Central Nervous System

Sheet 8

Subject | physiology

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Correction | ...

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The auditory pathway:

The sound waves are transmitted through a medium, enter the external auditory meatus and lead to vibrations in the tympanic membrane, 3 bones of hearing and the perilymph in the cochlea. As the fluid moves, the basilar membrane with hairy cells on it will also move. This mechanical change of the cilia will open ion channels and lead to action potential in the hairy cells "receptor neurons".

**** The axons of these hairy cells (which are found in the spiral organ of corti and considered the 1st order neuron) will be collected together to transmit the information to CNS through cochlear nerve.**
The fibers of the 1st order neurons of the cochlear nerve enter the brainstem (upper part of medulla) directly; where they synapse with 2nd order neurons in the cochlear nucleus.

****The cochlear nucleus itself is arranged in a way that different frequencies will have different organizations there; the higher frequency will synapse inside "in the middle" of this nucleus, while the lower frequency will synapse outside "at the edges of this nucleus".**

**This designation mainly preserves the labeled line principle and the ability of detecting different frequencies (the fibers of a specific group of hair cells should not converge together until their destinations).

Note: The cochlear nucleus is a complex of two nuclei; ventral/anterior one and dorsal/posterior one.

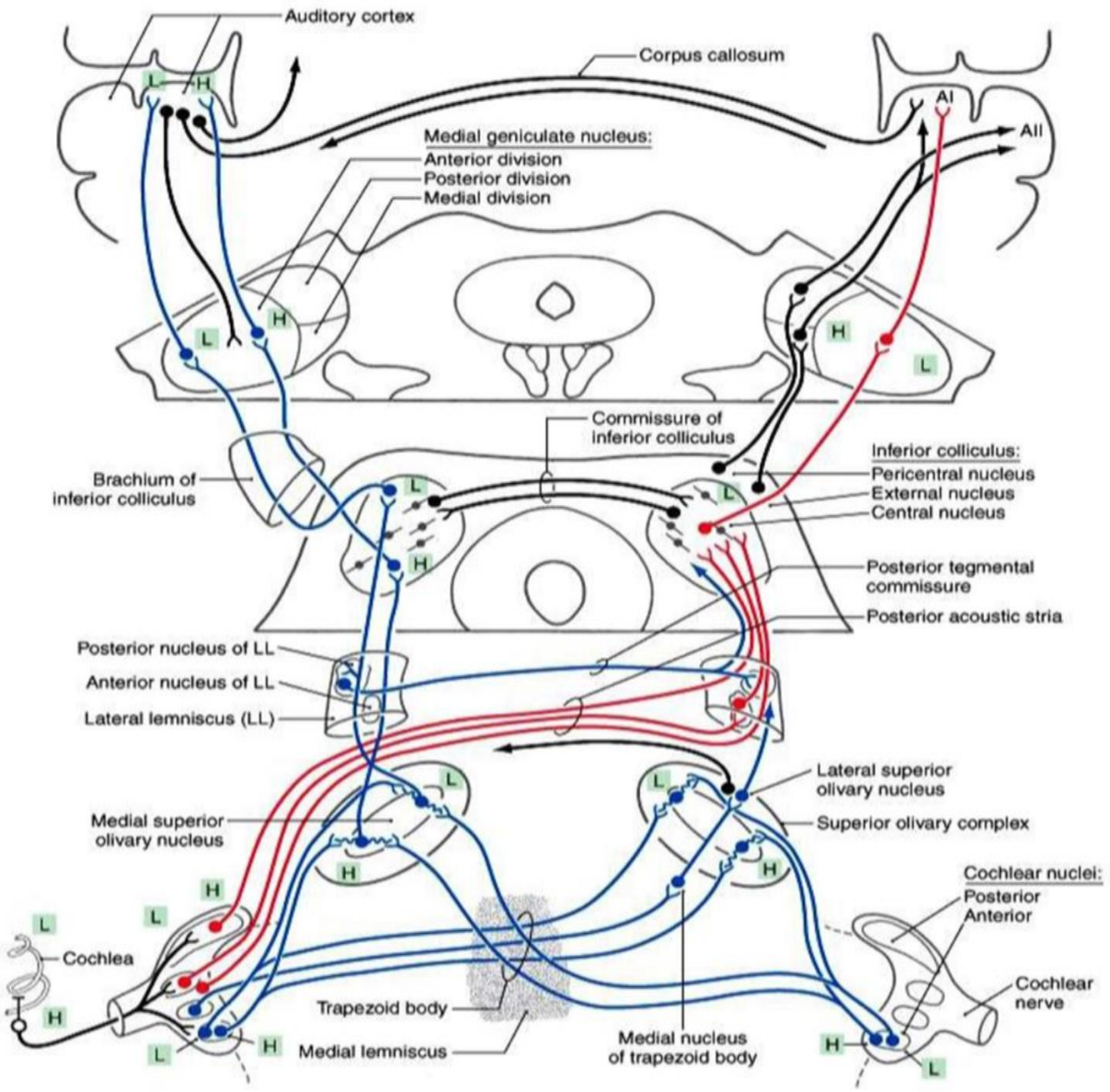
**As we took earlier, for most fibers to reach the cortex they must pass through the thalamus. The auditory pathway is not an exception; the 2nd order neurons from cochlear nucleus will synapse with a 3rd order neuron in the medial geniculate nucleus in the thalamus. Then the 3rd order neurons go to the 1ry auditory cortex (area 41 and 42) in the temporal lobe of the cortex.

