Cerebellum

By

Dr. Amr Medhat Abbas

Professor of Medical Physiology

Learning outcomes:

- **At the end of the lecture, you will be able to:**

1. Describe the structure of the cerebellum anatomically and functionally.
2. Describe the neural connections of the cerebellum.
3. Explain the functions of the cerebellum.
4. Explain the principal motor disorders caused by neocerebellar syndrome.

Internal structure of cerebellum

❑Anatomically,

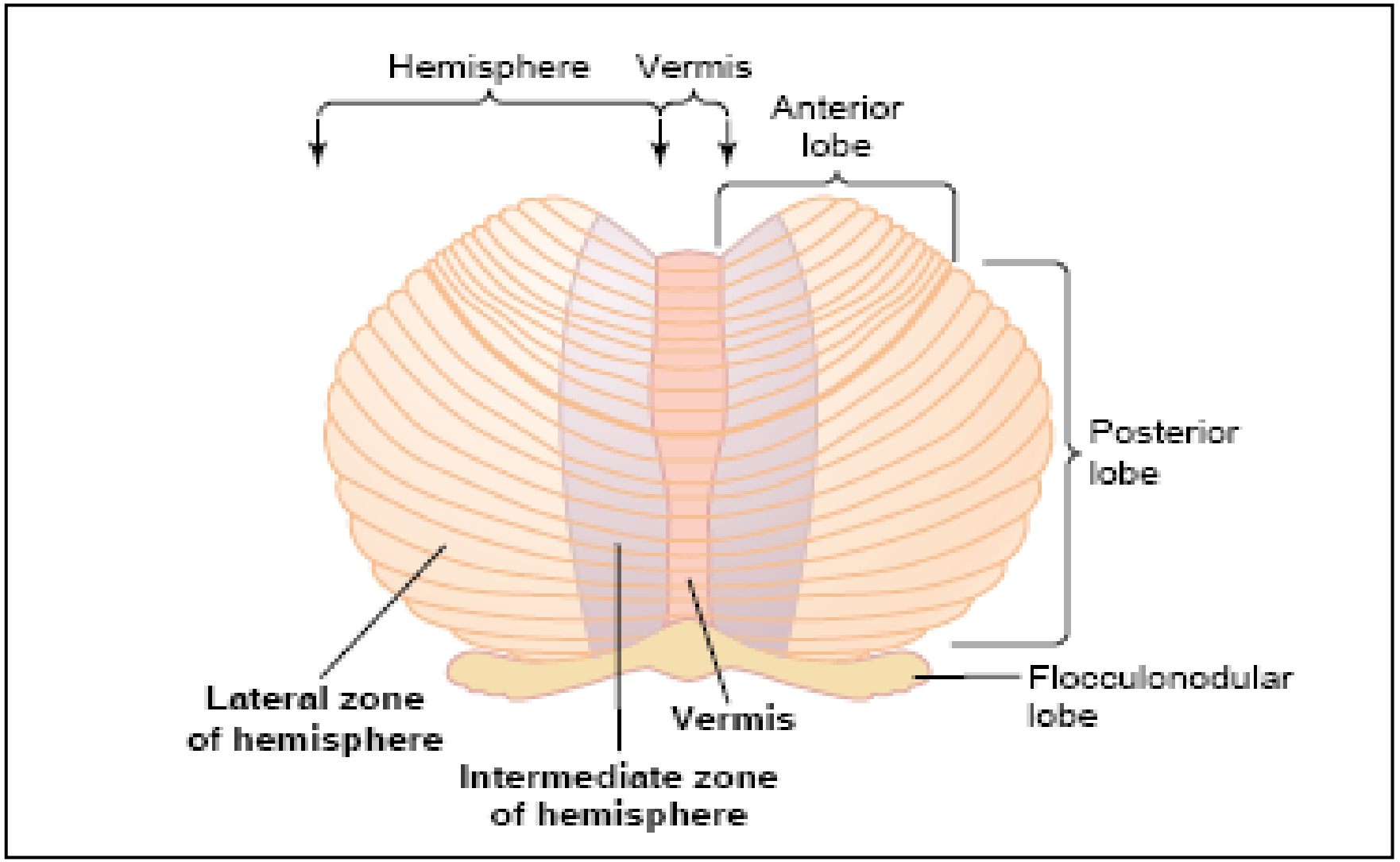
➢The cerebellum is composed of an **outer cortex** surrounding a ***core of white matter*** which consists of ***deep cerebellar nuclei*** **(Dentate nucleus, Globose & emboliform nuclei and fastigial nucleus)**.

