BAYLOR COLLEGE OF MEDICINE




Cochlear Implants

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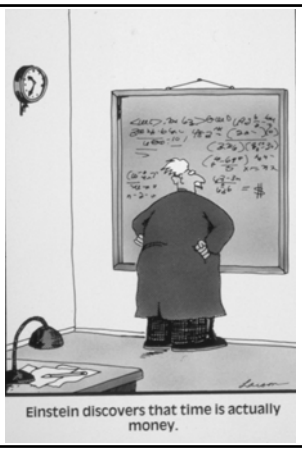
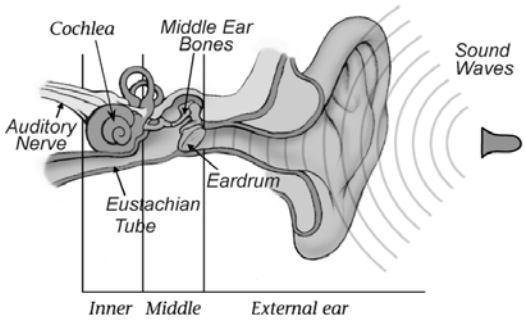
Dept. of Otorhinolaryngology & Communicative Sciences

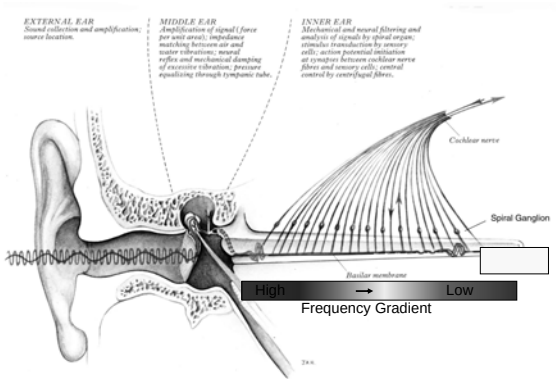


Background

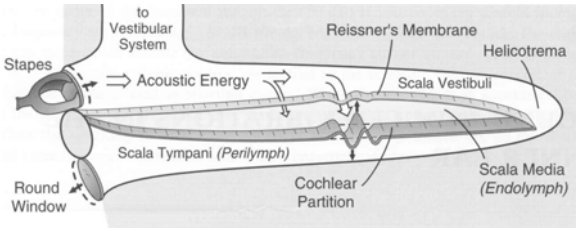
- **Hearing allows us to be conscious of what goes on around us**
- **Always "working" to warn us of danger**
- **Hearing allows communication**
- **Hearing loss affects 28 million Americans (1/10)**
- **Isolation from society**