****Note:1ry auditory cortex is mainly 41, we'll talk about 42 later***

That was a general overview of the pathway. But as you can see there are two different pathways in the picture below and we'll discuss each one of them.

1- **The monaural pathway**

the 1st order neuron synapse with a 2nd order neuron in the dorsal cochlear nucleus, cross the midline and pass through inferior colliculi of the midbrain; where they synapse with other neuron which in turn will synapse again in the medial geniculate nucleus of the thalamus to reach the cortex.



***There aren't multiple stops in this pathway and the processing mechanisms are less*, so it has a great importance in preservation of the amplitude, time and order of the sound being heard. It specializes in transmitting high-resolution sounds.**
Monaural pathway (monoaurical), as the name implies, receives information from one ear only; so the right ear will terminate in the left cortex

2- The bi-auricle pathway
It's opposite to the first pathway; it starts from the anterior cochlear nucleus and the fibers coming out from the nucleus will go to both sides of the cortex; the sound from the right cochlea will go to the right and left hemispheres of the cortex.

How these fibers reach the cortex?

Neurons from one side of ventral cochlear nucleus will go and synapse with both superior olives (right and left), then ascend up as lateral lmeniscus to synapse in the inferior colliculi of the midbrain. Finally from the medial geniculate nucleus in the thalamus fibers ascend up to the 1ry auditory cortex.

Note: Superior Olives/ superior olivary complex is a group of nuclei in brainstem that have an important role in hearing and processing of the sound. They determine the command after a sensory input is received; if there is a need for a quick reflex or this info must be sent to the brain. they can be divided into two parts; medial (measures the time difference and the angle of the sound) and lateral (employs intensity to localize the sound).

****Obviously there are many stops along this pathway so the resolution of the sound will be less but this pathway has an advantage in localization of the sound.**
It's important for the brain to receive information from both ears to be able to detect the location of the sound. This is achieved by comparing the amplitude (in which ear it was higher) and the time (which ear delivered the sound faster). Then we can know from which side the sound is coming. and vice versa.

So, to determine the location of the sound we must compare the differences in inputs from both ears.
Difference in input includes two factors: (A) difference in delivery time, and (B) difference in amplitude.

Clinical cases

1- If the left ear or left cochlear nerve or left cochlear nucleus was injured, the patient will completely lose hearing on the left side. This patient will be able to hear from his right ear and both sides of the cortex will be activated.

2- If the left medial geniculate was injured, the right medial geniculate will compensate and this patient will hear from both ears.

