

# Cochlear Implantation

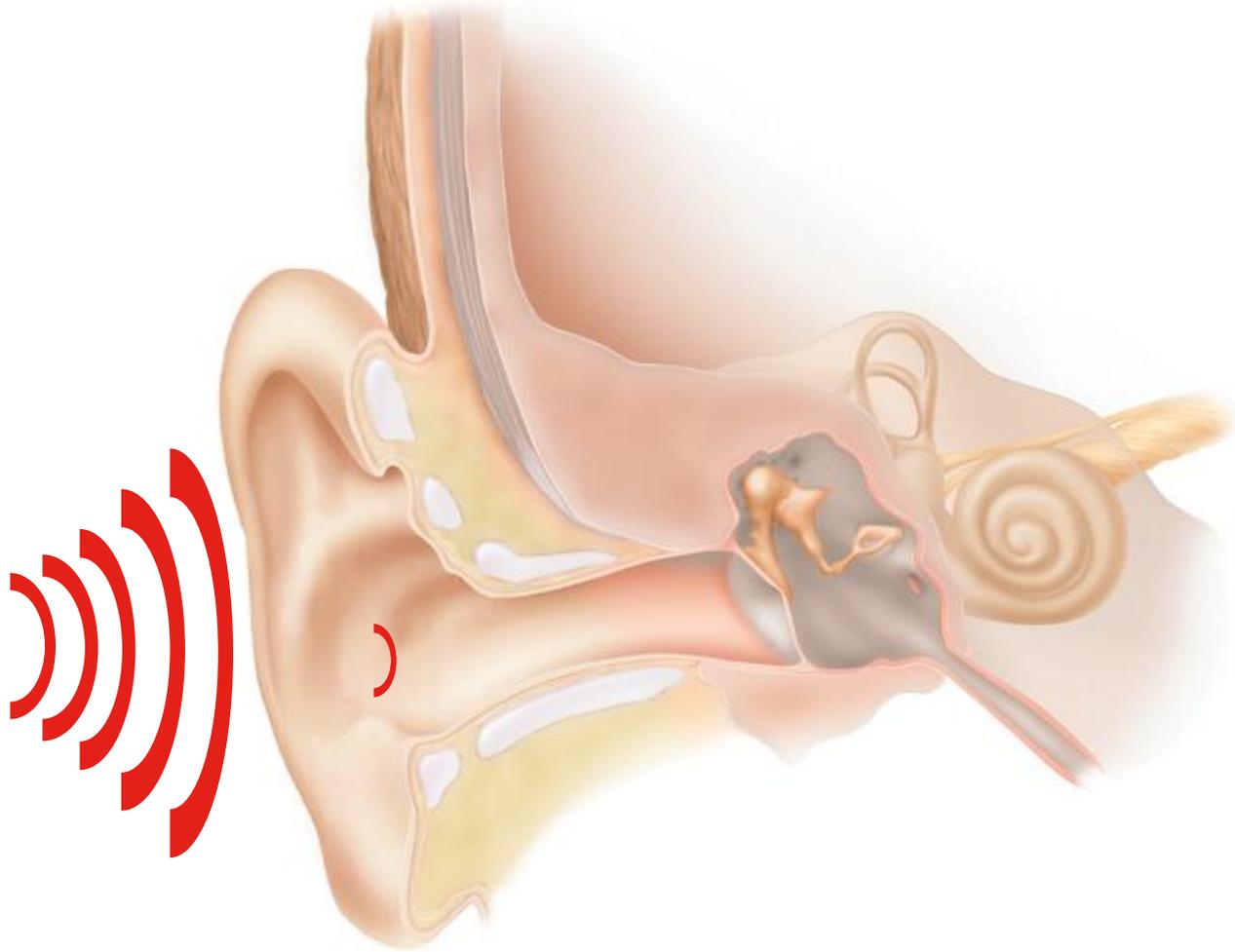
**Edward Milligan, MD**

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OBVAMC

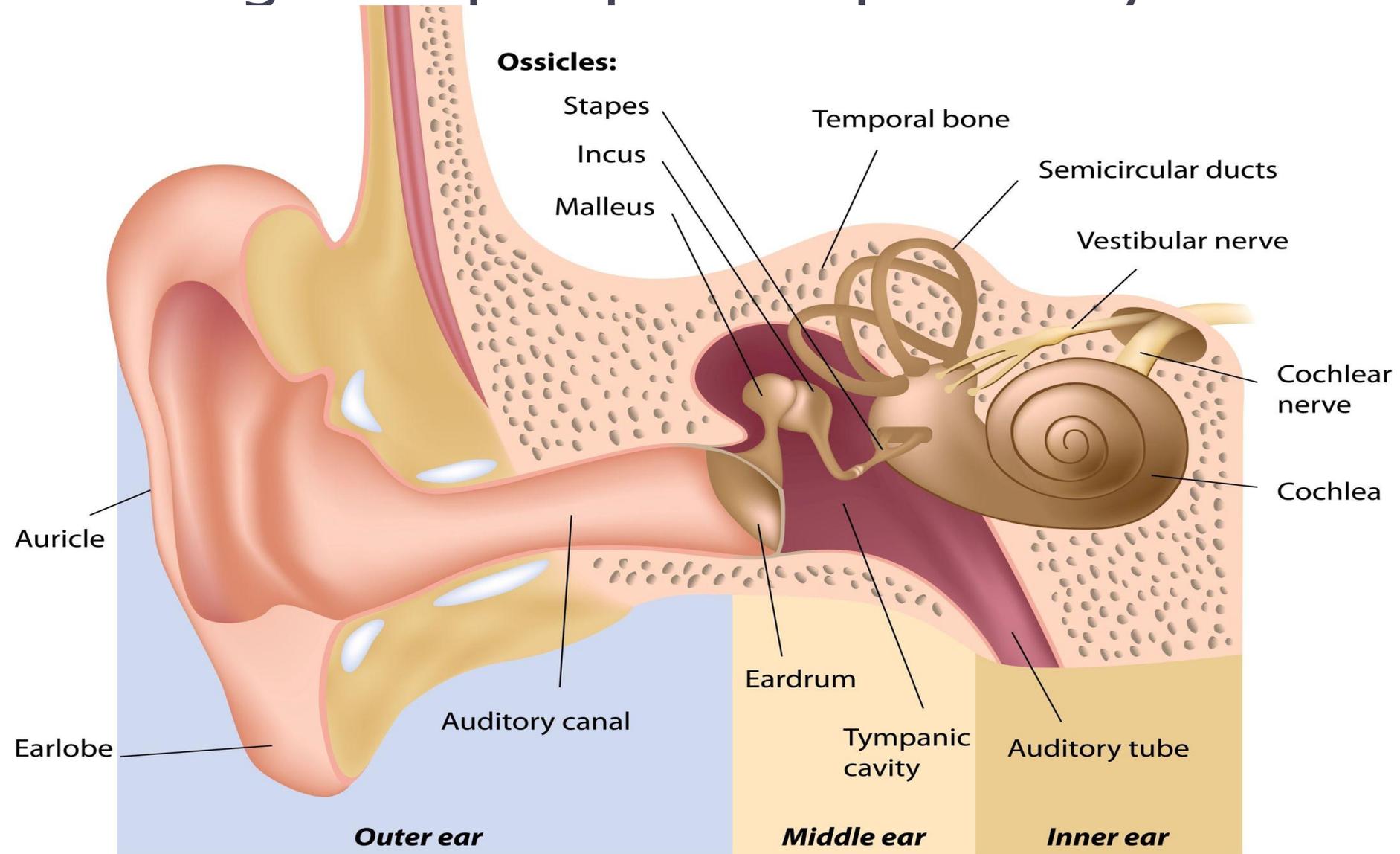
# Goals

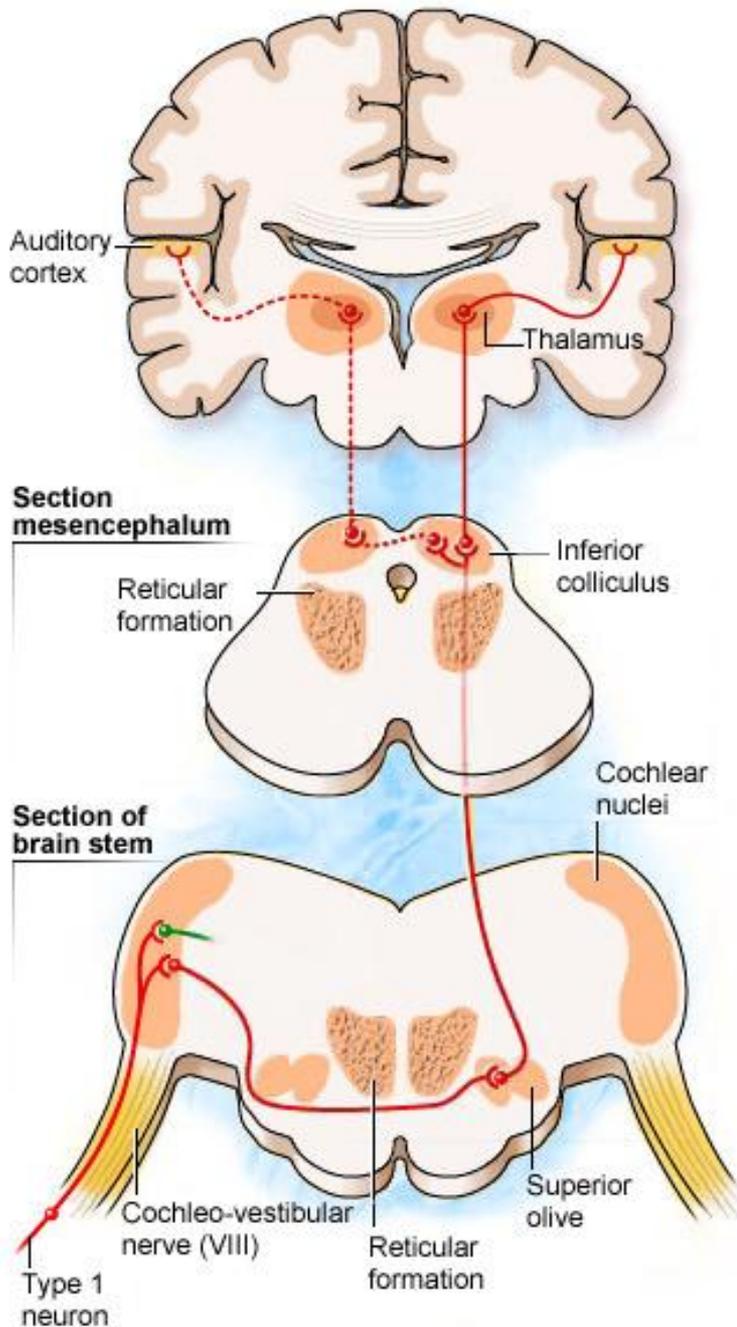
- Overview of hearing pathology
- Review of types of hearing loss and rehabilitative options for each type, including hearing aids, cochlear implants and bone conduction hearing aids (BAHA)
- To gain a basic understanding of cochlear implantation, including technology, patient selection and surgery

# Review of the auditory pathway



# Hearing loss can occur anywhere along this peripheral pathway





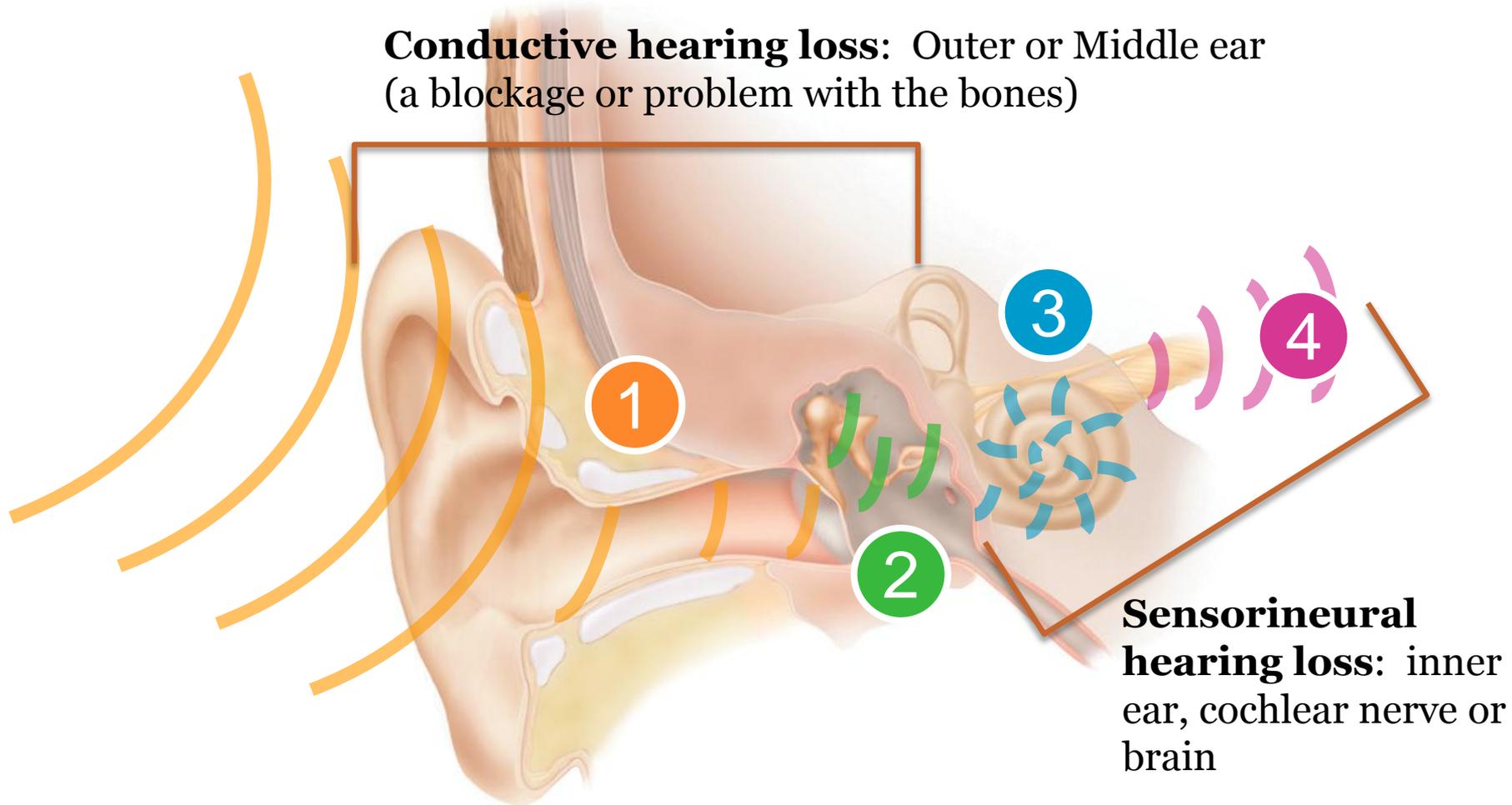
# Central auditory pathway

- **E.C.O.L.I.**

- **E:** CN VIII
- **C:** Cochlear nucleus
- **O :** superior olive
- **L :** lateral lemniscus
- **I:** inferior colliculus
- **Auditory cortex:** superior temporal gyrus

