**Anatomical Functional Areas of the Cerebellum:**

The cerebellum consists of a three-layered cortex surrounding four pairs of centrally located nuclei. The surface cortex exhibits numerous folds called folia that are similar to the gyri of the cerebral cortex. The cerebellar cortex is divided into three major subdivisions: anterior, posterior, and flocculonodular lobes. The anterior and posterior lobes are further divided in the sagittal plane into a midline portion, the vermis; a slightly more lateral portion with ill-defined borders, the intermediate zone; and, most laterally, the large lateral hemispheres.

The vermis and the intermediate zone contain a somatotopic map of the body surface that reflects peripheral sensory input from muscles, tendons, joint capsules, and some cutaneous receptors.

The lateral hemispheres receive input primarily from the cerebral cortex via the basilar pontine nuclei, and portions of each hemisphere exhibit a fractured somatotopic organization. This means that some body regions are spatially segregated from their adjoining parts. For example, a lower limb territory might be located adjacent to a portion of the face, and some body regions are represented in more than one location.

The nuclei of the cerebellum include the medial or fastigial nucleus; the globose and emboliform nuclei, which are collectively referred to as interposed nuclei; and the lateral, or dentate, nucleus. The output of these nuclei is directed to the cerebral cortex via the thalamus and to the brain stem.

**Neuronal Circuit of the Cerebellum:**

**Input (Afferent) Pathways to the Cerebellum**

- The largest afferent projection, the pontocerebellar system, originates from cells of the basilar pontine nuclei. Nearly all regions of the cerebral cortex project to cells in the pontine nuclei, which then give rise to pontocerebellar axons. This is the primary route over which cortical information is transmitted to the cerebellum.
- The olivocerebellar projections originate from cells in the inferior olivary nuclei.
- Spinocerebellar fibers originate in the spinal cord or medulla.
- Reticulocerebellar fibers originate from a variety of cell groups in the brain stem.
- Vestibular fibers originate from the vestibular nuclei and the vestibular sensory apparatus.

**Output (Efferent) Signals from the Cerebellum:**

• The midline portions (vermis) of the cerebellar cortex project to the fastigial (medial) cerebellar nucleus and then to the vestibular nuclei and reticular formation.
• The cortex of the intermediate zone projects to the globose and emboliform nuclei (interposed nuclei) and then to the ventrolateral and ventral anterior thalamic nuclei. From the thalamus, signals are transmitted to the cerebral cortex and basal ganglia.
• The lateral hemispheres project to the dentate (lateral) cerebellar nucleus and then to the ventrolateral and ventral anterior thalamic nuclei, which project to the cerebral cortex.

**Functional Unit of the Cerebellar Cortex—The Purkinje Cell and the Deep Nuclear Cell:**

The three layers of the cerebellar cortex, beginning nearest the pial surface, are the molecular layer, the Purkinje cell layer, and the granular layer. The fundamental circuit through the cerebellar cortex, which is repeated some 30 million times.
The principal cell type is the Purkinje cell, which receives input to its fan-shaped dendritic tree located in the molecular layer. This input comes from two main sources: (1) climbing fibers that originate from cells of the inferior olivary complex and (2) parallel fibers that represent the axons of granule cells. The granule cells receive synaptic input from mossy fibers, which are formed by all the other cerebellar afferent systems.
Recently, however, another class of afferent fibers apparently forming synaptic contact with Purkinje cells—multilayered fibers—has been shown to originate from biogenic amine cell groups, such as the locus ceruleus, and other nuclei including portions of the hypothalamus.
The fundamental cerebellar circuit is completed by the axon of the Purkinje cell, which forms synaptic contact in one of the cerebellar nuclei, although a few Purkinje axons extend into the vestibular nuclei. The transmission of signals

through the fundamental circuit is influenced by three additional considerations:

1. Purkinje cells and cerebellar nuclear cells exhibit a high level of background activity, which can be modulated upward or downward.
2. The cells of the central nuclei receive direct excitatory input from climbing fibers and most mossy fiber systems, whereas the input from Purkinje cells is inhibitory.
3. Three other inhibitory interneurons (basket cells, stellate cells, Golgi cells) in the cerebellar cortex also influence the transmission of signals through the fundamental circuit.

