. Efferent Signals

Afferent

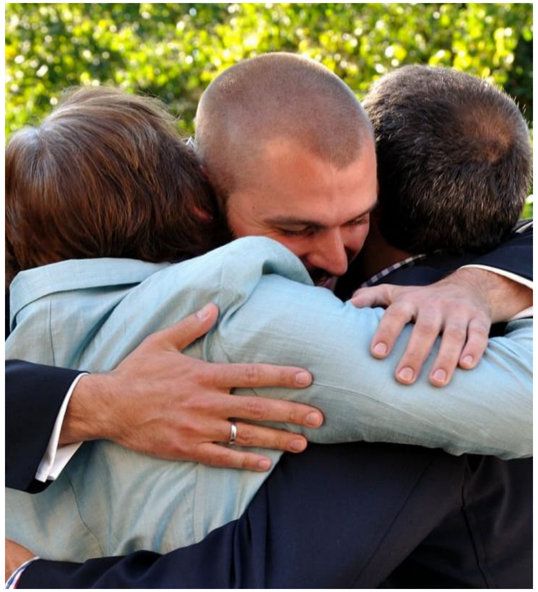


Efferent

Afferent signals are sent to the central nervous system to give us information about our environment and our body homeostasis

Once you've processed this information, the central nervous system sends instructions to the rest of the body using **efferent signals**.

We perform voluntary movements for a variety of reasons

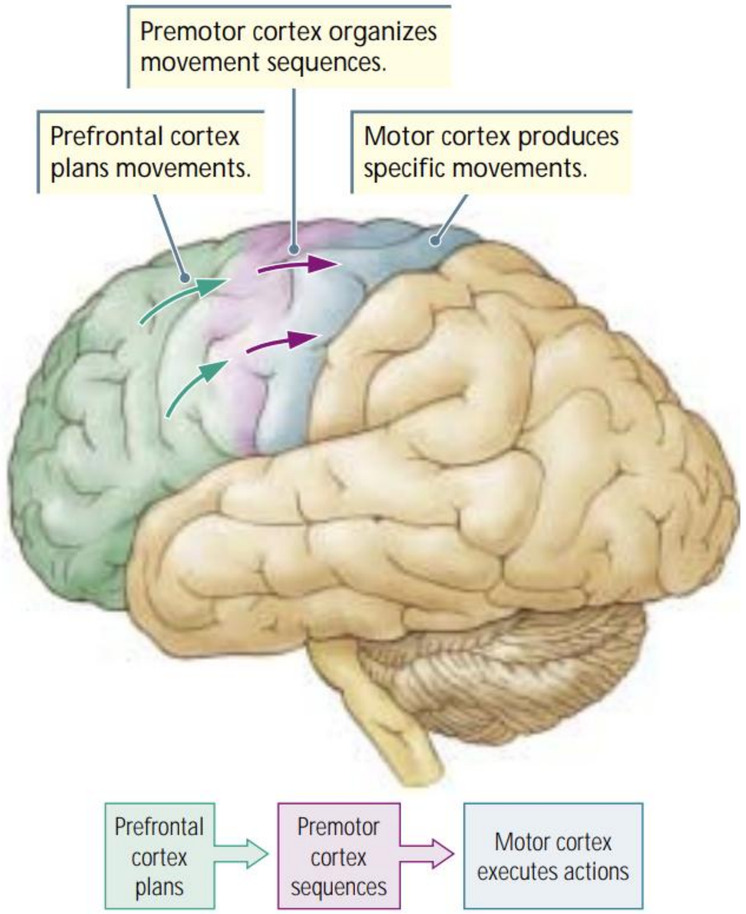


Think about your voluntary movements:

- Why do you choose to move?
- What movements do you choose?

Left: Pickpic; Middle: Flickr.com; Right: Flickr.com; Bottom; Giphy.com

Movement and the Brain:
Planning and Initiating Movement



Kolb & Whishaw, An introduction to Brain and Behavior, 3rd Ed. Ch11

Prefrontal cortex

- Neurons involved in decisions to move; planning the desired movement outcome
- e.g. I plan to sit 10 rows up in the lecture theatre

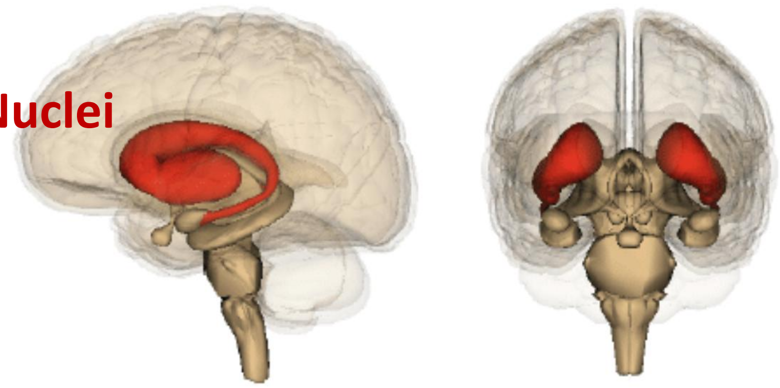
Premotor cortex

- Neurons involved in organizing movement sequences to achieve the outcome
- e.g. walk to the stairs, climb up 10 stairs, step into the aisle, sit down in a seat

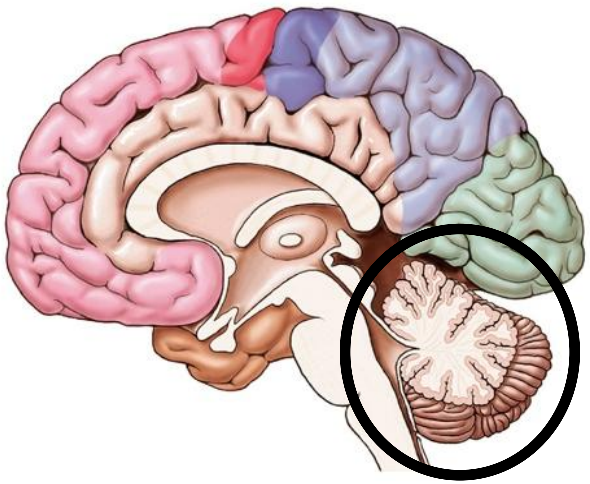
Primary motor cortex

- Neurons involved in directing voluntary movement
- e.g. activate knee and hip flexors to step up, activate tibialis anterior to dorsiflex foot…etc.

