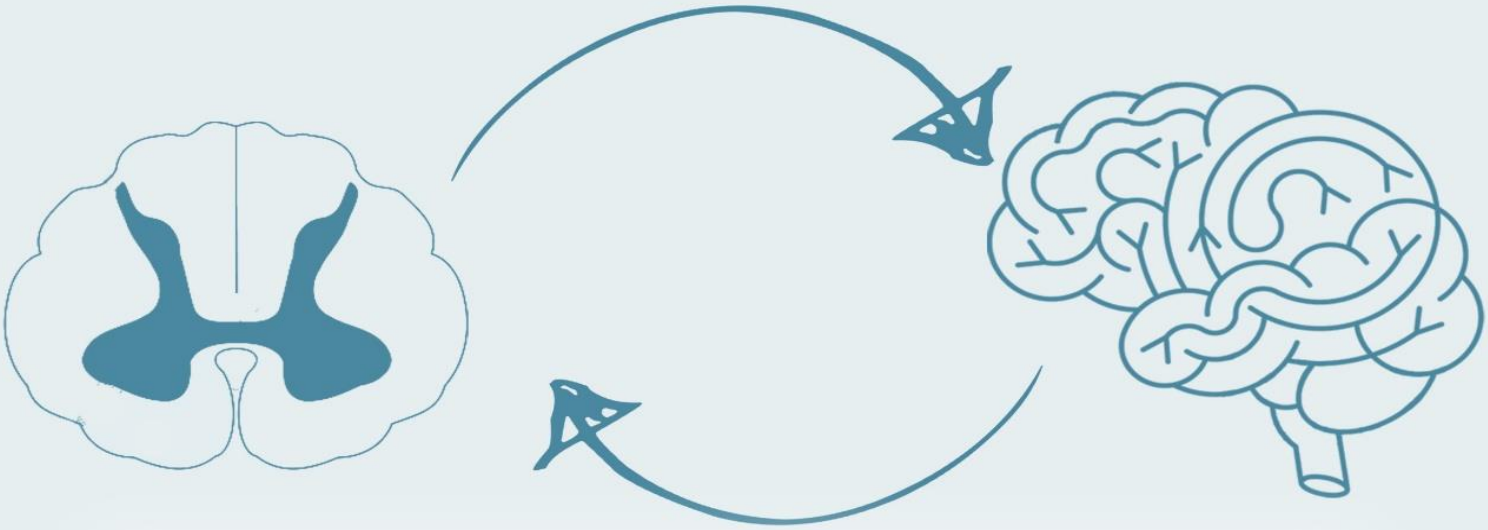


CNS

physiology

slides | sheets

number	9
Done by	Dawood Alatefi
Correction	Enas Ajarma
Doctor	Loai Alzghoul

In the previous lecture we started talking about the auditory system and we said that there are two pathways, and finally we talked about auditory reflexes, acoustic startle reflex and middle ear reflex.