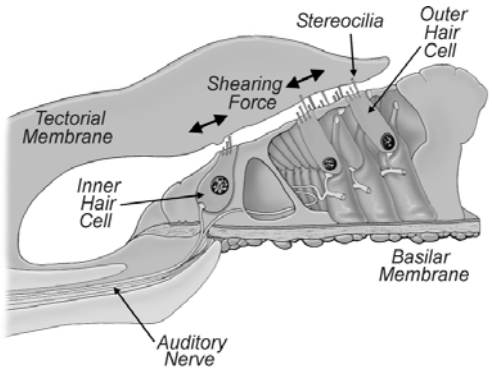


Anatomy of the Ear



Sound Propagation in the Inner Ear

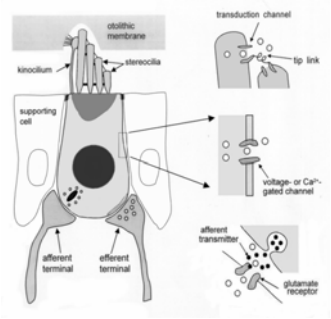




The Organ of Corti

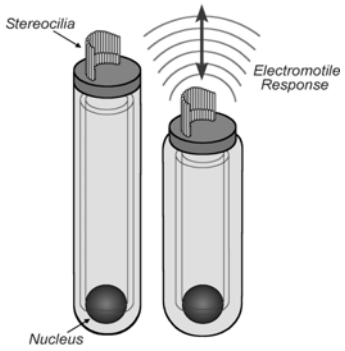
All Hair Cells Have Two Functions

Mechano-Electrical Transduction



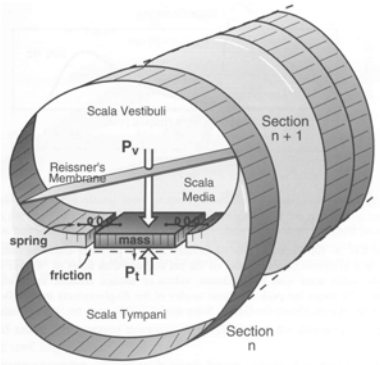
Neurotransmission

Outer Hair Cells Carry Out Electro-Mechanical Transduction

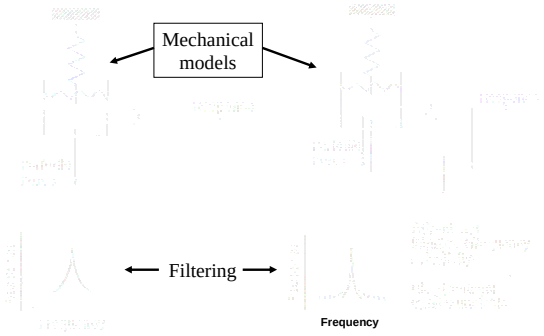


Passive Cochlear Model

- **Mass**
- **Stiffness**
- **Damping**



Passive Active

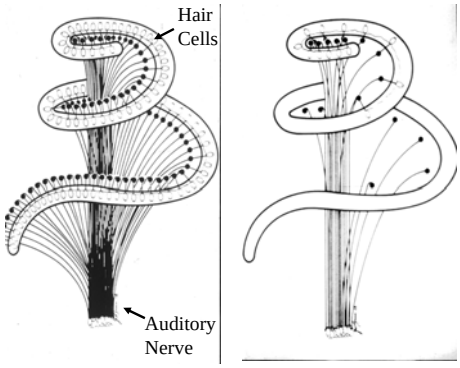


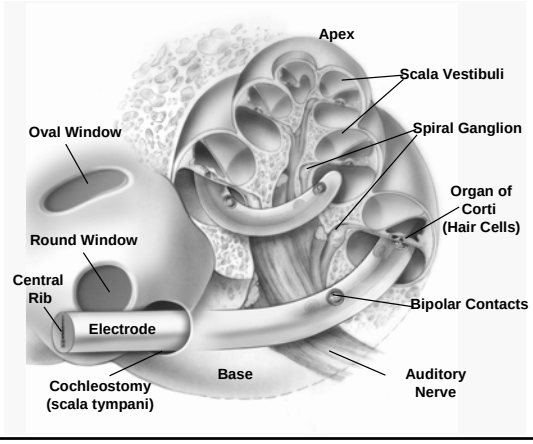
Sensorineural Hearing Loss

- **Mechanisms of sensorineural hearing loss**
  - **Congenital malformations (otic capsule may or may not be involved)**
  - **Stria vascularis**
  - **Spiral ganglion cells**
  - **Organ of Corti / hair cells**
- **Presbyacusis (age related hearing loss)**
- **Noise induced hearing loss**

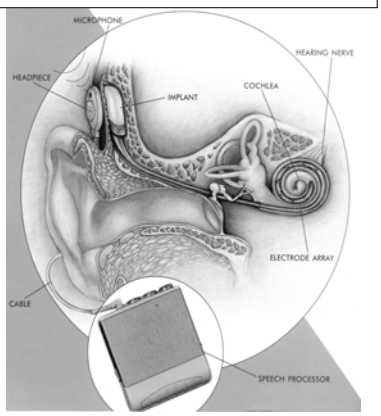
Loss of OHCs (12,000 max)

Normal Cochlea Hearing-Impaired





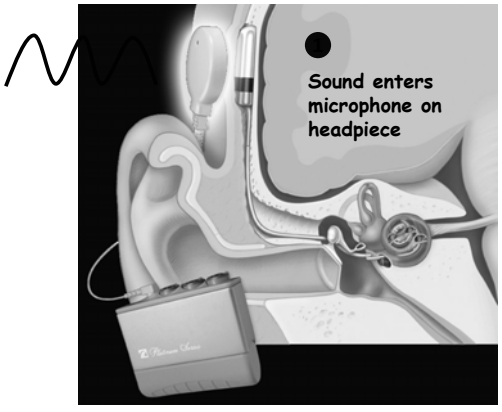
Clarion™ Cochlear Implant

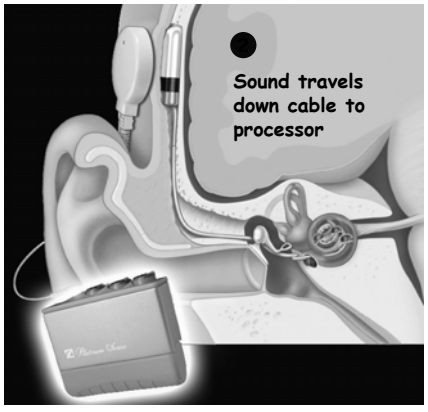


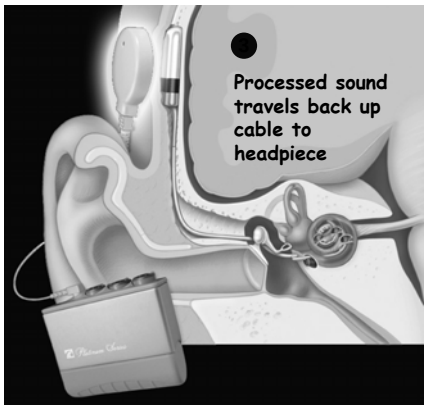
Common Components of all Cochlear Implant Systems

