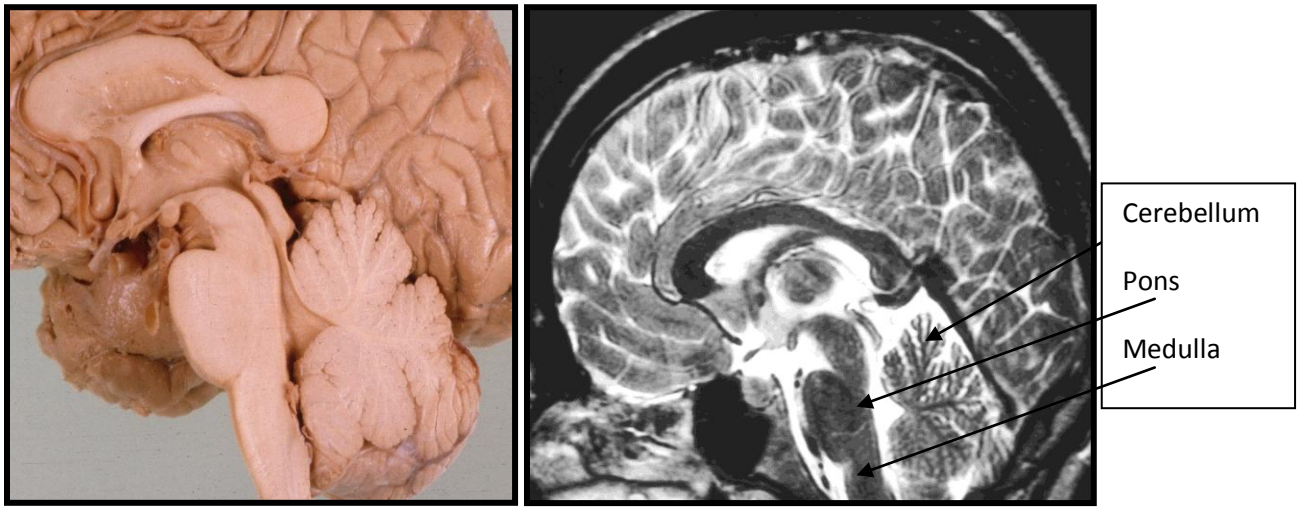
In this lecture we will talk about:

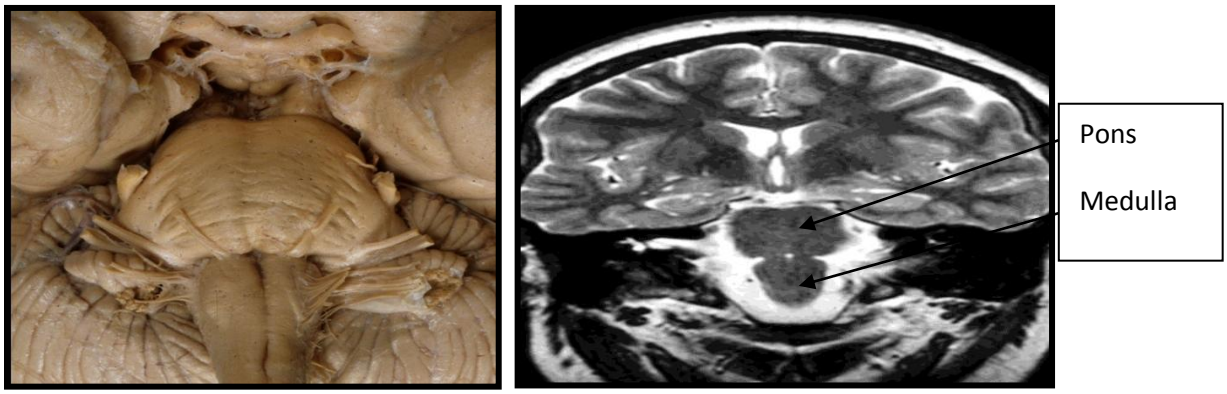
- MRI images of the cerebellum
- The cerebellum function
- Anatomy of the cerebellum
- Connection mass between cerebullum & cerebral cortex
- Cells and fiber of the cerebellum
- Lesions of cerebellum