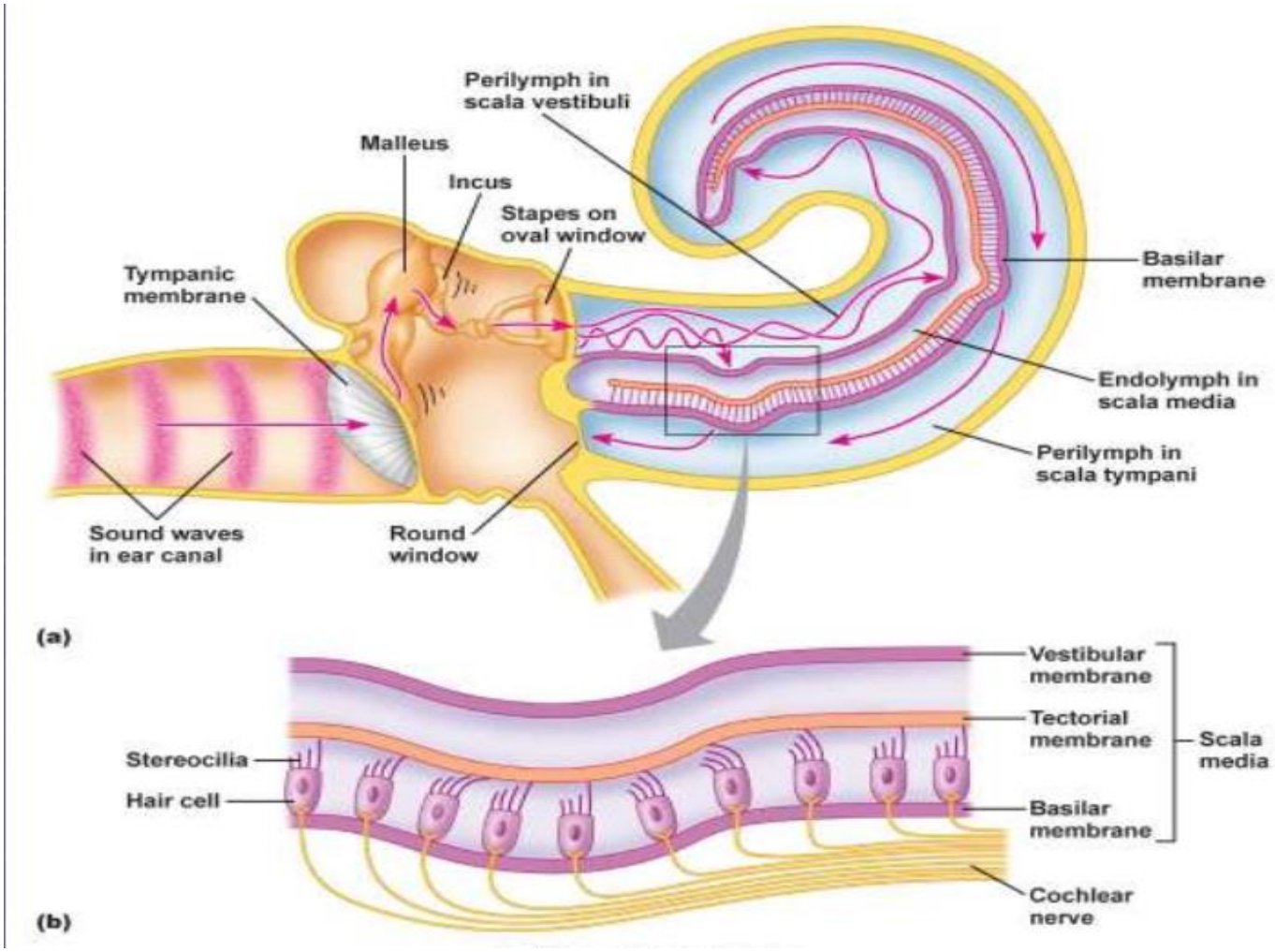
- In the **acoustic startle reflex** a sudden sound make you involuntary move toward it, and it involved in the tectospinal tract.
- When you are in a party , once you enter the sound is high and you become annoyed and can't hear anything, after a while the voice become calm. This happens due to **middle 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.

