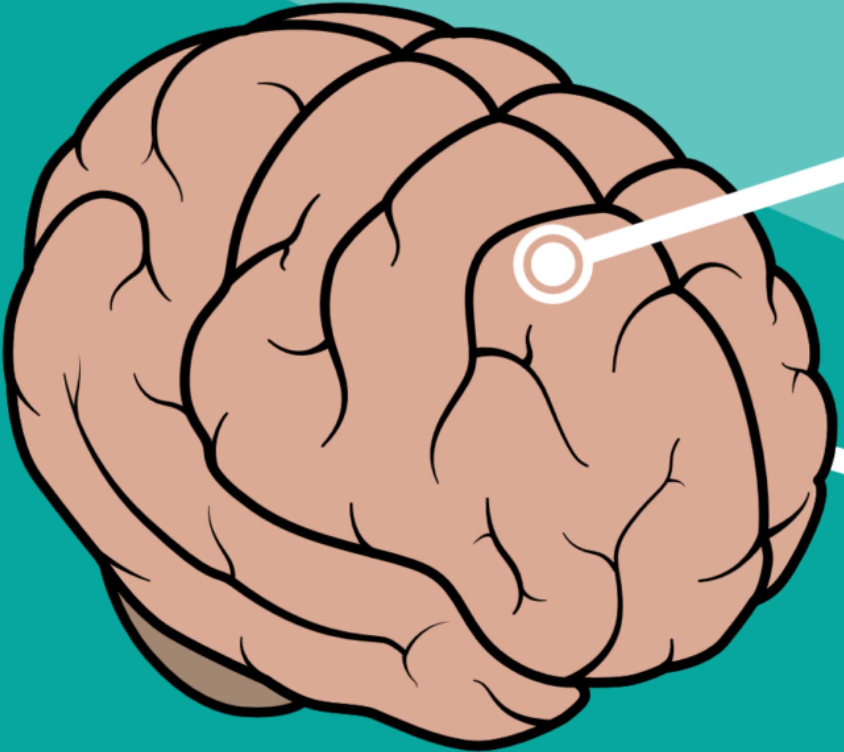
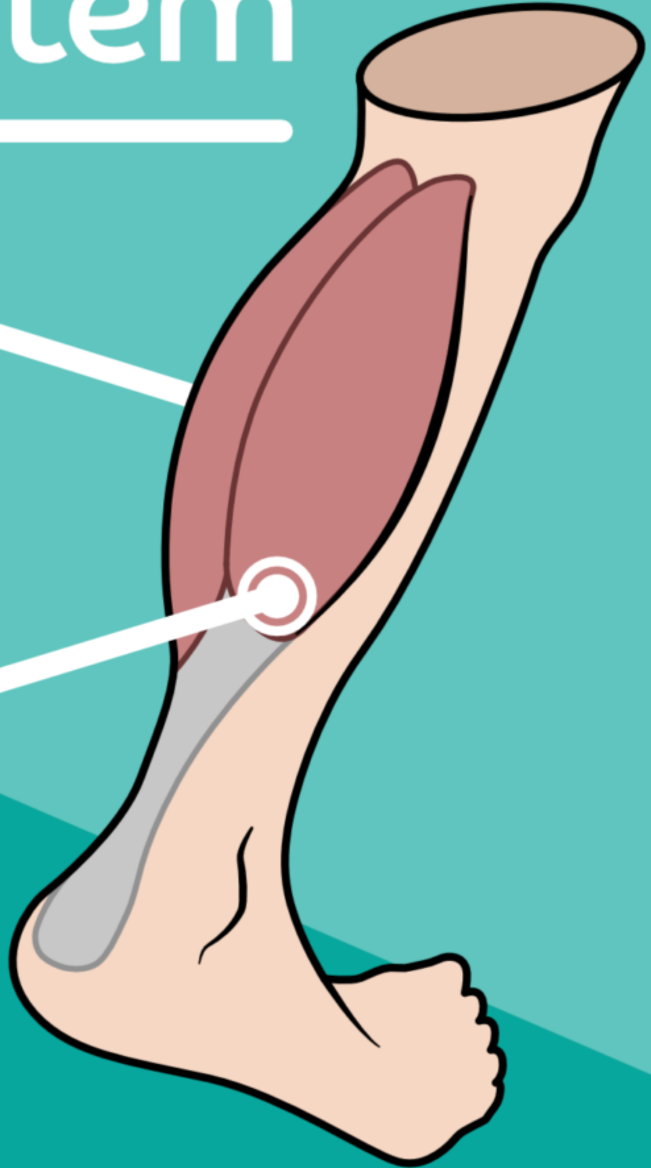
Sensorimotor System



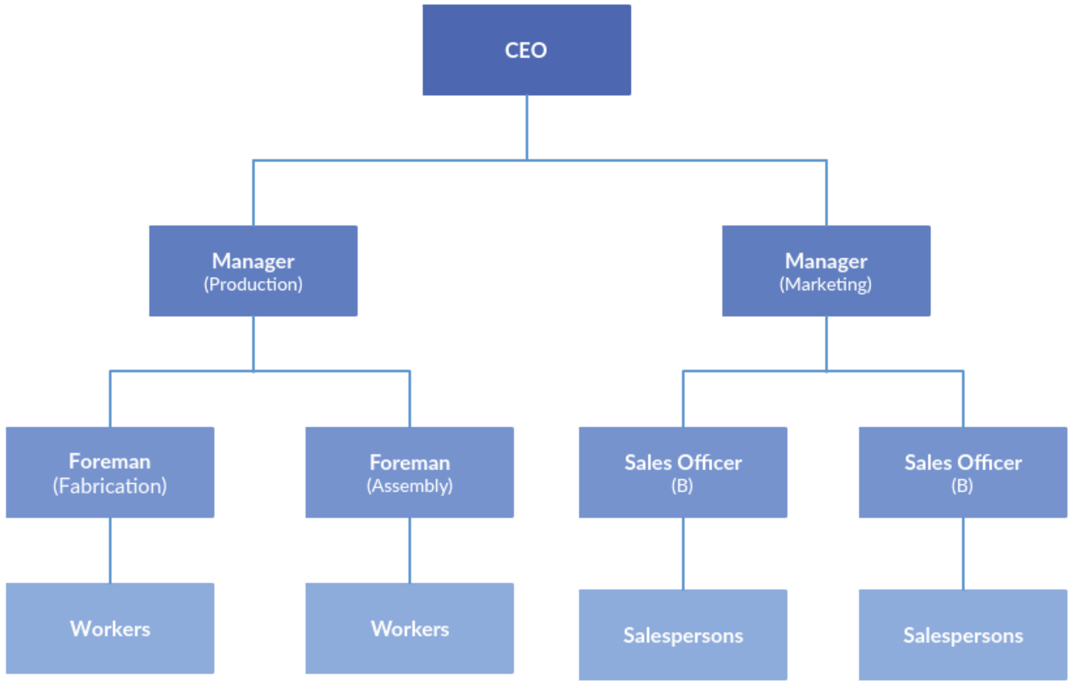
How you move



Tristan Hynes, PhD

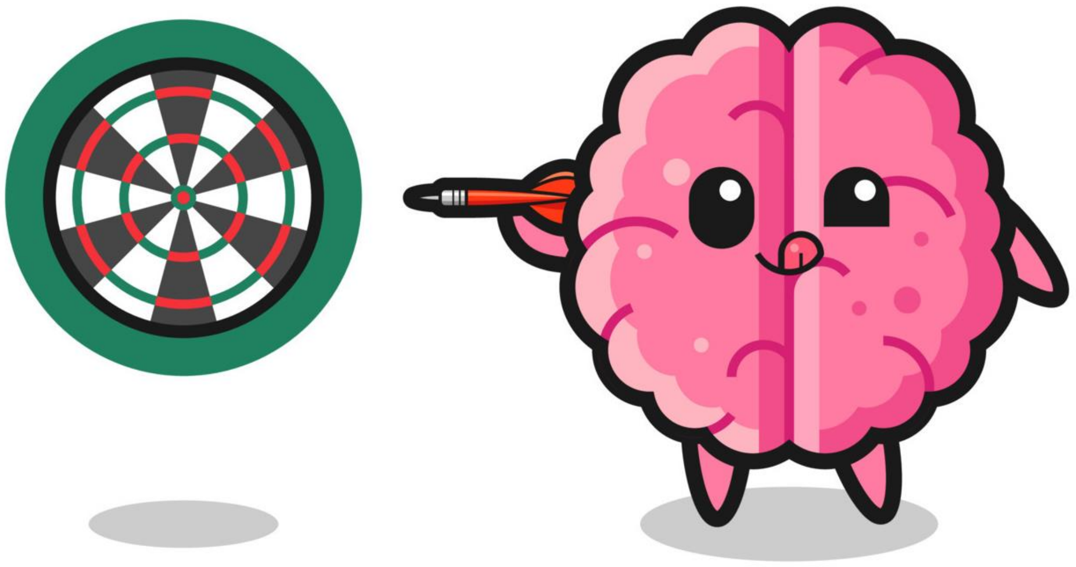
The Sensorimotor System is Hierarchically Organized