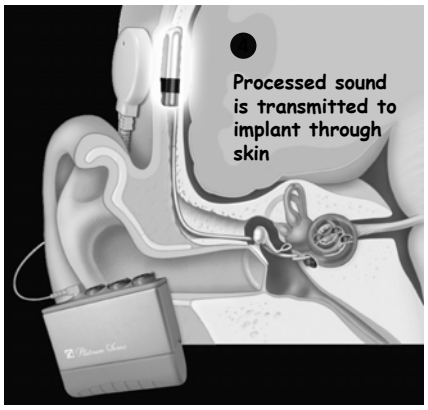
Nucleus 3 system

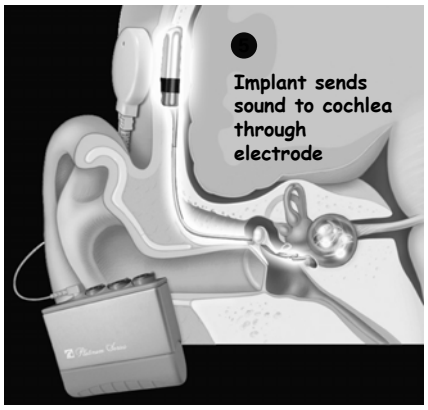
- Microphone & Cable
- Speech Processor
- Antenna/Transmitter
- Receiver/Stimulator
- Electrode Array

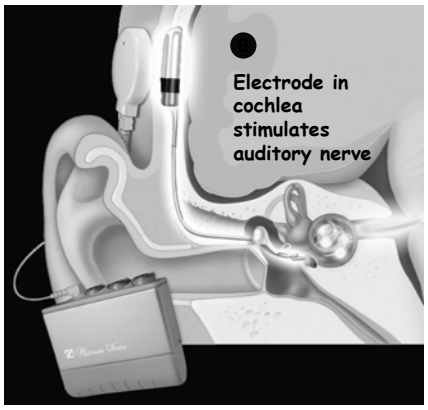








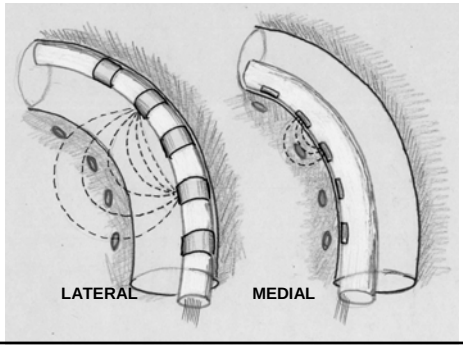




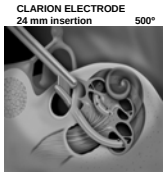
Advances in Implant Technology

- Technological advances have resulted in improvements in patient performance
- In turn, improvements in patient performance have resulted in expanded audiological criteria!

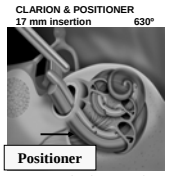
Optimal Electrode Placement at Medial Wall



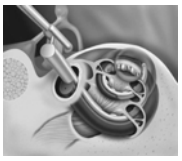
Advances in Electrode Design



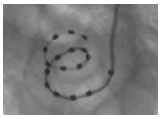
Spiral Electrode
(1990)



Spiral Electrode
with Positioning
System (EPS)
(1998)



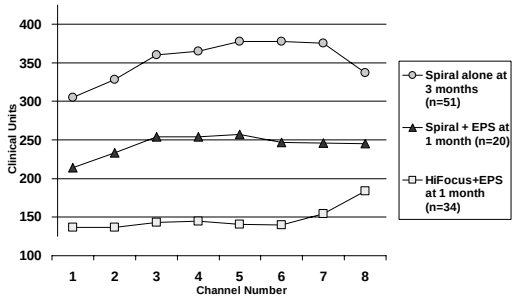
HiFocus Electrode
with Positioning
System (EPS)
(1999)



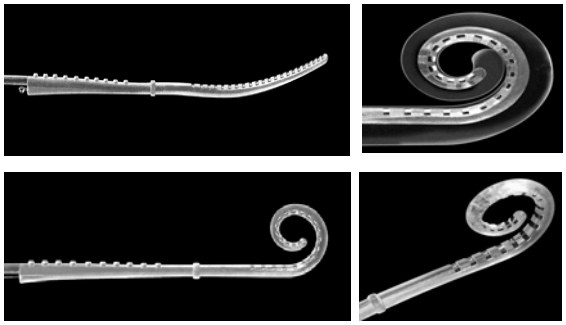
Design changes implemented so that the electrode closely hug the modiolus

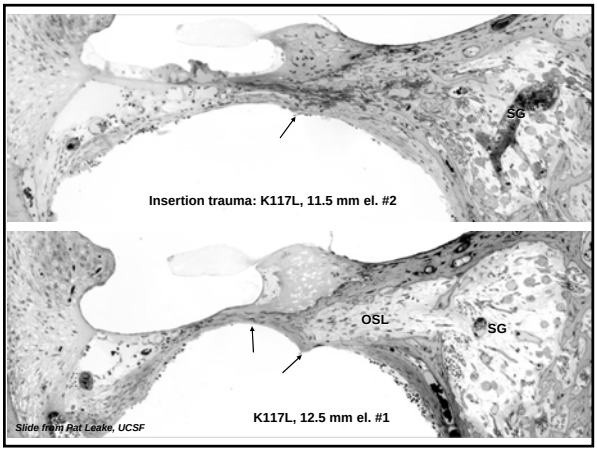
Mean Most Comfortable Levels

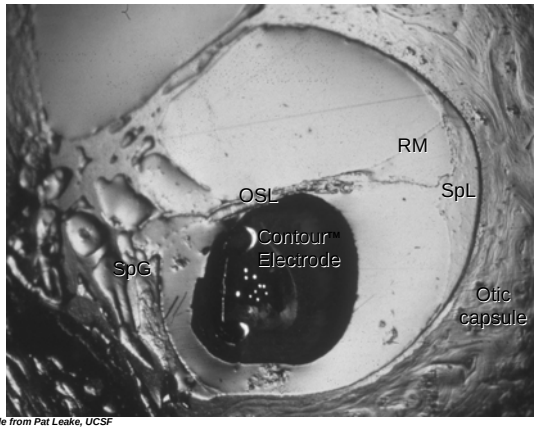
Three Electrode Configurations
Monopolar Pulsatile Stimulation



