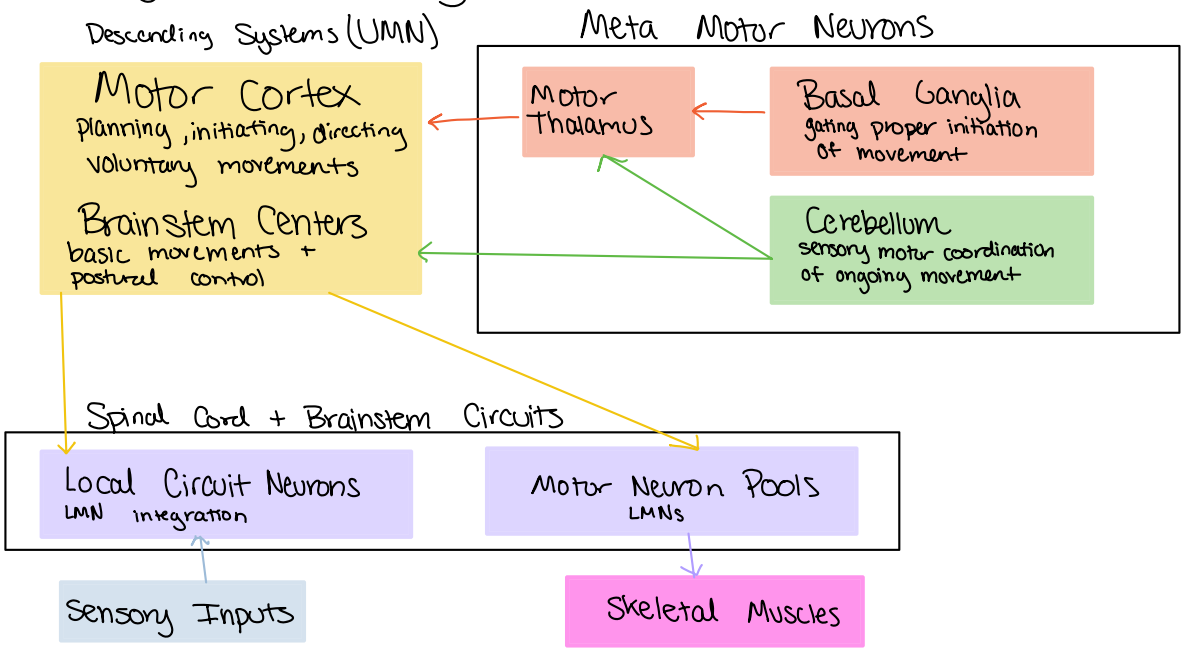
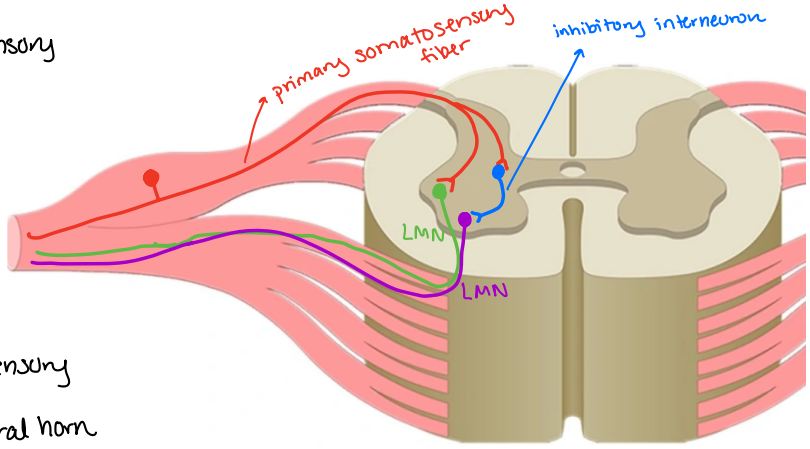
Motor System Hierarchy



Local Circuit (Segmental) Motor Control

- sensory inputs can make LMNs fire producing reflexive contraction (Unconcious reflex control)
- primary somatosensory fibers connect to LMNs
  - monosynaptic - direct synapse from somatosensory fiber to LMN
  - polysynaptic - somatosensory → interneuron → → LMN (interneuron is typically inhibitory w/ GABA)



- LMNs that are activated by primary somatosensory fibers are found in all spinal levels in the ventral horn and all motor cranial nerve nuclei