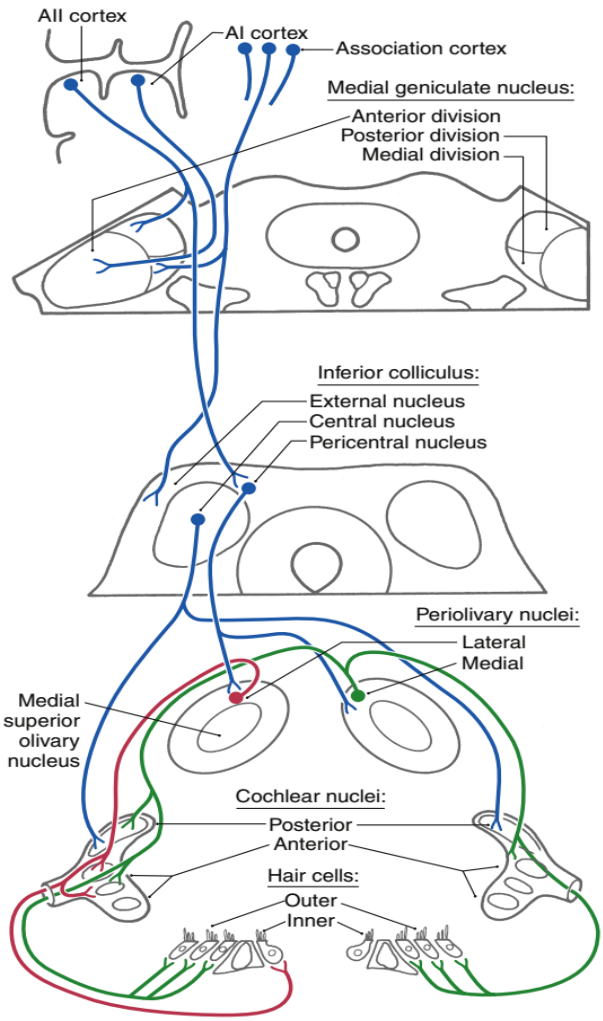
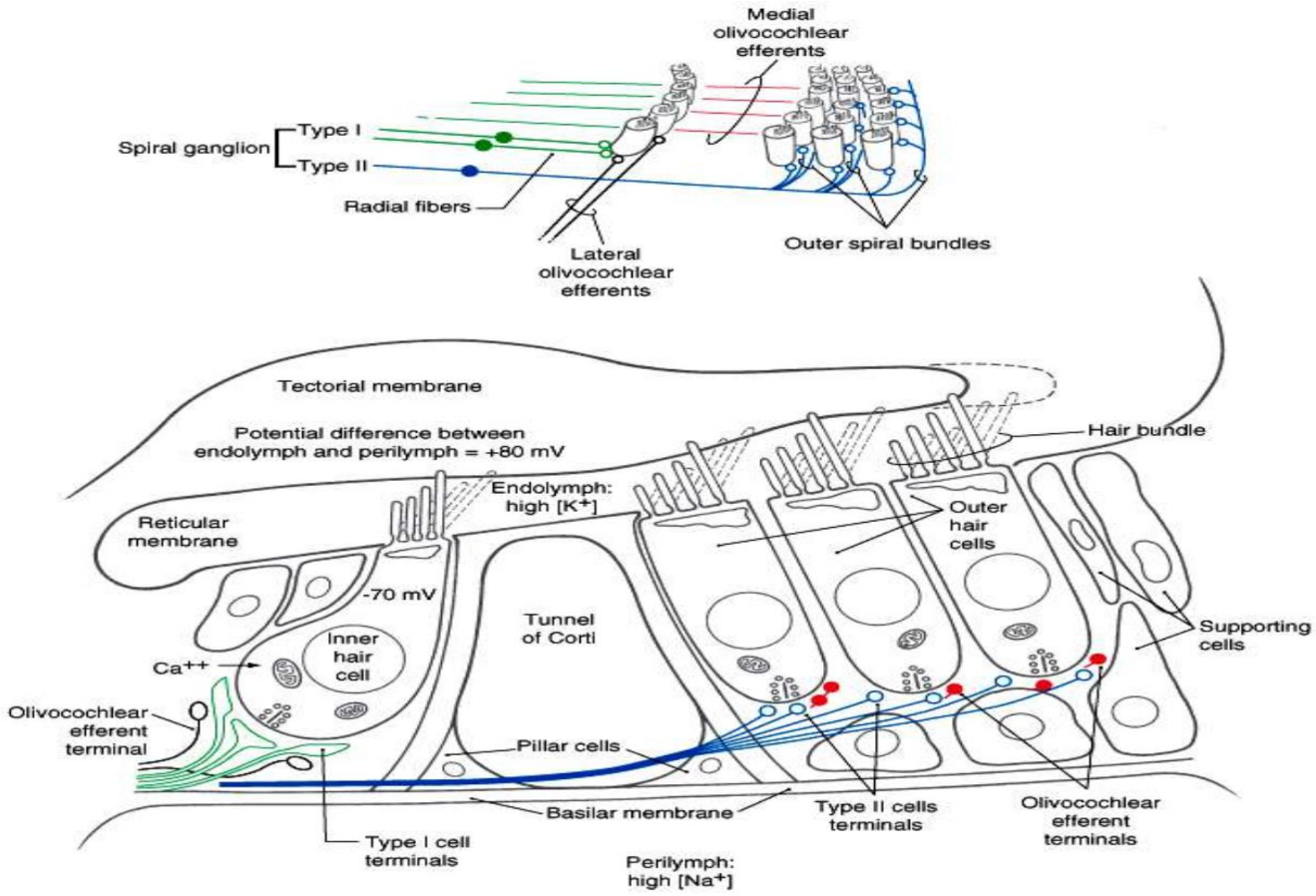


Figure 21-13. Descending auditory pathways that modulate sensory processing at central and peripheral auditory sites. The lateral olivocochlear efferents are shown in red and the medial olivocochlear efferents in green. *AI* and *AII*, primary and secondary auditory (cortices).

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

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.

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.

- **<u>Hearing loss(deafness):</u>**

Hearing loss can be either <u>conductive hearing loss</u> or <u>sensorineural hearing loss</u>. If the vibration can't reach to the hair cells and activate them(as in olfaction if we can't activate the receptors-receptors is

functioning but the stimulus can't reach them-) in this case it is conductive hearing loss. But if the hair cells themselves or the nerve are not function or any defect in the pathway up to the cortex it is then sensorineural .