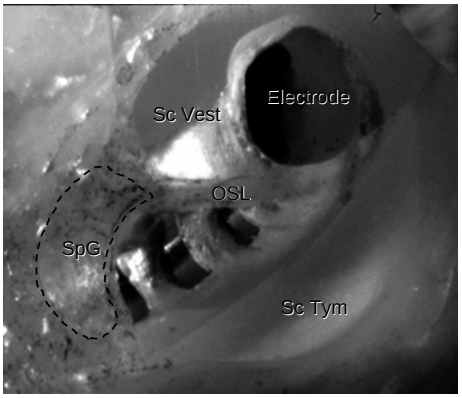
Nucleus Contour Electrode







Slide from Pat Leake, UCSF



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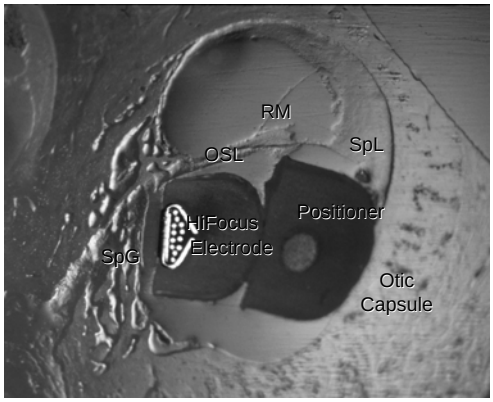


Slide from Pat Leake, UCSF

External Equipment

Speech Processors

- Automatic, Continuous Functionality Check of All External and Internal Components
- Multiple Indicator Lights
- Programmable Acoustic Alarm
- ESD Resistant
- Easy to Adjust Controls

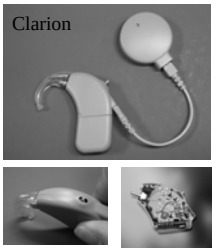
- ▷ Built-in microphone tester
- ▷ Multiple Signal-to-Noise ratio options for FM/Accessories

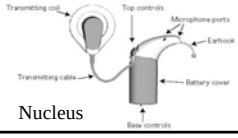
"mini-computer"

BTE Sound Processor

- Runs all processing strategies plus new ones under development
- Rechargeable batteries for low operating cost
- Compatible with all CLARION internal implants
- Same functionality as Body worn PSP, except no warning lights/alarms
- Check functionality with Sensor

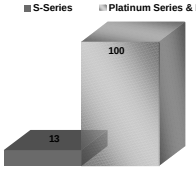
Clarion





Nucleus

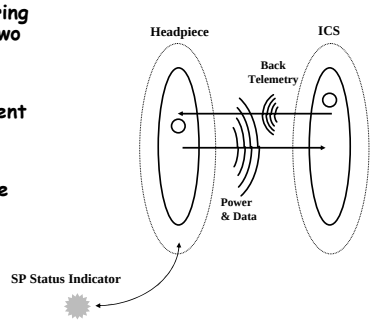
CLARION Sound Processor Development



Million Instructions Per Second (MIPS)

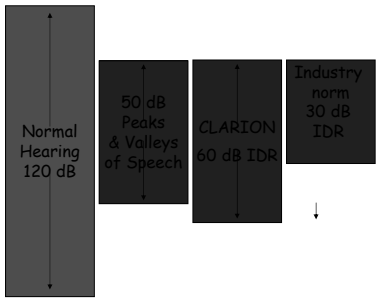
Continuous Two-Way Telemetry

- Ongoing monitoring achieved with two distinct carrier frequencies
- Normal concurrent signal operation
- Benefit for children who are unable to communicate

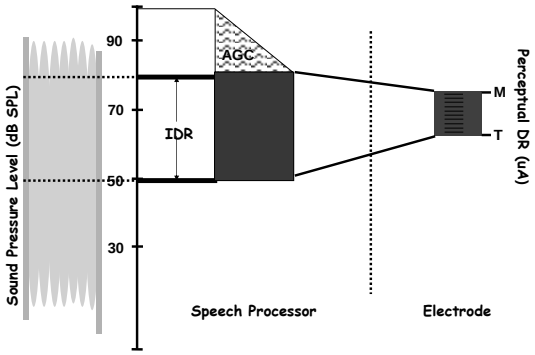


Input Dynamic Range (IDR)

