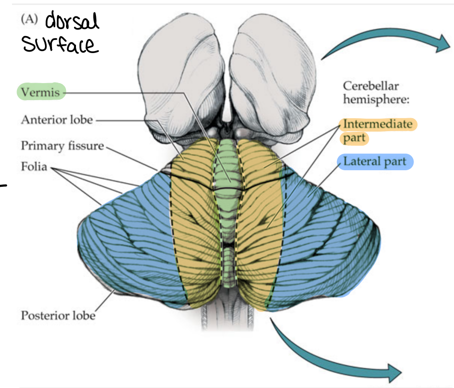
Cerebellum

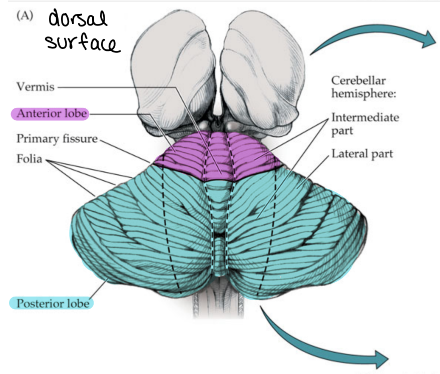
Regions of the Cerebellum

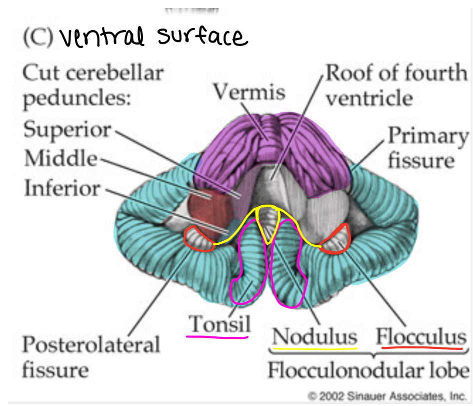
1. Left and Right hemispheres – composed of intermediate (medial) part and lateral part
2. Vermis – separtes the left and right hemisphere (s
   - sometimes called arbor vitae
3. paravermal – specifies medial hemispheres excluding the vermis



Lobes of the Cerebellum

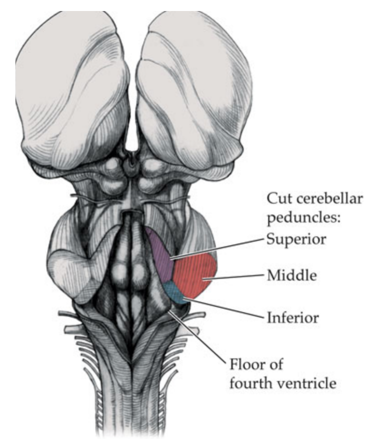
1. Anterior Lobe
2. Posterior Lobe ⟶ contains the tonsils (seen on ventral surface)
   - tonsil herniation – results in coma
3. Flocculonodular Lobe – important for balance
   - Flocculus – hemispheric part
   - Nodulus – vermal part

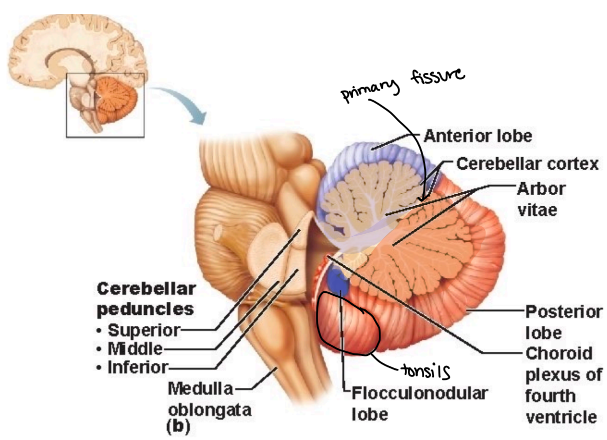




Cerebellar Peduncles

1. Superior – brachium conjuctivum
   - output to midbrain and thalamus (crosses in decussation of cerebellar peduncle)
   - small ventral spino cerebellar input
2. Middle Peduncle – brachium pontis
   - input from pons (pontine nucleus)
3. Inferior Peduncle – Restiform Body
   - inputs and outputs from medulla and spinal cord





