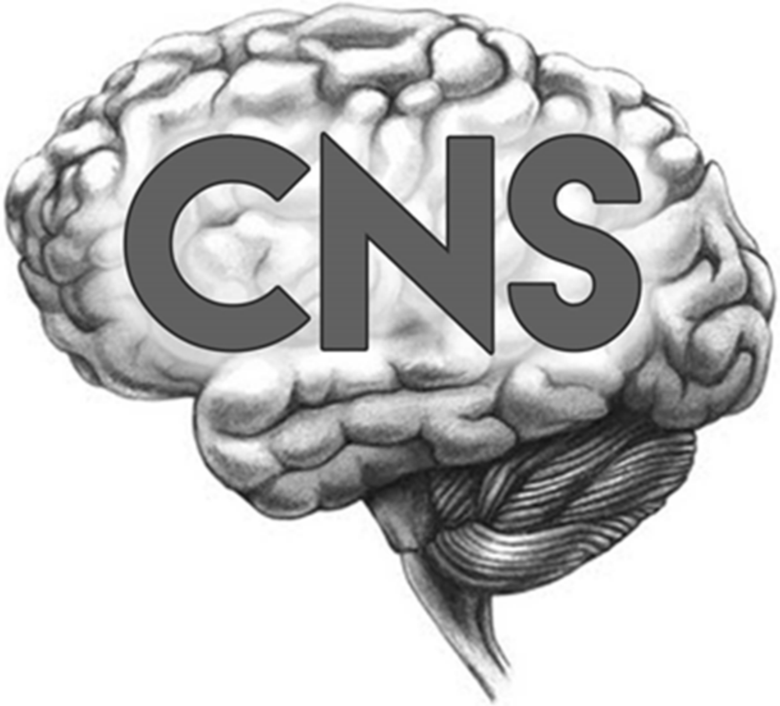

PHYSIOLOGY

☑ Sheet ○ Slide ○ Handout

Number

18

Subject

Auditory sensation

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Price:

(sec-3record)

Recall

Last time we started talking about auditory sensation, it's one of the special sensations. Today we are going to talk about the rest of the special sensations continue the auditory and begin with smell and taste sensation.
Last lecture we have defined the **decibel**, talked about the **Ossicular System** (the three middle ear bones), we begun talking about the structure of the **cochlea** & **Organ of corti** and we have mentioned the receptors.
Today: we will follow-up the auditory pathway to its cortical presentation and finishing it.
Remember from the last lecture:

- ✓ **Frequency** (cycles per second = Hertz) and **wave length** are used to describe sounds.
- ✓ When looking at "the sound" around the tuning fork we can notice alteration of areas of pressure and areas of no-pressure مناطق ضغط و تخلخل
  these areas represents the cycles >> when measured by second, we will obtain the FREQUENCEY.
- ✓ The frequency of the audible sound is between 20 – 20,000 Hz. (note : this applies for children >> when we get older the range become less from both tails)
- ✓ The **loudness** or the **intensity** of the sound is a measurement of the amplitude of the sound. (u might have the same frequency with a different loudness or the same amplitude with a different amplitude)
- ✓ The intensity is measured by Decibels (calculated in log. Scale to increase the range >> instead of **0-120** decibel the range become **0-10^120**)
  we can talk about **decibels in term of pressure** , as in the following :
  - Sound pressure level (SPL) unit is decibel
    - SPL (dB) = 20 log P/P_R
      - P= the sound pressure in N/m^2 (N=Newton, m = meter)
      - P_R= reference pressure (either 0.0002 $dynes/cm^2$, the absolute threshold for human hearing and equal 20 micropascal, or 1 dyne/ cm^2)

  note : the P_R represent the threshold (the slightest sound u can hear)
  or u can describe the **decibel in terms of intensity** as follows :
  - Decibel (dB) = 10 log I/I_R
    - I = intensity of sound, I_R= reference intensity

  we can notice that if we wanted to convert the intensity into pressure we have to multiply by 2 (notice in the two laws >> there is 10 at the intensity law while 20 in the pressure law "10*2=20")
- ✓ The sound travel much slower than light (the Dr. said that in the TV the sound waves are transmitted on the light tracts in some way>> so that we can see the photo accompanied with its sound).

