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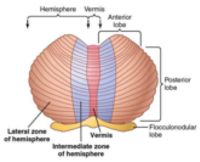
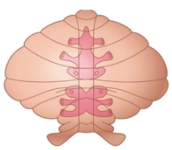
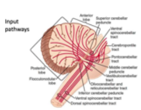
Cerebellum



- There are **four areas** on **each hemisphere** that **represents different specific function** for the **cerebellum**
  - In the **vermis** it represents the **axial muscles**
  - The **intermediate zone** represents the **distal areas (limbs)**
  - The **lateral zone doesn't represent anything** for the body parts
- When **they excited the cerebellum** they **found no change in perception** of **sensation nor movement** so **they called it the silent area/ brain**
  - But **when removed** they **found great impairment of the movement**



- When we talk about the **function** of the **cerebellum** we can describe it as one word which is **coordination**
- The **cerebellum** like the **cerebrum** has the **cerebellar cortex**, **deep nuclei** and **we have input pathways** (**afferent**) and **output pathway** (**efferent**)
- so the **cerebellum is receiving signals from** the **cerebral cortex:**
  - **mainly motor information** like **planning/ intention** of **certain movements** (what the **decision the cerebral cortex took** to **perform this type of movement**)
  - **also receives information from** the **brain stem** (**from different areas like the vestibular nuclei** by the **vestibulocerebellar pathway** and **reticular formation** for **balance** and **muscle tone** and **olivocerebellar pathway** (from the inferior olivary nucleus)



  - **also receives information** from the **spinal cord (dorsal spinocerebellar tract** and **ventral spinocerebellar tract**)
- One of the **important functions** of the **cerebellum** is to **compare the tension of movement** to the **actual movement** that **occurred**, **if there is any discrepancies** it will **send corrective feedback mostly** to the **cerebral cortex** and the **rubrospinal tracts**

Input Pathways

Dorsal spinocerebellar tracts

- The **signals transmitted** in the **dorsal spinocerebellar tracts come mainly** from the **muscle spindles** and **to a lesser extent from other somatic receptors throughout** the **body**, **such as Golgi tendon organs**, **large tactile receptors** of the **skin**, and **joint receptors**.
- **All these signals apprise** the **cerebellum** of **the momentary status of**
  - (1) **muscle contraction**,
  - (2) **degree** of **tension** on the **muscle tendons**,
  - (3) **positions** and **rates of movement** of the **parts of the body**,
  - (4) **forces acting** on the **surfaces of the body**.

Ventral spinocerebellar tracts

- The **ventral spinocerebellar tracts receive much less information** from the **peripheral receptors**.
- **Instead**, they are **excited mainly by motor signals arriving** in the **anterior horns** of the **spinal cord from**
  - (1) the **brain through** the **corticospinal and rubrospinal tracts**
  - (2) the **internal motor pattern generators** in the **cord itself**.
- Thus, this **ventral fiber pathway tells** the **cerebellum which motor signals** have **arrived** at the **anterior horns**; this **feedback** is **called the efference copy** of the **anterior horn motor** drive.
  - Essentially**,** it **allows** the **cerebellum** to **compare** the **intended motor commands with** the **actual motor output, enabling fine-tuning** and **coordination** of **movements.**
- The **spinocerebellar pathways** can **transmit impulses at very high velocities**.
- This **speed** is **important** for **instantaneous appraisal** of the **cerebellum** of **changes** in **peripheral muscle actions**.

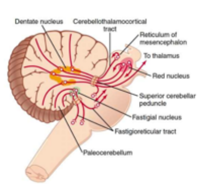
Inferior olivary nucleus

- In addition to signals from the spinocerebellar tracts, **signals** are **transmitted into** the **cerebellum from** the **body periphery through** the **spinal dorsal columns to** the **dorsal column nuclei** of the **medulla** and **are then relayed to the cerebellum**.
- **signals are transmitted up** the **spinal cord through** the **spinoreticular pathway** and the **spino-olivary pathway to** the **inferior olivary nucleus**.
- **Signals are then relayed from both** of **these areas to the cerebellum**.
- **Thus**, the **cerebellum continually collects information about the movements and positions** of **all parts** of the **body even though it is operating** at a **subconscious level**

