

## Cerebellum

### Objective

- To understand the organization of input-output and local (intrinsic) circuits of the cerebellum
- To understand the relationship between the cerebellum and the vestibular system
- To learn to distinguish cerebellar from corticospinal (pyramidal) signs  
NTA Ch. 10
- Key Figs: 10-2; 10-3; 10-5; 10-7; 10-8; 10-9; 10-10; 10-20; 10-22  
Clinical Case  
#8 Head tilt and unsteady gate; CC8-1

### Self evaluation

1. Be able to identify all structures listed in key terms and describe briefly their principal functions
2. Use neuroanatomy on the web to test your understanding

### D-1a Organization of cerebellum

The cerebellum consists of pairs of deep nuclei (fastigial, interposed, and dentate) and an overlying cortex. The principal functional circuit of the cerebellum is that information is distributed both to the deep nuclear neurons and to cortical neurons (left side of slide). Information routed through the deep nuclei is modulated by cerebellar cortical projection neurons (Purkinje cells), whose output is inhibitory. The right side of the slide shows the key features of the functional organization of the spinocerebellum, cerebrocerebellum, and the vestibulocerebellum.

### D-1 Gross relationship

Note that the cerebellum lies in the posterior cranial fossa, beneath the occipital lobe, from which it is separated by the tentorium cerebelli.

### D-2 Gross Relationships

Identify the tentorium. Another fold of dura mater, the falx cerebelli, separates the posterior aspects of the two lobes of the cerebellum at the posterior-cerebellar incisure. The cerebellum fills much of the posterior fossa. Using the plaster model of the brain stem, locate the superior, middle, and inferior cerebellar peduncles, which is where the cerebellum is connected to the dorsal part of the pons and medulla. What are the fiber compositions of the three cerebellar peduncles?

## **M-1 Midsagittal MRI**

Identify the various components of the brain stem. Notice the spatial arrangement of the pons, fourth ventricle and cerebellum. What portion of the cerebellum is imaged in this slide? What are the functions of this portion of the cerebellum?

## **H-2 Vasculature**

Using this slide, review the arterial supply to the cerebellum. Locate the vertebral and basilar arteries on the ventral surface of the brain stem, and branches arising from them: the posterior inferior cerebellar artery, the anterior inferior cerebellar artery and the superior cerebellar artery.

## **cbImnucs Cerebellar nuclei (movie)**

Key:

Fastigial nucleus=yellow

Interposed nuclei=purple

Dentate nucleus=green

## **D-12 Cerebellar circuits**

Prior to examining the microscopic anatomy of the cerebellum, we will want to consider its input/output organization and local circuits. Use slide D012 to review the major elements of the cerebellar circuits and the glomeruli.

The cerebellar cortex has an intricate synaptic organization whereby two main excitatory inputs – the mossy and climbing fibers – determine the activity of only one output system – the Purkinje neurons (NTA Fig. 12-12). There is also a serotonergic and noradrenergic innervation of the cerebellum. The climbing fibers, and to a lesser extent the mossy fibers, also impinge upon the neurons of the deep cerebellar nuclei, possibly providing them with background excitation. Climbing fibers, all of which originate from the contralateral inferior olivary nucleus, wrap around the Purkinje neurons and make numerous synaptic contacts on smooth portions of the somatic and dendritic membrane and on small spines of Purkinje cell dendrites. Each Purkinje neuron receives only one climbing fiber. Excluding the aminergic projection, all other sources of cerebellar input give rise to mossy fibers. (The aminergic projection is not limited to the molecular layer.) Mossy fibers do not terminate on Purkinje cells directly, but rather on the dendrites of granule cells. The granule cells – the only excitatory neuron in the cerebellar cortex – send their axons into the molecular layer where they bifurcate to give rise to parallel fibers. Each parallel fiber extends about 2 mm along the folium and intersects the dendrites of many Purkinje neurons, making one, or at most, a few synapses with each Purkinje cell. In contrast to the small degree of divergence between climbing fibers and

Purkinje cells, there is enormous divergence in the mossy fiber input to the cerebellar cortex.