# Two types of hearing loss

**Conductive hearing loss:** Outer or Middle ear  
(a blockage or problem with the bones)



# Etiology of Conductive hearing loss

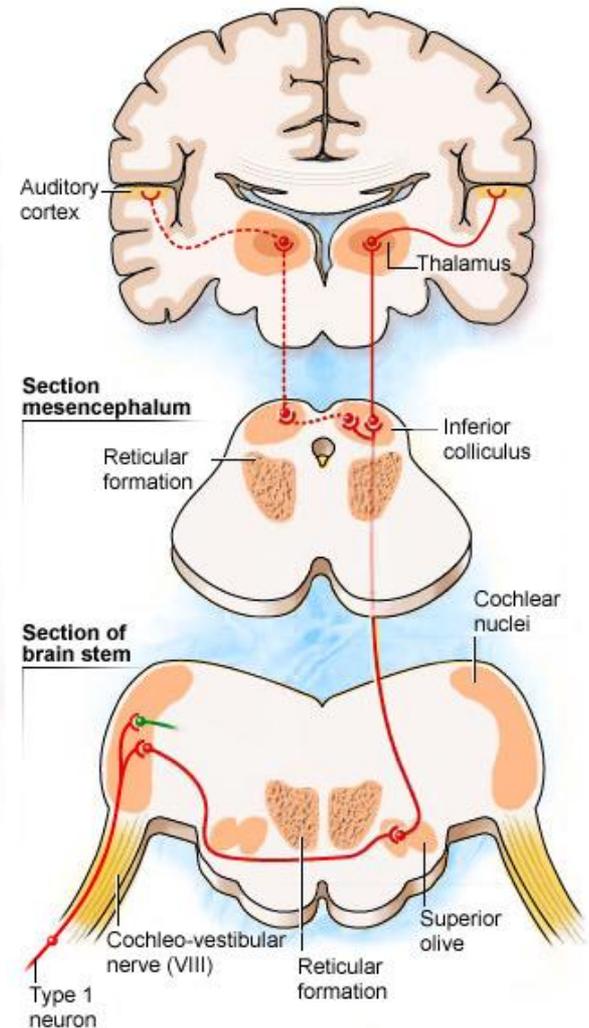
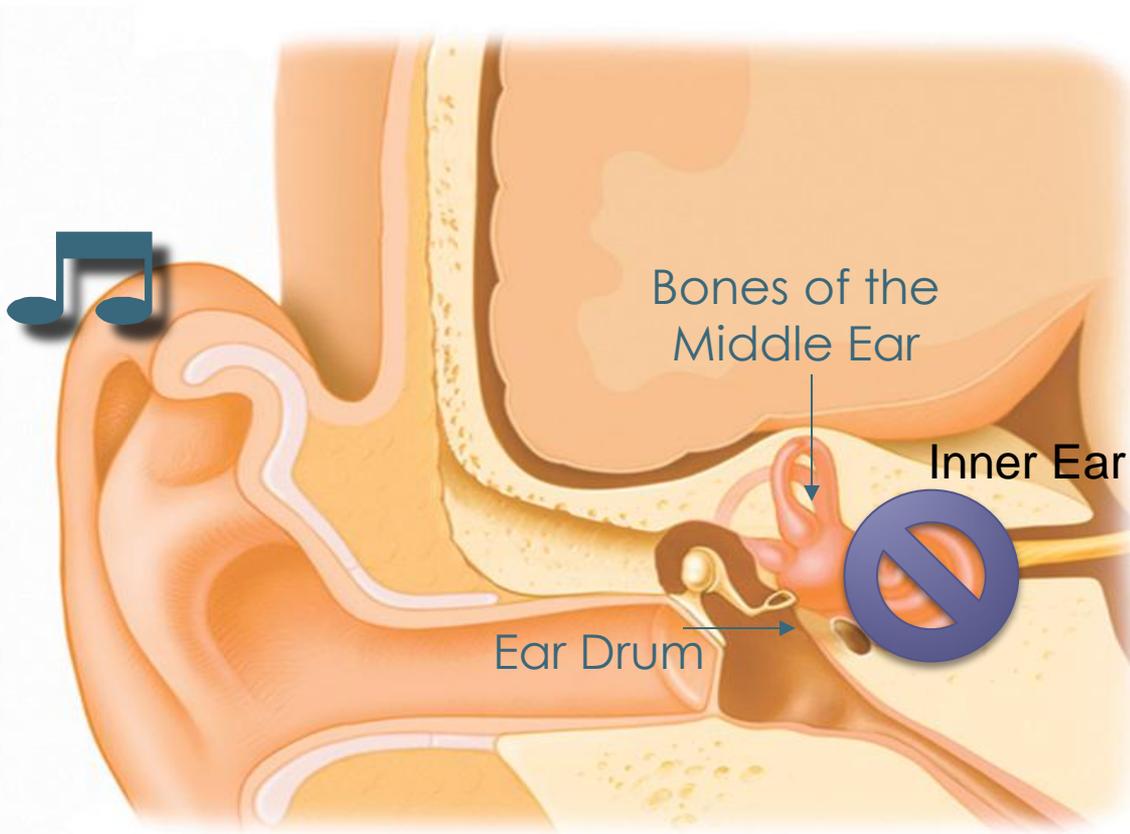
## Outer ear

- Cerumen
- Infectious (otitis externa or “swimmers ear”)
- Tumor or mass
- Foreign body
- Congenital or acquired stenosis of external auditory canal
- Congenital atresia
- Temporal bone trauma/fracture

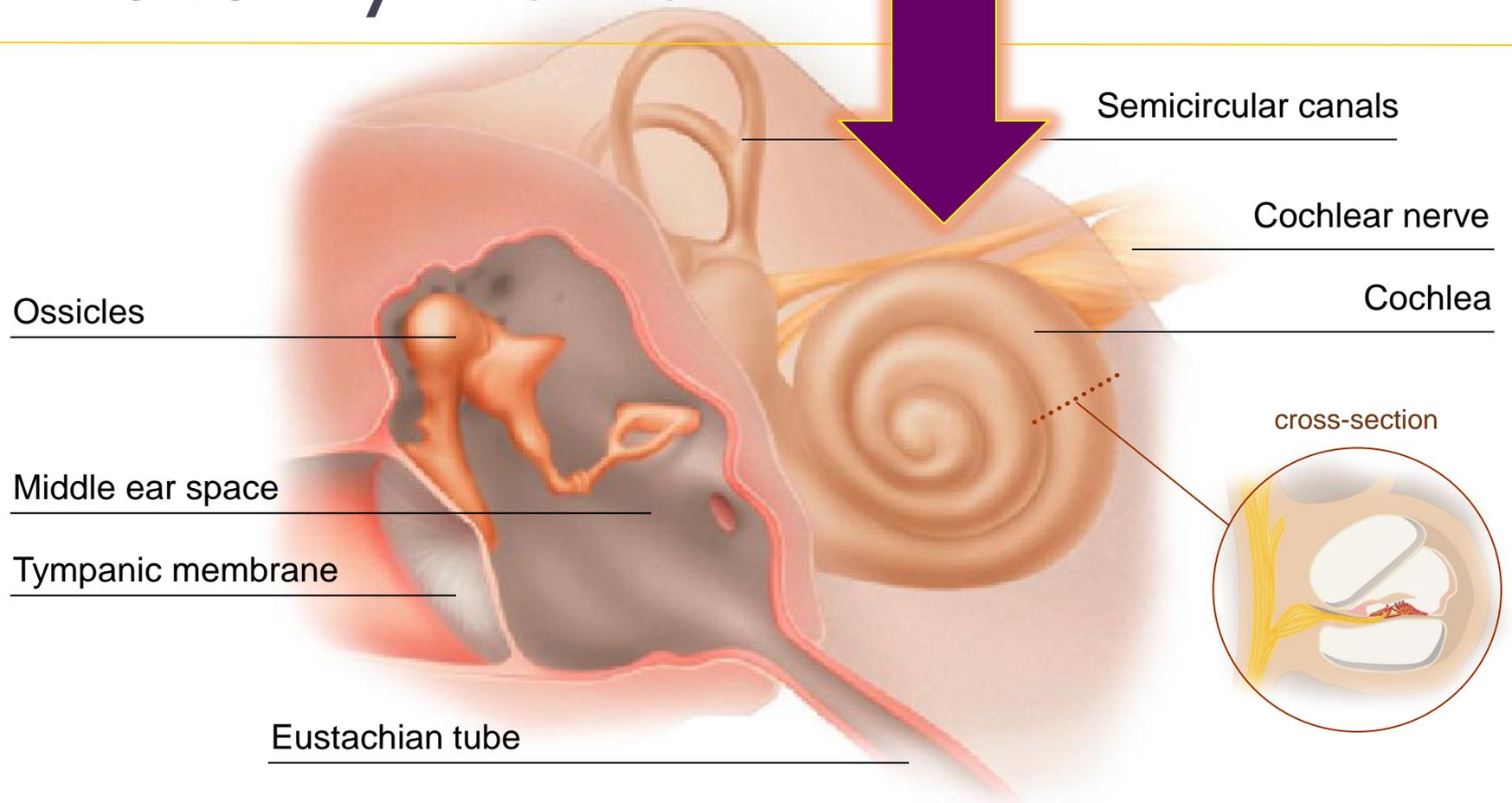
## Middle ear

- Tympanic membrane abnormality (eg. Perforation)
- Ossicular abnormality (eg. Otosclerosis)
- Infectious: otitis media
- Cholesteatoma
- Tumor or mass in middle ear (eg. Paraganglioma or glomus tumor)
- Temporal bone trauma/fracture
- Eustachian tube dysfunction

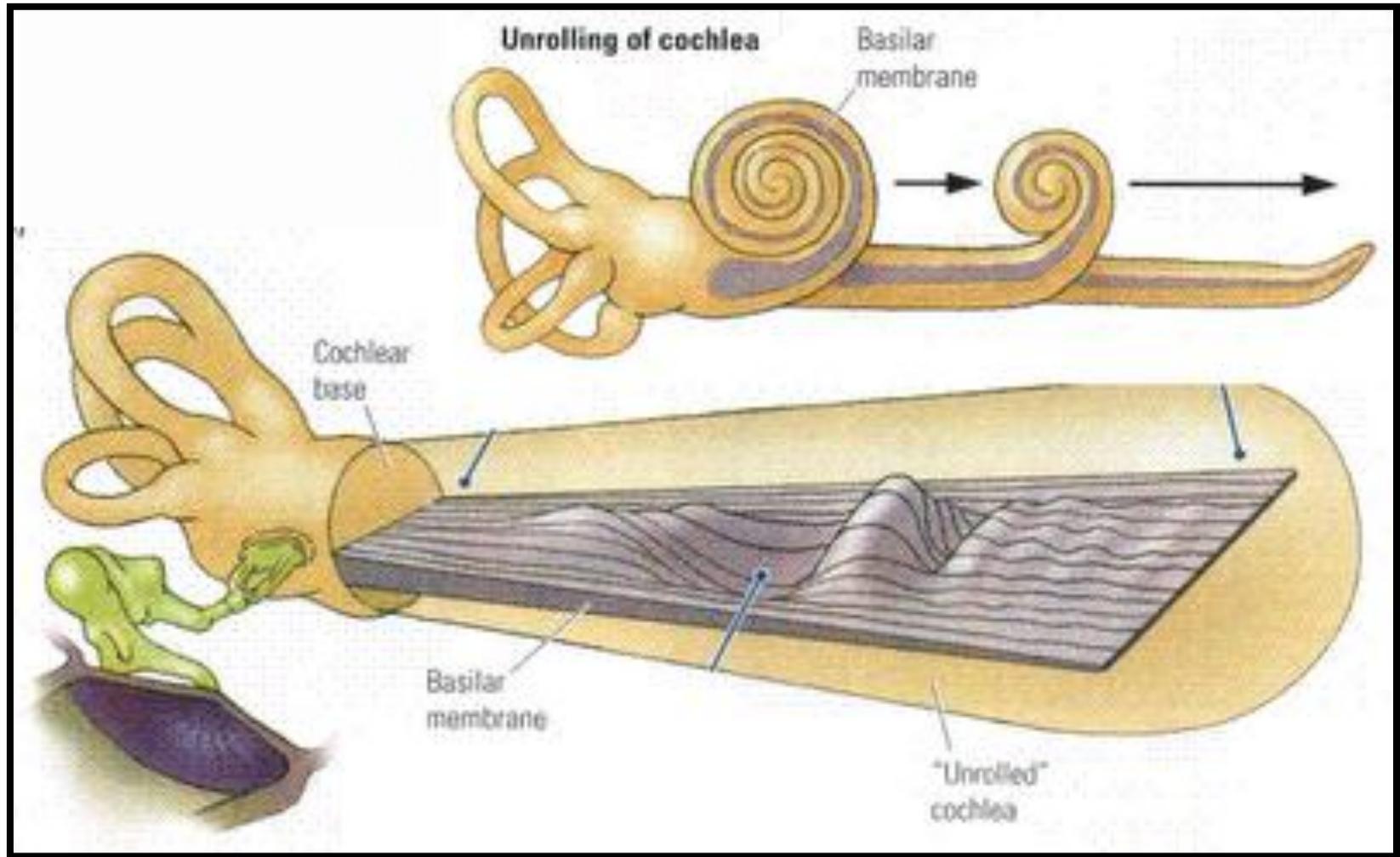
# Sensorineural hearing loss



# Anatomy Review

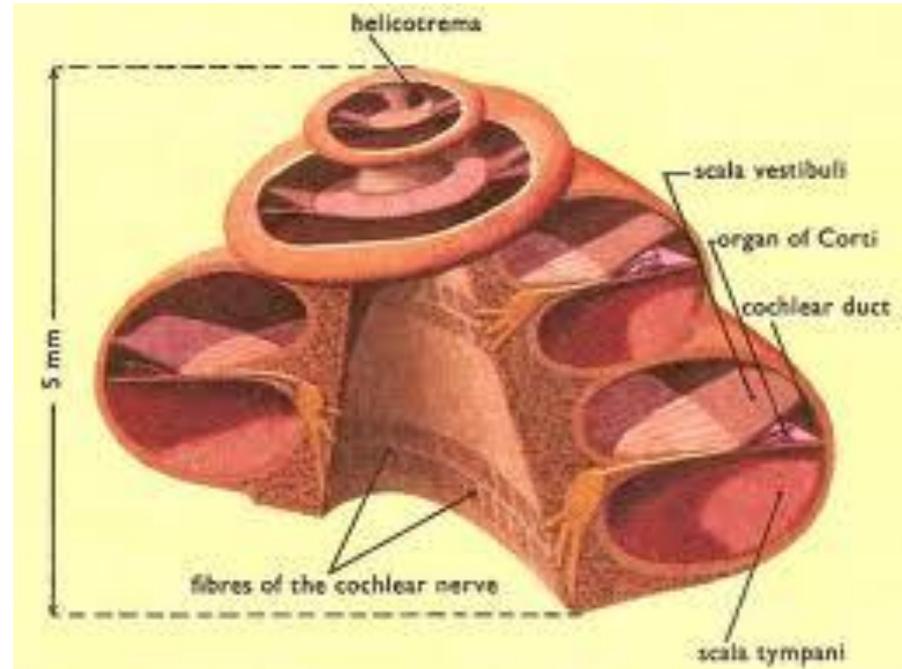


Cochlea ~ derived from latin meaning “snail”

