

PHYSIOLOGY OF CEREBELLUM

1

Objectives:

- ❖ Understand cell types / nuclei of the cerebellum
- ❖ Describe the divisions and **functional divisions** of the cerebellum; vestibulocerebellum, spinocerebellum and cerebrocerebellum.
- ❖ Define the **physiological roles of the cerebellum** in regulation of movement, tone and balance.
- ❖ Explain the **abnormalities associated with cerebellar disease**: Cerebellar nystagmus, changes in muscle tone, ataxia, drunken gait, scanning speech, dysmetria (past-pointing), intention tremors, rebound phenomenon and adiadochokinesia.

(Girls Slides Version)

We advise you to study the anatomy lecture first. After studying this lecture it is better to reread it to connect the dots and understand the full picture.

Done by:

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★ References:

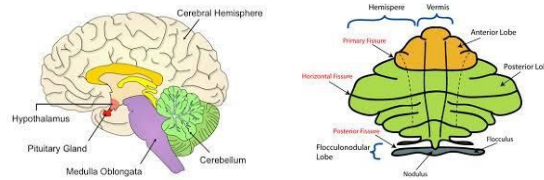
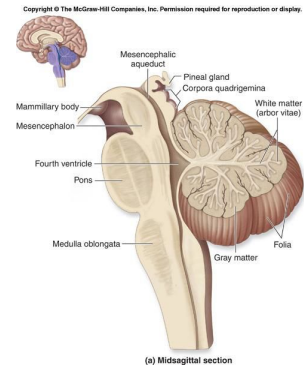
- 435 girls slides and notes.

Color index: Important - Further explanation - Doctors Notes - Numbers.

*Please check out [this link](#) before viewing the file to know if there are any additions or changes.

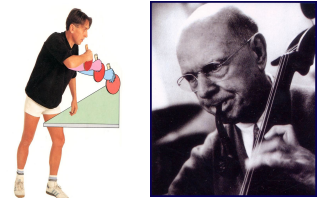
Cerebellum “General Info”

- Occupies a prominent position beside the main sensory and motor systems in the brain stem.
- It is connected to the brain stem by three cerebellar¹ **peduncles**: superior, middle and inferior.
- Various fibers enter and leave the cerebellum through these peduncles.



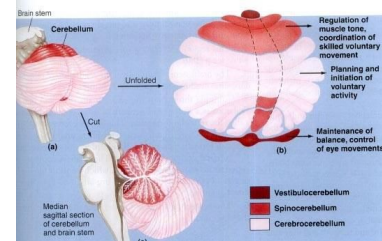
❖ Cognitive Functions of cerebellum

- **Maintenance of equilibrium** (balance, posture, eye movement.)
- **Coordination of half-automatic movement of walking and posture maintenance.** “تنظيم الحركات الإرادية الأوتوماتيكية التي نسويها بدون تركيز مثل حركة اليدين أثناء المشي”
- **Adjustment of muscle tone.** “Stretch reflex”
- **Motor Learning – Motor Skills.** “التطور الحركي يعني أن المخ يخزن الحركات الدقيقة ويعدلها حتى تصبح مهارة مثل عازف البيانو أو رياضة معينة”



Anatomical and Functional Divisions of the Cerebellum

- Anatomically: The **anterior & posterior lobes** on each side constitute **2 large cerebellar hemispheres**, which are separated by a narrow band called the **vermis**. “The cerebellum has 2 hemispheres separated by the vermis. Each hemisphere has an anterior and posterior lobes.”
- **Note that:** Archicerebellum=Vestibulocerebellum (in flocculonodular lobe) .. Neocerebellum=cerebrocerebellum. Paleocerebellum= Spinocerebellum.



❖ Functional Divisions of the Cerebellum (See the Pictures)

- **Vestibulocerebellum** → Balance and eye movements.
- **Cerebrocerebellum** → Motor planning.
- **Spinocerebellum** → Motor execution.