Deep Cerebellar Nuclei

- Fastigial - most medial
- Interposed - formed by Globus and emboliform nuclei
- Dentate - most lateral

Functional Regions + Symptoms

Case of Crossless Symptoms

- no motor or sensory system defects except:
  - has positive romberg sign
  - has ataxia on right side
    - wide based gait → veers to the right
    - cannot stand on right leg alone
    - intentional tremor right upper extremity
    - dysdiadochokinesa and dysmetria on right side

right cerebellar region

Cerebellar Disorders

- Cerebellar Ataxia — no paralysis, but serious movement problems
- vestibulocerebellar ataxia — similar to vestibular nerve damage (difficulty staying upright)
  - results due to damage of flocculonodular lobe
  - leaning off midline, sway of body w/ eyes open or closed
  - nystagmus and vertigo
  - similar but less severe that direct vestibular nerve/nuclei damage
- spinocerebellar ataxia — "truncal ataxia or drunken sailor's gait." proximal limbs most affected results in stumbling
  - due to damage to anterior lobe and vermis
  - anterior lobe has strong spinal cord projections → alcohol can temporarily create this effect
  - back and proximal lower limb muscles are affected the most
  - increase sway, staggering, wide base of support → difficulty walking in straight line
- cerebrocerebellar ataxia — appendicular ataxia w/ distal limbs most affected. Intentional tremor, dysdiadokinesia, dysmetria
  - due to damage to posterior lobe of cerebellum (outside of vermis and paravermal cortex)
  - appendicular ataxia (neocerebella ataxia)
  - dysmetria → can't have finger move from nose to dr. finger"
  - dysdiadochokinesia - can't do rapid movement
  - intentional tremor (essential tremor) → closer gets to goal, more tremor

→ effects are ipsilateral to lesions

The Romberg Test and Sign

- Normally verticle position is maintained by visual, proprioceptive, and vestibular inputs
    - if proprioception is lost, vision can stabilize position
    - if vision is "removed" by closing eyes, sway increases since only vestibular sensation remains
- Romberg Test
    - compare sway with eyes open vs. closed
        - Positive Romberg: sway increases with closure of the eyes
    - positive romberg sign indicates loss of unconcious proprioception
        - cerebellum doesn't know where your limbs are located from proprioception so if sway stays the same w/ eyes open, lesion to cerebellum
        - indicates damage to Dorsal Spinocerebellar Tract → no sway w/ eyes open, sway w/ eyes closed
        - sway when looking up, but not forward, damage to vestibular system

Cerebellar Inputs

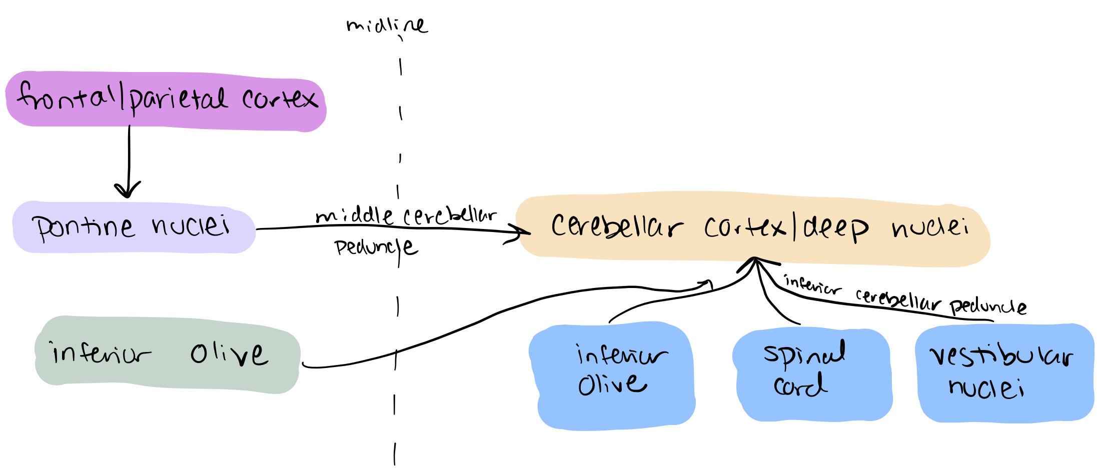
Spinal Cord

- unconcious proprioception via ipsilateral spino and cuneocerebellar tracts

Vestibular – head position and acceleration via vestibular nuclei (ipsilateral)