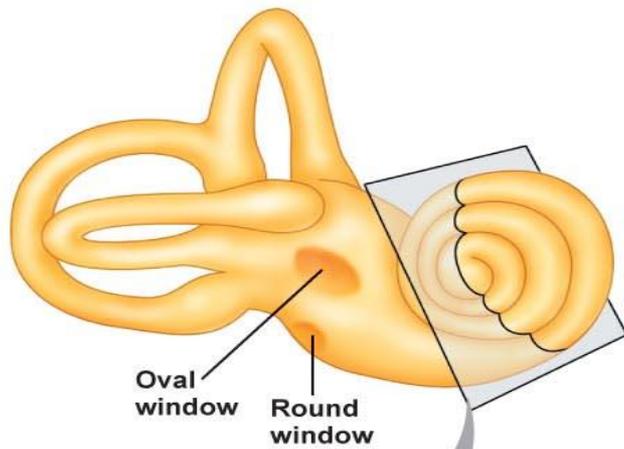


# Anatomy of the Cochlea

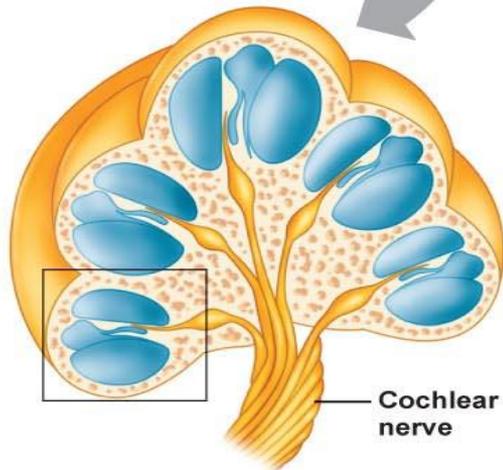
- Cochlea: 2 1/2 turns in humans
- 3 fluid filled compartments
  - Scala vestibuli (perilymph)
  - Scala media (endolymph)
  - Scala tympani (perilymph)
- Organ of Corti is located in the scala media converts acoustic signals to electrical impulses and transmits them to the cochlear nerve
- Central modiolus which houses spiral ganglion neurons from the cochlear nerve



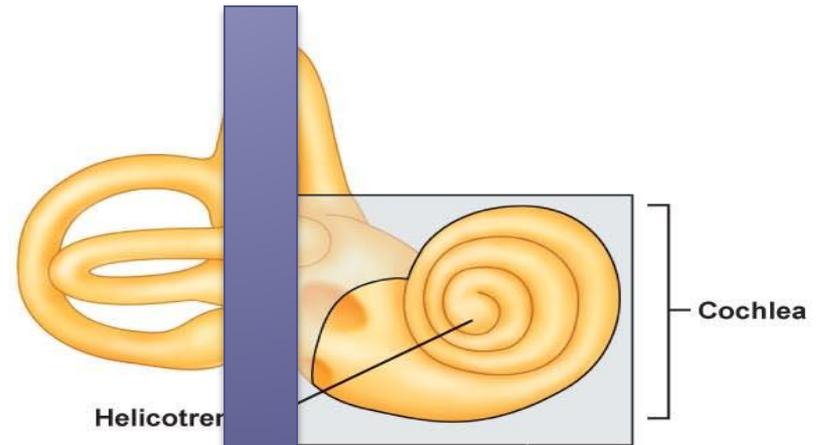
# Anatomy of the Cochlea



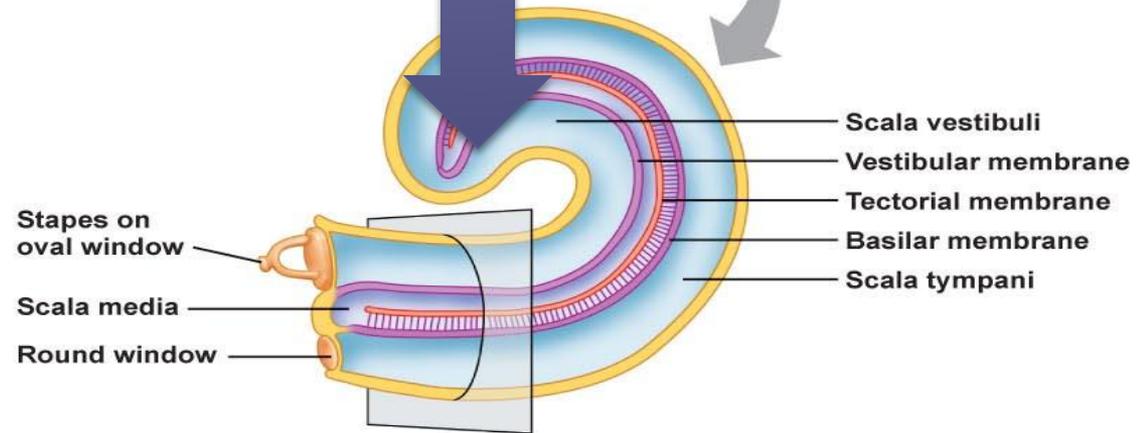
(a)



(c)

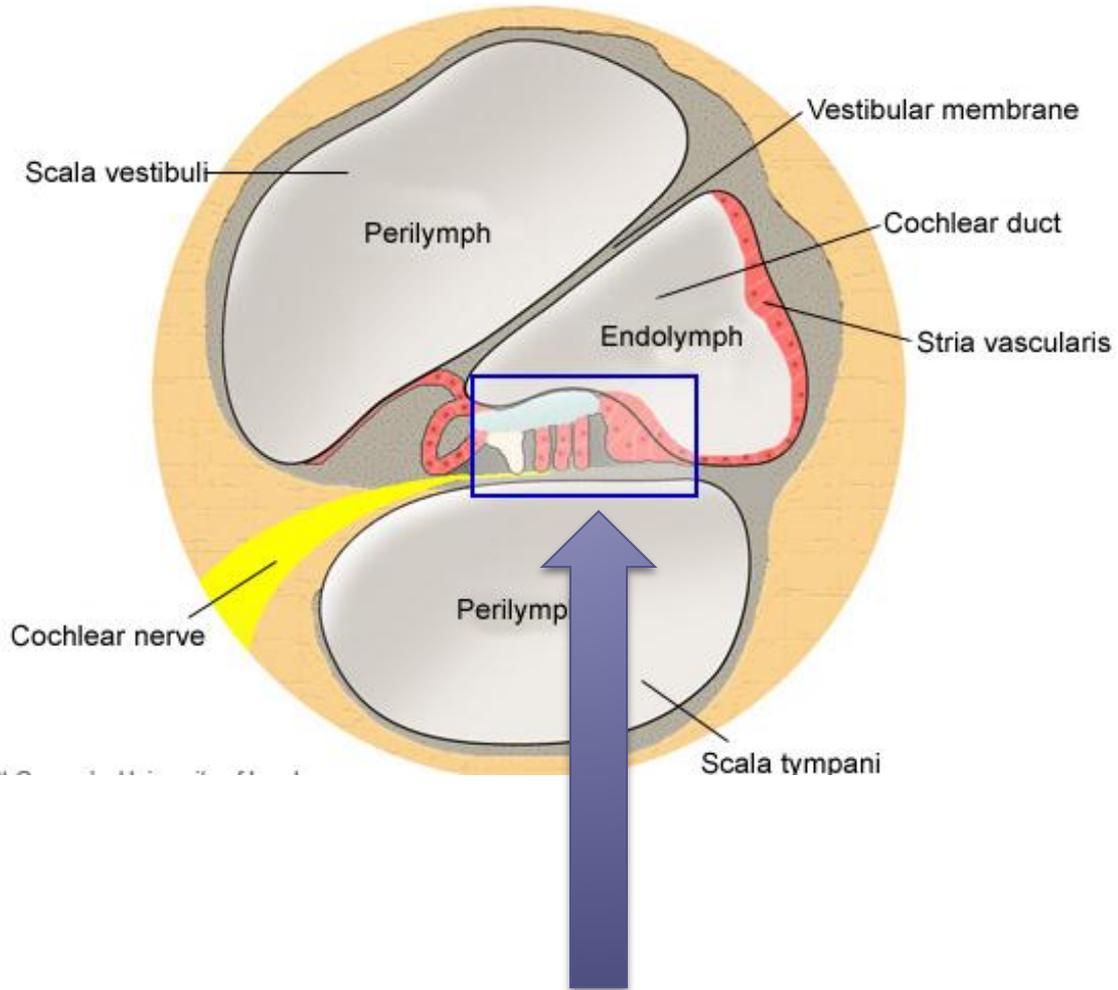
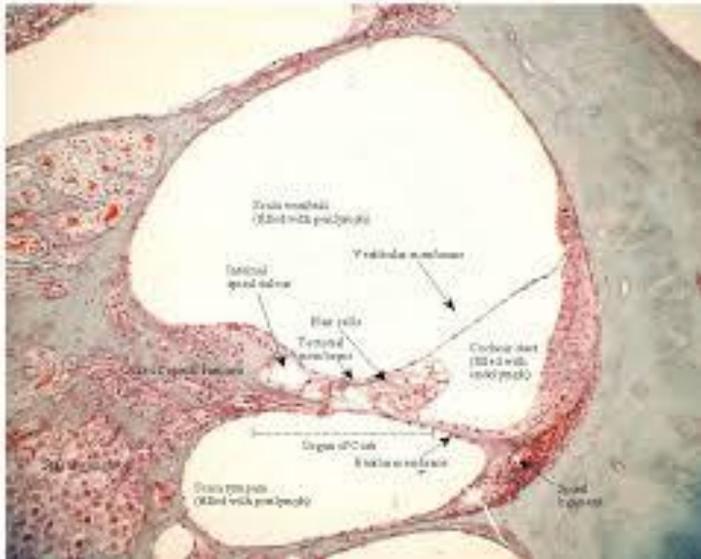


(b)

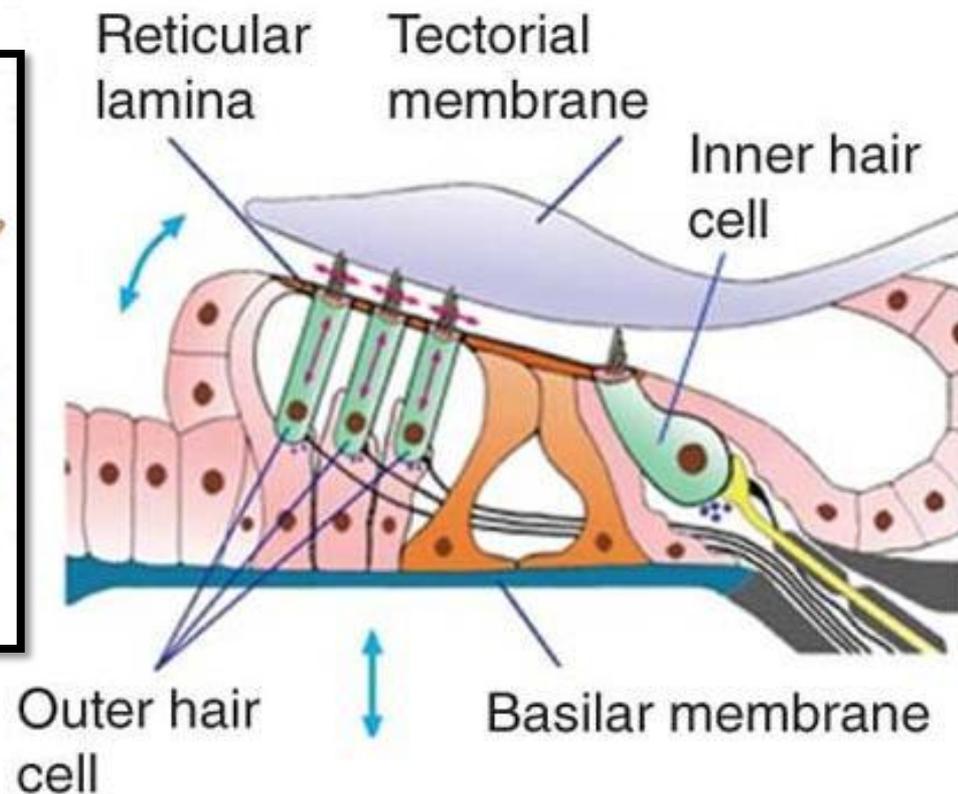
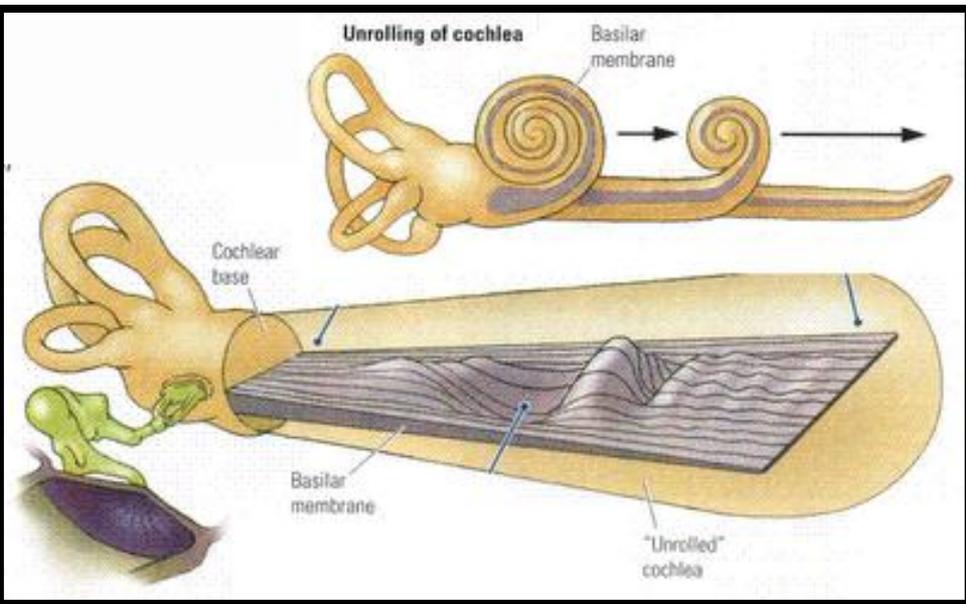


(d)

