CNS
Doctor 2021

Physiology

Modified (16)

Writer: Sana Al-Sokhon
Corrector: Malak Alkateeb
Doctor: Fatima Ryalat

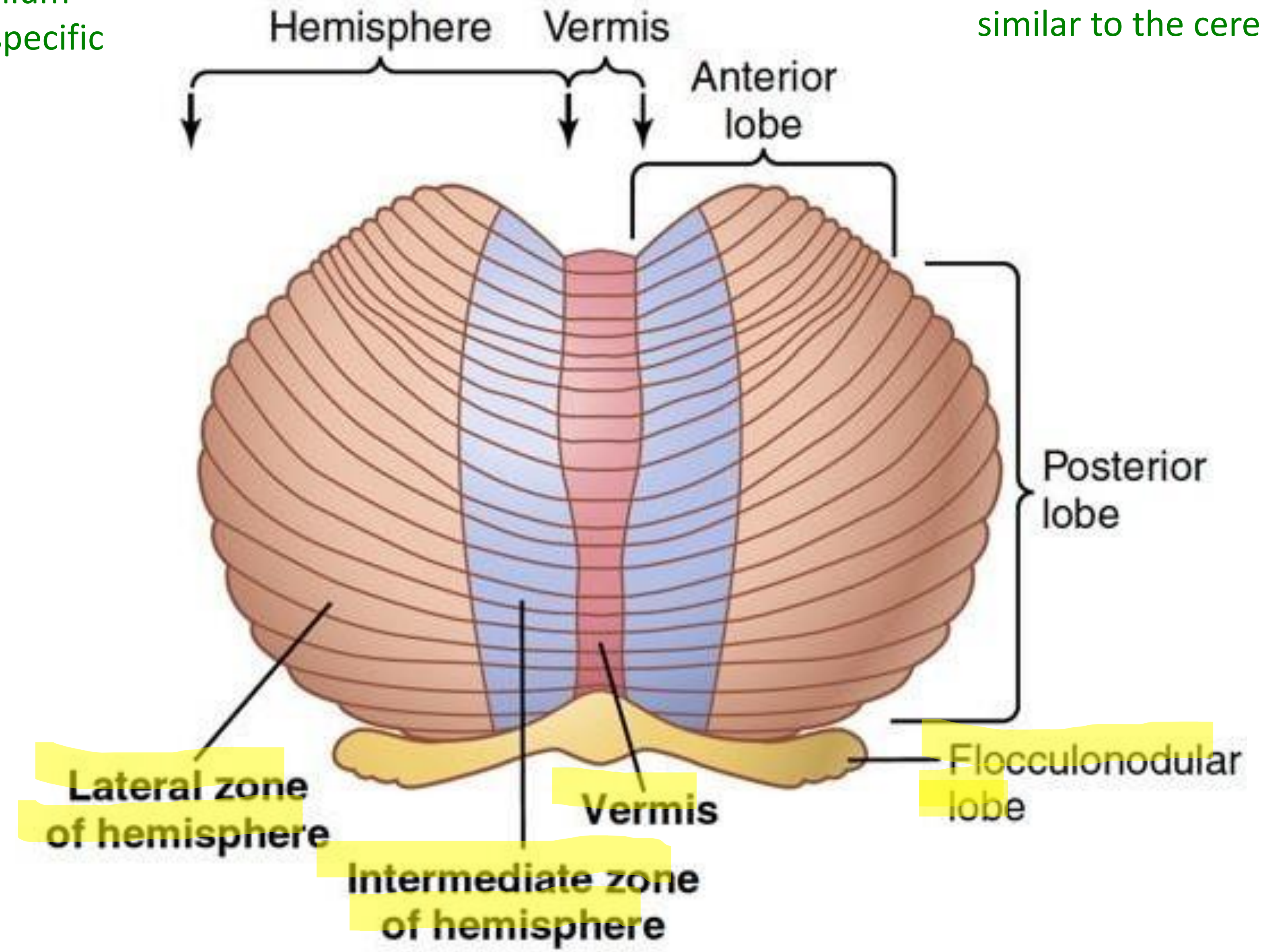
Neurophysiology

Cerebellum

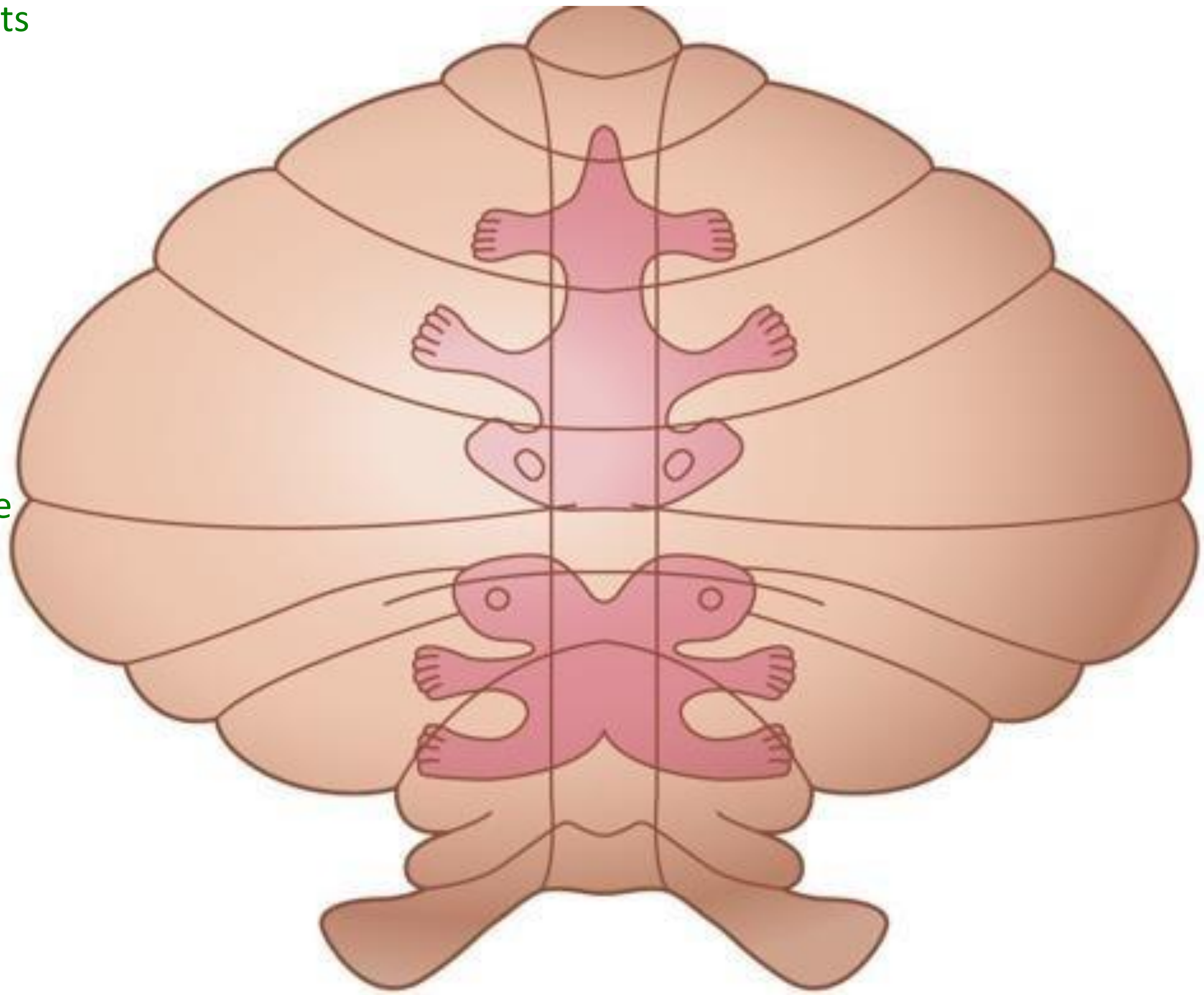
Fatima Ryalat, MD, PhD

We will be concerned with these highlighted parts of cerebellum which represent different specific functions for cerebellum:

Cerebellum : little brain ,very similar to the cerebrum



There are topographical representation of different parts of the body on the cerebellum (not very well advanced as in cerebrum):
-vermis part of cerebellum: it represents the axial and proximal muscles.
-intermediate zone :represents the distal muscles.
-lateral zone :there is no representation of body parts.



when they perform electrical stimulation for the cerebellum to know its functions, they found no change in the perception of sensation and no change in movement (silent area or silent brain), but when they excise the cerebellum, they found great impairment in the movement