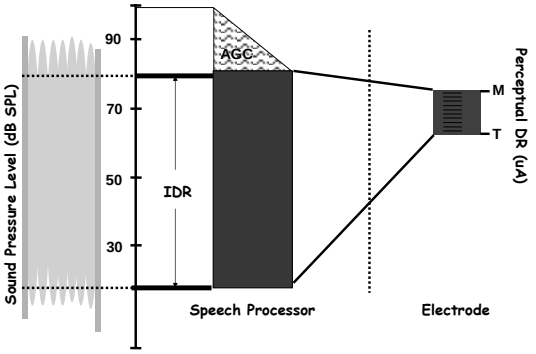
- The normal ear captures widely fluctuating speech intensities ranging over 50 dB as well as speech from talkers when they are far away or speaking softly
- CLARION captures the widest range of incoming sounds through its electronics and software

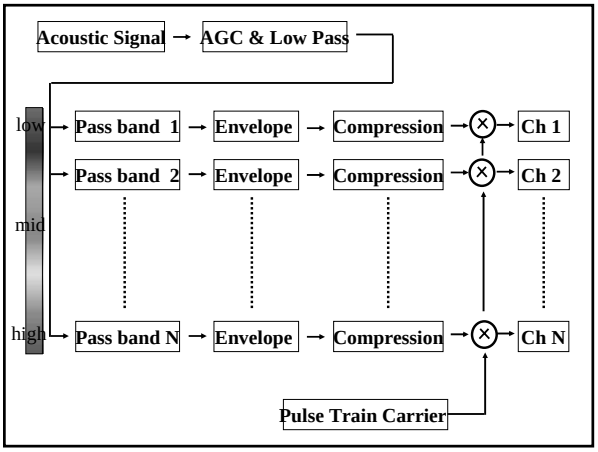


"Narrowed" IDR (30 dB)



"Widened" IDR (60 dB)