Excitatory and inhibitory interneurons within the cerebellar cortex modulate the incoming excitatory information to determine which Purkinje cells fire and for how long. Purkinje cells send their axons to the deep cerebellar nuclei and to the vestibular nuclei, where they inhibit the ongoing activity of neurons in these nuclei.

There are three classes of inhibitory interneurons: the stellate cells, the basket cells, and the Golgi neurons. In the molecular layer, the stellate and basket cells, which receive excitatory input from the parallel fibers, establish inhibitory synaptic contacts with the Purkinje neurons, the former at the level of the distal dendrites, the latter at the proximal dendrites and soma. The third inhibitory interneuron is the Golgi cell. It also receives its principal input from the parallel fibers in the molecular layer (where it has an elaborate dendritic tree) but distributes its terminals back to the granule cells. This extensive network of inhibitory interneurons results in sharpening the borders of focally excited populations of Purkinje neurons and in cutting off the input after it has been received. Thus, a localized mossy fiber input produces the brief firing of a sharply defined population of Purkinje neurons.

Under the light microscope small clear spaces can be seen within the granular layer. These are the cerebellar glomeruli which contain the bulbous expansions of mossy fibers (the major presynaptic element), surrounded by dendrites of granule cells (the major postsynaptic element) and axons of Golgi neurons (the other presynaptic element). The entire complex is surrounded by a glial sheath. The glomeruli are the principal sites where mossy fibers make their synaptic terminations.

## **D-6 Overview of layers and cellular elements**

Examine slides D-6 (low-power view) and D-7 (medium-power view) of sections through cerebellar folia in Nissl-stained material. Observe the three layers: molecular, Purkinje, and granular.

The relatively acellular molecular layer lies just beneath the pial surface. The two types of neuron found in this layer are (1) the stellate cells (small neurons located in the outer two-thirds of the molecular layer), and (2) the basket cells, which are located near the Purkinje cell bodies. The dendrites of the basket cells extend upward in the molecular layer, toward the pial surface. Their axons arise from one side of the cell bodies, making multiple synaptic contacts on the somata and axon hillocks of Purkinje cells. One basket cell may contact as many as 10 Purkinje cells and each Purkinje cell may receive contacts from several basket cells.

The innermost layer of the cortex is the granular layer. This layer is packed with neurons. In the Nissl-stained slide (D-7) this layer appears to be composed of closely packed nuclei ranging from 5 to 8  $\mu\text{m}$  in diameter. Occasional clear spaces are the sites of cerebellar glomeruli, which do not stain by the Nissl method. The

granular layer is primarily composed of granule and Golgi cells. There are about 1/10 as many Golgi cells as Purkinje cells.

#### **D-7 Overview of layers and cellular elements**

See text for D006

### **D-8 Purkinje cells - silver stains**

Immediately beneath the molecular layer is a single layer of Purkinje cell bodies. These are large, flask-shaped neurons whose dendrites arborize upward into the molecular layer and whose axon descends into the white matter beneath the cortex. The axons of all other neurons of the cerebellar cortex are intrinsic to the cortex.

### **D-9 Purkinje cells - silver stains**

This is high-power view of a Purkinje neuron. A basket cell axon and several basket synapses also can be seen.

### **D-10 Fiber elements**

On this slide, which shows a silver stain, myelin appears black.

### **D-11 Fiber elements**

This is a transverse section through a cerebellar folium. Notice the axons of basket cells running parallel and close to the Purkinje cell layer.

### **C-7 Spinal cord - ascending and descending pathways**

Review the locations of the dorsal and ventral spinocerebellar pathways

### **X-5 Spinal cord - myelin stain**

On these slides we will consider the origin of the spinocerebellar pathways and where in the spinal cord white matter they ascend. Review basic spinal cord anatomy on this slide (regions of the gray matter and white matter; identify the four levels). Where are the cells of origin of the DSCT and VSCT located?