Movement and the Brain: Modifying and Refining Movement



Basal nuclei in red, www.physio-pedia.com/Basal_Ganglia



Martini et al., Visual Anatomy and Physiology (3rd ed), Module 13.11, pg 530.

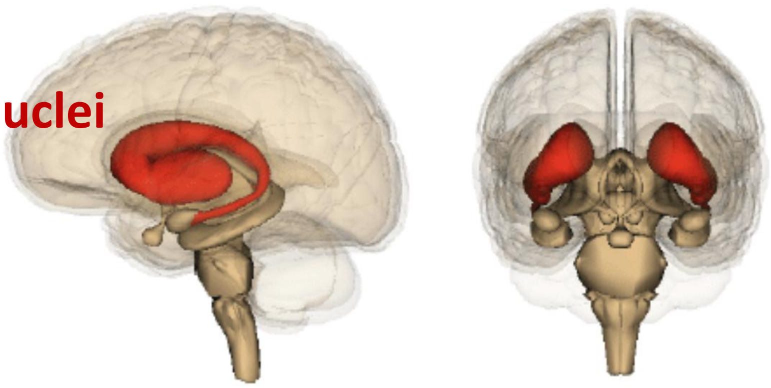
Basal Nuclei

- Influence posture and automatic movements
- Refine movements – select which to allow and which to inhibit
- How? By altering sensitivity of neurons projecting into the corticospinal or other pathways

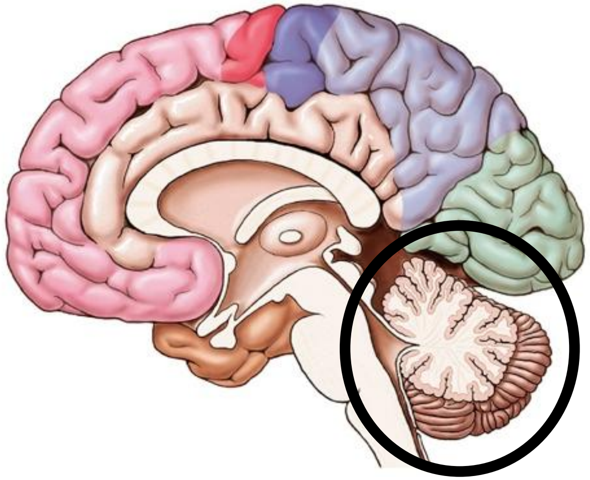
Cerebellum

- Stores and facilitates learning, planning and execution of motor programs (ex. walking program)
- Monitors sensory input (proprioceptors, balance) to compare actual movement to planned movement
- Organizes timing of muscle contractions and modifies ongoing activity (critical for posture & balance)

Movement and the Brain:
Modifying and Refining Movement



Top: Basal nuclei in red, www.physio-pedia.com/Basal_Ganglia



Martini et al., Visual Anatomy and Physiology (3rd ed), Module 13.11, pg 530.

For interest only: Damage to basal nuclei is typically associated with movement disorders described as hypokinetic (not enough movement) or hyperkinetic (too much movement).

For interest only: Damage to the cerebellum is typically associated with ataxia (poor muscle control; clumsy movement). Examples: drunken gait, lack of coordination, slurred speech.

Did you catch it?

- What are the three major brain regions that plan and initiate voluntary movement?

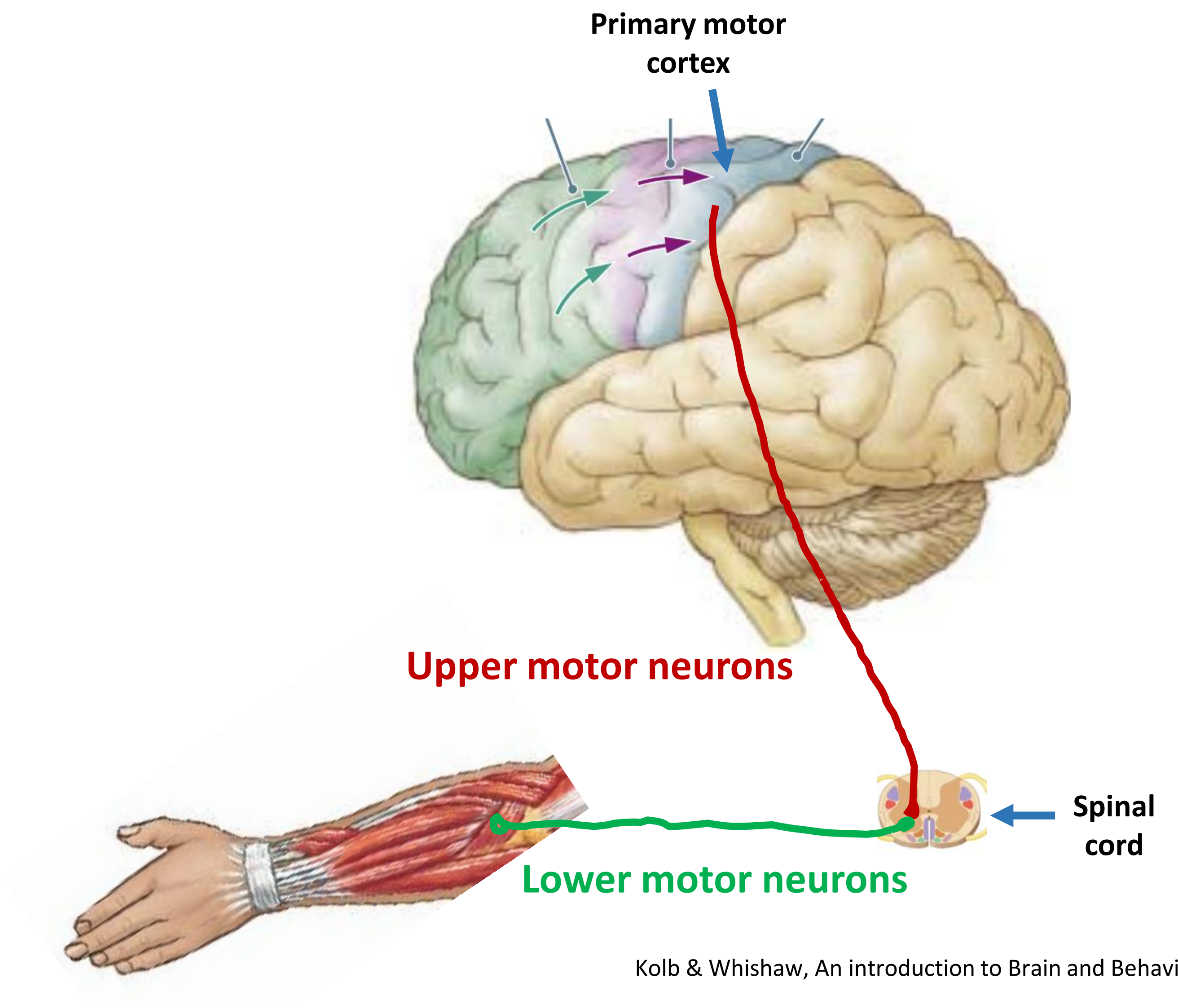
- What is the order for information to move through them, and what is each region’s primary function?