Inferior Olive – projects to cerebellum via inferior cerebellar peduncle (olivocerebellar tract) → mainly crossed, but possibly some ipsilateral projection in early life

Cerebellar Cortex – motor cortex and much more and ultimately contralateral via pontine nuclei + fibers



Spinal Projections

· Tracts: spino and cuneocerebellar tracts

· Projects to: vermis + paravermal cerebellar cortex, which contain a sensory homunculus

Dorsal Spinocerebellar Tract

· ipsilateral spinal cerebellar afferent

· Originates: in clarke's nucleus (located in T1-L2) Sacral and lower lumbar levels travel via gracilus tract to reach clarke's

· Travels: dorsal spinocerebellar tract to inferior cerebellar peduncle to spinocerebellum

· Crossing: no crossing

· Damage: produces trunk and lower limb ataxia (ipsilateral romberg sign)

Cuneocerebellar Tract

Originates: external cuneate nucleus

Travels: via cuneocerebellar tract through inferior cerebellar peduncle

Function: proprioception from upper limbs. Fibers from upper limbs travel via fasiculus cuneatus

Crossing: none

Damage: produces upper limb ataxia (neck?) → doesn't normally produce positive romberg sign

Ventral Spinocerebellar tract

Originates: in lumbar cord

Bilateral Projections to spinocerebellum

- ipsilateral projection: inferior cerebellar peduncle
- crossed projection: inferior cerebellar peduncle to contralateral cerebellum and superior cerebellar peduncle to ipsilateral cerebellum (recrossed fibers)

Damage: Bilateral, so no loss w/ unilateral lesion

Cortical Projections

Cerebral Cortex

- primary + secondary motor cortex
- somatosensory inputs as well
- no direct projection to cerebellum

Corticopontine Fibers

- cortex to ipsilateral pontine nuclei
- pontine nuclei to contralateral cerebellum (posterior lobe)

CorticoOlivary Fibers

- cortex to ipsilateral inferior olive

- olivocerebellar to contralateral cerebellum

- Cerebral cortex contrals the contralateral cerebellum

Cerebellar Cortical Histology

Types of Neurons:

- purkinje cell ⟶ gabaergic output neuron of cerebellar cortex. exist in purkinje cell layer
- intrinsic neurons
    - granule cells ⟶ excitatory create granule cell layer beneath purkinje cell layer and axons run in molecular layer
    - molecular layer:
        - basket cells ⟶ fibers make basket around purkinje cell fibers (inhibitory)
        - stelate cells ⟶ inhibitory
    - golgi cells ⟶ inhibitory in granular cell layer
- Afferent fibers (input fibers)
    - extrinsic ⟶ from outside cerebellum mossy or climbing fibers
    - intrinsic – parallel fibers are fibers of granule cells that travel in molecular layer

Mossy fibers

- travel to a Granular cell (also activate Golgi cells – local inhibition) → proprioception of movement
- mossy fibers travel from spinal cord, pons, reticular nuclei
- granule cells synapse on many purkinje cells via parallel fiber and also activate basket cells (local inhibition)

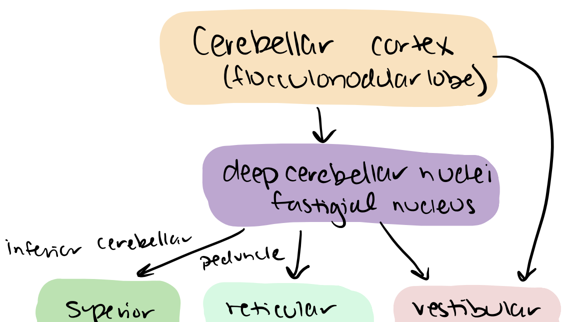
Climbing fibers ⟶ how well a movement worked

- originate from inferior olive
- travels to a purkinje cell

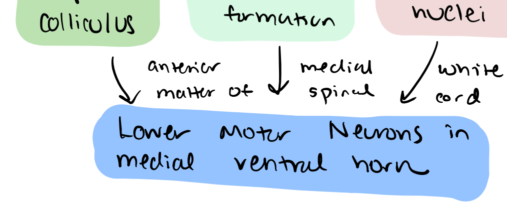
Purkinje cell

- integrates activity
- projects to deep nuclei
- inhibitory projection b/c modulates movement, doesn't elicit movement