- **Conductive deafness:**

Due to impaired sound transmission in external and middle ear. It impacts the sound frequencies. Causes includes:

- Plugging of the external auditory meatus, with cerumen(ear wax or foreign body).
- Otitis externa and otitis media
- Perforation of eardrum
- If the tympanic membrane is damaged
- Calcification of the three bones of hearing
- Osteosclerosis

- **Sensorineural deafness:**

In this case the vibrations can reach to the cochlea but there is other distal problems;

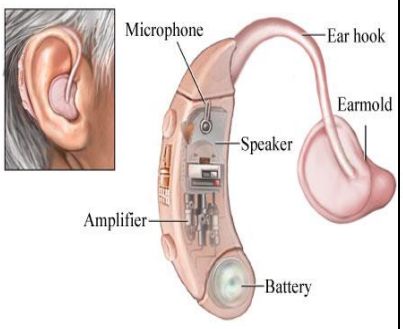
- Due to loss of cochlear hair cells
- Problems with cranial nerve VIII
- Lesions within the central auditory pathway
- Impairs the ability to hear certain pitches(permanent)

Causes include :

- Prolonged exposure to noise

- Some antibiotics which causes autotoxicity(degeneration to hair cells) such as aminoglycosides.
- Tumors and vascular damage(pontine auditory hallucinosis)

What does Hearing Aids do?



It is an amplifier. Normal person can hear up to 20 decibel (dB) ,he can detect less than 20 dB sounds, but when he has hearing loss, now he need stronger sound to hear(he need sound higher than 20 dB), so this device is design to do this function, and it is useful in certain types of hearing loss, but if he for example has autotoxicity which destroyed the hair cells which is responsible for example for sounds from 10-20 KHz(10,000-20,000 Hz) then in this case this device is not useful and the patient need cochlea implantation where the cochlea is removed and implant a device which do activation to the nerve.

As we said when we talked about pain that there is deafferentation pain where the CNS get activated and produce pain, a removed limb produces phantom limb. If there was a tumor or lesion in the auditory pathway especially at its proximal levels, usually associated with pontine(lesion in the pons), in this case there will be a deafness but other centers will get activated and the patient hear sounds which does not exist and we call it **auditory hallucinosis** and because it is usually associated with pons we call it **pontine auditory hallucinosis**. in these patients there is perception of sounds as music or anything else. It can happens to some peoples who has temporal lobe seizures.

- **<u>Auditory tests:</u>**

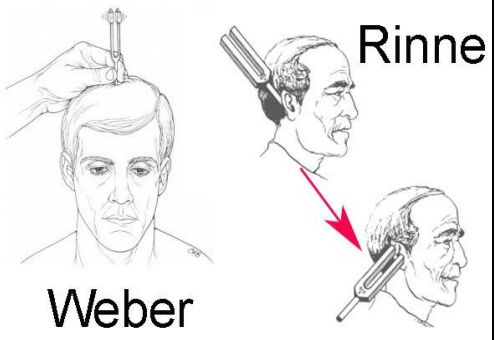
The purpose of these tests is to know if there is loss or not and to distinguish it is conductive or sensorineural. The most common two are

Rinne and **weber** tests. Sound is a vibrations so any thing will vibrate the basilar membrane is considered a sound. If there were any vibrations directly reached to the bones of the skull, the cochlea will vibrate and you will hear a ringing sound. But because the middle ear function is amplification, so the sound which will go through middle ear will be stronger and better than the sound which will go directly to the cochlea through the bone. So that normal person hearing through air (EAM and middle ear pathway) is better than hearing through bone.

There are two tests that help us to differentiate between the two types of deafness:

1- **Weber test**: Indicative for conduction or nerve deafness.

2- **Rinne test**: Compares air conduction with bone conduction.

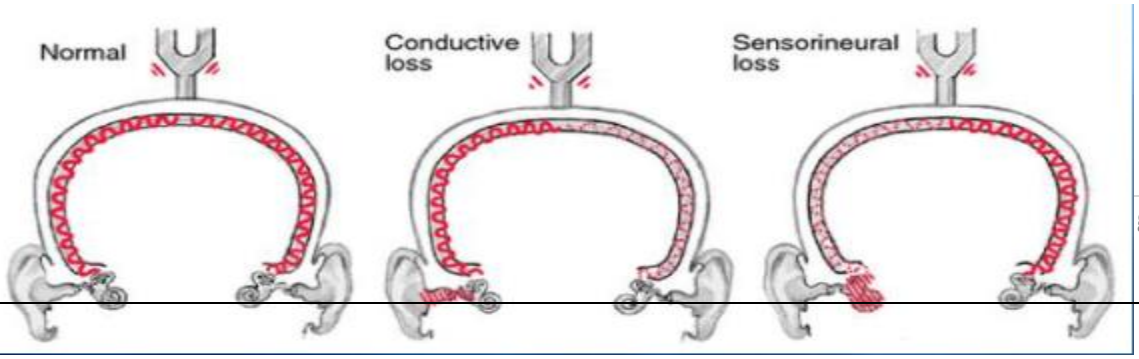


- **Weber test:**

Procedure: We strike the tuning fork(الشوكة الرنانة) and put it on patient's head, normally it's heard to same degree in both ears (it's not important if he hears it strongly or weakly, but it must be equal – no lateralization).