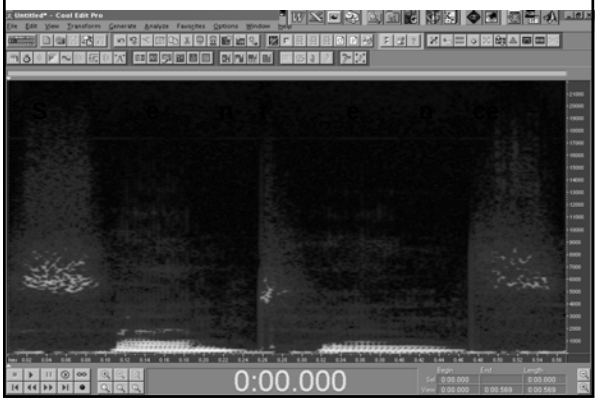
BTE Decals

Six inter-changeable color headpiece caps

Nucleus

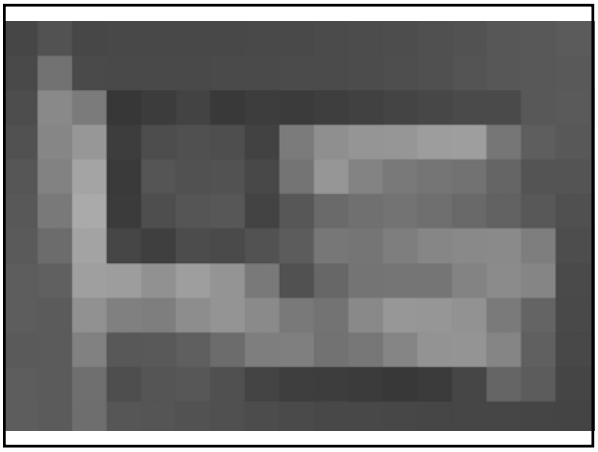
Speech Processing

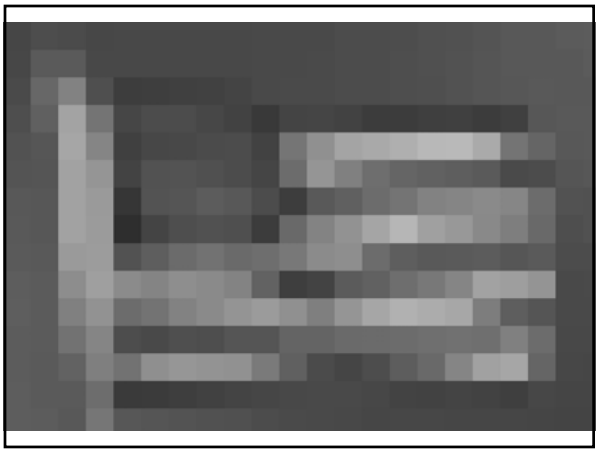
Speech Spectrum

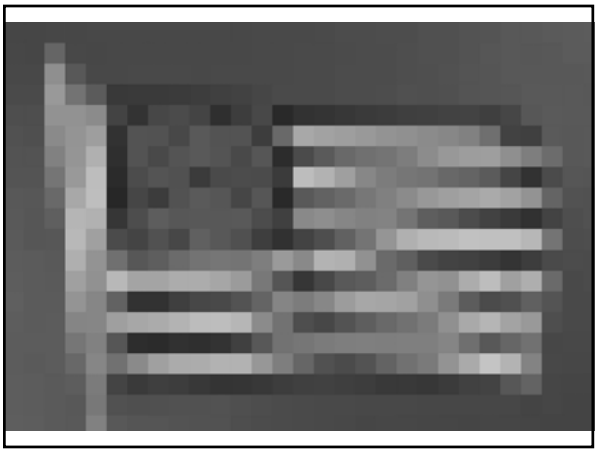


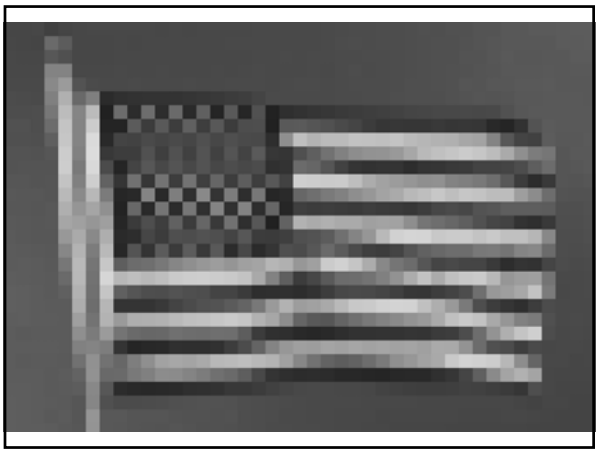
Spectral Resolution (Number of Channels)

- Most important factor is the number of spectral channels of information
  - number of distinct pitch channels
- Number of effective channels is not the same as the number of electrodes



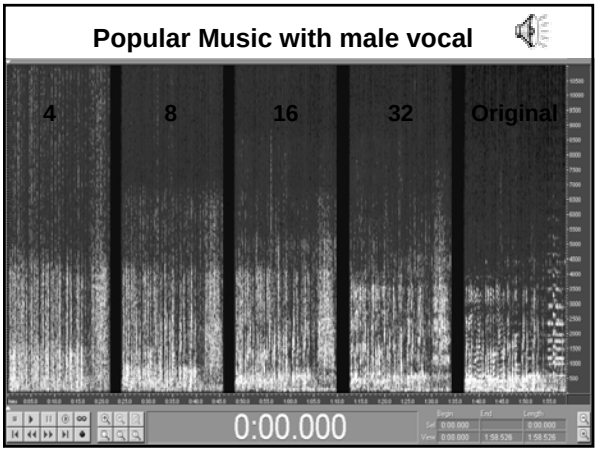


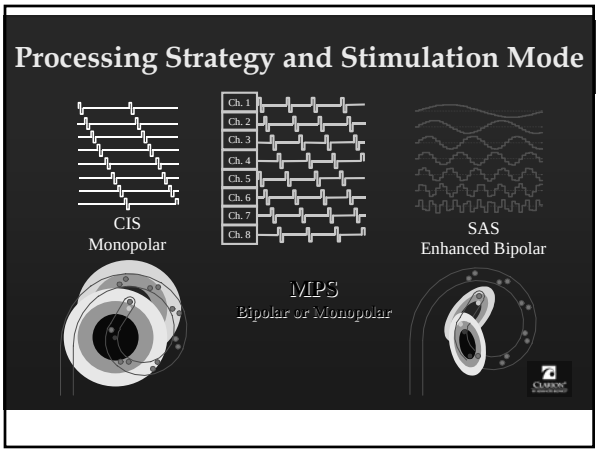




Spectral Cues in Music

- While spectral and temporal fine structure are not necessary for speech recognition they constitute the very heart of music, illustrating the different demands of speech and music on peripheral sensory processing
- Melody recognition requires many more spectral channels than speech
- "The cochlea isn't designed for speech… the cochlea is designed for music" (Ed Burns)





Who is a CI Candidate?

Who Should Get a Cochlear Implant? Children

- Children aged 12 mos-17 years
- Profound sensorineural hearing loss of 90 dB or greater in both ears (No Response ABR)
- Lack of benefit from high powered hearing aids
  - 3-6 month Required Hearing Aid Trial
  - < 2 on Questions 3, 5, & 6 on the IT-MAIS Questionnaire
- Older child (>6yrs): Some auditory skills
  - 0-20% on tests of open-set word recognition (PB-K or MLNT)

Don't Wait!
The Younger the Better!

Who Should Get a Cochlear Implant? Children

- Rehabilitative or educational setting where development of listening and speaking skills are emphasized
- Positive family environment where device use through listening and speaking is encouraged

Adults
Who Should Get a Cochlear Implant?

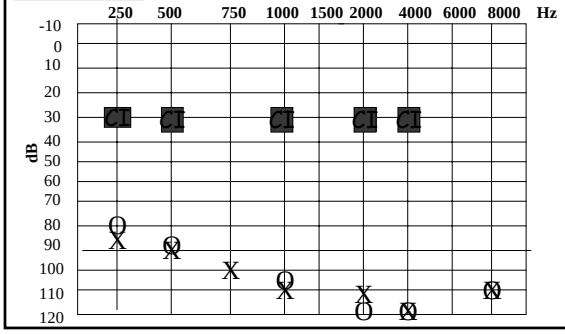
- Healthy adult over 18 years of age, no upper age limit
- Severe-Profound sensorineural hearing loss of 70 dB or greater in both ears
- Postlingual onset of deafness (after age 6 yrs)
- Prelingual adults that are members of the hearing community (lip readers, verbal intent)
- Lack of benefit from hearing aids
  - HINT Sentence score < 50%