➢ **MRI images of the cerebellum**:

Cerebellum is one of the motor regulators which is located posterior to the Pons and medulla



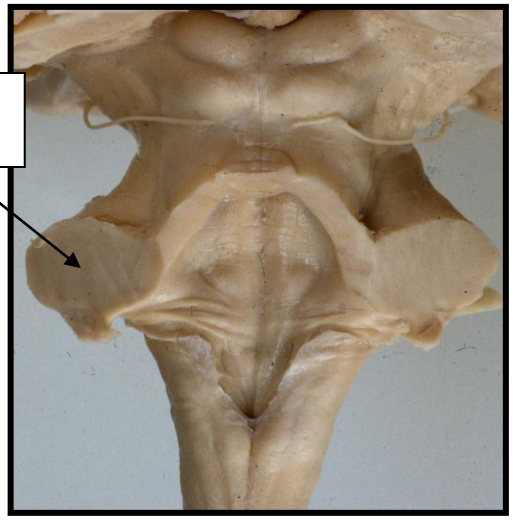
* This MRI shows the location of the cerebellum >>>> posterior to the Pons and medulla

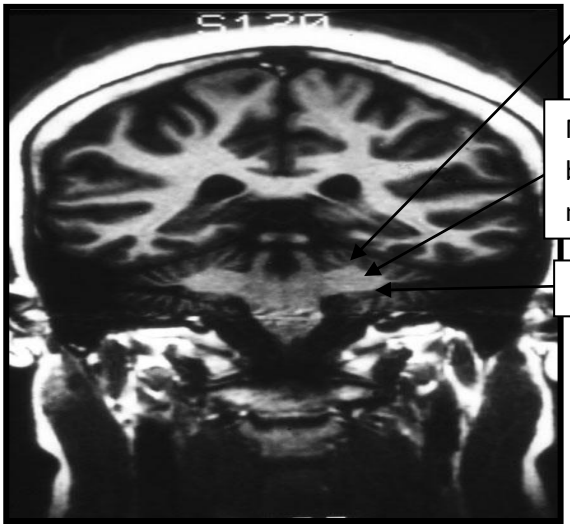


* We can see in this MRI section the Pons and medulla

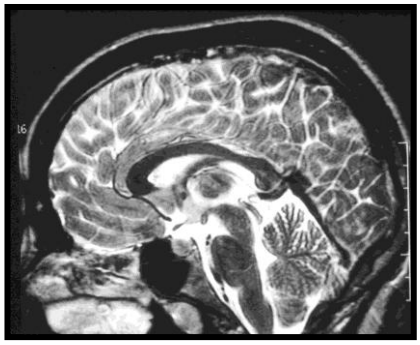
The cerebellum is connected to Cerebral Cortex, Midbrain, Pons, Medulla and Spinal cord via Fibers forming or passing through 3 peduncles (superior, middle and inferior)

*In this MRI we can see these 3 peduncles:



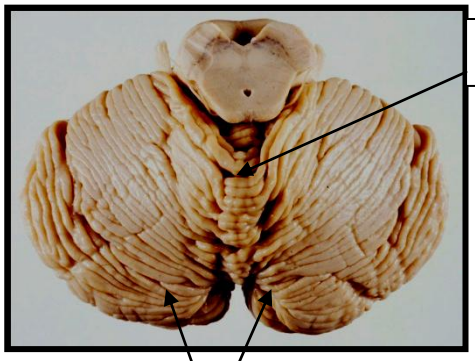


* This MRI shows midsagittal view of the cerebellum



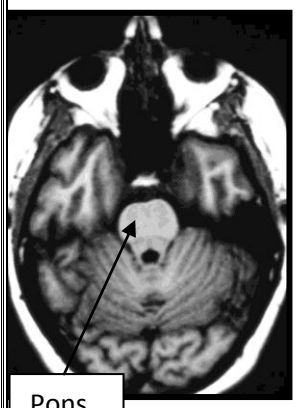
Cerebellum is divided into:

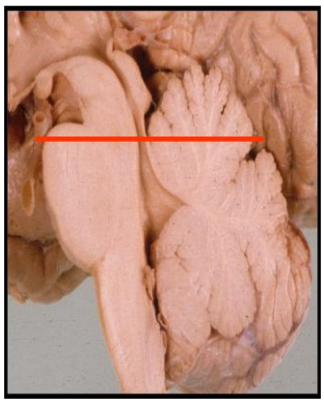
1. 2 hemispheres and vermis
2. Anterior ,posterior and flocculonodular lobe



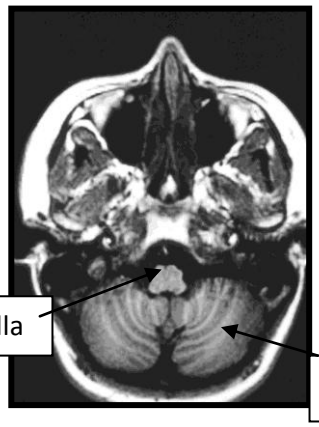
Cortex

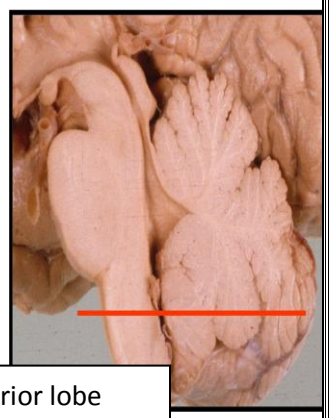
1st IMR image: rostral part





2nd IMR image: caudal part





Posterior lobe

In the 1st MRI image we can see the anterior lobe while in the 2nd MRI image shows the posterior lobe

How we know?!!

The only way to determine where the section in the cerebellum is according to brainstem

Pons >>>> upper part >>> ant lobe

Medulla >> lower part >>> post lobe

- Function of the cerebellum :

The function of the cerebellum is coordination; it works by 2 loops: feedback & feed forward loops

If I want to hold a cup how the cerebellum helps me to do so?

By comparing the input and needed result I want to do, so the cerebellum helps me in achieving the needed result

Let's take this equation

15 + X = 22

What is the value of X? X=7(we know the answer by the help of posterior parietal lobe)

The cerebellum works like this, how?

The input in the → equation is 15

→ Example (holding the cup) is the position of my hand & the position of the cup

The output in the → equation is 22

→ Example is holding the cup

How to reach the output in the → equation by adding 7

→ Example by giving orders to hold the cup (function of the cerebellum)

We have said that the cerebellum works in 2 loops:

1- The feedback loop : mainly enfaced & reflexes(quick circuit)
   When I hold the transmitter in proper way in order to do this movement, I should know the pressure that is need to hold it.
   In this condition I have intention to hold it in this amount and sensation which is the pressure in mechanoreceptor in my skin (here we want to make the intention and the sensation go parallel to each other & this is done very quickly through cerebellum).
   The sensation & proprioception will go to cerebellum >>> cerebellum modulates directly the spinal cord (very little fibers is connected directly to spinal cord so it's neglected for simplicity) and extrapyramidal tract.
2- The feed forward loop : (long-term circuit)
   When someone catches a thrown ball, how he does that?
   Visual sensation >>sees it (gives the primitive information to the association visual area)
   Association visual area >>> calculates its speed & determines its direction
   3 dimensional & calculation >>>> knows where it will be at this time
   Premotor >>>> knows that I should move my hand
   In this case the catcher don't perceive the sensation he's expecting it >>>> that's why we call it feed forward
   We can see that the cerebellum can work in 2 way:
   By modulating movement directly as in reflexes, in this case the modulations go directly to spinal cord and extrapyramidal tract mainly the vestibular pathway **OR** by modulating it indirectly as in feedforward loop here the modulations go to premotor cortex and motor cortex.