- <u>In nerve deafness</u>: If it was in the right ear he will hear the sound from the left ear.

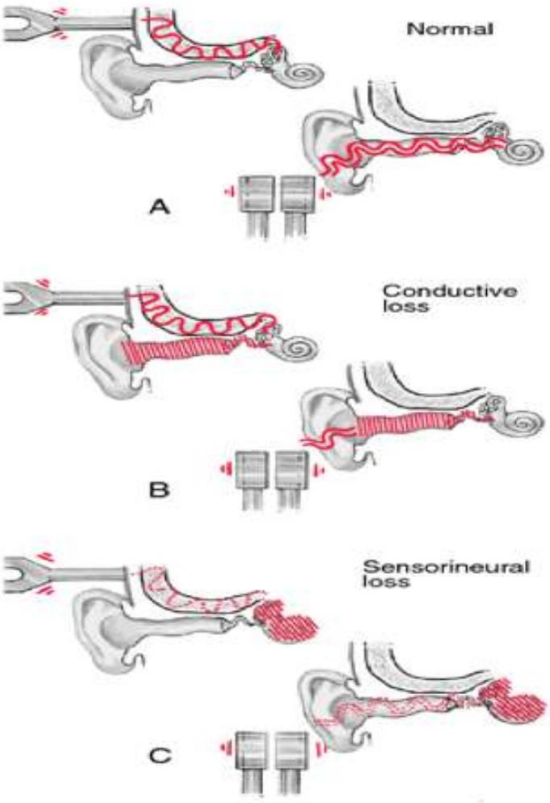
- <u>In conduction deafness</u>: If it was in the right ear (e.g. a problem in external or middle ear or the ear drum), he will hear it louder on the right ear (on the affected side). Even his right ear is closed and cannot conduct sound, but he hears because the sound conducted through bone and because there is no conduction to the noise around, the sound will be louder in the affected ear as the healthy one will conduct both the noise and the vibration through the bone .



TO SUM UP : if the patient has nerve defect , he will hear from the opposite ear (if the defect in the right he will hear from the left and vice versa) . whereas if the patient has conduction defect , he will hear the sound louder from the affected ear .

➢ Rinne test:

Principle: In a Normal Ear, Air conduction is better than bone conduction (AC is better than BC).



- <u>Positive Rinne test: (Normal people)</u>

1- We strike the tuning fork and put it on the mastoid process. The person will hear the sound for a period of time, the sound will decline gradually from the fork, you ask him to tell you when he is not hearing any more. Note that he is now hearing using bone conduction.

2- After the sound disappears. Put the fork in front of the ear, the person will hear again because AC is better than BC. This is positive Rinne test and this happens in normal people.

- <u>Negative Rinne test:</u>

1- Same as above.

2- Same as above. However, when you put the fork in front of the ear, the patient will not hear again.

3- Now to confirm the negative result, you do the opposite. Put the fork in front of the ear at first, and ask the patient to tell you when he stops hearing.

4- When no more sound heard, you put the fork on the mastoid process. The patient will hear the sound again. This indicates that the patient is hearing from the bone better than air. This is negative Rinne test which indicates that the patient has a **conduction problem**.

Those two tests are done in the doctor clinic but if the patient was expected to have the problem we refer the patient to do something called audiogram which will test for more than one tone so that if the patient has a selective loss to certain tones it will appear in the test .(usually conduction defect affects all tones , whereas the neuronal defect may affect selective tones) .

As we said before that tones are associated with organization, where each tone has separate line which start from the basilar membrane and remain preserved up to the cortex. So every tone will make activation to different area of 41(primary auditory cortex). In sometimes some neurons not all are damaged and there comes the importance of the audiogram. In the audiogram the patient is placed in a soundproof room and a headset is placed in one of his ear(right then left ear separately) and we start giving him sound with certain tone(frequency) and we increase the tone gradually and the patient is supposed to give a sign when he start hearing the sound. Then we increase the frequency and repeat the steps.

- Normal person can detect from 0-20 dB
- If he needed more than that then he has hearing loss either mild or moderate or severe or profound hearing loss