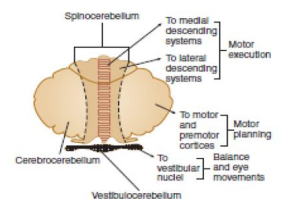
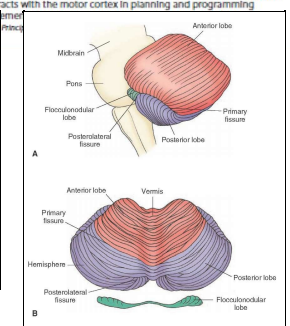
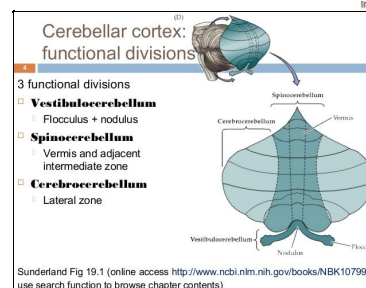
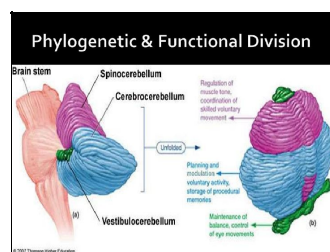
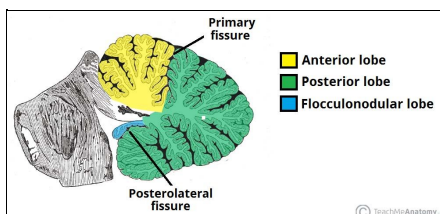


FIGURE 12-19 Three functional divisions of the cerebellum. The nodulus in the vermis and the flanking flocculus in the hemisphere on each side form the vestibulocerebellum which has vestibular connections and is concerned with equilibrium and eye movements. The rest of the vermis and the adjacent medial portions of the hemispheres form the spinocerebellum, the region that receives proprioceptive input from the body as well as a copy of the “motor plan” from the motor cortex. The lateral portions of the cerebellar hemispheres are called the cerebrocerebellum which interacts with the motor cortex in planning and programming.

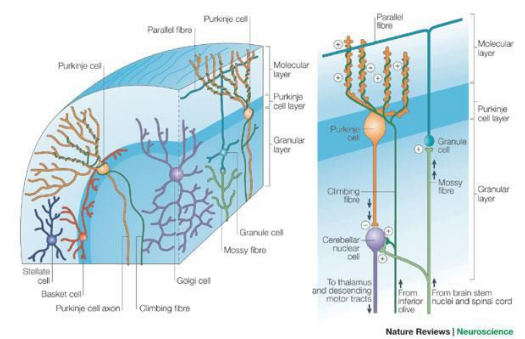
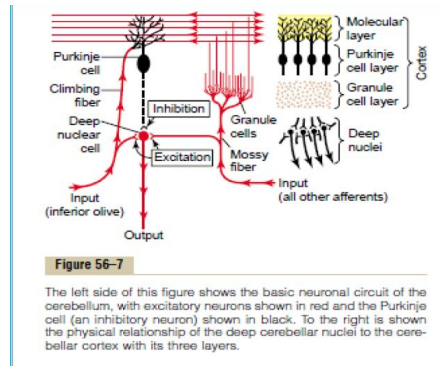
Extra pictures (important to understand)



¹ From the word “cerebellum”

Structures and Connections of the Cerebellum

1. Purkinje cell
2. Granule cell
3. Basket cell
4. Golgi cell
5. Stellate cell
6. Climbing fiber
7. Mossy fiber
8. Parallel fiber
9. Inferior olivary
10. Deep cerebellar Nuclei



- The CB has an **external layer of gray matter (cerebellar cortex)**, and an inner white matter. “مثل جوز الهند، من برا غامق ومن داخل أبيض”
- The **cortex** (gray matter) is deeply infolded, giving a large surface area , and it **contains five 5 different cell types:**

Golgi	Inhibitory interneurons (جيس يثبت الجدران GBS)	Release GABA
Basket		
Stellate		
Purkinje	Output cells, inhibit the deep nuclear cells (DNCs).	
Granule (has GABA A receptors)	Excitatory (Has NMDA glutamate receptor also)	Release glutamate

The White Matter in the Cerebellum

- The white matter contains **3 deep nuclei:**
 1. **Dentate** “in the **cerebrocerebellum**”
 2. **Fastigial**
 3. **Interpositus (formed of globose and emboliform nuclei)** “in the **spinocerebellum**”
- All **afferent** fibers relay first at the deep nuclei and the cerebellar cortex, then the latter discharges to the deep nuclei, from which the **efferent** fibers originate and leave the CB. “In less sophisticated words, afferent fibers go to the deep nuclei then to the cortex. Then efferent fibers are discharged from the cerebellar cortex to the deep nuclei”
لما تطلع الديدب نيوكلايبي ديستشارج كثير تقوم القشرة المخيخية بتثبيطها “وقفي تراك زودتيها”

Afferent (input) Pathways

- The CB receives both **sensory and motor** information through a rich **afferent** nerve supply. This arises from other areas of the brain and the peripheral receptors. Eventually the afferent nerve supply enters the CB via the **3 cerebellar peduncles**. “see the picture and notice the tracts we studied in previous lectures and notice the peduncle they enter from”

