V, VI - Cerebellum

Objectives:

1. Draw a simplified diagram of cerebellar connections including mossy fibers, granule cells, parallel fibers, Purkinje cells, climbing fibers and deep nuclear cells.

2. Name the effect that Purkinje cells have on deep nuclear cells.

3. Name the synapse in the cerebellum that one theory says is modified during motor learning.

4. Draw a diagram dividing the cerebellum into medial and lateral regions and draw the major input-output connections of each region.

5. Name the effects of lesions in the medial and lateral cerebellum.

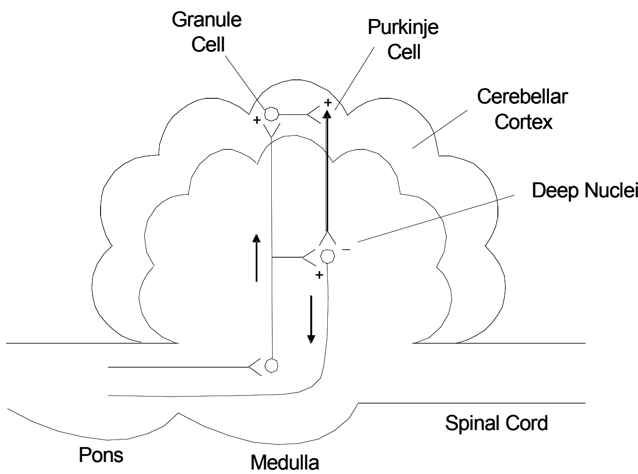
6. Name one possible overall function of the cerebellum.

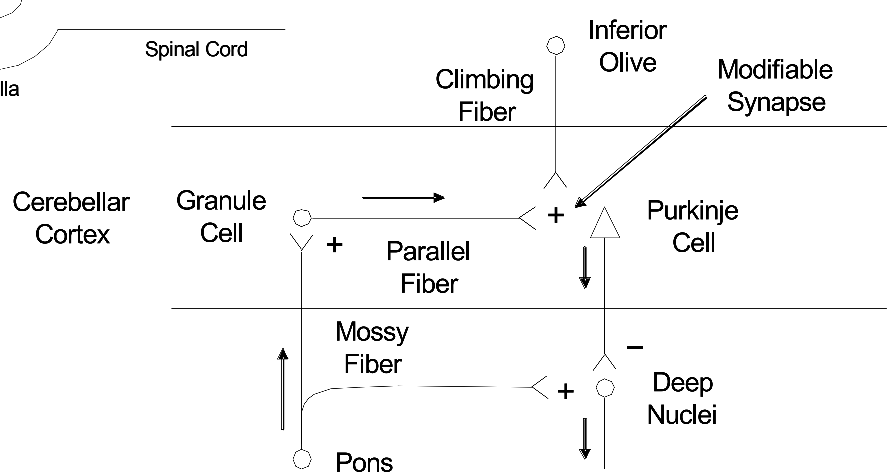
7. Describe the four following specific functions of the cerebellum: i) Achievement of accuracy in movements, ii) Feedforward movement control, iii) Motor recalibration and learning, iv) Contribution to cognition.

Answers to Objectives:

The name cerebellum comes from Latin meaning little brain. The cerebellum consists of only 10% of the volume of the brain but contains more than half of all the neurons in the brain. The cerebellum has a cerebellar cortex and deep nuclei. The cerebellar cortex has only 5 basic cell types which are connected (wired-up) the same way in all regions (like a computer). After a lesion in the cerebellum there is no change in sensory thresholds. Subjects can still make movements but they are inaccurate and uncoordinated (ataxic).