# Cross section of the Cochlea with arrow at the hair cells

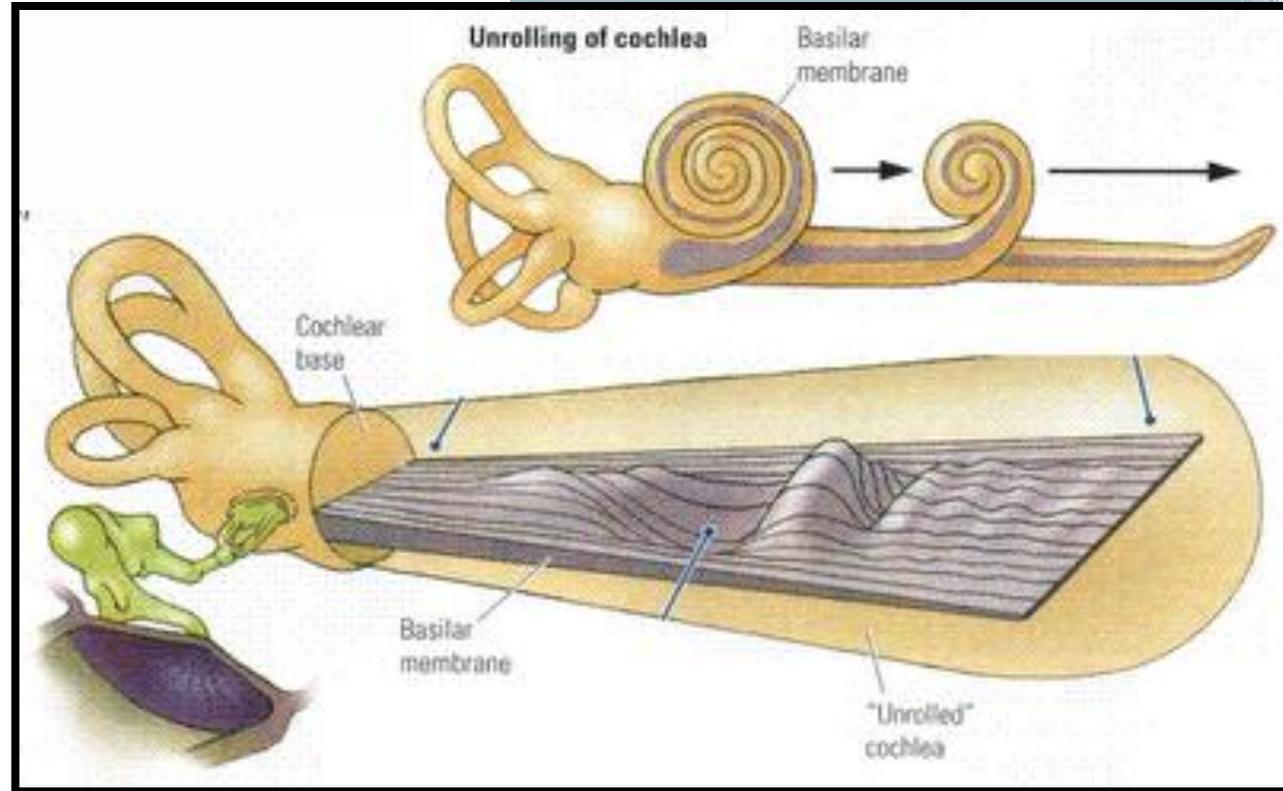


# Anatomy of the Organ of Corti

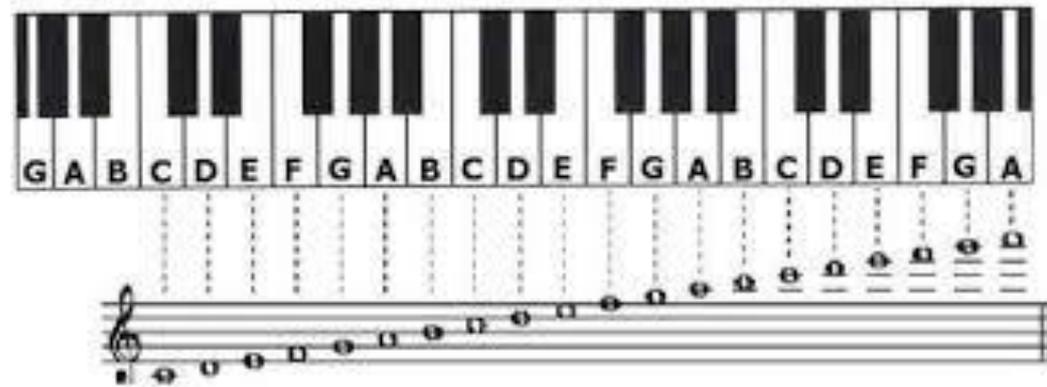


Cilia of hair cells are embedded in tectorial membrane. Movement of the basilar membrane causes cilia to move, opening K channels and changing electrolyte composition. Electrolyte shifts lead to a receptor potential → action potential in the spiral ganglion cell dendrites thereby converting acoustic sound to electrical impulses

Cells of the inner ear are like piano keys with each one corresponding to a different frequency

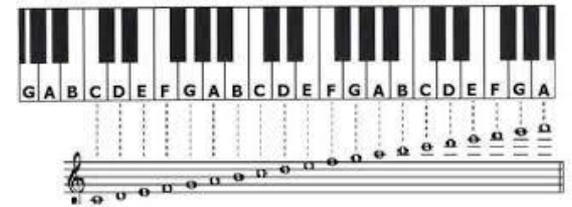


## ***PIANO / KEYBOARD***

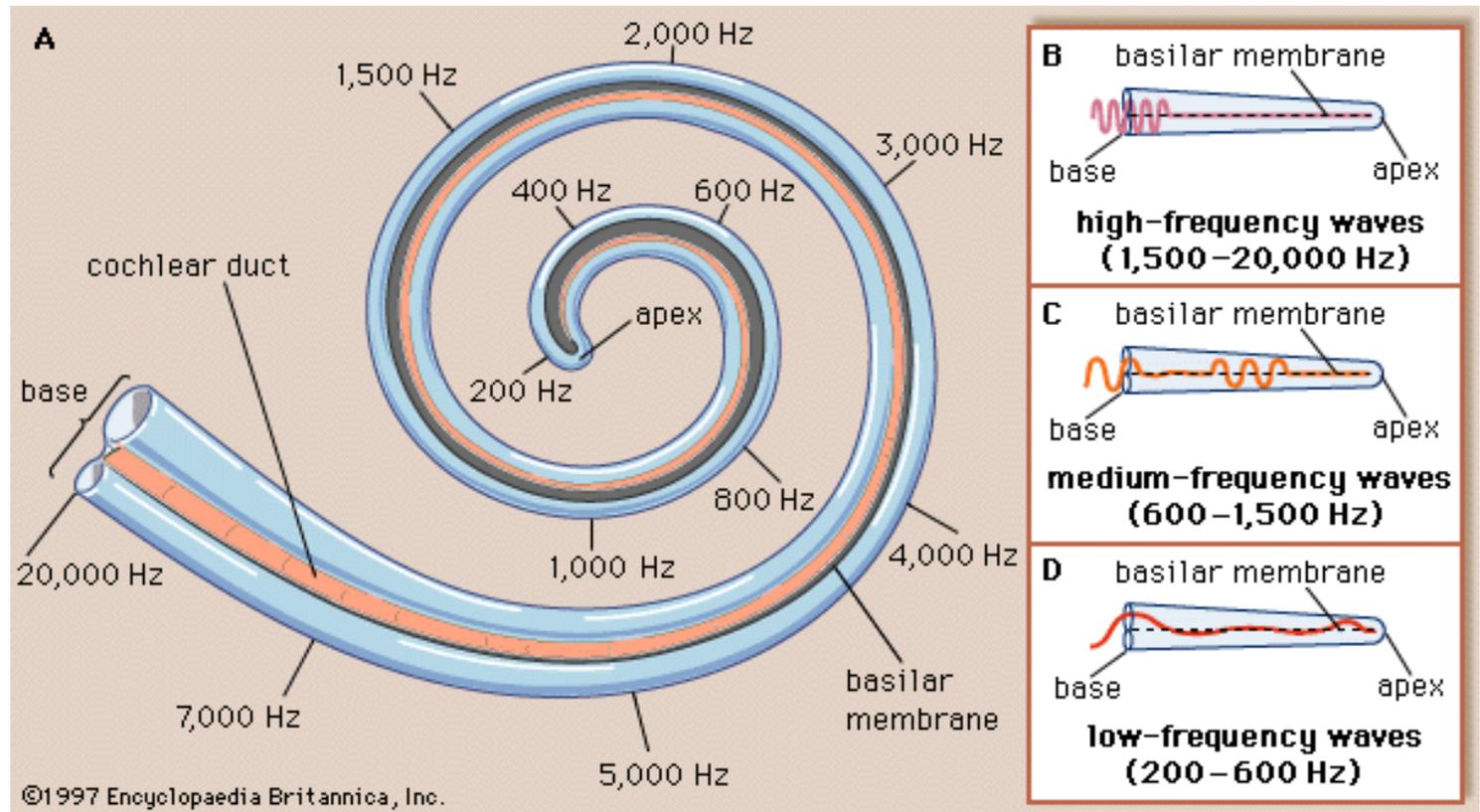


# Tonotopic organization

PIANO / KEYBOARD

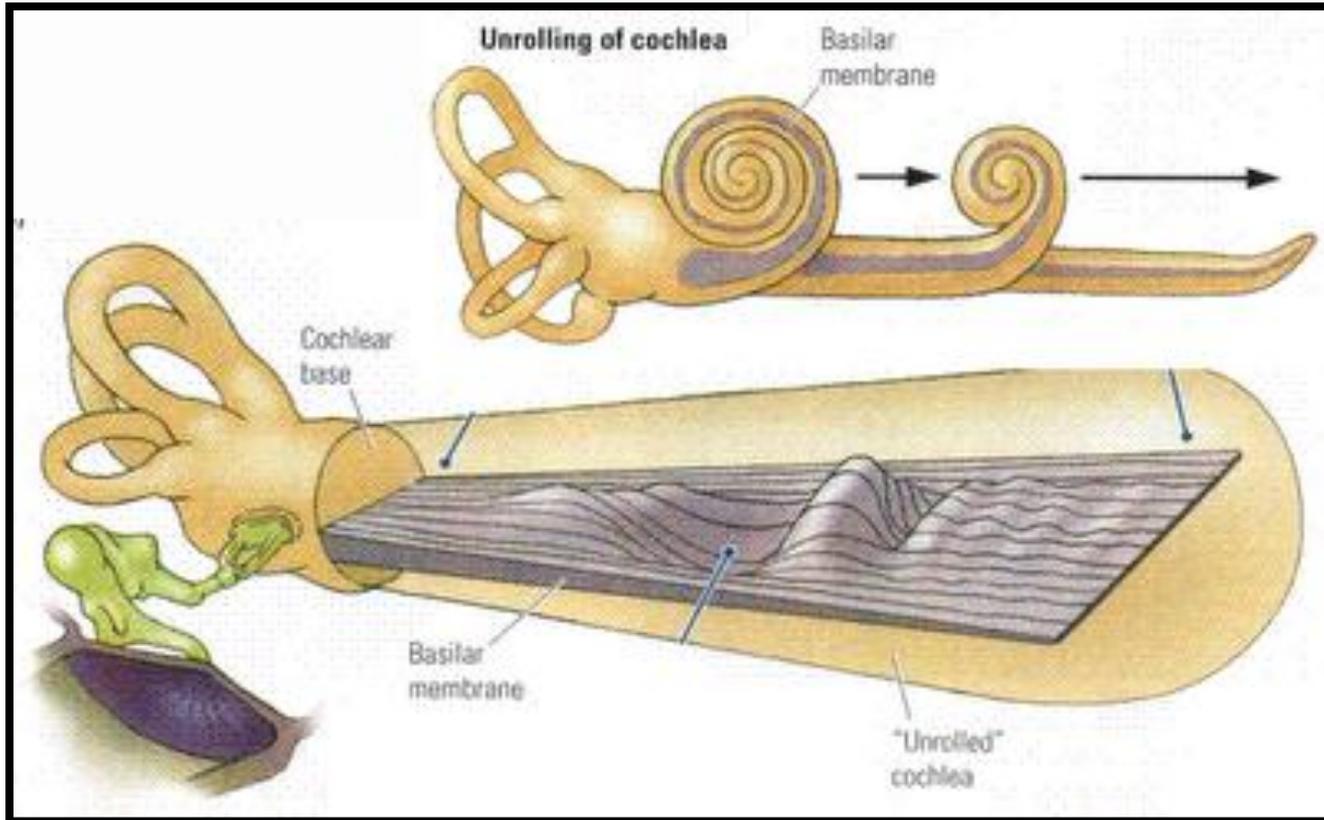
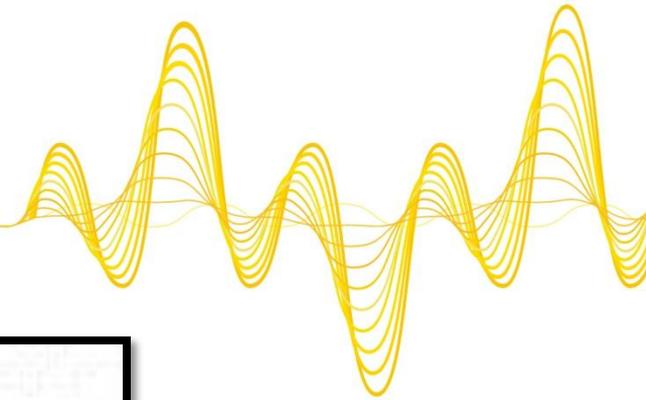


- Base: high frequency
- Apex: low frequency



Physical properties of the basilar membrane allow different frequencies to attain maximal amplitude at different positions.

Different causes of hearing loss may preferentially affect different parts of the cochlea and therefore different frequencies

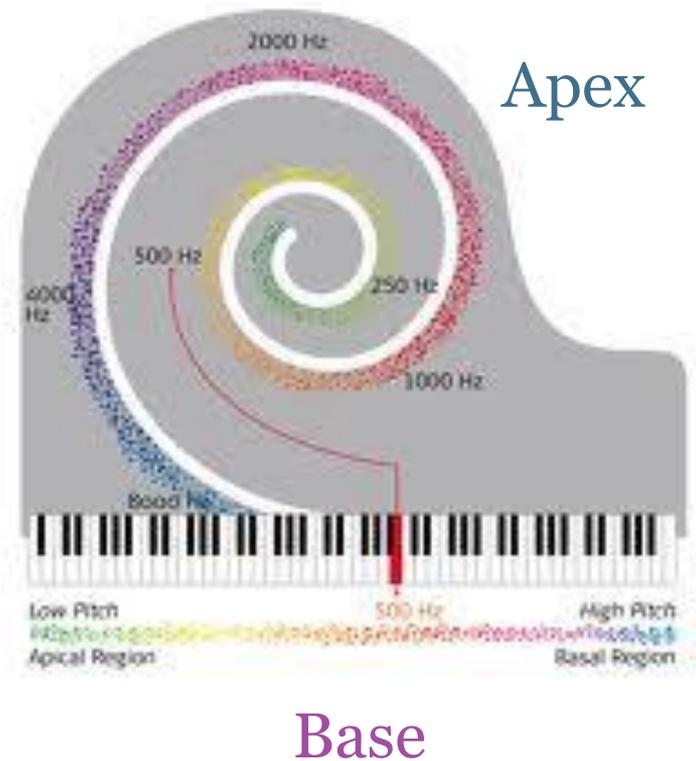


**Noise damage**  
affects high  
frequencies

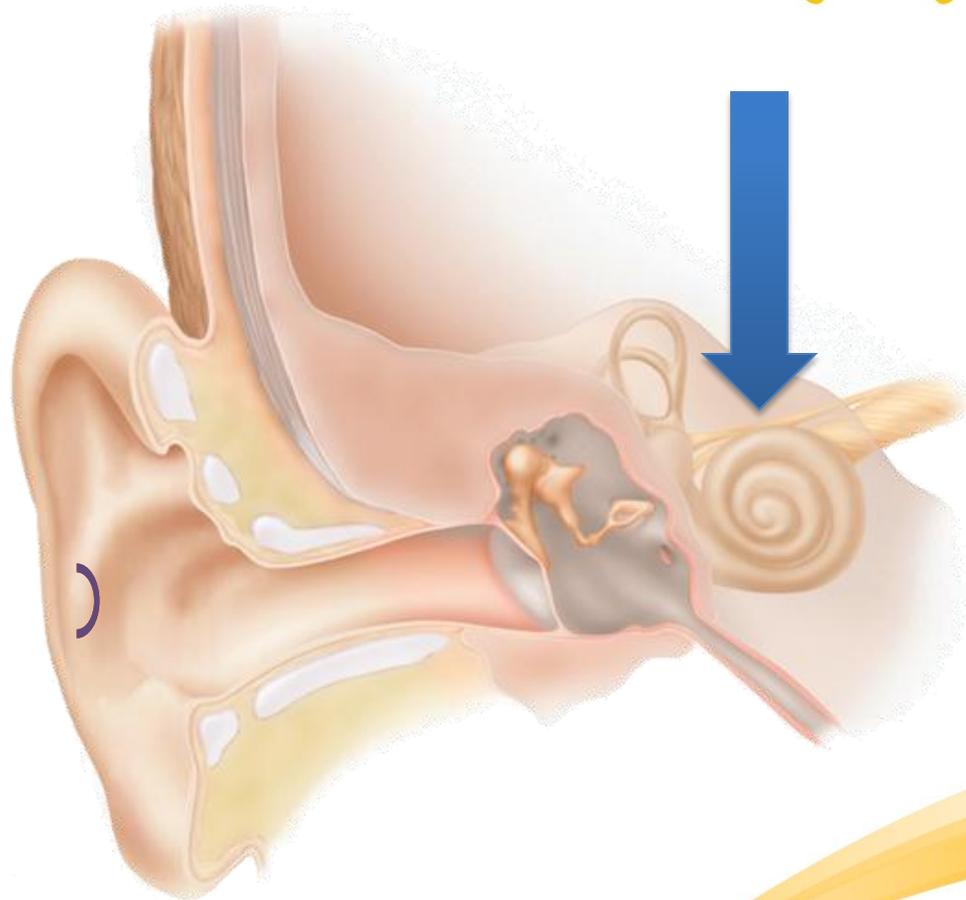
**Meniere's disease**  
first affects low  
frequencies