***Any damage before the superior olive "from outside", the hearing will be lost on the side of damage. But if the injury is at or after the level of the superior olive, both ears will be able to detect sounds.**
*** In the 2nd case, where the injury is in or after the superior olive, there will be a loss of some aspects of discrimination of the sound or the localization "but not that significant"**
***In any damage, the localization will be affected a little bit.**
***Localization will be mostly affected if the injury is in the superior olives (they are the parts responsible for measuring the differences in input) or before.**
***Medial geniculate nucleus injuries will affect the resolution on the contralateral ear not the localization. (It doesn't have a significant role in localization)**

Her we will talk about the reflexes:

- **In the acoustic startle reflex a sudden sound make you involuntary move toward it, and it involved in the tectospinal tract.**
- **When you are in a party , once you enter the sound is high and you become annoyed and can't hear anything, after a while the voice become calm. This happens due to middle ear reflex that causes contraction of the middle ear muscles making the vibration less so you hear the sound lower .**
- **However there is a nother phenomena : first scenario is when you are in a party and middle ear reflex happen to you and contraction happen in the middle ear muscle making the vibration less so you hear the sound lower and all the sounds getting lower, and your friend in the party come to you and try saying something to you but you do not hear him and you tell him to say again and whatever he try to rise, his sound can't overcomes the high sounds in the party but this time you will hear him clearly and you understand what he say !**

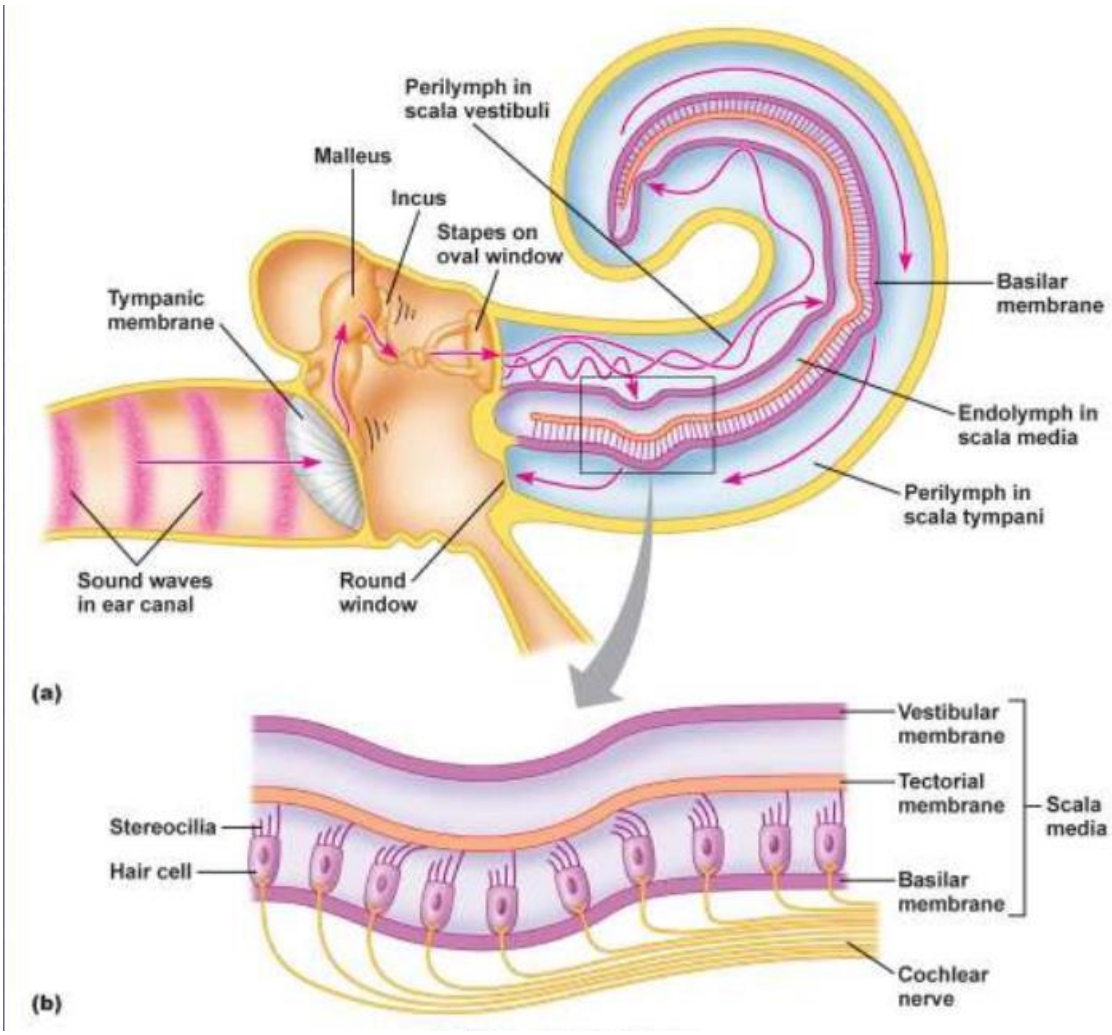
.another scenario that Females understand more than males, the girl is sitting in the entrance of the faculty , she hears her name or important information, suddenly she hears the talking of girls far away although the sound is not higher than the loudness around.

