

COCHLEAR IMPLANT

SEMINAR IN PHYSIOLOGY AND
INSTRUMENTATION

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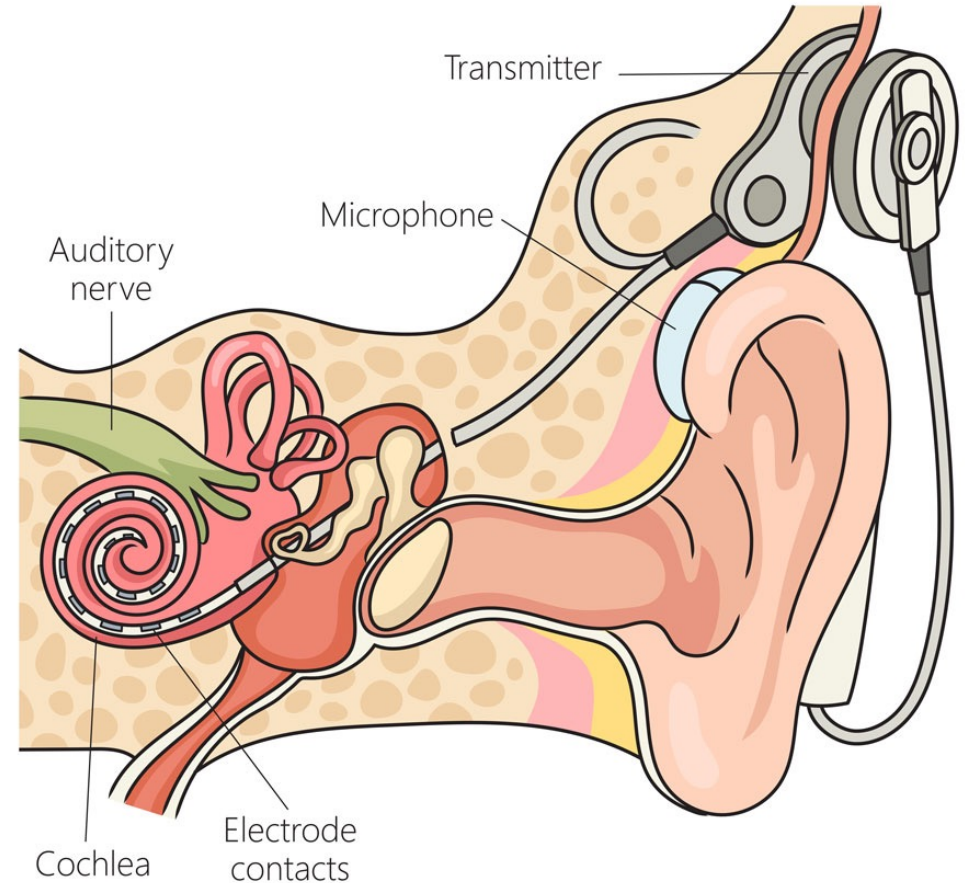
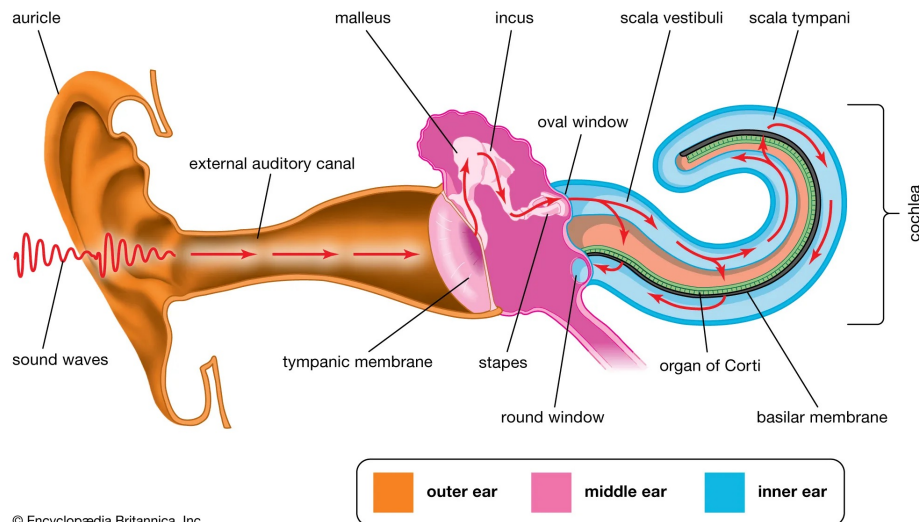
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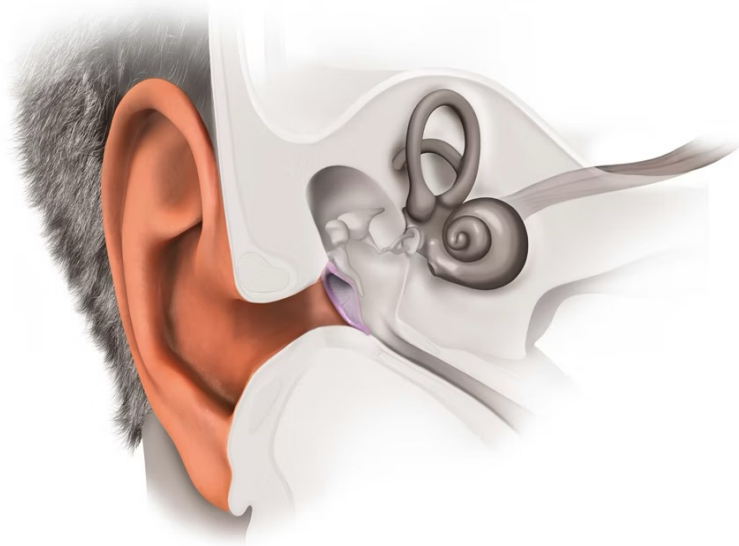
INTRODUCTION

What is a cochlear implant?