Function of the Cerebellum in Overall Motor

Control (p. 686)

The Cerebellum Has a Turn On/Turn Off Function. During nearly every movement, certain muscles must be

rapidly turned on and then quickly turned off. Because mossy and climbing fiber afferents can form direct

excitatory contact with cerebellar nuclear cells (the cerebellar output neurons), it is possible that such connections establish the turn on signal. However, mossy and climbing fiber afferents also pass through the cerebellar cortex, where they can activate Purkinje cells that inhibit cerebellar nuclear neurons and in this way specify the turn off signal. Such a theory has some merit because cerebellar lesions are known to produce an inability to perform rapid alternating movements (e.g., pronation-supination of the wrist). This deficit is known as dysdiadochokinesia.

Purkinje Cells May Learn to Correct Motor Errors. It has been proposed that the role of the climbing fiber input to a Purkinje cell is to modify that cell's sensitivity to parallel fiber input. The climbing fiber input is more vigorous when a mismatch occurs between the anticipated result of a movement and its actual result. Gradually, as the movement is practiced, the mismatch declines and climbing fiber activity begins to return to its previous level of activity. During the time of increased climbing fiber activity, the Purkinje cell can become more or less responsive to parallel fiber input.

The Vestibulocerebellum Joins with the Brain Stem and Spinal Cord to Regulate Equilibrium and Posture. The vestibulocerebellum is a combination of the flocculus and nodulus of the cerebellum and certain of the vestibular nuclei of the brain stem. It is believed that the role of these brain components is to calculate the rate and direction of movement, that is, where the body will be in the next few milliseconds. This computation is the key to moving to the next sequential movement or to maintaining equilibrium. Because the vestibulocerebellar circuitry is associated mainly with axial and girdle muscles, this system seems to be primarily involved in setting and maintaining the posture appropriate for a movement.

The Spinocerebellum Is Involved in the Control of Distal Limb Movements. The spinocerebellum consists of the intermediate zone of the anterior and posterior lobes plus most of the vermis of the anterior and posterior lobes. It is that portion of the cerebellar cortex that receives the bulk of the ascending spinal cord projections (spinocerebellar and cuneocerebellar tracts), particularly the input from muscle spindles, Golgi tendon organs, and joint capsules. It also receives input from the cerebral cortex via the pontine nuclei, so it receives information concerning intended movements as well as ongoing movements.

This part of the cerebellum may be involved in damping movements. For example, when an arm is moved, momentum develops and must be overcome to stop the movement. When lesions affect the spinocerebellum, overshoot develops: That is, the arm might extend past the target in one direction; then, as a correction is made, the arm may overshoot in the opposite direction. This is sometimes interpreted as an intention or action tremor.

Extremely rapid movements such as the finger movements of a touch-typist are called ballistic movements. This implies that the entire movement is preplanned to go into motion, travel a specific distance, and then come to a stop. Saccadic eye movements are also ballistic movements. These types of movements are disrupted when the spinocerebellum is damaged.

The movement is slow to be initiated, its force development is weak, and it is slow to be terminated; this results in overshoot or past pointing.

The Cerebrocerebellum Is Involved with the Planning, Sequencing, and Timing of Movement. The lateral cerebellar hemispheres receive the bulk of their input from the cerebral cortex via the pontine nuclei and essentially do not receive any projections directly from the spinal cord. The plan of an intended, sequential movement is thought to be transmitted from the premotor and sensory cortex to the basilar pons and then to the cerebellar nuclei and cortex of the lateral hemisphere. Interestingly, it has been reported that activity in the dentate nucleus reflects the movement that will be performed, not the ongoing movement.

When the lateral hemisphere is damaged, the timing of sequential movements is lost; that is, a succeeding movement may begin too early or too late, and complex movements such as writing or running are uncoordinated and do not progress in an orderly sequence from one movement to the next. The timing function involved in estimating the progression of auditory and visual phenomena may also be disrupted. For example, an individual can lose the ability to predict on the basis of sound or sight how rapidly an object is approaching.

**Clinical Abnormalities of the Cerebellum:**

• Dysmetria and ataxia—movements that overshoot or undershoot the intended target. The effect is called dysmetria, and the abnormal movements are described as ataxic.
• Past pointing—failure of a movement signal to be terminated at the proper time, and the limb continues past or beyond its intended target.
• Dysdiadochokinesia—inability to perform rapid, alternating movements. The switch that shifts from flexion to extension (or vice versa) is not timed properly.• Dysarthria—speech defect that involves inappropriate progression from one syllable to the next. This is slurred speech in which some syllables are held and others are dropped too quickly.

• Intention tremor—a type of tremor present only when a voluntary movement is attempted and that intensifies as the limb nears its target.

- Cerebellar nystagmus—in effect, a tremor of the eyes when attempting to fixate on a point in the periphery of the visual field.
- Hypotonia—decreased muscle tone in the affected muscles, accompanied by diminished reflexes.