How come? Different sounds will go to the basilar membrane to different areas but we have make lowering to all vibrations at the level of the middle ear .Normally we have ability to rise the vibration tones selectively and make its intensity more (selective activation), this account for a characteristic in the cochlea.

In the cochlea there are a basilar membrane and a tectorial membrane and between these two the hair cells lie. If we assumed that the distance between the tectorial membrane and the basilar membrane is 5mm, so the whole tectorial membrane is situated on the hair cells and the hair cell carry it , if there was 0.5mm vibration this will vibrate the hair cells in certain angle, graded potential of

certain value is produced . if the sound was more, the vibration will be more and the displacement will be more and graded potential is more.

Selective activation implicate that the CNS can drive specific part of the basilar membrane and make it shorter than other parts(i.e.: it can make the tectorial membrane become more tight to the basilar membrane in that area). Assuming that the distance is 5mm normally and after CNS order this area -only-became less 4mm for example . The selection of this area particularly to make selection to specific frequencies over others as we said before that different areas of the basilar membrane are specific for different frequencies and by that the cochlea reduce the range of frequencies to be able to find only specific sound. Beside selecting specific area, we also said that the CNS will tight that particular area and the purpose of this is to make amplification for this specific frequency, so you select your friend frequency and amplify it. This loop system is called olivocochlear descending feedback loop



olivocochlear descending feedback loop:

the orders which will go tectorial membrane and make it tight on the basilar membrane come from the superior olive. this is one thing, but how your body know your friend tone (frequency). It is the cortex which is the source of this loop system. In this loop the auditory cortex projects to the medial geniculate nucleus and nuclei of the inferior colliculus. The inferior colliculus projects to the periolivary nuclei(medial and lateral superior olivary nuclei), which in turn send olivocochlear efferents to the outer hair cells of the cochlea.
The motor movement involve type of hair cells called outer hair cell. Inside the organ of corti there are two types of hair cells, one big type is composed of one hair cell aligned in one line along the basilar membrane and every cell of this type gives