- Cerebellum is divided by ***2 fissures*** **(primary and postero-lateral fissures)** into ***3 lobes:***

1.Anterior lobe.

2.Posterior lobe.

3.Flocculo-nodular lobe.


Hemisphere
Vermis
Anterior lobe
Posterior lobe
Flocculonodular lobe
Lateral zone of hemisphere
Intermediate zone of hemisphere
Vermis

❑Functionally,

Cerebellum divided into:

1- Vestibulocerebellum **(flocculonodular lobe**; **archicerebellum**): Composed of the **flocculo-nodular lobe (F.N.L)** which is closely related in its functions to the vestibular system

2- Spinocerebellum **(vermis + intermediate zone;** paleocerebellum): Consists of the **vermis and the intermediate zones** of the cerebellar hemispheres. Most of its sensory information comes from the spinal cord.

3- Cerebrocerebellum **(lateral zone;** neocerebellum): Composed of the **lateral zones** of the cerebellar hemisphere. Almost all of its afferent signals originate from the cerebral cortex and reach it through the pons.

Vestibulo-cerebellum

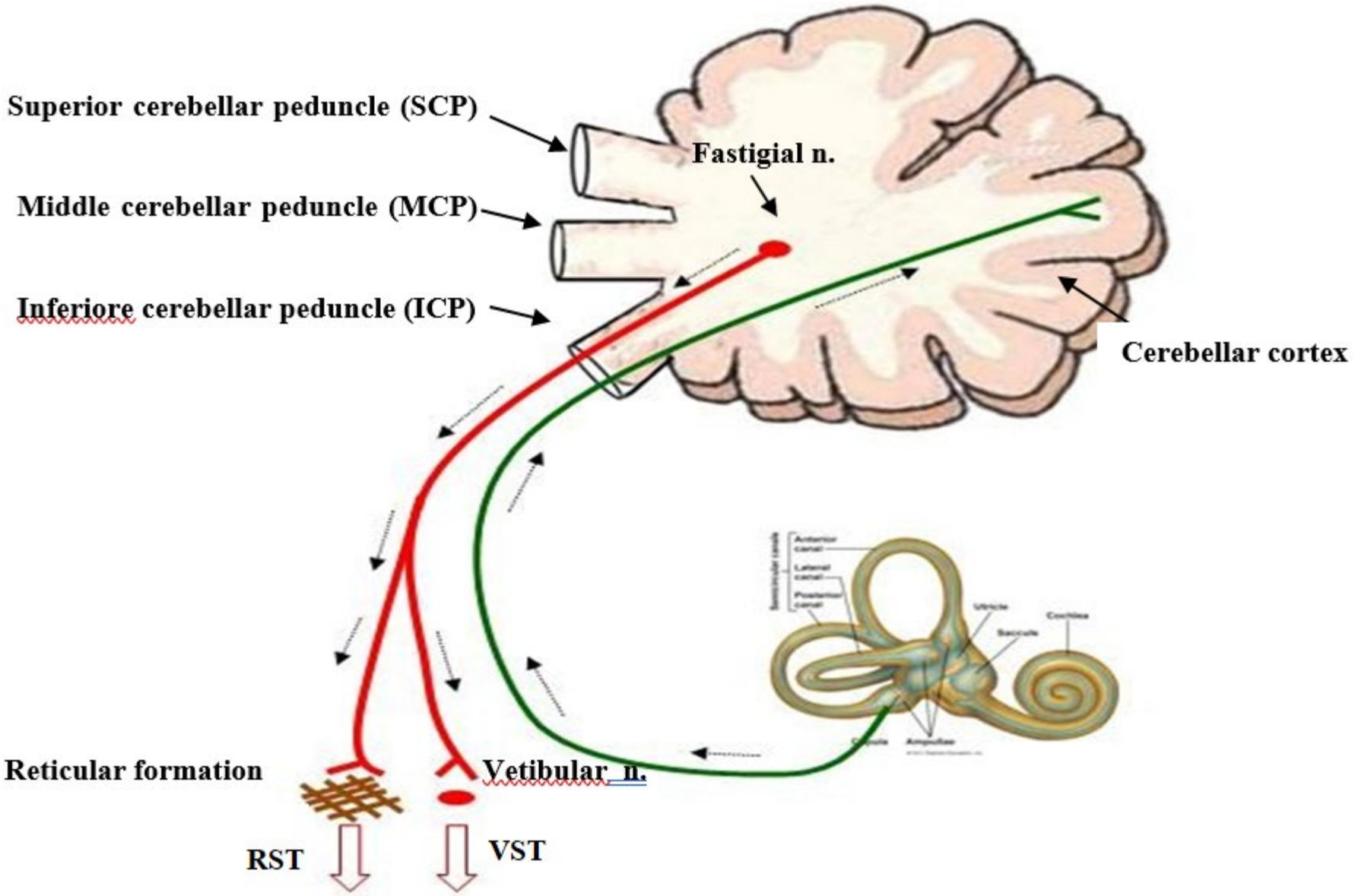
❑ Neural connections:

➢ *Input or afferent:*

Vestibular apparatus → **vestibular nuclei** → inferior cerebellar peduncle → **cortex of F.N.L**.

➢ *Output or efferent:*

Cortex of F.N.L → **Fastigial nucleus**→ inferior cerebellar peduncle → **Vestibular nuclei** → **Vestibulo-spinal** and **reticulospinal tracts** → adjust **tone of postural muscles**.


Superior cerebellar peduncle (SCP)
Middle cerebellar peduncle (MCP)
Inferiore cerebellar peduncle (ICP)
Fastigial n.
Cerebellar cortex
Reticular formation
Vetibular n.
RST
VST

❑ Functions:

1. Control of equilibrium:

- **Disturbed equilibrium or altered head position** → stimulation of vestibular receptors → **Vestibulo-cerebellum**.
- **Vestibulo-cerebellum** **interpretates** these impulses then immediately sends **corrective signals** → **Fastigeal N** → then **through:**

a) ***Vestibulospinal tract*** (VST) & ***reticulospinal tract*** (RST) → motor neurons of **axial muscles & proximal limb muscles** → affect their **muscle tone** → **maintain body posture**.

b) ***Medial longitudinal bundle*** **(M.L.B)** → **III, IV & VI cranial nuclei** → **coordinate eye movement** with head movement → maintain **clear vision** → keep **equilibrium**.

❑Cerebellar lesions:

Flocculo-nodular Lobe disorders:

- These disorders **impair equilibrium.**

- This is **manifested by** swaying during standing and unsteady wide based gait **(waddling gait)**.

Spino-cerebellum

❑ Neural connections:

➢ *Input or afferent:*

a- Brain & brain stem centers:

1-Cerebral cortex.

2- Red nucleus.

3- Reticular formation

Impulses from these centers inform cerebellum about the ***plan of movement ordered by the higher centers.***

b- Proprioceptors: Ventral spinocerebellar tract (VSCT) & lateral spinocerebellar tract (LSCT) carry impulses from proprioceptors regarding the ***actual performance of muscles***.

➢ ***Output or efferent:***

i. From vermis:

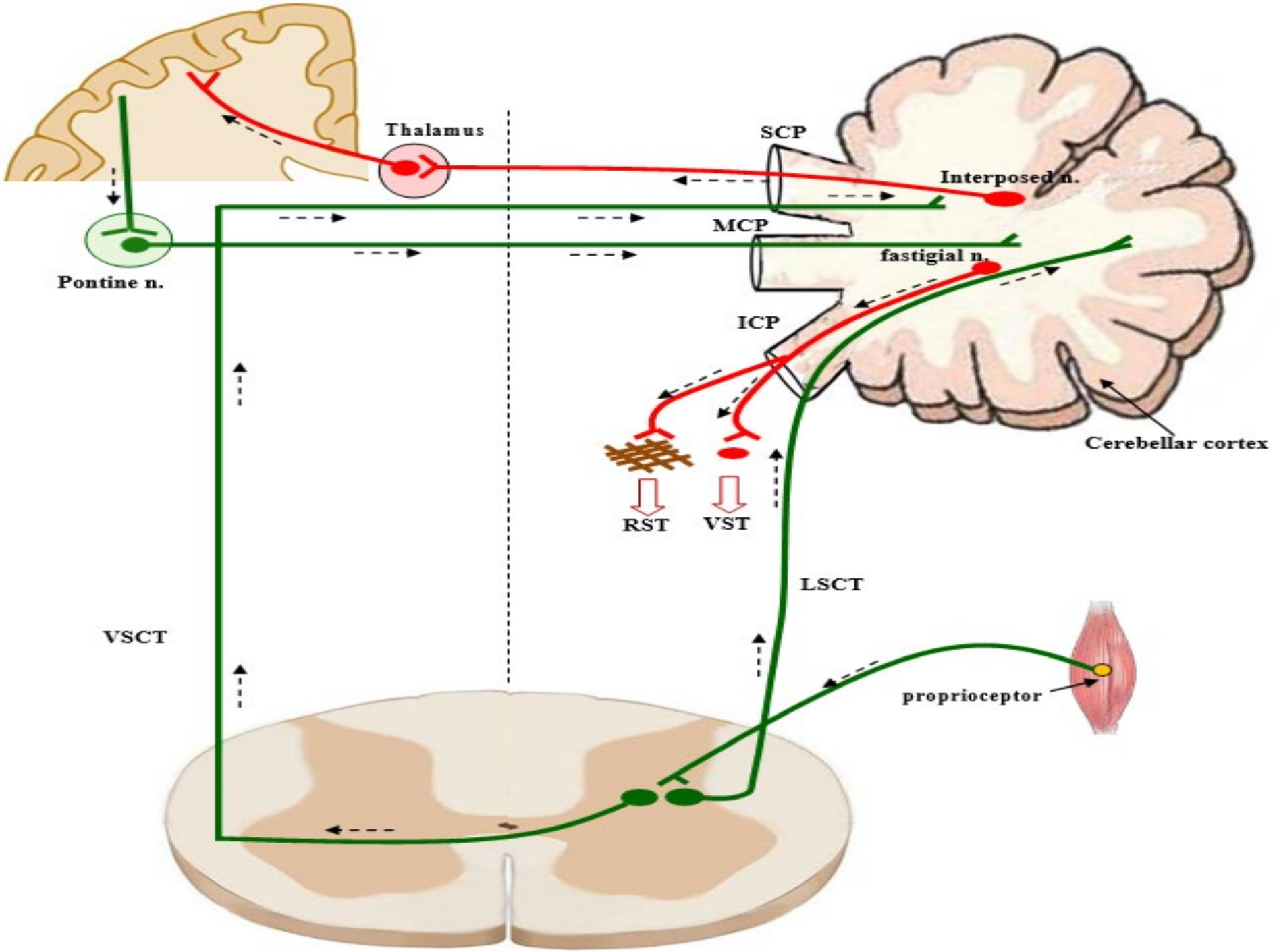
vermis → fastigial nucleus → reticular formation & vestibular nuclei → vestibulo-spinal (VST) & **reticulo-pinal tracts** (RST) → **antigravity muscles**.

ii. From paravermal (intermediate) zone:

- **Intermediate zone → interposed nucleus (globose and emboliform)** → superior cerebellar peduncle →

1) Contralateral thalamus → motor cortex → corticospinal tract → distal limb muscles.

2) Contralateral red nucleus → rubro-spinal tracts → distal limb muscles.


Thalamus
SCP
Interposed n.
MCP
fastigial n.
Pontine n.
ICP
Cerebellar cortex
RST
VST
LSCT
VSCT
proprioceptor

❑ Functions:

I. Vermal zone: *Regulation of body posture:*

- It receives information from ***proprioceptors*** about ***position*** and ***movements*** of every part of the body .
- ***Disturbed body posture*** →stimulation of proprioceptors → vermis.
- ***Vermis*** interpretates these impulses, then immediately sends **corrective impulses** → **fastigial N.** → then through **VST** & **RST** → adjusts the **tone of antigravity muscles** → maintain posture against the effect of gravity.

II. Paravermal (intermediate) zone: *Regulation of voluntary movement:*

1.Servo-comparator function (Fine-tuning)

- ***Spino-cerebellum is informed about:***

  a) The **intended plan of movement** from the **motor cortex** (via **cortico-ponto-cerebellar tract**), and

  b) The **performance of movement** from **muscles** (via **spino-cerebellar tracts**).

