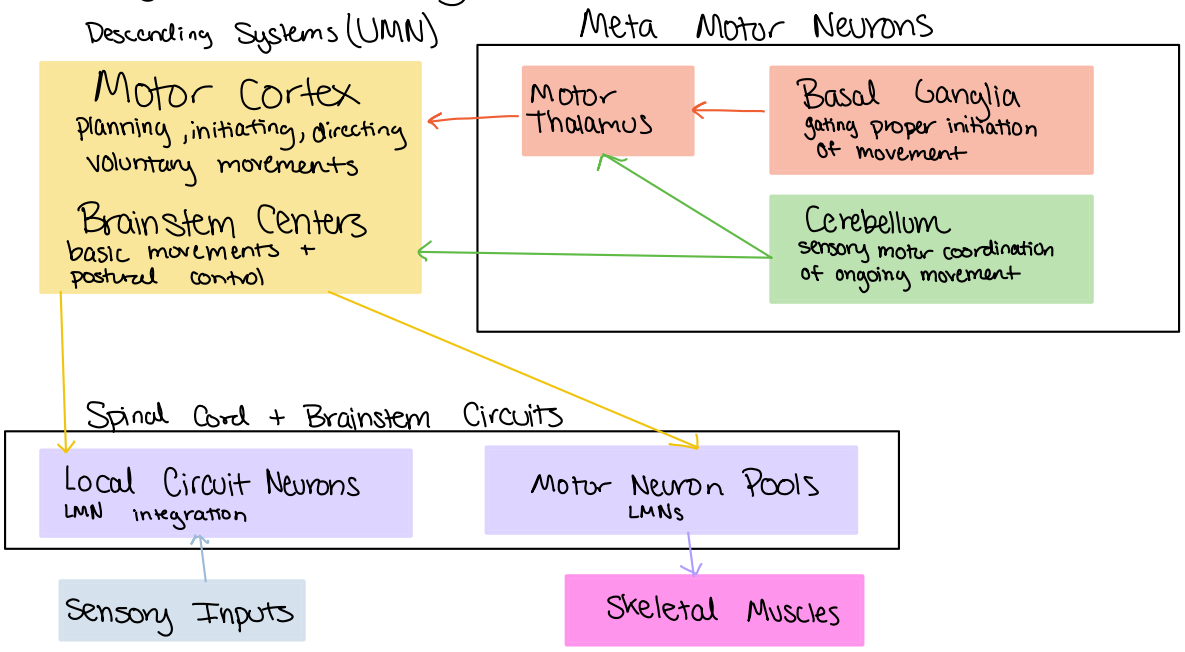
# Motor System Hierarchy




## Levels of Control in the Motor System Hierarchy

### ① Lower motor neurons (LMNs)

- project directly to skeletal muscles → muscles that move you
- located in the spinal cord + brainstem
- alpha motor neurons → large LMNs that project to extrinsic muscle fibers (force producing muscles)
- local circuit neurons (or segmental neurons) → located in spinal segment and are responsible for segmental reflex control (ex. knee jerk)
- In the spinal cord there are somatic motor neurons → project to musc that developed from somites. Found in the medial ventral horn
- In the brainstem, LMNs are found in the branchial and somatic nuclei
  - neurons in brachial motor nuclei project to muscles that develop from brachial arches
  - all cranial nerves have LMNs except 1, 2, 8 (purely sensory nerves)

### ② Upper Motor Neurons

- project to LMNs
- Located in the:
  - motor cortex → travel via corticospinal + corticobulbar tract
  - brainstem → travel via tectospinal (→ tectum), rubrospinal (→ red nucleus), reticulospinal (→ reticular nucleus), and vestibulospinal (→ vestibular nucleus) tracts
- Upper motor neurons originate in the brain (and brainstem) and travel downward to the spinal cord (and brainstem) to connect to the lower motor neurons

