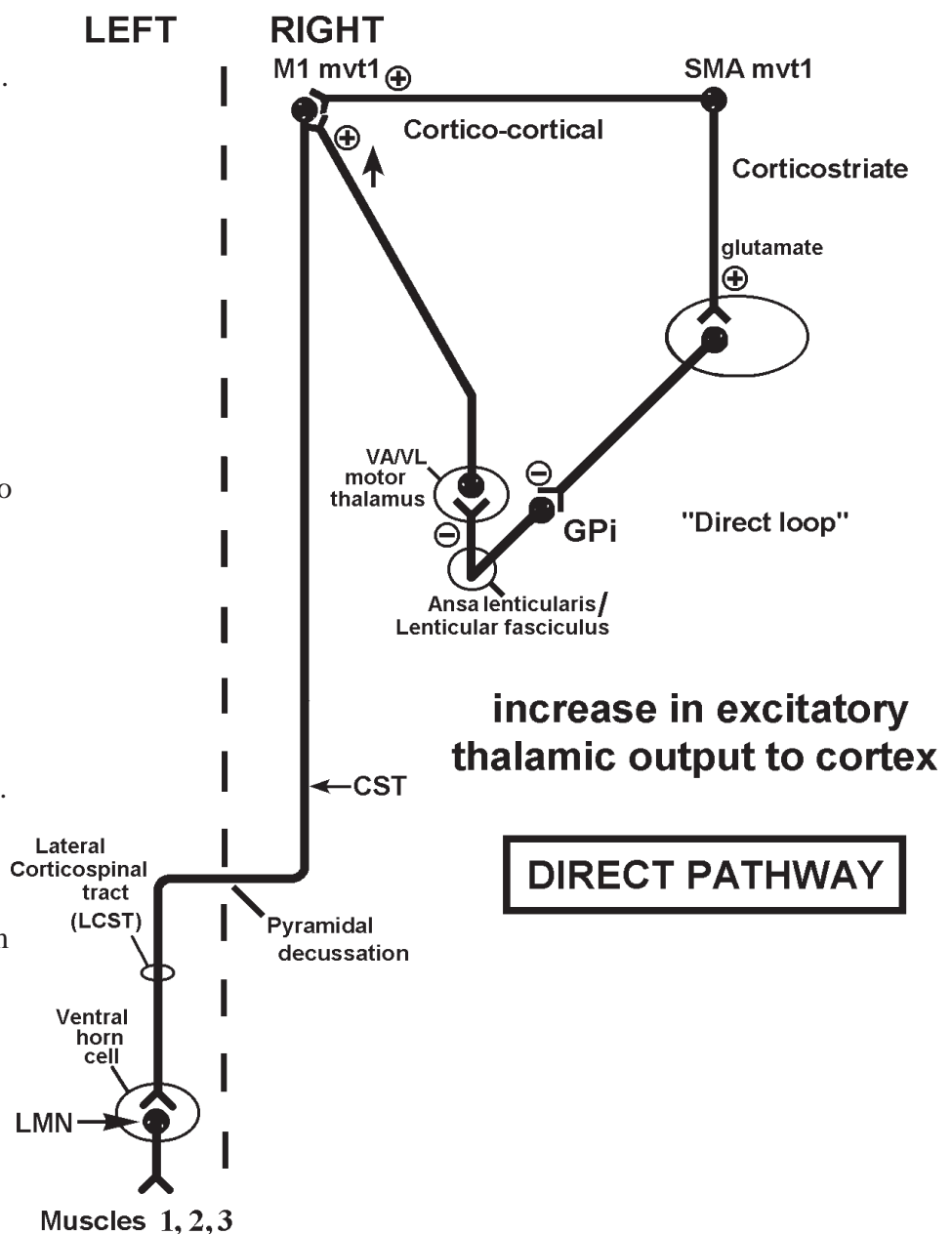


Cerebellum

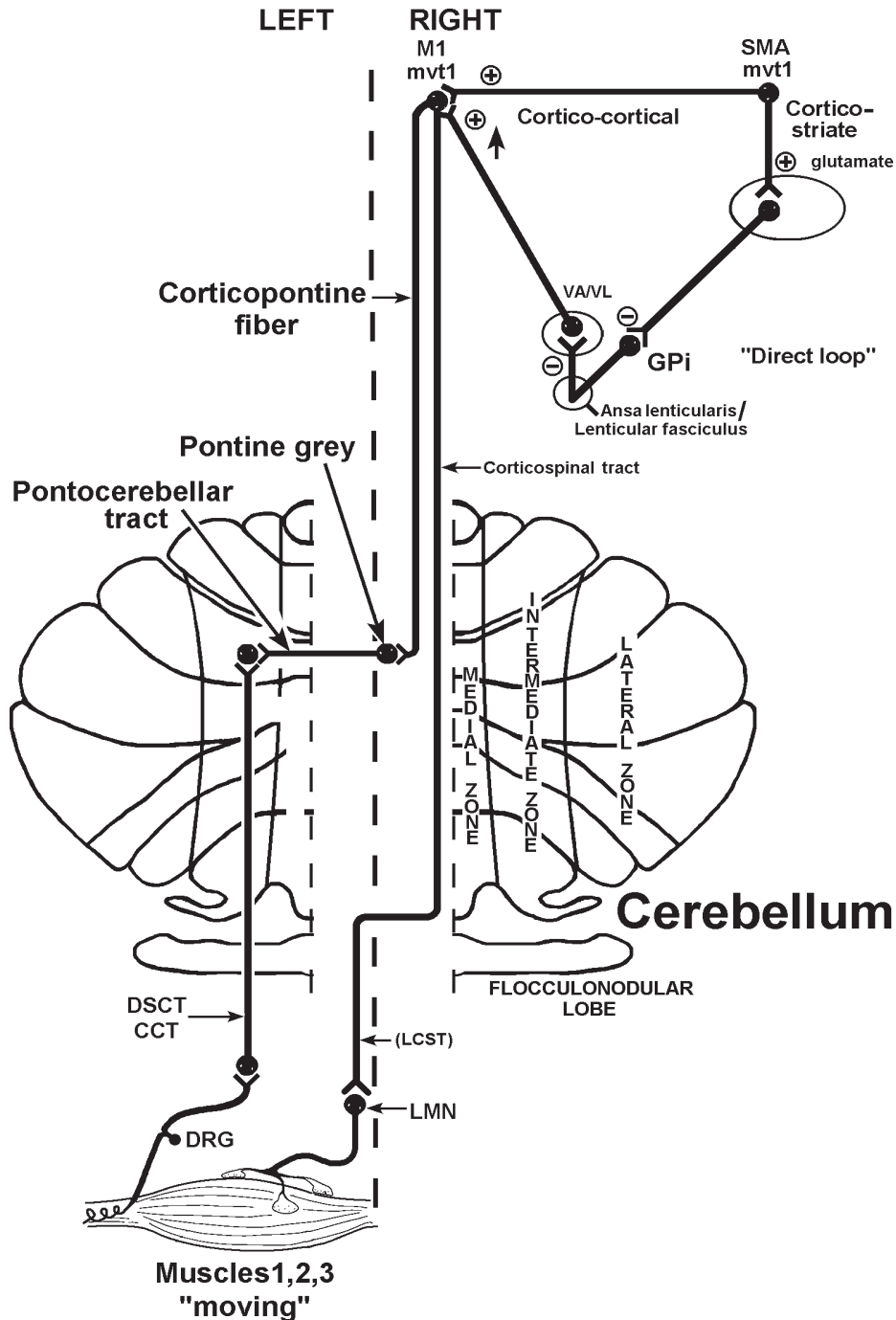
Our journey through the motor systems will now focus upon the “little brain,” the **cerebellum**. We will first present an **OVERVIEW** of cerebellar organization and connectivity as a natural extension of the discussion of the **current** and **planning** pathways just described. In this **OVERVIEW** (defined in Webster’s as “a short description of something which provides general information about it, but **NO** details”), many pathways that you already know will be briefly presented and there will be terms that you have not heard before. **DON’T PANIC!!** By its name, an **OVERVIEW** is just a sketch of where we are going. **EVERYTHING** in the **OVERVIEW** will be covered in detail later. So try to get the “big picture” from the overview and relate it to what you already know. Relax and have fun filling in the details later.

Let’s keep working with a movement that involves a couple of sequences (movements 1 and 2). Remember, the first sequence started with a **SMAmvt1** cell sending information directly to a **MImvt1** cell. At the same time, the **SMAmvt1** cell sends the same signal into the **direct loop** of the basal ganglia, so that the VA/VL can help **MImvt1** reach an appropriate firing rate. The **MImvt1** cell is a corticospinal neuron that sends its information to the contralateral LMNs in the spinal cord for **execution** of movement 1.

Now, for the **OVERVIEW**. The **MImvt1** cell also sends the same signal about the current movement (1) to the ipsilateral **pontine grey**. From the brain stem lectures you should (hopefully) remember these **corticopontine** fibers. You should also remember



that cells in the pontine grey have axons called **pontocerebellar fibers** that cross and enter the **middle cerebellar peduncle** and terminate in the cerebellar cortex. Each side of the cerebellum is divided into four different zones or regions called the flocculonodular, medial, **intermediate**, and lateral. The M1mvt1 information is conveyed (via corticopontine and pontocerebellar fibers) to the **intermediate zone**. That is, the M1mvt1 information does **NOT** reach the entire contralateral

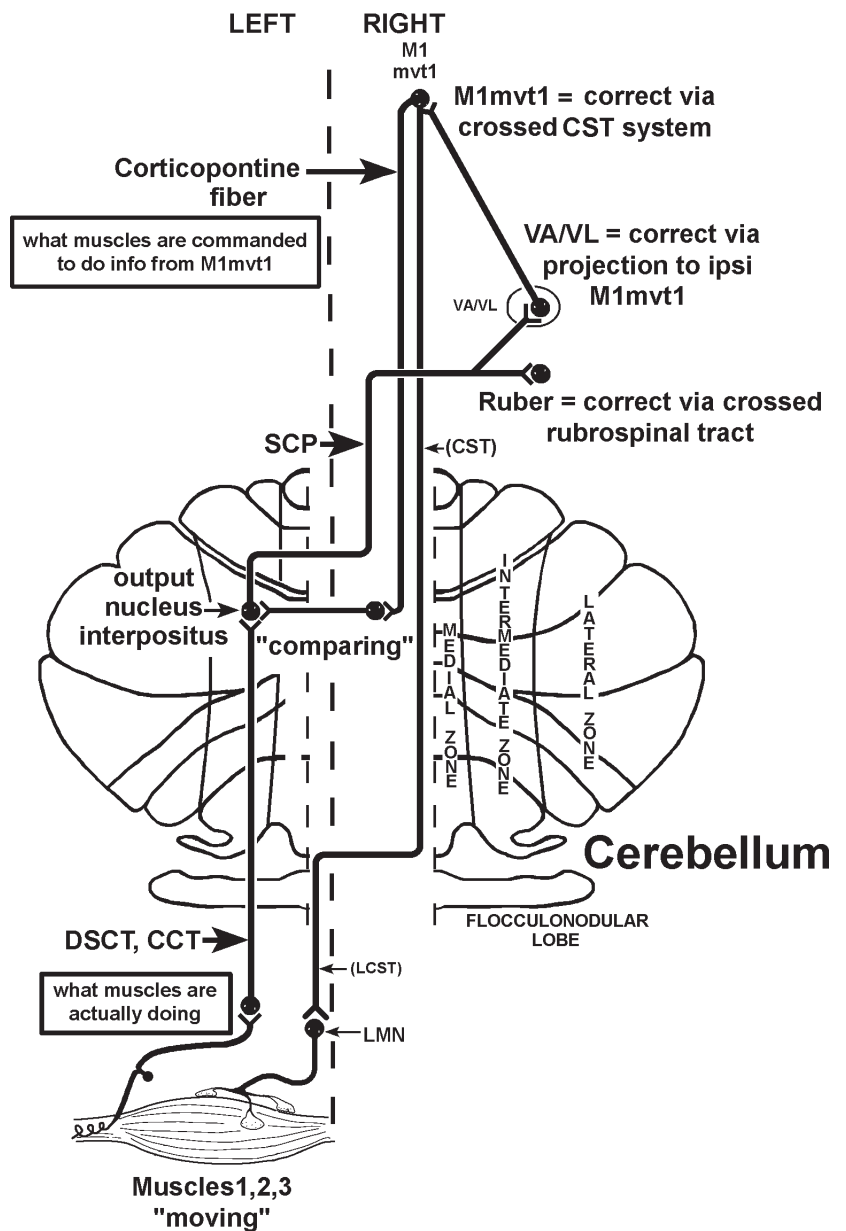


cerebellum (via the pontine grey), but instead reaches only one region and this is called the intermediate zone. As movement 1 is evolving, (remember, the **M1mvt1** corticospinals are firing away) the dorsal spinocerebellar and cuneocerebellar pathways are signaling to the cerebellum exactly **what** the muscles are doing. This unconscious proprioceptive information also reaches the

intermediate zone of the cerebellum. Thus, the incoming sensory information about **what** is happening in the muscles during movement 1 is “compared” to the information carried by the pontocerebellar fibers concerning what M1mv1 is **commanding** muscles 1,2,3 to do. Thus, the **intermediate zone** of the cerebellum is a region in which **comparisons** are made between the **movement being commanded by M1mv1** and what the muscles involved in the movement **are actually doing**.

You can see that one function of the cerebellum, (and in particular the intermediate zone), is to **update** and **correct** the ongoing or current movement. It integrates/compares the pontocerebellar and spinocerebellar information about the current movement and then sends updated, corrective signals to other parts of the motor systems that actually carry out the correction/update. You might recall from the brain stem lectures that the superior cerebellar peduncle is a major outflow tract of the cerebellum. The axons in the SCP arise from cells in **deep cerebellar nuclei**. Each cerebellar zone has a deep cerebellar nucleus. In the case of the **intermediate zone** (comparing/updating), axons arising in nucleus **interpositus** enter the **superior cerebellar peduncle**, cross, and synapse within the red nucleus and the motor related (VA/VL) nuclei of the thalamus. Signals sent down the rubrospinal tract update and correct the ongoing movement at the level of the spinal cord. In contrast, VA/VL inform M1mv1 about the correction that in turn is carried out via the corticospinal projection of M1mv1.

What you have learned so far in the overview of the cerebellum is pretty dense. To make sure you are getting the **MAIN POINTS**, try the practice questions on the next page. If you get them correct, go onto the next paragraph. If not, go back and read this section again. Repetition is good!