# Many etiologies of Sensorineural hearing loss....

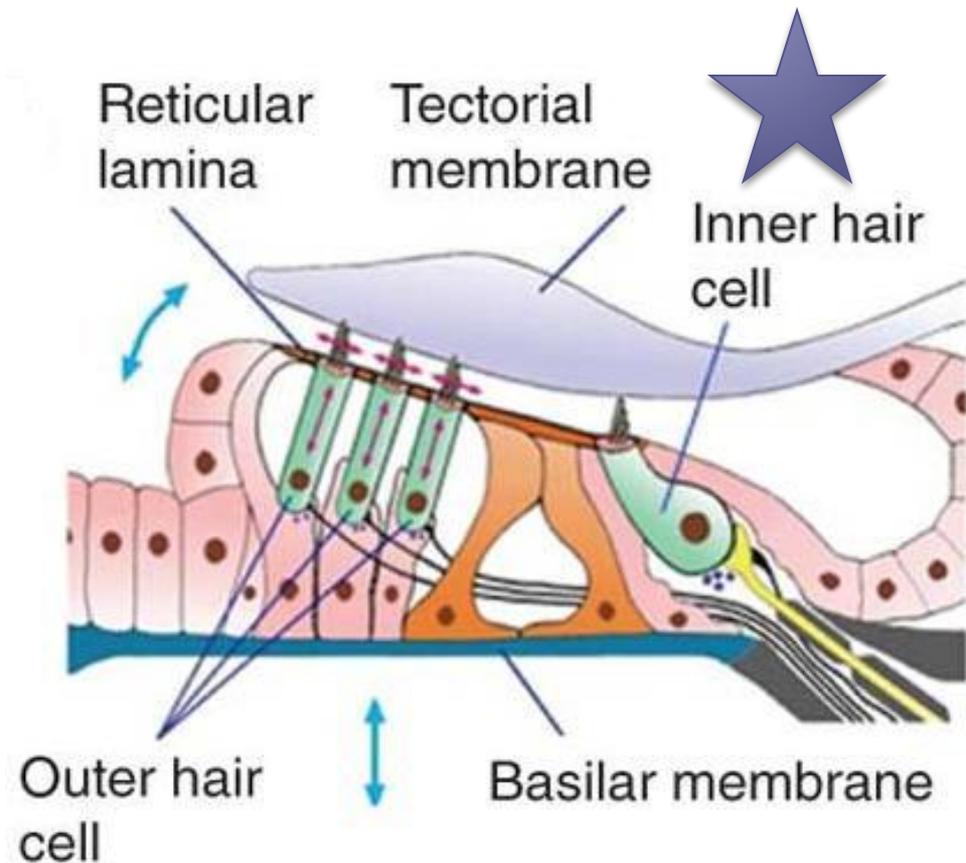
- Congenital
- Inflammatory
- Infectious
- Ototoxicity
- Noise-induced
- Presbycusis (age-related)
- Sudden SNHL (idiopathic)
- Vascular ischemia
- Auto-immune
- Meniere's disease
- Intra-cranial tumor or mass



Sensorineural hearing loss  
most often affects the cochlea



# SNHL is predominately localized to one anatomic location: Inner hair cells



- SNHL can be attributed to damage or loss of **the inner hair cells** in >95% of individuals with SNHL
- Intra-cranial tumors, cerebrovascular disease are possible, but infrequent causes of SNHL

# Mixed hearing loss



## ***Combination of conductive and SNHL***

- Problems with the outer or middle ear and in the inner ear
- Combination of sensorineural and conductive hearing loss
- May include possible causes from sensorineural hearing loss and conductive hearing loss

*Hearing loss can be in one or both ears and does not have to be from the same cause*

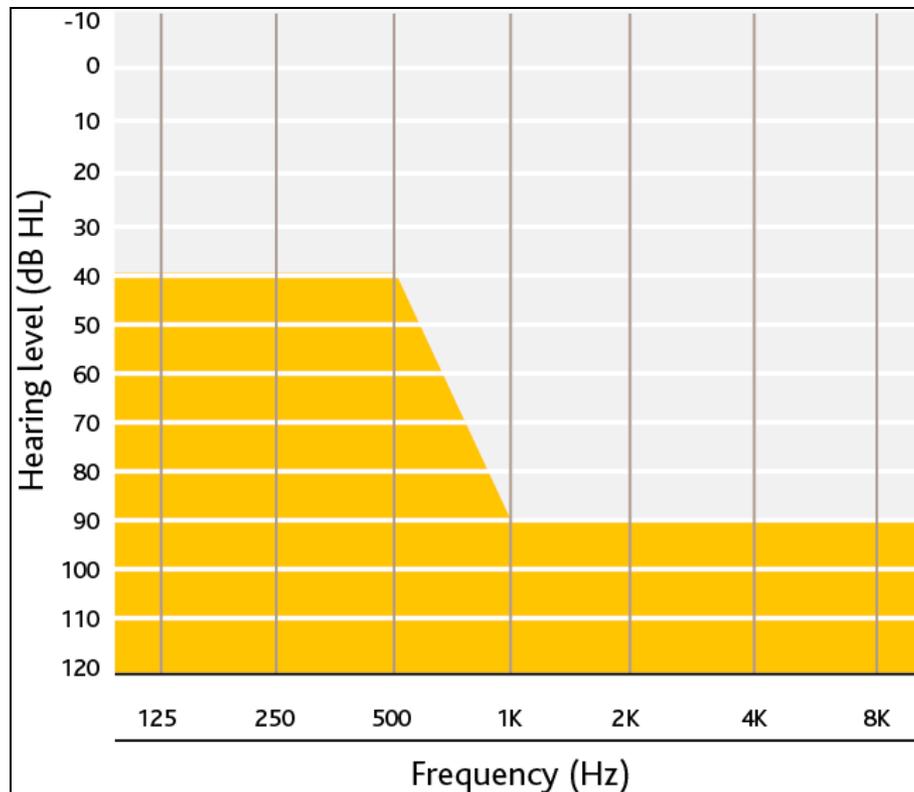


### ***Single-Sided Deafness (Unilateral Profound Hearing Loss)***

- No hearing or very little hearing in one ear and normal hearing in the other ear
- Commonly caused by: sudden deafness, birth defects, genetics, head trauma, Meniere's disease, ototoxicity

# How is the type and degree of hearing loss diagnosed?

## Behavioral AUDIOGRAM (gold standard)

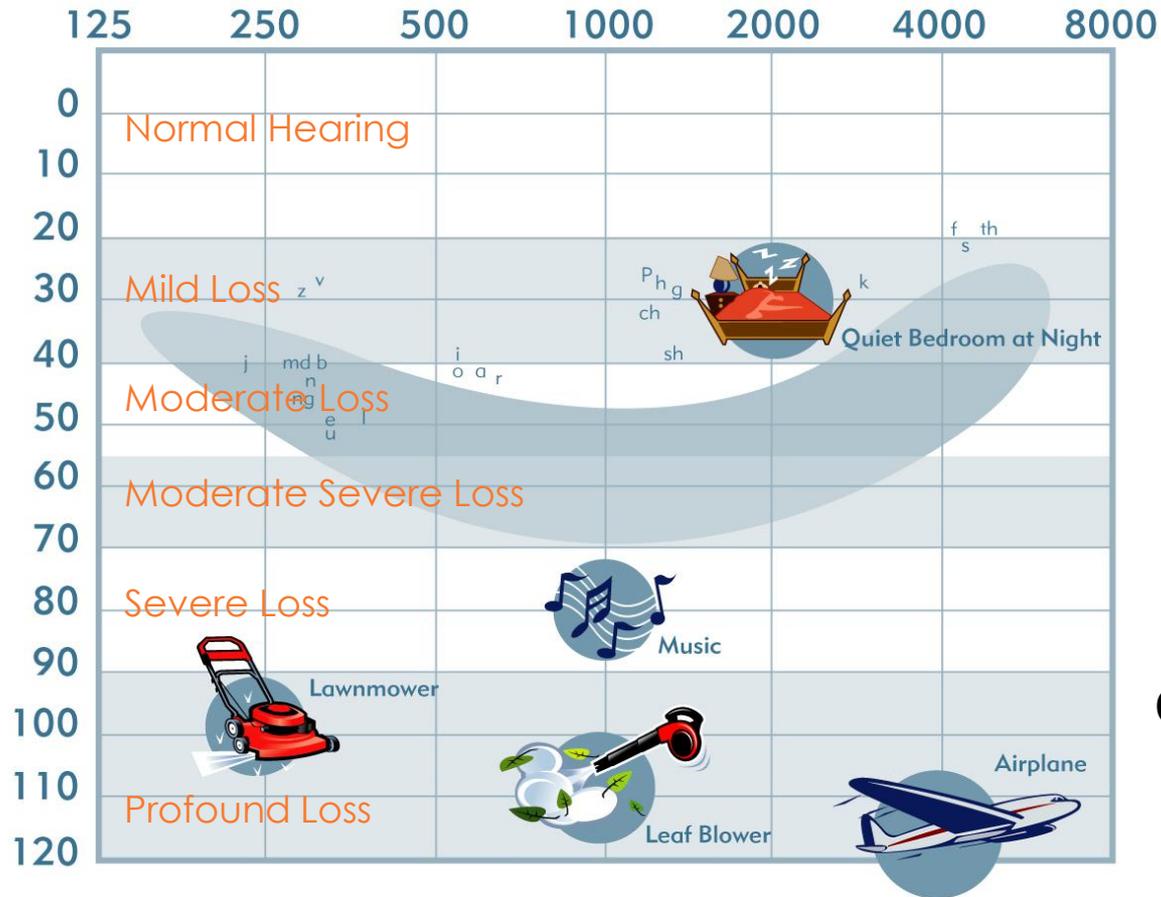


# Degrees of Hearing Loss

Degree of hearing loss	Softest sound able to be heard (in decibels)	Frame of reference
<b>Mild</b>	26 to 40 dB	Able to hear the loud or more intense vowel sounds, but may miss some of the softer consonant sounds, have difficulty hearing soft spoken people and young children and may have to ask people to speak up or repeat themselves on occasion
<b>Moderate</b>	41 to 55 dB	In addition to missing consonant sounds, vowel sounds then become more difficult to hear. People often comment that without hearing aids they hear, but can't always understand
<b>Moderately Severe</b>	56 to 70 dB	Without hearing aids, speech becomes inaudible, whereas with hearing aids, speech may still be difficult to understand
<b>Severe</b>	71 to 90 dB	Without hearing aids, speech is inaudible, but loud sounds like a baby crying or a dog barking are audible. Hearing aids may no longer be enough for people with severe hearing loss
<b>Profound</b>	91+ dB	Without hearing aids, speech is inaudible, but very loud sounds like a lawn mower or jet airplane are audible. Hearing aids may no longer be enough for people with profound hearing loss

# Frequency

Loudness dB



Cochlear Implant

Speech Discrimination Testing: % correct, words presented above threshold

# Treatment for hearing loss

- Treatments depend on the type and degree of hearing loss
- ***The patient cannot choose the type of treatment used, the hearing loss determines this***