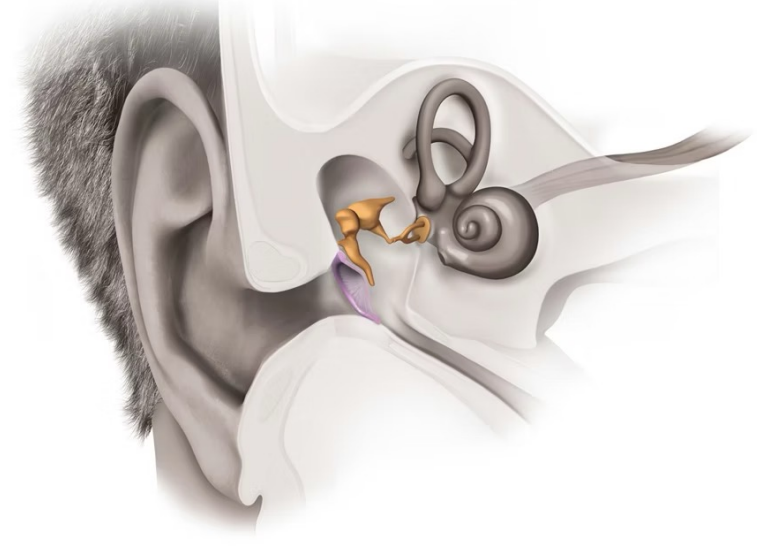
- Electronic device that bypasses the acoustic processing of sound by cochlea and converts the sound into electrical signals in order to send them to the auditory nerve and to the brain, where they are interpreted as sound.
- Help people with severe or complete Sensorineural hearing loss.



PHYSIOLOGY ASPECTS: HOW DO WE HEAR?



External ear: Acoustic waves enter through the outer ear and travel through the auditory canal to the tympanic membrane (eardrum), which vibrates in response of air moving in the ear canal.

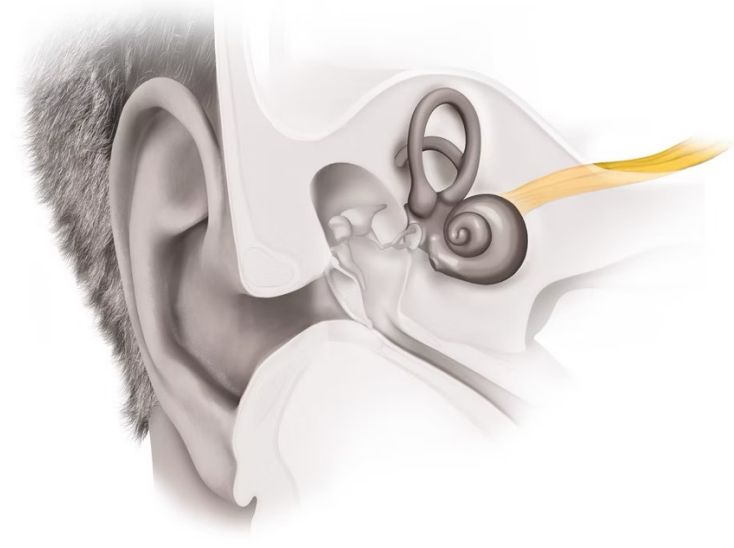


Middle ear: Acts as mechanical transformer. The eardrum makes the ossicles which are small bones in the middle ear (the malleus, incus, and stapes) move. The movement of these bones causes the oval window to move forward and backward, sending the vibrations into the inner ear.

PHYSIOLOGY ASPECTS: HOW DO WE HEAR?



Inner ear: When the vibrations reach the cochlea, they move tiny hair cells inside it. These hair cells convert mechanical motion into the electrochemical signals that are recognized by the nervous system.