1. Which of the following statements is **TRUE**?

- A. corticopontine **fibers** conveying **MImvt1** information synapse in a region of the cerebellum called the **intermediate zone**
- B. the **intermediate zone** of the cerebellum receives information about the movement being planned versus the movement currently being carried out
- C. the **intermediate zone** of the cerebellum is involved in **comparing** the movement **command** with sensory information about **what** the muscles are doing
- D. the **intermediate zone** of the cerebellum “tells” the **ipsilateral** ruber and VA/VL about corrections needed for the **ongoing** movement
- E. the **intermediate zone** of the cerebellum has a deep nucleus that is called the dentate

2. Which of the following statements is **TRUE**?

- A. cells in the pontine grey targeted by corticopontine fibers from **MImvt1** send their axons to the ipsilateral intermediate zone of the cerebellum
- B. the rubrospinal tract is an uncrossed pathway
- C. the DSCT is a crossed pathway
- D. corticopontine fibers comprise a crossed projection
- E. the **intermediate zone** of the cerebellum is involved in **comparing** the movement **command** with sensory information about **what** the muscles are doing

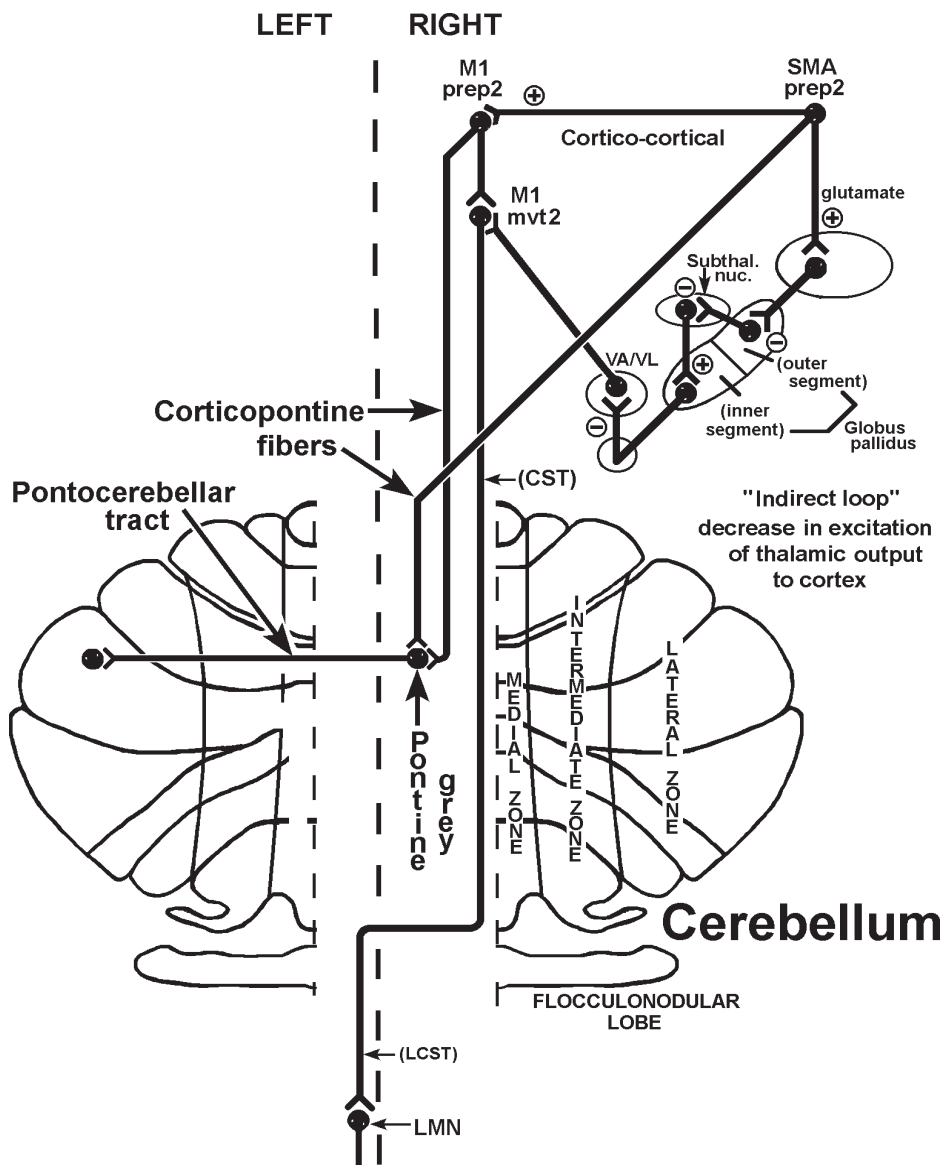
Answers

1. C 2. E

While movement #1 is taking place, **movement 2 is being planned**. You will recall that **SMAprep2** cells inform **MIprep2** cells about the planned (next) movement. In addition, **SMAprep2** sends the same planning information into the **Indirect** loop of the basal ganglia. Remember, the basal ganglia are inhibiting VA/VL and movement #2.

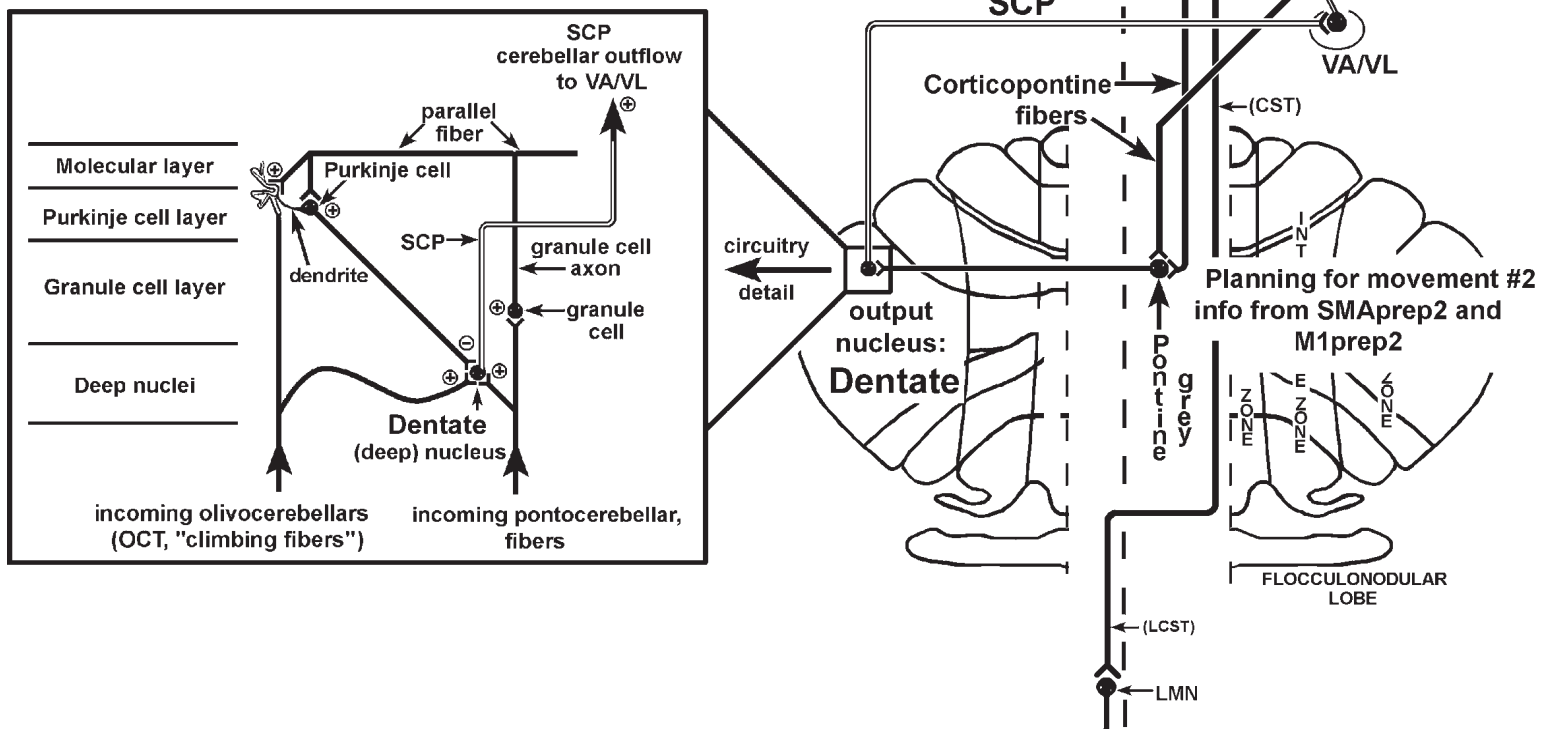
The **SMAprep2** and **MIprep2** cells send their **planning information** to the ipsilateral pontine grey (corticopontine) These “planning” **pontine grey** cells are in a different part of the pontine grey than those receiving corticopontine input about the current movement (1). These “planning” pontocerebellar cells send their axons into the opposite **middle cerebellar peduncle** (pontocerebellar) and terminate in the **lateral zone** of the cerebellum. You might ask, “what does the lateral cerebellum contribute to the plan for movement 2 that is not processed by **SMAprep2** or **MIprep2**?” One hypothesis is

that the **lateral zone** is involved in the storage and/or retrieval of long-term memory for motor skills. That is, when movement #2 was initially learned, circuitry in the lateral zone “learned” something about the movement that can now assist the SMA and MI. Thus, when **SMAprep2** and **MIprep2** information reaches the lateral zone (via corticopontine and then pontocerebellar fibers), specific cerebellar circuits that were laid down when the movement was initially learned are activated. So, information about movement 2 is contained not only in cortical areas (**SMAprep2** and **MIprep2**), but also in the lateral zone of the cerebellum.



The integrated **planning** information is conveyed out of the **lateral zone** of the cerebellum via the deep cerebellar nucleus of the lateral zone, the **dentate nucleus**. Axons of dentate neurons enter the superior cerebellar peduncle, cross, and terminate in **VA/VL**. From the VA/VL, the planning information reaches **SMAprep2** and **M1prep2** cells.

Lateral zone of the Cerebellum



Well, most of the hard stuff has been covered in this overview. How about another practice question or two in order to see if you are getting the drift.

1. Which of the following statements is **TRUE**?
 - A. information regarding the **ongoing** movement reaches the **lateral zone** of the cerebellum
 - B. the **intermediate** zone is a “comparator/updater”
 - C. information about a **planned** movement is conveyed to the **red nucleus**
 - D. cells in the **lateral zone** of the cerebellum receive **direct** input from corticopontine fibers
 - E. information regarding a movement being **planned** reaches the **intermediate zone** of the cerebellum

2. Which of the following statements is **TRUE**?
 - A. fibers in the superior cerebellar peduncle end exclusively in the ruber/duber
 - B. the dentate nucleus is involved in updating
 - C. the lateral zone of the cerebellum receives information from Clarke’s column
 - D. cerebellar lesions result in contralateral motor deficits
 - E. none of the above are **TRUE**

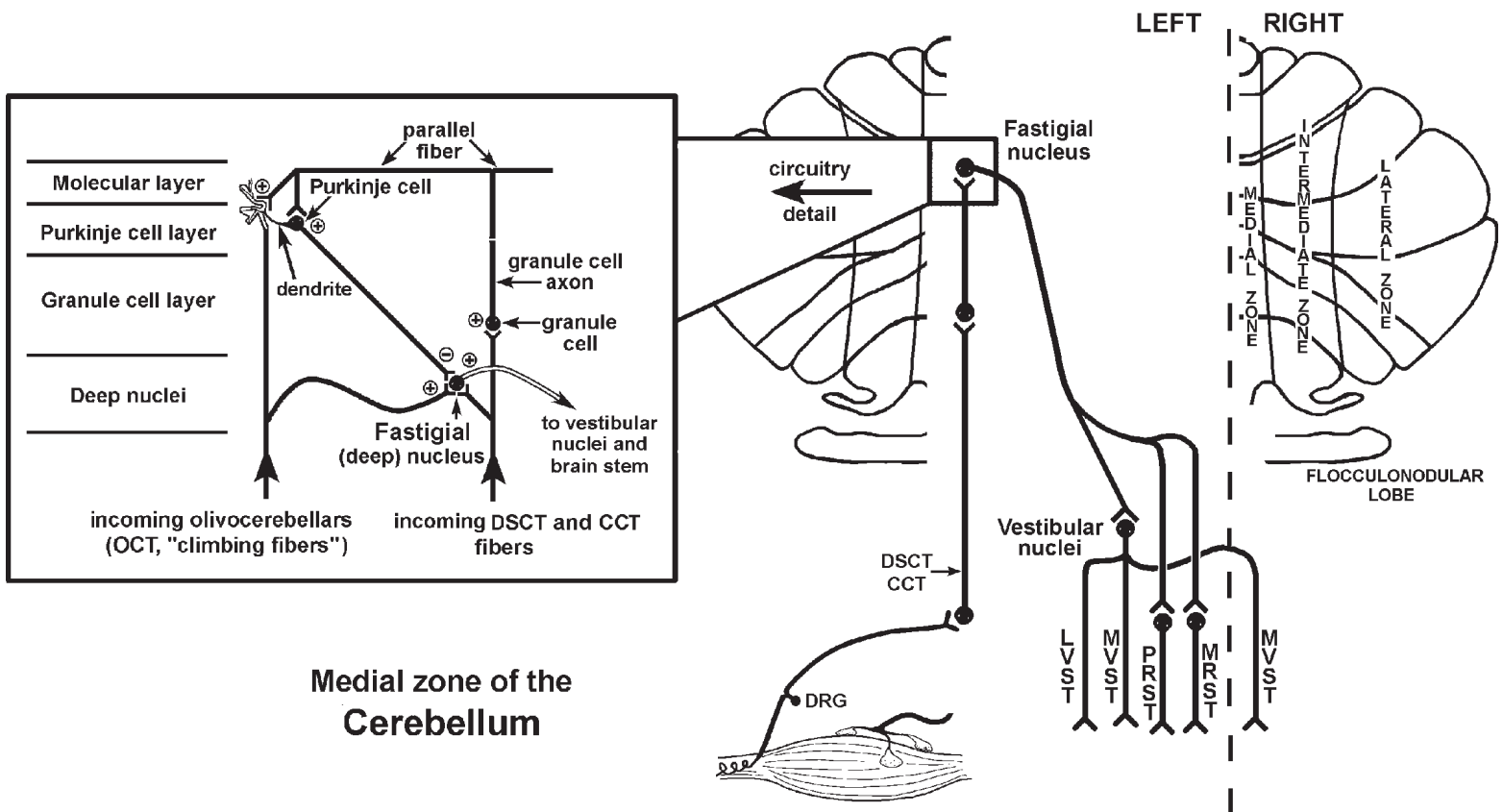
Answers 1. B 2. E

We can see from the **OVERVIEW** thus far presented that the cerebellum is involved with updating/comparing and the planning of movements. There are other parts of the cerebellum that are involved in other aspects of motor functions. These are the **medial zone** and the flocculonodular lobe/zone.