- Three principles of sensorimotor function (1)
  - Hierarchically organized
    - Organized like a large company
    - President (association cortex) gives direction to lower levels
    - Lower levels (motor neurons and muscles) take care of details
    - This organization is beneficial because it allows higher levels to focus on complex functions



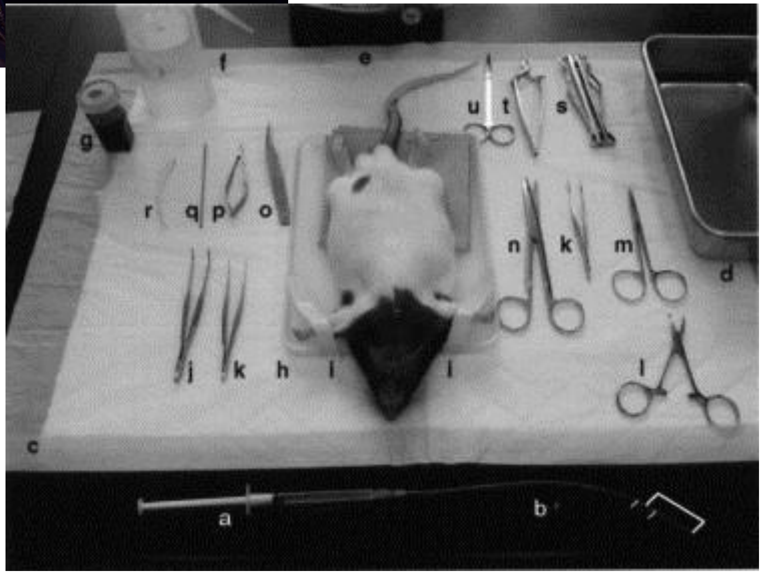
Motor Output Is Guided by Sensory Input

- Three principles of sensorimotor function (2)
  - Motor output is guided by sensory input
    - Sensorimotor system carefully monitors the external world
    - Able to adjust its own actions
      - Only ballistic movements are not guided by sensory feedback
    - Sensory inputs help with:
      - Picking things up
      - Adjusting to unanticipated external forces
      - Maintaining constant force



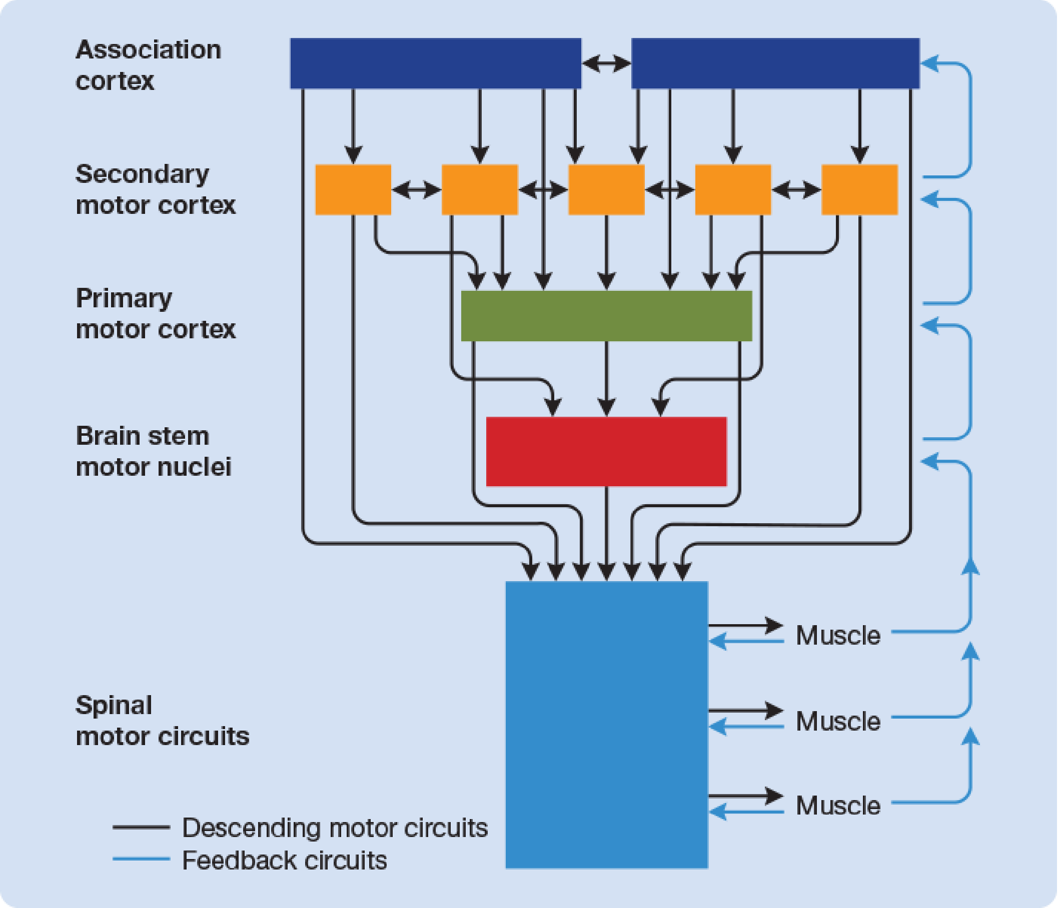
Learning Changes the Nature and Locus of Sensorimotor Control

- Three principles of sensorimotor function (3)
  - Learning and sensorimotor control
    - Initially, actions are under conscious control
    - With practice, they become integrated sequences of action
    - They are automatically adjusted without conscious regulation



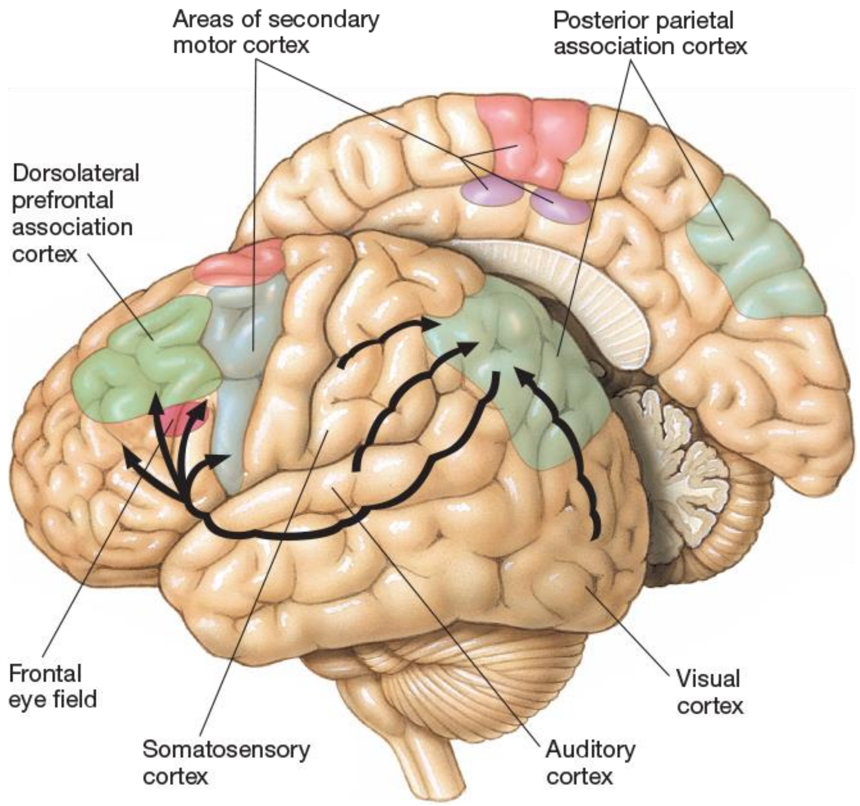
General Model of Sensorimotor System Function

- Characteristics of the general model
  - Hierarchical structure
  - Functional segregation
  - Parallel descending pathways
  - Feedback circuits