- What are the roles of the basal nuclei and cerebellum in refining movement?

Movement of the limbs and trunk is controlled by the corticospinal pathway

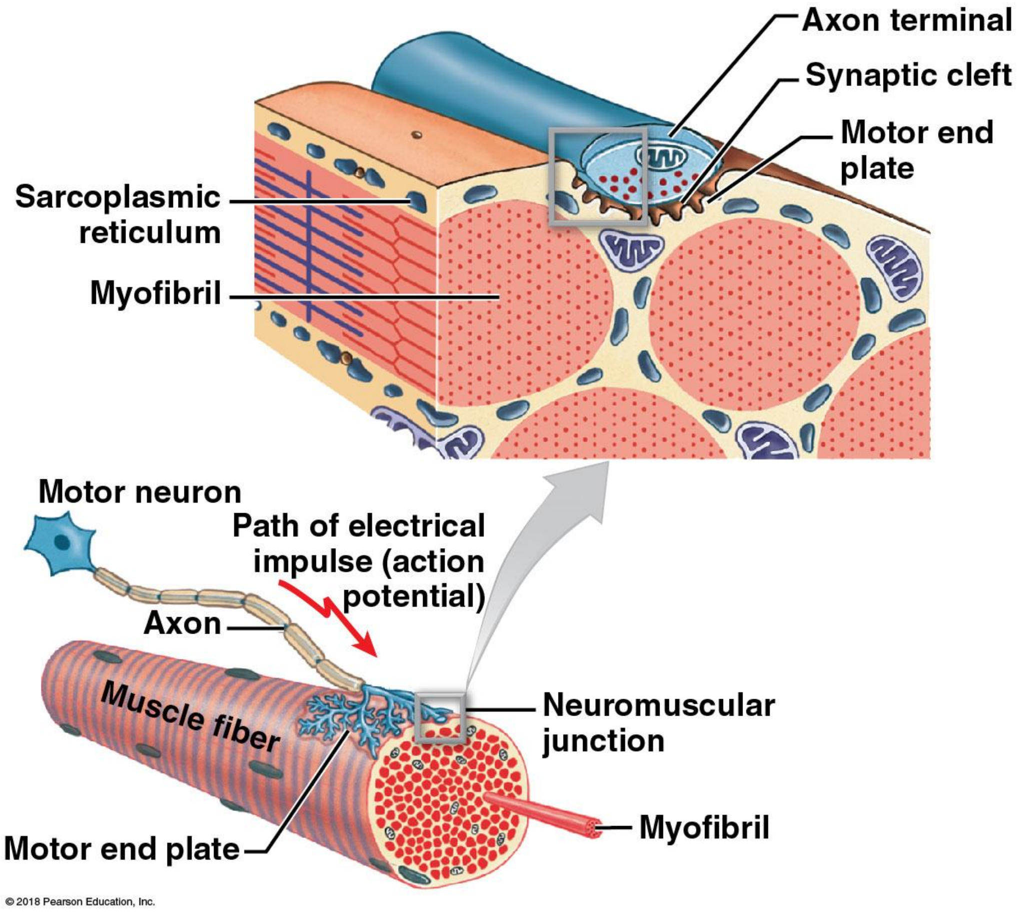
Corticospinal pathway

1. upper motor neurons in primary motor cortex fire action potentials that propagate along axons extending down the spinal cord
2. to activate lower motor neurons in spinal cord, to fire action potentials that propagate along axons within peripheral nerves
3. to **skeletal muscle**



Kolb & Whishaw, An introduction to Brain and Behavior, 3rd Ed. Ch11

The Neuromuscular Junction (NMJ) is the communication point between nerves and skeletal muscle