- Spino-cerebellum **compares** the **intention** of the motor cortex with the **actual performance** of the muscles.
- **If not appropriate**, the spino-cerebellum sends **corrective signals** to the **motor cortex**, which by its turn through descending **CBS** tract adjusts the **muscle activity**.

2. Predictive & damping function:

- *Damping* ***means*** ending of the movements without oscillation at the proper site
- The cerebellum assesses the **rate of movement**, **calculates the time needed to reach the intended point** & then transmits inhibitory impulses to the motor cortex to **stop the movements at the exact intended point.**

❑Cerebellar lesions:

Vermal disorders:

- These disorders cause **inability to sustain the upright posture**, due to failure to adjust the tone of antigravity muscles.

Cerebro-cerebellum

❑ Neural connections:

➢ *Input or afferent:*

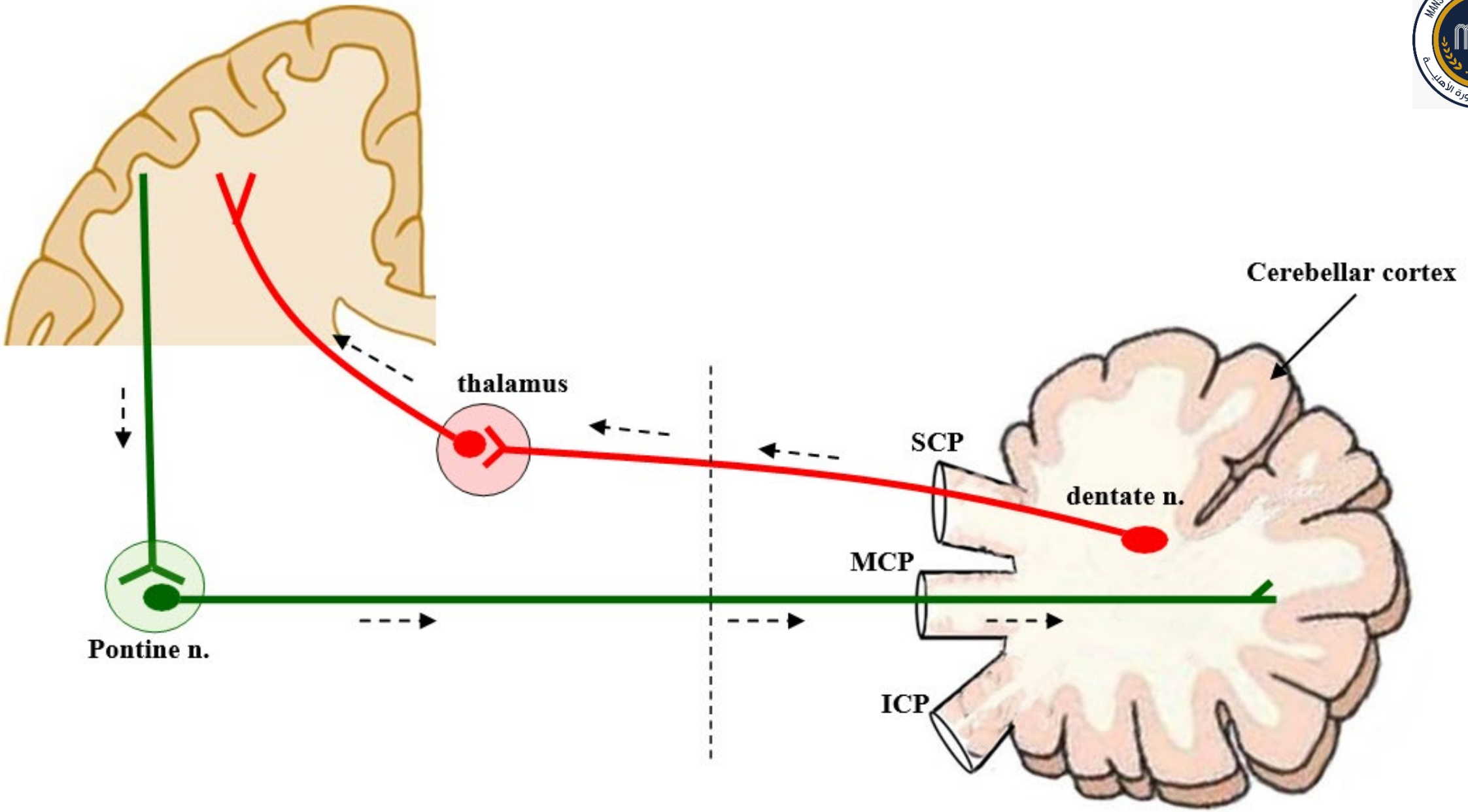
- Cerebral cortex → **pontine nuclei** → **middle cerebellar peduncle** via **cortico-ponto-cerebellar pathway**.
- ***This pathway provides the cerebellum with:***

1)The **plan** of movement.