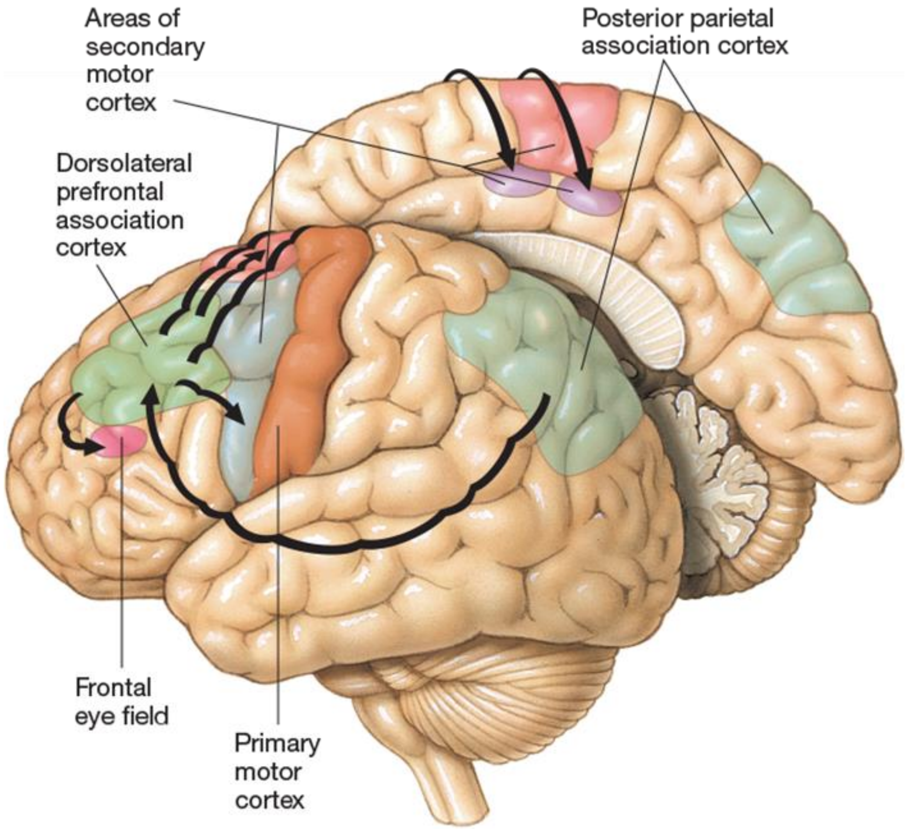
Posterior Parietal Association Cortex

- Posterior parietal association cortex
  - Provides information on where body parts are in relation to the external world
  - Receives input from visual, auditory, and somatosensory systems
  - Output goes to secondary motor cortex
  - Stimulation of this area makes subjects feel they are performing an action
- Posterior parietal association cortex damage
  - Apraxia (inability to perform movements on command)
    - Occurs when posterior parietal association cortex is lesioned
    - Associated with left hemisphere damage
    - Symptoms are bilateral



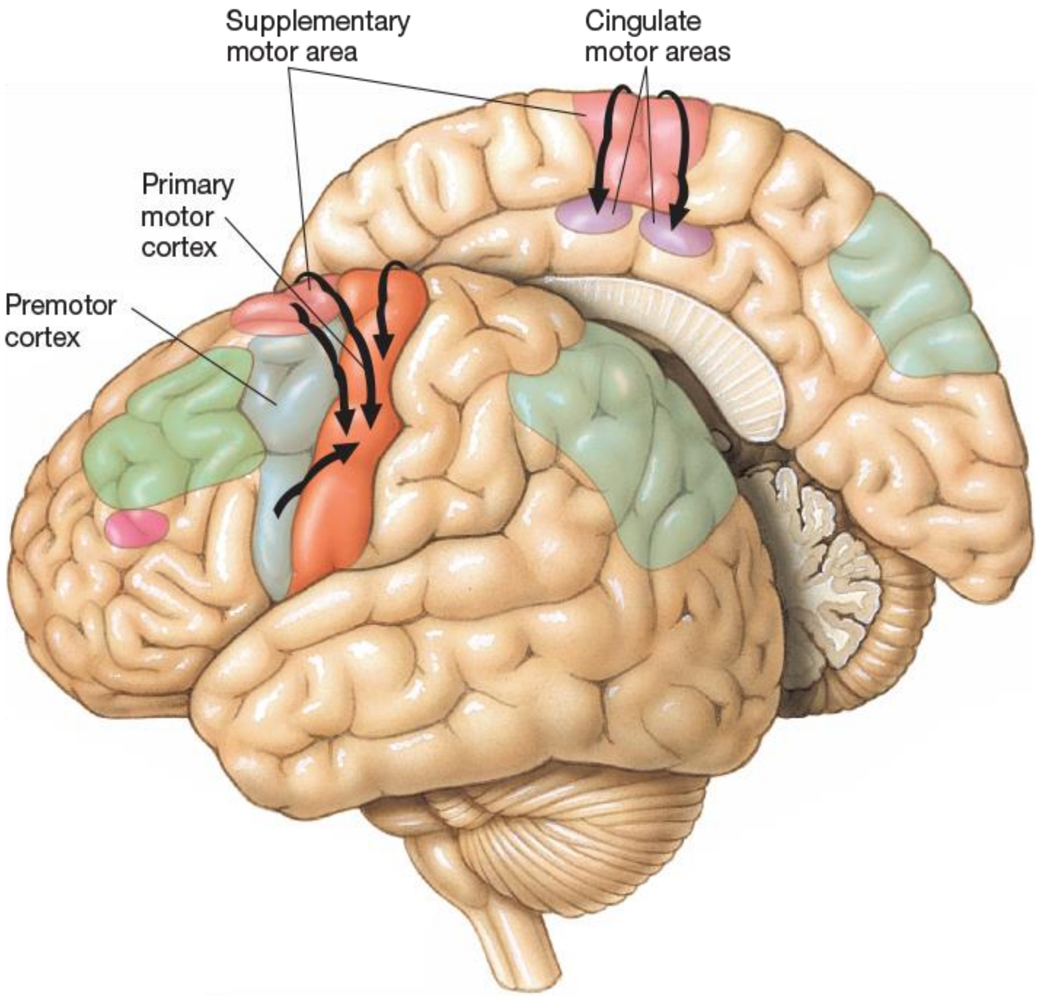
Dorsolateral Prefrontal Association Cortex

- Receives projections from posterior parietal cortex
- Projects to secondary motor cortex, primary cortex, and frontal eye field
- Involved in assessments of external stimuli
- May work with posterior parietal cortex in decisions regarding voluntary response initiation