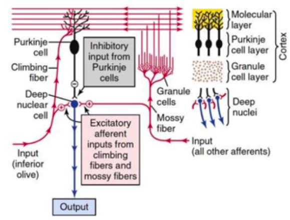
Output Pathway

Deep cerebellar nuclei

- **on each side** of the **cerebellum** there are **three deep cerebellar nuclei**: the **dentate**, **interposed**, and **fastigial**.
  - **Sometimes** the **vestibular nuclei**
- **All the deep cerebellar nuclei receive signals** from **two sources**:
  - (1) the **cerebellar cortex**.
  - (2) the **deep sensory afferent tracts** (directly from it) to the **cerebellum**.
- **Each time an input signal arrives** in the **cerebellum**, it **divides and goes in two directions**:



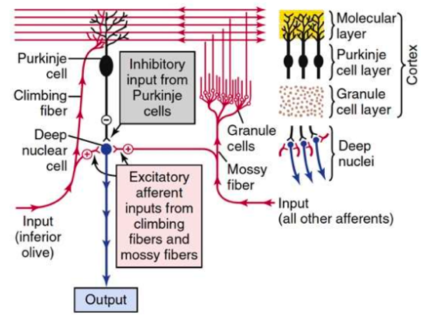
  - (1) **directly** to **one of the cerebellar deep nuclei** and
  - (2) to a **corresponding area of the cerebellar cortex overlying** the **deep nucleus**.
- Then, a **fraction of a second later**, the **cerebellar cortex relays** an **inhibitory output signal** to the **deep nucleus**.
- **all input signals** that **enter the cerebellum eventually end** in the **deep nuclei** in the **form** of **initial excitatory signals followed** a **fraction of a second later** by **inhibitory signals**
- **From** the **deep nuclei**, **output signals leave** the **cerebellum** and **are distributed to other parts of the brain**.
- the **cerebellar cortex** is **made** up of **3 layers**
  - the **outermost**: **molecular layer**
  - **second layer**: **purkinje cell layer**
  - **deepest layer**: **granule cell layer**



Neural circuit of the functional unit

- **functional unit centers** on a **single, very large Purkinje cell** and on a **corresponding deep nuclear cell**.
- The **output from the functional unit** is **from a deep nuclear cell**.
- This **cell** is **continually under both excitatory** and **inhibitory influences**.
  - And as we said these signals that are received are two types either
    - **Direct** from the **afferent** :**stimulatory** all the time
    - From the **cerebellar cortex through Purkinje** cells : **inhibitory** all the time
- The **excitatory influences arise from direct connections** with **afferent fibers** that **enter** the **cerebellum from** the **brain or the periphery**.
- The **inhibitory influence arises entirely** from the **Purkinje cell** in the **cortex of the cerebellum**.
- The **afferent inputs** to the **cerebellum** are **mainly of two types**, **one called the climbing fiber type** and **the other called the mossy fiber type**.
- Basically There are **2 types of fibers come to** the **cerebellum**; (follow along the picture below)
  - 1.**Climbing fibers** come from **inferior olivary nucleus**
    - **Climbing fibers synapse** with **deep cerebellar nucleus** and it's **connection** is **excitatory**
  - 2. **Mossy fibers** are all **other afferents**.
    - **Mossy fibers** also **synapse** with **deep cerebellar** nucleus and it's **connection** is **excitatory** but it **will go and stimulate granular cells**, the **axons of granular cells go** to **molecular layer**, when it **reach the surface**; it **divide horizontally** (on the **right and left**) they **form parallel fibers**.
- **Dendrites** of **purkinje** cells are **stimulated by**:

- 1.**parallel fibers** (which are the **axons of granular** cells)
- 2.**climbing fibers**
  - The **efferent of purkinje** cells go and **synapse** with **deep cerebellar nuclei**, their **signals are inhibitory signals**.



Climbing fibers

- The **climbing fibers** all **originate from** the **inferior olives of the medulla**.
- There is **one climbing fiber for about 5 to 10 Purkinje cells**.
- **After sending branches** to **several deep nuclear cells** (which is **excitatory**) , the **climbing fiber continues** all **the way to the outer layers** of the **cerebellar cortex (** which is the **molecular layer)**, where it **makes about 300 synapses with** the **soma** and **dendrites of each Purkinje cell**.
  - A **single stimuli** from a **climbing fiber** is **enough** to **produce** an **action potential** in the **purkini cell** (so its **strong)**