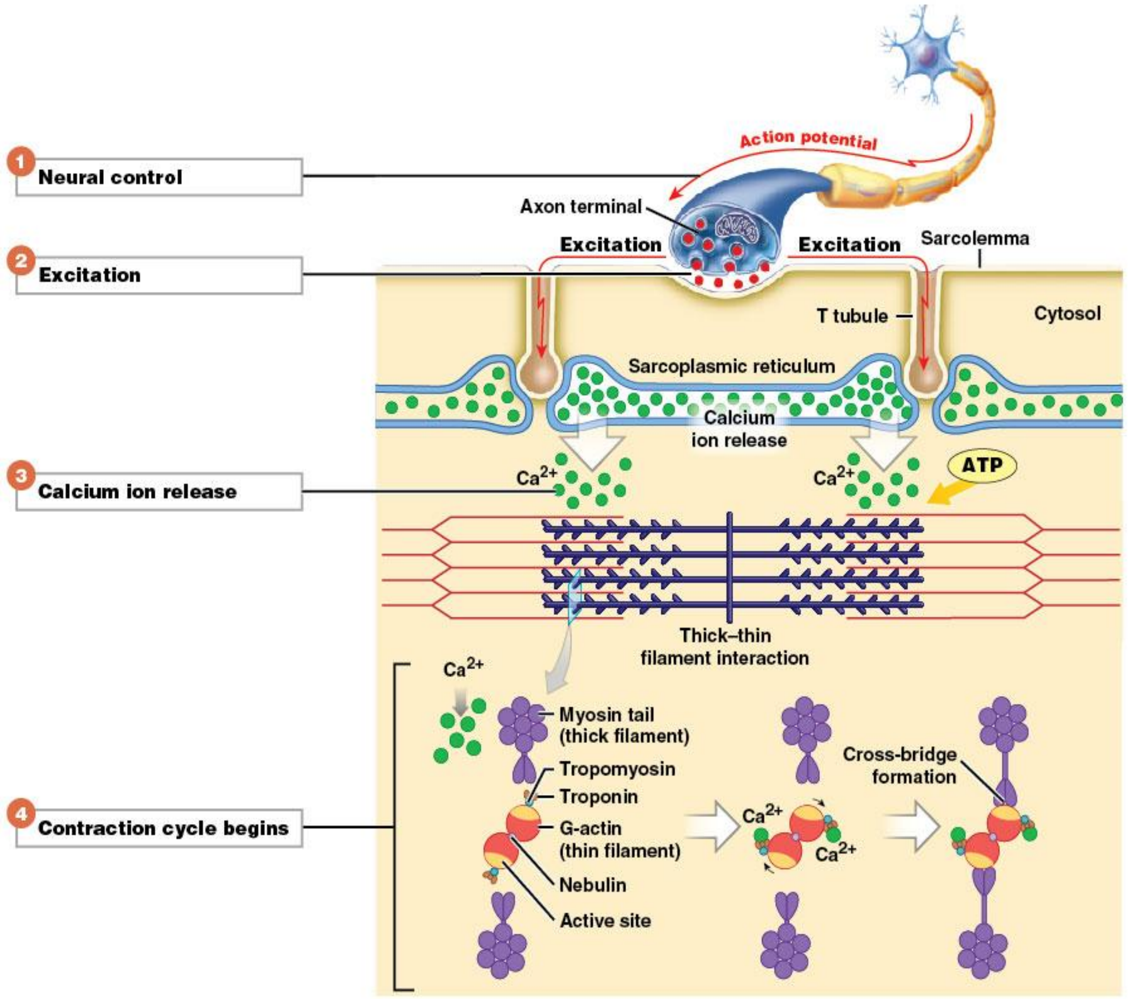


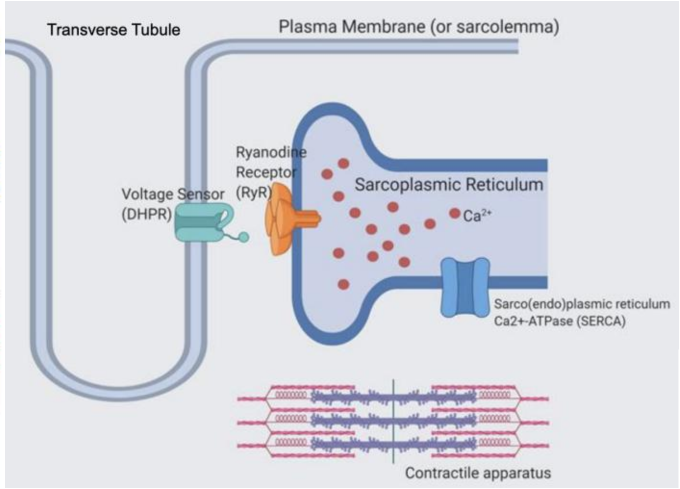
Martini et al., Visual Anatomy and Physiology (3rd ed), Module 9.6, pg 366.

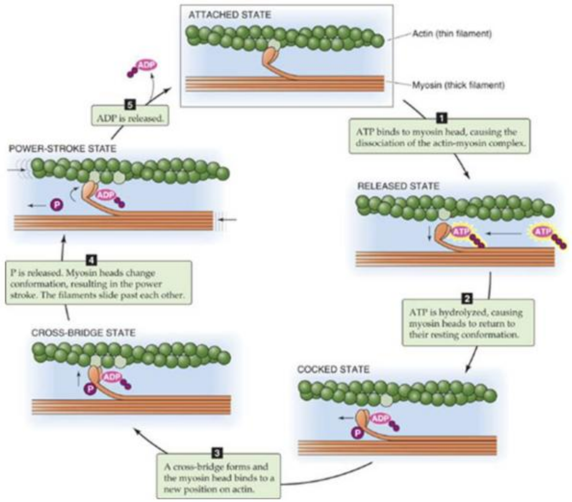
Key features of the neuromuscular junction (NMJ):

- A specialized type of chemical synapse
- Between axon terminal of a motor neuron and skeletal muscle fibre
- The neurotransmitter released is Ach, so is always excitatory
- Ach binds to chemically-gated Na^+ channels and propagates the action potential to the sarcolemma of the muscle fibre
- Summation is usually not needed – since there's no inhibitory local potential, when an action potential arrives at the NMJ, the connected muscle fibres contract

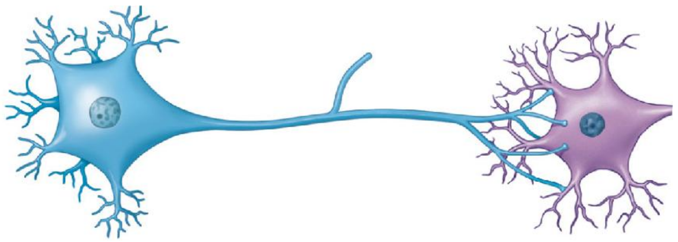
Closing the loop: the NMJ allows us to translate motor signaling from the brain into muscle tension





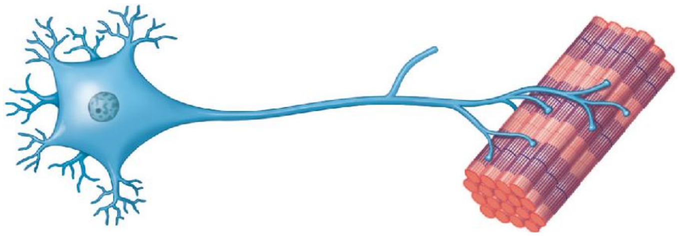


Neuron-neuron synapse vs neuromuscular junction cheat sheet



Neuron-neuron

- Synapses are tiny, each synapse may be one of thousands on the post-synaptic cell
- Variety of neurotransmitters
- Inputs may be excitatory or inhibitory (EPSPs & IPSPs)
- Requires summation: Single presynaptic AP will rarely bring postsynaptic cell to threshold



