Function of the cerebellum

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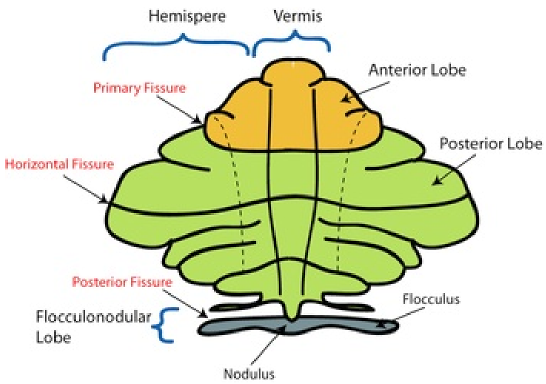
Functional anatomy of the Cerebellum

The Cerebellum consists of:

1. the cortex which is the area that receives and integrates all the afferent inputs entering the cerebellum. The integrated signal is transmitted to the cerebellar nuclei in the white matter,
2. the cerebellar nuclei which receive directly afferent inputs and integrated inputs from the cerebellar cortex. It is the area where all efferent output signals leave the cerebellum,

   →Dentate nucleus
   →Emboliform nucleus
   →Globose nucleus
   →Fastigial nucleus



Schematic representation of the major anatomical subdivisions of the cerebellum.

- **Flocculonodular compartment:** also called the vestibulocerebellum, where vestibular efferents from the vestibular nuclei enter and inform the cerebellum about the orientation of the head and body in space and gravitational field. This information derive from the vestibular apparatus in the inner ear (semicircular canals, utricle and saccule).
- **Vermis:** also called the spinocerebellum, where somatosensory efferents enter and inform the cerebellum about stimuli applied on cutaneous receptors and proprioceptors in deep structures such as muscles. This information derive for example from the Meissner' s corpuscle mechanoreceptors in the thick skin of the foot plantar aspect (cutaneous) and from Golgi tendon organs and muscle spindles in the muscles (proprioception).
- **Lateral hemispheres:** also called the cerebrocerebellum, where cortical efferents enter and inform the cerebellum about motor program of the cerebral cortex. For example, motor activities from the motor cerebral cortex through corticobulbar and corticospinal tracts are inspected by the cerebellum.

Function of the Cerebellum

Primarily, Ceasum acts as a comparator that compensates for errors in the movement by comparing and contrasting intention with performance. It receives information about the desired program of muscle contraction from the cortical motor areas. It also receives continuous updated sensory information from the periphery about the present state of muscles and compares that state with the desired program and if there are any deviations, it acts in order to restore them in order to induce the appropriate performance of a movement:

Control of Muscle tone
Control of Posture and Equilibrium
Control of Voluntary movements

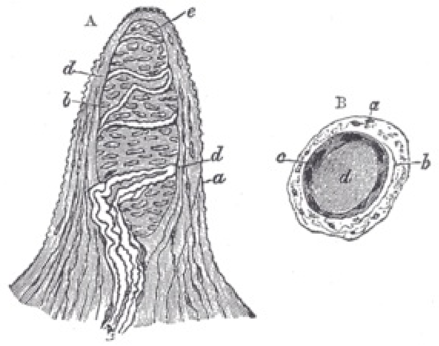
Cerebellar Reflex Arc

In order for the cerebellum to perform its functions it requires sensory input from many different parts of the human body including the brain, subcortical structures and periphery. The signals are transmitted to the cerebellum where they are integrated and passed to the cerebellar nuclei. From their efferent output leaves the cerebellum and reaches various structures. This process is referred to as the reflex arc of the cerebellum and consists of:

1. Sensory receptors
2. Afferent pathways
3. CNS
4. Efferent pathways
5. Effectors

1. Sensory receptors

- Cutaneous receptors: they are mechanoreceptors that detect primarily tactile stimuli. The most important cutaneous mechanoreceptors for the cerebellar functions are the Meisner's corpuscles that are located in the non hairy body skin areas, especially in finger tips and soles. These provide information about the contact of feet with the ground playing a key role for maintenance of muscle tone and equilibrium along with posture from the cerebellum.
- Proprioceptors: they are receptors found in muscles. The muscle spindles give information about the tension of the muscle of intersest and the Golgi tendon organs provide information about the tension of tendons induced by muscle stretching