The ear is composed from: external, Middle & inner ear. Look at figure1

External ear

- the **auricle** of the ear helps u to discriminate if the sound comes from posterior or anterior side (other systems are specialized in differentiating if the sound is coming from ur Rt or Lt side)
- the **external auditory meatus** and the **auditory canal** for sound transmission
- The **Tympanic membrane**, which will vibrate in the same frequency as the sound waves. clinical correlation : the otoscope is used to examine the tympanic membrane , if there is otitis-media the tympanic membrane will be Red+ bulging =inflamed. And it could be easily perforated if you insert a sharp object into your-ear.
- The overall Fx of the external ear is the conduction of the sound waves.

Middle ear

- Here we can find a connection b/w the nasopharynx and the middle ear = **Eustachian tube**.
- three **ossicles** (malleus, incus, Stapes) the ossicles vibrate in the same frequency of the tympanic membrane and the original sound waves,
  rem : the middle and external ear are filled with normal air so there's no additional resistance applied there, while the inner ear is filled with fluid >> so there is an additional resistance applied to the sound waves at the inner ear.
  So when the stapes hits the oval window the sound waves will be transmitted in the fluid of the Scala vestibule which requires a higher pressure (or intensity) to maintain the real sound waves intensity. >> This guide us to the overall Fx of the middle ear,,
- The overall Fx of the middle ear is to match the resistance of sound waves in the air with the resistance of sound waves in the inner-ear fluid
  so the Fx of the middle ear is Impedance Matching.
- **The Impedance Matching (resistance matching):** serve in increasing the intensity of the sound waves. Several factors aid in this Fx:
  1. Different surface areas of the tympanic membrane & the stapes/the oval window
     - The tympanic membrane has a surface area of 55 sq. mm
     -the stapes/ oval window has a surface area of 3.2 sq. mm
     so the difference between the In-gate and the out-gate of the middle ear is **17 times**>> this increases the pressure (the intensity) it's like the بوق
     the general rule says that if u manage to collect the sound from a large area and

concentrate it in a smaller area then u will amplify this sound >> this is exactly what happens in the middle ear.
these factors increase the pressure around **17 times**

2. The **ossicles** work as a lever system كالبكرات >> this factor increase the pressure of sound waves around **1.3 times**.

   So the total amplification is (1.3 * 17 =22 times) >> by this the middle ear has amplified the intensity of the sound waves enabling it to vibrate the higher-resistant-fluid in the inner ear.

- ✓ There are two muscles at the middle ear : Stapedius connected to the stapes (supplied by facial n) & tensor tympani which is connected to the tympanic membrane (supplied by Trigeminal n)
  when the sound is too loud >> this might injure the cochlea >> so these muscles protect the cochlea when they contracts >> they make the three ossicles very rigid >> the ossicles are unable to vibrate or conduct the sound.>> this is called the Attenuation reflex (attenuate= decrease the vibration)
  these muscles serve another Fx as they Serve to damp (mask) low frequency sounds in loud environment .i.e., your own voice

Inner ear / cochlea

- ✓ The cochlea is a snail like structure , when u spread it u will notice that it is composed from 3 Scala: look at figure2
  1. Scala vestibuli, closed by oval window.
  2. Scala tympani, closed by round window.
  3. Scala media or the cochlear duct.
- ✓ At the apex of the cochlea the scala vestibuli and the scala tympani are continuous in an area called **helicotrema** .
- ✓ Fluids :
  1. perilymph (like the ECF rich in Na^+) found in scala vestibuli and tympani.
  2. Endolymph (like Intracellular fluid , rich in K^+) found in scala media.
- ✓ Membranes: look at figure3
  1. **Ressiner's or vestibular membrane** (b/w the scala vestibuli and media)
  2. **Basilar membrane** (separate the scala media and the scala tympani) -more details later.
  3. **Tectorial membrane** coves the "hairs" of the hair cells of organ of corti.
- ✓ **Organ of corti** contains the receptors for hearing, situated above the basilar membrane. Receptors of hearing = hair cells. They are arranged as 1 row of inner hair cells and 3 rows of outer hair cells >> so there are 3-4 times as many outer hair cells than inner hair

cells around 12000 outer hair cells and 3500 inner hair cells.
The inner row is the most important for hearing, while the outer hair cells are capable of doing lateral inhibition and are generally more sensitive.
The hair cells are supplied by afferent and efferent branches of the cochlear nerve.
rem: the efferent fibers are cortico-fugal fibers that aid in sharpening the signals through lateral inhibition>> increase the sensitivity.