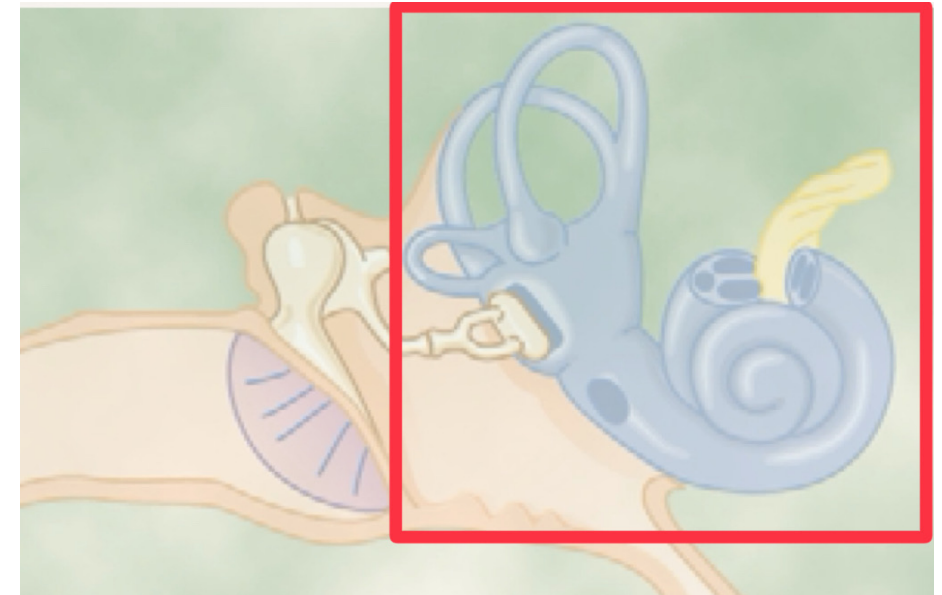
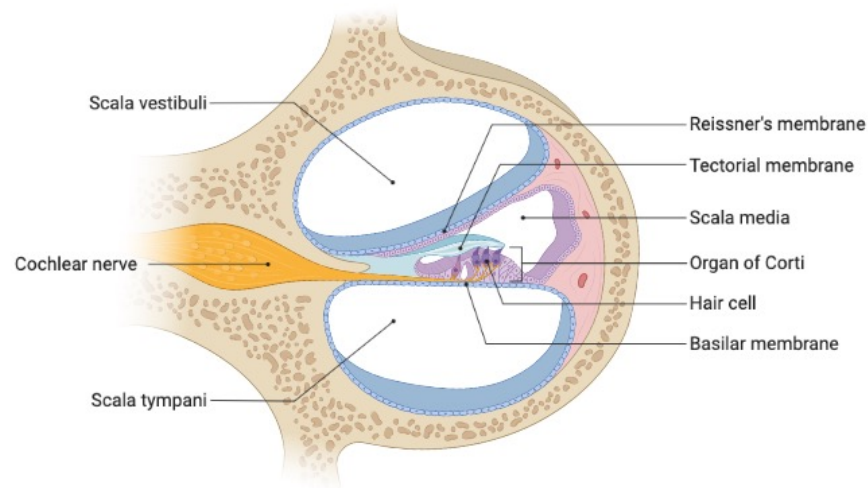
Auditory Nerve: The auditory nerve carries the electrical signals from the cochlea to the brain. When these signals reach the brain, we recognize them as sound.

A CLOSER LOOK AT THE INNER EAR

Cochlea is spiral-shaped with $2\frac{1}{2}$ turns and with three fluid-filled chambers:

- Scala vestibuli
- Scala media
- Scala tympani

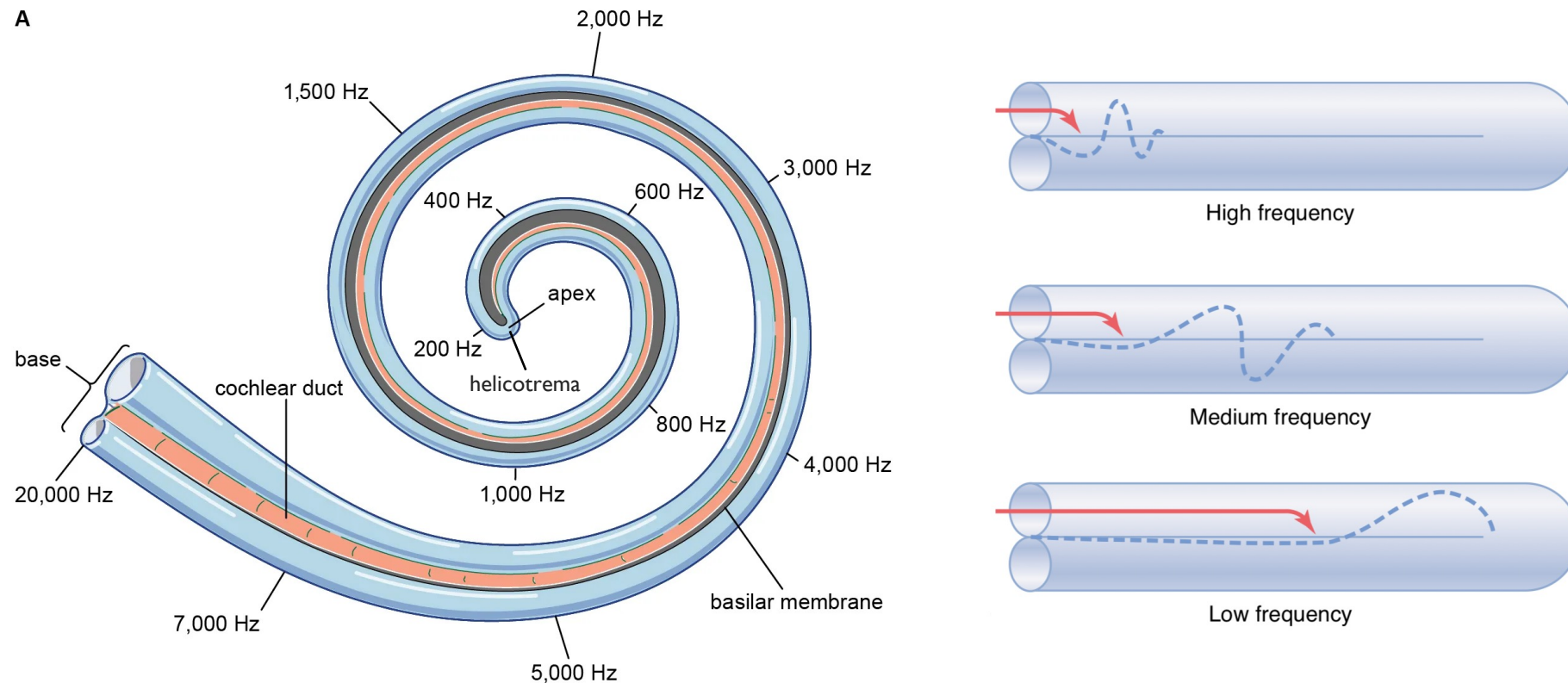
The fluid-filled chambers allow sound vibrations to travel through the cochlea, move the basilar membrane, and bend the hair cells so that sound can be converted into electrical signals.