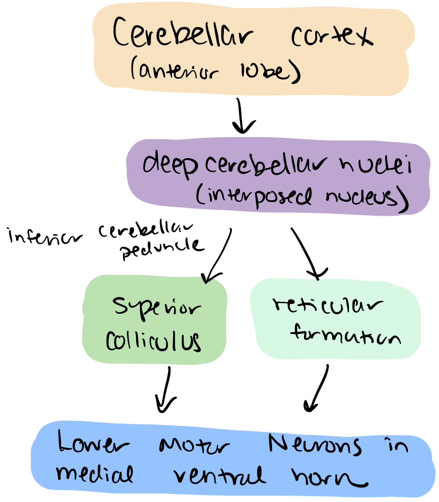
Descending Cerebellar Outputs



- flocculonodular lobe to vestibular nuclei and fastigial nucleus
- deep cerebellar nuclei to upper motor neurons in superior colliculus, reticular formation, vestibular nuclei
- Upper motor neurons to LMNs in medial ventral horn



· Ipsilateral projects



· anterior lobe to interposed nuclei

· interposed nucleus to primarily reticular nuclei

· UMN to LMN in medial ventral horn

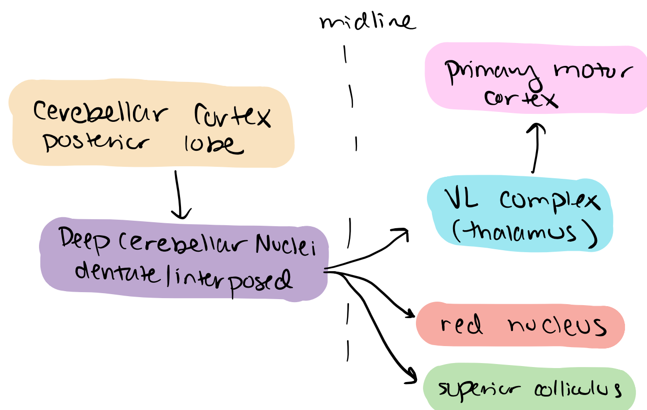
· ipsilateral control

Ascending outputs

· posterior lobe of cerebellar cortex to interposed and dentate nucleus

· superior cerebellar peduncle contralateral to

- · Red nucleus to contralateral spinal cord (rubrospinal tract)
- · Superior colliculus to contralateral CN 3,4,6 and cervical spinal cord
- · motor thalamus — VA and VL Nuclei to Motor Cortex



Double Cross

· cerebellum provides ipsilateral motor control

· Cerebellar cortex to deep nuclei (IP and dentate)

- · deep nuclei to red nucleus and motor thalamus via superior cerebellar peduncle decussation
- · red nucleus via rubrospinal tract recrosses, thus ipsilateral
- · motor thalamus (VA + VL) projects to motor cortex via internal capsule and recrossing during projections from motor cortex to spinal cord via pyramidal decussation ⟶ therefore ipsilateral control

Textbook Notes Cerebellum

· Ataxia - type of irregular uncoordinated movement that can be a result of cerebellum damage

① ataxia is ipsilateral to lesion

② midline cerebellar lesions of vermis of flocculonodular lobes cause unsteady gait and eye movement abnormalities — truncal ataxia

③ lateral cerebellar lesion to the vermis cause ataxia of the limbs — appendicular ataxia

Tonsil herneation - brain swelling can lead to intracranial pressure which can cause the tonsils to be pushed through foramen magnum, compressing the medulla and causing death

Functional Regions of the Cerebellum

Lateral Regions

Function: motor planning for extremities

Pathways: lateral corticospinal tract

Project to: dentate nuclei (largest of deep cerebellar nuclei) ⟶ active before a voluntary movement occurs

Intermediate Hemispheres

Function: control of distal appendicular muscles | distal limb coordination

Pathway: lateral corticospinal tract, rubrospinal tract,

Project to: Interposed nuclei ⟶ active during movements

Vermis + Flocculonodular Lobe

Function: proximal limb + trunk coordination | balance + vestibulo-ocular reflexes

Pathways: anterior corticospinal tract, reticulospinal tract, vestibulospinal tract, tectospinal, MLF