- ✓ **The basilar membrane** has a narrow base (near the round window) and a wide apex (near the helicotrema)

the basilar membrane is consisted from fibers, at some areas it's fixed and others it's free.

the basilar membrane is tonotopically organized

-look at figure4
-the fibers at the narrow base are shorter , wider and rigid >> they only vibrate as a response of high frequency sounds.
-the fibers at the wide apex are cylinder, thinner and longer >> they only vibrate as a response of low frequency sounds.
- In the middle >> middle frequency.
هذا الغشاء يشبه آلة القانون الموسيقية. (مخترعات الإنسان هي مجرد محاكاة لما خلقه الخالق)

and as the hair cells will respond to the specific vibration of the basilar membrane and hair cells transmit the info to the corresponding cortex >> the cortex will recognize the sound at its specific frequency too. (so all the auditory pathway is tonotopically organized).-more details later

the auditory cortex is tonotopically organized

-its **posterior** part recognize the **high** frequency sound >> which its input comes from the hair cells which reside on the **apex** of the basilar membrane.
-its **anterior** part recognize the **low** frequency sound >> which its input comes from the hair cells which reside on the **base** of the basilar membrane.
rem: auditory cortex is at the temporal lobe.

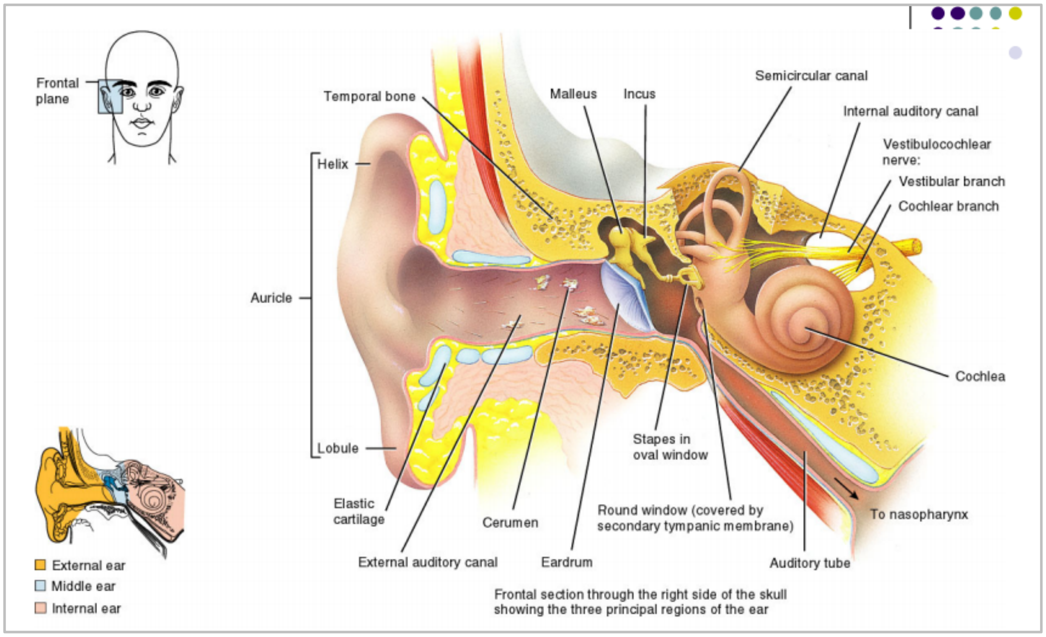


Figure 1 *: outer, middle & inner ear*

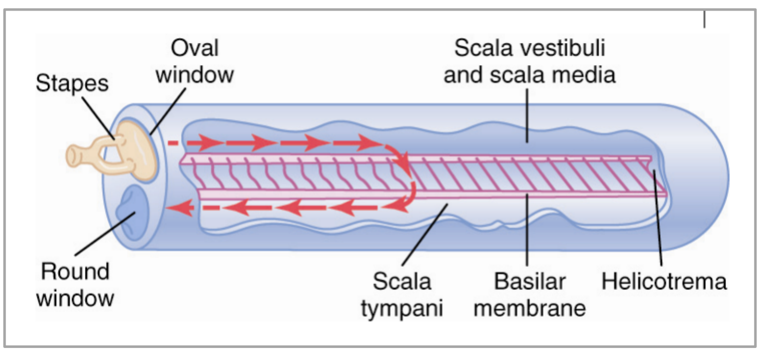


Figure 2 *: the cochlea- spread ,*
notice the oval widow , the round window and the Helicotrema