A CLOSER LOOK AT THE INNER EAR

Inside the scala media is the **basilar membrane** (which contains 20000 to 30000 basilar fibers). Different parts of the basilar membrane respond to different pitches, this is called tonotopy.

- **Base:** reacts to high-frequency sounds. (Basilar fibers are stiff and short)
- **Apex:** reacts to low-frequency sounds. (Basilar fibers are thinner and long)

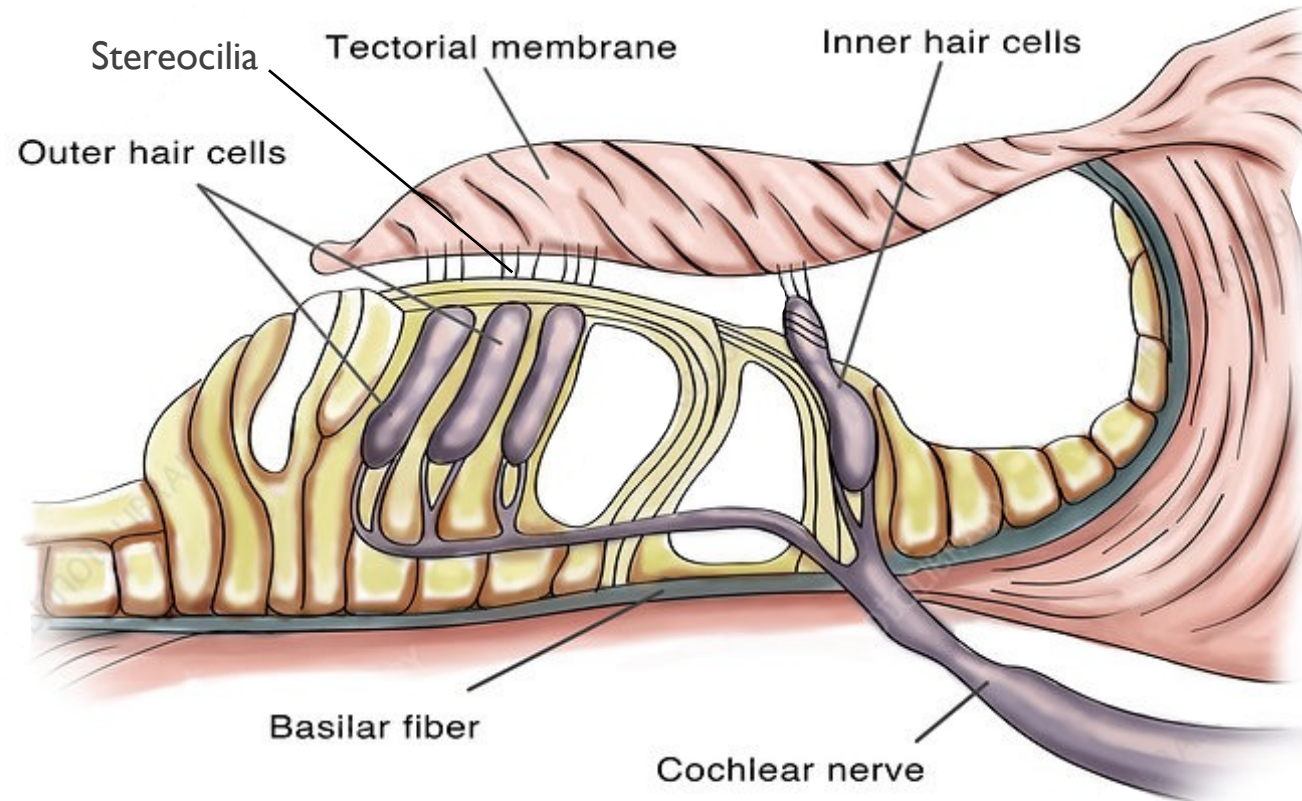


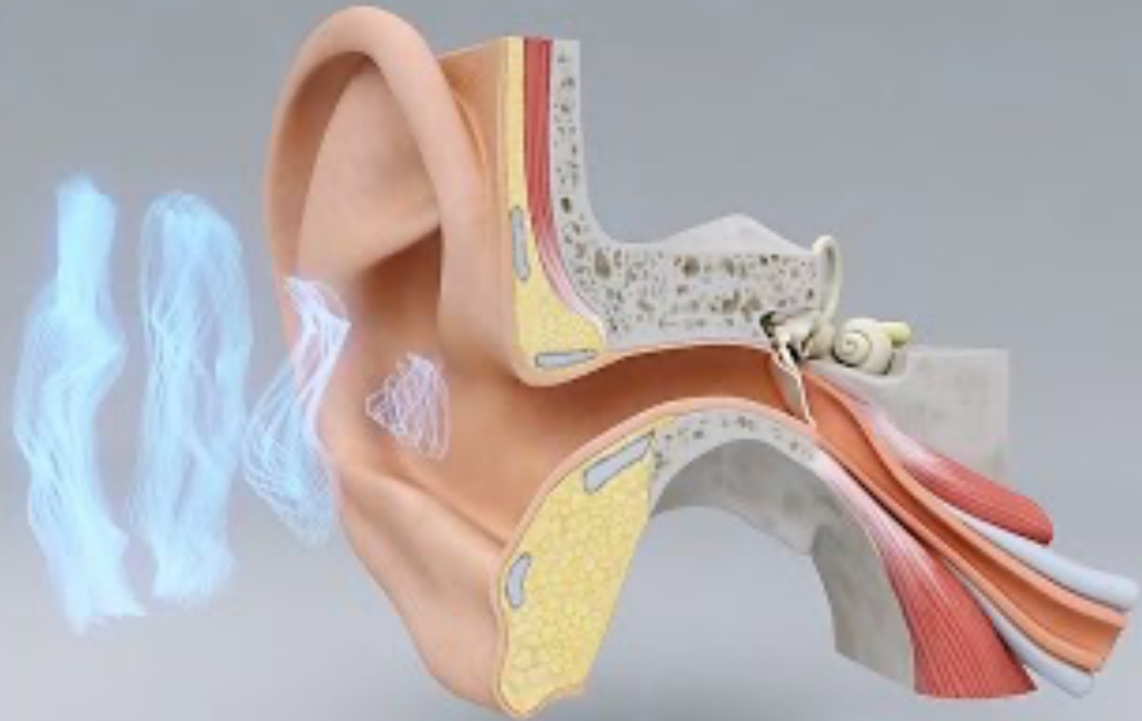
A CLOSER LOOK AT THE INNER EAR

On top of the basilar membrane is the **Organ of Corti**.

- Contains inner hair cells (IHCs): main sensory receptors for sound.
- Contains outer hair cells (OHCs): amplify and fine-tune vibrations.

When the hair cell cilia bend with the movement of the basilar membrane, ion channels open, causing the hair cell to depolarize. This triggers the release of neurotransmitters, which activate the auditory nerve. The nerve then sends electrical signals to the brain, which interprets them as sound.





<https://youtu.be/4AcS2AfJ9OM?si=iobb2QWYbk0Em533>

TYPES OF HEARING LOSS

There are four main types of hearing loss, and usually each type is treatable.

	Causes	Treatment