Neuron-skeletal muscle

- Synapses are huge, each muscle fibre receives input from only one neuron at one site
- Only acetylcholine (ACh) used
- Inputs are only excitatory (no inhibition)
- No summation required: AP from motor neuron very likely to bring muscle fibre to threshold

Precision vs. Power: Motor Units

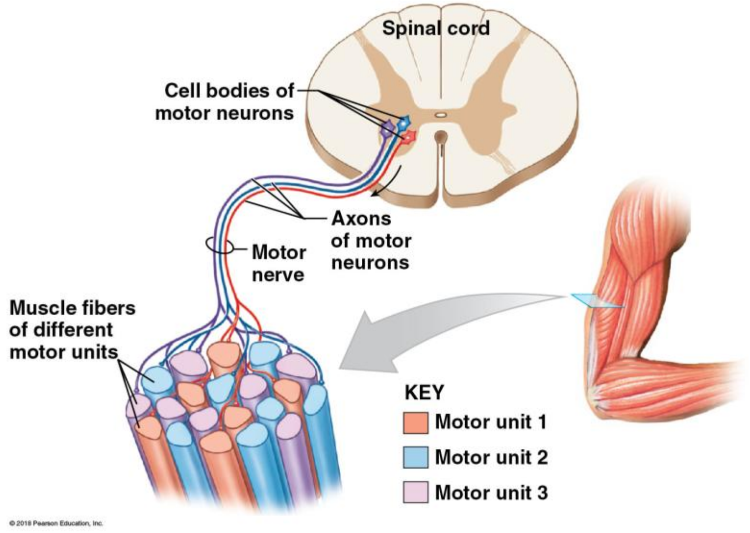
A motor unit is made of a single lower motor neuron plus all the skeletal muscle fibres it innervates.

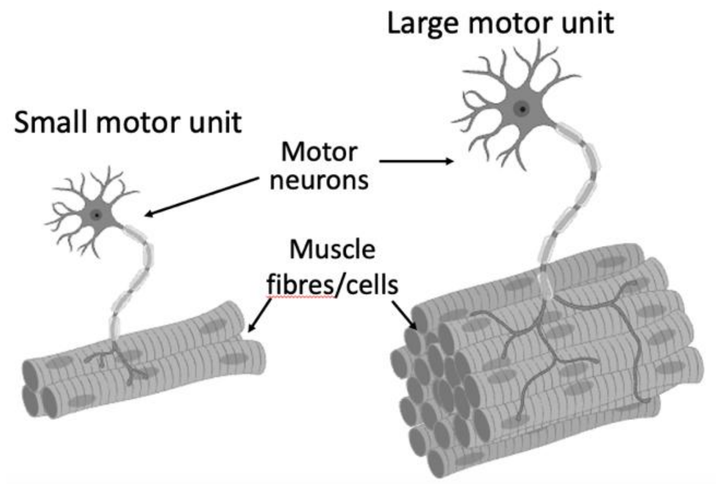
Small motor unit:

- A motor neuron plus the **few muscle fibres** it activates
- can produce more precise movement (e.g. of hand, lips, tongue)

Large motor units:

- A motor neuron plus the **many muscle fibres** it activates
- can produce more forceful movements (e.g. of limbs)





Small and large motor units - J.Schack – Made with BioRender 2024

Example exam question

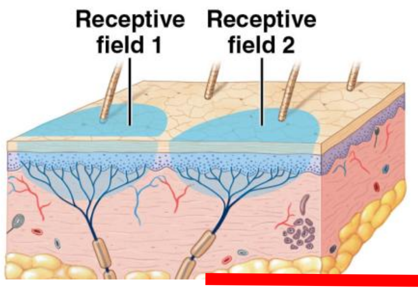
A primary responsibility of the basal nuclei in the brain is to:

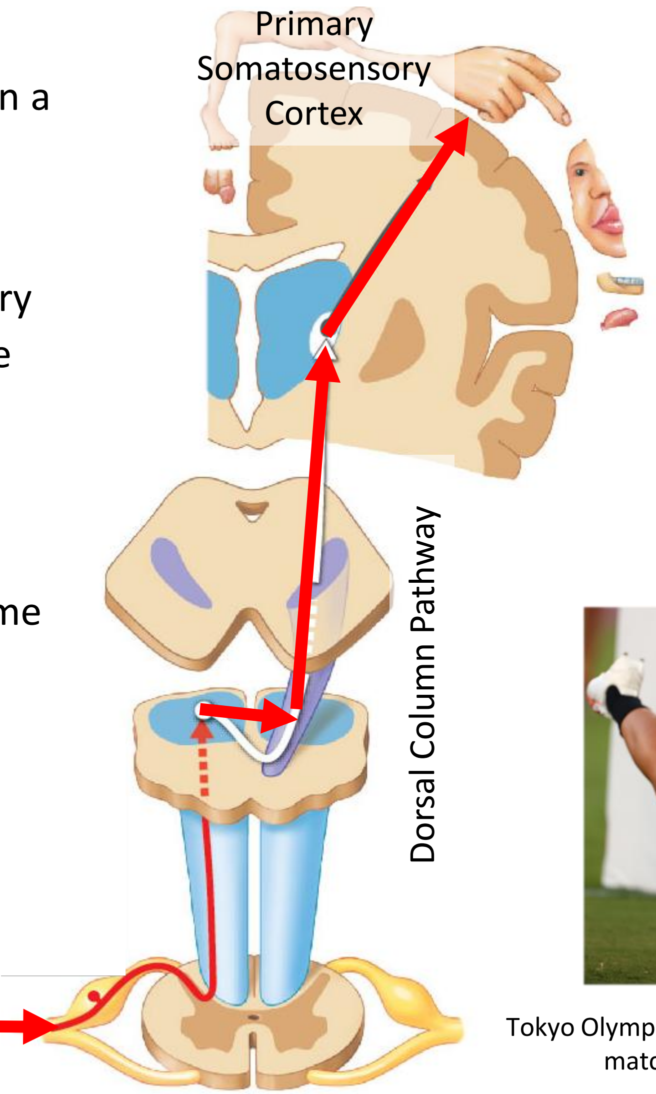
A. perform high-level planning of desired movement outcomes.
B. organize movements into sequences.
C. initiate specific voluntary movements.
D. refine movements by altering neuron sensitivity.