### ③ Meta Motor Neurons

- highest level of organization

- neurons are w/in the basal ganglia and cerebellum
- function: motor motivation

## LMN Pools

- groups of LMNs are in the anterior ventral horn called pools (some similar pools in cranial nerve nuclei) → all pools contain alpha motor neurons
- Pools are organized by:
  1. Region of the body innervated
     - medial pool: controls proximal and axial muscles (upper arm, shoulder, back, neck)
       → course motor control
     - lateral pool: controls distal muscles (fingers/feet)
       → fine motor control
  2. Type of Movement
     - anterior pool contains extensor muscles
     - posterior pool contains flexor muscles
- the thoracic level of the spinal cord doesn't have a lateral motor pool

## Alpha vs. Gamma Motor Neurons

- both alpha + gamma motor neurons are in the ventral horn

Alpha Motor Neurons: Large motor neurons that project to extrinsic muscle fibers (muscles that produce force). They are considered LMNs

Gamma Motor Neurons:

- project to intrinsic muscle fibers (contract muscle spindles)
- not considered a LMN
- don't impact strength and can't produce movement alone

## Lower Motor Neuron Syndrome – damage to LMN cell body (neuronopathy) or axon (neuropathy)

- LMN syndrome has 3 major characteristics:
  1. Neurogenic Atrophy of Muscles – axon normally releases growth factors that make muscles keep growing. If axon is damaged, growth factors disappear. If axon is reconnected, it can grow back.
     - neurogenic atrophy occurs in weeks, while disuse atrophy takes much longer
  2. Flaccid Paralysis – instantly after axon is cut, muscle can't move, or if partially cut,

ipsilateral loss of strength, reflexes, and tone

③ Fasiculations and Fibrillations

1. separation of proximal/distal axon (initial injury)
2. Degeneration of proximal axon
3. fasiculations occur w/in a day of LMN damage due to axon leaking $Na^+$, which starts action potential. B/c distal axon is still connected, muscle fibers twitch synchronously resulting in visible muscle twitches
4. degeneration of distal axon
5. fibrillations occur - muscle fibers still twitch, but not synchronously, so twitches aren't visible. Once fibrillations occur it's difficult for regeneration of axon

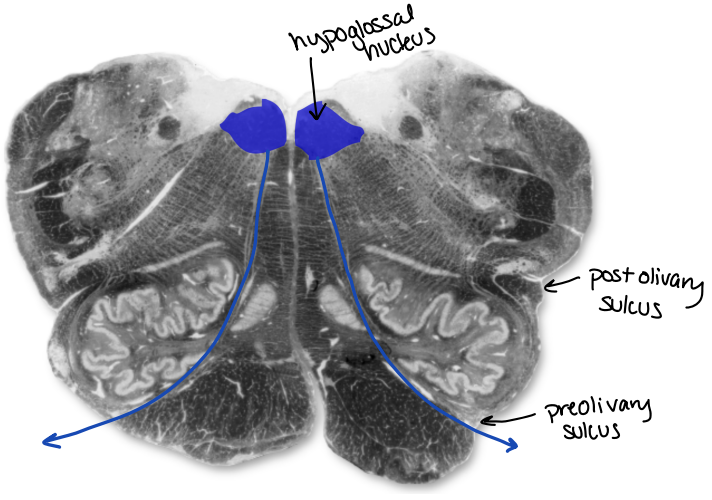
## Upper Motor Neuron Syndrome

- damage to nuclei or axon of upper motor neuron
- results in spastic paralysis → increased muscle tone and reflexes

## Hypoglossal Nerve

Nuclei:

- LMNs in the hypoglossal nerve are located in the hypoglossal nucleus in the middle medulla (mainly above the obex)




Exits: Fibers exit the medulla in the preolivary sulcus and exit the skull via the hypoglossal canal

Projects TO: extrinsic and intrinsic muscles of the tongue

- extrinsic (protrusor muscles) → stick tongue out
- intrinsic (tongue to tongue) → connect tongue to iself and allow for shaping tongue for speech

Function:

- enables tongue movement
- helps w/ speech, swallowing, and movement of substances inside the mouth
- tongue is protruded (aka sticking tongue out) when muscles contract