# Treatment options for Hearing Loss

## Hearing Aids



Various types of hearing loss

## Cochlear Implant



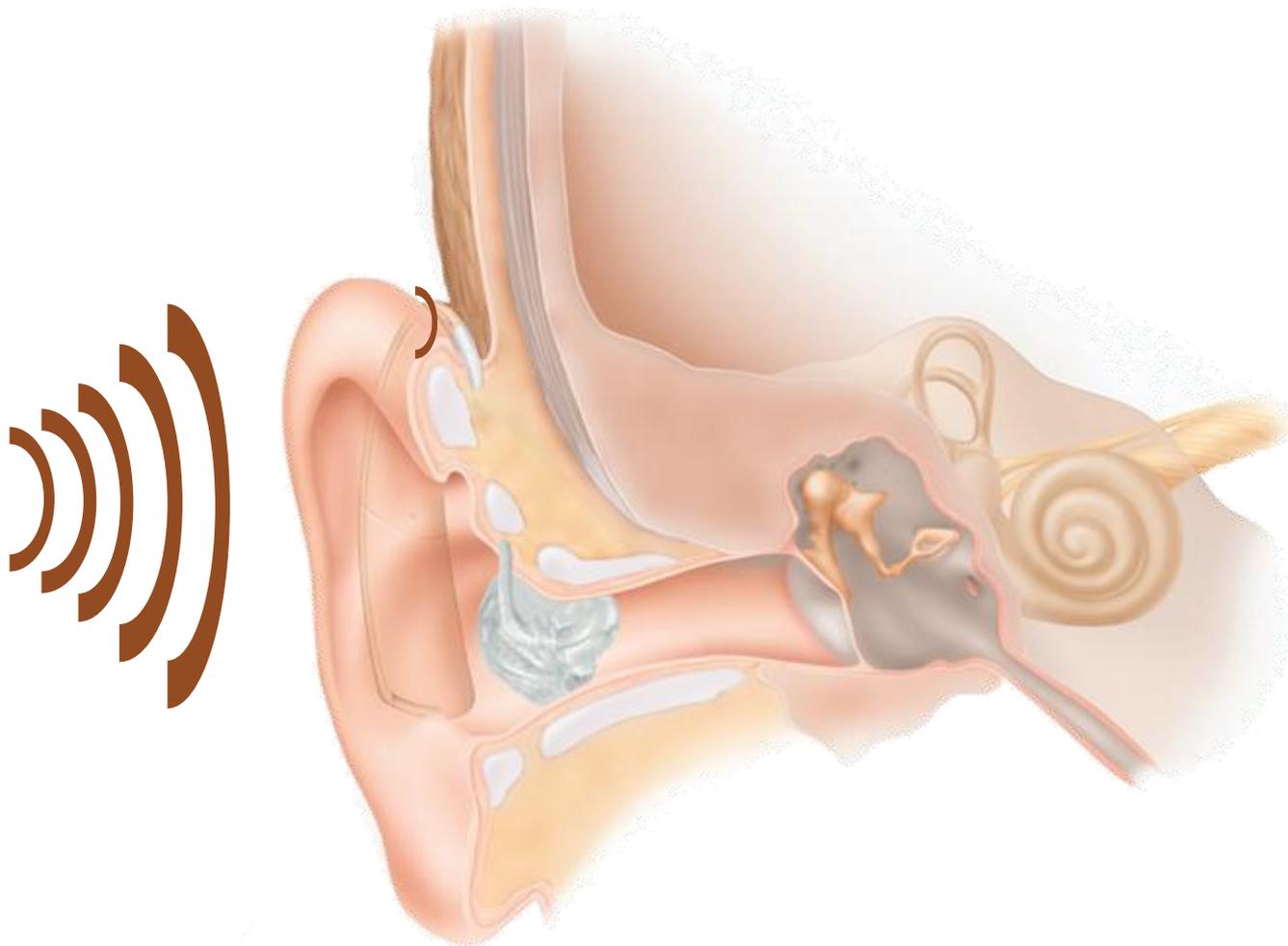
Sensorineural hearing loss

## The Baha® System (direct bone conduction)

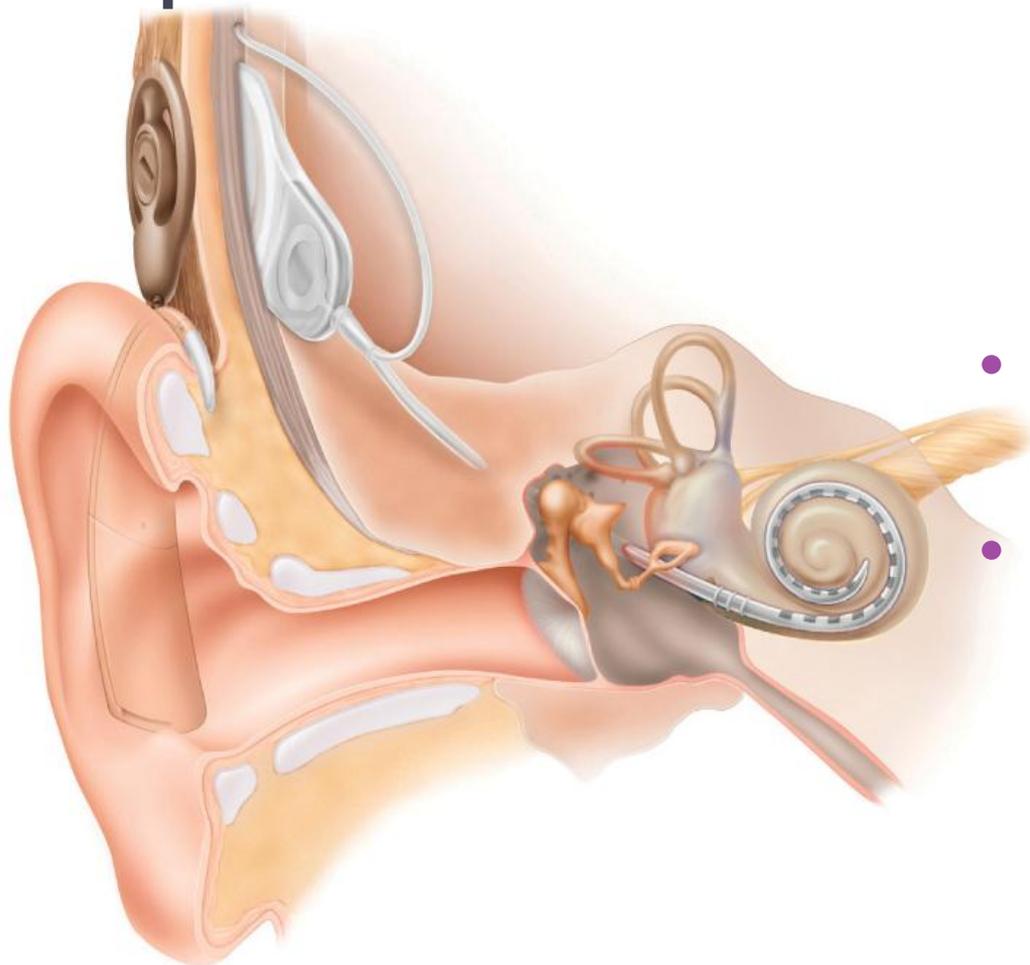


Conductive hearing loss,  
mixed hearing loss, and  
single-sided deafness

# How a Hearing Aid Works



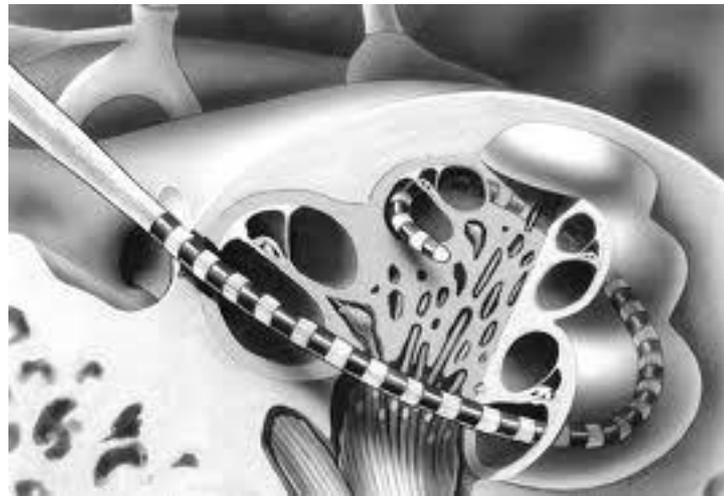
# Cochlear implants:



- When there is too little cochlear reserve (ie the remaining hair cells are not functioning), a hearing aid is not enough.
- These patients are CI candidates
- In general, CI are considered for severe-profound SNHL (when hearing aids are not adequate)

# What is a cochlear implant?

- A cochlear implant is a surgically implanted electronic device that allows restoration of sound perception by bypassing the inner hair cells and transmitting electrical impulses directly to the auditory nerve through a surgically implanted, intra-cochlear electrode.



# Cochlear Implant

- Invented in 1961 by William House, MD (“Father of neurotology”) and simultaneously by Professor of Engineering Graeme Clark
- Consists of 2 parts:
  - externally worn processor
  - Surgically implanted device
- Standard of care for individuals with moderately-severe to profound SNHL
  - adults
  - children



# How Does it Work?



- 1 The **internal implant** is placed just under the skin, behind the ear
- 2 The external **sound processor** sits behind the ear

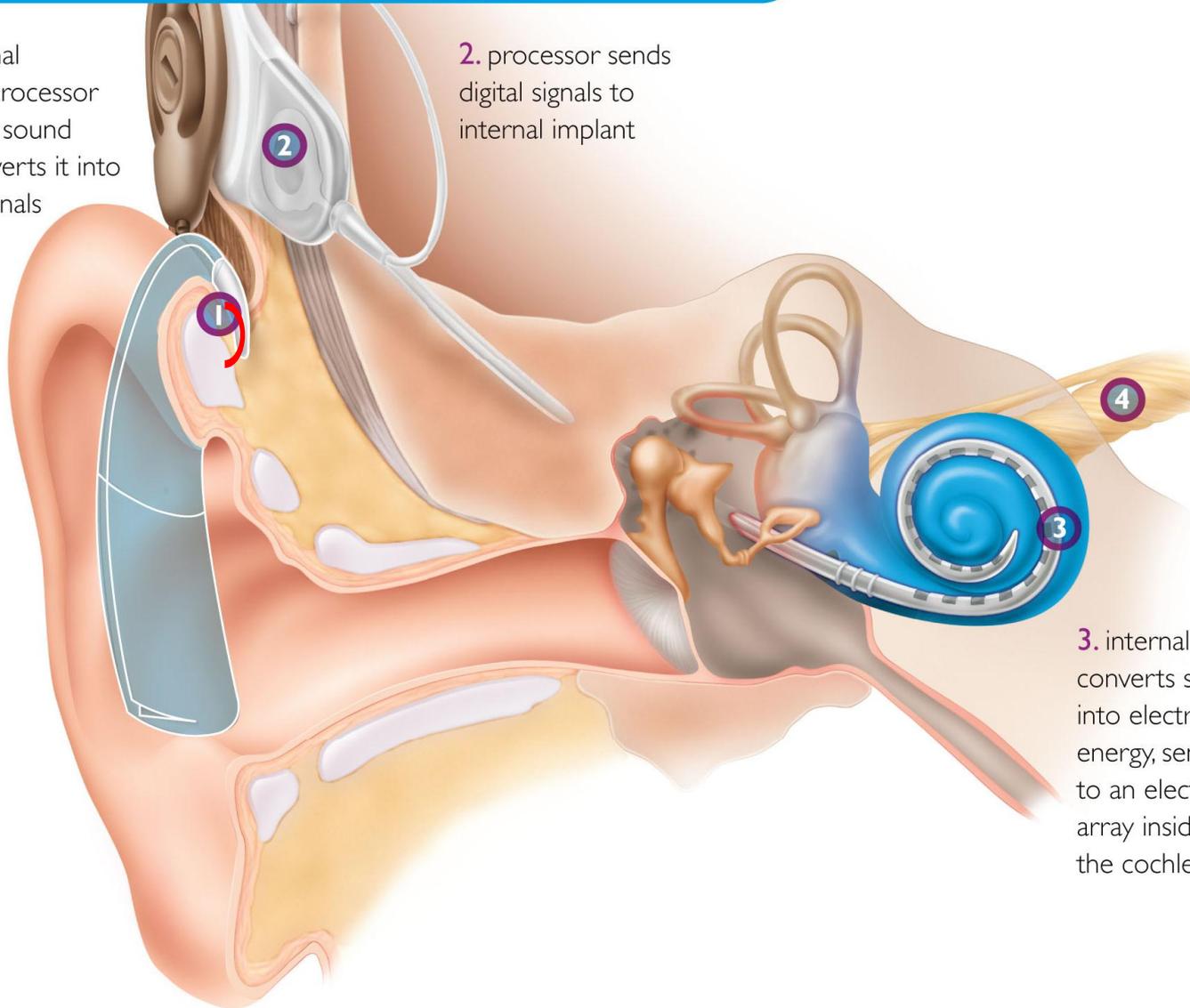
## How a cochlear implant works:

1. external sound processor captures sound and converts it into digital signals

2. processor sends digital signals to internal implant

4. electrodes stimulate hearing nerve, bypassing damaged hair cells, and the brain perceives signals; you hear sound

3. internal implant converts signals into electrical energy, sending it to an electrode array inside the cochlea



# Who is a candidate for a cochlear implant?

- Adults or children with moderate-severe to profound SNHL bilaterally who receive inadequate benefit from hearing aids
- Medically able to undergo procedure and follow up (programming, rehab.)
- Understanding of the process and post operative course
- No minimum or maximum age
- **Absolute contraindication:** absence of the cochlea or cochlear nerve (cochlear nerve aplasia)



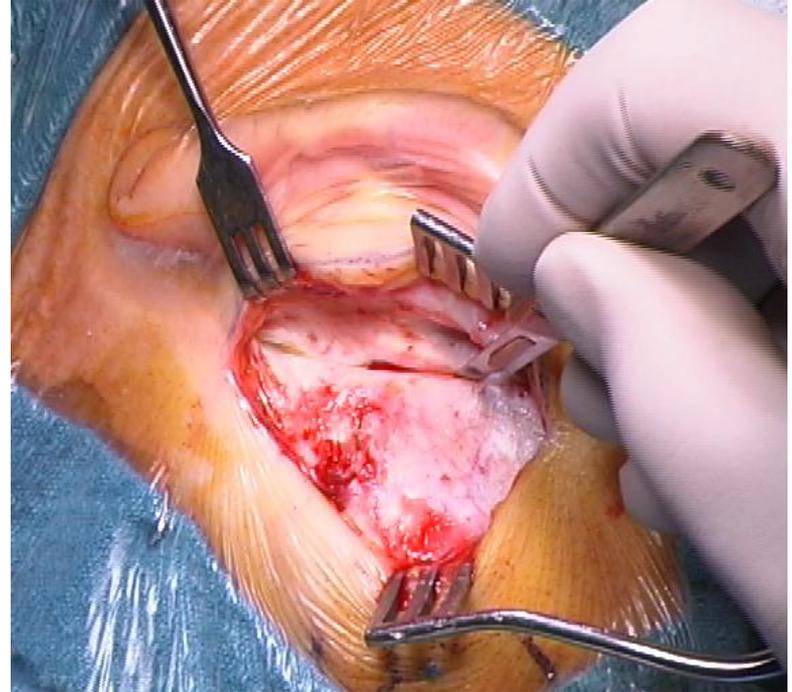
# Cochlear implant surgery

- A routine outpatient procedure – it is NOT brain surgery
- Performed under general anesthesia
- About 2 hours surgical time
- Requires minimal or no hair shaving
- Involves a small incision with low post-operative pain
- Major complications are rare