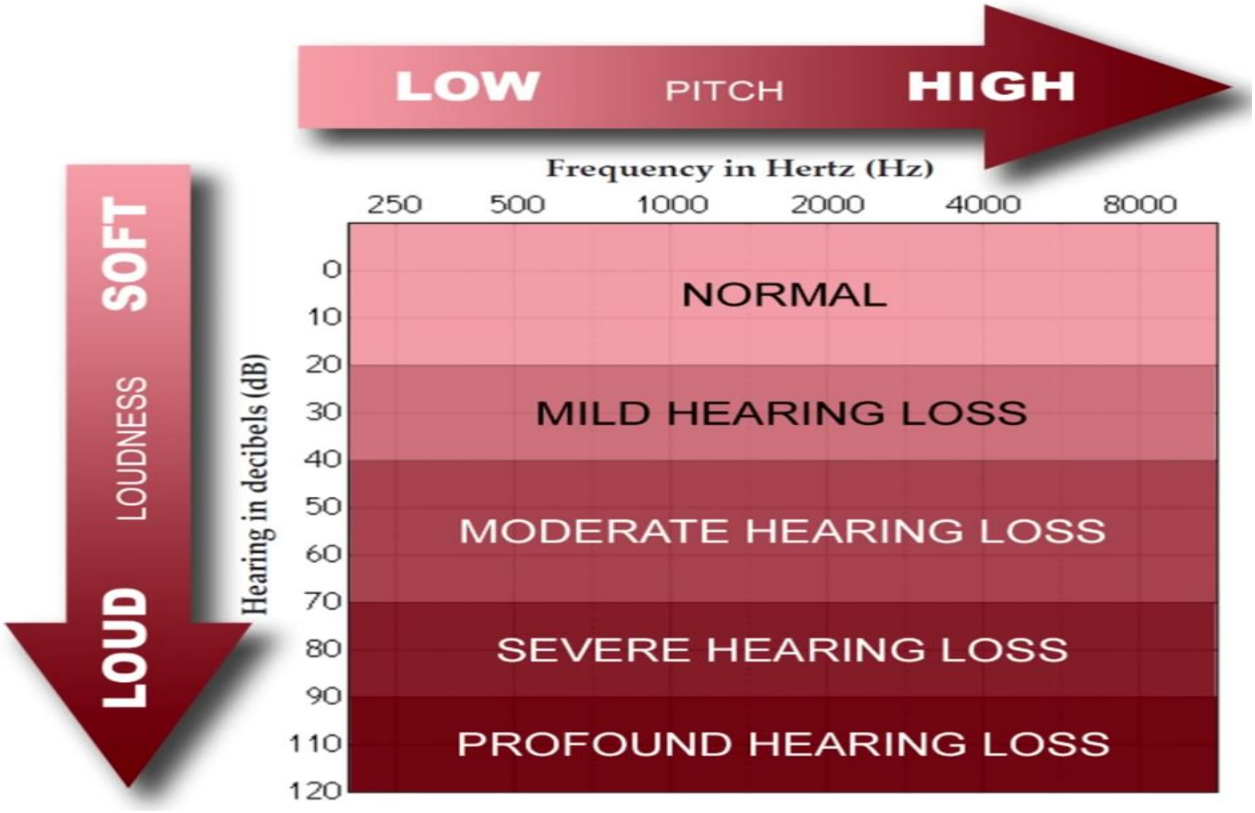
  Before we give some examples about audiogram we need to go through some points about audiogram not mentioned by the doctor.

Audiogram:

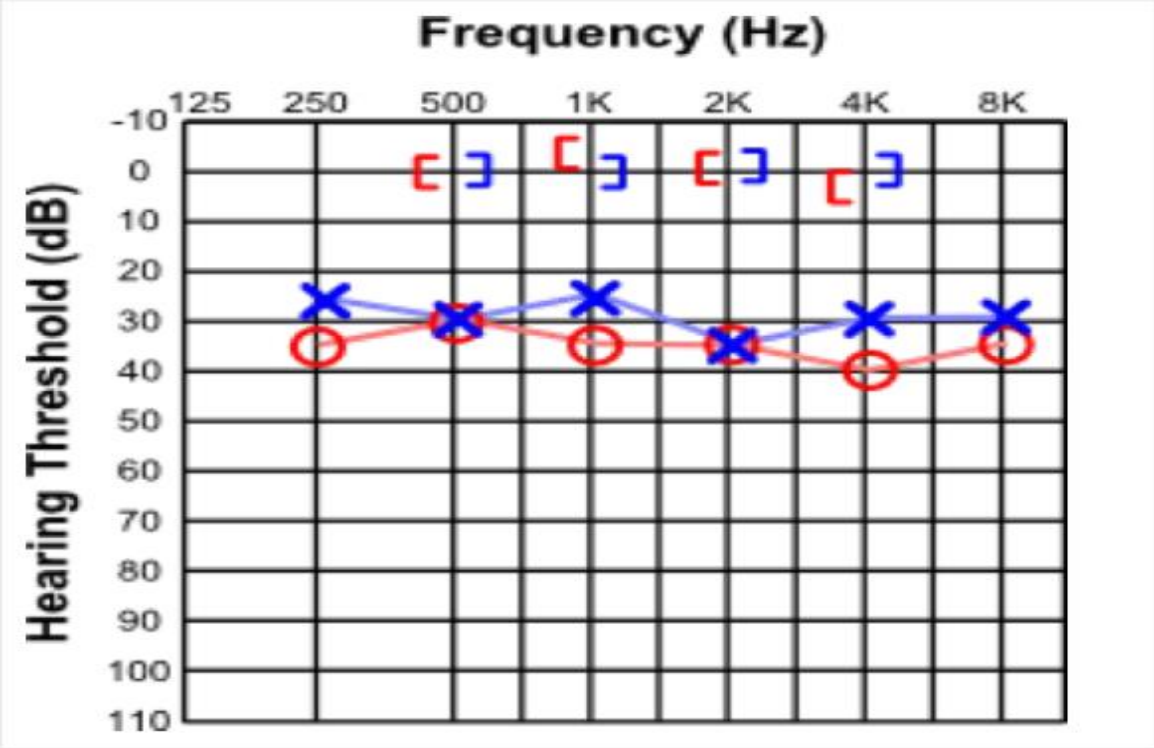
it is a graph that shows information about person's hearing abilities.