1. **Draw a simplified diagram of cerebellar connections including mossy fibers, granule cells, parallel fibers, Purkinje cells, climbing fibers and deep nuclear cells.**





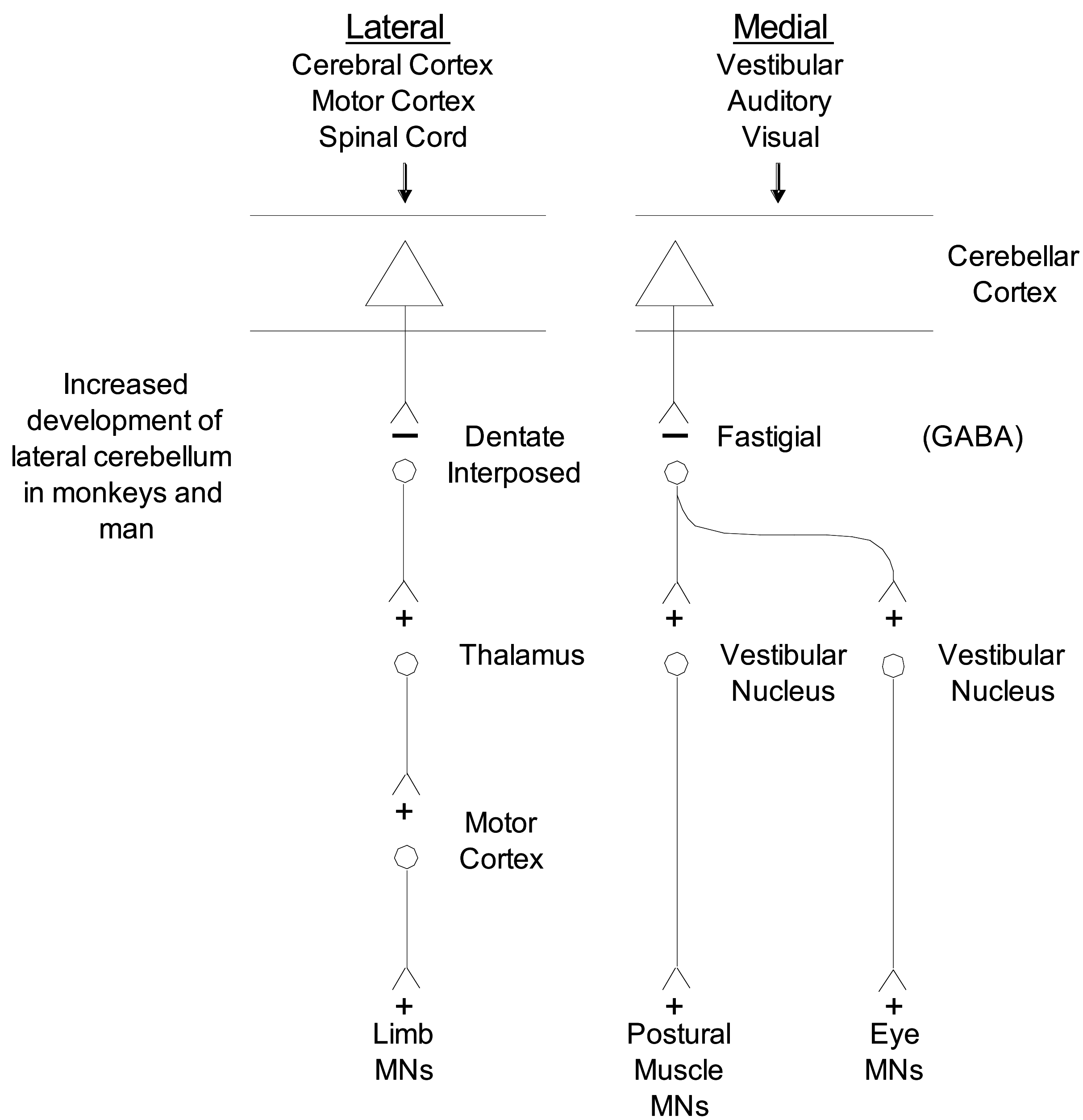
2. **Name the effect that Purkinje cells have on deep nuclear cells.**

Inhibit deep nuclear cells.

3. **Name the synapse in the cerebellum that one theory says is modified during motor learning.**

The climbing fiber modifies the parallel fiber Purkinje cell synapse (to produce long term depression at this synapse).

4. **Draw a diagram dividing the cerebellum into medial and lateral regions and draw the major input-output connections of each region.**



5. **Name the effects of lesions in the medial and lateral cerebellum.**

<u>Lateral</u>

- Slowed Movement
- Dysmetric Arm Movements
- Intention Tremor
- Arm Ataxia
- Dysarthria

<u>Medial</u>

- Dysmetric Saccades
- Gaze Evoked Nystagmus
- Disordered Smooth Pursuit
- Disorders Stance
- Gait Ataxia

6. Name one possible overall function of the cerebellum.

To contribute supplementary neural discharge to make movements, reflexes and cognition more accurate for the given conditions.