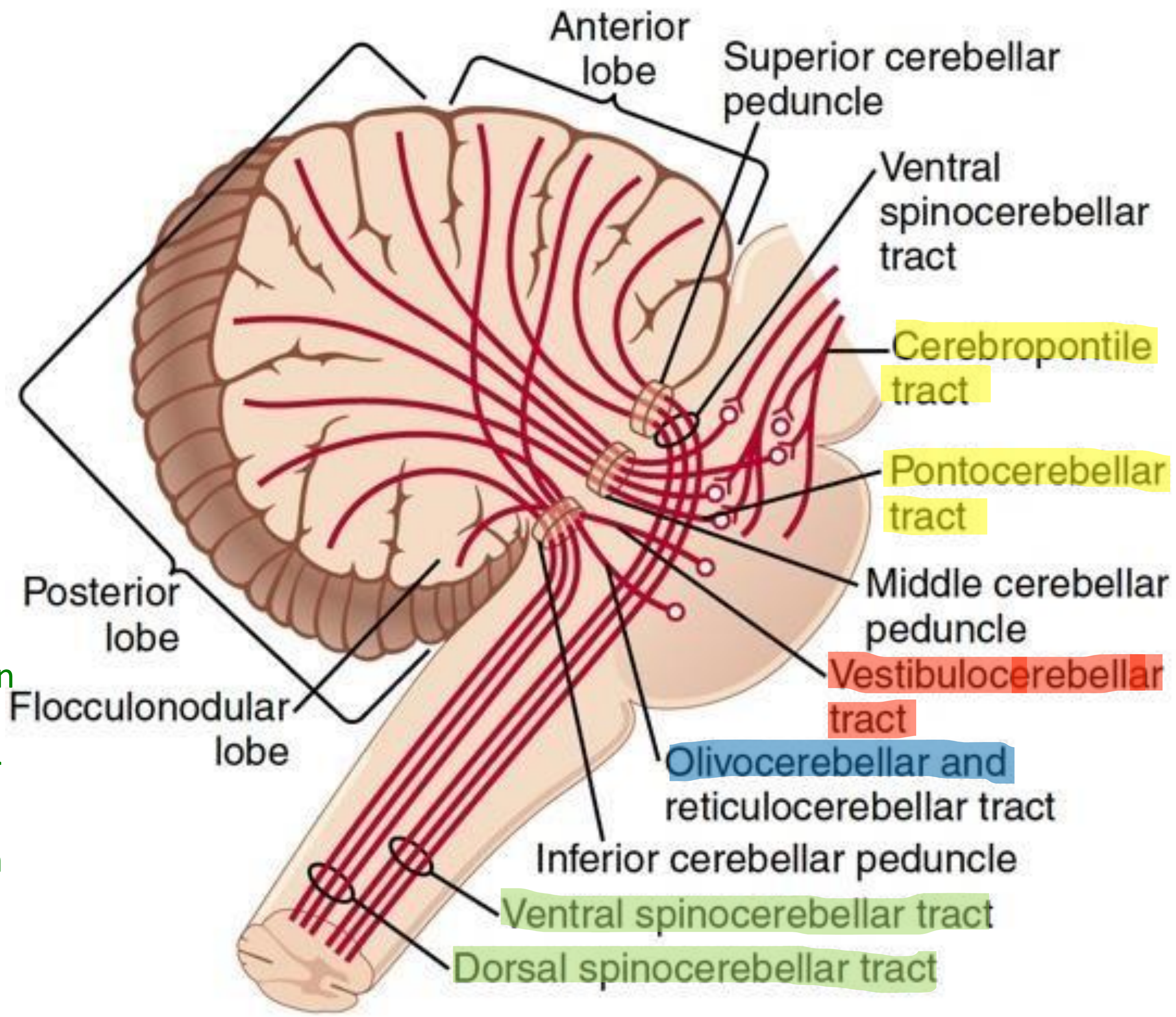
-The function of the cerebellum in one word is "coordination" .

Input pathways:

- Just like the cerebrum ,the cerebellum have :

1-cortex
2-deep nuclei
3-input pathway (afferent pathway)
4- output pathway (efferent pathway).

-input signals to the cerebellum come from:
1-cereberal cortex through cerebropontile tract then through pontocerebellar tract
The type of information that come through this signal will be the plan of movement (intention of the movement).
2-from brainstem through:
a)Vestibulocerebellar tract :which gives information about balance.
b)Olivary cerebellar tract which come from inferior olivary nucleus.
c)Reticulocerebellar tract : which gives information about muscle tone.
3- from spinal cord through:
a)Dorsal spinocerebellar
b)Ventral spinocerebellar



Dorsal spinocerebellar tracts

- The signals transmitted in the dorsal spinocerebellar tracts come mainly from the muscle spindles and to a lesser extent from other somatic receptors throughout the body, such as Golgi tendon organs, large tactile receptors of the skin, and joint receptors.

Dorsal spinocerebellar tracts

- All these signals apprise the cerebellum of the momentary status of
- (1) muscle contraction,
- (2) degree of tension on the muscle tendons,
- (3) positions and rates of movement of the parts of the body,
- (4) forces acting on the surfaces of the body.

Ventral spinocerebellar tracts

- The ventral spinocerebellar tracts receive much less information from the peripheral receptors.

- Instead, they are excited mainly by motor signals arriving in the anterior horns of the spinal cord from
- (1) the brain through the corticospinal and rubrospinal tracts
- (2) the internal motor pattern generators in the cord itself.

Ventral spinocerebellar tracts

- Thus, this ventral fiber pathway tells the cerebellum which motor signals have arrived at the anterior horns; this feedback is called the efference copy of the anterior horn motor drive.

-They called “efferent copy” because they give information about the actual movements in the periphery.

- The spinocerebellar pathways can transmit impulses at very high velocities.

- This speed is important for instantaneous apprisal of the cerebellum of changes in peripheral muscle actions.

Inferior olivary nucleus

- In addition to signals from the spinocerebellar tracts, signals are transmitted into the cerebellum from the body periphery through the spinal dorsal columns to the dorsal column nuclei of the medulla and are then relayed to the cerebellum.