The **medial zone** of the cerebellum receives sensory information (unconscious proprioception) from the **dorsal spinocerebellar** and **cuneocerebellar** tracts (just like the intermediate zone). This sensory information reaches the ipsilateral **medial zone** via the **inferior cerebellar peduncle** (what other fibers are in this peduncle?). To exit the cerebellum, the axons of cells in the **deep cerebellar nucleus** of the medial zone, the **fastigial**, pass ipsilaterally via the inferior cerebellar peduncle to reach the **vestibular nuclei** and the **pontine** and **medullary reticular formation**.

You know that the **vestibular nuclei** project to the **PPRF** (for horizontal eye movements) and the **spinal cord** (via the MVST and LVST) and that these two pathways are important components of the postural and balance-related **ventromedial** brain stem system. You already know that **pontine reticulospinal (PRST)** and **medullary reticulospinal tract (MRST)** fibers travel in the ventral funiculus and are also part of the descending ventromedial system. The **PRST** enhances the **antigravity reflexes** of the spinal cord. Thus, this pathway facilitates **extensors of the lower limb** and **flexors of the upper limb** in order to help maintain posture against the force of gravity. This is an important component of motor control, since most of the time the activity of ventral horn cells maintains, rather than changes, muscle length and tension. The **MRST** has the opposite effect of the **PRST**, in that it frees the antigravity muscles from reflex control (is inhibitory). Therefore, the descending cortical pathways that reach the pontine and medullary reticular formation preside over control of a delicate balance between the two pathways.

Now that we know about three zones of the cerebellum, let's try another practice question before going on to the fourth zone.



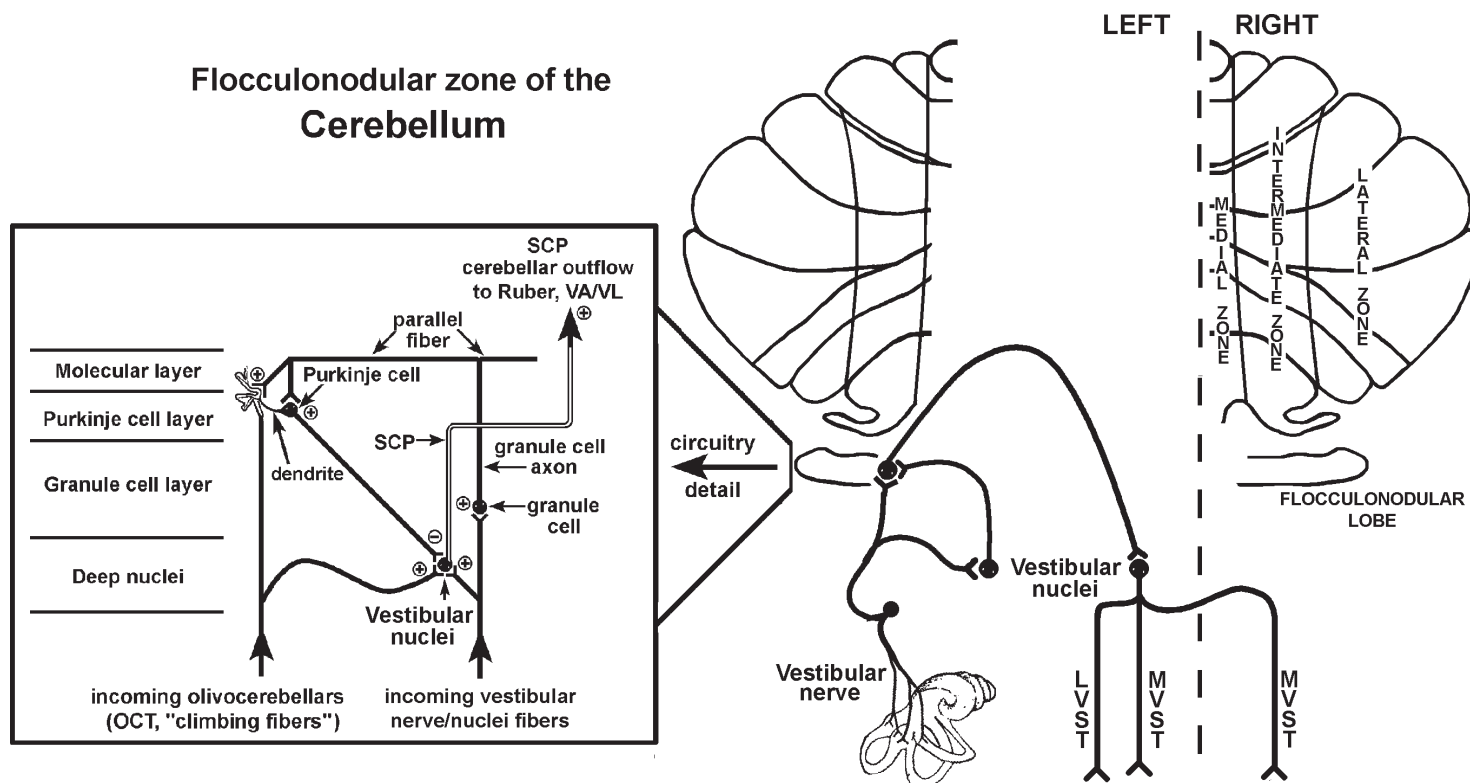
Medial zone of the Cerebellum

Which of the following statements is **TRUE**?

- A. the medial zone of the cerebellum is connectionally related to the reticular formation
- B. the deep nucleus of the medial zone of the cerebellum is the dentate
- C. the medial zone of the cerebellum exhibits connections with the ruber
- D. the medial zone of the cerebellum has a major influence on VA/VL
- E. the medial zone of the cerebellum receives a major pontocerebellar projection

Answer A

The remaining zone of the cerebellum is called the **flocculonodular** or **vestibular zone lobe**. This zone receives only vestibular information from the **vestibular nerve** and the **vestibular nuclei**. Interestingly, the deep cerebellar nuclei of the flocculonodular lobe is/are the **VESTIBULAR NUCLEI**, which as you already know give rise to the **LVST** and the **MVST**. Unlike the dentate, interpositus and fastigial, which are deep cerebellar nuclei that lie in the cerebellum, the vestibular nuclei are in the brain stem.



As mentioned several times, the material covered so far has been dealt with in a cursory manner, the details of which will follow. Trust us! For now, we want you to understand the basic concepts presented in this overview. To see if you know them, do the following Practice Question. If you can answer it, you are doing GREAT! If you can't, re-read the section!

Which of the following associations is/are is **TRUE**?

- A. lateral zone—dentate, planning, memory, SMAprep2 input via pons, comparing
- B. intermediate zone—fastigial, pontocerebellar fibers, updating
- C. vestibular cerebellum or flocculonodular lobe—LVST, MVST, pontocerebellar input
- D. medial zone—fastigial, DSCT, CCT
- E. pontine grey—lateral zone, intermediate zone, corticopontine fibers, middle cerebellar peduncle, planning, inferior cerebellar peduncle

Answer D

THE ULTIMATE OVERVIEW

The cerebellum is involved in taking the MImvt1 signal and comparing it with the DSCT and CCT signals. It makes corrections via its outflow to the ruber (rubrospinal makes correction) and VA/VL; the latter project to MImvt1 for the correction. This updating/comparing/correcting takes place in the intermediate part or zone of the cerebellum and the outflow nucleus is the interpositus via the superior cerebellar peduncle to reach the ruber and VA/VL. The rubrospinal tract causes a fast correction while the VA/VL projection enables the thalamus to tell MI to make a certain correction.

The cerebellum is also involved in the **planning** of the next movement. Planning information from SMA and MI reaches the cerebellum and is integrated with circuits that contain other types of information regarding the planned movement. This planning takes place within the lateral region or zone of the cerebellum and the outflow nucleus is the dentate via the superior cerebellar peduncle to reach the VA/VL, which in turn tells planning areas of MI and SMA about the planning information that it “picked up” in the cerebellum.

The cerebellum is also involved in the control of posture, balance, and eye movements. It does this via the medial and flocculonodular zones. Thus, the medial zone receives DSCT and CCT unconscious proprioception and uses the outflow of the fastigial to control the reticular formation (PRST and MRST) and the LVST and MVST. We do not know what the circuitry of the cerebellum “does” to the DSCT and CCT signals, but there must be some integration before the fastigial sends information out of the cerebellum.

The flocculonodular lobe receives only vestibular inputs and uses the vestibular nuclei as its deep cerebellar nucleus to control posture, balance and eye movements. Again, we do not know what happens to the vestibular information within the cerebellum.

A great Practice Question for **THE ULTIMATE OVERVIEW** is on the next page.

Which of the connectional/functional associations are **TRUE**? (more than one is correct)

- A. planning—fastigial
- B. updating—vestibular nuclei
- C. MImvt1—dentate
- D. superior cerebellar peduncle—fastigial
- E. DSCT—lateral zone
- F. CCT—dentate
- G. vestibular nerve—intermediate zone
- H. vestibular nuclei—lateral zone
- I. eye movements—dentate nucleus
- J. fastigial—middle cerebellar peduncle
- K. dentate—VA/VL
- L. MVST—fastigial
- M. LVST—fastigial
- N. flocculonodular lobe—fastigial
- O. ruber—fastigial
- P. VA/VL—fastigial
- Q. MRST and PRST—interpositus
- R. corticopontine fibers—inferior cerebellar peduncle

Answer K, L, M

ONE MORE TIME

The cerebellum is involved in taking the MImvt1 signal and comparing it with the DSCT and CCT signals. It makes corrections via its outflow to the ruber (rubrospinal makes correction) and VA/VL; the latter project to MImvt1 for the correction. This **updating/comparing/correcting** takes place in the intermediate part or zone of the cerebellum and the outflow nucleus is the interpositus via the superior cerebellar peduncle to reach the ruber and VA/VL. The rubrospinal tract causes a fast correction while the VA/VL projection enables the thalamus to tell MI to make a certain correction.

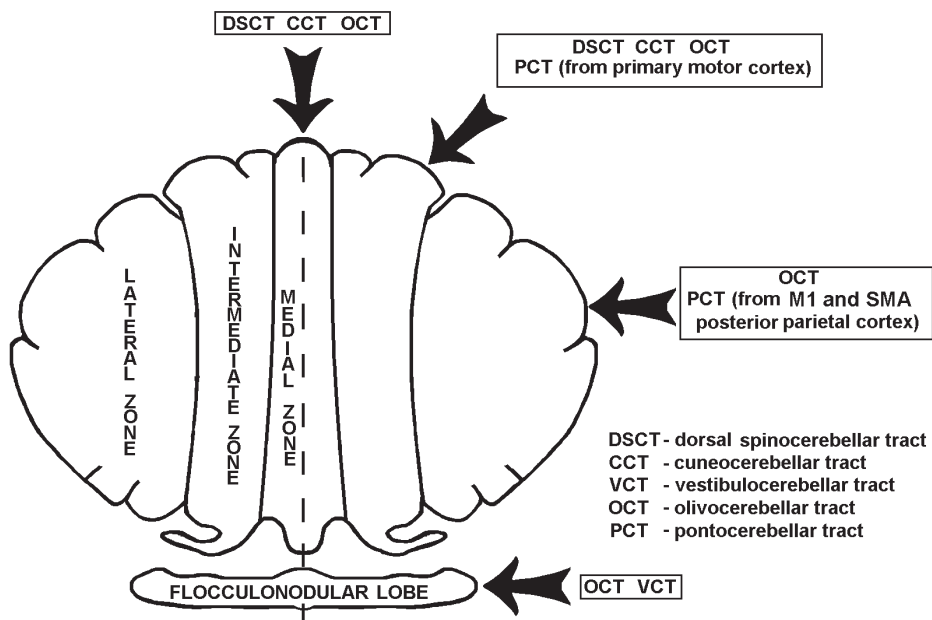
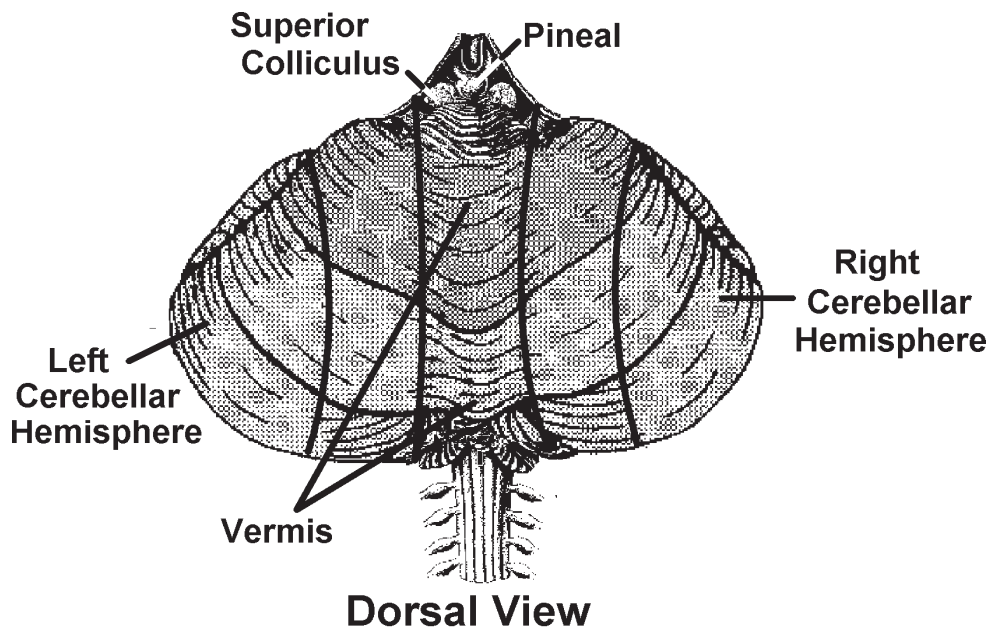
The cerebellum is also involved in the **planning** of the next movement. Planning information from SMA and MI reaches the cerebellum and is integrated with circuits that contain other types of information regarding the planned movement. This planning takes place within the lateral region or zone of the cerebellum and the outflow nucleus is the dentate via the superior cerebellar peduncle to reach the VA/VL, which in turn tells planning areas of MI and SMA about the planning information that it “picked up” in the cerebellum.