7. Describe the four following specific functions of the cerebellum: i) Achievement of accuracy in movements, ii) Feedforward movement control, iii) Motor recalibration and learning, iv) Contribution to cognition.

i) <u>Achievement of Accuracy in Movements</u>

Saccades - Every time a saccade is made, the cerebellum contributes to its starting (acceleration) and stopping (braking). Specifically, fastigial neurons have an early burst of activity for one direction of saccade (acceleration), and a late burst time-locked with the end of the saccade for the opposite direction (braking). Loss of this contribution with cerebellar lesions leads to saccadic dysmetria.

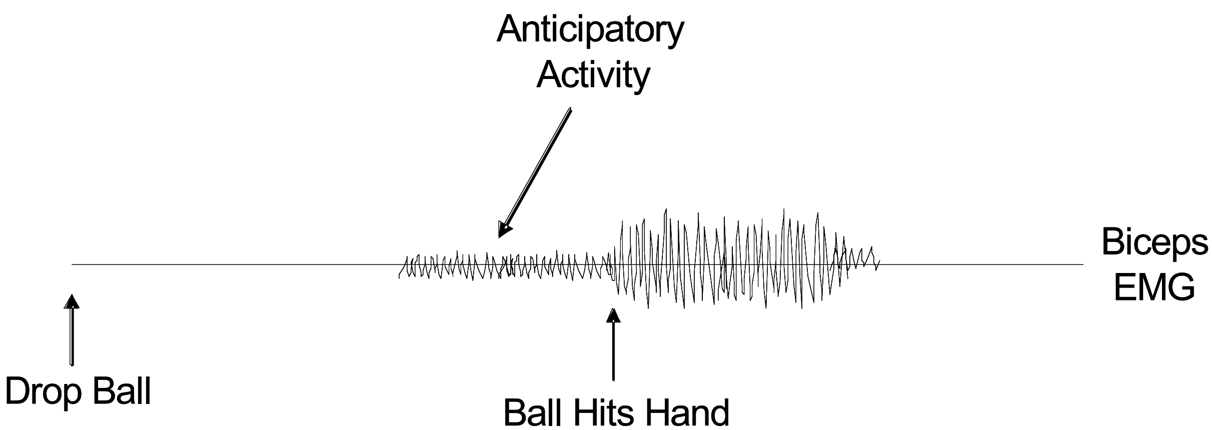
Eye Fixation - To hold the eye in the new position after a saccade requires the correct level of tonic (continuous) discharge in the contracting muscle. This is required to hold the eye against the elastic pull from the stretched eye muscle (the antagonist muscle). With a cerebellar lesion this system is not properly "tuned-up" which results in a series of drift-saccades, i.e., in gaze-evoked nystagmus.

Vestibular Postural Reflexes - To stand or walk accurately requires appropriate postural responses to vestibular stimulation. This presumably involves (as with saccades) a cerebellar contribution to vestibular postural reflexes. Lesions of the cerebellum produce disorder in these responses. Consequently, patients have difficulty in maintaining balance when standing (stance instability) and when walking (gait ataxia).

Arm movements - As with the fastigial nucleus and saccades, dentate neurons discharge during arm movements presumably to improve their acceleration and braking. Cerebellar lesions remove this additional signal for the generation of arm movements. Consequently, cerebellar patients show disorder in starting (slowed movement) and disorder in stopping (hypermetria).