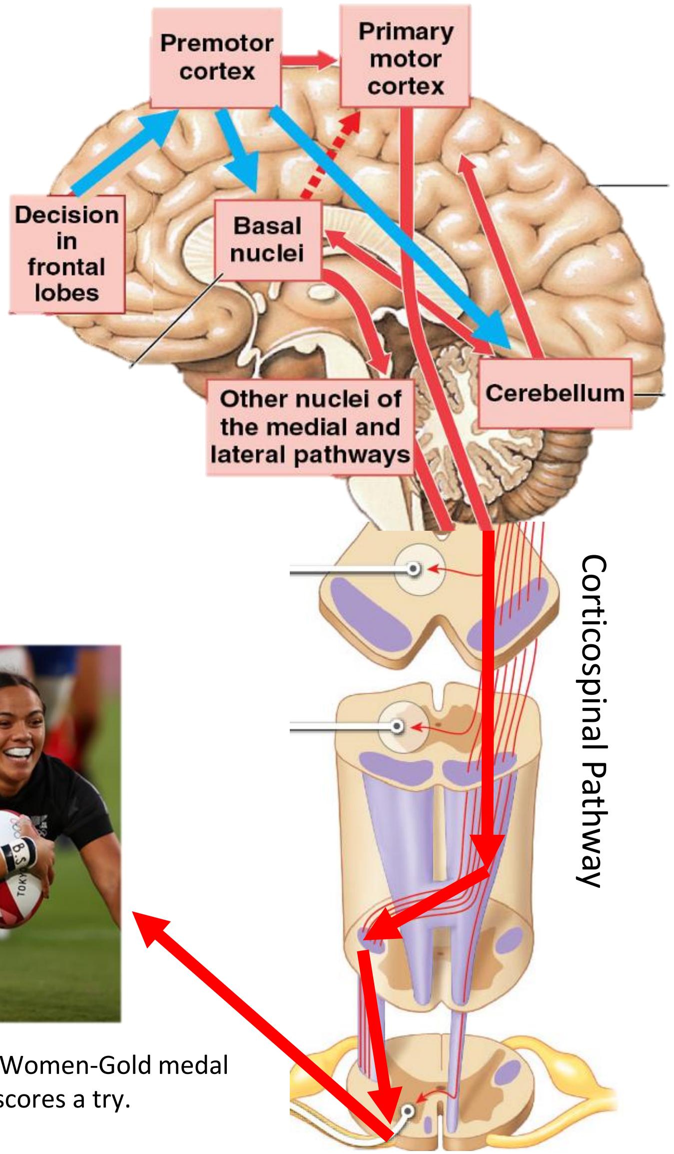
Voluntary movement utilize a complex processing pathway, increasing latency of the response

Voluntary response

- 100+ ms latency (the time delay between a stimulus and motor action)
- Highly variable latency
- Path: sensory receptors to somatosensory cortex, then from brain back through the motor neurons
- Requires complex processing of the environment/situation
- Focus & training can reduce response time

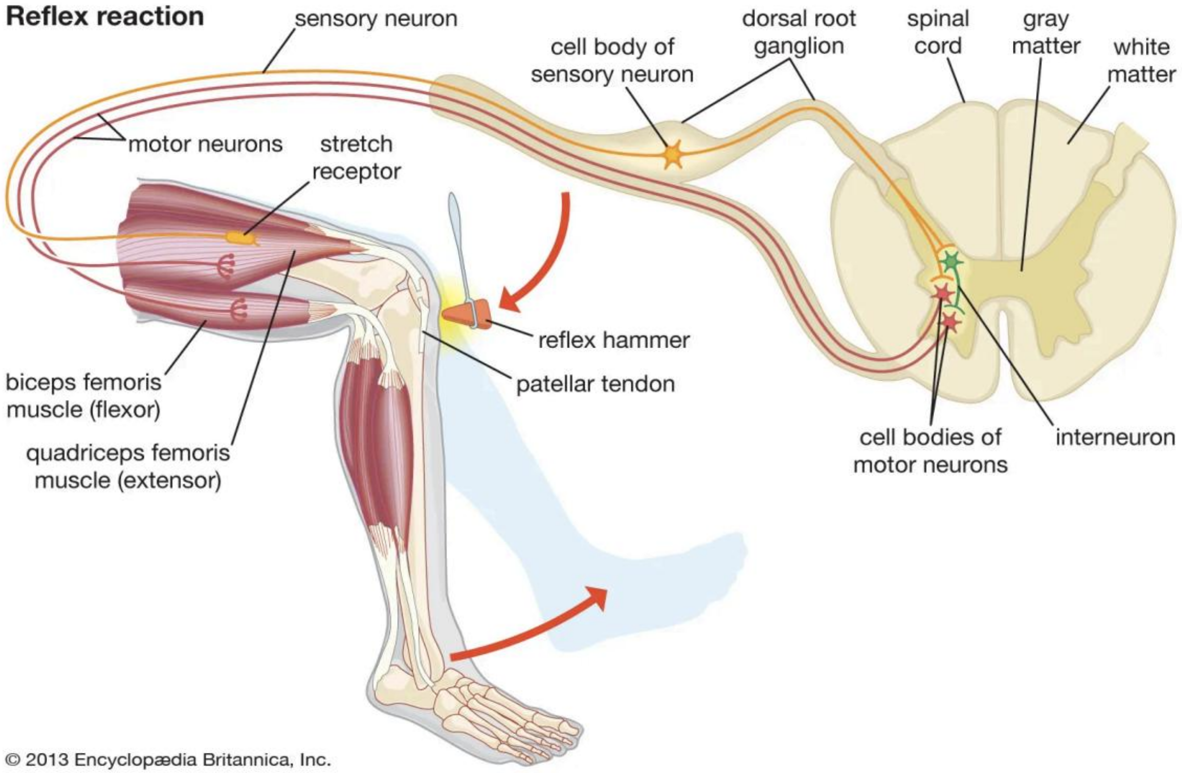






Tokyo Olympics-Rugby Sevens-Women-Gold medal match. Stacey Waaka scores a try.

