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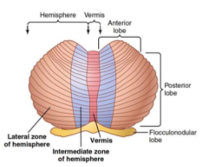
Cerebellum and brain stem

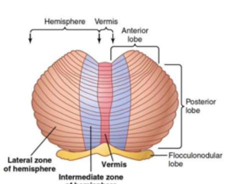
Functional subdivisions of the cerebellum

Vestibulocerebellum

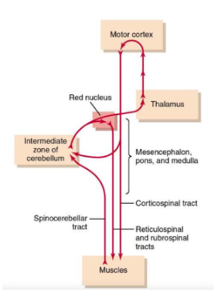


- This **level consists principally** of the **flocculonodular cerebellar lobes** and **adjacent portions** of the **vermis**.
- It **provides neural circuits** for **most of the body's equilibrium** and **postural movements**.
- **loss** of the **flocculonodular lobes and adjacent portions** of the **vermis** of the cerebellum **causes extreme disturbance of equilibrium** and **postural movements**.
- In **people with vestibulocerebellar dysfunction**, **equilibrium** is **far more disturbed during performance** of **rapid motions than during inactivity**, **especially** when **these movements involve changes in direction of movement**.
- It is **important** in **controlling balance between agonist** and **antagonist muscle contractions** of the **spine**, **hips**, and **shoulders during rapid changes** in **body positions**.
- **during control** of **equilibrium**, it is **presumed that information from both** the **body periphery** and the **vestibular apparatus** is **used** in a **typical feedback control circuit** to **provide anticipatory correction** of **postural motor signals necessary** for **maintaining equilibrium even during extremely rapid motion**.

Spinocerebellum

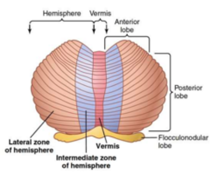


- This level **consists** of **most of the vermis** and the **intermediate zones**.
- It **mainly helps coordinate the reciprocal contractions** of **agonist** and **antagonist muscles** in the **peripheral portions** of the **limbs**, **especially** in the **hands, fingers**, and **thumbs**.
- **After** the **intermediate zone** of the **cerebellum has compared** the **intended movements with** the **actual movements**, the **deep nuclear cells** of the **interposed nucleus send corrective output signals**
  - (1) **back** to the **cerebral motor cortex through** the **thalamus**.
  - (2) to the **magnocellular portion** of **the red nucleus** that **gives rise** to the **rubrospinal tract.**



- **Ballistic movements**
  - **Ballistic movements** are **controlled** by **having the entire movement preplanned** and **set into motion to go** a **specific distance** and **then to stop.**
    - E.g typing
  - The **major changes occur** in **these ballistic movements when** the **cerebellum** is **removed are the movements** are **slow to develop and to stop**.

Cerebrocerebellum

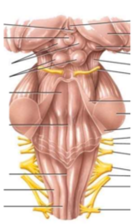


- This level **consists** of the **lateral zones of the cerebellar hemispheres**.
- It **receives all its input from** the **cerebral cortex**, **no direct input from** the **peripheral parts of the body**.
- It **transmits** its **output information back to the brain**, **functioning** in a **feedback manner** to **plan sequential voluntary body** and **limb movements**.
  - The input will come from the cerebral cortex to the lateral zone of the cerebellar hemisphere to get integrated and then the output will go through the dentate nuclei to the cerebral cortex again through the thalamus
  - So there is no direct communication with the peripheral parts of the body
- **destruction** of the **lateral zones of** the **cerebellar hemispheres**, **along with their deep nuclei**, the **dentate nuclei**, can **lead to extreme incoordination** of **complex purposeful movements** of the **hands**, **fingers**, and **feet** and of the **speech apparatus**.
- **these portions** of the **cerebellum** are **concerned** with **two other important but indirect aspects** of **motor control**:
  - (1) **planning** of **sequential movements**.
  - (2) "**timing**" of the **sequential movements**.
    - **Planning**
      - the **lateral cerebellar zones appear** to be **involved not with what movement** is **happening** at a **given moment but with what will be happening during** the **next sequential movement** a **fraction** of a **second** or **perhaps even seconds later** .
      - **one** of the **most important features** of **normal motor function** is **one's ability to progress smoothly from one movement** to the **next** in **orderly succession**.
      - In the **absence** of the **large lateral zones** of the **cerebellar hemispheres**, this **capability is seriously disturbed** for **rapid movements**.
    - **Timing**
      - **Another important function** of the **lateral zones of the cerebellar hemispheres** is to **provide appropriate timing** for **each succeeding movement**.