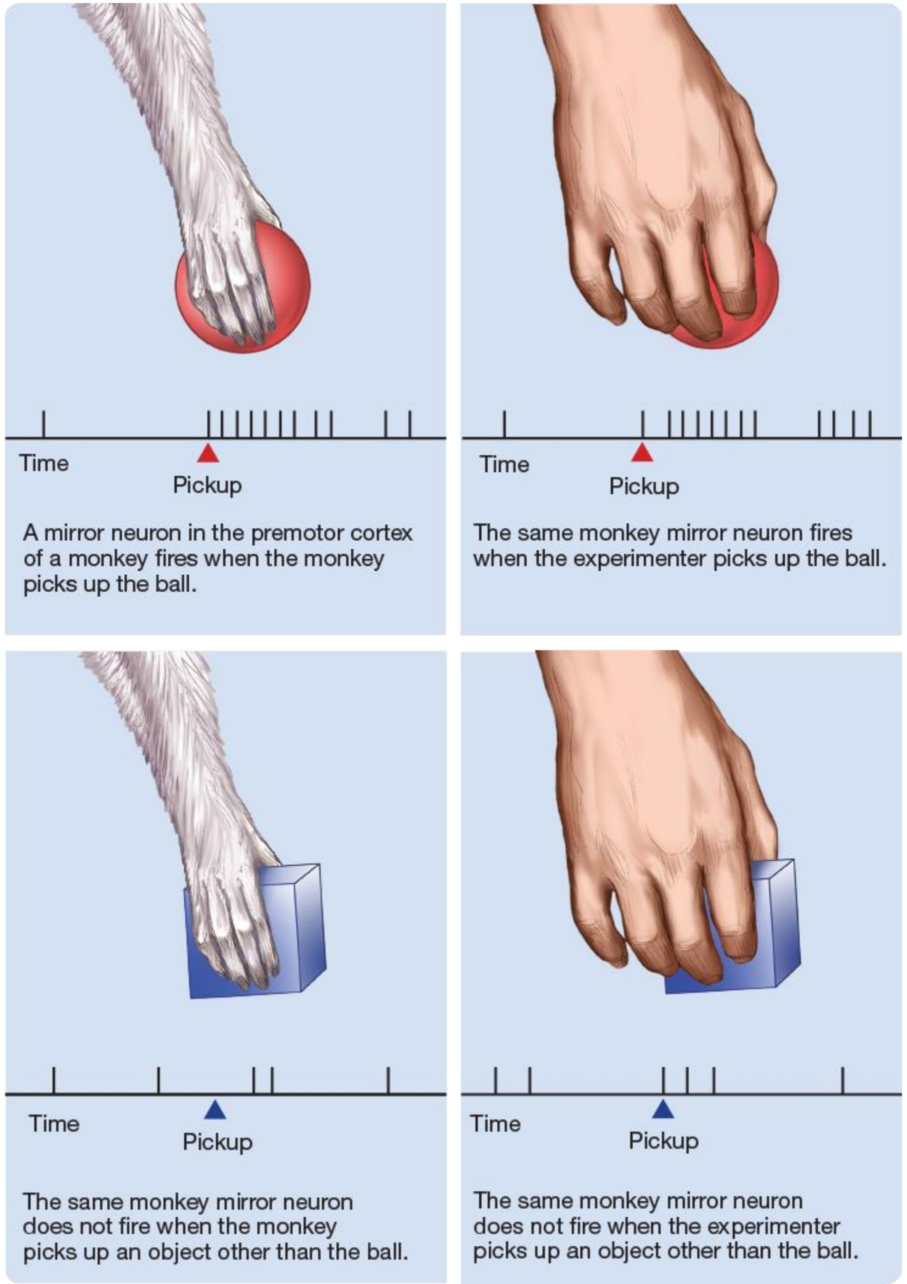
Secondary Motor Cortex

- At least eight areas of secondary motor cortex
  - Two areas of premotor cortex
  - Three supplemental motor areas
  - Three cingulate motor areas
- Project to primary motor cortex, each other, and brainstem
- Produce complex movements (before and during voluntary movements)
- Exact role of these areas is unclear
- Premotor areas encode spatial relations and program movements



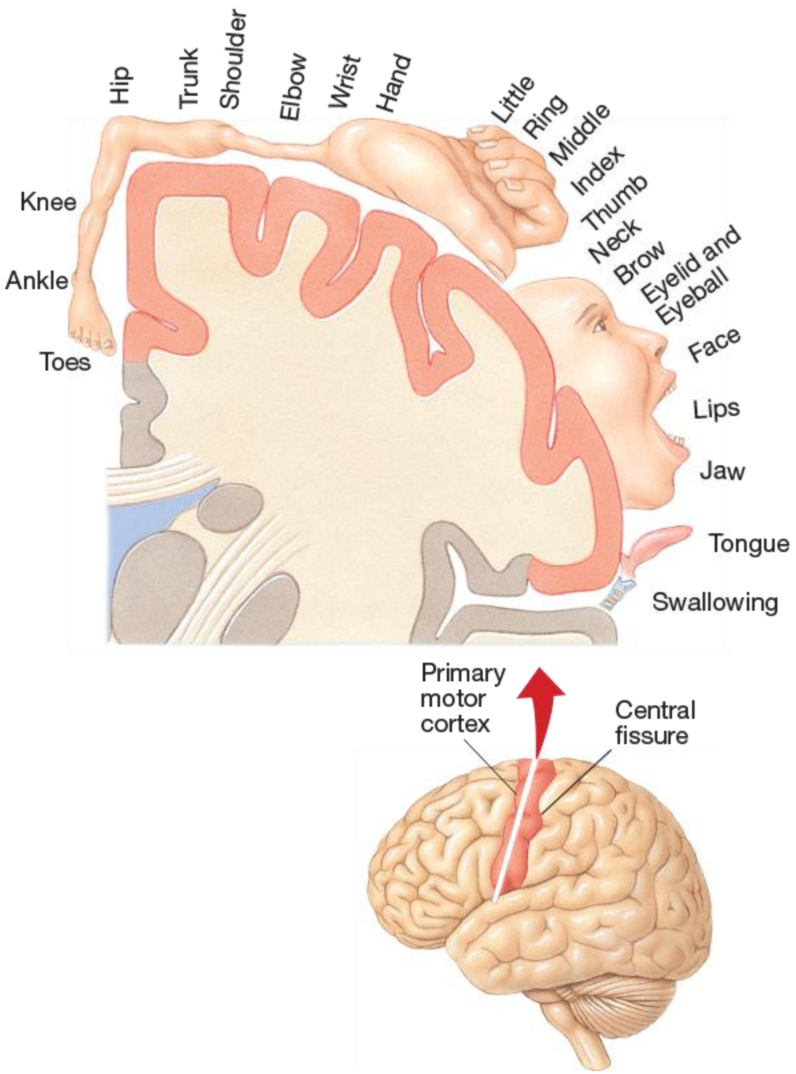
Mirror Neurons

- Mirror neurons
  - Fire when an individual makes goal-directed movements
  - Fire when an individual observes someone else performing goal-directed movements
  - May be a mechanism for social cognition
  - Motor cortex in humans also contains mirror neurons



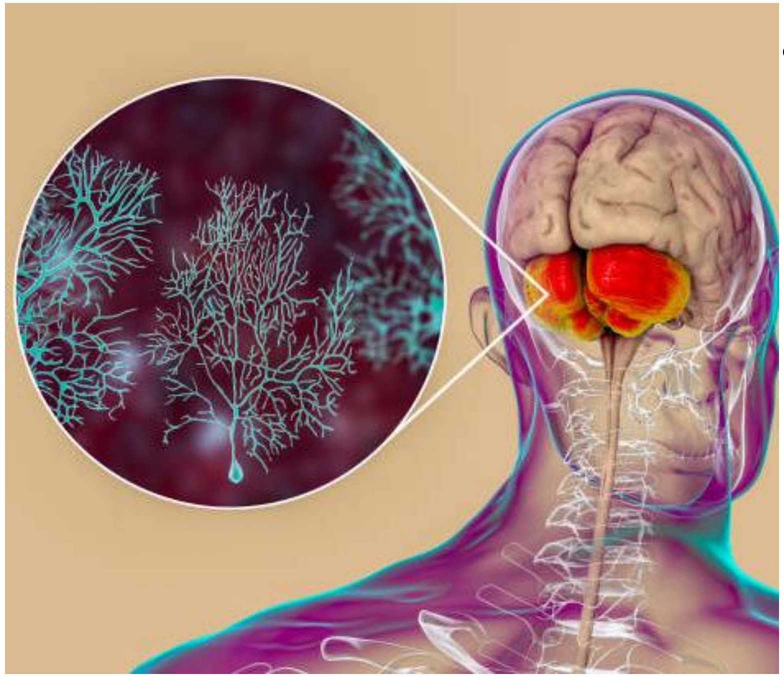
Primary Motor Cortex Function

- Conventional View
  - Precentral gyrus of frontal lobe
  - Somatotopically organized (Penfield)
  - There is overlap in the motor homunculus
  - Body is disproportionately represented
  - Each area receives feedback from muscle and joints
  - Neurons code for preferred direction of movement
- Current view
  - Body is diffusely represented; regions can overlap
  - Neurally controlled prosthetics are being tested
  - Effects of primary motor cortex lesions
  - Astereognosia



Cerebellum

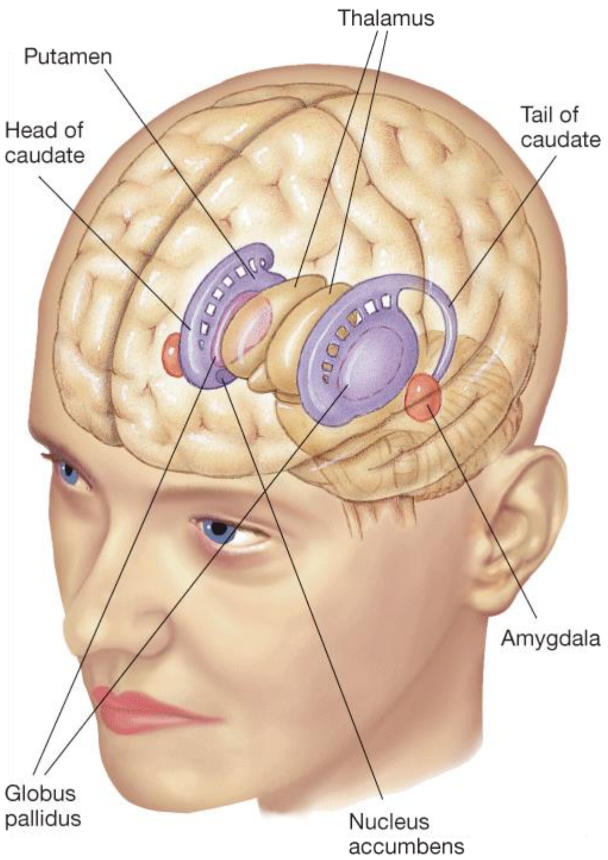
- Functions
  - Subcortical sensorimotor structure
  - Only 10% of brain's mass, but it contains over half of the brain's neurons
  - Organized systematically into lobes
  - Does not transmit signals to spinal cord
  - Integrates and coordinates activity of structure in sensorimotor system
  - Receives inputs from primary and secondary motor cortex, brainstem motor nuclei, somatosensory and vestibular systems
  - Corrects deviations from intended movements
  - Motor learning
  - Diverse sensory, cognitive, and emotional responses