- signals are transmitted up the spinal cord through the spinoreticular pathway and the spino-olivary pathway to the inferior olivary nucleus.

Inferior olivary nucleus

- Signals are then relayed from both of these areas to the cerebellum.

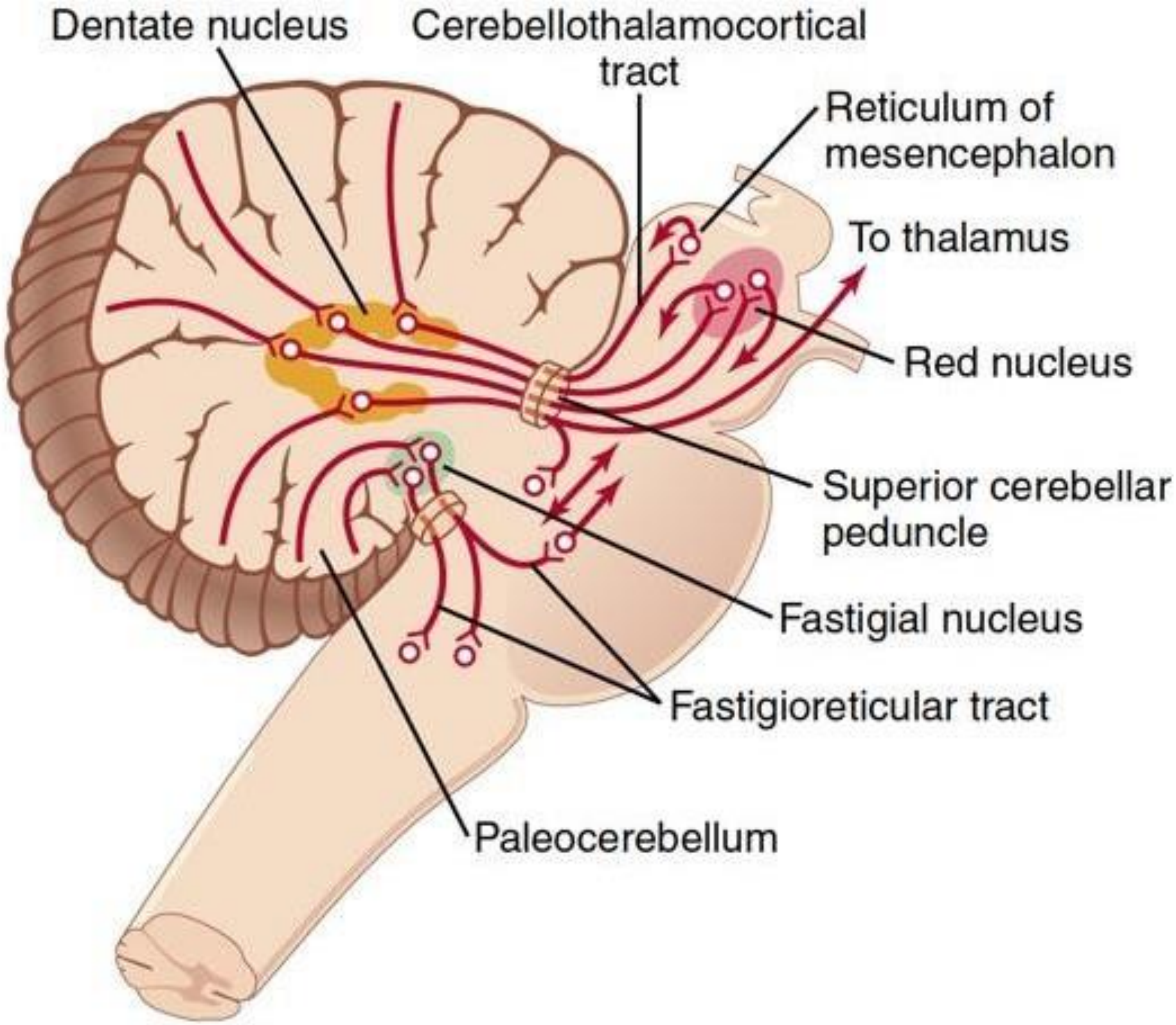
- Thus, the cerebellum continually collects information about the movements and positions of all parts of the body even though it is operating at a subconscious level.

- In summary the signals that will reach to the cerebellum are:
1- actual movement from motor & sensory signals.
2- the plan of movement
After that the cerebellum will compare them ,and if there is any disturbances it will send corrective feedback mostly to the cerebral cortex and rubrospinal tract.

Output pathways:

Any output from the cerebellum it must come through deep nuclei in the cerebellum like dentate ,fastigial ,globose , vestibular

-vestibular nuclei physiologically they add them to the deep nuclei in the cerebellum because they highly integrated in function, as well as there is functional area in the vermis related to them ,but anatomically they aren't in the cerebellum .



Deep cerebellar nuclei

- on each side of the cerebellum there are three deep cerebellar nuclei: the dentate, interposed, and fastigial.