# Pre-incision: non-sterile field



# Incision (and fibro-periosteal flap)

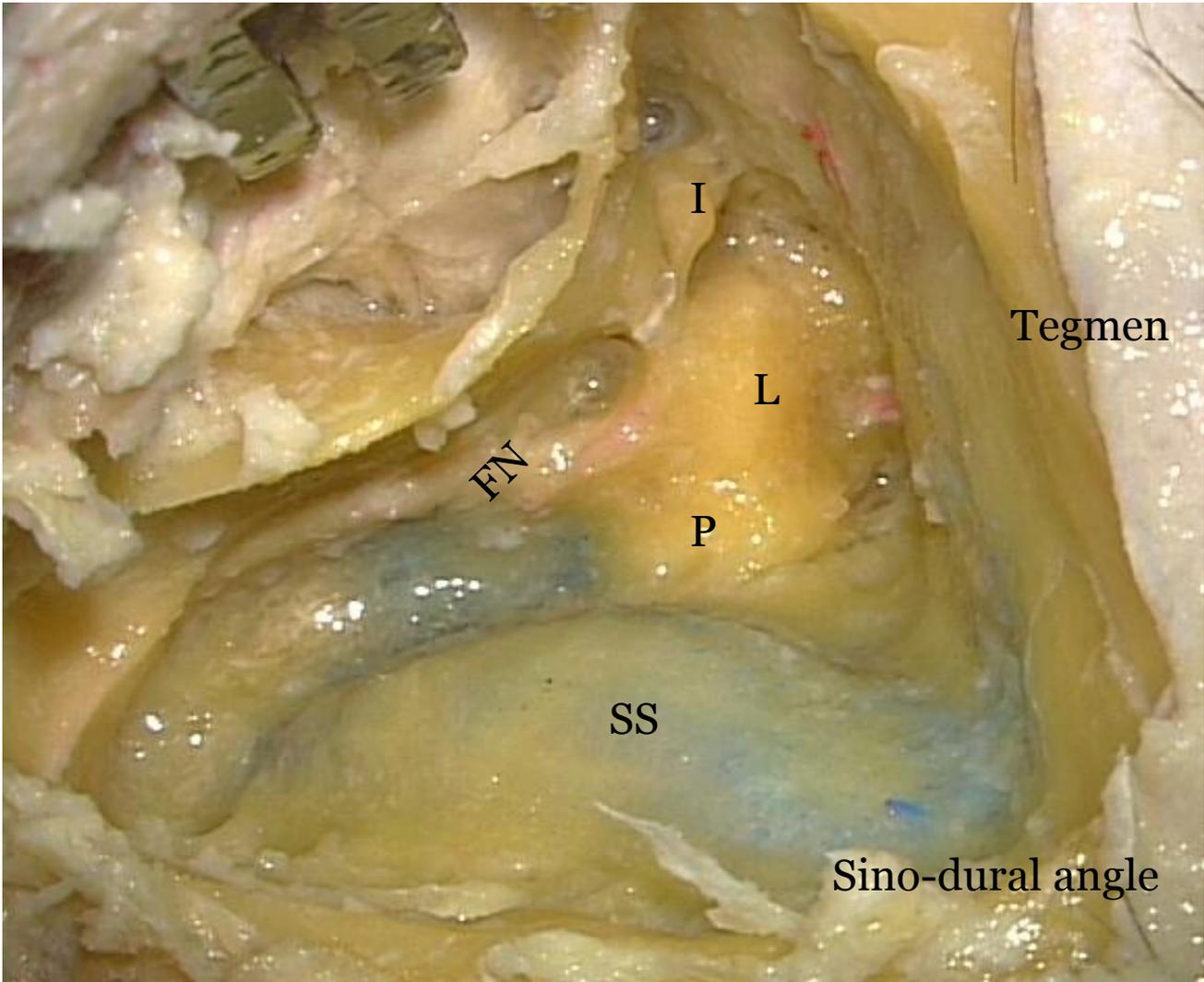


# Cochlear implant surgery

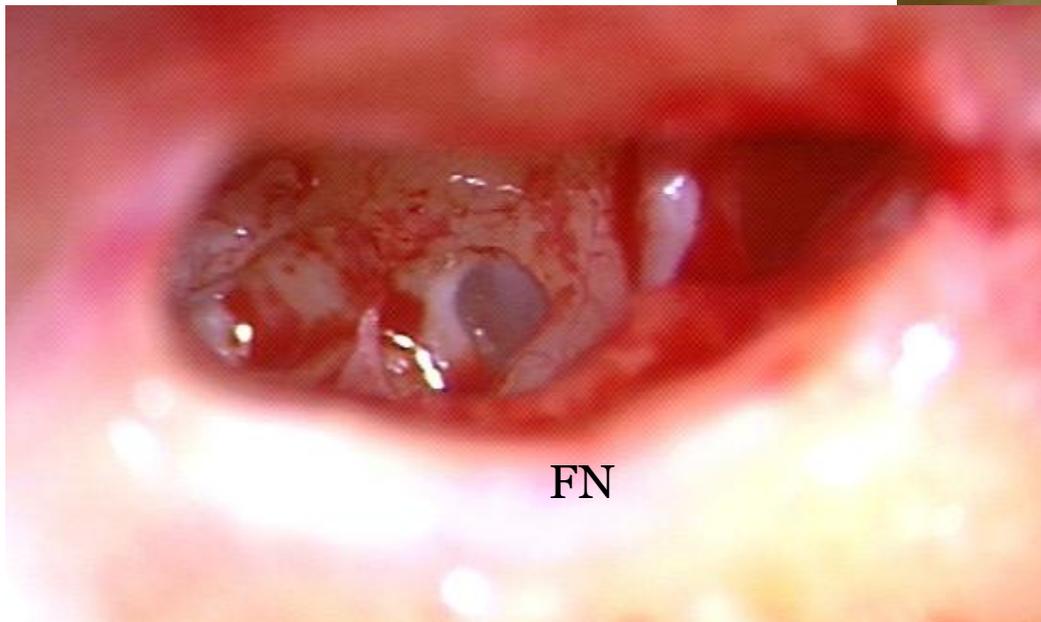
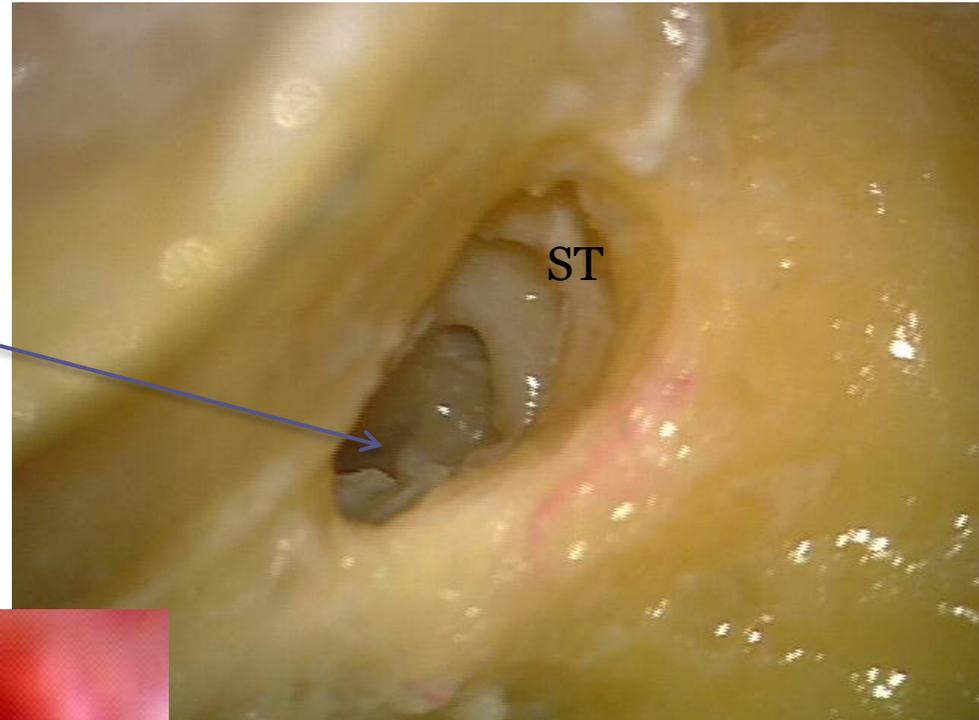
- Drill the mastoid bone until reach the inner ear
- Careful of many landmarks:
  - Brain
  - Sigmoid sinus
  - Semicircular canals
  - Facial nerve



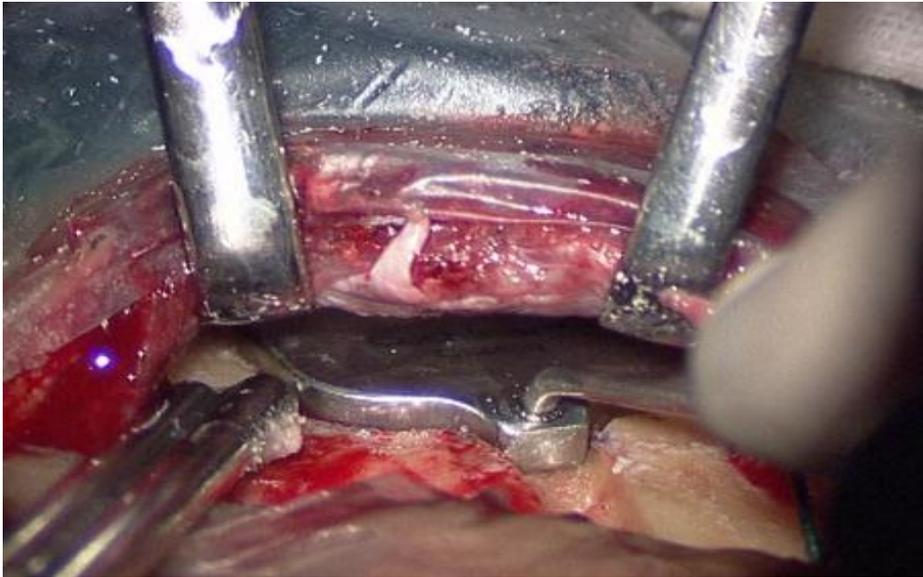
# Cochlear implant surgical procedure



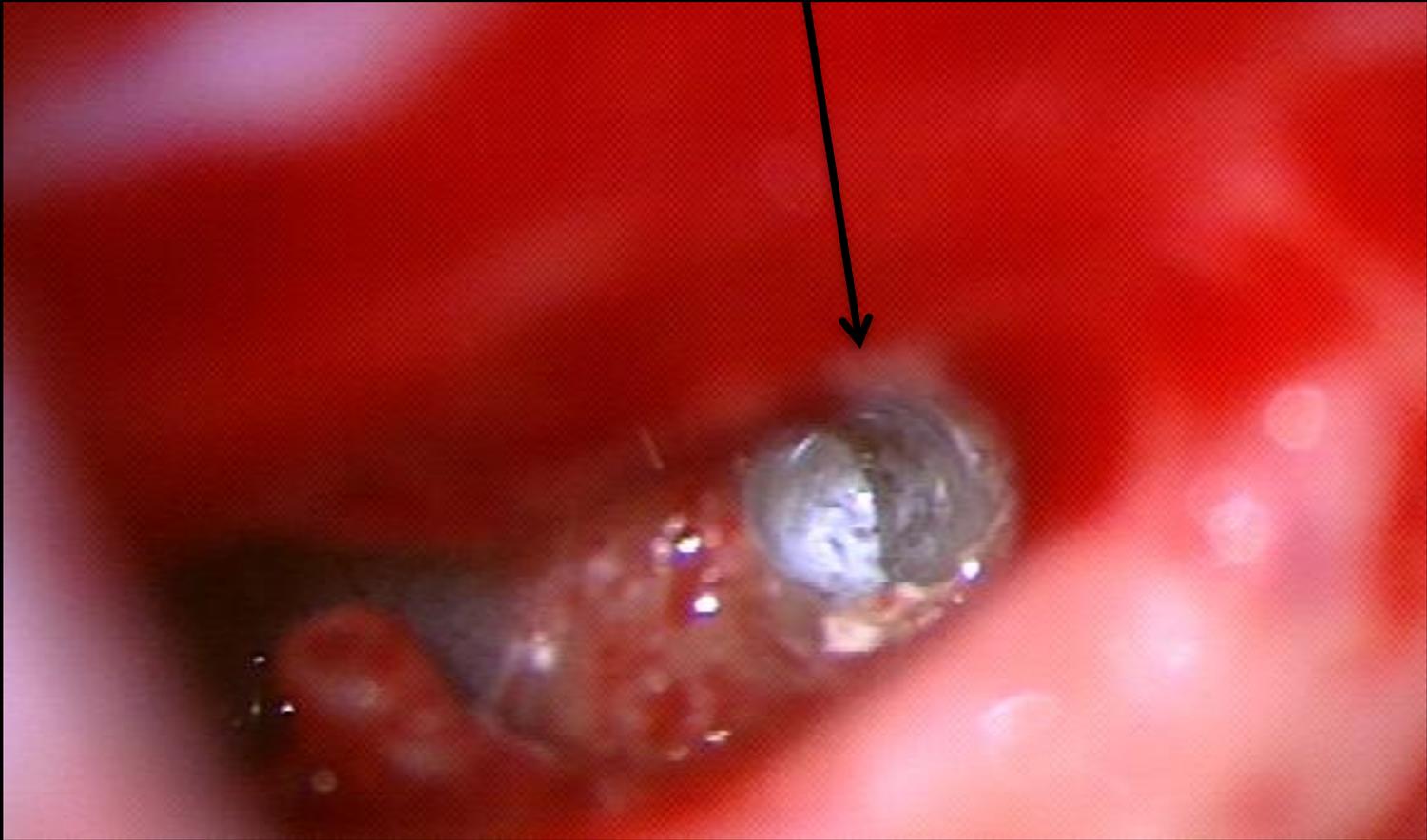
Enter the middle ear through the mastoid via a “facial recess approach”



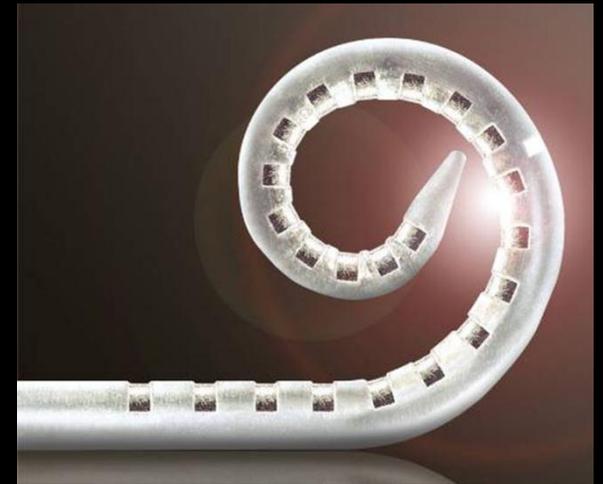
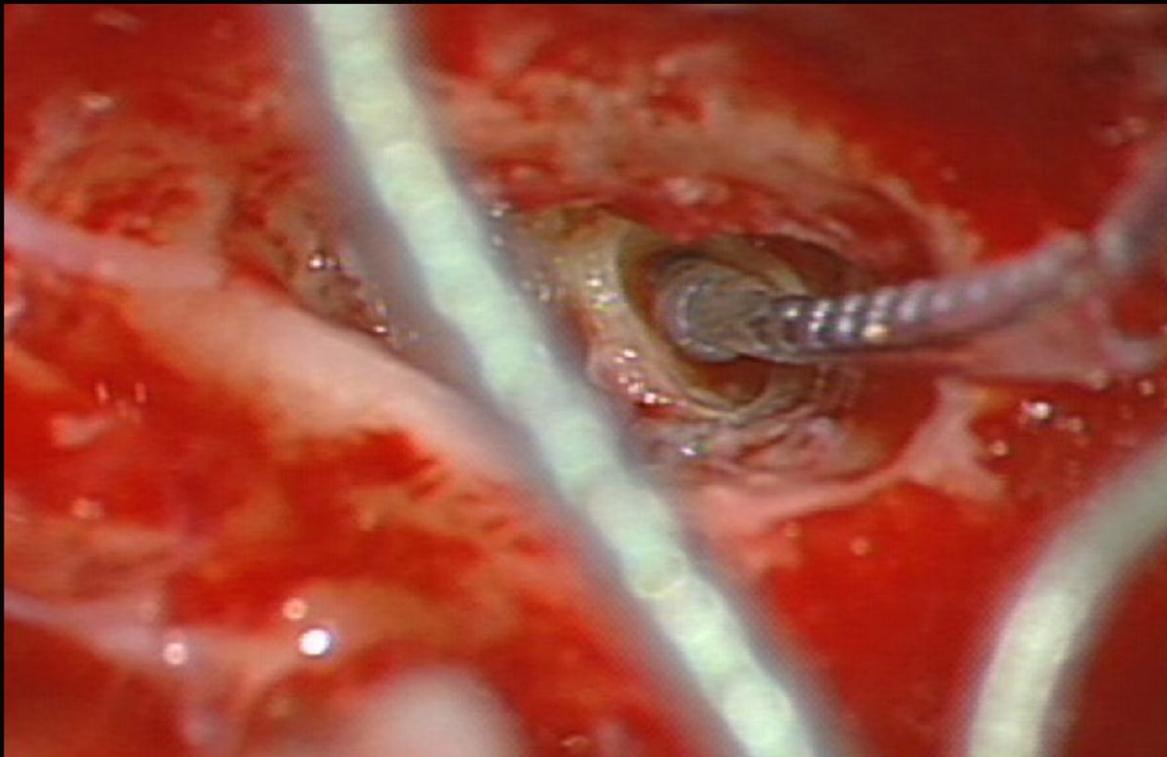
Secure the receiver  
stimulator under the skin

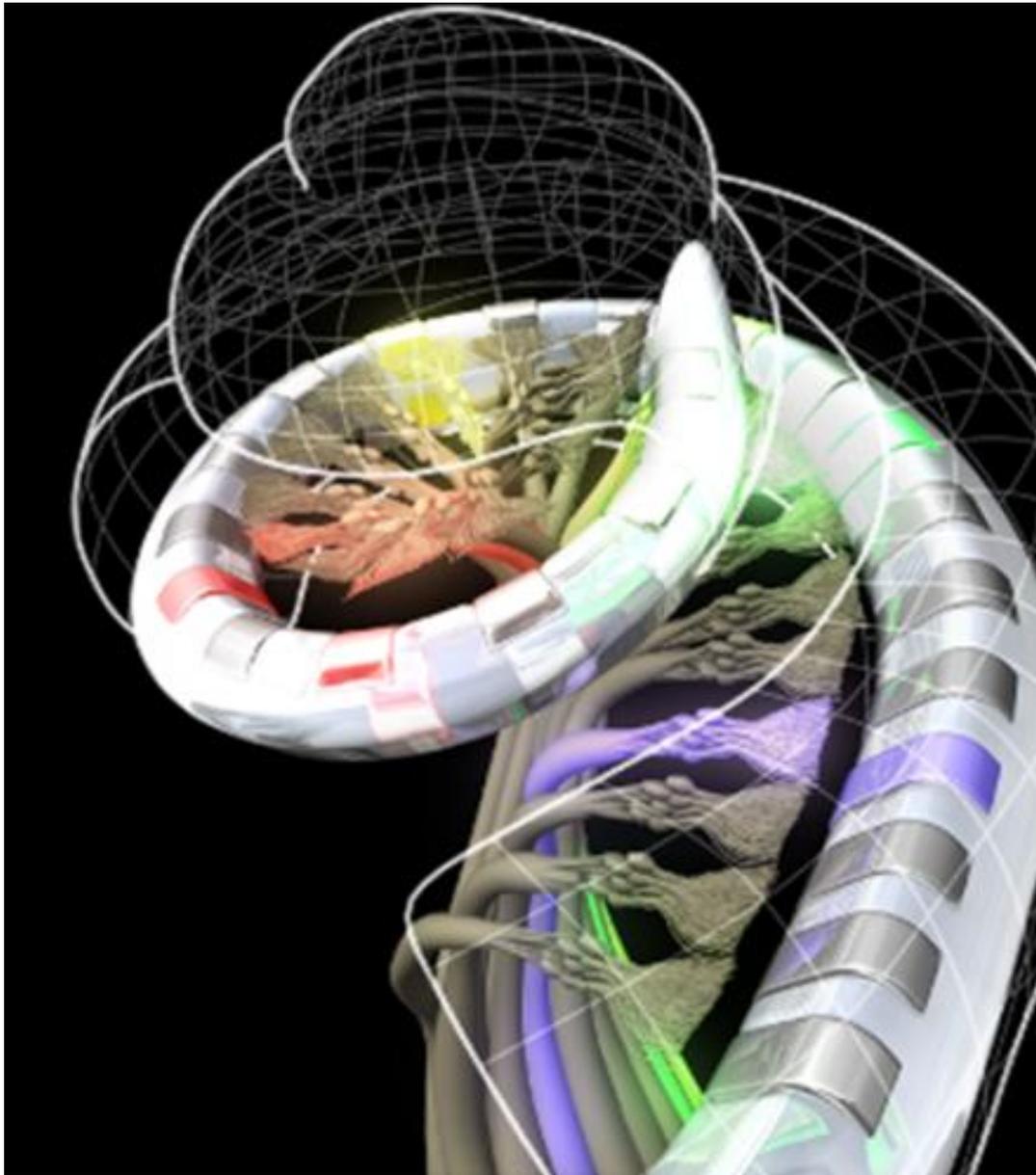


# Cochleostomy with endostium exposed



# Electrode insertion





## After surgery: Speech processing

- Externally work speech processor converts receives acoustic sound and converts it to electrical signals
- This coding strategy allows stimulation of various electrodes within the intra-cochlear electrode array
- Various speech coding and processing strategies allow the implant to be customized to maximize each patient's understanding of speech