For cerebellum to do that usually it involves 3ways:

- ✓ ***By acting as a comparator*** : compare what I want to do and the result wither in direct or in feed forward
- ✓ ***By storing information***: after comparing we should store the correct order so the cerebellum must be able to memorize and store
- ✓ ***By acting as a timing device :*** timing and sequence

Ex : If I ask a child to hold an egg for the 1st time, he either drop it or break it; that's because he doesn't give the needed order to hold the egg, he may hold it shallower so he drop it or hold it more powerful so he break it that's because his cerebellum doesn't have information for this process . Time after time the child starts to correct the order until reaching the needed order to hold it properly, once this happens the order will be stored forever and this is how we learn complex movements.

(Note: 1- Correction usually happens during the development not during the first time we do the movement, that's why the movement of the children is shaky & difficult)

2- The cerebellum is associated with complex motor skills, spot skills and functional skills**)**

The cerebellum receives input from the:

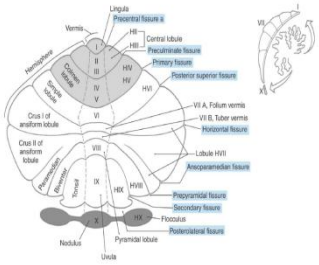
- Sensory cortex (somato, visual as in ex. of the feed forward loop)
- Association cortex
- Vestibular system
- Spinocerebellar tracts(receiving from the body directly)

So we can see that the cerebellum receive input from all the brain

The cerebellum output able to directly control:

- Motor cortex
- Thalamus motor nuclei
- Extra-pyramidal tracts
- Association cortex
- Spinal cord

➢ Anatomy of the cerebellum:



From ant –post view: 1- anterior lobe – lobules from 1to 5

2- Posterior lobe- lobules from 6to 9

3-nodular lobe – lobule 10

From medial – lateral: 1- vermis 2- paramedian 3- lateral hemisphere

Internally main output is the nuclei:

These nuclei are the Fastigial nucleus, inerpositus nucleus and dentate nucleus that are mainly taken from vermis, paramedian and lateral hemisphere of cerebellum respectively.

We have said that the connections go to all brain (all cortexes) and also to subcortical especially to brainstem (which is non-voluntary including non-voluntary motor>>> extrapyramidal, non- voluntary of balance >>> vestibular (also it is extrapyramidal), visceral control (vital signs &respiration which is also non-voluntary).

➢ Connection mass between cerebullar cortex & cerebral cortex

From medial to lateral:

*Vermis>>>>>makes connection with the non- neocrotex part of the cerebral cortex (the vermis is associated with visceral & limbic system)

*Paramedian >>> makes direct connection mainly with body directly, subcortical and brain stem

***Lateral** cortex in the cerebellum >>> connect mainly with neocrotex (associated with association cortex mainly the prefrontal cortex)

From ant to post:

*Anterior lobe >>> connect mainly to motor (connected with premotor area, brainstem and spinal cord) & also connected with sensory

*Posterior lobe >> connect mainly to non- motor (prefrontal & posterior parietal)

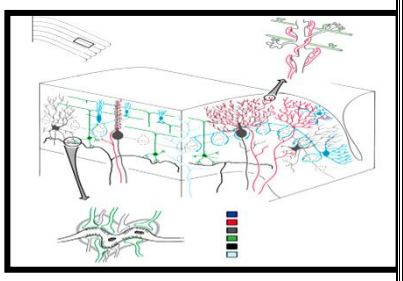
*flocculoNodular lobe >>> connect mainly with vestibular (connection with vestibular ganglia, vestibular nuclei and vestibulospinal pathway)

Type of interconnection btw cortex and cerebellum:

So we can see that there is interconnection between the cortex & cerebellum, these interconnection may be either

- Direct
- Indirect(mainly)
  From cortex>>> Pontine nuclei >>> cerebellar cortex >>> cerebellar nuclei>>> Red nucleus >>>thalamus then back to cortex
  Most of the pontine nuclei will be involved in connection with cerebellum (frontopontine: from frontal cortex to pontine nuclei to cerebellum also occipital pontine, temporal pontine and parietal pontine) and the main nuclei that have connection with the cerebellum are the olivary complex (include more than one sub nuclei: superior olivary, inferior olivary and principle olivary)