- In the **absence** of these **cerebellar zones**, **one loses** the **subconscious ability** to **predict how far** the **different parts** of the **body will move in a given time**.
- **Without this timing capability**, the **person becomes unable** to **determine when the next sequential movement needs** to **begin**.
- As a result, the **succeeding movement may begin too early** or, **more likely, too late**.
- Therefore, **lesions in the lateral zones** of the **cerebellum cause complex movements** (e.g., those required for writing, running, or even talking) to **become incoordinate** and **lacking ability** to **progress** in **orderly sequence from one movement** to the next.
- **Such cerebellar lesions** are **said** to **cause failure of smooth progression of movements**.

- **Predictive function** of **cerebrocerebellum**
  - The **cerebrocerebellum** also **helps** to "**time" events other than movements** of the **body**.
  - For **example**, the **rates of progression** of **both auditory** and **visual phenomena can be predicted by the brain**.
  - the **cerebellum** is **particularly helpful** in **interpreting rapidly changing spatiotemporal relations** in **sensory information**.

Brain stem

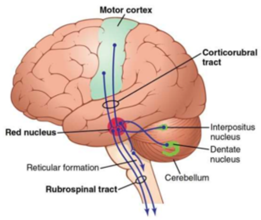


- the brain stem is composed of the pons, medullar and the mid brain
- composed of white matter that has many tracts (ascending and descending) and has many nuclei in the gray matter either nuclei for the cranial nerves or nuclei to serve different integrative functions
- in this lecture we will only focus on the motor part of the brain stem
- when we talk about the motor function of the brain stem its very important to talk about the red nucleus which is located in the mid brain

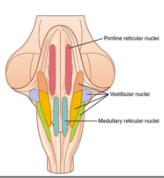
Red nucleus

- located in the midbrain
- Red nucleus **receives a large number** of **direct fibers from** the **primary motor cortex through** the **corticorubral tract**, **as well as branching fibers from** the **corticospinal tract as** it **passes through** the **mesencephalon**.

- **These fibers synapse** in the **lower portion of** the **red nucleus**, the **magnocellular portion**, which **contains large neurons similar** in **size** to the **Betz cells** in the motor **cortex**.
- The **neurons of the red nucleus have similar dynamic** and **static characteristics**, **except** that a **greater percentage** of **dynamic neurons** is in the **red nucleus** and a **greater percentage of static neurons** is in the **primary motor cortex**.



- This **may be related** to the **fact** that the **red nucleus is closely allied** with the **cerebellum**, and the **cerebellum plays an important role** in **rapid initiation** of **muscle contraction**
- The **magnocellular portion** of the **red nucleus** has a **somatographic representation of all the muscles** of the body, **as does the motor cortex**.
- **Therefore**, **stimulation of a single point** in **this portion** of the **red nucleus causes contraction of either** a **single muscle** or a **small group of muscles**.
- **However**, the **fineness of representation** of the **different muscles** is **far less developed than** in **the motor cortex.**
- **These large neurons then give rise** to the **rubrospinal tract**, **which crosses** to the **opposite side** in the **lower brain stem** and **follows a course immediately adjacent** to the **corticospinal tract** into the **lateral columns of the spinal cord**.
- The **rubrospinal fibers terminate mostly** on the **interneurons of the intermediate areas of** the **cord gray matter**, **along** with the **corticospinal fibers, but some** of the **rubrospinal fibers terminate directly** on **anterior motor neurons**, **along** with **some corticospinal fibers**.
- The **red nucleus** also **has close connections** with the **cerebellum**, **similar** to the **connections between the motor cortex** and the **cerebellum**.
- The **corticospinal and rubrospinal tracts together** are **called the lateral motor system** of the **cord**, in **contradistinction** to a **vestibuloreticulospinal system**, which **lies mainly medially** in the **cord** and is **called the medial motor system** of the **cord**.