Sensorineural Hearing Loss: Happens when the hair cells of the cochlea are missing or damaged.	Genetic factors, Aging (presbycusis), Noise exposure, Head trauma, Environmental factors.	Cochlear implants, Middle ear implants, Electric-acoustic stimulation (EAS).
Conductive Hearing Loss: Happens when sound can't reach the inner ear.	Damage in the middle ear, Obstructions in the outer or middle ear like ear wax, fluid, infections, or tumors, Birth defects (atresia, microtia).	Middle ear implants, Bone conduction implants, Bone-anchored hearing aids (BAHA), Bone conduction hearing aids (non-surgical).
Mixed Hearing Loss: Combination of both sensorineural and conductive hearing loss.	Problems in both the inner and the outer or middle ear.	Middle ear implants, Bone conduction implants.
Neural Hearing Loss: Happens when the auditory nerve is damaged or missing.	Damaged or missing auditory nerve	In many cases, an Auditory Brainstem Implant (ABI).

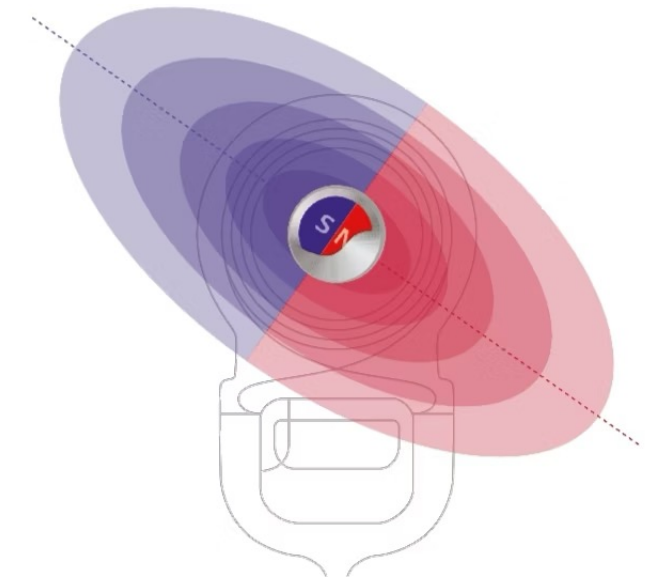
TECHNICAL DESCRIPTION

A cochlear implant system has two main components:

Audio processor: Which is externally worn and detects sounds and sends them to the internal implant.

Cochlear Implant: The internal implant which is placed just under the skin behind the ear.

The two components are kept together by a magnet.