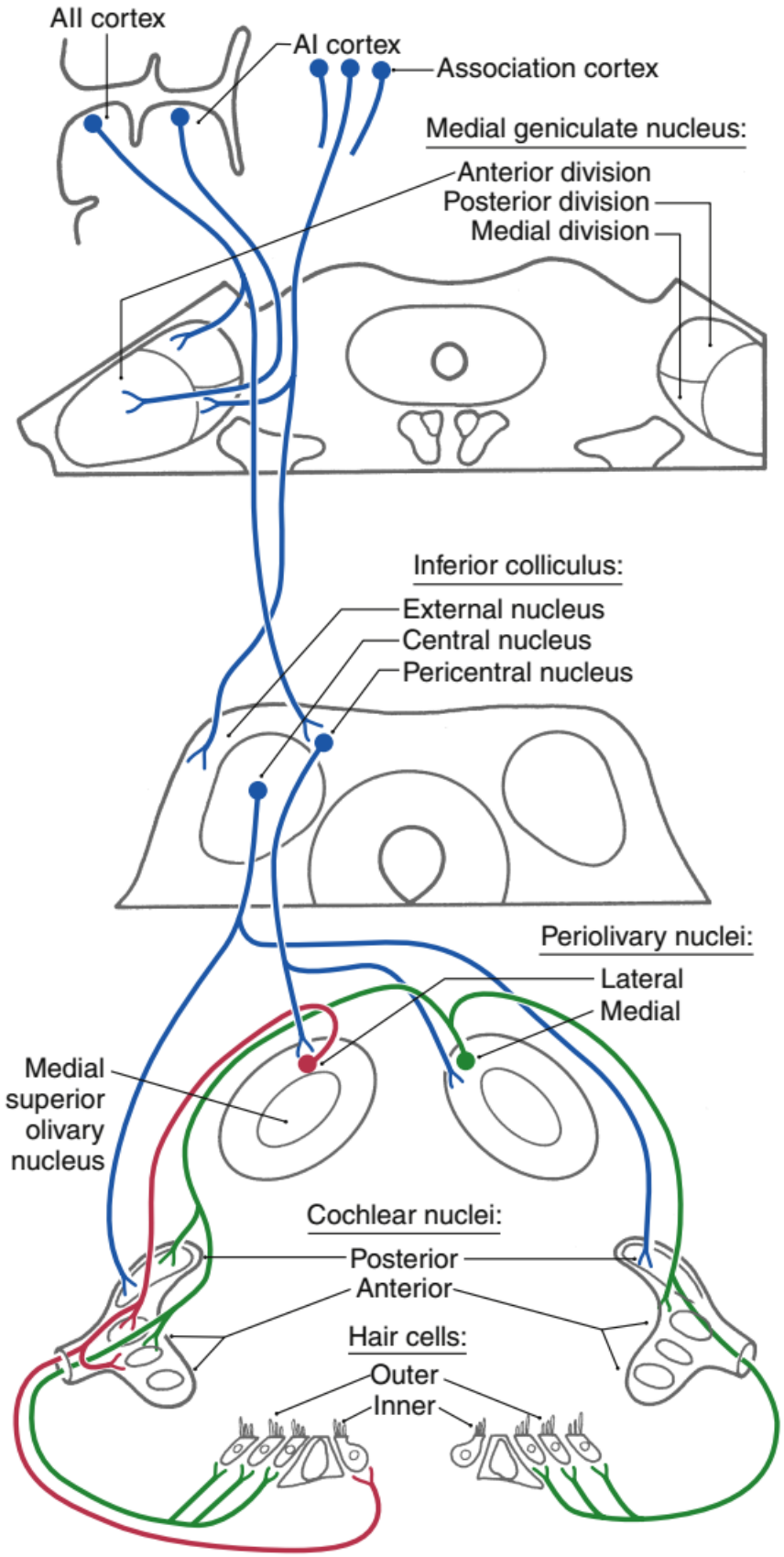
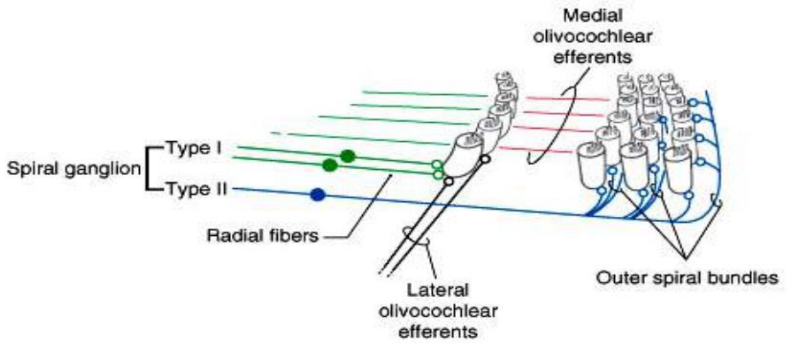