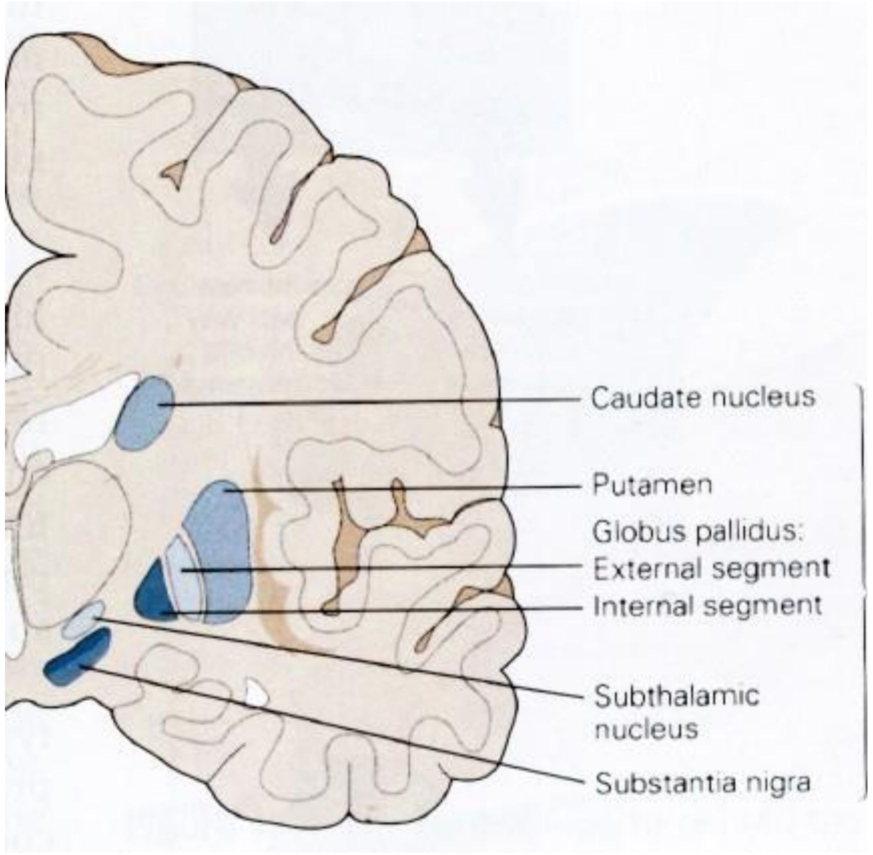


- Effects of diffuse damage to cerebellum
  - Loss of ability to precisely control movement
  - Inability to adjust motor output to changing conditions
  - Inability to maintain steady posture
  - Inability to exhibit coordinated locomotion
  - Inability to maintain balance
  - Cannot speak clearly
  - Cannot control eye movements

Basal Ganglia

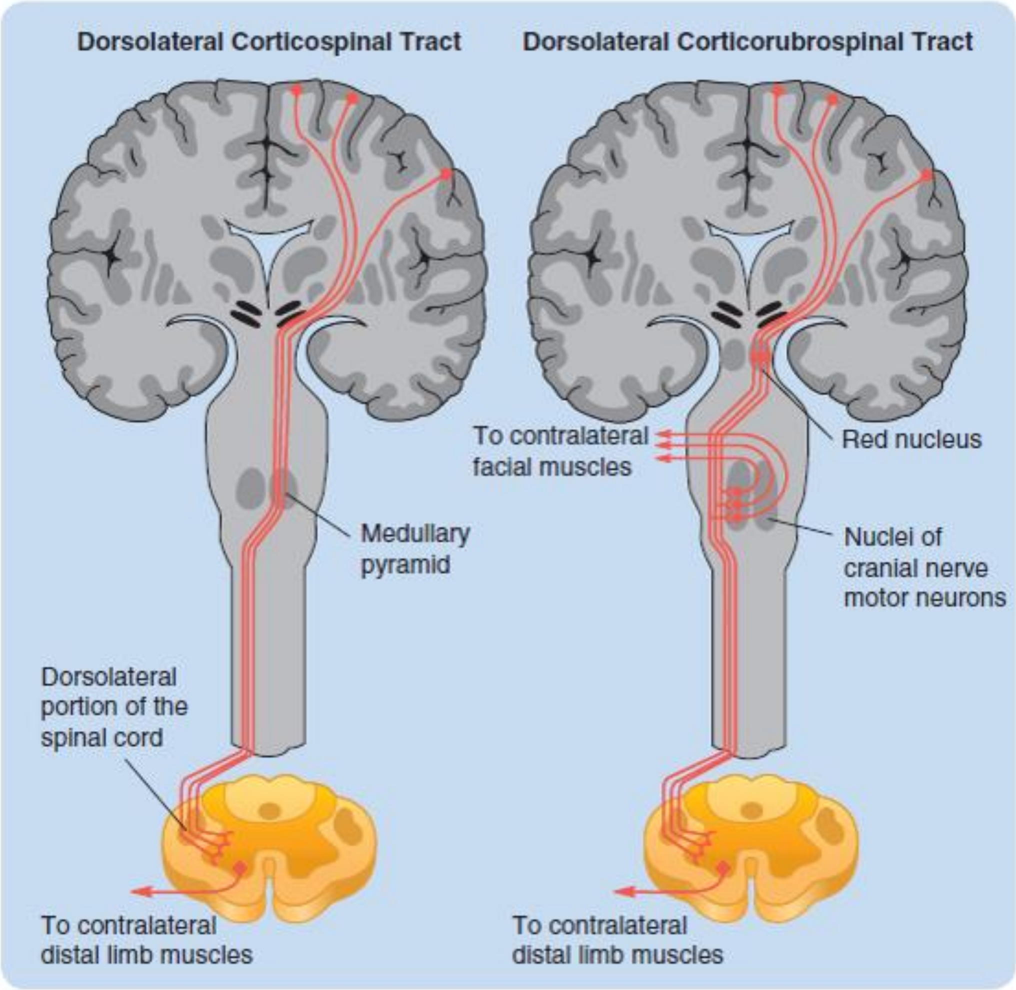
- Functions (subcortical sensorimotor structure)
  - Integrates and coordinates the activity of sensorimotor structures
  - Receives information from cortex
  - Sends out information to motor cortex via thalamus
  - Response vigor
  - Helps sequence movements (e.g., habits)
  - Varied nonmotor cognitive tasks (e.g., motivation)