The cerebellum is also involved in the control of posture, balance, and eye movements. It does this via the medial and flocculonodular zones. Thus, the medial zone receives DSCT and CCT unconscious proprioception and uses the outflow of the fastigial to control the reticular formation (PRST and MRST) and the LVST and the MVST. The flocculonodular lobe receives only vestibular inputs and uses the vestibular nuclei as its deep cerebellar nucleus to control posture, balance and eye movements.

NOW FOR SOME DETAILS!!

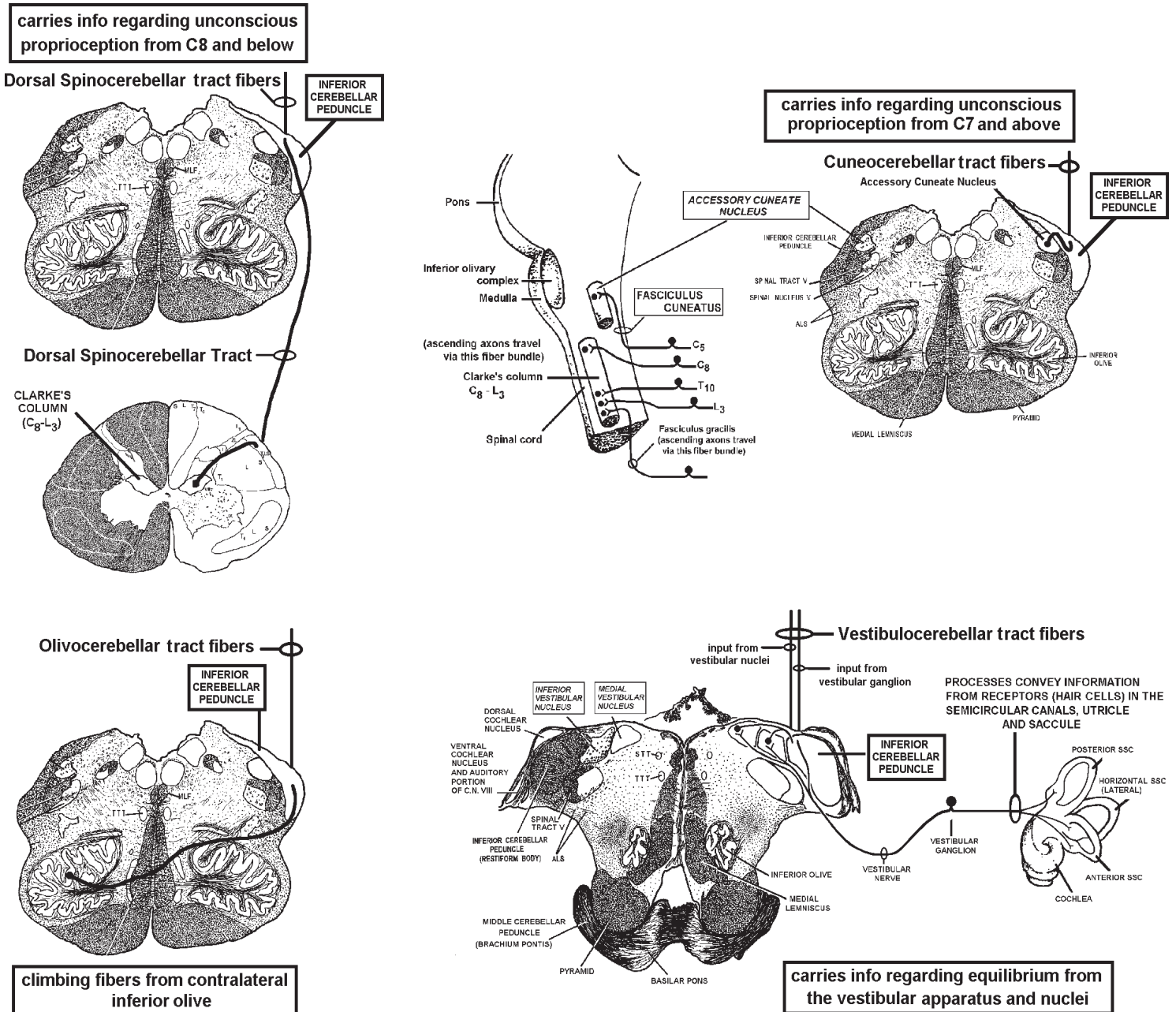
In the overview we mentioned the lateral, intermediate, medial, and flocculonodular (vestibulocerebellum) zones of the cerebellum. These are just general areas of the cerebellum. For instance, if we look at the **dorsal view** of the cerebellum, you can approximate where most of these zones are. You can see the solid lines that run rostral (near the superior colliculus) to caudal (near the spinal cord). You can see such areas as the **vermis**, which is the medial worm-like part of the cerebellum. This vermis region was identified by the **OLD-** time anatomists and consists of the two (right and left) medial zones. You can also see the more laterally placed cerebellar **hemispheres**, which correspond mainly to the lateral zones.

It is difficult to see the flocculonodular lobe as it is tucked underneath. In the lower of the two drawings, the flocculonodular lobe is shown at the caudal end of the dorsal view of the cerebellum. **The main point that you need to know is that different regions of the cerebellum receive different inputs and project to different parts of the brain stem and thalamus.**

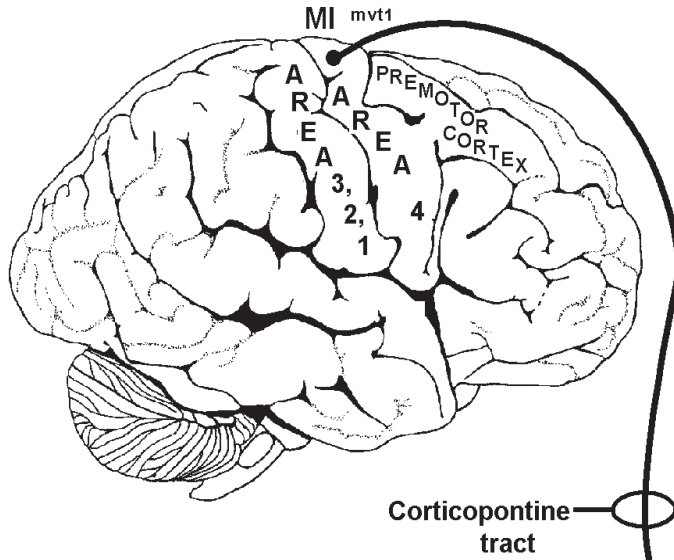


In the overview, we mentioned the peduncles. Now, for some details about those peduncles, most of which you already know!!

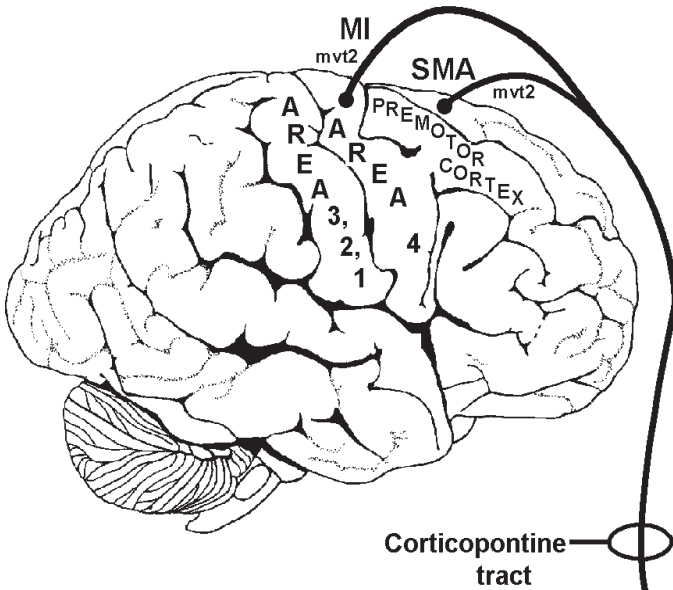
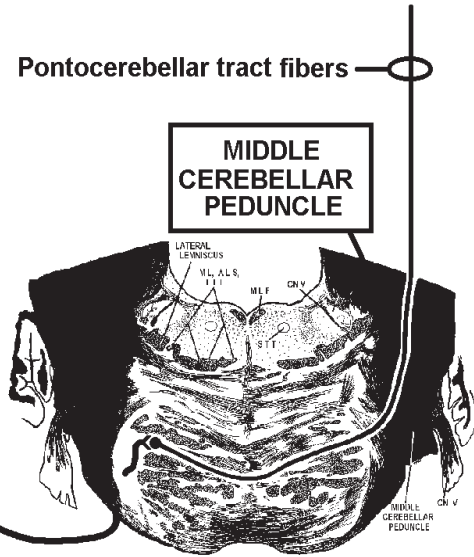
We know that the **inferior cerebellar peduncle** (restiform body) contains the **dorsal spinocerebellar tract** (DSCT) fibers. These fibers arise from cells in the **ipsilateral** Clarke's column in the spinal cord (C8-L3). We also know that this peduncle contains the **cuneocerebellar tract** (CCT) fibers. These fibers arise from the **ipsilateral** accessory cuneate nucleus. The largest component of the inferior cerebellar peduncle however consists of the **olivocerebellar tract** (OCT) fibers. These fibers arise from the **contralateral** inferior olive. These were not discussed in the overview but will be presented later. Finally, some of you might remember from Point #13 that **vestibulocerebellar tract** (VCT) fibers arise from cells in both the **vestibular ganglion** and the **vestibular nuclei** and pass in the inferior cerebellar peduncle to reach the cerebellum. In the overview we learned that the **DSCT** and **CCT** terminate in the **medial** and **intermediate zones**, while **VCT** fibers reach the **flocculonodular lobe**.



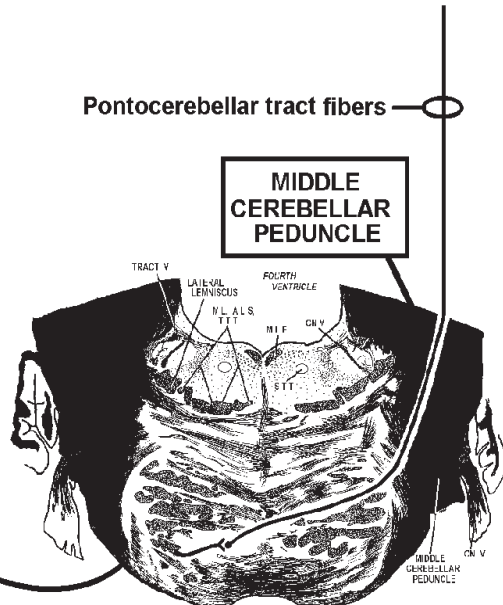
We also know that the **middle cerebellar peduncle** (brachium pontis) contains the **pontocerebellar tract** (PCT) fibers. These fibers arise from the **contralateral** pontine grey. **In the overview we learned that there are pontocerebellar fibers conveying information that they received from MI_{mvt1} about the current movement; they go to the intermediate zone. There are also pontocerebellar fibers that are carrying information regarding SMA_{prep2} and MI_{prep2} planning/memory data; these reach the lateral zone.**



carries info that started in the contra motor cortex and has been relayed via the contra pontine grey



carries info that started in the contra MI and SMA and has been relayed via the contra pontine grey



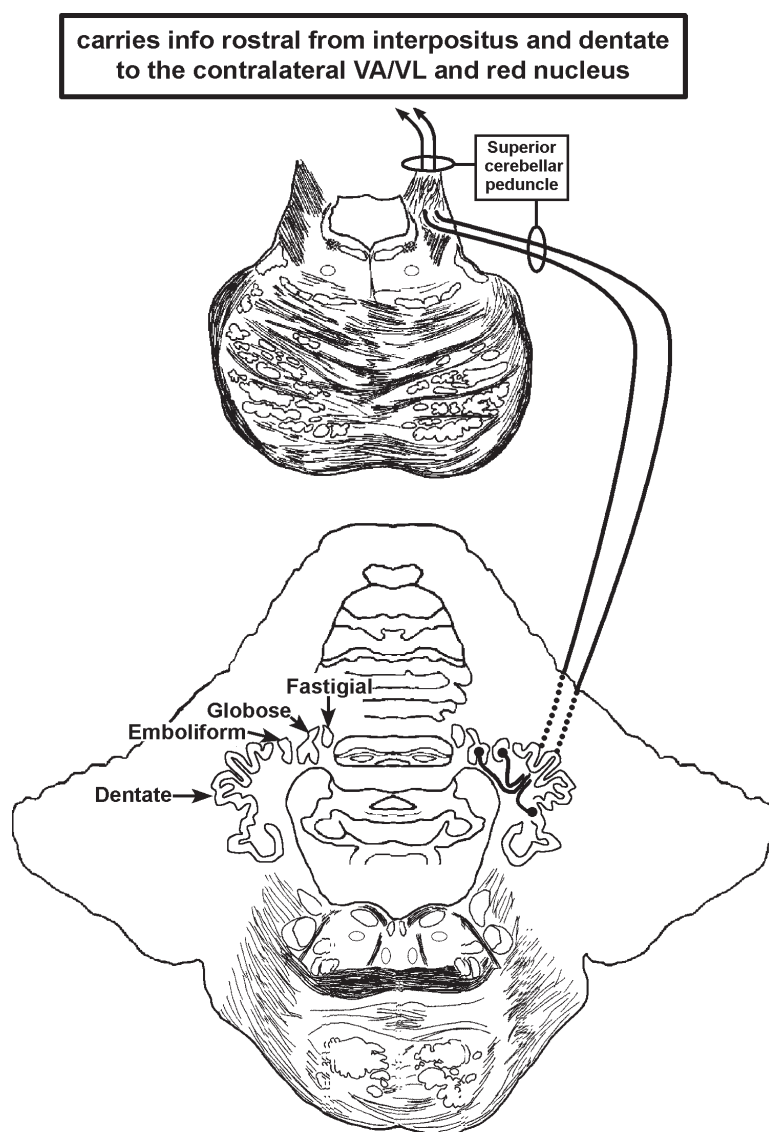
Finally, we know that the **superior cerebellar peduncle** (brachium conjunctivum; Point 18) is the primary **efferent** peduncle of the cerebellum. It contains fibers that arise from two deep cerebellar nuclei. These fibers pass rostrally for a while (ipsilaterally) and then cross at the level of the inferior colliculus to form the decussation of the superior cerebellar peduncle. These fibers then continue rostrally to terminate in the red nucleus and the motor nuclei of the thalamus (VA/VL). **In the overview we learned that SCP fibers associated with the intermediate zone (comparing, updating) arise from nucleus interpositus and terminate in the red nucleus and VA/VL. The information reaching VA/VL from nucleus interpositus is conveyed to MI. The fibers in the SCP that are conveying information from the lateral zone (planning, memory) arise in the dentate nucleus and terminate in the VA/VL. From VA/VL, the planning information reaches SMA and MI.**

LET'S REVIEW

INFERIOR CEREBELLAR PEDUNCLE = DSCT, CCT, OCT, VCT

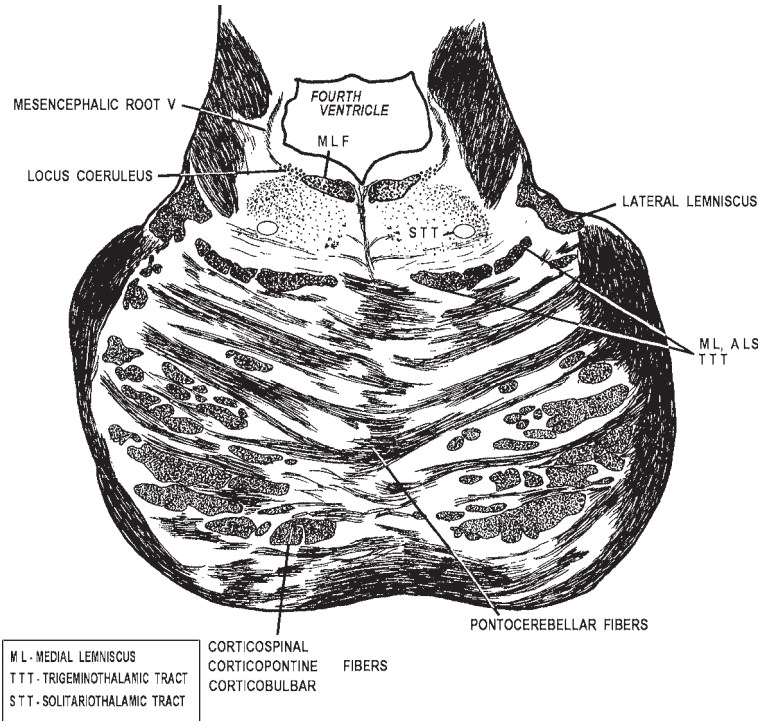
MIDDLE CEREBELLAR PEDUNCLE = PONTOCEREBELLARS

SUPERIOR CEREBELLAR PEDUNCLE = EFFERENT FIBERS



Try the questions below to see how you stand regarding the identity and components of the three cerebellar peduncles.