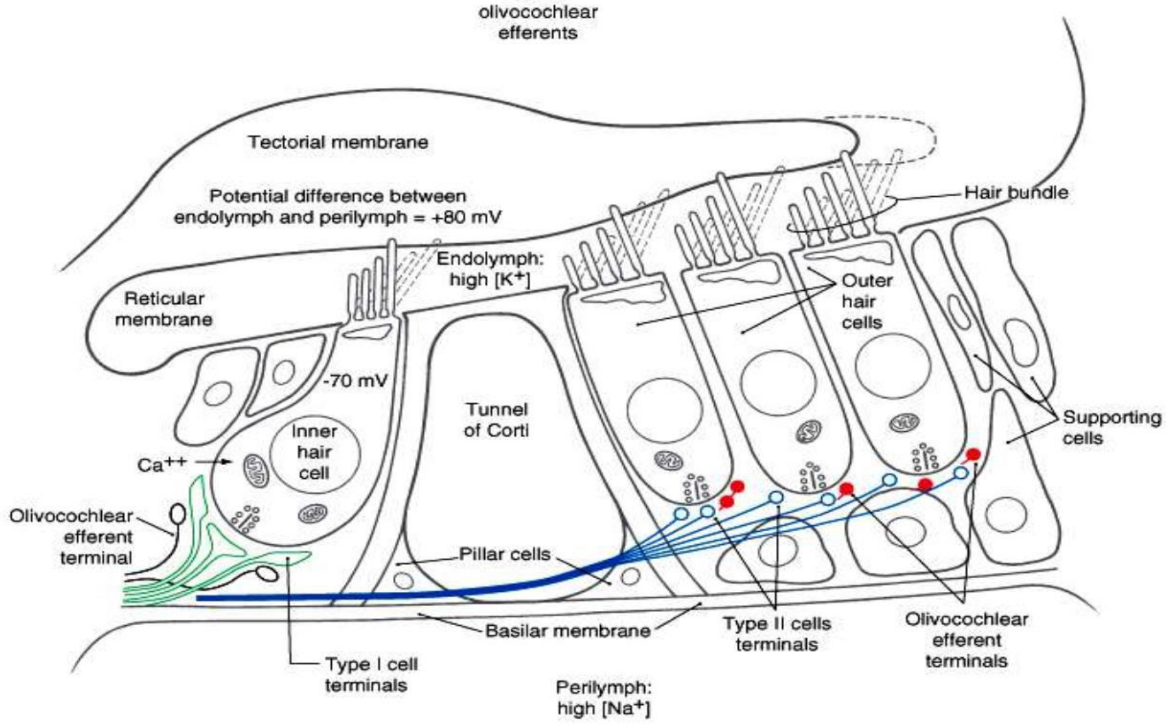


