Cerebellum
John T. Povlishock, Ph.D.

OBJECTIVES

1. To identify the major sources of afferent inputs to the cerebellum
2. To define the “pre-cerebellar” nuclei from which the mossy and climbing fiber systems originate
3. To correlate cerebellar cortical cell type with its excitatory/inhibitory function (i.e., histology of the cerebellar cortex with function)
4. To identify the deep cerebellar nuclei, and define the major cerebellar outputs and their targets
5. To recognize the role of the cerebellum in the control of movement
6. To recognize the neurological deficits associated with cerebellar damage

I. INTRODUCTION

The cerebellum plays a role in the synergy of muscle action. This synergistic influence on muscles is especially important in voluntary movements, although the cerebellum does not initiate such movements. It contributes to the maintenance of equilibrium and influences smooth coordination of somatic motor activity. The cerebellum is involved in the determination (calculation) of the appropriate size (metrics) and speed (velocity) of movements. It plays an important role in the learning of movements (“motor learning”).

II. GROSS ANATOMY OF THE CEREBELLUM

The cerebellum has a midline “worm-like” vermis and lateral hemispheres. Two principal fissures (primary fissure, pre-nodular or posterolateral fissure) separate the cerebellum into three lobes.

- **Anterior lobe** (Paleocerebellum)- receives spinal input (spinocerebellars)
- **Posterior lobe** (Neocerebellum)- receives cortical input via the basilar pons (pontocerebellars)
- **Flocculonodular lobe** (Vestibulocerebellum)- receives vestibular input (vestibulocerebellars)
The afferents (enter) and efferents (leave) the cerebellum through three pairs of large white bundles called the **superior, middle, and inferior cerebellar peduncles**, which connect the cerebellum to the midbrain, pons, and medulla respectively.
Three-dimensional drawing of the relation of cerebellar peduncles. (Left lateral view of dissected specimen).

Figure 2
From Basic Clinical Neuroanatomy, Young and Young
III. **PRINCIPAL AFFERENTS**

The cerebellum receives three major inputs: from the spinal cord (*spinocerebellars*), cerebral cortex (*pontocerebellars*), and vestibular complex (and vestibular ganglion; *vestibulocerebellars*), and these inputs target its three lobes. Each of these three inputs terminates as “**mossy fibers**” on the dendrites of granule cells of the cerebellar cortex. *Olivocerebellars* are a fourth major input from the inferior olivary nucleus which terminate as “**climbing fibers**” on Purkinje cells in all three lobes.
A. **Spinocerebellars**- from the nucleus dorsalis of Clarke (dorsal spinocerebellars) and dorsal horn and intermediate zone of the spinal gray (ventral spinocerebellars); project to the anterior lobe and posterior lobe vermis (pyramis and uvula, lobules VIII and IX). The dorsal spinocerebellars are uncrossed and enter via the inferior cerebellar peduncle whereas the ventral are crossed and enter the cerebellum by way of superior cerebellar peduncle. In addition to the ventral and dorsal spinocerebellars a cuneocerebellar pathway is found. This pathway provided proprioception from the neck and upper limb. Afferent proprioceptive information is derived from axons traveling in the fasciculus cuneatus. These synapse on the lateral cuneate nucleus which gives rise to the cuneocerebellar tract which enters the cerebellum peduncle.

B. **Pontocerebellars**- from the basilar pontine nuclei via the middle cerebellar peduncle (brachium pontis) to the posterior lobe; these fibers relay input from the cerebral motor cortex via the cortico-ponto-cerebellar system. Typically, the pontine nuclei project to the contralateral middle cerebellar peduncle.

C. **Vestibulocerebellars**- from the vestibular complex (second-order) and vestibular ganglion (first-order) via the inferior cerebellar peduncle to the flocculonodular lobe.

D. **Olivocerebellars**- from the inferior olivary nucleus via the inferior cerebellar peduncle to all three lobes. The olivocerebellars project to the cerebellum via the contralateral inferior cerebellar peduncle.

IV. **HISTOLOGY OF THE CEREBELLAR CORTEX**

* Link to Netter Image 111.41
* Link to Netter Image 111.42

The cerebellar surface is composed of numerous narrow folds called folia. All folia have the same basic histologic structure and can be divided into three principal layers: molecular layer (stellate and basket cells), Purkinje layer (Purkinje cells), and granular layer (granule and Golgi cells). Lying deep to the cortex is the subcortical white matter that carries fibers to and from the cortex.

**Mossy fibers** (spinocerebellars, pontocerebellars, vestibulocerebellars) **end on granule cell dendrites in “cerebellar glomeruli”**. Then granule cells project their axons into the molecular layer as **parallel fibers**, affecting the profuse dendritic arborization of Purkinje cells.

**Climbing fibers** (olivocerebellars) end directly on the soma and proximal dendrites of Purkinje cells.
Climbing fibers (olivocerebellars) end directly on the soma and proximal dendrites of Purkinje cells.