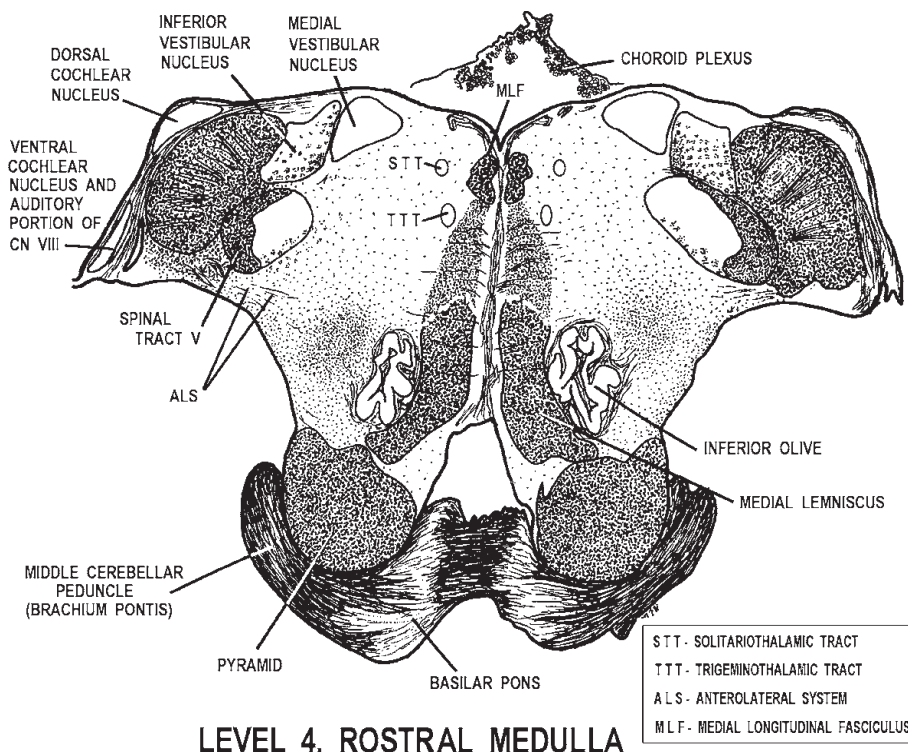
1. A. Name the peduncle that lies adjacent to the fourth ventricle in the section below. _____



LEVEL 7. ROSTRAL PONS

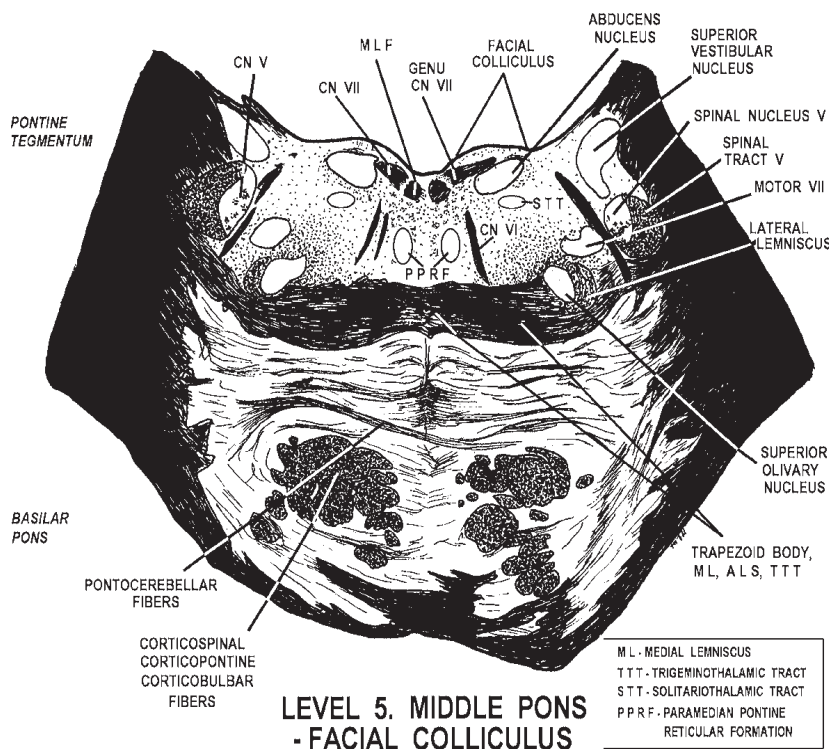
B. Where are the cells of origin of the axons in this peduncle? _____

2. A. Name the peduncle present in the dorsal part of the section below. _____



LEVEL 4. ROSTRAL MEDULLA

- B. Name four fiber tracts that contribute to this peduncle _____, _____, _____, _____
3. A. Name the peduncle present in the section below. _____

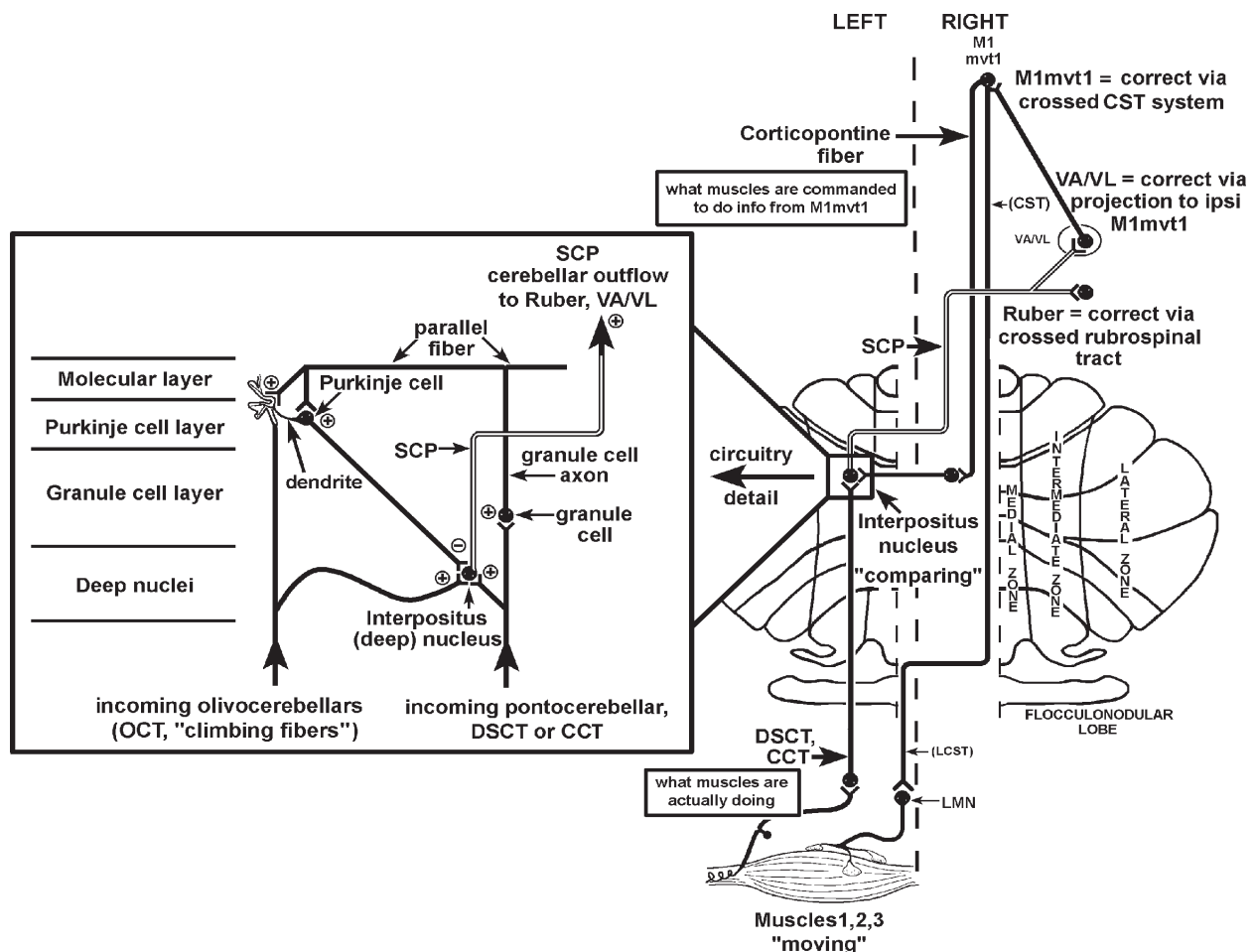


- B. Where are the cells of origin of the axons in this peduncle? _____
4. Which of the following statements is **TRUE**?
- A. the lateral zone of the cerebellum is functionally related to ACh cells that inhibit striatal neurons (THINK!)
- B. the medial zone of the cerebellum is functionally related to the dorsolateral pathway of the brain stem
- C. the VA/VL is functionally related to the ventromedial pathway of the brain stem
- D. the lateral zone of the cerebellum is functionally related to the GPe
- E. the intermediate zone of the cerebellum is functionally related to striatal cells that are inhibited by DA (dopamine)

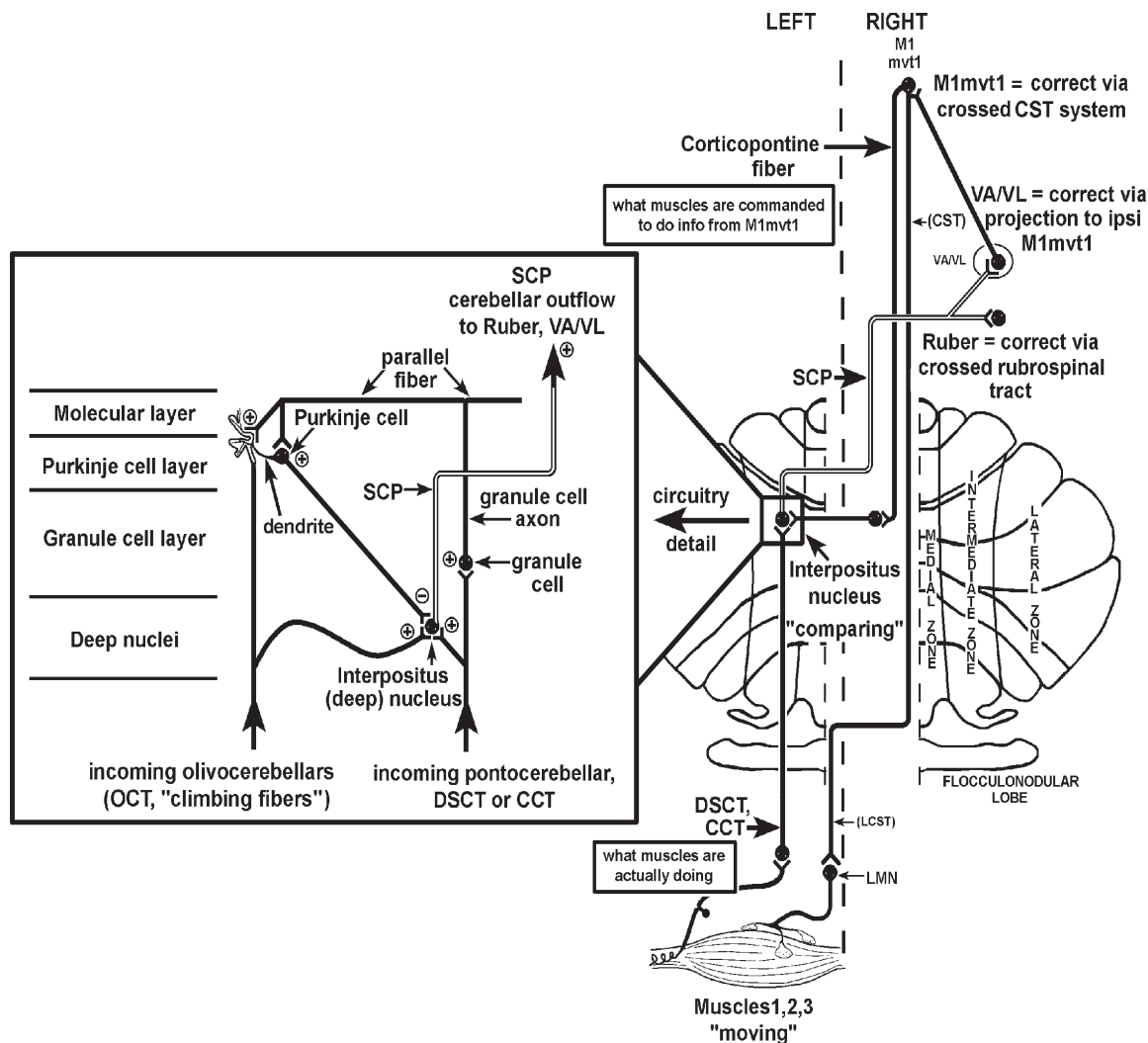
Answers

1. A. superior cerebellar peduncle
B. deep cerebellar nuclei
2. A inferior cerebellar peduncle
B. OCT, DSCT, CCT, VCT
3. A. middle cerebellar peduncle
B. contralateral pontine grey
4. D