Figure 21-13. Descending auditory pathways that modulate sensory processing at central and peripheral auditory sites. The lateral olivocochlear efferents are shown in red and the medial olivocochlear efferents in green. *AI* and *AII*, primary and secondary auditory (cortices).

efferent through three or four neurons, so that it has better representation to give better resolution. In the other side there are other type of smaller cells composed of three cells compact in small area and five to six of them give afferent through one neuron to CNS so that they don't give better resolusion, however this type of cells have motor function where motor supply from CNS effect them. Direct efferent feedback to outer hair cells, in particular, may influence cochlear mechanics and consequently the sensitivity and frequency selectivity of the cochlea. Efferent induced changes in outer hair cell membrane potentials result in changes in the height of the cells and the stiffness of their stereocilia. These changes modulate basilar membrane motion and thereby influence cochlear function. The tight coupling of the basilar membrane to the tectorial membrane by the outer hair cells enables this efferent mechanism to feed energy back to the cochlea to amplify responses to specific tones. The cochlear amplifier effect is important in selectively tuning the cochlea to important sounds.





Pontine auditory hallucinosis

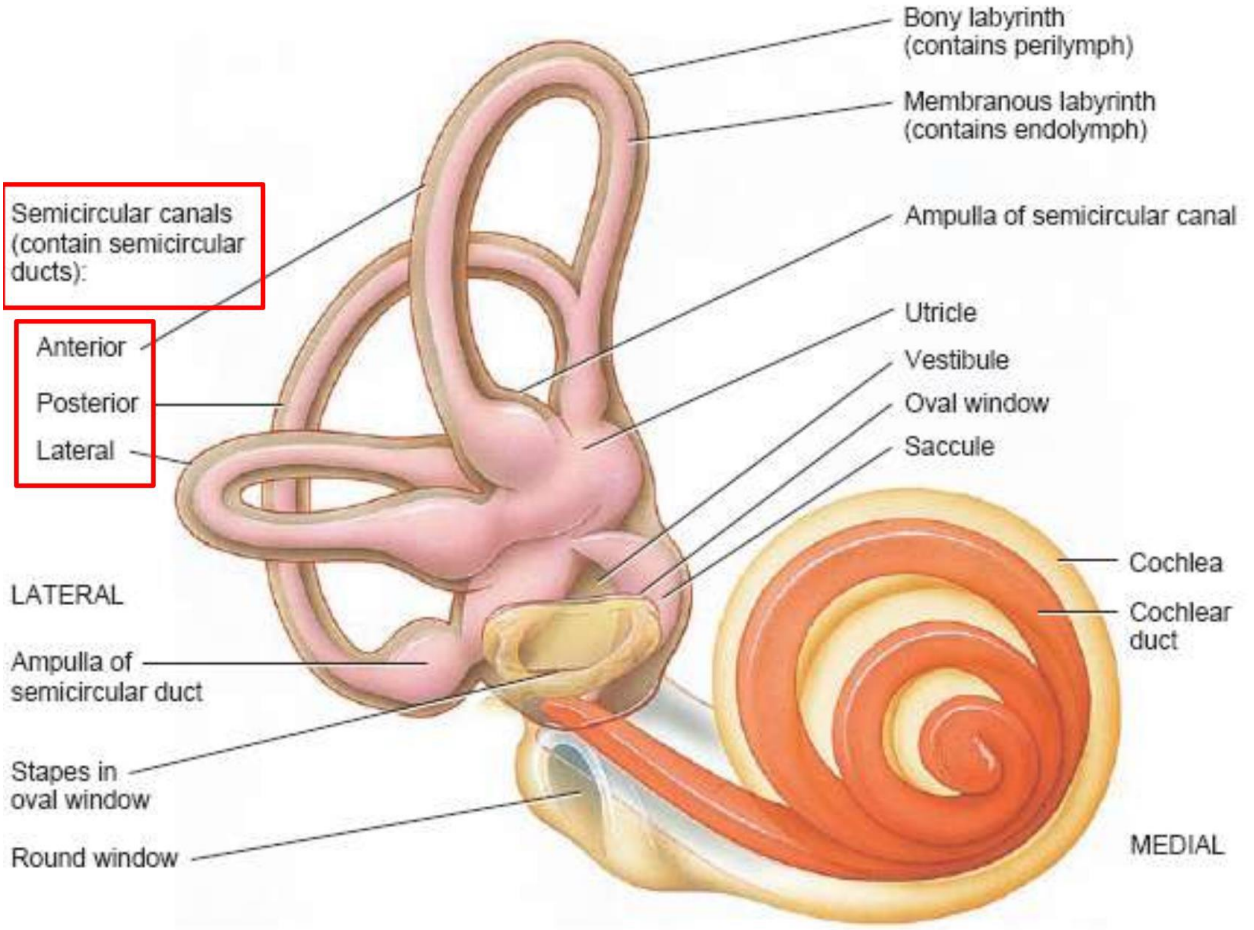
** perceived auditory events that sounds like
and an orchestra out of tune, buzzing insects, or strands of music, which are accompanied by more typical symptoms of pontine lesions of auditory , such as cranial nerve deficits and long tract signs. A perception of noise or sounds may also be experienced by patients with temporal lobe seizures or a temporal lobe lesion that damages auditory cortices

What is the medical importance of this reflex? It is not medically important that you can hear your friend sound when you are in a party. **Actually it is the main pathway that will cause tinnitus(طنين الأذن).** **Tinnitus** is a non specific term, and one of the most important causes it the case we talked about before , when you are in a party where you hear loud sounds and music and after you leave tinnitus remain in your ears to a while, **why?** Because after you get in the party, middle ear reflex happen quickly to you, and vibrations become less, but your brain try to hear somethings and try to distinguish their sounds from other sound, so that the brain activate the olivocochlear feedback, so tectorial membrane become closer in specific areas to get specific frequencies(your friend frequency in our example), and when you leave middle ear reflex stop but olivocochlear feedback remain more time so you hear some sounds although it is not there(tinnitus).

*If someone hair cells are died and have hearing loss , his brain try to activate these cells and try to make them more sensitive. If someone have inflammation, external auditory meatus infection middle ear infection, also the same, the brain will try to fix the problem and try to make the hair cells more sensitive to be able to hear, so tinnitus happen. So tinnitus is undiscriminitive sign , can happen due to many causes such as diabetes or some degenerative disorders because it will cause degeneration to the nerve and because conduction through the nerve will be less so tinnitus. Other causes include high blood pressure , tumors , thyroid conditions, some medications such as antidepressants, sedatives, antibiotics, anti-inflammatories, and aspirin.
*If the patient does not hear , he has hearing loss or deafness.

Vestibular system

In the inner ear there are two structures:
1-cochlea; which is responsible for hearing.
2- labyrinth; which is important in the vestibular system which will give information about position and body movement.
The labyrinth is a hard-shelled cavity filled with a fluid similar to the fluid present inside the cochlear duct which is called endolymph.