ii) Feedforward Movement Control

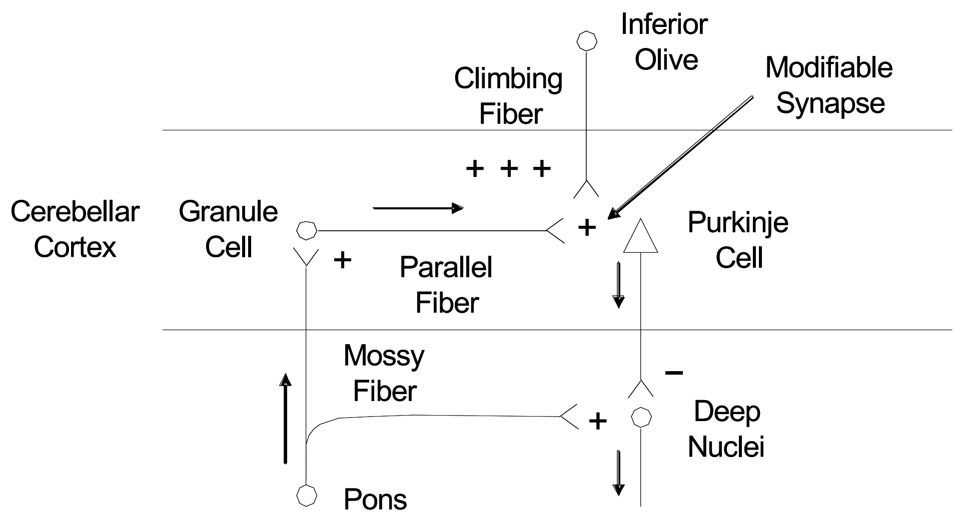
When a perturbation is expected the movements which occur are based on feedforward (anticipatory) control. For example, when catching a ball dropped from a height, visual information is used by the cerebellum to predict (anticipate) the time of ball impact. This enables biceps muscle contraction to occur before the ball hits the hand which prevents excessive movement of the hand. If only feedback mechanisms occurred (as a result of stretch of the biceps muscle after ball impact) it would take a relatively long time to generate muscle contraction, the hand would be displaced downwards, and the ball would likely be dropped.



iii) Motor Recalibration and Learning (Error Detection and Correction)

Visual - Motor Task
Motor acts can be recalibrated within seconds or minutes. For example, when subjects put on glasses which shift the visual world 30° to the left, they initially throw to the left where they see the target. However, after about 20 or so throws with visual feedback they recalibrate (learn) and now throw on-target. If they take off the glasses the first throw goes to the right. This is called the negative after-effect and demonstrates that recalibration/learning has taken place. One suggested mechanism for recalibration is changing the strength of the parallel fibre-Purkinje cell synapse by means of input from climbing fibers (the teacher).

Cerebellar patients cannot recalibrate or do so slowly. For example, in the glasses-throwing experiment, after putting on glasses a normal subject starts throwing to the left but recalibrates and ends throwing at the target. In contrast, a cerebellar patient after making 30 throws would still throw to the left. On taking off the glasses a normal subject throws to the right. However, on taking off the glasses a cerebellar patient would throw straight ahead because no learning had taken place.