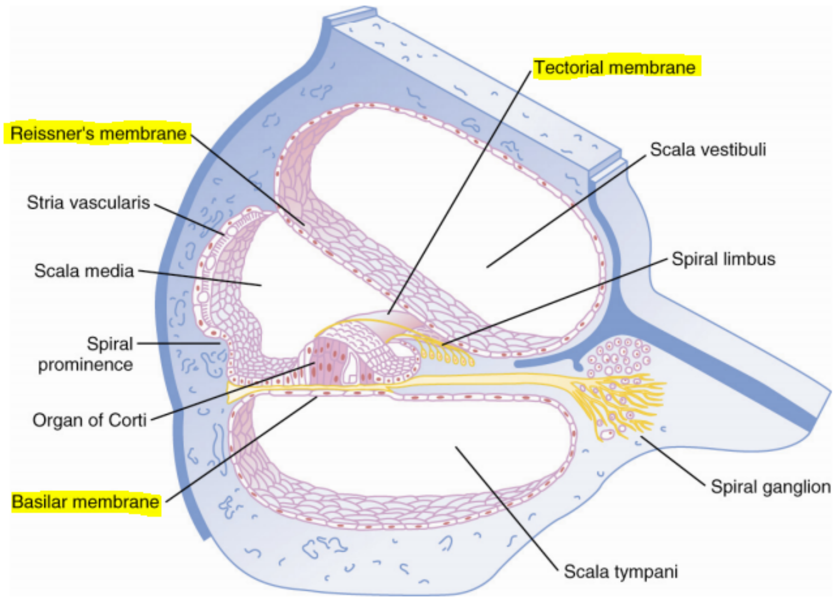


Figure 3: membranes of the inner ear , highlighted.

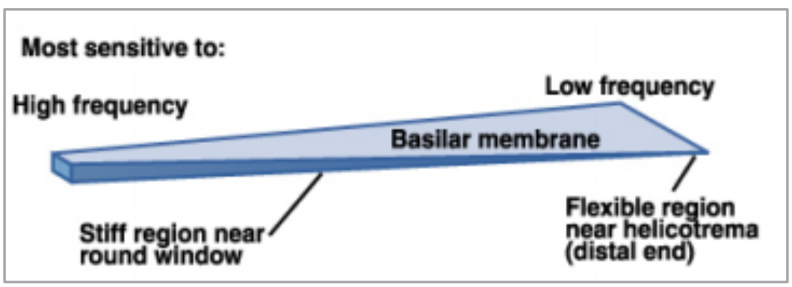
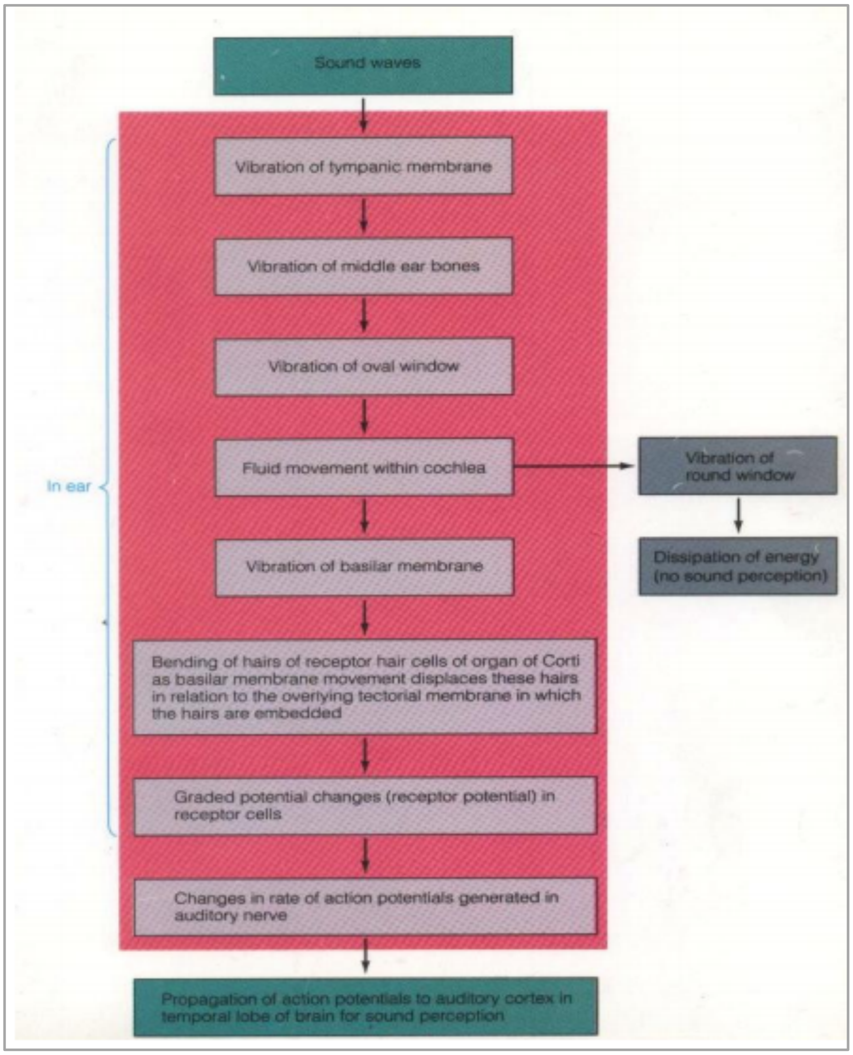