Spinal Cord Withdrawl Reflex

Cutaneous reflex → multisynaptic reflex

1. Step on tack
2. activates nociceptors on A delta or C fibers, which travel to lower lumbar or upper sacral levels and releases substance P

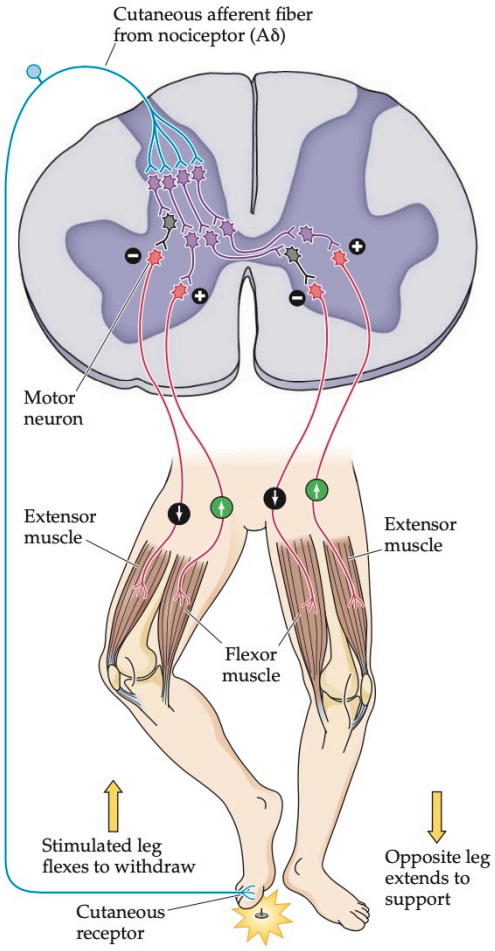
Ipsilateral side:

- flexing the knee (lower lumbar) → cutaneous afferent fiber synapses onto excitatory interneuron which excites (releasing acetylcholine) LMN that projects to flexor muscle (hamstring)

- inhibit the knee extensor (lower lumbar) → sensory fiber synapses onto inhibitory interneuron, which then inhibits movement of the extensor muscle (quads)
- flexing hip (upper lumbar levels)

- fibers ascend levels via the:
  - dorsolateral fasciculus (1-2 levels) → Lissauer's tract
  - propriospinal fasciculus (3-4 levels)

  → pain fibers that don't leave spinal cord



Contralateral Side:

- extend opposite leg/hip for support → inhibit flexor muscle and activate extensor muscle to keep leg firm and supported
- fibers cross to the contralateral side via
  - interneurons that travel across midline (ventral white commissure)
  - anterolateral fasciculus (to other levels)

Withdrawal reflex of Cornea

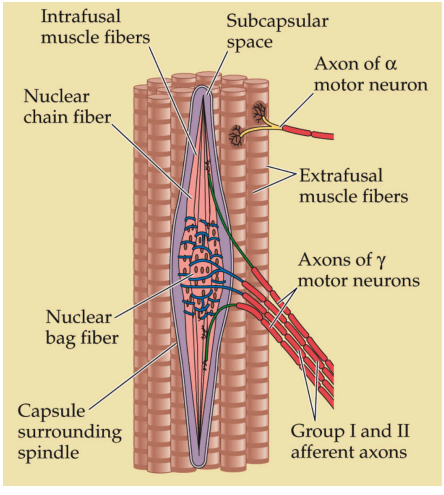
- cornea reflex → trigeminal nerve brings in information cornea and causes facial nerve to close eyelid
- afferent fibers → trigeminal nerve brings pain information
- extrinsic fibers → facial nerve to close eyelid

Muscle Spindles → 1 muscle spindle to 1000 muscle fibers

Extrinsic Muscle Fibers (myofibrils)

- innervated by alpha motor neurons (LMNs) → damage would result in LMN syndrome

Intrinsic Muscle Fibers (Muscle Spindle)



- sensory mechanoreceptors component
  - muscle spindles are composed of bag and chain fibers, which detect stretch / change in muscle length
  - muscle spindles are connected to type 1a (Bag fibers) and type 2 (Chain fibers) primary afferent sensory nerve fibers
- contractile fibers (myofibrils)
  - innervated by gamma motor neuron axons → damage doesn't result in LMN syndrome or paralysis

Deep Tendon Reflex (Stretch Reflex)