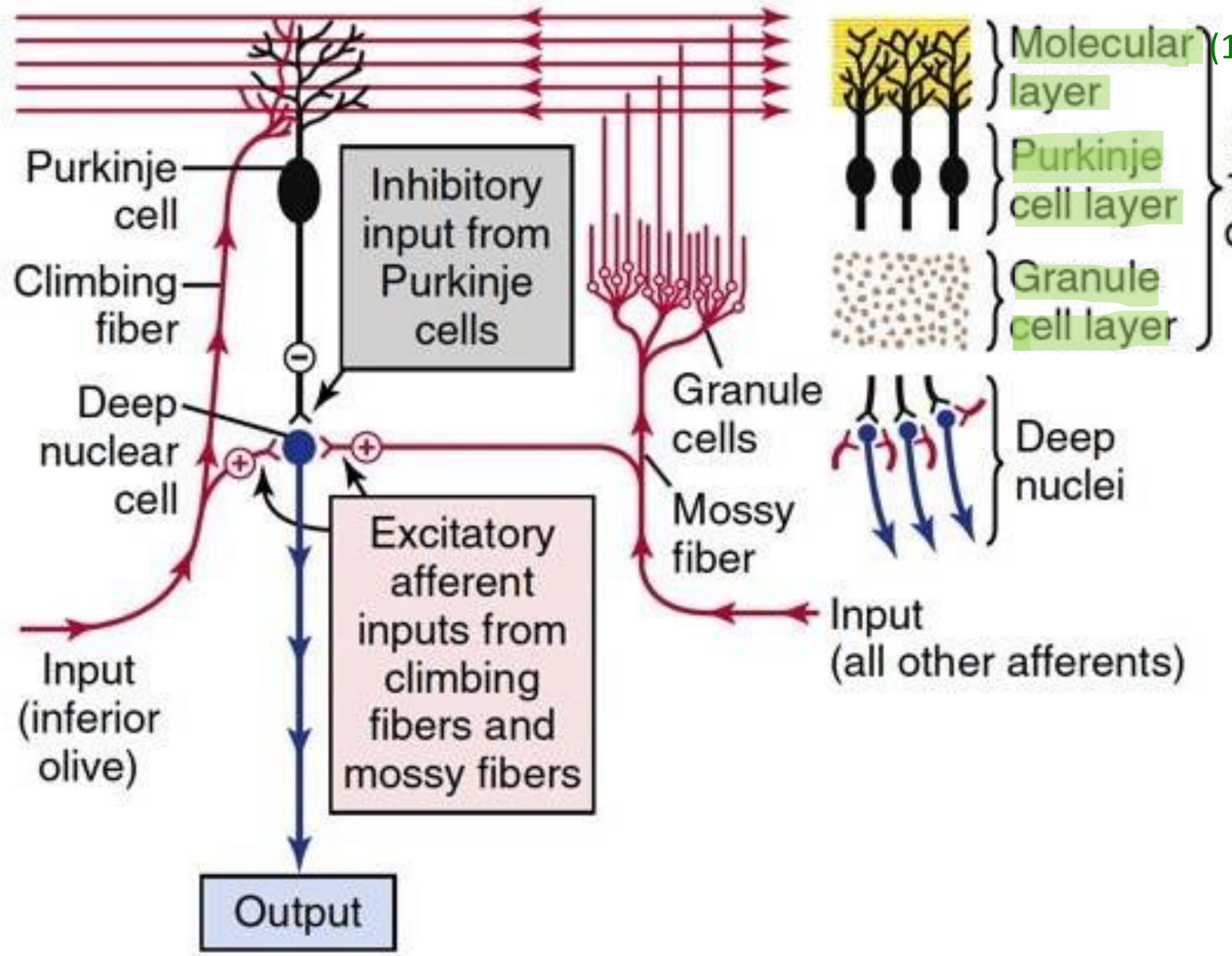
- All the deep cerebellar nuclei receive signals from two sources:
- (1) the cerebellar cortex.
- (2) the deep sensory afferent tracts to the cerebellum.

-Remember :cerebral cortex have 6 layers ,but cerebellar cortex have 3 layers :

-Again, the deep nuclei (blue in color in the image) receive 2 types of signals:

1) Direct from afferent which is stimulatory all the time (red in color)

2)OR from the cerebellar cortex through Purkinje cell which is inhibitory all the time (black in color).



(1) The outermost layer

(2) The second layer

(3)Third layer (the deepest one)

-according to the image above :

The input fibers 2 type:

1- climbing fibers → come from inferior olivary nucleus to the cerebellum
firstly ,it will give direct branch to the deep cerebellar nuclei (excitatory branch)
Then ,it continue up to the molecular layer of the cerebellar cortex , and there it will synapse so many times with different dendrites and maybe the soma of the Purkinje cell .