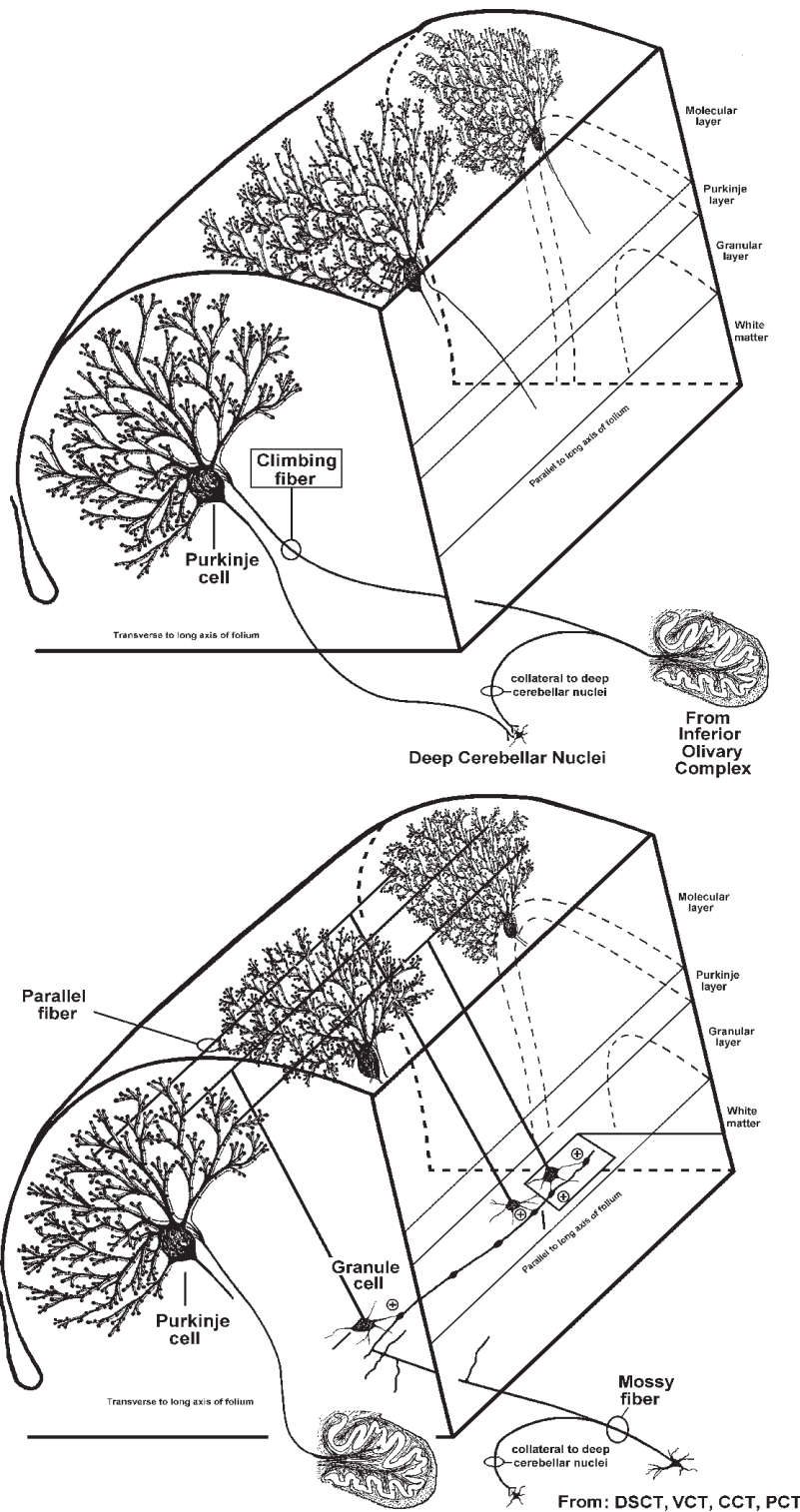
In the **overview** section you learned that the cerebellum receives **afferent signals** from DSCT, CCT, pontocerebellar and vestibulocerebellar fibers. **It also receives olivocerebellar fibers and they reach all zones.** Information is sent **out** of the cerebellum via axons arising in the various **deep cerebellar nuclei** (vestibular nuclei, fastigial, interpositus, dentate). This is true, but there are a “few cells” between the incoming afferents and the deep nuclei outflow. In the not-too-distant-past, we spent considerable time on these “in between cells.” However, several years ago we decided that you don’t need this information to be good docs, but we do want to show you the circuitry so that you at least hear the names of the cells. The drawing below is the schematic seen earlier where the inputs and output of the **intermediate zone** are depicted. **However, a new wrinkle has been added!** The space between the inputs and the deep nucleus/output is filled with the circuitry that we will briefly present. The same circuitry exists **between the inputs and outputs** in all four zones.



Cerebellar afferents that arise from the pons, the accessory cuneate nucleus, or Clarke's column enter the cerebellum and terminate as **mossy fibers**. These fibers excite a deep nucleus (interpositus) and then excite **granule cells**. Granule cells send axons dorsally in the cerebellar cortex, where they branch and become **parallel fibers**. Parallel fibers then excite **Purkinje cells**. If the cerebellar afferent arises from the **inferior olive** it is called a "**climbing**" fiber. As these fibers enter the cerebellum they send a branch to, and excite, the interpositus and then "climb" up and excite the **Purkinje cell** (the CF synapses also end on the cell body of Purks, which is not shown in the drawing above). The Purkinje cells in the intermediate zone **INHIBIT** (GABA-ergic) cells in nucleus interpositus. Keep in mind the mossy and climbing fibers are **exciting** the interpositus, so the inhibitory Purkinje cell input kind of "sculpts" this excitatory input to the interpositus. **REMEMBER, ALL PURKINJE CELLS INHIBIT THEIR DEEP CEREBELLAR NUCLEI, WHILE ALL DEEP NUCLEI EXCITE THEIR TARGETS.**



Let's review. The information destined for the intermediate zone comes into the cerebellum via mossy (DSCT, CCT, pontocerebellars, vestibulocerebellars) and climbing fibers (inferior olive) fibers. The information is sent through the maize of circuitry (mossy-granule cell-Purk-deep cerebellar nucleus; climbing-Purk-deep cerebellar nucleus). Once it gets to the deep nucleus(ei) it can head out of the cerebellum. The **EXCITATORY** signal sent out of the cerebellum (via the interpositus) is the result of the Purkinje cell inhibitory modulation of the excitatory inputs (mossy and climbing fibers) reaching the deep nuclei. **Finally, we do not have a clear understanding of what the circuitry does.**



1. Which of the following associations is/are **TRUE**?

- A. climbing fiber—inhibits Purk cell
- B. climbing fiber—contacts granule cell
- C. climbing fiber—inhibits deep nucleus
- D. climbing fiber—processes become parallel fibers
- E. climbing fiber—arises from pontine grey
- F. mossy fiber—arises from “da olive”
- G. granule cell—excites deep cerebellar nuclei
- H. mossy fiber—inhibits deep cerebellar nuclei
- I. mossy fiber—inhibits Purk cell
- J. mossy fiber—terminates on Purk cell
- K. Purk cell—excites interpositus
- L. Purk cell—excites dentate
- M. Purk cell—excites fastial
- N. Purk cell—inhibits vestibular nuclei

Answer is N

2. Which of the following statements regarding climbing fibers is **TRUE**?

- A. those ending in the flocculonodular zone arise from the inferior olive
- B. those ending in the medial zone arise from the inferior olive
- C. those ending in the intermediate zone arise from the inferior olive
- D. those ending in the lateral zone arise from the inferior olive
- E. all of the above are **TRUE**

Answer is E

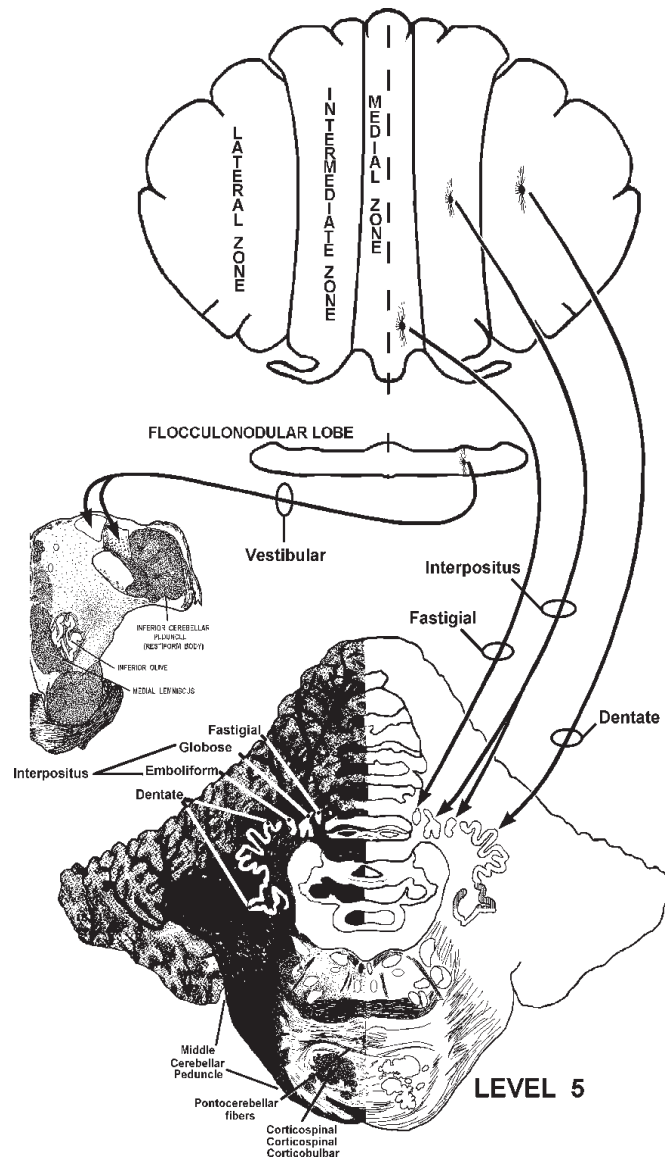
3. Which of the following statements regarding mossy fibers is **TRUE**?

- A. those reaching lateral zone are solely pontocerebellar
- B. those reaching intermediate zone are pontocerebellar, DSCT and CCT
- C. those reaching medial zone solely DSCT and CCT
- D. those reaching the flocculonodular zone are from the vestibular ganglion
- E. all of the above are **TRUE**

Answer is E

Now, back to the **deep cerebellar nuclei**. You already know a lot about them from the overview, but let's reiterate some important facts.

You need to know that Purkinje cells **INHIBIT** the deep cerebellar nuclei and ultimately affect the output of the cerebellum. Let's look at the distribution of Purkinje cell axons. Purkinje cells in the four different zones, **MEDIAL, INTERMEDIATE, LATERAL AND FLOCCULONODULAR**, project to the different deep cerebellar nuclei, fastigial, globose+emboliform=interpositus, and dentate (feel good every day) from medial to lateral. These deep cerebellar nuclei can be seen below in an old friend from the brain stem, level 5. You have not seen the dorsal part of this section before, but it shows three of the four sets of **deep cerebellar nuclei**. The distribution of Purkinje cell axons to the cerebellar nuclei is actually quite easy to remember because it is topographically organized. The most **lateral** deep cerebellar nucleus, the **dentate**, receives its Purkinje cell input from the **lateral** zone of the cerebellum. Remember that this **lateral** zone of the cerebellum receives its input from olivocerebellar and pontocerebellar fibers carrying planning information from MI and SMA. The **interpositus** nucleus receives its Purkinje cell input from the **intermediate** zone of the cerebellum. The **intermediate** zone of the cerebellum receives its input from olivocerebellar and pontocerebellar fibers carrying information from primary motor cortex (area 4) **AND** from the DSCT and CCT. The Purkinje cells that innervate the medially located **fastigial** nucleus lie in the **medial** zone of the cerebellum which, as you certainly remember, receives input from the DSCT, CCT and OCT.



Purkinje cells in the flocculonodular zone (or lobe) also need a deep nucleus. Unfortunately there isn't a deep nucleus left for the flocculonodular zone, so the Purkinje cells of the flocculonodular lobe terminate in the **VESTIBULAR NUCLEI**, which we can consider as a "surrogate" deep cerebellar nucleus. Those Purkinje cell axons that are destined for the vestibular nuclei travel in the inferior cerebellar peduncle (along with the fibers from the vestibular nerve and nuclei that are entering the cerebellum).

As mentioned earlier, the signals from the Purkinje cells that terminate in the deep cerebellar nuclei are **inhibitory**. Think of the inhibitory signal as increasing or decreasing depending upon what is happening in the cerebellum (via the **intrinsic circuitry**) Also remember that the deep cerebellar nuclei receive **EXCITATORY** inputs from the collaterals of both mossy and climbing fibers as they pass through the deep white matter on their way to the overlying cerebellar cortex. The interplay of the inhibitory (Purkinje cell) and excitatory (mossy and climbing fiber) inputs to the deep nuclei determines their output signals to the other parts of the brain.

LET'S REVIEW

PURKINJE CELLS IN THE:

LATERAL ZONE OF CEREBELLUM FEED INTO AND INHIBIT THE **DENTATE**

INTERMEDIATE ZONE FEED INTO AND INHIBIT THE **INTERPOSITUS (globose and emboliform)**

MEDIAL ZONE FEED INTO AND INHIBIT THE **FASTIGIAL**

FLOCCULONODULAR LOBE FEED INTO AND INHIBIT THE **VESTIBULAR NUCLEI**

HERE'S ANOTHER PRACTICE QUESTION!