Inferior
Olive
Climbing
Fiber
Modifiable
Synapse
+ + +
Cerebellar
Cortex
Granule
Cell
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+
Purkinje
Cell
Parallel
Fiber
Mossy
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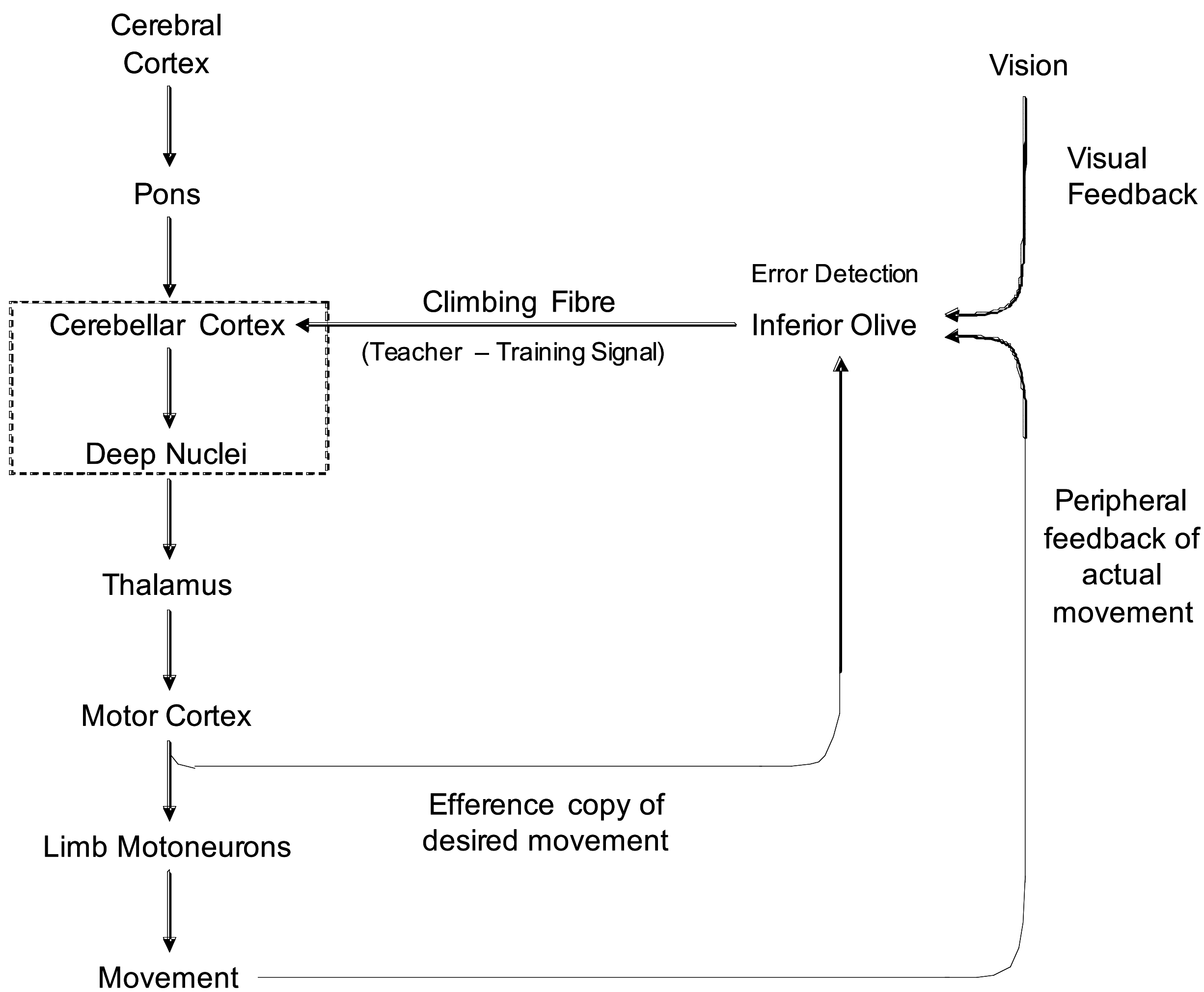
+
Deep
Nuclei
Pons


Cerebral
Cortex
Vision
Pons
Visual
Feedback
Error Detection
Climbing Fibre
Cerebellar Cortex
Inferior Olive
(Teacher – Training Signal)
Deep Nuclei
Peripheral
feedback of
actual
movement
Thalamus
Motor Cortex
Efference copy of
desired movement
Limb Motoneurons
Movement

Vestibular - Ocular Reflex
The strength (gain) of the VOR is normally appropriate, i.e., head acceleration generates the correct eye movement (velocity) to keep the object of interest stationary on the retina. When a subject wears magnifying lenses the image of the visual world is magnified which now makes the VOR inappropriate. However, after the lenses have been worn for some days the VOR adapts, i.e., the strength of the reflex is changed (changed eye velocity) to make it appropriate for the new lenses. This same mechanism occurs when a normal subject changes the prescription (magnification) of their glasses. At first there is visual blurring and disturbance of visual postural control during head movements, but within a few days the reflex adapts and gaze stabilizes. Subjects with lesions of the cerebellum cannot change the strength of the VOR.

Classical (Pavlovian) Conditioning
Lesions of the cerebellum disrupt the acquisition and retention of the classically conditioned eye-blink reflex.

iv) <u>Contribution to Cognition</u>

Ability to judge elapsed time - Ability to judge duration of tones, speed of moving objects, is disordered in cerebellar patients.

Verb association task - dog (bark). In this task there was increased activity in the cerebellum. Cerebellar lesions produced disorder.

Peg board task - Increased activity in lateral cerebellum