❖ Afferent fibers types

- Those afferent fibers coming from the 3 peduncles are categorized depending on their types and where they are coming from:

1. The climbing fibers:

- From the **inferior olivary nucleus**. نوع مستقل بذاته جاي من هنا بس
- It learns the cerebellum to **perform new patterns** of movements **precisely**. مثل ما قلنا أحد
”وظائف المخيخ هو التطور الحركي للحركات الدقيقة، هذه الألياف مسؤولة عن هذه الوظيفة“

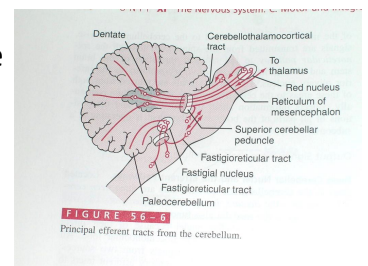
2. The mossy fibers:

- **From all other afferent fibers** that enter the cerebellum + some fibers coming from the inferior olivary nucleus (so they are greater “in numbers” than the climbing fibers).
- Help the **precise execution** of the voluntary movements (concerning their initiation, duration and termination), which occurs by **controlling the turn on and turn off** output signals from the cerebellum to the muscles. تتحكم بمدى الحركة ومتى تنتهي

- كل موسي فايبرز لما يدخلو المخيخ قاصدين يتجهون للبركينجي لكن في طريقهم لازم يبعثو ابلسس الى **deep cerebellar nuclei** يفهموها ان احنا جاين من الحته الفلانيه قاصدين ال **cerebellar cortex**.
- ايش تعني: **controlling the turn on**: اول ما يبدأ يشتغل ال **cerebellar cortex** يبعث ابلسس الى **deep cerebellar nuclei** عشان تشجعه تقوله ممتاز استمر.
- **controlling turn off**: الي هو لما ابي اوقف الحركة يجي البركينجي يبعث اشرا تثبيطية الى الديب نيوكلياي يقولها وقفي تشجيع وتحفيز ال **cerebellar cortex** مش عايزين نتحرك

Efferent (output) Pathway

- There are **3 main efferent pathways** from the 3 parts of the CB which are the **axons of the 3 deep nuclei**.
- They leave the cerebellum through the **superior and inferior** peduncles.



- لا تنسى حنا قلنا أن afferent fibers عندهم 3 مسارات ويطلعون من all the 3 peduncles. لكن هنا الوضع مختلف.
- هنا ال efferent fibers داخل المخيخ لها 3 مسارات يمشون عبر ال three deep nuclei of the white matter لكن بالنهاية يطلعون من المخيخ عبر مخرجين the superior and inferior peduncles.
- فكر في المسارات Pathways وكأنها جميع الأروقة في المدرسة، و ال Peduncles هي البوابات اللي الأروقة توصل لها.

Functions of the Cerebellum

- The CB is called the **silent area** because its stimulation does **not** give rise to any sensation and cause almost **no motor movements**.
- المخيخ ما هو “مصدر” لأي حركة بذاتها هو مجرد منظم، أيضاً مو مصدر إحساس يعني لو يكون مخيخ الشخص مكشوف ووخزته بآبرة مراح “يחס”
- It is important in the **precise execution of rapid** muscular movements.

- Damage to the CB causes almost total incoordination of muscular movements although the muscles are not paralyzed. “لأن المخيخ هو مصدر الحركات، يعني حركة العضلات موجودة لكن مو منظمة”
- The cerebellum is concerned **only** with **subconscious** control of motor activity, and its function as well as the involved part include the following: (Mentioned in the first page in general)

1. Control of equilibrium & postural movements:

- **The function of:** the **vestibulocerebellum**.
- **How?** It receives information from the **vestibular apparatus** → **fastigial nucleus** → the **brainstem**, and through the **vestibulospinal** and **reticulospinal** tracts. (See physiology: motor tracts) + (Anatomy lecture CN VIII)
- It controls equilibrium & postural movements by affecting the activity of the **axial muscles** (trunk & girdle muscles).



★ **One example** that causes a lesion in the vestibulocerebellum is a tumor called **medulloblastoma**. (Pathology: malignant, blue cells, common in children)

- This tumor leads to **trunk ataxia** that is characterized by **equilibrium disturbances**.
- The patient sways on standing, cannot maintain the erect posture, needs support, and walks by a staggering or **drunken gait** and has **nystagmus**².

2. Control of the Stretch Reflex

- **Function of:** The **cerebrocerebellum** and **spinocerebellum**.