### Hypoglossal Nerve Damage

- ipsilateral flaccid paralysis of the tongue
- tongue deviates towards the side w/ the lesion b/c stronger side can push farther

# Spinal Accessory Nerve

- has a spinal root and a cranial root (no LMNs)

Nuclei:

- spinal accessory nuclei (spinal portion of the spinal accessory nerve) in spinal cord + pyramidal decussation level of the spinal cord → contains somatic LMNs
- nucleus ambiguous — cranial portion is located in nucleus ambiguous in the open medulla (Branchial LMN)

Exits:

- spinal portion exits via ventral horn and enters the cranium via foramen magnum
- cranial portion exits medulla via postolivary sulcus and meets the spinal portion to exit via the jugular foramen (CN9 + CN10)

Projects To:

- sternocleidomastoid and trapezius muscles (in the throat) → only spinal portion

Function:

- provides motor function to muscles essential for head + neck movement

LMN Lesion of CN11:

- ipsilateral LMN syndrome affecting trapezius and sternocleidomastoid muscles
- ipsilateral shoulder paralysis
- cannot rotate head to the contralateral side b/c of ipsilateral sternocleidomastoid muscle weakness

# Oculomotor (CN3), Trochlear (CN4), Abducens (CN6) Nerves

Nuclei (somatic motor):

CN3 → occulomotor nucleus (part of superior colliculus) → in midbrain

CN4 → trochlear nucleus (part of inferior colliculus) → in midbrain

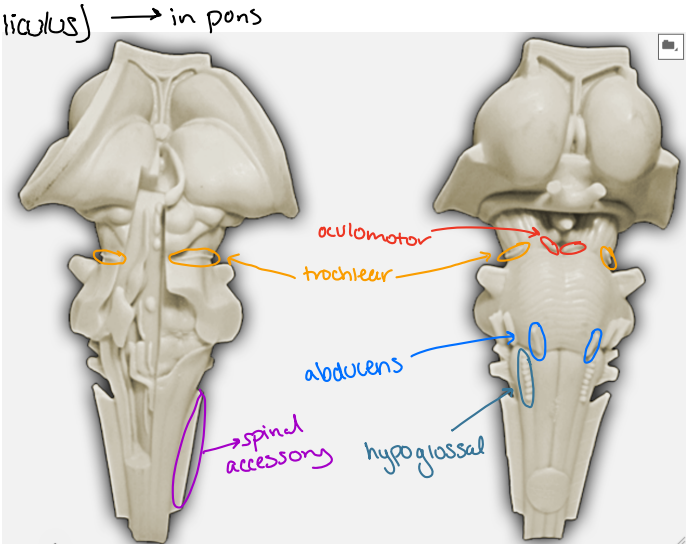
CN6 → abducens nucleus (part of facial colliculus) → in pons

Exits:

CN3 → interpeduncular fossa

CN4 → caudal to inferior colliculus on the dorsal side of the brainstem. Crosses midline before exiting

CN6 → pontomedullary junction




Projects To:

LR6SO4

CN3 → superior, inferior, medial rectus muscle, inferior oblique, levatur palpebrae

CN4 → superior oblique muscle ($SO_4$)

CN6 → lateral rectus muscle ($LR_6$)

Function:

CN3 → moves eyeball and opens eyelid (levator palpebrae)

CN4 → moves eyeball (superior oblique muscle)

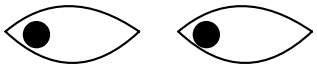
CN6 → moves eyeball (lateral rectus muscle)

## Types of Eye Movements

Abduction: eyes move away from the midline

Adduction: eyes move towards the midline

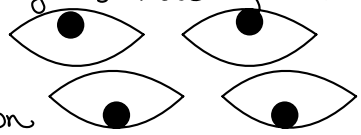
- abduction and adduction can occur at the same time



→ when looking left, right eye is adducting and left eye is abducting (away from midline)