# Outcomes: generally excellent

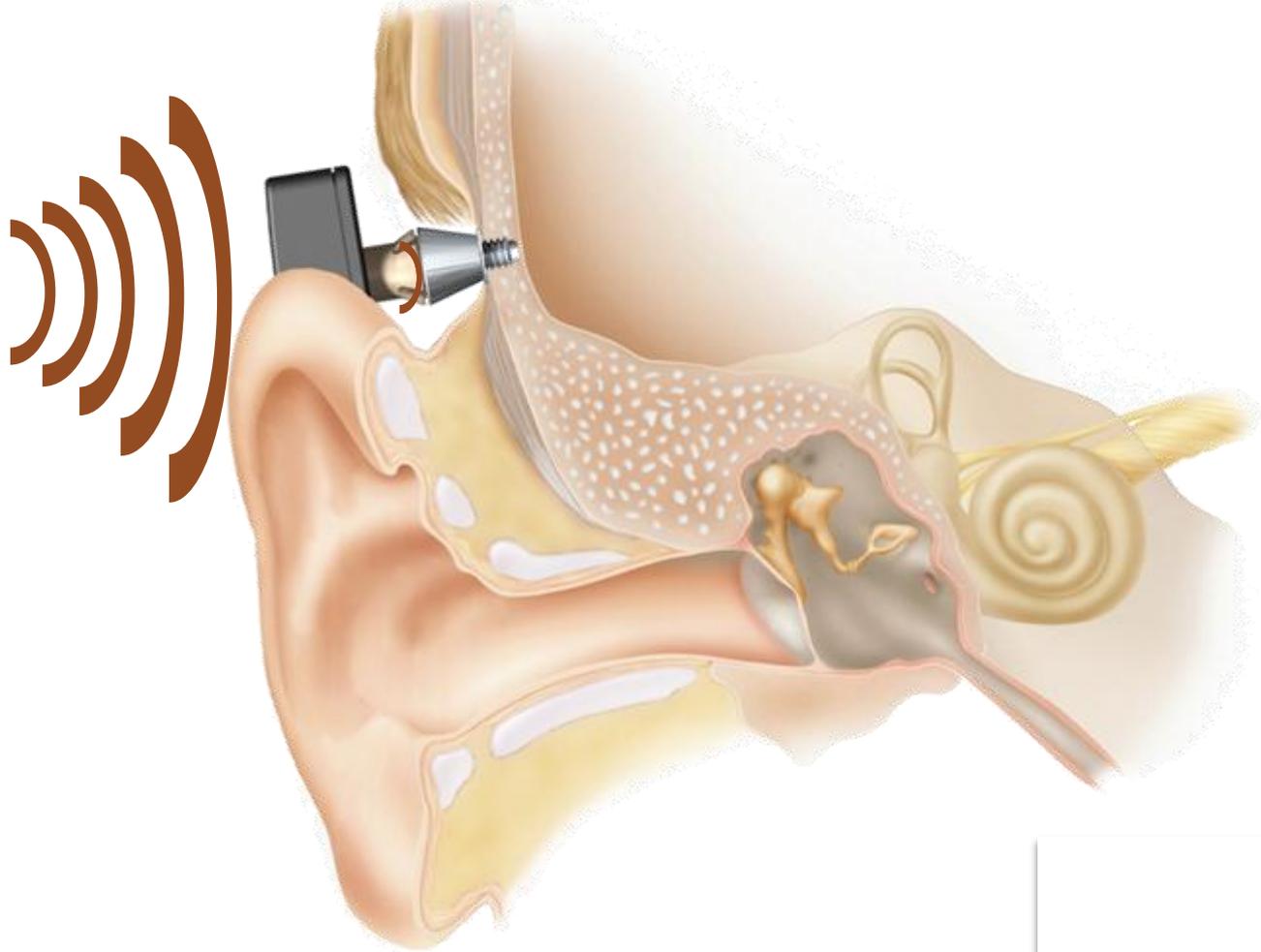
- Post-lingually deafened adults (and individuals deafened after age 4)
- Speech understanding in quiet environments
- Able to use the telephone, watch tv without closed captioning
- Continual improvement over time
- Ongoing technological improvements

# What if you have:

- 1) severe hearing loss on only one side (*single-sided deafness*)
- 2) cant wear a hearing aid due to infection?
- 3) or have a conductive hearing loss that can not be fixed with surgery



Then a Bone conduction hearing aid is used (BAHA)



# How Does it Work?



- 1 The **titanium implant** is placed in the bone just behind the ear
- 2 The external **sound processor** connects to the implant via the abutment

# Baha System Components

*A direct bone conduction system has three parts:*

## **Baha 3 Sound Processor**



Picks up sound and converts to vibration

## **Abutment**



Transfers vibrations from sound processor to implant

## **Implant**



Titanium - placed in bone behind ear where it osseointegrates and transfers vibrations directly to cochlea via bone conduction

# BAHA Surgery

- A routine outpatient procedure – often done under LOCAL anesthesia
- About 20 minutes surgical time
- Low post-operative pain
- Major complications are rare

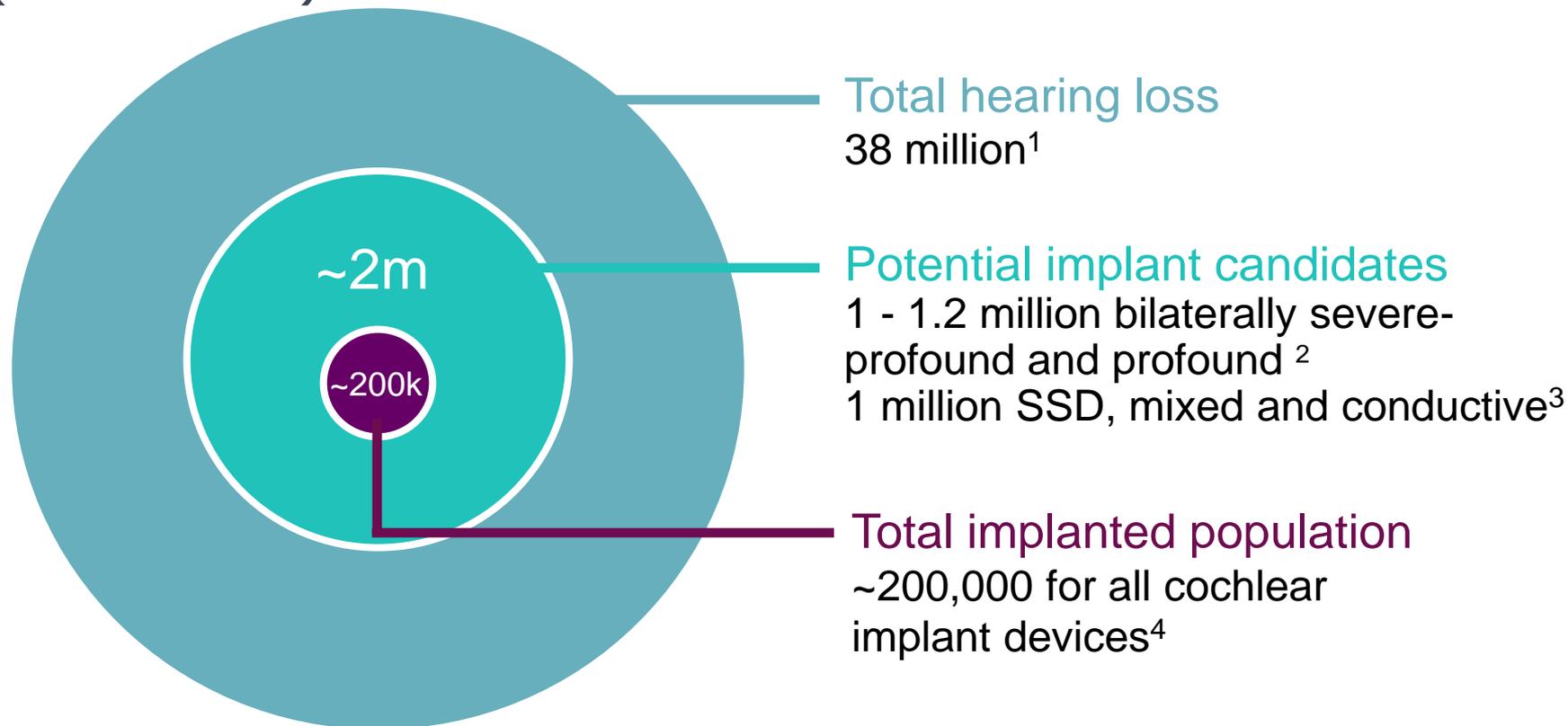
# Burden of hearing loss

One in every 10 Americans experience some form of hearing loss<sup>1</sup>

That's about 38 million people!<sup>2</sup>

# Hearing Loss in the U.S.

(estimated)



<sup>1</sup> <http://www.chchearing.org/about-hearing-loss/understanding-hearing-loss>

<sup>2</sup> Blanchfield, B.B., et. Al. (2001). The severely to profoundly hearing-impaired population in the United States: Prevalence estimates and demographics. JAAA. 12, 183-189.

<sup>3</sup> National Institute on Deafness & Communication Disorders (NIDCD) 2004.

<sup>4</sup> Retrieved from [nidcd.nih.gov/health/statistics/quick.htm](http://nidcd.nih.gov/health/statistics/quick.htm), August 15, 2012.

# Hearing loss burden in veterans...

- Hearing loss and tinnitus are among the **TOP 2** medical complaints of returning OIF and OEF veterans
- Aging veterans are living longer and experiencing progressive hearing loss
- Increasing burden of hearing loss in coming years among veterans of all ages

# Benefits of cochlear implants extend beyond hearing...

- Cost-effectiveness and quality of life metrics associated with of CI has been **well-proven for ALL ages**
- For younger veterans, CI allows improved speech understanding which leads to:
  - Retention of employment
  - Ongoing re-education/job training
  - Decreased depression/anxiety
  - Ability to undergo treatment for PTSD
  - Decreased isolation



# Benefits beyond hearing...

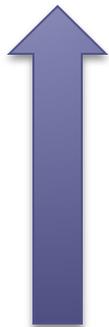
- For elderly patients, CI allows:
  - Ability to remain in own home
  - Improved ability to perform ADLs
  - Overall improved metrics of health
    - Can understand and interact with their healthcare provider
  - Recent research suggesting improved cognitive function/reduction of dementia

# Current (*and future*) hearing rehabilitative options at OBVAMC

## Hearing Aids



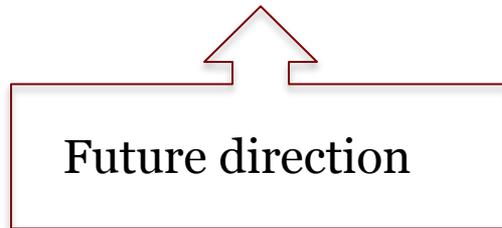
Various types of hearing loss



## Cochlear Implant



Sensorineural hearing loss

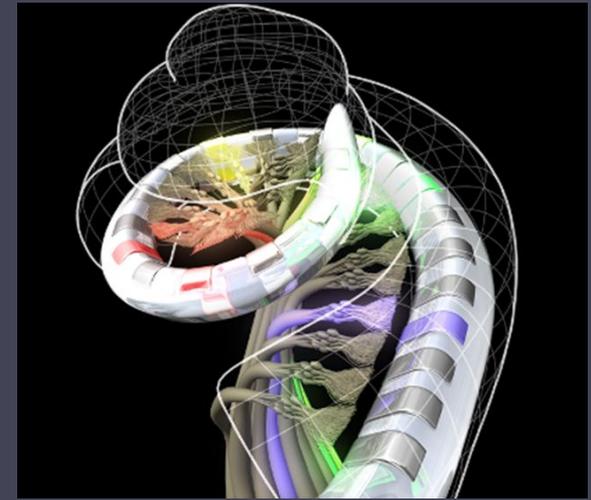
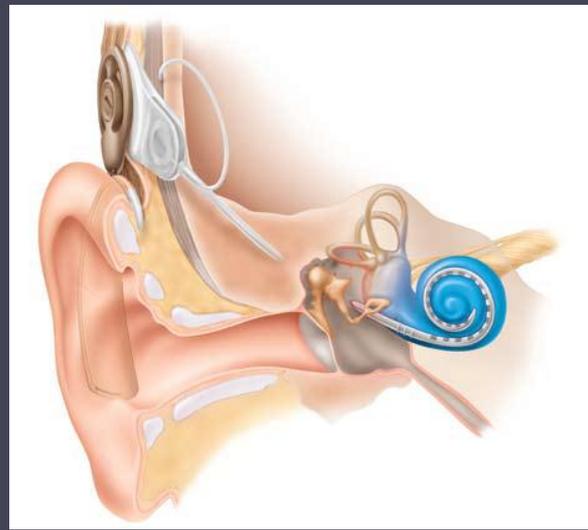
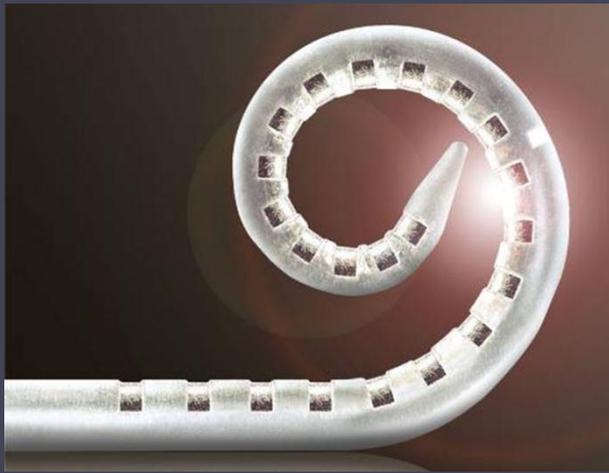


## The Baha® System (direct bone conduction)



Conductive hearing loss,  
mixed hearing loss, and  
single-sided deafness





Thank you!

Any questions?