What is the rostral-caudal distribution of these cells?

### **A-4 Spinal cord-Lumbar crush - myelin stain**

Examine slide A004 (lumbar crush) for degeneration of the spinocerebellar tracts. Do they ascend on the ipsilateral or contralateral side? Through which peduncles do they enter the cerebellum?

### **Background information:**

These afferent pathways project to the cerebellar cortex as well as to the deep nuclei, in particular, the interposed nuclei. Information from spinal levels is conveyed to the cerebellum by both direct paths and indirectly by a relay in the brain stem. The dorsal and ventral spinocerebellar tracts are direct paths that

convey input from the legs. The cuneo- and rostral spinocerebellar pathways are direct paths that convey information from the arms.

(a) Dorsal spinocerebellar pathways. The dorsal spinocerebellar tract (DSCT; NTA Fig. 10-7A) relays information from peripheral receptors in the leg and lower trunk to the cerebellum. Primary afferent fibers enter the dorsal columns and ascend and descend a few segments. Collaterals of these fibers re-enter the spinal gray matter and synapse on cells of Clarke's nucleus located in the medial part of the lamina VII from the T1 to the L2 level in humans. The dorsal spinocerebellar tract arises from the cells of Clarke's nucleus. These cells send their axons into the ipsilateral lateral columns. The axons ascend to the medulla whereupon they enter the ipsilateral inferior cerebellar peduncle to terminate finally in the ipsilateral leg areas of the cerebellar cortex. The cuneocerebellar tract is the arm equivalent (i.e., C1 to T4-5) of the dorsal spinocerebellar tract (NTA Fig. 10-7A). The cells of origin of this tract are located in the accessory (or external) cuneate nucleus. From this level the cuneocerebellar fibers course with the dorsal spinocerebellar tract fibers and terminate in the arm area of the ipsilateral cerebellar cortex. The receptor types associated with these tracts include muscle spindle afferents and tendon organ afferents as well as cutaneous mechanoreceptors. Dorsal spinocerebellar and cuneocerebellar tract cells receive afferent input from restricted parts of the body and have small receptive fields. These tracts participate in the fine control of posture and movement.

Lesions of spinocerebellar pathways occur in a group of important degenerative diseases, such as Friedrich's ataxia. This is a familial disease in which stricken individuals make movements that are uncoordinated (i. e. ataxic). This motor disorder is attributable, in large measure, to demyelination of spinocerebellar tracts. In addition, there exist a large number of degenerative conditions collectively known as the olivo-ponto-cerebellar atrophies.

## **X-20 Intermediate medulla**

Identify the accessory cuneate and vestibular nuclei and the inferior olive. What are the connections and functions of these nuclei? Identify the inferior cerebellar peduncle. What cerebellar afferents course through this peduncle?

### **Additional information:**

Afferent fibers from the vestibular nerve and nuclei reach the flocculonodular lobe as well as parts of the posterior vermis via the inferior cerebellar peduncle. These inputs are especially

important in the control of eye movements, posture, and movements of the head and neck.

(c) Relay nuclei for indirect spinocerebellar paths. The lateral reticular nucleus (LRN), located just lateral to the inferior olivary nucleus, projects entirely to the cerebellum via the ipsilateral inferior cerebellar peduncle. This projection is relatively diffuse and reaches the entire cerebellum. The LRN receives its input from spinal neurons as well as descending input from the cortex and red nucleus.

Neurons of the inferior olivary nuclei project to all parts of the contralateral cerebellar cortex in a precise topographic fashion via the inferior cerebellar peduncle and end as climbing fibers. Spinal afferents coursing in all quadrants of the spinal cord (including the dorsal columns) reach the medial portions of the principal olive and the dorsal accessory olive. These olivary neurons then project to the cerebellar vermis and the intermediate part of the cerebellar hemisphere. Olivary neurons also receive descending input from midbrain and cerebral cortex. One of these inputs is from the ipsilateral red nucleus (parvocellular division) by way of the central tegmental tract.

