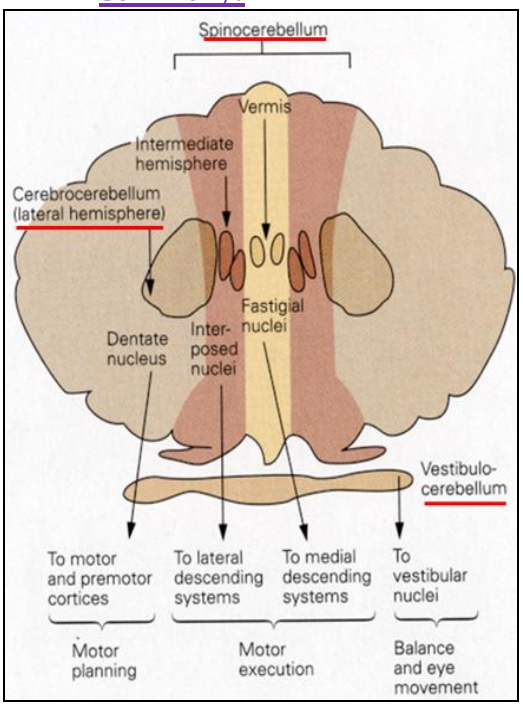
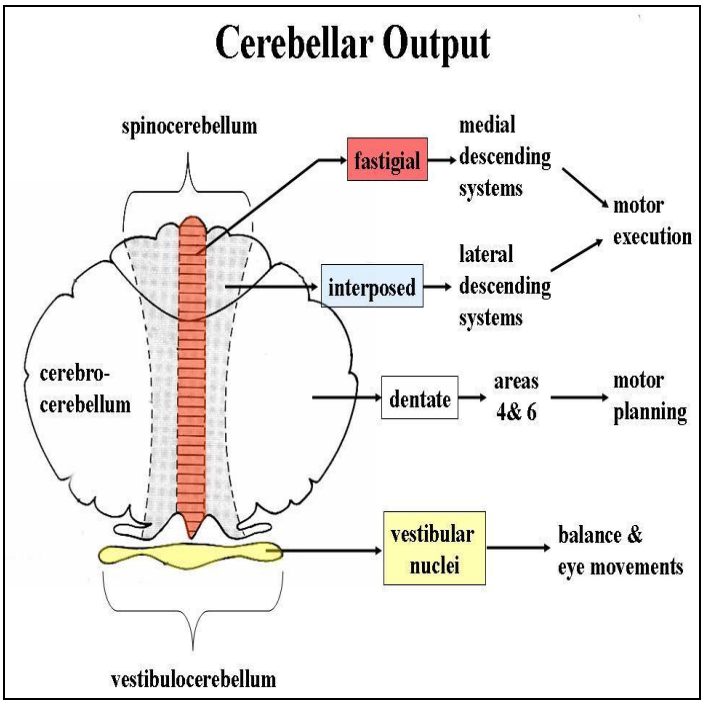
Unit VIII – Problem 5 – Physiology: Cerebellum

- **The word "cerebellum" means: "the small brain"**. Note that the cerebellum is not completely separated into 2 hemispheres (they are not clearly demarcated) → **the vermis is connecting both cerebellar hemispheres.**
- **Cerebellum contains a very huge number of granular cells** (more than all neurons of the central nervous system!) → therefore, you will notice that the grey matter of the cerebellum is bigger than that of the cerebrum.
- **The motor system:**
  - **Remember from the previous lectures that the pyramidal tract from the cortex will descend to terminate either in:**
    - ✓ The lateral part of the ventral horn of the spinal cord: to control fine movements (such as movements of the hands).
    - ✓ Or the medial part of the ventral horn of the spinal cord: to control axial muscles (aiding in maintenance of posture).
- Also from previous lectures, remember that the idea of movement is generated in the pre-frontal cortex and then it will travel to the pre-motor area which has a lot of programs for the same movement → these programs will be sent to basal ganglia so it can chose only one of them and return it back to the pre-motor cortex (area 6) → then to cerebellum → and eventually to primary motor cortex (area 4).
- **Cerebellar components:**
  - **Cerebellar cortex:**
    - ✓ Vestibulocerebellum.
    - ✓ Spinocerebellum.
    - ✓ Cerebrocerebellum.
  - **Deep cerebellar nuclei:**
    - ✓ Fastigial nucleus.
    - ✓ Interposed nucleus.
    - ✓ Dentate nucleus.
  - **Cerebellar peduncles:**
    - ✓ Superior peduncle: connecting it with the midbrain. This peduncle contains efferent pathways mostly to the motor & pre-motor cortices and superior colliculus.
    - ✓ Middle peduncle: connecting it with the pons. This peduncle contains afferent fibers from contralateral pons (cortico-ponto-cerebellar fibers).
    - ✓ Inferior peduncle: connecting it with the medulla. This peduncle contains multiple afferents (from vestibular nuclei, spinal cord and brainstem) and efferents (to vestibular nuclei and reticular formation)
- **Vestibulo-cerebellum = Archicerbellum = fluculo-nodular lobe:**
  - **Input**: from vestibular nuclei.
  - **Output**: to vestibular nuclei which will send fibers up and down:
    - ✓ Ascending fibers: known as the medial longitudinal fasciculus which functions in internal connection between the nuclei of 3rd, 4th and 6th cranial nerves in the brainstem.
    - ✓ Descending fibers: known as vestibulospinal tract which functions in stimulation of anti-gravity muscles (extensors).
  - **Functions:**
    - ✓ Balance.
    - ✓ Tone of extensor muscles.
    - ✓ Movement of eyes with movement of head.
  - **Note**: vestibulocerebellum is the only part of the cerebellum which is not connected to deep cerebellar nuclei and projecting instead to vestibular nuclei.