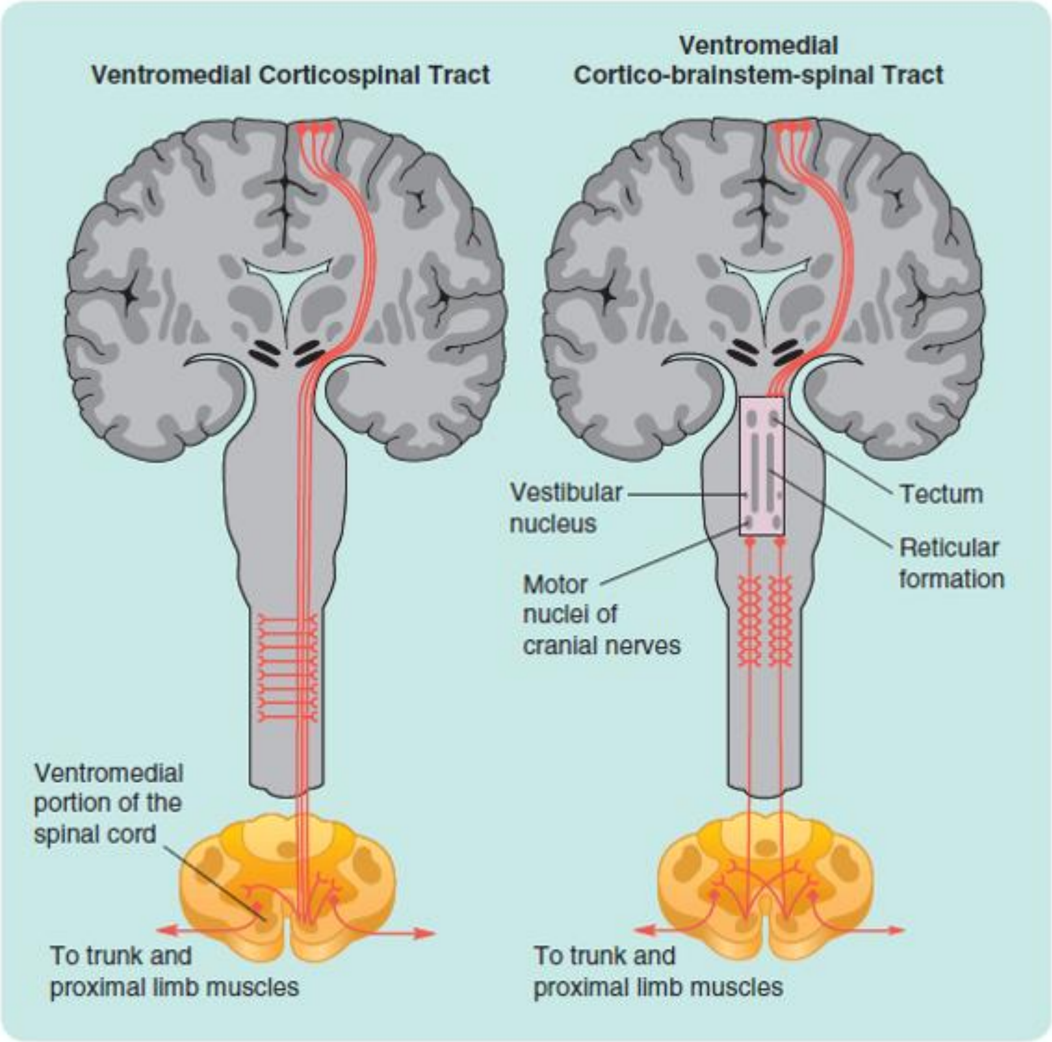
Dorsolateral Motor Pathway

- Dorsolateral tract
  - Begins in primary motor cortex
  - Descends through medullary pyramids
  - Decussates
  - Descends in contralateral dorsolateral white matter of spinal cord
  - Most axons synapse on interneurons in contralateral spinal gray matter



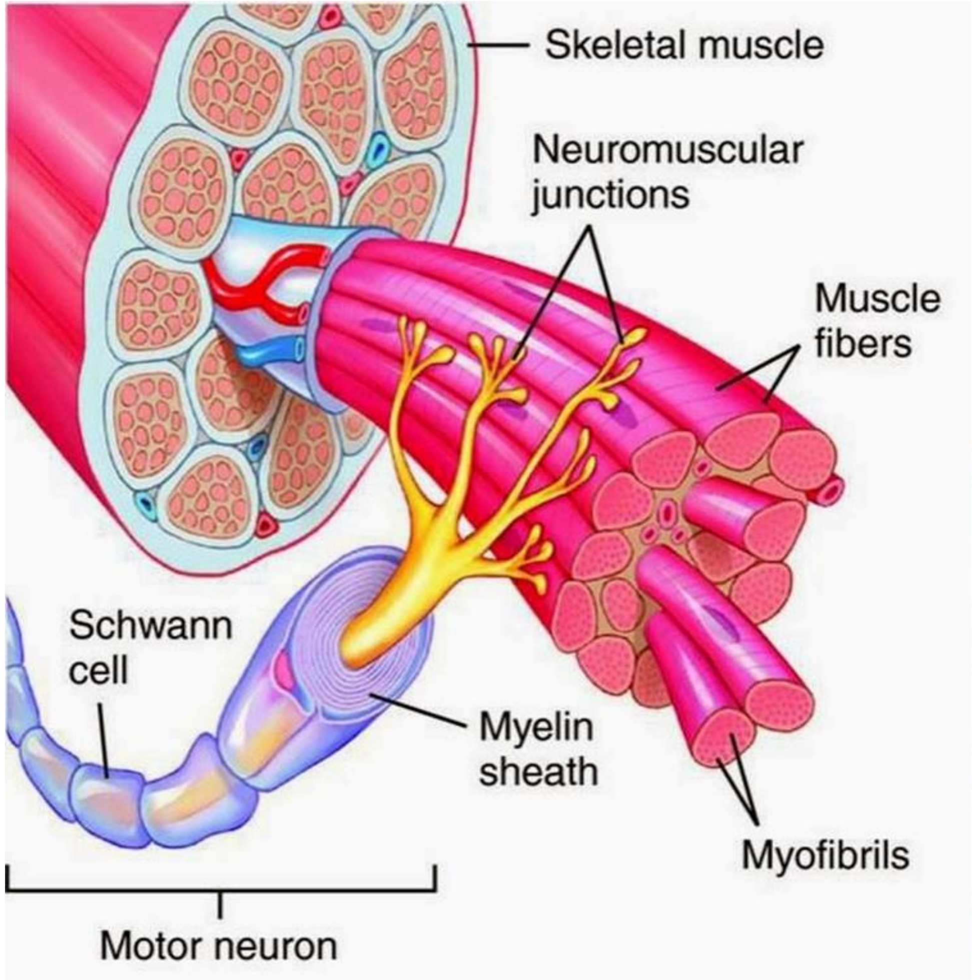
Ventromedial Motor Pathway

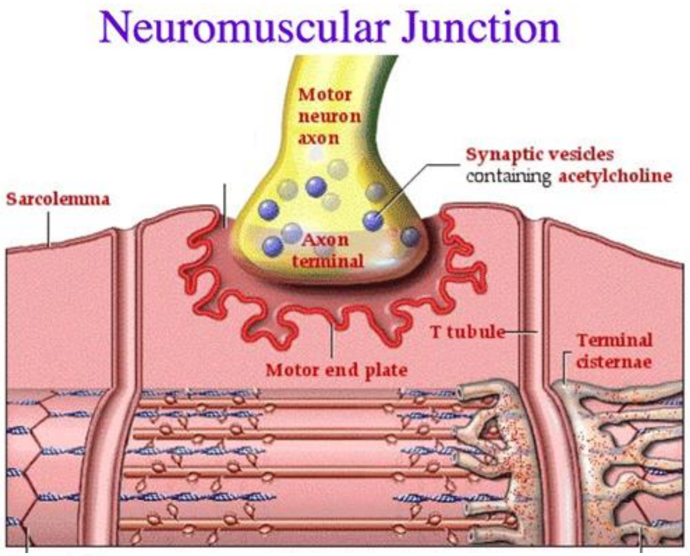
- Ventromedial tract
  - Descends ipsilaterally and terminates bilaterally on interneuron pools of spinal cord
  - Controls motor neurons of trunk and proximal limb muscles (e.g., shoulders and hips)

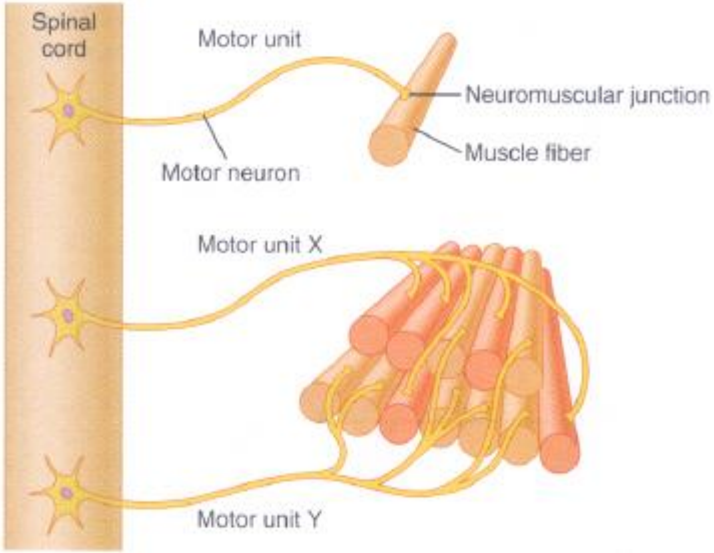


Muscles & Motor Units

- Motor unit
  - Single motor neurons
  - Individual skeletal muscle fibers
- Muscle
  - Muscle fibers bound together in membrane
  - Attached to bone by tendon
  - Motor neuron activates motor-end plate with acetylcholine
  - Motor pool: all motor neurons that innervate a single muscle