*** This labyrinth consist of five parts:

3 semicircular canal situated in three different axises **(X,Y,Z)**, and they are **lateral , anterior and posterior semicircular canals**. At the end of each semicircular canal there is a dilation called the **ampulla**.

*Beside the semicircular canals there is two dilation in the base of the labyrinth called **"utricle''and "saccule''**. The utricle is almost horizontal whereas the saccule is almost vertical.

* The function of this labyrinth is to detect the movement. Inside the ampulla of the semicircular canals there is a gelatinous membrane beneath it there are hair cells similar to the hair cells in the cochlea responsible for hearing. So that bending will open mechanical ion channels and graded potential and action potential is produced. The semicircular canals detect the rotational movement, so if you turn your face from right to left there is a rotational movement and the fluid will move in one of the semicircular canals and go to the ampulla and push the gelatinous membrane which move the hair cells firing action potential and detecting the movement. Because there is three semicircular canals each one in different direction each movement will move the hair cells in one or more of these canals and by that we can detect the rotational movement in different directions. Still we have the non rotational movement such as nodding and tilting the head which is the responsibility of the utricle and the saccule. In the utricle and the saccule there is also membrane called otolithic membrane which detect movement against gravity (linear movement) as tilting. So the utricle detect the horizontal movement and saccule detect the vertical movement.

***if you moved your head from right to left or from left to right how can your body differentiate between them "clockwise or counterclockwise''?** By the movement of the fluid. The vestibule work in pairs. The lateral in the right and the lateral in the left are aligned Opposite to each other i.e.:

we have **vestibular system** in each ear but the lining of hair cells of each one is opposite to the other. Let's review some points about the hair cells:

**The hair cells have hair extensions and have mechanical doors above and have a baseline firing, bending them will open the mechanical doors more and frequency of action potential will increase. If we bend them to the opposite side these doors will close and graded potential will decrease and in this case there

will be decrease and inhibition for the frequency of action potential, so that the hair cells in the two canals(right& left) are aligned against each other. When I turn from right to left the fluid will turn and one of the canals will bend and open and the other will bend and close.so when you turn from right to lift , the left will get excited and frequency of action potential increase whereas in the right the frequency will decrease and vice versa. And thus by the difference I can know if I'm turning clockwise or counterclockwise. And as we said they work in pairs, the two lateral work together and the anterior in the left side work with the posterior in the right and the posterior in the left with the anterior in the right. (Tilting and nodding is the responsibility of the utricle and the saccule.)

***The vestibular pathway From the labyrinth through the vestibular branch of the vestibulocochlear nerve to the brain stem. In the brain stem they will synapse with vestibular nucleus which is a complex of nuclei (4 or 5). From the vestibular nuclei and to the thalamus then to the cortex which is the conscious pathway. But opposite to all sensations there are no primary vestibular cortex. The vestibular pathway go to the cortex of other sensations that means it has no specific nuclei in the thalamus.**

*** One of the important cortical area it will go to is posterior insular and temporoparietal cortex which responsible for awareness about position and body movement and status , also it has multisensory cortex (association type of cortex which take a small part of the auditory and a big part of the vision cortex), and in order to reach this cortex It will go through pulvinar nucleus in the thalamus.**

*** It will go also to the 3a area (somatosensory cortex) so it has to go through the VPL nucleus in the thalamus .**

*** It will also go through other nuclei in the thalamus as posterior, inferior and others. And from there it will go mainly to : – The cortex: Mainly to 2 areas in the cortex one is in the posterior parietal lobe(area 5,7) which is association type of cortex which has a job in attention and surrounding.**

Second to area 6 which is the premotor cortex for frontal eye field area. There are other subcortical targets such as hippocampus and limbic system.

– The second target is extrapyramidal tract which is vestibulospinal tract from vestibular nucleus directly to the spinal cord to lower motor neurons(alpha, gamma).the medial tract mainly for head & neck , whereas the lateral for the trunk .

– The third is accessory nucleus to control the neck muscles through the accessory nerve . (vestibiloaccessory tract)

– Forth target go directly to the cerebellum(for coordination)

– Fifth target is nuclei of eye movement (the vestibular can unconsciously move your eyes opposite to your body movement , that's why you can look at your friend and talk to him while you are walking downstairs .)