-almost a single stimulus from the climbing fiber is enough to produce an action potential in the Purkinje cell (the type of action potential is called "complex spikes ", they strong spikes then followed by weaker spikes for prolonged period of time).
-Complex spikes : it is a characteristic in the Purkinje cell in response to the stimulation by the climbing fiber .

-as you can see in image above :the climbing fiber gives 2 signals to the deep cerebellar nuclei
1)Immediately stimulatory signal (direct)
2)Delay inhibitory signal (it takes time to reach the molecular layer then it goanna branch with dendrites and soma until reach the threshold then action potential will reach the deep nuclei .

2- Mossy fibers :come from other all fibers

- in summary the deep nuclei will get stimulated by excitatory signal which come directly from the climbing fiber ,then within fraction of second it will be followed by inhibition .
- It is important characteristic for the cerebellar function because the movement of the muscles in the limbs is oscillatory pendular movement ,so in order to make damping (smoothen)to this type of movement we have to make excitation followed by certain delay period by inhibition to prevent oscillation in the movement .
- Another importance : if the patient has cerebellar lesion one of the best test the doctor must do is “finger- nose test”

when the doctor ask the patient to touch his own nose then touch doctor fingertip while the doctor is moving his finger (changing the direction)

It is important to ask the patient to make the test as rapid as he can(to know if the cerebellar function intact or not) ,because some patients have cerebellar impairment ,but their cerebral cortex takes over ,however there will not be perfect it will be slower kind of movement and less precise ,so asking him to do the movement quickly and if he can't do it quickly ,then it will be very evident that he has cerebellar lesion .

Patient with cerebellar lesion will have oscillatory movement because there is impairment in the inhibition signal in the cerebellum ,the patient also will overshoot the target (doctor fingertip or his own nose) and he will take a time to reach the specific target .

https://youtu.be/GkPQ1Iy1D88?si=lzG0N1vDQp4OEpaD (extra video for more clarification)

-How we learn new skilled movements ?

When you learn a new motor skill you will not be able to do it exactly very well from the first time ,your cerebellar has to learn ,just like when a child learns swimming ,he must practice more and more and the repitition differ from one person to another for his cerebellar to learn how to coordinate different movements together (cerebellum learns by trials and errors).

-Again, cerebellum compare between the actual movement and the intention of movement, if there is any discrepancy ,it will send corrective feedback to the cerebral cortex and rubrospinal tract until it reaches the perfect movement.

Deep cerebellar nuclei

- Each time an input signal arrives in the cerebellum, it divides and goes in two directions:
- (1) directly to one of the cerebellar deep nuclei and
- (2) to a corresponding area of the cerebellar cortex overlying the deep nucleus.
- Then, a fraction of a second later, the cerebellar cortex relays an inhibitory output signal to the deep nucleus.

Deep cerebellar nuclei

- all input signals that enter the cerebellum eventually end in the deep nuclei in the form of initial excitatory signals followed a fraction of a second later by inhibitory signals. From the deep nuclei, output signals leave the cerebellum and are distributed to other parts of the brain.

Neural circuit of the functional unit

- functional unit centers on a single, very large Purkinje cell and on a corresponding deep nuclear cell.
- The output from the functional unit is from a deep nuclear cell.
- This cell is continually under both excitatory and inhibitory influences.

Neural circuit of the functional unit

- The excitatory influences arise from direct connections with afferent fibers that enter the cerebellum from the brain or the periphery.

- The inhibitory influence arises entirely from the Purkinje cell in the cortex of the cerebellum.

- The afferent inputs to the cerebellum are mainly of two types, one called the climbing fiber type and the other called the mossy fiber type.

Climbing fibers

- The climbing fibers all originate from the inferior olives of the medulla.
- There is one climbing fiber for about 5 to 10 Purkinje cells.
- After sending branches to several deep nuclear cells, the climbing fiber continues all the way to the outer layers of the cerebellar cortex, where it makes about 300 synapses with the soma and dendrites of each Purkinje cell.

Complex spike

- This climbing fiber is distinguished by the fact that a single impulse in it will always cause a single, prolonged (up to 1 second), peculiar type of action potential in each Purkinje cell with which it connects, beginning with a strong spike and followed by a trail of weakening secondary spikes.
- This action potential is called the complex spike.

Mossy fibers

- The mossy fibers are all the other fibers that enter the cerebellum from multiple sources—the higher brain, brain stem, and spinal cord.
- 1-These fibers also send collaterals to excite the deep nuclear cells.(direct excitatory branch)
- 2-They then proceed to the granule cell layer of the cortex, where they also synapse with hundreds to thousands of granule cells.

- Cerebellum is about 10% of the brain weight ,but it has more than 50% of the brain cells.

Mossy fibers

- In turn, the granule cells send extremely small axons, less than 1 micrometer in diameter (they are very short and tiny fibers), up to the molecular layer on the outer surface of the cerebellar cortex.