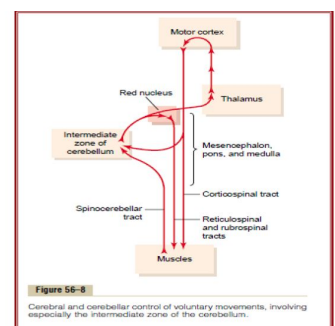
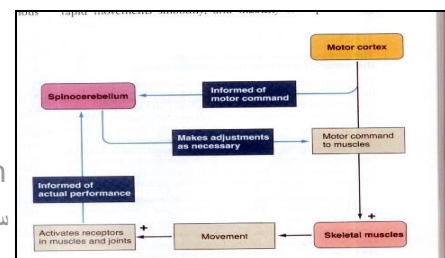
Cerebrocerebellum	Spinocerebellum
exerts a facilitatory effect on the stretch reflex.	exerts an inhibitory effect.
increases the muscle tone.	Decreases the muscle tone.

Normally the **facilitatory** effect **predominates** (so cerebellar diseases often result in **hypotonia**).

- تخيل العضلات عبارة عن كورة وفيها جهازين واحد ينفخ والثاني يسحب الهواء، اللي ينفخ سريع فبالتالي الكورة بتكون منفوخة لكن تخيل الجهاز هذا يخرب! بينسحب الهواء من الكورة وهكذا العضلات.

3. Control of voluntary movements

● قشرة الدماغ cortex ترسل أمر حركي للعضلات، المخيخ وبالتحديد Spinocerebellum ياخذ نسخة من الأمر هذا يشيك عليه، هل هو مناسب؟ يعدل على سرعة الانقباضات مثلاً وما شابه. طيب كانت الأوامر الحركية بحد ذاتها كويسة يجي يروح للمستقبلات في العضلات receptors ويفعلها. يعني المخيخ ينظم الحركات الإرادية إما عبر التعديل على الأوامر الحركية من الدماغ أو أنه يفعل المستقبلات في العضلات والمفاصل.



- Each cerebellar hemisphere is connected by efferent and afferent pathways to the **contralateral cerebral cortex** (the cortico-ponto-cerebello-dentato-thalamo-cortical circuit).

² condition of involuntary eye movement, acquired in infancy or later in life, that may result in reduced or limited vision.

- The **cerebellum** exerts its effects on the same side of the body.

Vermis "Medial of the spinocerebellum"	Intermediate zones "spinocerebellum"	Lateral zones "cerebrocerebellum"
controls muscle movements of the axial body , neck, shoulders and hips.	controls muscle contractions in the distal portions of both the upper and lower limbs (especially the hands, fingers, feet and toes).	Help in the planning of sequential movements.

- كل نصف من المخيخ مرتبط مع النصف المعاكس من المخ، يعني لو أحد كان عنده خلل في حركة الجزء الأيمن من جسمه بتفكر أول شي بالنصف الأيمن من المخيخ (بما أنه يتحكم بنفس الجهة) ويتفكر بالنصف الأيسر من المخ (لأنه يتحكم بالجهة المعاكسة)

4. Other functions like co-ordinating involuntary postural movements

- The CB co-ordinates involuntary postural movements initiated by **extra-pyramidal system** by **acting as a comparator "between orders & performance"** (in the same way as involuntary movement) and correcting errors so movements do not overshoot. **involuntary movement associated .eg: swinging arms while walking. This is what we meant in the beginning: Coordination of half-automatic movement of walking and posture maintenance.**

Defects Produced by Cerebellar Lesions in Humans "The Neocerebellar Syndrome"

- **Due to:** Damage of the **deep cerebellar nuclei** as well as the **cerebellar cortex**.
- **Manifestations:** occur on the **same side** of the lesion (**ipsilateral**).
 - i.e a lesion of the left cerebellar hemisphere produces its effects on the left side of the body.
- **When do we have a bilateral dysfunction of the cerebellum?**
- In generalized conditions like **alcoholic intoxication**, **hypothyroidism**, inherited cerebellar degeneration (**ataxia**), **multiple sclerosis** or **non metastatic disease**.

❖ Manifestations of Neocerebellar Syndrome

"HAM"

- Hypotonia: (WHY)? →** Due to loss of the facilitatory effect of the CB on the stretch reflex, and it is associated with **pendular knee jerk**.
- Athenia: (Muscle Weakness): (WHY)? →** due to difficulty in initiation and maintenance of muscle contraction **secondary to** loss of the potentiating signals by the **mossy fiber circuit**.
- Motor ataxia:** Incoordination of the voluntary movements, Especially the rapid movements (Becoming abnormal in rate, Range, Force and direction).