Figure 4 : the basilar membrane is tonotopically organized.

What happens when there are soundwaves

1. The soundwaves will vibrate the air
2. Enter the external auditory meatus>> pass through the canal
3. Vibrate the tympanic membrane>> this vibration will be transmitted through the ossticles .
4. The stapes will move in and out, when it moves in it will cause vibration of the fluid at the scala vestibuli.
5. The vibration of the perilymph at the scala vestibuli will cause depression of the basilar membrane.
   (so the basilar membrane goes down and up)

6. Some sound waves are dissipated - تفرغ the round window (no sounds perception via this pathway) if it didn’t reach the basilar memb.
   look at the following diagram and figure5.



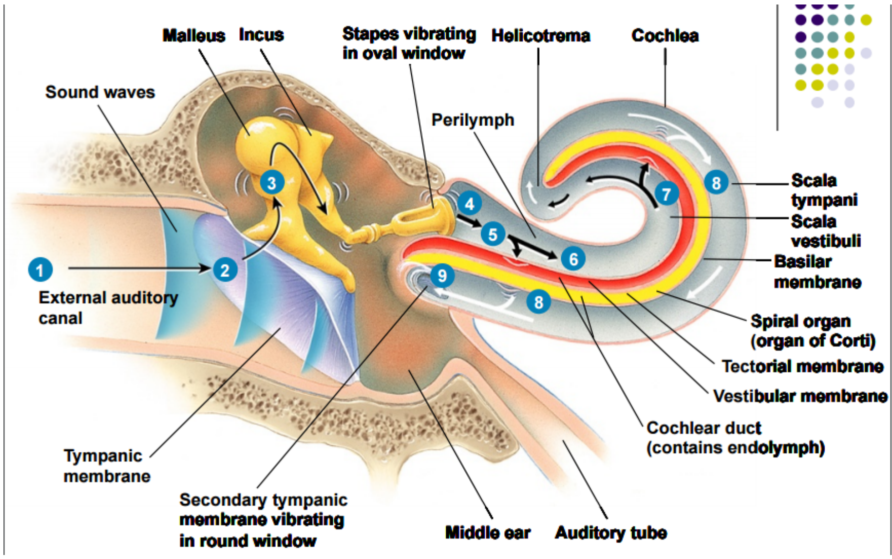


Figure 5 *: follow the soundwaves tract , EXCELLENT figure*

What happens when there is vibration- at the level of hair cells?

We have mentioned before that the hair cells are surrounded by **basilar** (down)**and tectorial** (up) **membrane.**

now look at figure5

when the basilar membrane goes up, the stereocilia of the hair cells will have a kind of friction with the tectorial membrane>> this friction cause the opening of certain ion channels mainly K+ channels (rem the hair cells are at the scala media which is filled with the K^+-rich-endolymph)>> depolarization of the receptors>> this will open voltage-gated Ca++ channels >> subsequently there will be release of NT >> this will stimulate afferent neuronal fibers.

When the basilar membrane goes down, the ion channels close >> hyperpolarization.

To sum up: at the same frequency of the sound the hair cells can respond by either depolarization or hyperpolarization >> this depends on how the basilar membrane moves.