Meissner's corpuscle

2. Afferent pathways

a) Afferent pathways from brain

Corticopontocerebellar tract: originates mainly in the motor premotor areas. It passes by way of the pontine nuclei and pontocerebellar tract to the contralateral cerebellar hemisphere.
Olivocerebellar tract: originates in the brain stem inferior olivary nucleus which receives input from the Basal Ganglia, Reticular formation, motor cortex and spinal cord.
Vestibulocerebellar tract: originates in the vestibular nuclei and terminates in the flocculonodular cerebellar area.
Reticulocerebellar tract: originates in different levels of the reticular formation and terminates mainly in vermis.

b) Afferent pathways from periphery

Posterior spinocerebellar tract
Anterior spinocerebellar tract

3. CNS (cerebellum)

4. Efferent pathways

5. Effectors

Muscle tone control

Definitions:

- Muscle tone refers to the easiness by which the muscle is passively stretched during resting state.
- Muscle tone refers to the muscle resistance to any passive stretch during resting state.

Use:

- to protect from muscle over stretching
- to help in posture maintenance

Explanation: The muscle fibers during resting conditions are not completely relaxed because that would have led to dissociation of the sarcomeres; thus they keep a minimal continuous contractility in order to prevent that. The golgi tendon organs (GTOs) in tendons and the muscle spindles (MSs) in the muscles detect any of these stretching stimuli and send signals to a the spinal cord in a reflex arc manner, and to the upper CNS levels triggering a nervous signal that keeps the muscles minimally and continuously contracted. However, the cerebellum is the organ which determines the sensitivity of the GTOs and MSs, therefore:

- Hypotonia indicates a diminished muscle contraction response to a relatively moderate stretching stimulus, due to a relatively low sensitivity of the GTOs and MSs because of downregulation from the cerebellum because of certain cerebellar disorders (e.g. cerebellar ataxia)
- Hypertonia indicates an exaggerated muscle contraction response to a relatively moderate stretching stimulus, due to a relatively high sensitivity of the GTOs and MSs because of upregulation from the cerebellum because of certain cerebellar disorders (e.g. Parkinson's disease)

Posture and Equilibrium Control

Voluntary Movement Control

Introduction

Due to the fact that body movement is a very complicated function, when it comes to the matter of its control there is a rather huge confusion about which nervous part is responsible for what and why; thus it is essential to differentiate the roles performed by every single CNS part involved in this process in an individual and algorithmic manner. These CNS parts are primarily but not exclusively:

- Cerebrum (primary motor cortex)
- Cerebellum
- Basal ganglia (more correctly known as basal nuclei)

Cerebrum v. Cerebellum v. Basal ganglia in muscle movement

1. The decider and implementer

The cerebrum is the part where the following algorithm is perceived:

- the thought to perform a movement (to reach the pencil)
- the decision to perform the movement (to move in order to reach the pencil)
- the appropriate type of movement (to move the hand, and not the foot, toward the pencil)
- the specific goal of the movement (to catch my pencil and start answering the pathology test)

2. The architect

The basal ganglia is the part where the following algorithm is perceived:

- the implementation of the cerebrum's decision (to prepare a plan to reach the pencil)
- the construction of the movement (to contract the arm, forearm and hand muscles to reach the pencil)
- the specificity of the movement (contract and relax individual muscles accordingly in a specific trajectory towards the pencil)
- the delivery of the plan movement (to provide the cerebrum with the plan)

N.B. Any order for the beginning of any movement is always and only given by the cerebrum.

3. The builder

The cerebellum is the part where the following algorithm is perceived:

- the supervision of the movement (to check the performance of each muscle and compare it with that planned)
- the alteration of the movement (to keep any deviations to the minimum)
- the correction of the movement (to perform the same cycle over and over again until the pencil is reached)