#### **X-25 Rostral medulla**

The inferior olive and the inferior cerebellar peduncle can be identified on this slide. Identify the medial and inferior vestibular nuclei. What class of cerebellar afferents does the inferior olive give rise to? In addition to the olivary axons, what other cerebellar inputs course through the inferior peduncle?

#### **X-30 Pons and deep cerebellar nuclei**

The four pairs of deep cerebellar nuclei can be identified on this slide. The dentate nucleus is easily distinguished from the other deep nuclei. Identify the vestibular nuclei. The pontine nuclei also can be seen on this slide. From what structure do the pontine nuclei receive most of their input? Through which peduncle do the axons of the pontine nuclei project?

#### **X-37 Rostral pons**

Identify the superior cerebellar peduncle. Most of the axons of the peduncle that are located laterally have not yet decussated, whereas those located close to the midline are decussating.

#### **X-40 Caudal midbrain**

This is the principal level of the cerebellar decussation.

### **X-45 Superior cerebellar peduncle and cerebellothalamic and cerebellorubral fibers**

The cerebellar fibers have all decussated by this level. They are more dispersed. They are now termed the cerebellorubral and cerebellothalamic tracts. From which deep nuclei do most of the fibers in the peduncle originate? Where specifically do the fibers from the different nuclei project?

### **C-5 Parasagittal section through brain stem and cerebellum following injection of HRP conjugated with wheat germ agglutinin (HRP-WGA) in red nucleus.**

In this slide, which you used in the motor pathway lab, the red nucleus of a cat was injected with a tracer that is transported retrogradely and anterogradely. Note the retrograde labeling of cell bodies in the cerebellum and anterograde labeling of rubrospinal tract fibers. Can you identify which deep cerebellar nuclei are labeled? (Slide courtesy of Dr. Alan Gibson, Barrow Neurological Institute.)

### **X-75 Ventral lateral nucleus of the thalamus**

Identify the ventral lateral nucleus. Where is the ventral lateral nucleus located in relation to the ventral posterior nucleus? To what region of the cerebral cortex does the ventral lateral nucleus project?

### **X-150 Oblique section through the superior cerebellar peduncle**

The section shown in this slide is cut in the same plane as the superior cerebellar peduncle. Use this slide to review the “ascending” cerebellar efferent pathway: from the cerebellar cortex to the deep nuclei, and then to the red nucleus and ventral lateral nucleus. Be certain to identify the plane of this section on the brain stem model. On this slide, review the anatomical basis of the presence of ipsilateral signs with cerebellar damage (Hint: double-crossed).

### **X-100 Sagittal section, close to the midline**

This section cuts through the decussation of the superior cerebellar peduncle. The red nucleus, a major recipient of the axons in the superior cerebellar peduncle, can also be seen on the slide. What is the other major termination of the superior cerebellar peduncle?

## Key Structures and Terms

Stellate

Basket

Golgi

Granule

Purkinje

Layers:

(Try to remember which cells are in which layers)

Molecular

Purkinje

Granular

Cerebellar Peduncles

Inferior

Middle

Superior

Cerebellar Subdivisions and Nuclear Groups:

Anterior lobe

Posterior lobe

Flocculonodular lobe

Vermis

Intermediate hemisphere

Lateral hemisphere

Fastigial

Interposed

Dentate

Vestibular

Thalamic Nuclei:

Ventral lateral

Fiber Bundles and Paths:

DSCT

Spino-olivo cerebellar

Ponto-cerebellar

Rubro-olivo-cerebellar

Thalamic fasciculus

Arteries:

Posterior inferior cerebellar

Anterior inferior cerebellar

Superior cerebellar