- Here the axons divide into two branches that extend 1 to 2 millimeters in each direction parallel to the folia. (they are called parallel fibers)
- It is into this molecular layer that the dendrites of the Purkinje cells project and 80,000 to 200,000 of the parallel fibers synapse with each Purkinje cell. (so, it will be slow kind of conduction and weak synapse between them, so we need to stimulate many granulate cells (many parallel fibers) in order to induce an action potential in Purkinje cells).

-however in climbing fiber ,almost one single stimulus is enough to induce an action potential in Purkinje cells.
But both have the same net effect which is inhibitory signal from Purkinje cell .

- The mossy fiber input to the Purkinje cell is quite different from the climbing fiber input because the synaptic connections are weak, so large numbers of mossy fibers must be stimulated simultaneously to excite the Purkinje cell.
- Furthermore, activation usually takes the form of a much weaker, short-duration Purkinje cell action potential called a simple spike, rather than the prolonged complex action potential caused by climbing fiber input.

- One characteristic of both Purkinje cells and deep nuclear cells is that normally both of them fire continuously(even at rest);
- the Purkinje cell fires at about 50 to 100 action potentials per second, and the deep nuclear cells fire at much higher rates.
- Furthermore, the output activity of both these cells can be modulated.

Deep nuclear cells

- the climbing and the mossy fibers excites them.
- By contrast, signals arriving from the Purkinje cells inhibit them.
- Normally, the balance between these two effects is slightly in favor of excitation so that under quiet conditions, output from the deep nuclear cell remains relatively constant at a moderate level of continuous stimulation.

-for any output to leave the cerebellum ,it must pass through deep nuclei ,and the deep cerebellar nuclei always have two types of input excitatory from direct afferent fiber as well as inhibitory from cerebellar cortex through Purkinje cells ,and these two effects are important when we talk about agonistic &antagonistic muscles → at the beginning of movement there will be excitation for the agonistic muscle by the time of termination of movement there will be inhibition ,to start excitation for the antagonistic muscle .

- In execution of a rapid motor movement, the initiating signal from the cerebral motor cortex or brain stem at first greatly increases deep nuclear cell excitation.
- Then, another few milliseconds later, feedback inhibitory signals from the Purkinje cell circuit arrive. In this way, there is first a rapid excitatory signal sent by the deep nuclear cells into the motor output pathway to enhance the motor movement, followed within another small fraction of a second by an inhibitory signal.

Delay line

- This inhibitory signal resembles a “delay line” negative feedback signal of the type that is effective in providing damping. That is, when the motor system is excited, a negative feedback signal occurs after a short delay to stop the muscle movement from overshooting its mark. Otherwise, oscillation of the movement would occur.

Turn on/ turn off signals

- The typical function of the cerebellum is to help provide rapid turn-on signals for the agonist muscles and simultaneous reciprocal turn-off signals for the antagonist muscles at the onset of a movement.
- Then, on approaching termination of the movement, the cerebellum is mainly responsible for timing and executing the turn-off signals to the agonists and the turn-on signals to the antagonists.

Cerebellum learns

- The degree to which the cerebellum supports onset and offset of muscle contractions, as well as timing of contractions, must be learned by the cerebellum.
- ? Role of climbing fibers.