- **Spino-cerebellum:**
  - **Inputs**: fibers are coming from:
    - ✓ Dorsal spino-cerebellar tract: proprioception from lower limbs. It is passing to the cerebellum through inferior cerebellar peduncle.
    - ✓ Ventral spinocerebellar tract: proprioception from lower limbs. It is passing to the cerebellum through superior cerebellar peduncle.
    - ✓ Cuneocerebellar tract: proprioception from upper limbs.
  - **Output**:
    - ✓ To the spinal cord (rubrospinal tract which enhances contraction of flexor muscles is included)
  - **Function:**
    - ✓ Coordination of body movements through 2 systems:
      - ❖ *One which is regulating the medial side of the body and represented by the vermis from which fibers will project to fastigial nucleus.*
      - ❖ *Another which is regulating the lateral system of the spinal cord (controlling the limbs especially for fine movements) and represented by the paravermal area from which fibers will project to interposed nucleus.*
- **Cerebro-cerebellum:**
  - **Input**: cortico-pontine fibers reaching the cerebellar cortex through the middle cerebellar peduncle.
  - **Output**: from cerebellar cortex to dentate nuclei to red nuclei and eventually to thalami (dento-rubro-thalamic pathway) to reach pre-motor area (area 6) and motor cortex (area 4).
  - **Function**:
    - ✓ Coordination of movement and planning.
- **Summary:**

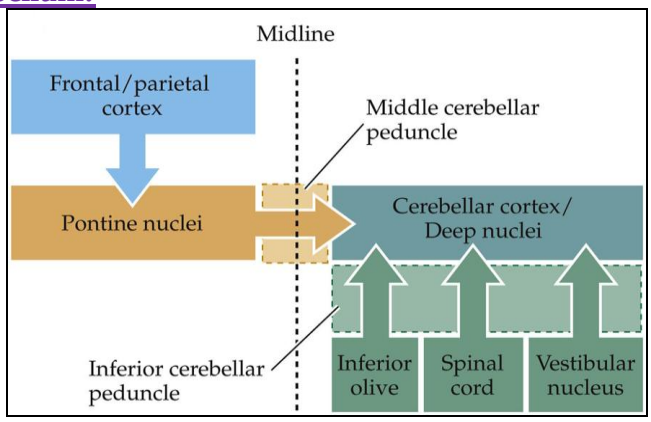




- **Note that the cerebellum is controlling the same side of the body** → therefore, lesions in the cerebellum will lead to ipsilateral manifestations.
- **Alcohol is affecting the anterosuperior part of spinocerebllum → resulting in incoordination of movement in the legs.**
- Huge bundle of fibers from the cortex will go to pons and they transmit copy of the intended movement to the cerebellum (cortico-ponto-cerebellar pathway). Note that the connection between the cortex and the cerebellum is not at the same side (which means

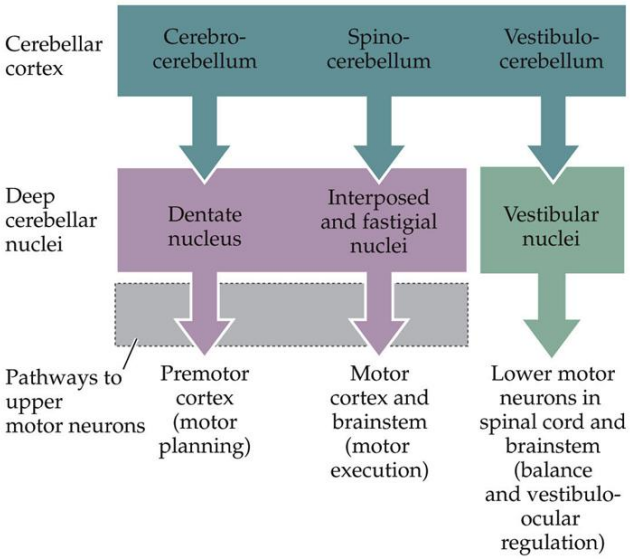
that those fibers from the cortex will cross in pons to terminate in the other side in the cerebellum but fibers will re-cross eventually so the cerebellum will be controlling the same side of the body as it was mentioned previously). The cerebellum is also receiving inputs from the spinal cord, vestibular nuclei and inferior olive which enable it to know what is happening during the movement (what is intended is compared with what has happened).