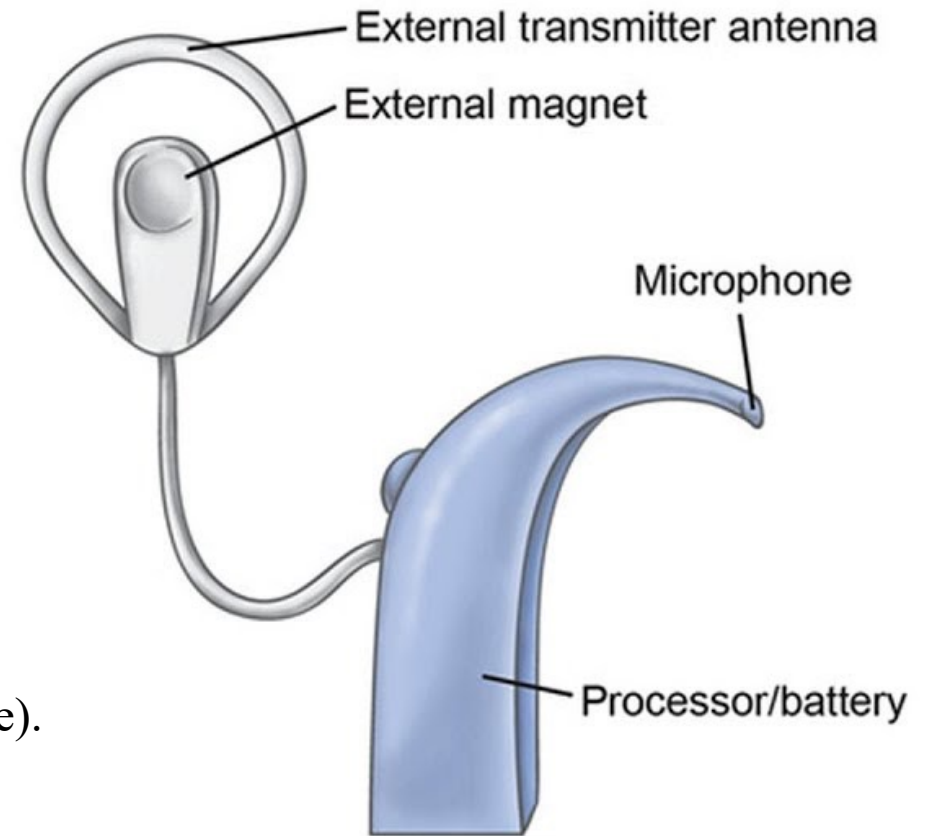


EXTERNAL COMPONENT OF THE COCHLEAR IMPLANT

Audio processor:

- **Microphones:** Capture acoustic sound from the environment.
- **Sound Processor:** Filters, analyzes, and converts sound into digital signals.
- **Transmitting Coil (Antenna):** Sends the coded signals across the skin to the internal implant via electromagnetic coupling.

Powering: Powered by batteries (rechargeable or disposable).

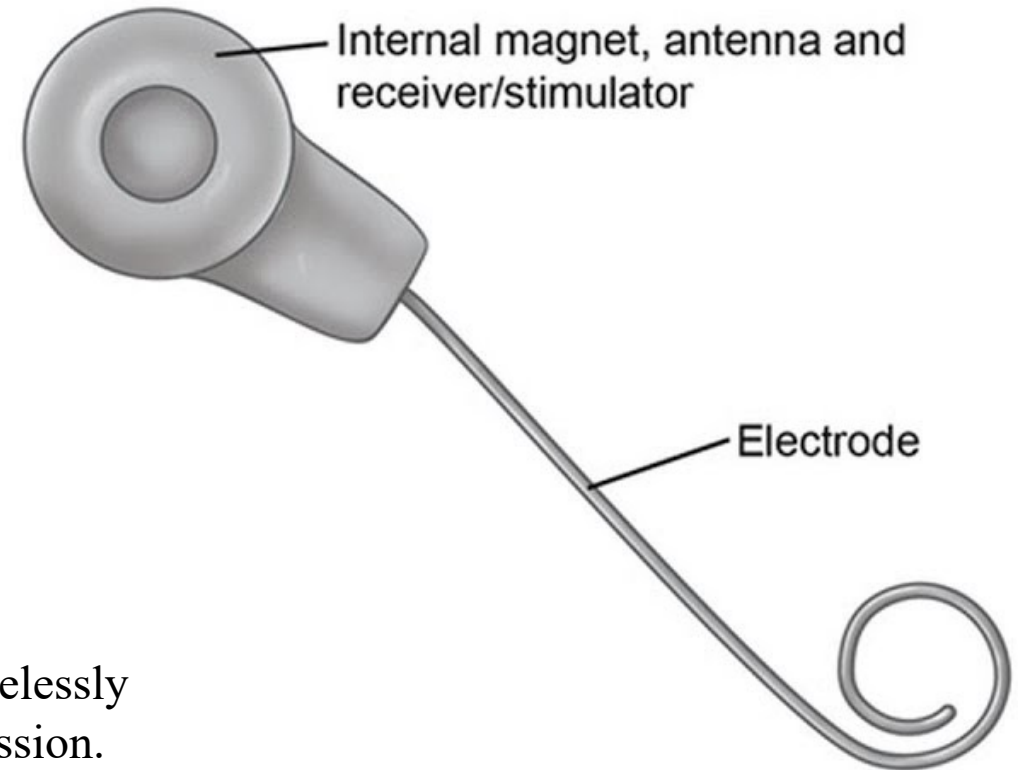


INTERNAL COMPONENT OF THE COCHLEAR IMPLANT

Cochlear Implant:

- **Receiver–Stimulator:** Implanted under the skin; receives signals from the external coil and converts them into electrical pulses.
- **Electrode Array:** Inserted into the cochlea; directly stimulates the auditory nerve to transmit sound information to the brain.