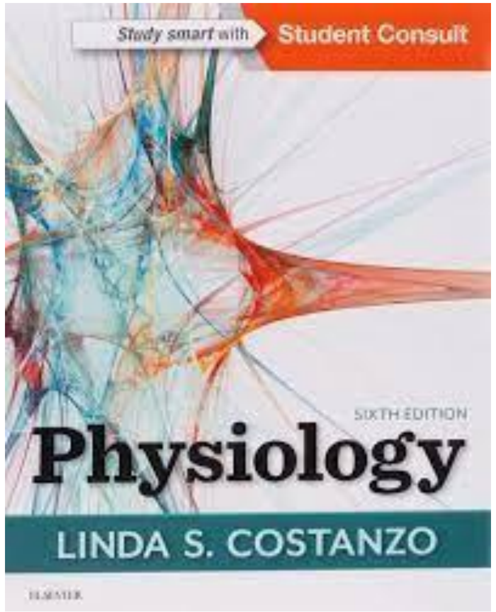
Basket and Stellate cells

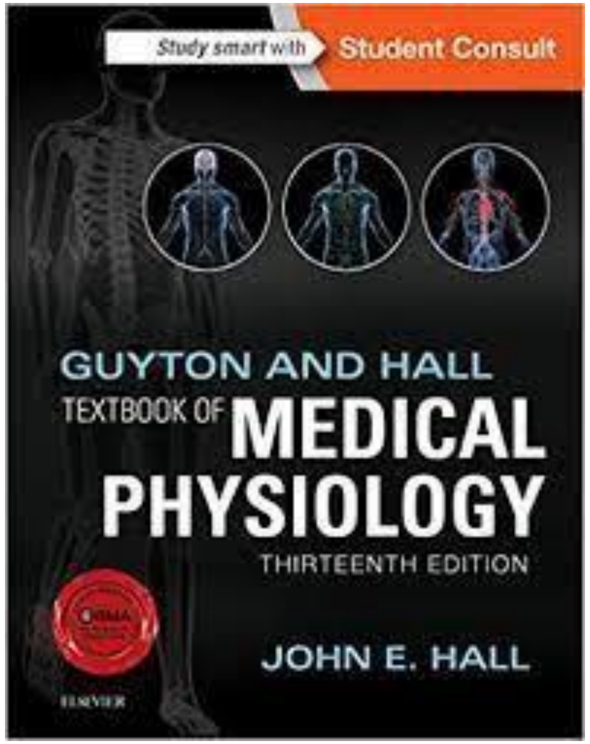
- basket cells and stellate cells are inhibitory cells with short axons.
- Both are located in the molecular layer of the cerebellar cortex.
- These cells send their axons at right angles across the parallel fibers and cause lateral inhibition of adjacent Purkinje cells, thus sharpening the signal.

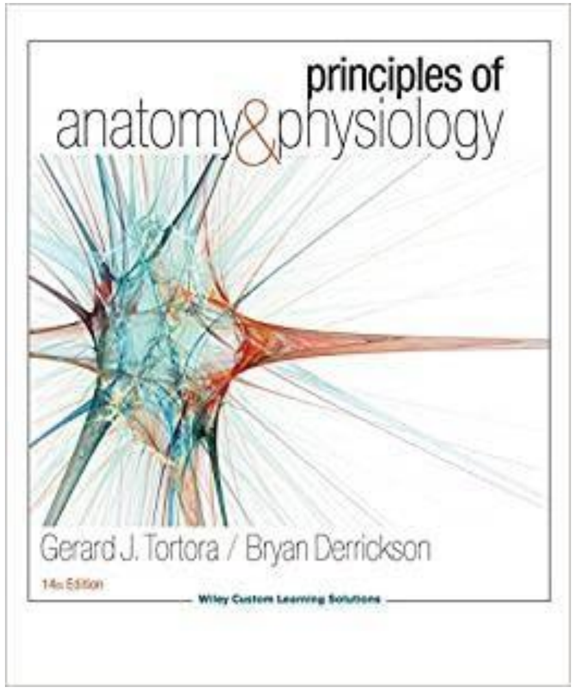
اللهم بقوتك وبغوثك وبغيرتك على حرماتك وبحاميتك لمن احتمى بآياتك نسألك يا الله يا سميع يا قريب يا مجيب يا منتقم يا جبار يا قهار يا شديد البطش يا من لا يعجزه قهر الجبابرة ولا يعظم عليه هلاك المتمردين من الملوك والأكاسرة، أن ترد كيد المحتلين في نحرهم وتجعل مكرهم محيط بهم وأن تنصر غزة وجميع المسلمين نصرا عزيزا.

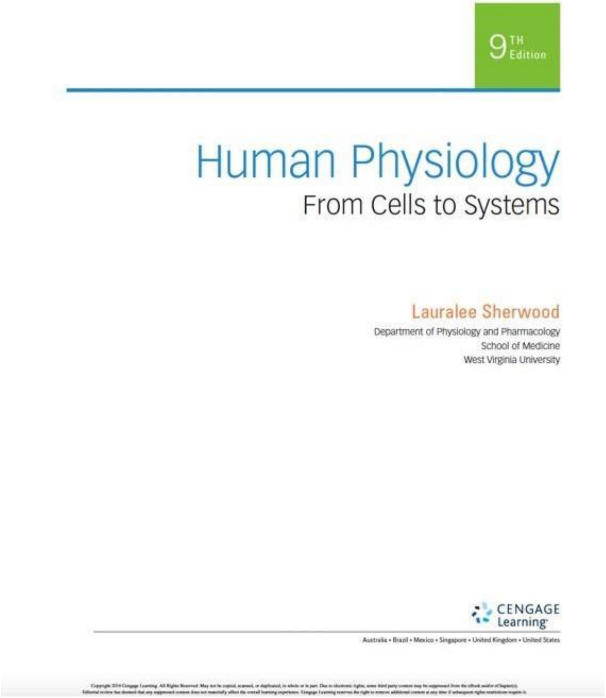
Thank you

References


Study smart with
Student Consult
SIXTH EDITION
Physiology
LINDA S. COSTANZO
ELSEVIER


Study smart with
Student Consult
GUYTON AND HALL
TEXTBOOK OF MEDICAL
PHYSIOLOGY
THIRTEENTH EDITION
JOHN E. HALL
ELSEVIER


principles of
anatomy&physiology
Gerard J. Tortora / Bryan Derrickson
14th Edition
Wiley Custom Learning Solutions


9TH Edition
Human Physiology
From Cells to Systems
Lauralee Sherwood
Department of Physiology and Pharmacology
School of Medicine
West Virginia University
CENGAGE Learning
Australia • Brazil • Mexico • Singapore • United Kingdom • United States