Complex spike

- This **climbing fiber** is **distinguished** by the **fact that a single impulse** in it **will always cause a single, prolonged** (up to 1 second), **peculiar type of action potential** in **each Purkinje cell** with which it connects, **beginning with a strong spike** and **followed by a trail** of **weakening secondary spikes.**
- This **action potential** is **called** the **complex spike.**
  - This **complex spike** is **followed by** a **weaker spike** for a **prolonged time**

Mossy fibers

- The **mossy fibers** are all the **other fibers** that **enter the cerebellum** from **multiple sources**–the **higher brain, brain stem, and spinal cord**.
- These **fibers also send collaterals** to **excite the deep nuclear cells**.
- They then **proceed to the granule cell layer** of the **cortex**, **where they also synapse** with **hundreds to thousands of granule cells**.
- In **turn**, the **granule cells send extremely small axons**, less than 1 micrometer in diameter, **up** to the **molecular layer** on the **outer surface of the cerebellar cortex**.

- Here the **axons divide into two branches that exten**d 1 to 2 millimeters in **each direction parallel to the folia**.
- It is **into this molecular layer** that the **dendrites of the Purkinje cells project** and 80,000 to 200,000 of the **parallel fibers synapse with each Purkinje cell**.
- The **mossy fiber input** to the **Purkinje cell is quite different** from the **climbing fiber input because** the **synaptic connections** are **weak**, so **large numbers of mossy fibers** must be **stimulated simultaneously** to **excite the Purkinje** cell.
- **Furthermore**, **activation usually takes the** form **of a much weaker**, **short-duration Purkinje cell action potential called** a **simple spike**, **rather** than the **prolonged complex action potential caused** by **climbing fiber input**.
- **One characteristic** of **both Purkinje cells** and **deep nuclear cells** is that **normally both of them fire continuously**;
- the **Purkinje cell fires** at about **50 to 100 action potentials per second**, and **the deep nuclear cells fire at much higher rates**.
- **Furthermore**, the **output activity of both these cells** can be **modulated**.

Deep nuclear cells

- the **climbing** and the **mossy fibers excites them**.
- By **contrast**, **signals arriving from** the **Purkinje cells inhibit them**.
- **Normally**, the **balance between these two effects** is **slightly** in **favor of excitation** so that **under quiet conditions**, **output** from the **deep nuclear cell remains relatively constant** at a **moderate level of continuous stimulation**.
    - Since we have **two ways** in which it causes **excitation** and **one way** that causes **inhibition** so the **net effect** is **excitation**
        - From the **deep nuclear cell - excitation**
        - From the **mossy fibers – excitation**
        - From the **purkinje fibers - inhibition**
- In **execution** of a **rapid motor movement**, the **initiating signal from the cerebral motor cortex** or **brain stem** at **first greatly increases deep nuclear cell excitation**.
- Then, **another few milliseconds later**, **feedback inhibitory signals from** the **Purkinje cell circuit arrive**.
- In this way, there is **first a rapid excitatory signal sent by** the **deep nuclear cells into** the **motor output pathway** to **enhance the motor movement**, **followed within another small fraction** of a **second by an inhibitory signal**.

Delay line

- This **inhibitory signal resembles** a "**delay line**" **negative feedback signal** of the type that is **effective in providing damping** (**smoothen the movement**)
- That is, **when the motor system is excited**, a **negative feedback signal occurs after** a **short delay** to **stop the muscle movement from overshooting its mark**. **Otherwise**, **oscillation of the movement would occur**.

Turn on/ turn off signals

- The **typical function** of the **cerebellum** is to **help provide rapid turn-on signals** for the **agonist muscles** and **simultaneous reciprocal turn-off signals for** the **antagonist muscles at the onset of a movement**.
- Then, on **approaching termination** of the **movement**, the **cerebellum is mainly responsible** for **timing** and **executing the turn-off signals** to the **agonists** and the **turn-on signals to the antagonists.**

Cerebellum learns

- The **degree** to **which the cerebellum supports onset** and **offset of muscle contractions**, as **well as timing of contractions**, **must be learned by the cerebellum**.
  - The **cerebellum learns** by **trial and error**
- ? Role of climbing fibers.

Basket and Stellate cells

- **basket cells** and **stellate cells** are **inhibitory cells with short axons**.
- **Both are located in the molecular layer** of the **cerebellar cortex.**
- **These cells send their axons** at **right angles across** the **parallel fibers** and **cause lateral inhibition** of **adjacent Purkinje** cells, **thus sharpening the signal**.