- The **corticorubrospinal pathway serves** as an **accessory route for transmission** of **relatively discrete signals from** the **motor cortex** to the **spinal cord**.
- **When** the **corticospinal fibers** are **destroyed but** the **corticorubrospinal pathway** is **intact**, **discrete movements can still occur**, **except** that the **movements for fine control** of the **fingers** and **hands** are **considerably impaired**.

<u>Reticular nuclei</u>

- The **reticular nuclei** are **divided** into two **major groups**:
    - (1) **pontine reticular nuclei**.
    - (2) **medullary reticular nuclei**.

- **Reticular nuclei function mainly antagonistically to each other**, **with** the **pontine exciting the antigravity muscles** and the **medullary relaxing these same muscles**.
    - **Pontine reticular nuclei**
        - The pontine reticular nuclei **transmit excitatory signals downward** into the **cord through** the **pontine reticulospinal tract** in the **anterior column** of the **cord**
        - The **fibers** of this pathway **terminate** on the **medial anterior motor neurons** that **excite** the **axial muscles** of the **body**, **which support the body against gravity**: the **muscles of the vertebral column** and the **extensor muscles of the limbs.**
        - The **pontine reticular nuclei** have a **high degree** of **natural excitability.**
        - In addition, they **receive strong excitatory signals** from **the vestibular nuclei**, as well as from **deep nuclei of the cerebellum**
        - Therefore, **when the pontine reticular excitatory system** is **unopposed** by the **medullary reticular system**, it **causes powerful excitation** of **antigravity muscles throughout the body**.
    - **Medullary reticular nuclei**
        - The medullary reticular nuclei **transmit inhibitory signals** to the **same antigravity anterior motor neurons via** the **medullary reticulospinal tract**, **located** in the **lateral column of the cord**.
        - The **medullary reticular nuclei receive strong input collaterals from** the following:
        - (1) the **corticospinal tract**; (2) the **rubrospinal tract**; and (3) **other motor pathways**.
        - **These tracts** and **pathways normally activate** the **medullary reticular inhibitory system** to **counterbalance the excitatory signals from** the **pontine reticular system**, so **under normal conditions** the **body muscles** are **not abnormally tense**.
- **Reticular nuclei**
    - The **excitatory and inhibitory reticular nuclei constitute** a **controllable system** that is **manipulated by motor signals** from **the cerebral cortex** and **elsewhere** to **provide necessary background muscle contractions** for **standing against gravity** and to **inhibit appropriate groups** of **muscles** as **needed so that other functions can be performed**.
- **Vestibular nuclei**

  - **All** the **vestibular nuclei function** in **association with the pontine reticular nuclei** to **control the antigravity** muscles.
  - The **vestibular nuclei transmit strong excitatory signals** to the **antigravity muscles via** the **lateral and medial vestibulospinal tracts** in the **anterior columns of the spinal cord**.
  - **Without this support** of the **vestibular nuclei**, the **pontine reticular system would lose much of its excitation** of the **axial antigravity muscles**.
  - The **specific role** of the **vestibular nuclei** is to **selectively control the excitatory signals** to the **different antigravity muscles** to **maintain equilibrium** in **response** to **signals from** the **vestibular apparatus**.
- **Vestibular signals**
  - **Most** of the **vestibular nerve fibers terminate** in the **vestibular nuclei**.
  - **Some fibers pass directly** to the **brain stem reticular nuclei** and **also to the cerebellar fastigial** and **flocculonodular lobe nuclei.**
  - The **fibers** that **end in the brain stem vestibular nuclei synapse** with **neurons** that **send fibers into** the **cerebellum**, the **vestibulospinal tracts** and **other areas of the brain** stem, **particularly the reticular** nuclei.
  - The **flocculonodular lobes** of the **cerebellum** are **especially concerned** with **dynamic equilibrium signals from** the **semicircular d**ucts.
  - **severe injury to either the lobes or** the **ducts causes loss of dynamic equilibrium during rapid changes** in **direction of motion** but **does not seriously disturb equilibrium under static conditions**.
  - **Signals transmitted upward** in the **brain stem from both the vestibular nuclei** and the **cerebellum via** the **medial longitudinal fasciculus cause corrective movements of the eyes every time** the **head rotates**, so the **eyes remain fixed** on a **specific visual object**.
  - **Signals also pass upward** to the **cerebral cortex**, **terminating** in a **primary cortical center for equilibrium**.