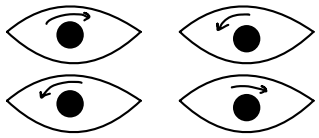
Elevation: both eyes looking up

Depression: both eyes looking down



Torsion: rotation of eye on its axis (small amount ~ 5%)

- intorsion – top of eye towards nose (medial rotation)
- extorsion – top of eye away from nose (external rotation)



Conjugate: both eyes move in the same direction (aka left, right, up, down)

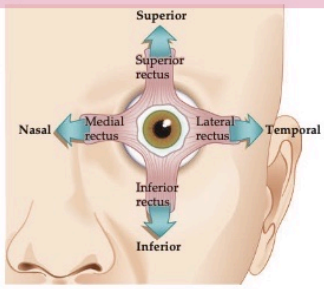
Convergence: both eyes move inwards (towards the nose)

Divergence: both eyes move outwards (away from the nose)

## Muscles involved in Eye movements

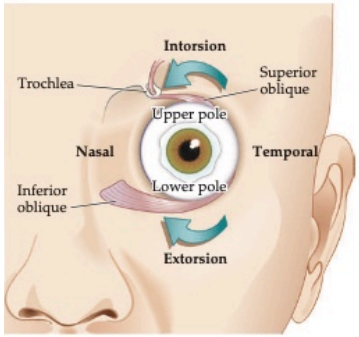
Rectus Muscles:

- superior rectus (CN3) → elevation
- inferior rectus (CN3) → depression
- medial rectus (CN3) → adduction
- lateral rectus (CN6) → abduction




Oblique Muscles

- superior oblique (CN4) → intorsion
- inferior oblique (CN5) → extorsion

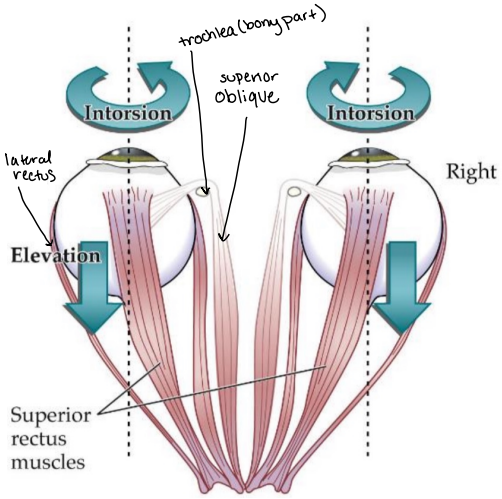



Moving the Eyelid

- levatur palpabrae (CN3) → opens eyelid

- Obicularis oculi (CN7) → closes eyelid

- Muscle contraction has different affects depending on the main axis of the eye

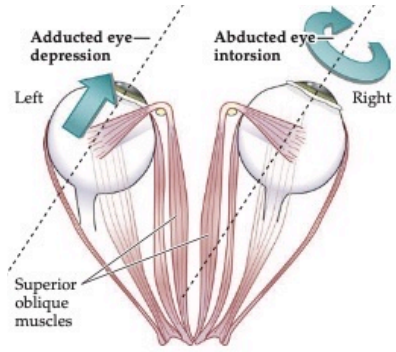



## Eyes Facing Forward

- superior rectus causes elevation + intorsion b/c it's attached 23° off of the eye's main axis
- inferior rectus causes depression + extorsion

## Eyes Facing Right

- if eye is abducted by 23° (right eye in diagram)
  - superior rectus (CN3) will only cause elevation
  - superior oblique (CN4) causes mainly intorsion
  - inferior oblique (CN3) causes mainly extorsion
- if eye is adducted by 23° (left eye in diagram)
  - superior rectus (CN3) will cause increased intorsion
  - superior oblique (CN4) causes depression
  - inferior oblique (CN3) causes elevation




## Damage to Trochlear Nerve (CN4)

- damage to nucleus results in contralateral paralysis
- damage to trochlear nerve (CN4) (after fibers cross) results in ipsilateral paralysis

## Damage to Abducens Nerve (CN6)

- results in inability to abduct ipsilateral eye