<u>Parts of the audiogram paper</u>

- The audiogram measure the sound intensity or loudness in decibels (dB) which is listed from 0 dB at the top to the Y axis to 120 dB at the bottom of the Y axis
- Running from the left to right is the frequency or pitch which is measured in Hz.
- The frequency start on the left side with 250 Hz and goes up to 8000 Hz on the right side
- On a typical audiogram you will see two lines, one red and one blue. The red line represent the hearing in the right ear and the blue line represent the hearing in the left ear. If the audiogram does not have colors then the line with “X” represent the left ear and the line with “O” represent the right ear.
- Square Brackets([ ]) (red=right ear . blue=left ear) are for bone conduction

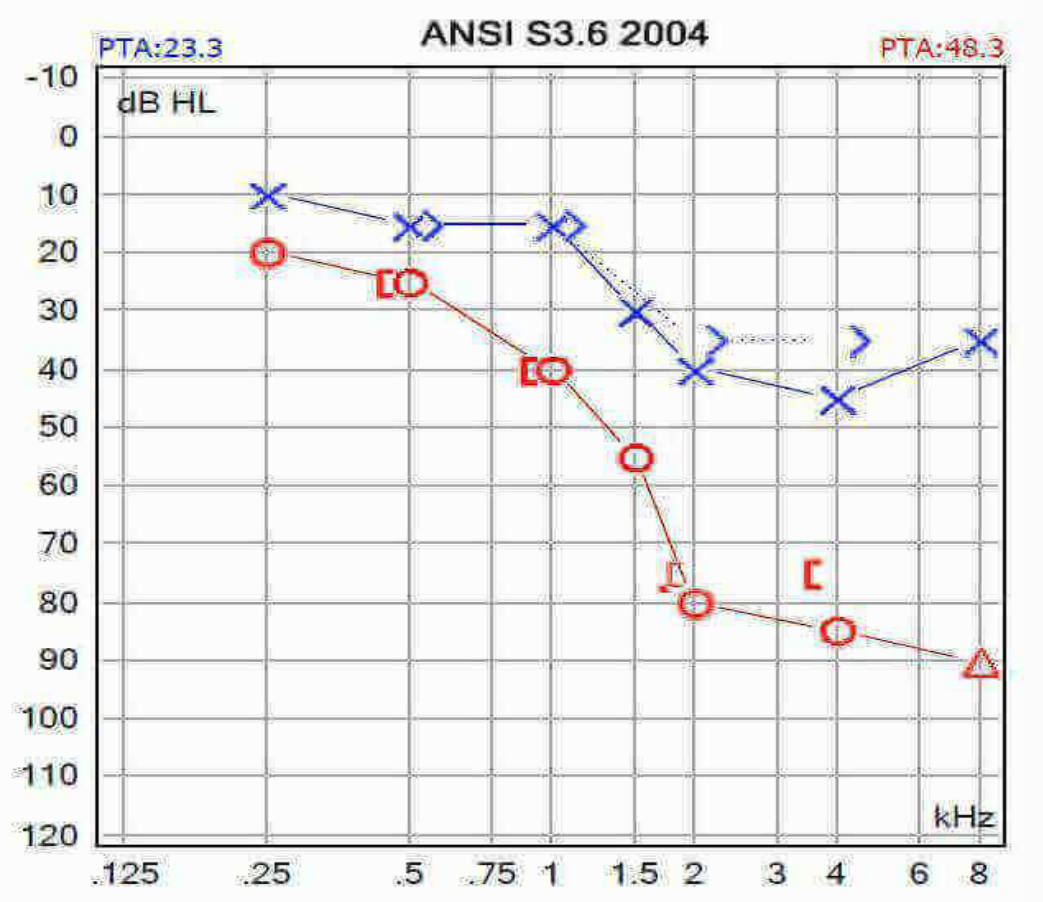


✓ Case 1:



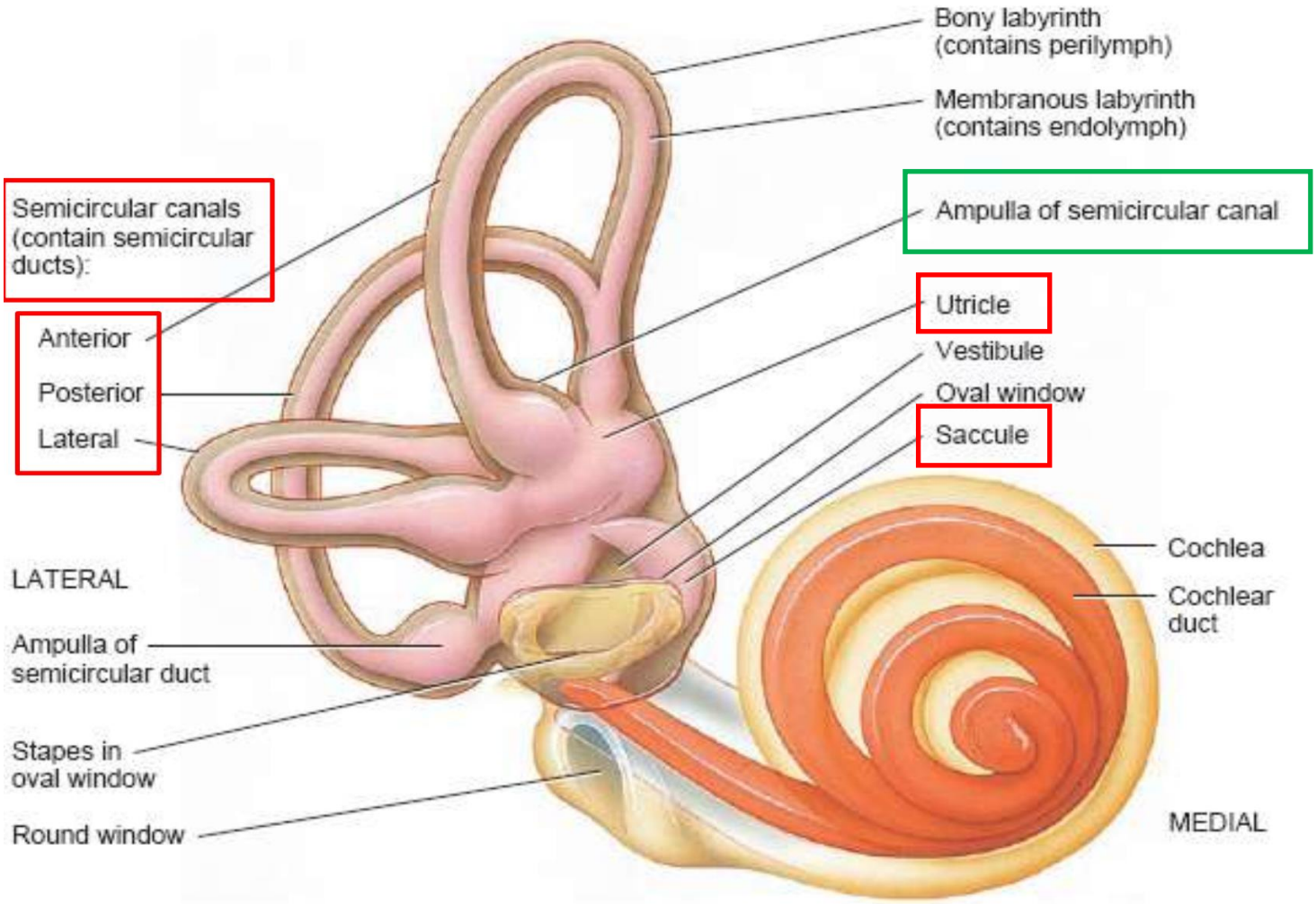
- Start look at the lines then the Brackets
- In this case as you see the blue and red lines fall into the 20-40 dB range so this patient has a mild hearing loss
- As you can see conduction through bones represented by Brackets is better than air because Brackets fall into the normal range of decibels(0-20 dB). so this patient has a conductive hearing loss.
- Because the blue and red lines and Brackets are distributed in the same range for both this means the loss is in both ears.

✓ Case 2:



- In this case there is a selectivity to high frequency from 1.5-8 KHz
- The loss is in both ears but it is more in the right ear.
- The conduction through bone and air are almost equal so it is sensorineuronal hearing loss but it is severe in the right ear and mild to moderate in the left ear.

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 .)