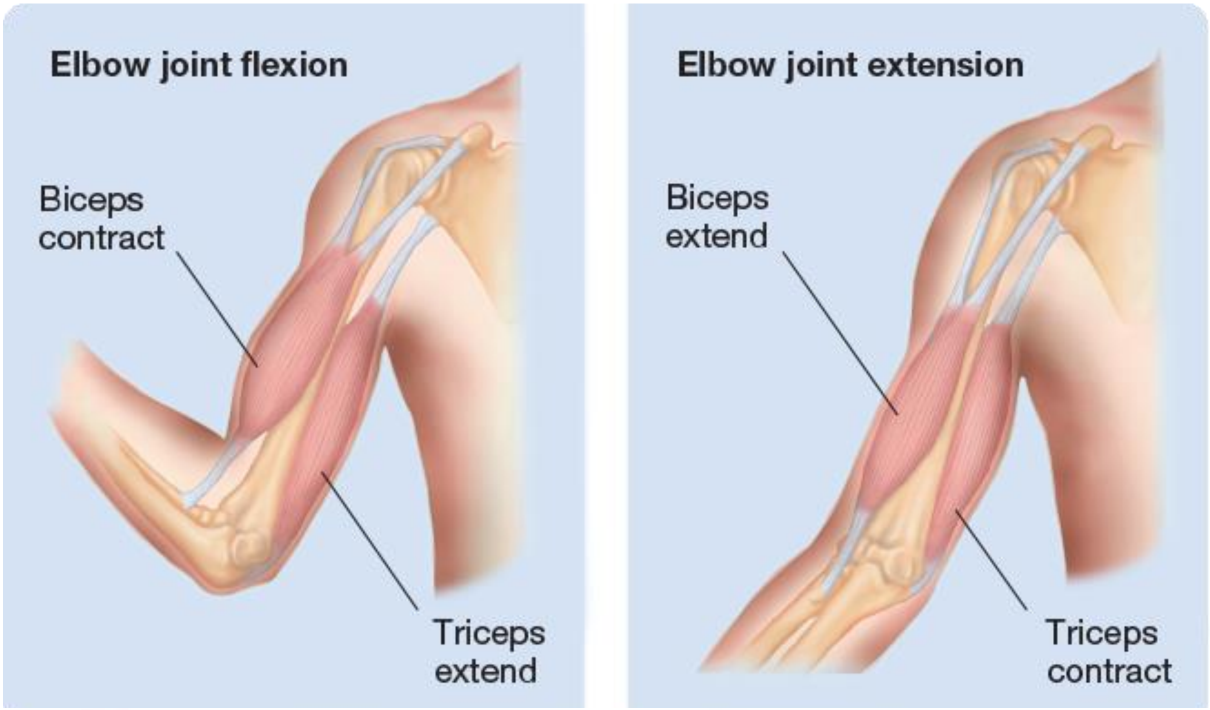


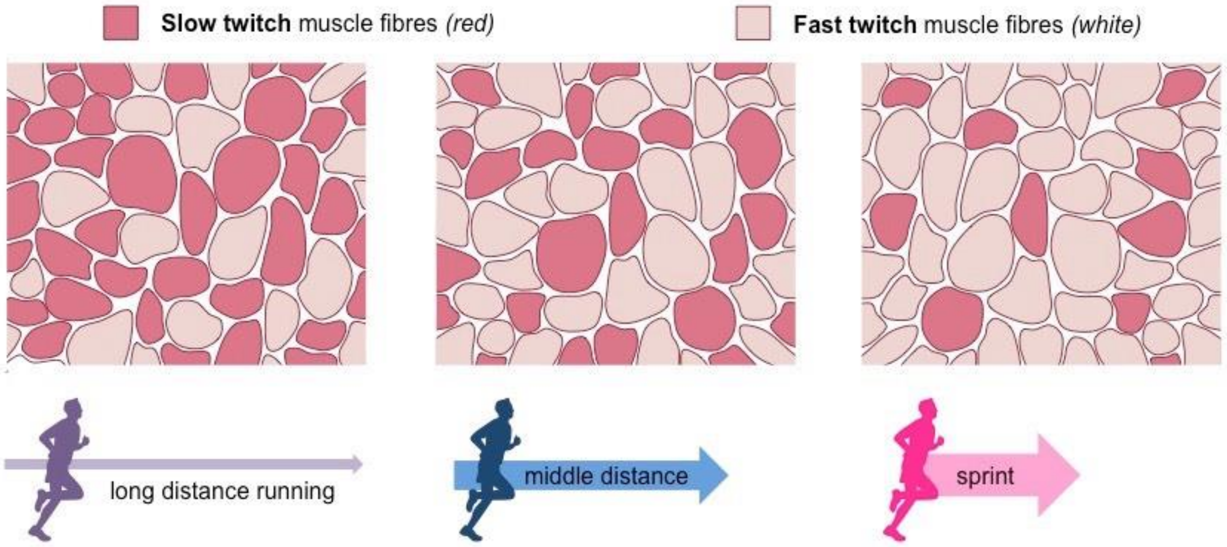




Muscle Properties

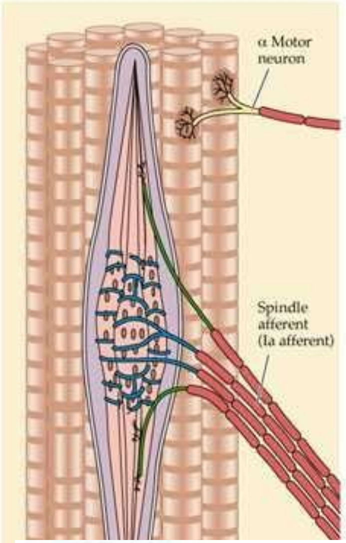
- Fast and slow
  - Fast contract and relax quickly
  - Fast are capable of greater force
  - Fast fatigue faster
  - Slow are capable of sustained contraction
- Flexors and extensors act in opposition
- Synergistic muscles/antagonistic muscles
- Isometric/dynamic contraction
- Increase tension in muscle
  - Recruit more motor neurons
  - Increase firing rates of existing motor neurons
  - Combination of the two

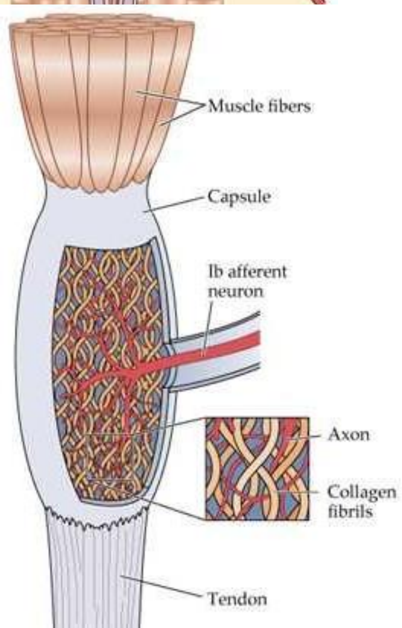


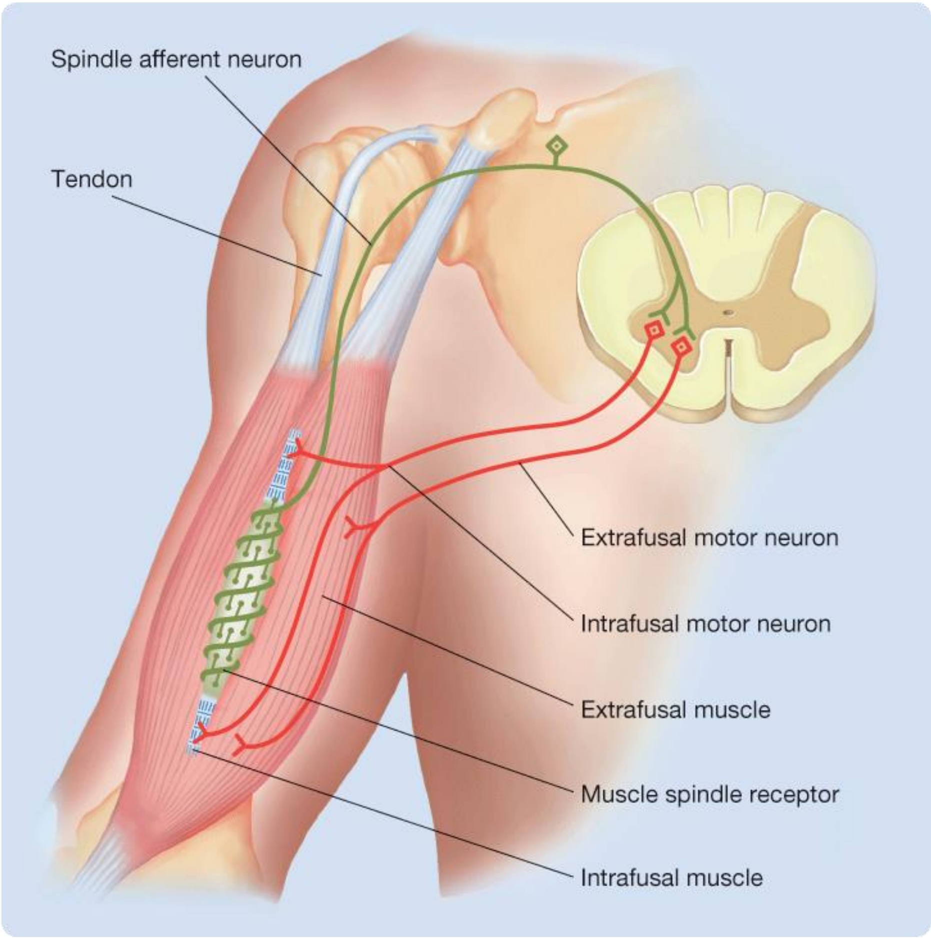


Receptors & Organs of Tendons & Muscles

- Golgi tendon organs
  - Embedded in tendons
  - Sensitive to muscle tension
  - Connected in series with muscles
- Muscle spindles
  - Connected in parallel with muscle fibers
  - Sensitive to muscle length
- Intrafusal and extrafusal fibers