ADDED BY THE DOCTOR, neocerebellar syndrome (Duration: 2:34)

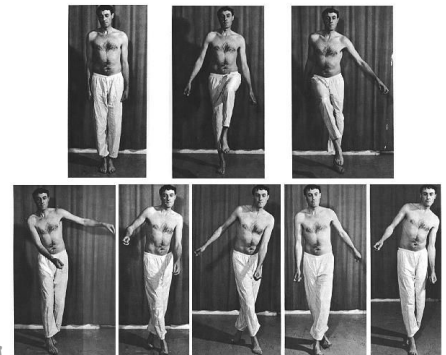
- **ADDED BY THE DOCTOR, Cerebellar disease family**

Ataxia

- **Definition:** incoordination of voluntary movements. It is either sensory or motor(or mixed).

❖ Clinical presentation

- Patient with Cerebellar Ataxia due to a **Left** cerebellar tumor.
- General look: Ataxic gait and position:
 - **Sways to the right** in standing position
 - Steady on the right leg
 - Unsteady on the left leg
 - Ataxic gait



لنذكر: وقف بشكل مستقيم و ارفع رجلك اليسار وتخليها الجهة المصابة بما أن المخيخ يَأثر بنفس الجهة، يتميل للجهة اليمنى بما أنها سليمة وثابتة.

❖ Motor ataxia:

- Is due to defect in the coordination of the **voluntary** movements. It commonly occur in lesions of either:
 - **The cerebellum or spinocerebellar tracts.**
 - **The labyrinth (vestibular apparatus).**
 - **The cortical motor areas.**

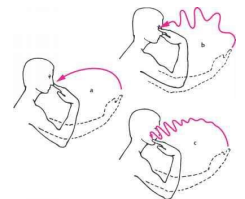
❖ Manifestations of Motor Ataxia

To remember them we created this mnemonic “Funny Deedee Rushed To Annoy aNd Slap Dexter”

1. **Dysmetria:** Inability to control the distance of the motor act, which may either overshoot the intended point (=hypermetria or past pointing) or stop before it. “يعني ما يقدر المسافة كويس أو أنه.” “مايقدر يوقف على النقطة المعينة هذه يا يوقف بعدها أو قبلها”

2. **Kinetic (intention, action or terminal) tremors:**

- This an oscillatory movement that **appears** on performing a voluntary movement (especially **at its end**) but is **absent at rest**. “This is an important point to differentiate Parkinsonism tremors which appear even at rest (resting tremors).”
شخص يرفع ملعقة بإرادته ويكون طبيعي لين نهاية الحركة يجيه رعشة
- **Demonstrated by:** the **finger-to-finger** or **finger-nose test**³.
- **It occurs secondary to dysmetria** and is due to a series of subconscious correction of the overshoot followed by overshoot of the correcting movements.



3. **Rebound phenomenon :**

- This is **overshooting of a limb** when a resistance to its movement is suddenly removed. (**loss of the braking function of the CB**).

³ See the picture in the next page

- **Demonstrated by:** the arm pulling or flexion test.

4. **Asynergia:** This is **loss of the harmony** between the three groups of muscles involved in performance of voluntary movement (the agonists, antagonists, and synergists).

5. **Failure of progression of movements:** manifested by:

- Adidokokinesia (=dysdiadokokinesia)**
Inability to perform alternate (opposite) movements successively at a rapid rate. Eg pronation and supination of the forearm or upward and downward movement the hand.
- Decomposition** (fragmentation of movements): Inability to perform actions involving simultaneous movements at more than one joint.

6. **Dysarthria:** This is **difficulty in producing clear speech**. **Due to:** incoordination of the speech muscles **secondary to loss of the predictive functions of the CB**. The syllables may be too long or too short, loud or weak and speech may be also **staccato or scanning** i.e cut off into separate syllables. المخيف عنده قدره على تنبأ الحركات: يعني بتتوقع الي جاي ايه فينظم قبل ما يحصل الحركه <بيسمح للحركه انها تتم بسرعه

7. **Nystagmus:** This is **tremor of the eyeballs** that occurs on looking to an object placed at one side of the head. (mainly in vestibulocerebellar damage). **Nystagmus is a very common feature of multiple sclerosis.**

8. **Staggering (drunken) gait:** The patient walks unsteady –on a wide base (**zigzag-like gait**) in a drunken (swaying) manner, and tends to **fall on the diseased side**. Such gait is more apparent with **archicerebellar** “vestibulocerebellar” damage.