Potential differences b/w different parts at the inner-ear:

- ✓ If u measured the **potential difference** between the endolymph and the perilymph = the difference will be +ve and equals +80mV, as the endolymph is more positive than the perilymph. This potential difference is called **intercochlear potential**. (endocochlear potential)

- ✓ Now the potential difference b/w the "inside of the hair cells " and the perilymph (say at the scala tympani)
  knowing that the perilymph is just like the ECF then this potential difference will be like any other potential difference b/w intracellular and extracellular , this equal -70 mV.
- ✓ The potential difference b/w inside the hair cells and the endolymph can be obtained by knowing the up-two givings , P = (-70) – (+80) = -150 mV.
  note the slides that discuss this topic are missed.

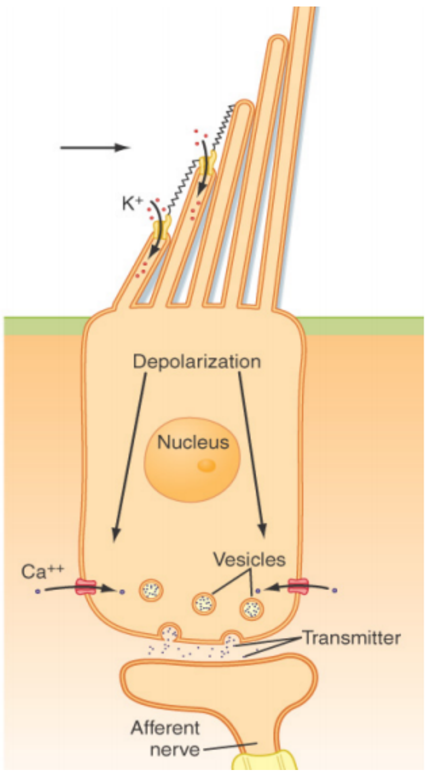


Figure 6 *: the effect of vibration on the hair cell >>*
they depolarize when the basilar membrane goes up,
note how the K enter then the Ca then NT are released >>
the afferent fiber is stimulated.

The dr. read this from the slides
tight junctions between the hair cells and the supportive cells prevent endolymph from reaching the bases of the hair cells
hair cells have -70 mV membrane potential to the respect to the perilymph.
hair cells have -150 mV membrane potential to the respect of the endolymph.
the strtia vascularis is responsible for the big amount of K+ at the endolymph.

Now, we can restructure the above mentioned mechanism of depolarization:
when there's stimulation (ie. Friction) >> the sterocillia move in one-direction>> **mechanical-receptor ion channels open** >> K+ channels open >> Depolarization>> Ca entry>> NT release>> afferent nerve stimulation.

notes :

- ✓ here the K+ will cause the cell to depolarize as the endolymph is rich in K , poor in Na.
- ✓ hair cells have basal rate of firing (sig >> enable +ve/ -ve control)
- ✓ so there are 3 stages of hair cell (rest , depolarization , hyperpolarization)
- ✓ when the hair cell de/hyper-polarized the corresponding afferent nerve fiber de/hyper-polarize , similarly.

(flash-back : the sound frequency determination)
So How do we know the frequency of the sound?
we have two theories

- ✓ According to the **place-theory** >> the site of the basilar membrane that vibrate will determine the frequency of the sound (it's the exact thing that we've mention at the "basiler membrane is tonotopically organized" section) -look at figure 6
- ✓ there is another theory called the **phase locked theory**(volley theory) >> this theory came to explain how the apex (the part of the basilar membrane near the helicotrema) is able to differentiate sounds of frequencies b/w (20-200 hertz) >> this cannot be explained by the place principible.
  according to this theory , any wave has different phases and each phase of the wave is "absorbed" at different part of the basilar membrane. -look at figure7

How we measure threshold?

-Look at figure8
let the patient hear sound waves of different frequencies >> then increase the intensity (the amplitude/ loudness) >> then measure what is the least intensity that can be heard for these different-frequency-sounds.
It was found that sounds with 2000 Hz have the least intensity (the threshold)

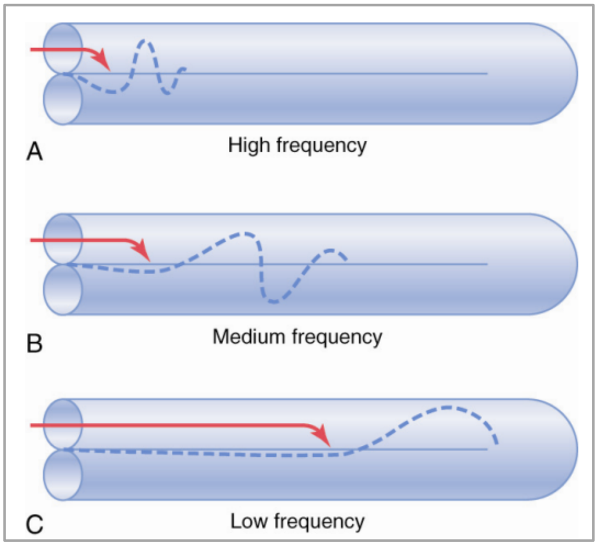


Figure 7 *: the place theory ,*
according to the frequency of the wave the basilar membrane vibrates.