Adult Referral Criteria

- PTA of >70dB in Both Ears
- Monosyllabic Word score of < 30% in Both Ears

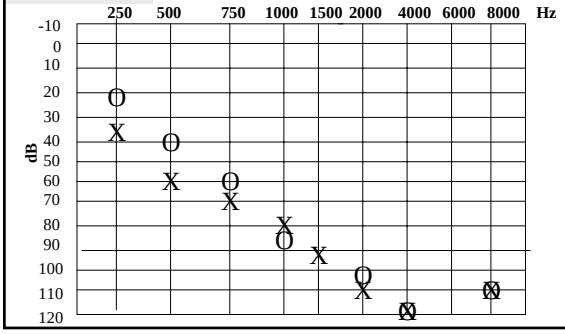
86 Yr. Old Adult
PTA=103dB AS
PTA=105dB AD
CNC Words:
=0% AS =0% AD

Audiological Measurement:
CI Candidate? **YES**



56 Yr. Old Adult
PTA=83dB AS
PTA=75dB AD
CNC Words
=12% AS =16% AD

Audiological Measurement:
CI Candidate? **YES**



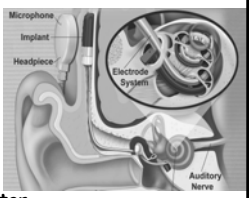
Evaluation & Expectations

Adult Evaluation: Pre-Operative

- Thorough Audiological assessment to determine degree and type of hearing loss and amount of benefit from acoustic amplification
- Include OAEs &/or Acoustic Reflex Testing
- Medical work up, including CT scan or MRI
- Counseling for realistic expectations

Cochlear Implant Surgery

- About 2.5 hours
- General anesthesia, Outpatient
- Procedure
  - Incision
  - Drill facial recess
  - Trough for electrode lead
  - Bony bed for receiver/stimulator
  - Secure receiver/stimulator with sutures
  - Cochleostomy for electrode insertion
  - Pack with fascia and close incision

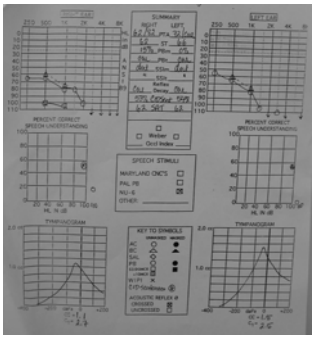


Covered by Insurance

Don't take "NO" for an answer

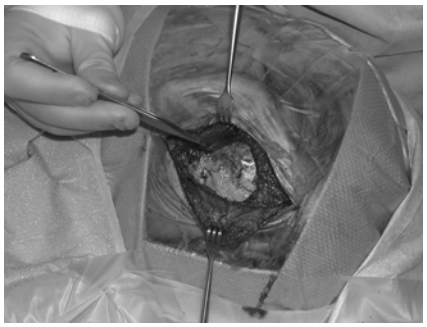
Cochlear Implant Surgery

72 year old male with progressive sensorineural hearing loss

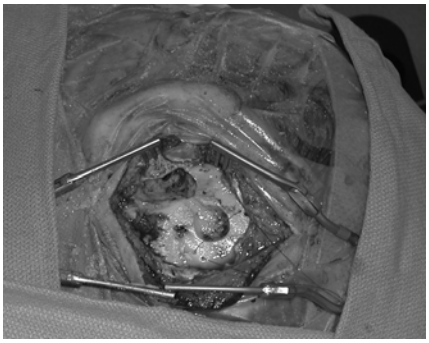


A Post-Auricular Incision

Exposure of the Mastoid Cortex

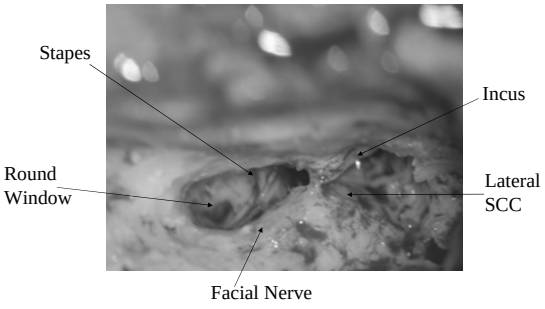


Drilling the Mastoid and Countersinking the Implant

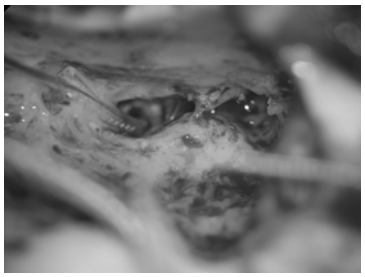


Securing the Implant

The Facial Recess



Placement of the Electrode



Complications

COMMON

- Hearing loss - in everyone
  - New techniques to reduce HL
- Variable outcomes
- Chorda tympani nerve injury

UNCOMMON

- Infections - uncommon
- Flap necrosis - uncommon
- Tinnitus & Imbalance - usually self limited
- Facial nerve injury - congenital abnormality
- MENINGITIS - a problem of mythic proportions

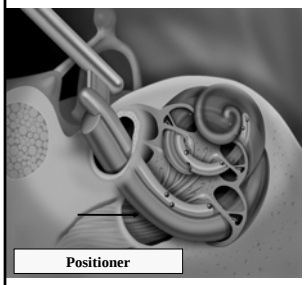
Risk factors for meningitis

Inner Ear Malformations
Prior history of meningitis
Young children (esp.< 5 yrs).
Otitis media
Immune dysfunction
Prior ear surgery

Meningitis in Cochlear Implantation

- 91 people worldwide (N=60,000)
- 17 deaths
- 53 US cases (N= 25,000)
  - Ages 18 mos to 84 yrs; Most under 7 years of age (n=33)
  - Signs and Sx <24hrs to >6 yrs
  - 50% developed meningitis < 1 year postop (N=32)
  - 29 Advanced Bionics CLARION (1996;N=7500)
  - 22 Cochlear Nucleus (1985; N=16,500)
  - 2 MED-EL (2001; N=770)

Design Flaws?