2)Sensory information regarding **postural state of the body**.

➢ ***Output or efferent:***

- Cerebellar cortex of **lateral zone→ dentate nucleus→ superior cerebellar peduncle→ VL nucleus of contra-lateral thalamus → cortical motor areas**.
- ***This pathway mediates*** the role of the cerebellum in **adjustment of motor commands** before being discharged from cerebral cortex.


Cerebellar cortex
thalamus
SCP
dentate n.
MCP
Pontine n.
ICP

❑ Functions: *Regulation of voluntary movement:*

(I) Predictive (planning and timing) function:

a) Sequence planning:

- The cerebro-cerebellum receives afferent impulses from the **cortical association areas** (the site of ideas for voluntary movements) about the **intension** of performing a certain voluntary movement **before** the movements starts.

- Then, the cerebro-cerebellum sends to the **motor area of cerebral cortex** (that initiate movements) the **plan of the sequential movements** required to execute the intended voluntary movement.
- The cerebro-cerebellum **plans for the next movement** while the present movement is occurring.
- Thus, it is not involved with what is happening at a given moment, but with what will occur in the **subsequent moment**.

b)Timing planning:

- The cerebro-cerebellum provides **proper timing for each movement**.

- Such function is necessary for **smooth transition** from one movement to the next and **joining** of sequential movements.

Neocerebellar syndrome

- **Cause:** cerebellar hemispheric ***(paravermal and lateral zones)*** **lesion**.
- **The principal motor dysfunctions caused by cerebellar hemispheric lesions include:**

I. ***Hypotonia:*** Due to decreased supraspinal facilitation of stretch reflex (muscle tone).

II. ***Asthenia:*** Leading to weakness of movements

III. ***Ataxia (asynergia):*** refers to the **incoordination** of voluntary movements in **absence** of UMNL and LMNL.

Manifestations of ataxia:

1-Rebound phenomenon:

- When the patient flexes his forearm strongly against a resistance, then the resistance is **suddenly removed**, the patient **cannot stop** inward movement of his forearm in proper time, and may thus strike his body.
- This is due to **failure of the "damping" function**.

2-Dysmetria:

- The moving limb usually **overshoots** the intended point **(hypermetria),** due to **failure of "damping" functions**.

3-Intention (Kinetic) Tremors:

- Occur during voluntary movements.
- Due to **hypermetria** of the acting muscles.
- Thus, the limb oscillates throughout the whole movement.

4-Nystagmus:

- Represents the **kinetic tremors** of the **extra-ocular muscles** during **movements of the eye**.

5-Unsteady Gait:

- **Unsteady drunken gait** due to **dysmetria** and **kinetic tremors** of the lower limb muscles.

6-Decomposition of complex movements:

- A voluntary motor act is carried out as **several successive steps**, due to **failure of sequence and timing planning**.
- The patient cannot perform movement that involve **two joints** at the same time **e.g.** touching the knee of one leg with the heel of the opposite foot **(heel-knee test)**.

7-Dysdiadochokinesia:

- The patient is **unable to perform rapid successive opposite movements**, **e.g.** supination & pronation of the hands.
- Movements become **slow** and **irregular**, due to **failure of sequence and timing planning**.

8-Scanning speech (Dysarthria).

- Speech becomes **slow** and **decomposed**.
- Each word is fragmented and pronounced as **several separate syllables**.
- Due to **failure of sequence and timing planning**.

References

1. Costanzo, Linda S. "BRS Physiology (Board Review Series)." (2018).
2. Ganong, William F. "Review of medical physiology." (2020).
3. Hall, John E and Hall, Micheal E. “Guyton and Hall Textbook of medical physiology." (2021).