Project to: Fastigial nuclei

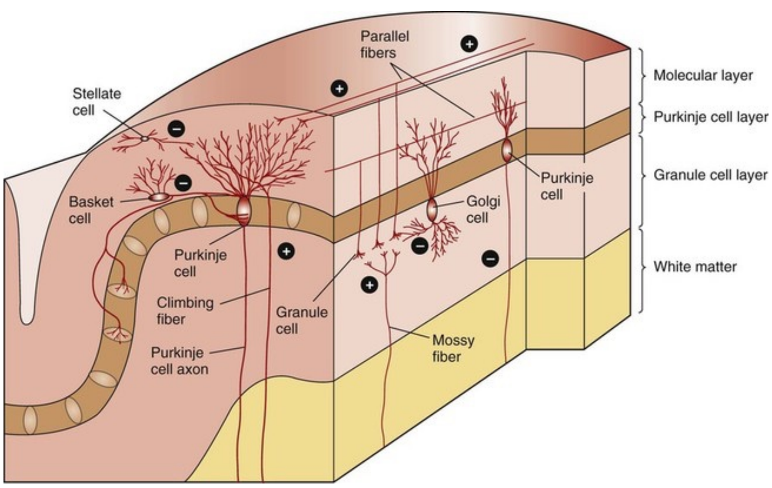
Cell Organization of the Cerebellum

Cerebellum has 3 cell layers:

① Granule cell layer - consists of granule cell bodies

② Purkinje cell layer - cell bodies of purkinje cells

③ molecular layer - consists of unmyelinated granule cell axons, purkinje cell dendrites, and interneurons



Two Primary input fibers

<u>Mossy Fibers</u> (extrinsic)

· originate from spinal cord, pons, reticular nuclei ⟶ carry information about proprioception of movement

· form excitatory synapses on granule cell dendrites (also activate golgi cells— local inhibition)

- granule cells send axons to molecular layer which then bifurcate to become parallel fibers
- each parallel fiber (intrinsic input fibers) then forms excitatory synapses with many purkinje cells and activate basket cells (local inhibition)

Climbing Fibers (extrinsic)

- Originate from cells in contralateral inferior olivary nucleus
- travel to a purkinje cell

Cell Layers

1. granule cell layer
   - granule cells → excitatory axons are parallel fibers that synapse in molecular layer
   - golgi cells → inhibitory intrinsic neurons in granule cell layer
2. Purkinje Cell Layer
   - purkinje cells → gabaergic output neuron of the cerebellar cortex that integrate activity
     - projects to deep cerebellar nuclei
     - inhibitory projection b/c modulates movement, doesn't elicit movement

Input Pathways

Spinal Cord

Function: unconcious proprioception

Tract: spinocerebellar + cuneocerebellar tracts

Crossing: None → ipsilateral projection

Peduncle: inferior cerebellar peduncle (restiform body)

Vestibular Nuclei

Function: head position + acceleration

Crossing: None → ipsilateral projection

Peduncle: inferior cerebellar peduncle (restiform body)

Inferior Olive

Tract: olivocerebellar tract

Crossing: mainly contralateral, some ipsilateral in early life

Peduncle: inferior cerebellar peduncle (restiform body)

function is to coordinate signals from spinal cord to cerebellum → regulates motor coordination + learning

Cerebral Cortex

Function: information from cerebral cortex/motor cortex travels to pontine nuclei, which travel to cerebellum

Crossing: contralateral

Peduncle: middle cerebellar peduncle

Spinal Projections

Tracts: spino + cuneocerebellar tracts

Projects to: vermis + paravermal cerebellar cortex (contains sensory homunculus)

Dorsal Spinocerebellar Tract
– ipsilateral spinal cerebellar afferent

Originates: clarke's nucleus T1 – L2 sacral + lower lumbar levels travel via gracilus tract to reach clarke's

Travels: dorsal spinocerebellar tract to inferior cerebellar peduncle to spinocerebellum

Crossing: none

Damage: trunk + lower limb ataxia (ipsilateral romberg sign)

Cuneocerebellar Tract

Originates: external cuneate nucleus

Travels: via cuneocerebellar tract through inferior cerebellar peduncle

Function: proprioception from upper limbs. Fibers from upper limbs travel via fasiculus cuneatis