- **Inputs to the cerebellum:**



- **Cerebrocerebellum**: from primary motor cortex, pre-motor cortex and sensory cortex to the cerebellum through pontine nuclei.
- **Vestibular nuclei** to vestibulocerebellum.
- **Spinal cord**: unconscious proprioception to spinocerebellum.
- **Olivocerebellar fibers** = climbing fibers (for error correction).
- **Visual and auditory signals** after relay in thalamus go to the vermis.

- **Outputs from the cerebellum:**



- **Ascending output** → is from dentate and interposed nuclei (why?) → because they are concerned with functions of primary motor and pre-motor areas.
- **Descending output** → is from fastigial and vestibular nuclei → going to the spinal cord → and concerned mainly with balance.
- **The corticospinal tract is reaching the cells in the ventral horn of the spinal cord and at the same time will stimulate the spinocerebellar pathway (Why?)** → so the cerebellum knows that the intended movement is going to start (although proprioception is mainly transmitted through this pathway).
- **Cerebellar units (30 million units):** they initiate & terminate movements, discovering mistakes and involved in learning complex movements.
  - **Mossy fibers (they are responsible for execution of movement):**
    - ✓ They are coming from cerebral cortex through pontine nuclei.

- ✓ They will give a branch to stimulate deep cerebellar nuclei "on-signal for initiation of movement".
- ✓ They are terminating in granular cells and from these cells axons will ascend to molecular layer, bifurcate and each fiber will connect to 10,000 purkinjie cells. Purkinjie cells in turn inhibit deep cerebellar nuclei GABAergic).

- **Climbing fibers (responsible for correction of wrong movements):**
  - ✓ Each fiber is connected to 1 purkinjie cell. Purkinjie cell in turn is inhibiting deep cerebellar nuclei.
  - ✓ These fibers originate from inferior olivary nuclei.
  - ✓ They also give a branch to stimulate deep cerebellar nuclei (same as Mossy fibers).

- **Cerebellar lesions:**
  - **There is no paralysis (Why?)** → because the motor system (corticospinal tract) is not affected.
  - **There is no sensory loss (Why?)** → because the cerebellum is not involved in transmitting sensations.
  - **These lesions will produce ipsilateral effect**. The dorsal spinocerebellar tract is reaching the cerebellum without crossing. Ventral spinocerebellar tract will cross at the level of entry to the spinal cord but it will recross again within the cerebellum (converting back to ipsilateral).
  - **There is hypotonia (decrease in muscle tone)** → because the cerebellum is involved in producing balance and maintaining posture through production of muscle tone.
  - **Vestibular effects (vomiting, nausea, unsteadiness and nystagmus):** the 8th cranial nerve is projecting from the vestibular system in inner ear → passing to vestibular nucleus (in medulla) → and then to cerebellum → aiding in maintenance of balance.
  - **Incoordination of movements known as ataxia.**
  - **Intention tremor**. Not that there are 2 types of tremor:
    - ✓ Resting tremor: occurring with lesions in extrapyramidal tracts or basal ganglia.
    - ✓ Intention tremor (which is happening during movement): occurring with lesion to the cerebellum.
  - **Dysmetria**: it is described as an inability to judge distance or scale so there will be lack of coordination of movement typified by the undershoot or overshoot of intended position with the hand, arm, leg or eye.
  - **Dysarthria**: condition in which problems effectively occur with the muscles that help produce speech, often making it very difficult to pronounce words.
  - **Tendon reflexes may be pendular** (متدلّ) due to hypotonia or not affected.
  - **A lesion in the medial part of the cerebellum** → producing axial/truncal ataxia.
  - **A lesion in the lateral part of the cerebellum** → producing appendicular ataxia (incoordination of fine movements mediated by the limbs).
  - **Dysdiodochokinesia**: difficulty in performing rapid alternating movements (supination/pronation).
- **Ataxia:**
  - **Truncal ataxia**: resulting from vermis lesion yielding a wide-based drunk-like gait (tested by: tandem gait).
  - **Appendicular ataxia**: resulting from lesion paravermal area. This will lead to incordination of movements in distal parts of limbs (tested by: finger-nose, heel-shin).
- **When a baby is born** → the cerebellum is still not mature → therefore he will have a wide-based gait walking on the tip of toes.
- **If there is a left cerebellar tumor:**
  - **The left side of the body will be affected (ipsilateral).**
  - **This will result in cerebellar ataxia which is characterized by:**
    - ✓ Swaying to the right in standing position (toward the normal side).

- ✓ The patient will be steady on the right leg (because it is normal).
- ✓ The patient will be unsteady on the left leg (because it is the one which is affected).
- ✓ The patient will have ataxic gait (incoordinated).