➢ Cells and fiber of the cerebellar cortex:



Main neurons in the cerebellum is purkinje cells (Purkinje cell is a GABA neuron that has many dendrites similar to medium spine neuron in the striatum of the basal ganglia)

Circuit in the cerebellum

There is excitatory input to nucleus also at different level this excitatory input will activate Purkinje cell which is inhibitory to nucleus >>> the end result is balance between excitation and the inhibition to nucleus which gives the main output

As in the basal ganglia, the cerebellum needs modulator in addition to its circuit to work (these modulators are the main modulators (neurotransmitters) that affect the cortex: serotonin from the raphe nucleus, norepinephrine from locus coeruleus and dopamine from ventral tegmental area and the opioids)

➢ Lesions in cerebellum

Motor deficits to cerebellum result in:

Motor symptom of cerebellum:

- Ataxia(means disturbances of equilibrium of the body and coordination of movements**,** It's either due to no good sensation is received or due to no good cerebellar calculation)
- Intention tremor
- Dysmetria (disturbed ability to gauge distances either loss of calculation in motor or vision)
- Attactic gait – patient loses balance (patient walk with abnormally wide distance between his legs)
- Nystagmus
- Dysdiadochokinesia (Awkward performance of rapid alternating movements)
- Dysarthria (non-fluance speak in the cerebellar lesion; still debatable if it is due to loss of motor connection to muscle speak or due to loss of non-motor connection to language area "burca")

Non motor symptom of cerebellum:

We have seen that the cerebellum is also connected to non-motor part:

VISCEROMOTOR FUNCTIONS

Lesion in the cerebellum will cause loss in VISCEROMOTOR FUNCTIONS (that is due to lesion in the posterior vermis or it nucleus "the Fastigial nucleus") that will lead to:

- Dilated pupils
- Flushed face
- Decreases in heart rate and blood pressure.

Limbic system

We have said that the cerebellum is highly connected with limbic system (limbic system means emotion and motivation); so lesion in the cerebellum will be associated with:

- pervasive disorder like autism
- Emotional & behavioral problems.

- **Dysarthria :**

As we have said that Dysarthria due to cerebellar lesion may be due to loss of motor function or due to loss of non-motor function

- **Association area and prefrontal cortex:** (lesion in 7th & 8th cerebellar lobules)

Association area:

If the cerebellar lesion affects the medial or lateral part of the 7th & 8th lobule this will lead to problem in cognition, visual and cause mutism (inability to speak under certain condition(such as stress), here the patient speaks normally, the strength and coordination of his speech muscle are normal too but when he is under stress or emotional status he can't speak)

Prefrontal cortex:

Also lesion in the 7th & 8th cerebellum lobule will cause attention and personality changes because the 7th & 8th lobule have the main connection with prefrontal cortex

Prefrontal cortex is involved in unconscious part of planning, so the unconscious planning is highly connected to cerebellum; in fact classical condition is mainly due to this interaction between prefrontal cortex (unconscious planning)& cerebellum), so classical condition can’t happen without the cerebellum

We have 2 types of memory:

1- Declarative memory that is mainly stored in cortex
2- Nondeclarative memory that is mainly stored in cerebellum >>> so lesion in cerebellum will affect the nondeclarative memory (pine point)

Note: Lesion in the lateral cortex and its nucleus dentate will affect the motor function of the cerebellum that is because of the connection between dentate nucleus and motor cortex

Lesion in cerebellar cortex and cerebellar nucleus VS lesion in cerebellar cortex only:

Lesion in cerebellar cortex and cerebullar nuclei >>> in this case the motor function will be lost forever **while** lesion in the cerebellar cortex only >>> in this case the loss of motor function is transient it will be return back after 2-3 month through adaptation, however the non motor function usually will not return back to normal .

Sorry for any mistake and good luck ^^

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