Reflex movements use simple neuronal loops to reduce response time

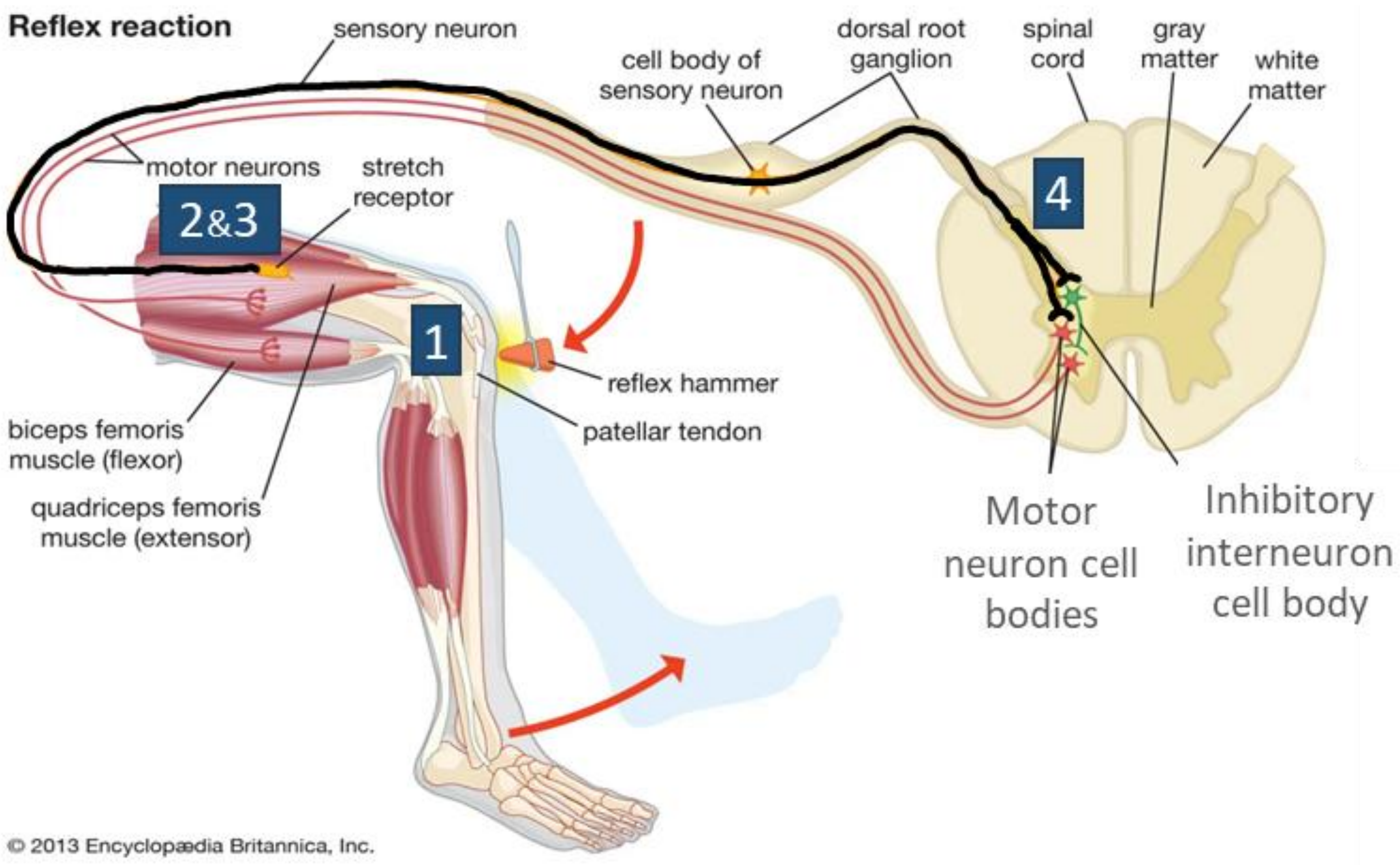


Reflex response to tendon tap

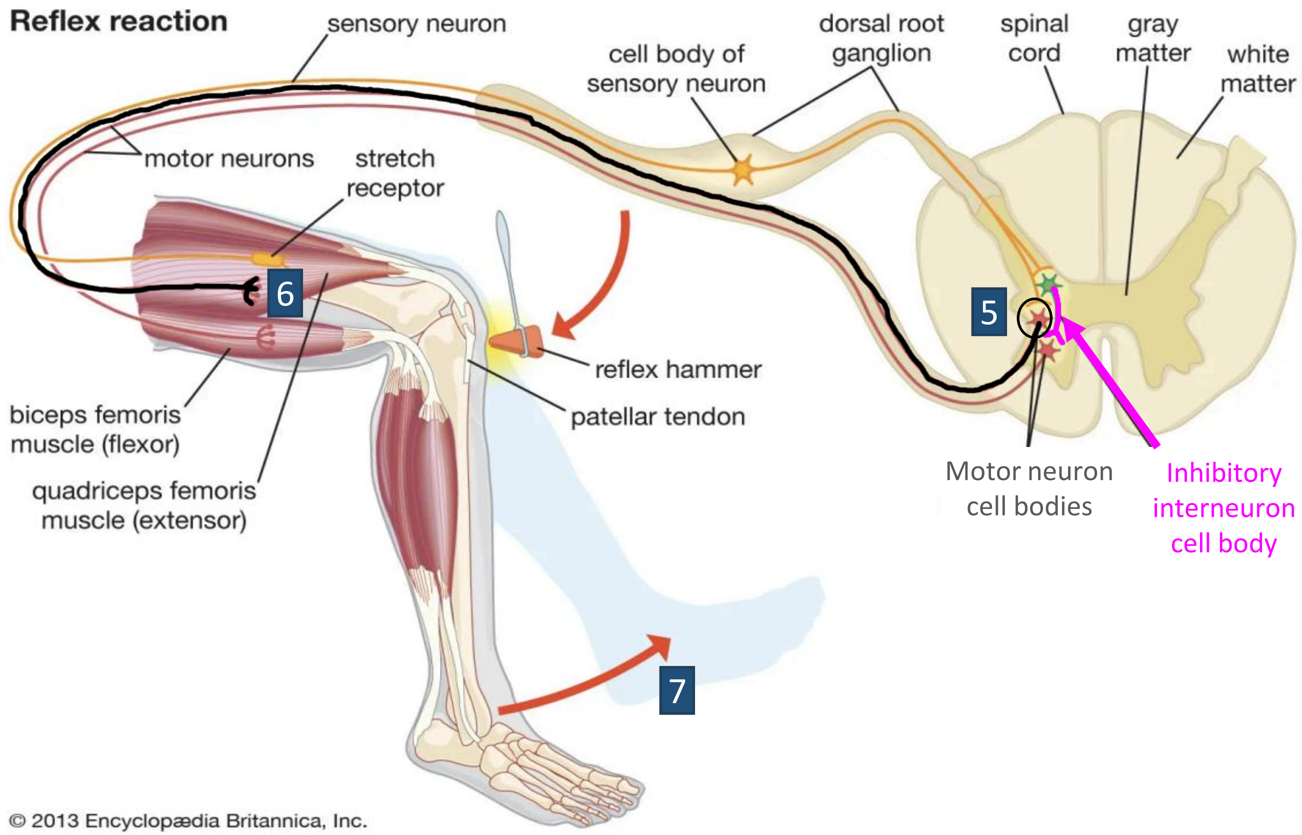
- ~ 30 - 40ms latency (e.g. time delay between tap and reflexive kick)
- Very consistent, reproducible response to sudden stretch
- Protects muscle from tearing
- Path: from stretched muscle spindles to spinal cord to stretched muscle
- Cannot be changed with training