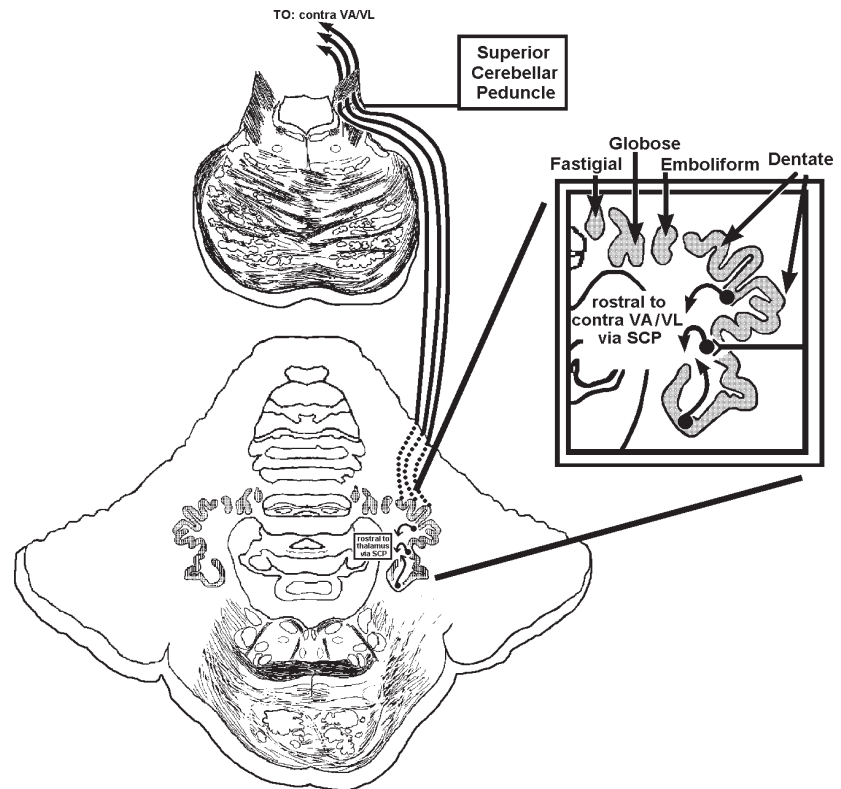
Which of the following statements is **TRUE**?

- A. Purkinje cells in the lateral zone excite the dentate
- B. Purkinje cells in the medial zone inhibit the vestibular nuclei
- C. Purkinje cells in the intermediate zone excite the fastigial
- D. Purkinje cells in the flocculonodular zone inhibit the fastigial
- E. Purkinje cells are excited by climbing and parallel fibers and inhibit deep nuclei

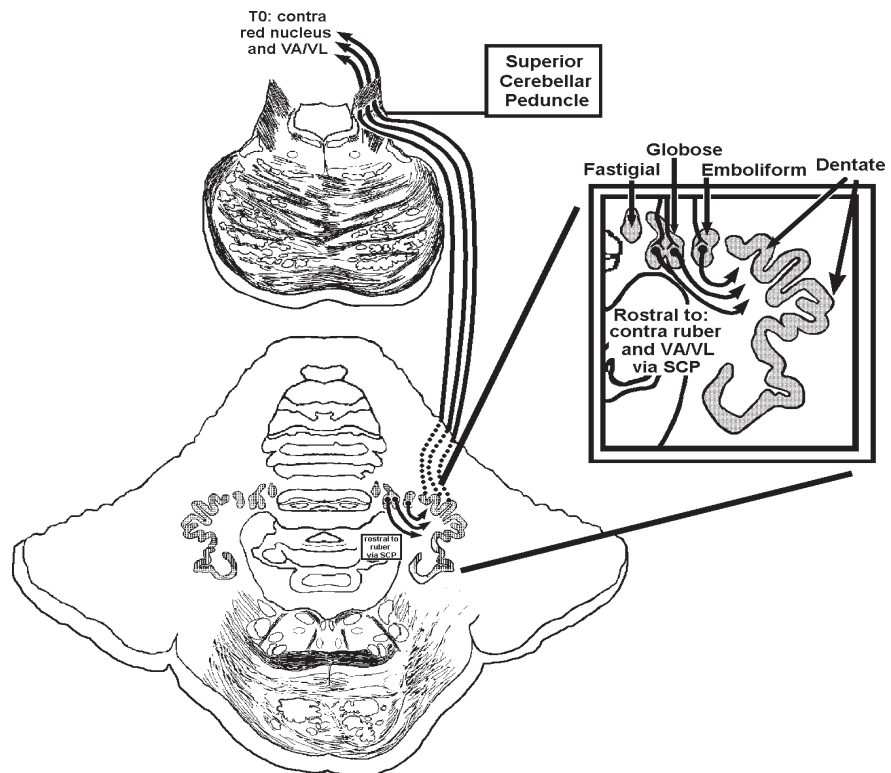
Answer is E

In the overview you learned that each zone has a deep nucleus into which Purkinje cells send their axons. Each deep nucleus sends its axons to different areas of the brain. Now that you know more about the deep nuclei, let's look at their projections.

The **dentate** nucleus receives input from the Purkinje cells in the lateral zone (and also mossy and climbing fiber input). Cells in the dentate project primarily to the contralateral **VA/VL** nuclei of the thalamus via the **superior** cerebellar peduncle. Cells in VA/VL project primarily to the SMA and MI.

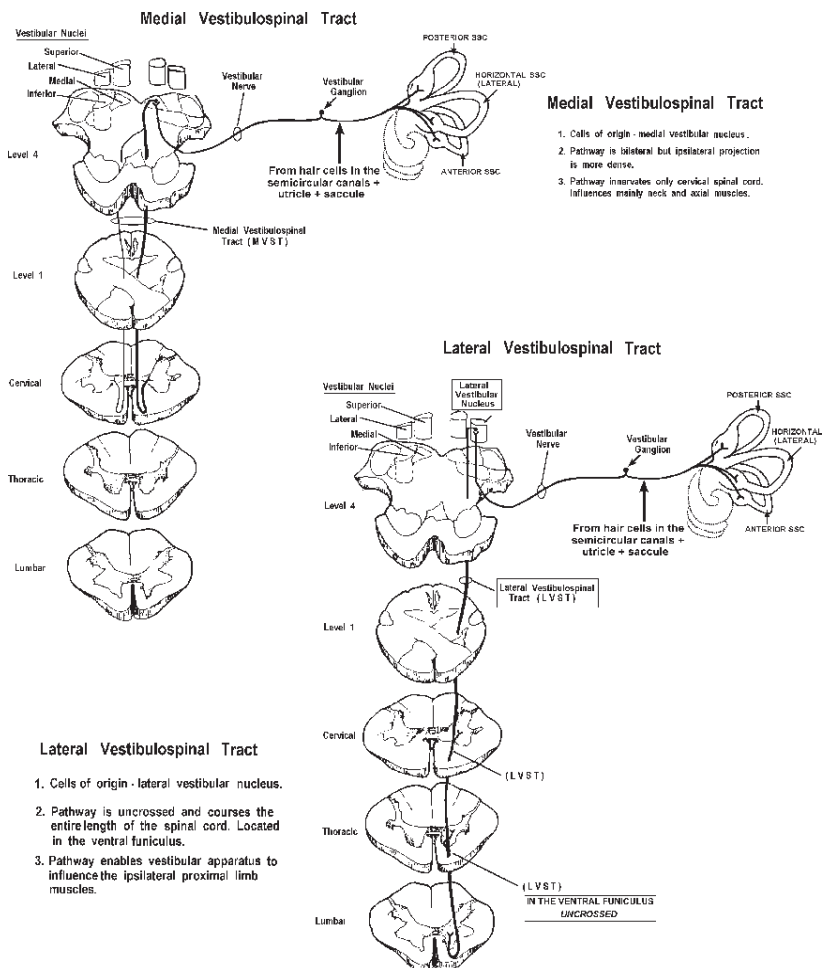
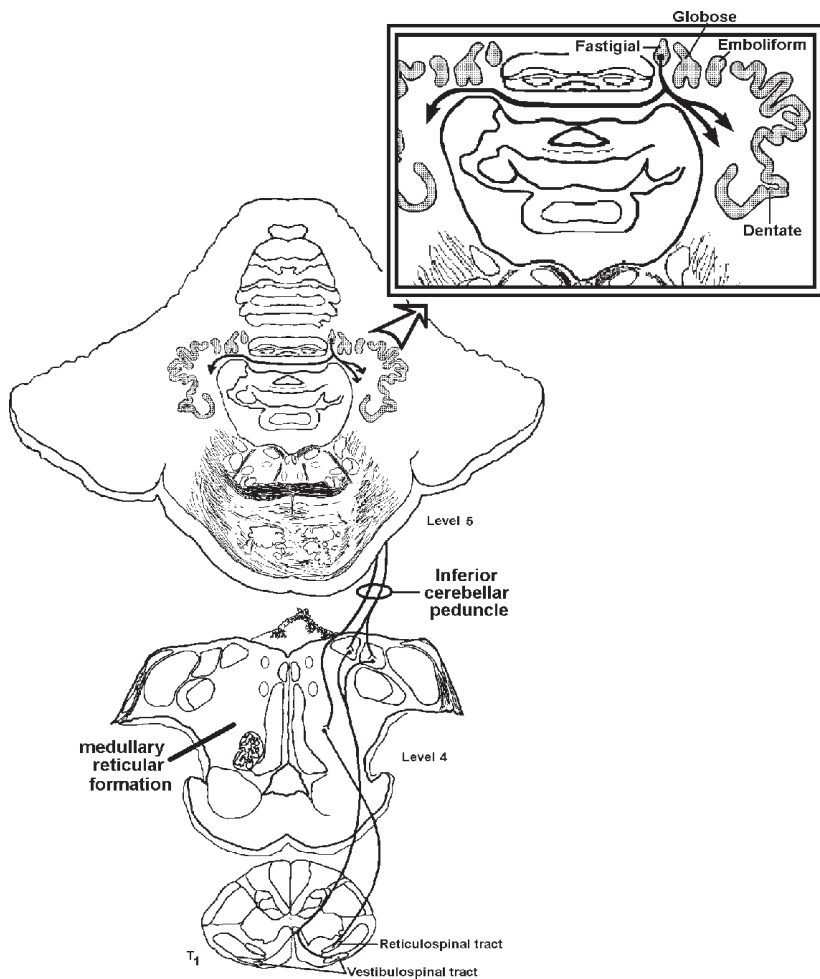


The **interpositus** nucleus receives input from the Purkinje cells in the intermediate zone (and also mossy and climbing fiber input) and projects to the contralateral **red nucleus** via the **superior** cerebellar peduncle. The ruber can then influence the **contralateral** spinal cord via the **rubrospinal** projection. The interpositus also projects to cells in VA/VL, which in turn projects directly to MI for any correction in the ongoing movement that is needed.



Now for the **FASTIGIAL** nucleus.

This nucleus receives input from the Purkinje cells of the medial zone of the cerebellum (and also mossy and climbing fiber input). To exit the cerebellum, the axons of cells in the fastigial nuclei take **two** routes that we did not discuss in the brain stem or spinal cord series of lectures. **Crossing** axons from the fastigial pass to the **vestibular** nuclei and the pontine and medullary reticular formation. The greater number of fibers leaving the fastigial nucleus are uncrossed and pass via the inferior cerebellar peduncle to reach the **vestibular nuclei** and to the pontine and medullary reticular formation. The **LVST, MVST, PRST, and MRST** then comprise the ventromedial system to control axial and proximal musculature. Remember that the vestibular nuclei also project to the contralateral PPRF for the control of horizontal eye movements.



Finally, you are already familiar with the **vestibular nuclei** from our lengthy discussion of them in the brain stem section. They serve as the **deep nuclei of the flocculonodular lobe** because they are the targets of the **Purkinje cells of the flocculonodular lobe**. The vestibular nuclei project to the **PPRF** and the **spinal cord** (via the MVST and LVST). The MVST and LVST are part of the ventromedial pathway for posture and balance.

HERE IS ANOTHER PRACTICE QUESTION!

Which of the following associations is **TRUE**?

- A. vestibular nuclei—inhibited by Purks, fastigial, LVST, MVST, flocculonodular lobe, excites ruber
- B. dentate nucleus— excites VA/VL, inhibited by Purks, , SCP, excited by climbers, inhibited by mossys
- C. interpositus—excites ruber-duber, inhibited by Purks, SCP, inhibits VA/VL
- D. fastigial—inhibited by Purks, excites PRST cells, excites vestibular nuclei, excites MRST, inhibited by climbers
- E. lateral zone—dentate, VA/VL, planning, memory, pontocerebellar, climbers, mossys

The correct answer is the third letter of one of the signs of Parkinson’s that means an abnormal repetitive shaking movement.

Lesions of the cerebellum

Lesions of the lateral zone of the cerebellum and dentate result in errors in the **direction, force, speed, and amplitude of movements**. This results in **ataxia**, which includes several symptoms or deficits. First there is **decomposition of movements**, which means that instead of a nice smooth movement, the movement consists of jerky parts of the movement. **Dysmetria**, also called **past-pointing**, occurs for example when the patient tries to touch their nose with their finger and ends up off target, shooting *past* the intended target. There is an inability to perform rapid alternating movements (pronation/supination for example) called **dysdiadochokinesis**. **Rebound phenomena** can be seen when you hold the patients tensed arm away from his/her sternum and chest and then let go. It will fly into their sternum. There also is tremor during the uncoordinated movement. This is called movement, or **intention tremor**. It is hard for me to explain why this might occur with lateral zone lesions but it might be due to the fact that there are problems in correctly stopping movements. This results in the movement going too far, after which there is a correction and then trailing oscillations that occur.

Lesions of the intermediate zone and nucleus interpositus are thought to result in similar deficits as those in the lateral zone and the dentate nucleus. Such lesions interrupt the ability of the cerebellum to correct movements once they are started. In contrast to cells in the dentate nucleus, cells in the interpositus fire **after** the movement has begun. Such cells are involved in updating ongoing movements versus planning these movements (dentate).

The **medial zone** receives mainly dorsal spinocerebellar and cuneocerebellar information, and projects to the reticular and vestibular nuclei. Deficits are related to balance and posture.

Finally, the influence of the **vestibulocerebellum (flocculonodular lobe)** on the vestibular nuclei also plays a role in posture and balance. Remember that the Purkinje cells in the flocculonodular lobe are inhibiting the vestibular nuclei (while neurons in the fastigial nucleus are exciting them). Therefore a **lesion** of the **right** vestibular zone (or flocculonodular lobe) will “release” the **right** vestibular nuclei from inhibition. Thus the right vestibular nuclei are in dominance. You can take it from here regarding the directions of stumbling and nystagmus.

A classic sign of lateral zone cerebellar damage is a decrease in tone (hypotonia). While this **hypotonia** is thought to result from malfunctioning of the descending control over the gamma efferent system.

Finally, there is incoordination of speech following cerebellar damage. This is called **dysarthria**.

TRY THIS PRACTICE QUESTION!

Which of the following is associated with cerebellar lesions?