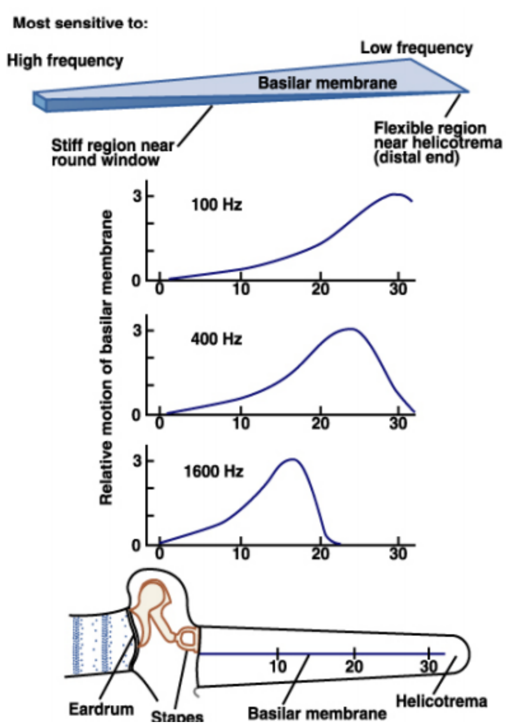


Figure 8 *: phase-locked theory , each wave have different phases of frequency each absorbed in different part of the basilar membrane*

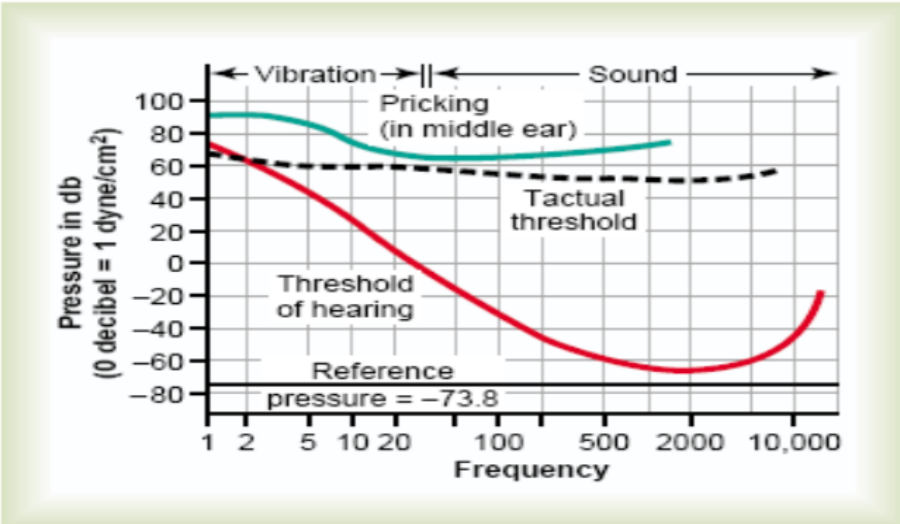


Figure 9 *: threshold of sound waves , the x axis represents the frequency (in Hz) while the Y axis represent the loudness of the voice (in decibel) , just look at the red line and notice how the least loudness occur at 2K Hz*

Auditory pathway

What is different about this sensory tract that there are a lot of crossing points here , there 4 crossing represented at figure10.
this implies that each side of auditory cortex receives information from both ears.
if one side of the cerebral cortex is destroyed> >that person won't suffer from unilateral deafness.
the unilateral deafness is obtained if the cochlear nerve or the basilar membrane are lesioned.

the tract :

- ✓ From the cochlea >> to cochlear nerve> >to cochlear nuclei.
- ✓ Some Fibers cross to the other side and reach the superior olivary nucleus bilaterally.
- ✓ Then fibers ascend as lateral lemniscus.
- ✓ Then synapse with the lateral lemniscus nucleus.
- ✓ Fibers ascend to the inferior colliculus. (another cross here , too) >> from here the tectospinal fibers arise >> this tract aids in movement of the head as a response of sound. (rem: the superior colliculus aid in movement of the head as response to the light also via the tectospinal tract).
- ✓ From the inferior colliculus to the MGB of the thalamus (receive from both inferior colliculi)
- ✓ Then to the auditory cortex. (anterior cortical parts for low frequency , posterior cortical parts for high frequency)

  rem : every area of the auditory tract is tonotopically organized.