The Stretch Reflex Response

1. Tendon tap causes sudden, fast stretch of quadriceps muscle
2. Proprioceptors/stretch receptors within the muscle get stretched
3. Mechanically-gated Na^+ channels open in membrane of dendritic endings of the proprioceptors/stretch receptors
4. Na^+ entry causes depolarization that leads to an action potential (AP), which propagates along sensory axon to spinal cord



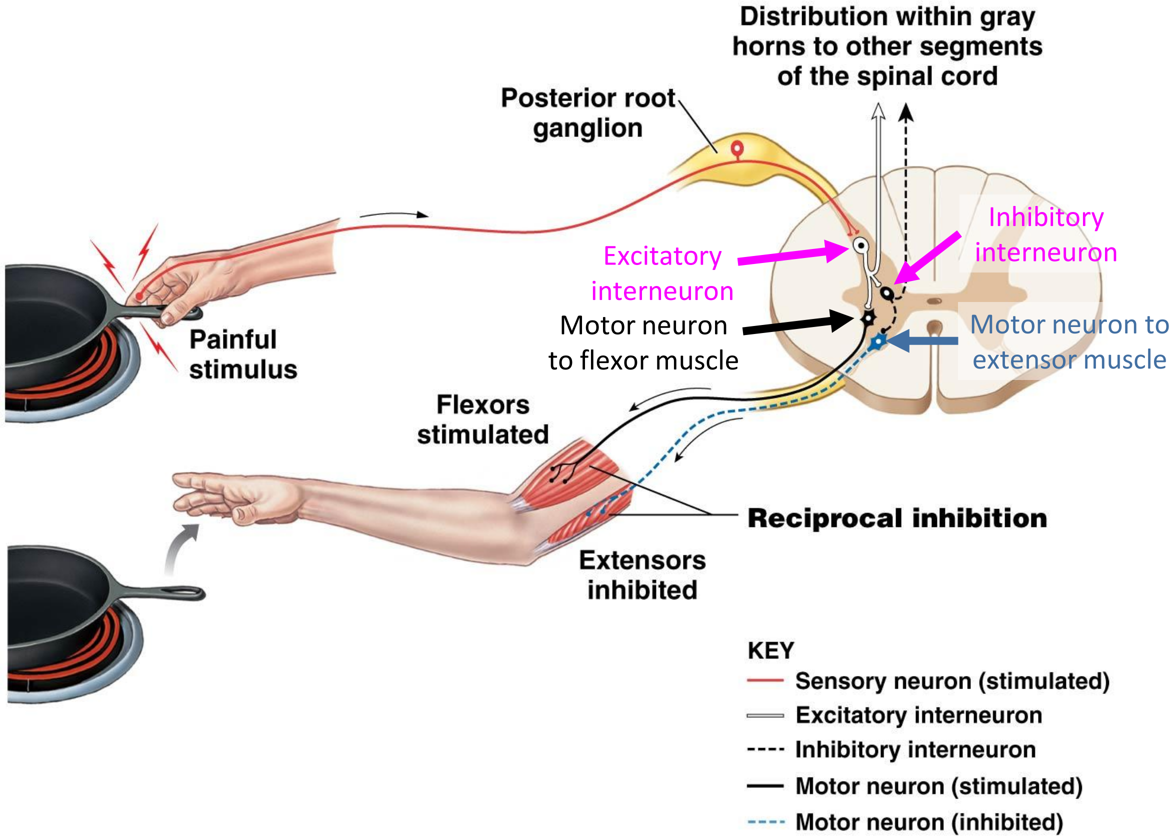
The Stretch Reflex Response



5. Synaptic transmission from sensory axon terminal causes depolarization in motor neuron cell body
6. AP fires and propagates along motor axon to NMJ of quadriceps
7. stimulating quadriceps to contract, causing foot to kick out

Note: the sensory neuron also stimulates an inhibitory interneuron which prevents activation of the motor neuron that innervates the hamstrings. This prevents opposition to knee extension

The Withdrawal Reflex



Martini et al., Visual Anatomy and Physiology (3rd ed), Module 12.14, pg 502.

Reflex response to painful stimuli

- Nociceptors activated
- Sensory neuron depolarizes and AP propagates to spinal cord
- Sensory neuron stimulates interneurons
  - leading to excitation of motor neurons that stimulate flexors
  - and inhibition of motor neurons that stimulate extensors
  - Enables withdrawal of the affected limb

What is an interneuron? Any ‘connector’ neuron that is neither sensory nor motor

Voluntary vs Reflex Responses Cheat Sheet

Voluntary movements

- Wide variety of movements of varying speed, duration, and complexity
- Typically involves complex patterns of sensory and motor processing
- Enables us to interact with the environment
- Initiated voluntarily by neurons in the brain
- Variable latency (100+ ms)
- Can improve with training

Reflex movements

- Rapid reproducible, automatic motor response to external stimulus
- Employs a simple neural circuit involving neurons within peripheral nerves and spinal cord
- Protective; prevents injury
- Does not require involvement of neurons in the brain
- Consistent latency (~40ms)
- Not generally trainable

Coming up in HUBS191…

Holiday!!!

Endocrine System
Philip Kelly

HUBS191