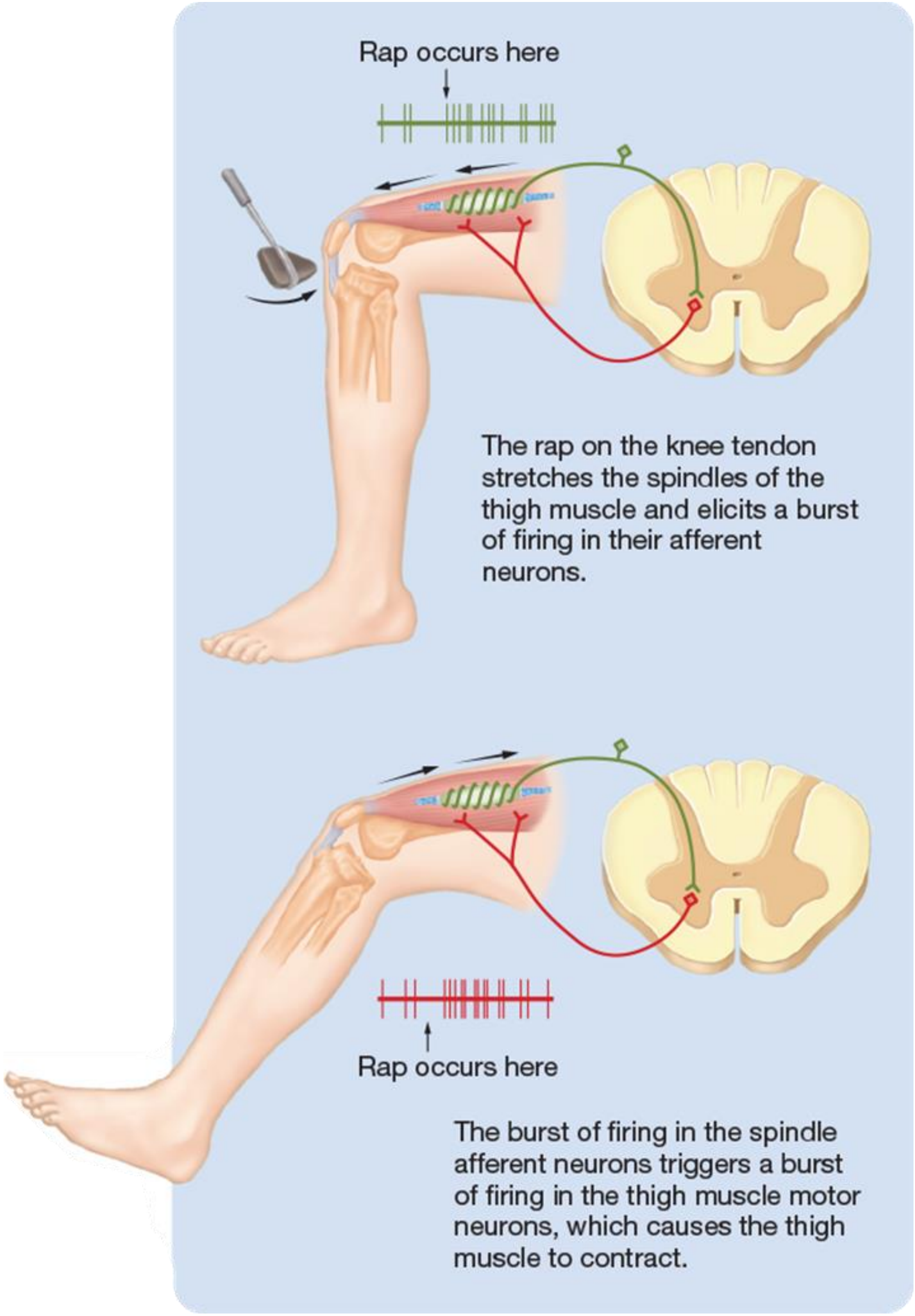






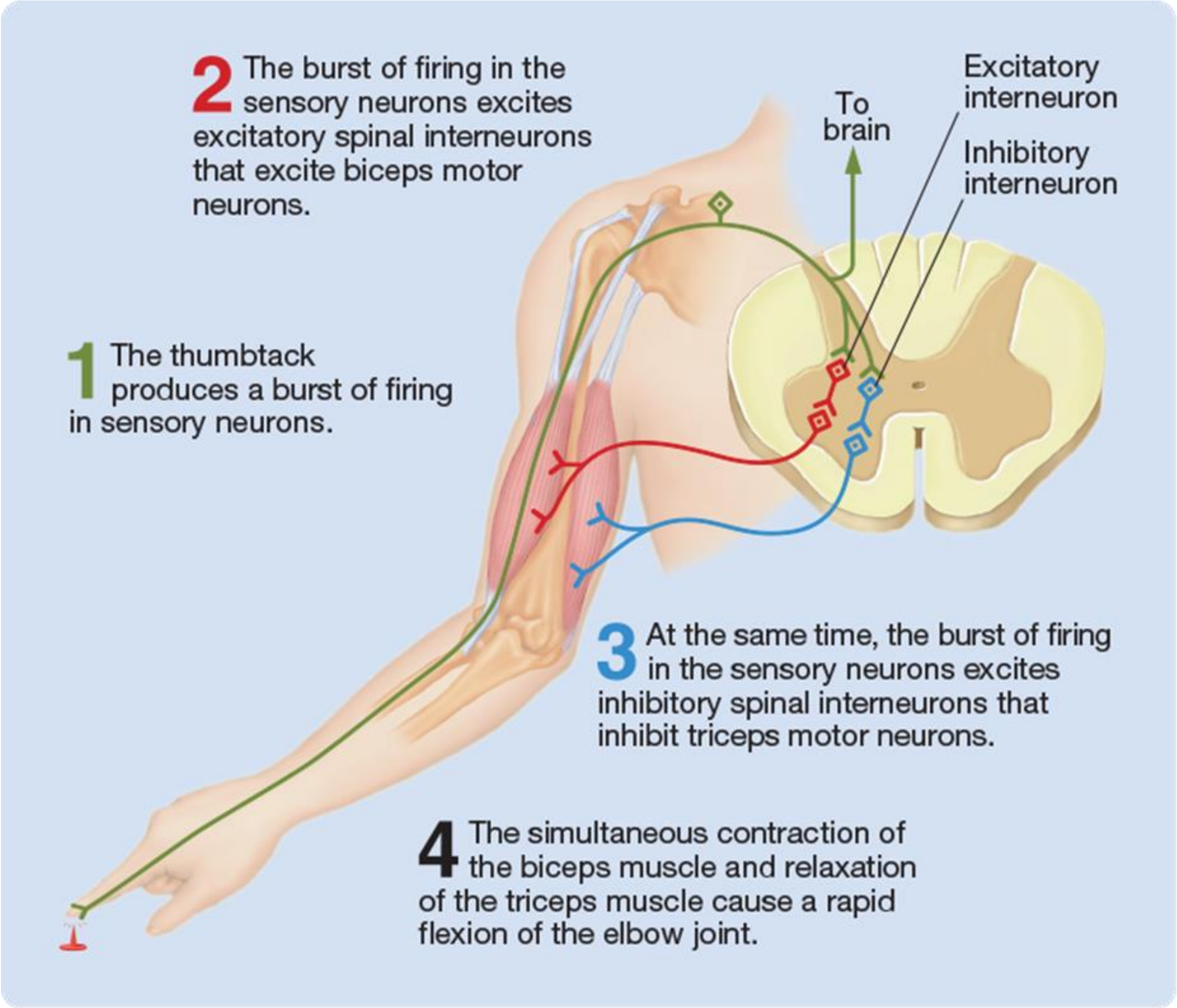
Stretch Reflex

- Stretch reflex
  - Patellar tendon reflex is an example
  - Monosynaptic
  - Intrafusal motor neuron adjusts length of intrafusal fibers
  - Functions to make adjustments in muscle tension in response to external forces



Withdrawal Reflex

- Sensory neurons carry signals evoked by painful stimulus
- Sensory neurons synapse on interneurons on flexors
- Takes 1.6 milliseconds for withdrawal to occur
- Withdrawal occurs before information travels to the brain
- Reciprocal innervation
  - When a muscle contracts, antagonistic muscles relax
  - Mediated by inhibitory interneurons



Walking: A Complex Sensorimotor Reflex

- Walking reflex
  - Integrates visual information from eyes
  - Integrates somatosensory information from feet, knees, hips, arms, etc.
  - Integrates information from semicircular canals
  - Produces integrated series of movements that involve the trunk, legs, feet, and upper arms
  - Program must be plastic to adjust to changes in terrain or changes in external forces
  - Grillner 1985 – Central Pattern Generator