From Basic Clinical Neuromatomy
Young and Young

Figure 4
V. INTRINSIC CONNECTIONS AND FUNCTION OF CELLULAR ELEMENTS

Excitatory:
- mossy fibers- on granule cells
- parallel fibers- on Purkinje cells, stellate, basket and Golgi cells
- climbing fibers-on Purkinje cells
- deep cerebellar nuclei- on brainstem, red nucleus, and thalamus (VL)
Inhibitory:

- basket cells- on Purkinje cells
- stellate cells- on Purkinje cells
- Golgi cells- on granule cells
- Purkinje cells- on deep cerebellar nuclei

**Figure 6**
From House, Pansky, and Siegel, A Systematic Approach To Neuroscience

VI. DEEP CEREBELLAR NUCLEI

Buried in the subcortical white matter of the cerebellum in the roof above the fourth ventricle are four pairs of deep cerebellar nuclei: fastigial, globose, emboliform, and dentate. The principal source of input to these nuclei are the axons of Purkinje cell. This input is organized in a linear fashion, with the vermis projecting to the most-medial nucleus, the fastigial, the paravermal zone projecting to the globose and emboliform nuclei, and the lateralmost hemisphere to the dentate nucleus.
VII. **CEREBELLAR EFFERENTS**

The deep cerebellar nuclei are the source of cerebellar efferents.

**Fastigial nucleus** has reciprocal connections with the vestibular complex through the juxta-restiform body (part of inf. cerebellar peduncle). It does not contribute to the superior cerebellar peduncle, i.e., it does not have a major thalamic projection.

**Globus and Emboliform nuclei** projects through the superior cerebellar peduncle to primarily the contralateral magnocellular red nucleus (origin of rubrospinals) and to parts of the reticular formation.

**Dentate nucleus** projects through the superior cerebellar peduncle to primarily the contralateral parvicellular red nucleus (origin of rubro-olivarys) and VL nucleus of the thalamus.

As noted those fibers traveling in the superior cerebellar peduncle consist primarily of efferent fibers from the dentate, emboliform and globuse nuclei. Those arising from the dentate nuclei form the dentatorubral, the dentatoththalamic and the dentatoreticular fibers. These fibers cross to the contralateral side in the midbrain in the decussation of the superior cerebellar peduncle. At that point, many fibers ascend, as noted, to the red nucleus and thalamus. Other fibers, however descend to the brainstem reticular nuclei and the inferior olivary nucleus.

The thalamic outputs of the cerebellum affect the contralateral motor cortex (via VL) where movements are planned and initiated for the opposite side of the body (but the same side, i.e., ipsilateral, to the origin of its cerebellar output). This explains why cerebellar deficits are expressed on the same side as the lesion.
The crossed descending limb of the superior cerebellar peduncle carries cerebellar efferents to “pre-cerebellar nuclei” such as the inferior olivary nucleus and basilar pontine nuclei, which project, in turn, back to the cerebellum, completing a feedback loop.

Figure 8

Neocerebellar connections with the cerebrum and some brainstem nuclei.

A feedback loop from the cerebrum to cerebellum to cerebrum is indicated in the following sequence: cerebral cortex → pontine nuclei → neocerebellar cortex → deep cerebellar nuclei → nucleus ruber → ventral lateral thalamic nucleus → cerebral cortex. Another loop is the sequence of cerebellar cortex → deep cerebellar nuclei → nucleus ruber → inferior olivary nucleus → neocerebellar cortex.

From Noback and Demarest, *The Human Nervous System*
Corticopontines originate from sensorimotor cortex and project to the basilar pontine nuclei, which project in turn to the cerebellum (granule cells). Granule cell axons (parallel fibers) project to Purkinje cells, which project in turn to the deep cerebellar nuclei. The globose, emboliform, and dentate nuclei project to the VL thalamus, which projects in turn back to the motor cortex.

Figure 9
VIII. CLINICAL CORRELATIONS/CEREBELLAR DISORDERS

Motor deficits following cerebellar lesions are manifested ipsilaterally. Dysfunctional cerebellar efferent signals are conveyed to the opposite ventral thalamus and motor cortex, and then, in turn, through the pyramidal tract (which crosses back to the original side), affecting motor performance on the same side as the lesion.
Cerebellar Disorders

The midline portions of the cerebellum are involved with gait and trunk movements; the lateral cerebellar hemispheres help coordinate movements of the distal limbs and speech.

Lesions of the cerebellum or of its output cause:

- **Intention tremor**: Worse with volitional movements such as reaching for an object; tested by finger-to-nose or heel-to-shin tests.
- **Dysmetria**: Inability to gauge distance, power, or speed of a movement. When the patient is asked to place his or her finger in front of the physician's and to imitate a rapid movement of the physician's finger to the side, the patient may overshoot or undershoot the movement.
- **Asynergy**: Lack of coordination between groups of muscles, causing movements to appear awkward and disjointed, instead of fluid.
- **Dysdiaochokinesis**: Impaired ability to stop one action and immediately follow it by the opposite action. It is tested by having patients alternately tap the palm and dorsum of their hand against a flat surface as rapidly as possible.
- **Asthenia**: Mild weakness and fatigability.
- **Speech disorders**: Slurred, jerky, rapid and marked changes in volume ("explosive"), or staccato.
- **Hypotonia**: Decreased skeletal muscle tone.
- **Diminished deep tendon reflexes**: When the knee-jerk is elicited, a pendulum-like movement of the leg may result (pendular reflex).