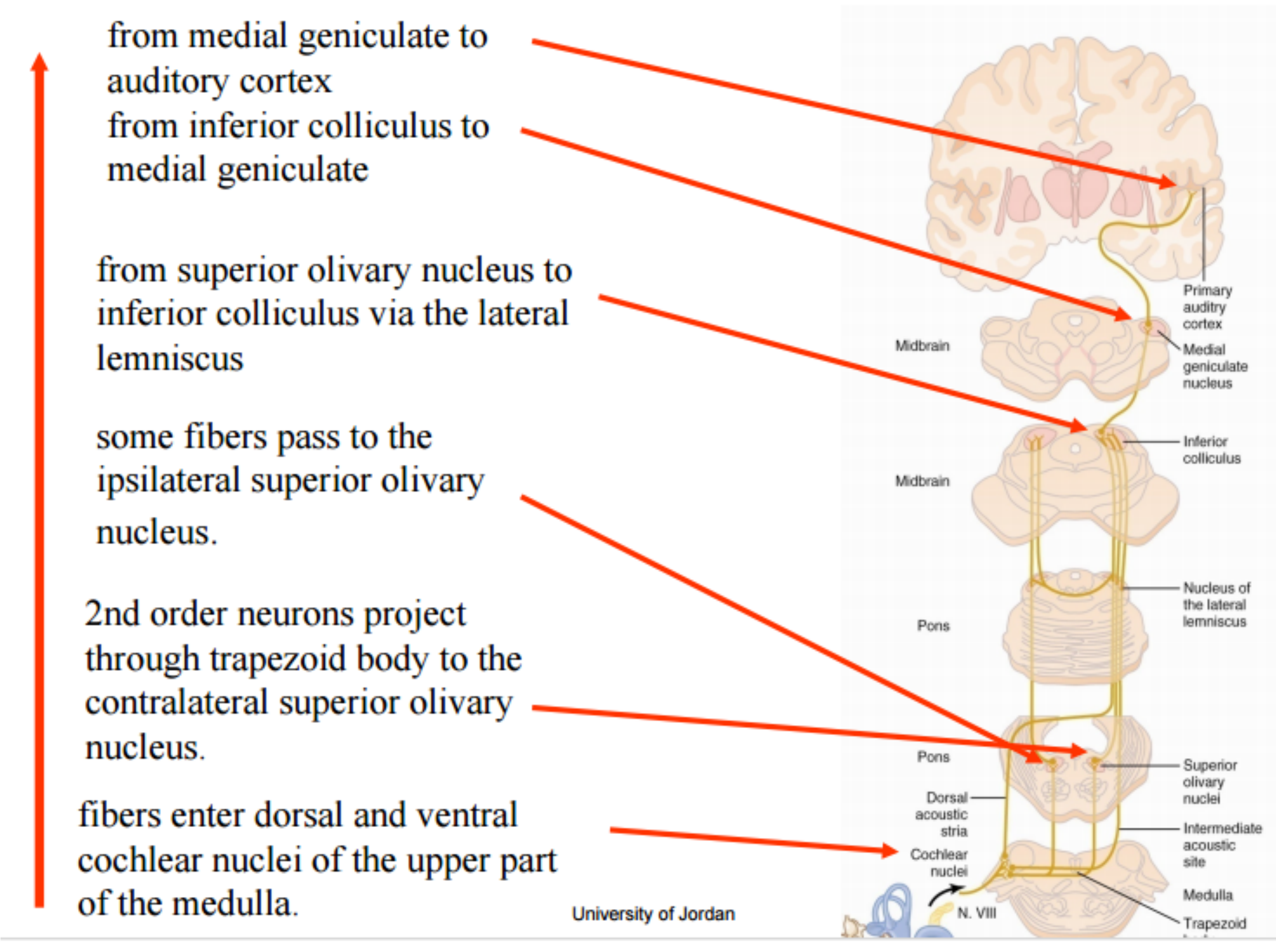


Figure 10 *: auditory tract.*

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