- sensory receptor that activates reflex → muscle spindle
- monosynaptic reflex

1. triceps stretched by tap
2. muscle spindle detects stretch → 1a fibers fire
3. 1a sensory fibers synapse on tricep's LMN
    - excitatory synapse → triceps muscle contracts
    - inhibitory interneuron synapse → biceps inhibited via interneuron
    - proprioception information travels to nucleus cuneatus

Examples:

Spinal Nerves – knee, elbow, ankle, wrist

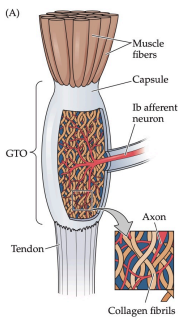
Cranial Nerves – jaw jerk (CN 5)

Why do we have this reflex? → example hold cup of coffee

- Brain sends feedforward command → hold the cup level
- Segmental feedback control to LMNs
    - load changes (aka more coffee is added to cup) resulting in passive stretch
    - LMNs correct by activating muscles to provide resistance

Golgi Tendon Organ

- somatosensory receptor
- innervated by 1b fibers
- senses tension in tendon
- important in active stretch



Passive Stretch

- activates muscle spindle → increased action potentials producing the deep tendon reflex
- activity of golgi tendon organ increases slightly, but not resulting in deep tendon reflex

Active Contraction

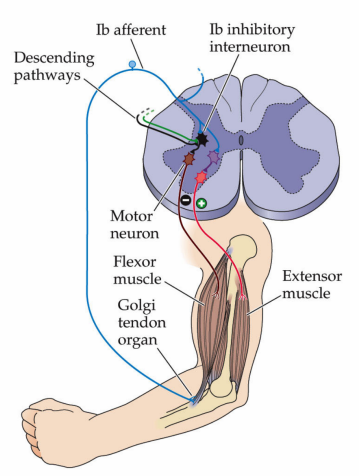
- muscle spindles don't activate and don't provide proprioception
- golgi tendon organ increase firing and provide proprioception

Golgi Tendon Organ – Autogenic Inhibition

- provides negative feedback during active stretch
    - signal of increased tension travels via 1b afferent fibers

which activates inhibitory interneurons

- inhibitory interneurons inhibit the stretched muscles LMNs and other interneurons activate antagonist muscle



- opposite action of stretch reflex
- provides proprioception to help control muscles
- may contribute to abnormal "clasp knife" reflex
  → feel higher than normal resistance when doing normal range of motion testing and then muscle suddenly releases w/ patients w/ increased muscle tone

Muscle tone

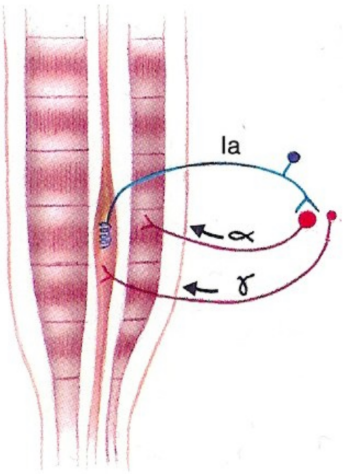
- normal muscle tone is resistance to passive stretch
- tone is due to two mechanisms: → we will focus on active tone
  - Active tone – due to spontaneous activity of LMNs
  - Passive tone
    - tense sarcomeres from actin/myosin crossbridging and titin tension
    - connective tissue stiffness

Pathological Active Muscle Tone

- very low tone w/ LMN disorders → loss of muscle innervation
- very high tone w/ UMN disorders → results in spasticity and rigidity due to loss of descending inhibition of gamma motor neurons

Gamma Activation of tone and Reflexes

- gamma motor neurons are tonically active, which causes muscle spindles to contract, which increases activity in 1a fibers, which then activate alpha motor neurons, which activate extrinsic muscles to raise tone
  → known as gamma loop (why muscle tone exists)
- descending motor pathway inhibits gamma loop → upper motor neurons inhibit gamma motor neurons
- Upper Motor Neuron Damage reduces descending inhibition resulting in spastic paralysis (increased tone + reflexes)
  - pathological tone limits functional movements
  - to reduce tone, cut dorsal roots (→ 1a fiber) at affected levels (dorsal rhizotomy) which lowers tone
    - rhizotomy also means you loose touch, proprioception, pain, temp, but get decreased tone
    - can cut only rootlets to reduce specifically muscle spindle sensation w/o other senses



1. afferent input from