Powering: Does not have its own battery. Powered wirelessly by the external coil through radio-frequency (RF) transmission.



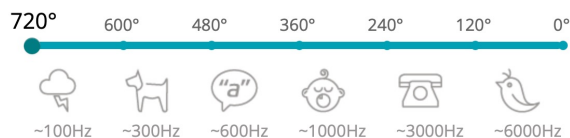
Electrode Array:

Connects the implant's electrical output to the auditory nerve.

Electrodes deliver electrical pulses to replace signals normally sent by hair cells.



Electrode Array Insertion Depth



- **Length and Coverage:** Full-length electrodes ($\sim 720^\circ$) stimulate the entire cochlea; shorter ($\sim 450^\circ$) preserve the natural low-frequency hearing that remains intact (EAS).
- **Biocompatibility:** Materials like silicone, polyurethane, and titanium reduce rejection, irritation, and cochlear damage.
- **Durability and Safety:** Designed to resist wear and fit the cochlea's complex anatomy without harming remaining functional tissue.



https://youtu.be/k93IZHZT4yc?si=JwpobNB_JSnq8bRf

SPECIFICATIONS – MED-EL

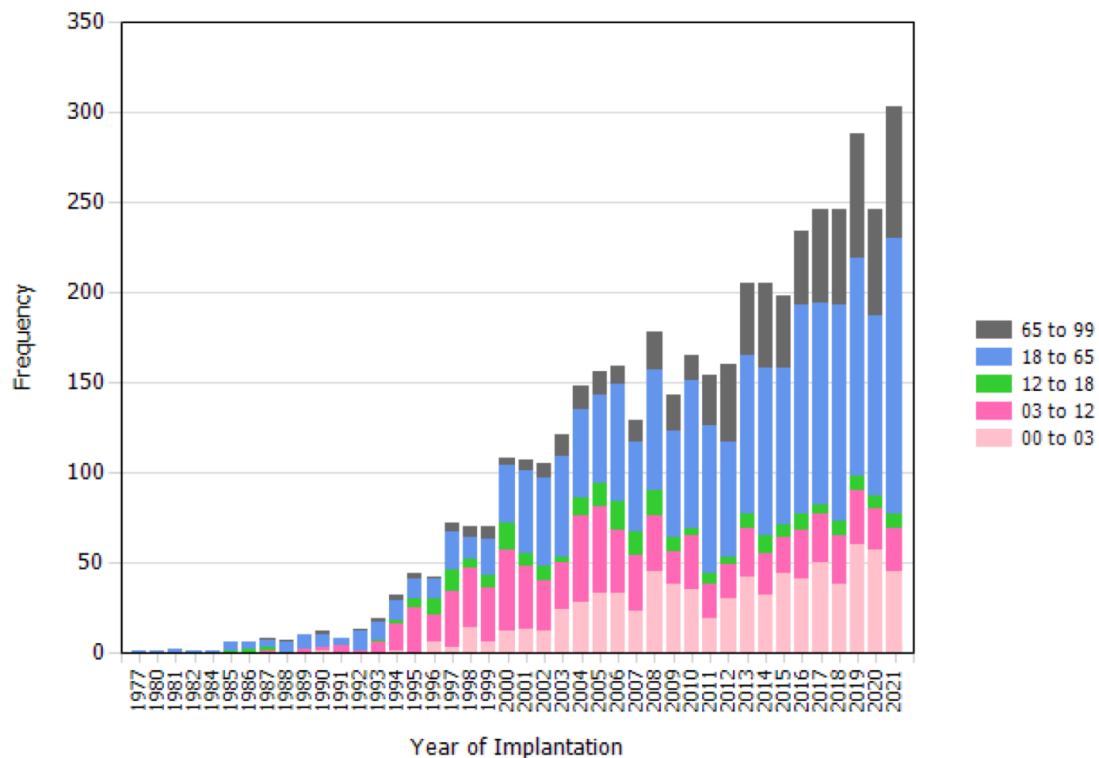
- **Frequency range:** 70Hz – 8.5kHz, supports speech & music.
- **Internal parts lifespan:** Designed for decades; highly reliable.
- **External processor lifespan:** 5–7 years; rechargeable lithium-ion batteries.
- **Battery life per charge:** 12–60 hours depending on model.
- **Water resistance:** Protected against splashes; avoid full submersion (or use protection/covers).
- **MRI-safe magnet:** Permits 3.0 T scans without needing surgical removal.