Crossing: none

Damage: upper limb ataxia → doesn't produce positive romberg sign

Ventral Spinocerebellar Tract

Originates: in lumbar cord

Travels: has bilateral projections to spinocerebellum

- ipsilateral projection → inferior cerebellar peduncle
- crossed projection → inferior cerebellar peduncle to contralateral cerebellum
  → superior cerebellar peduncle to ipsilateral cerebellum (recrossed fibers)

3 pathways of this tract

Damage: bilateral so no loss w/ unilateral lesion

Cortical Projections

Cerebral cortex
→ controls contralateral cerebellum

- primary + secondary motor cortex + somatosensory inputs
- no direct projections to cerebellum

Corticopontine Fibers

- cortex to ipsilateral pontine nuclei
- pontine nuclei to contralateral cerebellum (posterior lobe)

Cortico Olivary Fibers

- cortex to inferior olive
- olivocerebellar to contralateral cerebellum

Cerebellar Disorders

cerebellar ataxia – no paralysis, extremely uncoordinated harsh movements

Damage Location: Cerebellum

vestibulocerebellar ataxia – trouble maintaining upright position, nystagmus + vertigo (similar to vestibular nerve damage)

Damage location: flocculonodular lobe

spinocerebellar ataxia (truncal ataxia or drunken sailor's gait) – truncal ataxia back/proximal limbs most affected

Damage Location: Anterior Lobe + Vermis

Cerebrocerebellar (neocerebellar) ataxia – appendicular ataxia w/ distal limbs most affected. Results in intentional tremor (get closer to goal, more tremor), dysdiadokinesia, dysmetria (can't have finger move from nose to dr.'s finger)

Damage Location: Posterior Lobe

Romberg Test + Sign

- normally verticle position is maintained by visual proprioceptive, and vestibular inputs
  - proprioception lost ⟶ vision can stabilize position
  - if closed eyes, sway increases since only vestibular sensation remains

Romberg Test:

- compare sway w/ eyes open vs. closed
- positive romberg sign indicates loss of $\overbrace{\text{unconcious proprioception}}^{\text{dorsal spinocerebellar tract}}$ ⟶ no sway w/ eyes open. sway w/ eyes closed
- sway when looking up, but not forward ⟶ damage to vestibular system

Cerebellar Outputs

Flocculonodular Lobe (vestibulocerebellum) ⟶ Fastigial Nucleus ⟶ superior colliculus ⟶ LMNs in medial pool

Fastigial Nucleus —inferior cerebellar peduncle⟶ reticular formation ⟶ LMNs in medial pool

Fastigial Nucleus ⟶ Vestibular Nuclei ⟶ LMNs in medial pool

Flocculonodular Lobe ⟶ Vestibular Nuclei

LMNs in medial pool ⟶ proximal/axial muscles

Anterior Lobe ⟶ interposed nucleus ⟶ superior colliculus ⟶ LMNs in medial pool

interposed nucleus —inferior cerebellar peduncle⟶ reticular formation ⟶ LMNs in medial pool

midline

Posterior Lobe ⟶ Dentate/Interposed nuclei —superior cerebellar peduncle⟶ red nucleus ⟶ projects to contralateral spinal cord (rubrospinal tract)

Dentate/Interposed nuclei ⟶ superior colliculus ⟶ projects to contralateral CN 3,4,6 (tectospinal tract)

Dentate/Interposed nuclei ⟶ motor thalamus VA/VL ⟶ primary motor cortex

Why are ascending projections double crossed?

- Cerebellum provides ipsilateral control of movement
- neurons in red nucleus

- dentate → contralateral motor thalamus → cortex → corticospinal tract recrosses
- interposed → contralateral red nucleus → crosses immediately → therefore ipsilateral contro

Cerebellar Peduncles

Inferior (restiform body) - connects medulla to cerebellum

Outputs: from fastigial nucleus (flocculonodular), interposed nucleus (anterior lobe)

Inputs: cuneocerebellar tract, olivocerebellar tract (inferior olive), vestibular nuclei, ventral + dorsal spinocerebellar

Middle (Branchium Pontis) - input from the pons

Inputs: input from pons that relays input from cerebral cortex

Branchium Conjectivum (Superior) -

Inputs: ventral spinocerebellar

Outputs: dentate/interposed nuclei (posterior lobe) to motor thalamus