- A. left nystagmus following a lesion of the right flocculonodular lobe
- B. Babinski sign
- C. right nystagmus following a lesion of the right fastigial nucleus
- D. hyperreflexia
- E. hemiplegia
- F. resting tremor
- G. apraxia
- H. rigidity
- I. bradykinesia
- J. hemiballism
- K. chorea
- L. atrophy
- M. anesthesia
- N. analgesia
- O. pronator drift
- P. intention (movement) tremor
- Q. rebound
- R. dysdiadochokinesia
- S. past-pointing

Answers P, Q, R, S

WHAT ABOUT THE OLIVE?

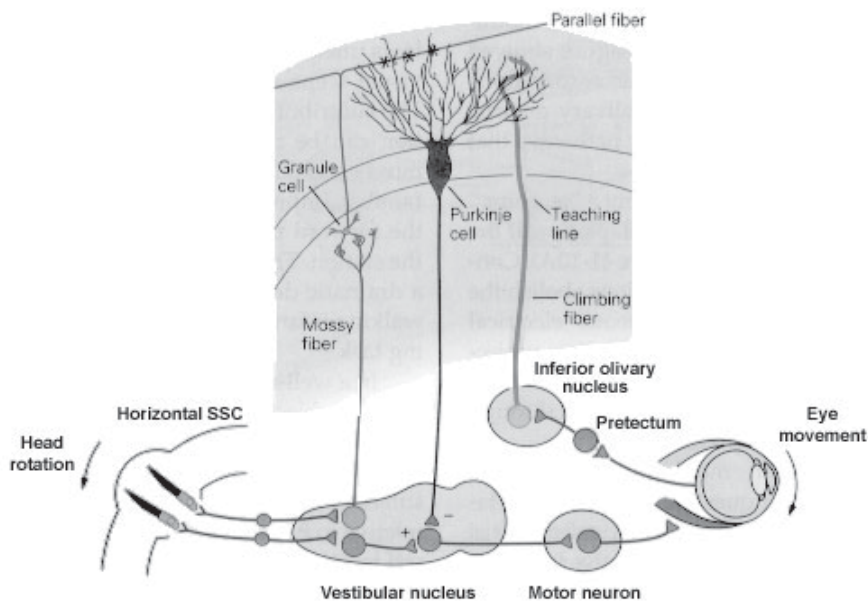
Ever since the inferior olive first appeared back there in the brain stem, we have said “you will learn more about the olive later in the course.” Well, here we are!! You already know that it projects to the contralateral cerebellum and the axons end as **climbing fibers**. Also, you know that olivocerebellar fibers terminate **throughout** the cerebellar cortex i.e., **they reach all four zones**. You even know a little bit about the circuitry of climbing fibers, in that they target deep nuclei and climb right up those Purk cells.

There is evidence that climbing fibers in the flocculonodular lobe might play a role in the plasticity of the **vestibulo-ocular reflex** (VOR; remember Point #13?). In this instance, plasticity refers to changes in the circuitry/functioning of the VOR. Hopefully you remember that the VOR helps stabilize the visual image on the retina as the head moves. So, a quick head movement to the **right** results in a compensatory horizontal conjugate eye movement to the **left**.

Now, consider what happens when you get a new pair of glasses. Say that they magnify things more than your old pair. This means that a **larger** compensatory eye movement is needed for the same degree head movement. Immediately after putting them on you notice things are a bit blurry and you might get dizzy. Remember, everything in the visual field is now **bigger** than before, so that during a head movement (over a certain number of degrees) to the **right**, the spot you are fixating on will move **more** to the **left** than before. Thus the eye movement to the **left** that is in reaction to the head movement to the **right** will **NOT** keep the image stable on the retina. The VOR is functioning as if you still have on your old glasses and the “gain” of the VOR is not large enough to move the eyes far enough to the **left** to stabilize the image. (Gain just refers to how much the eyes move in response to a certain head movement.

As you know, you do adjust after wearing the new lenses for a few hours/days. It is thought that this adjustment or adaptation of the gain is carried out by the olivocerebellar fibers that reach the flocculonodular lobe. For instance, a person who wore a new pair of glasses that were 2X the magnifying power of his/her old ones was found to have a VOR gain of **1.8** after a few days (1.0 is normal). How did this happen? You know that the vestibular nuclei receive information from the semicircular canals/CN VIII. They send the information to the flocculonodular lobe of the cerebellum via mossy fibers and also project to the contralateral PPRF, which in turn projects to the abducens nucleus. Thus, head **right**, increased firing of right CN VIII, left PPRF and left abducens; both eyes then go **left**.

When the eyes move to the left, cells in the retina send information to an area of the rostral brain stem called the **pretectum**. These pretectal cells can tell if the eyes and head movements match. If they don't match, there is slippage/blurring of the image and the pretectal cells know it. They in turn tell the inferior olive about the slippage and the climbing fibers comprise a "teaching line" to instruct the Purkinje cells to fire **LESS**. They would do this by modulating the efficiency of the mossy fiber/granule cell input from the vestibular nuclei. If the gain of the VOR is too small for the head movement (new glasses), the climbing fiber input would somehow **decrease** the efficiency of the vestibular mossy fiber/granule cell/parallel fiber input to the cerebellum and the Purks would fire less. This would means **less** inhibition on the vestibular nuclei and a slightly **bigger** compensatory eye movement to the **left** (the degrees of head movement did not change). This would stabilize the image on the retina during the head movement. **It has been found that no such adaptation of the VOR can occur following lesions of the flocculonodular lobe.**



Granted, this is just the flocculonodular lobe and nothing has been said about olivocerebellars in the other three zones. Well, studies are in progress, but right now you have to be satisfied with the flocculonodular lobe.

REMEMBER—CLIMBING FIBERS=MOTOR LEARNING

A NICE REVIEW CHART

Lower Motor Neuron	Upper Motor Neuron	Cerebellum	Basal Ganglia
Paralysis	Paresis (weakness)	No paralysis	No paralysis
Muscle atrophy	No atrophy	No atrophy	No atrophy
Areflexia & atonia	Hyperreflexia, hypertonia, spasticity	Ataxia, dysmetria, dysdiadochokinesia, hypotonia and intention tremor	Parkinson's: rigidity, resting tremor, bradykinesia Huntington's: chorea, hyperkinesia
Ipsi deficit in spinal cord	Contra deficit above decussation Ipsi deficit below decussation	Ipsi deficits	Contra

Practice Questions

1. Which of the following statements is **TRUE**?

- A. a Babinski sign is seen following cerebellar lesions
- B. cerebellar lesions result in atrophy
- C. a cardinal sign of cerebellar damage is hypotonia
- D. there are no speech problems following cerebellar lesions
- E. dysdiadochokinesia is another name for muscle weakness

2. Which of the following statements is **TRUE**?

- A. rebound phenomena refers to the inability to grab a rebound above the rim
- B. past pointing is a cardinal sign of corticospinal damage
- C. intention tremor is seen following lesions of the substantia nigra
- D. resting tremor is seen following lesions of the cerebellum
- E. atrophy is not a sign of cerebellar disease

3. Which of the following statements is **TRUE**?

- A. hypotonia occurs chronically following upper motor lesions
- B. spasticity is associated with lesions of the lateral cerebellum
- C. both cerebral cortex and cerebellar deficits involve the ipsilateral side of the body
- D. weakness is a cardinal sign of cerebellar disease
- E. ataxia is a cardinal sign of cerebellar disease

4. Which of the following statements is **TRUE**?

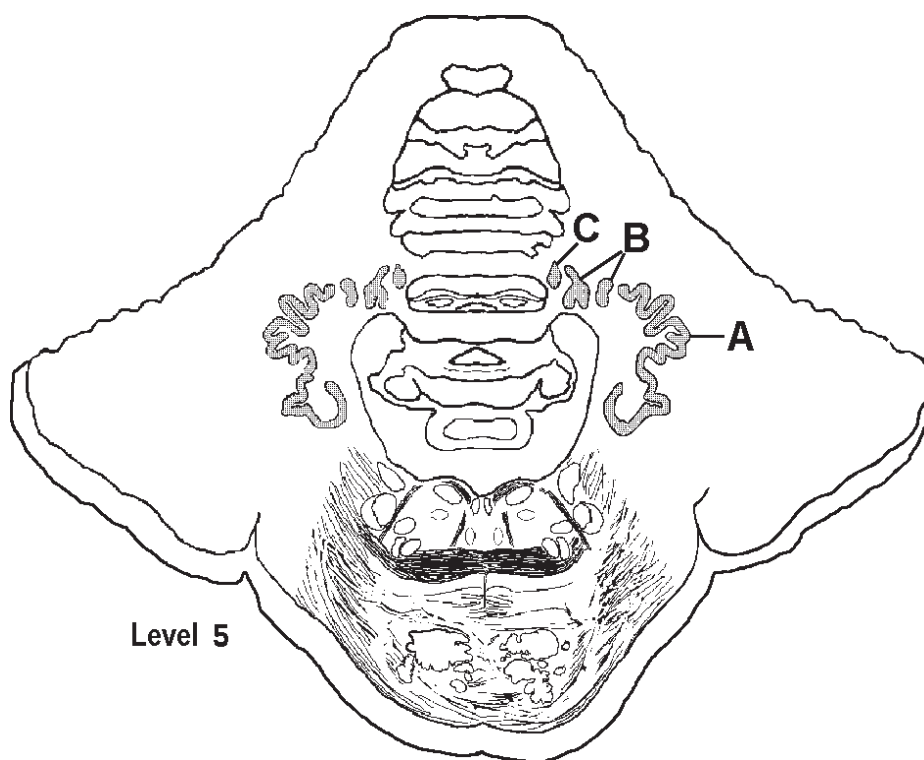
- A. the fastigial nucleus projects to the red nucleus
- B. the presence of nystagmus suggests damage to the corticospinal tract
- C. the inferior olive appears to play a role in the plasticity of the VOR
- D. the interpositus nucleus projects to the vestibular nuclei via the inferior cerebellar peduncle
- E. nystagmus is a sign of lower motor neuron disease

5. Which of the following statements is **TRUE**?

- A. a lesion of the **right** side of the flocculonodular lobe will result in **left** nystagmus
- B. a lesion of the **right** side of the flocculonodular lobe will result in staggering to the **right**
- C. a lesion of the **right** fastigial nucleus will result in staggering to the **left**
- D. a lesion of the **right** fastigial nucleus will result in **right** nystagmus
- E. a lesion of the **right** fastigial nucleus and the **right** vestibular nuclei will (in different cases) result in nystagmus of the **same** direction

6. Which of the following associations are **TRUE**?

- A-planning
- A-updating
- A-ruber
- A-VA/VL
- A-reticular formation
- A-vestibular nuclei
- A-pontocerebellar fibers conveying information from SMA
- B-ruber
- B-updating/comparing
- B-reticular formation
- B-primary motor cortex
- B-vestibular nuclei
- B-fires before movement
- C-nystagmus
- C-reticular formation
- C-ruber
- C-VA/VL
- C-bilateral efferent projection (but mostly ipsi.)



7. A 60 y.o. male presents with complaints of an unstable gait and some swaying of the trunk. His history is unremarkable except that for the past 15 years he has had increasing use of alcohol to his present level of approximately four hard liquor drinks per day. Most of his neurological exam is unremarkable. While he is sitting on a stool you notice a slight rocking or tremor-like movement of the trunk. His walking gait is broad based, with short regular steps, trunk is slightly inclined forward, arms are out with a mechanical arm swing. A test of reflexes demonstrates some hypotonia in the proximal muscles, but nearly normal reflexes. He claims that he walks fine on flat ground, but has difficulty and stumbles a lot when he is on uneven ground. He says that people have commented about his gait for many years, but he is just beginning to think something may be wrong. Which of the following could be true of this patient?

- A. he probably has a tumor pressing on the superior cerebellar peduncle
- B. he probably has degeneration of the vermal regions of the cerebellum due to extreme alcohol consumption.
- C. a MRI of his cerebellum would show increased space between the folia of the vermal region and the anterior lobe.
- D. all of his signs indicate damage to the lateral and intermediate zones of the cerebellum.
- E. two of the above statements are **TRUE**

8. A 45 y.o. woman presents with nausea, and tremor. Her history states she has been mildly hypertensive for many years, and has recently had TIAs. Her blood pressure is 180/120. A motor exam demonstrates reduced tone in the right upper and lower limbs, dysmetria and past pointing, and an intention tremor on the right side. Movements of her right limbs seem to be most affected and when asked to perform a rapidly alternating movement with her right hand, she clumsily performs the task. She has a normal flexor plantar reflex bilaterally and nearly normal strength in all her limb muscles. Which of the following could be true of this patient?

- A. the lesion is most likely in the premotor cortex
- B. the lesion is most likely in the medial zone of the cerebellum
- C. the inability to perform rapidly alternating movements is called past pointing
- D. if the lesion is in the cerebellum, she is probably weak
- E. none of the above statements is **TRUE**

ANSWERS

- 1. C
- 2. E
- 3. E
- 4. C
- 5. E
- 6. A. T; F; F; T; F; F; T
B. T; T; F; T; F; F
C. T; T; F; F; T
- 7. E (B, C)
- 8. E

THE ULTIMATE OVERVIEW (one more time!)

The cerebellum is involved in taking the MImvt1 signal and comparing it with the DSCT and CCT signals. It makes corrections via its outflow to the ruber (rubrospinal makes correction) and VA/VL; the latter project to MImvt1 for the correction. This updating/comparing/correcting takes place in the intermediate part or zone of the cerebellum and the outflow nucleus is the interpositus via the superior cerebellar peduncle to reach the ruber and VA/VL. The rubrospinal tract causes a fast correction while the VA/VL projection enables the thalamus to tell MI to make a certain correction.

The cerebellum is also involved in the **planning** of the next movement. Planning information from SMA and MI reaches the cerebellum and is integrated with circuits that contain other types of information regarding the planned movement. This planning takes place within the lateral region or zone of the cerebellum and the outflow nucleus is the dentate via the superior cerebellar peduncle to reach the VA/VL, which in turn tells planning areas of MI and SMA about the planning information that it “picked up” in the cerebellum.

The cerebellum is also involved in the control of posture, balance, and eye movements. It does this via the medial and flocculonodular zones. Thus, the medial zone receives DSCT and CCT unconscious proprioception and uses the outflow of the fastigial to control the reticular formation (PRST and MRST) and the LVST and MVST. We do not know what the circuitry of the cerebellum “does” to the DSCT and CCT signals, but there must be some integration before the fastigial sends information out of the cerebellum.

The flocculonodular lobe receives only vestibular inputs and uses the vestibular nuclei as its deep cerebellar nucleus to control posture, balance and eye movements. Again, we do not know what happens to the vestibular information within the cerebellum.