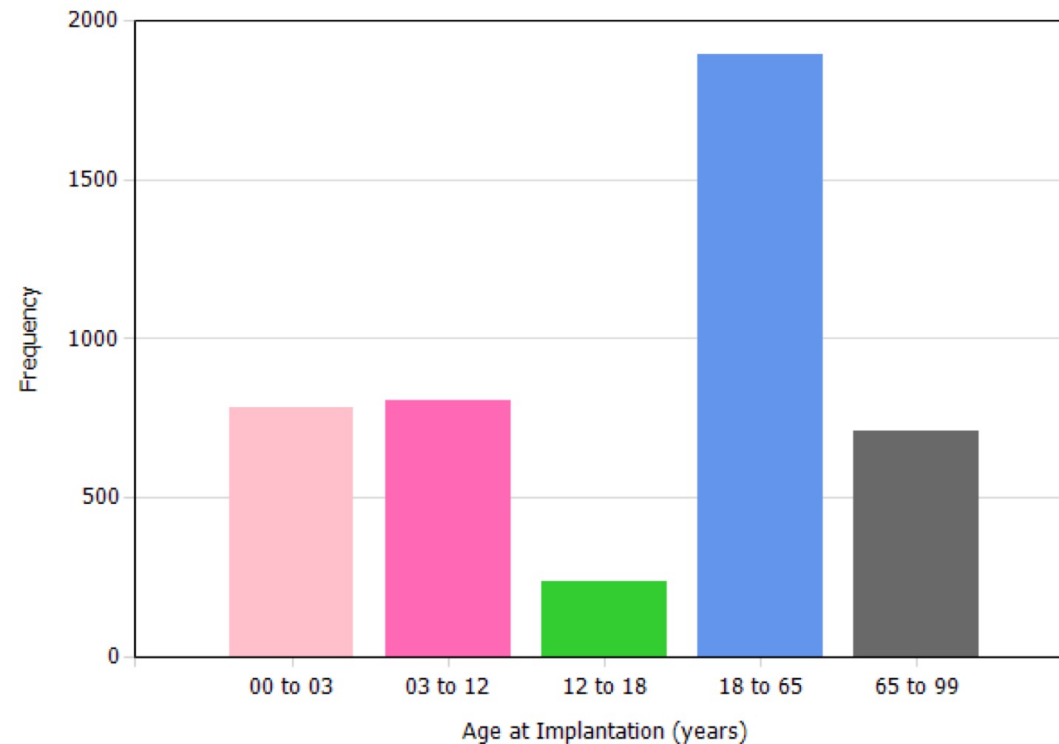
MEDICAL SIGNIFICANCE - SWITZERLAND

Destined for individuals with severe-to-profound sensorineural hearing loss.

CI Age Groups



Age Group at Implantation



Unispital-basel

CLINICAL APPLICATION

1. **Assessment:** Routine tests to confirm candidacy.
2. **Implantation:**
 - Surgical procedure: 1–2 hours, under local or general anesthesia.
 - Electrode array and internal device implanted.
 - Hospital stay: usually 1+ days.
3. **Activation:**
 - Occurs 4 weeks after surgery.
 - Audio processor turned on for the first time (first hearing).
 - Audiologist adjusts settings to match hearing preferences.
4. **Rehabilitation:**
 - Post-activation therapy (speech-language therapy and listening exercises) to adapt to the implant.
5. **Check-ups:**
 - 1–2 weeks after activation for initial adjustments.
 - Every 3–6 months for routine follow-up.



HISTORY OF COCHLEAR PROSTHESES

- 1800 (Volta): Attempted to create sound by electrically stimulating the ear (very uncomfortable).
- 20th century (Djourno & Eyries, Simmons): Discovered that different currents or locations along the nerve could create the sensation of different pitches.
- 1964 (House Ear Institute): First cochlear implant surgeries (single-channel implants - one electrode).
- 1970s (MED-EL): Multichannel implants (multiple electrodes placed along the cochlea).



FINANCIAL OVERVIEW

Cost of Cochlear Implantation:

- Total cost: > \$40,000
- Cost of the device: ~\$20,000

Many regions (Switzerland, Germany, Austria, UK, France, Sweden, United States) offer insurance reimbursement.
High cost offset by significant hearing benefits.

Major Cochlear Implant Companies:

- **Cochlear Ltd.** : Australia based but very active in the U.S. market. →
- Advanced Bionics : U.S.-based implant maker.
- MED-EL : Austrian company with a strong presence in the U.S. CI market.
- Oticon Medical : Denmark based, also listed among U.S. manufacturers.
- Sonova : Switzerland based, owns Advanced Bionics, a major CI brand.

Operational review

\$m	FY25	FY24	Change % (reported)
Cochlear implants (units)	53,968	48,040	↑ 12%
Sales revenue			
Cochlear implants	1,470.2	1,329.6	↑ 11%
Services (sound processor upgrades and other)	609.2	672.3	↓ 9%
Acoustics	276.4	256.3	↑ 8%
Total sales revenue	2,355.8	2,258.2	↑ 4%



FUTURE PERSPECTIVES

- **Combined acoustic + electrical stimulation:**

Preserve residual natural hearing.

- **Bilateral implants:**

Improved sound localization and speech understanding.

- **New electrode designs:**

More precise stimulation, better frequency coverage.

- **Closer mimicry of natural cochlear processing:**

More natural sound perception.

CONCLUSION

- Cochlear implants effectively treat sensorineural hearing loss.
- External and internal components work together to convert sound into electrical signals for the auditory nerve.
- Surgery is low-risk; rehabilitation is essential.
- Market is growing; cochlear implants are the most successful neural prostheses to date.



**THANK YOU FOR YOUR
ATTENTION!**

ANY QUESTIONS?