- Higher incidence with Clarion positioner
- Removed from the market
- HF1 electrode now available without the positioner

Post-Operative Evaluations: Device Fitting and Follow-up

- Initial stimulation: 3-6 weeks post surgery
- Adjustments made regularly based on feedback from patients, parents, therapists and educators
- Speech perception evaluations semi-annually to annually

Evolution of Implant Outcomes

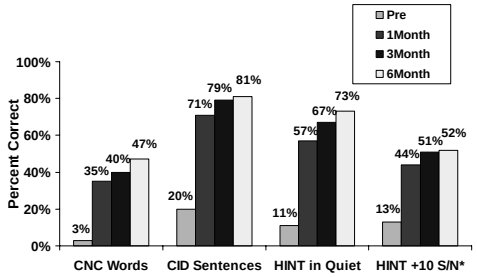
- Single-channel implants
  - Sound detection, perception of speech rhythm, lipreading enhancement
- First generation multichannel implants
  - Closed-set word identification, some open-set sentence recognition; poor open-set word recognition

Current Expectations

- Sound Field thresholds 20-45dB @ 250-6K Hz
- Cannot return to Hearing Aid in implanted ear
- >80% Postlingual Adults use the telephone
- >50% of Postlingual Adults enjoy music
- Near peak performance by 3 months!

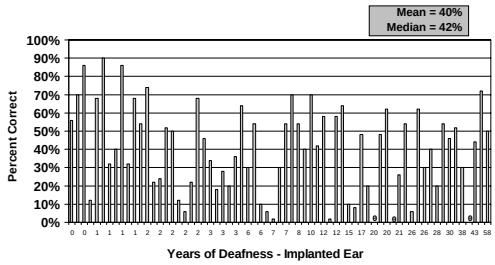
Open-Set Speech Recognition

N=56 Postlinguistic Patients
Six-Month Scores



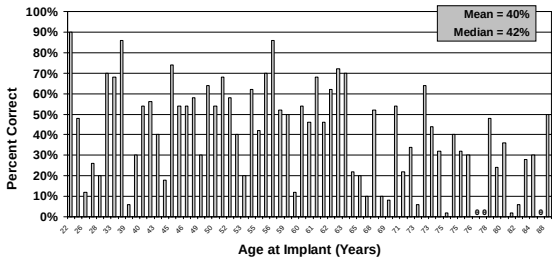
* Note: Only patients who score ≥ 20% on HINT Sentences in quiet are administered HINT Sentences in noise.

Individual CNC Word Scores at 3 Months and Duration of Deafness (n= 67)



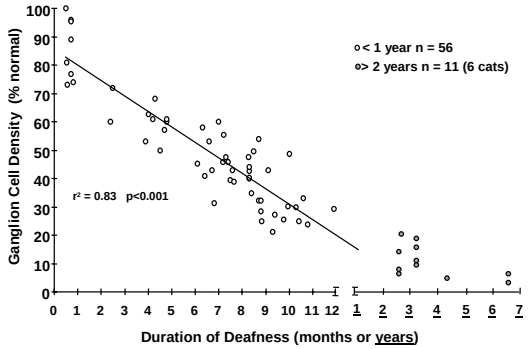
High levels of CNC word recognition were achieved by patients with long as well as short duration of deafness.

Individual CNC Word Scores at 3 Months and Age at Implant (n=67)



31% of the sample was implanted at > 70 years of age. Some of these older patients show high levels of word recognition at three months. Others may require more implant experience before they demonstrate open-set word recognition abilities.

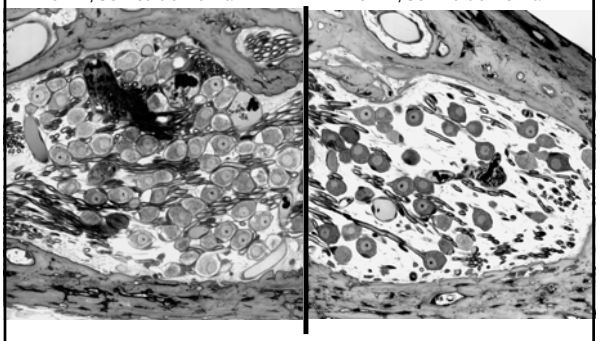
SPIRAL GANGLION CELL DEGENERATION FOLLOWING NEONATAL DEAFNESS



Slide from Pat Leake, UCSF

K117 L, GM1 Stimulated:
5 mm, SG = 80% of normal

K117R, GM1 Deafened Control:
5 mm, SG = 40% of normal

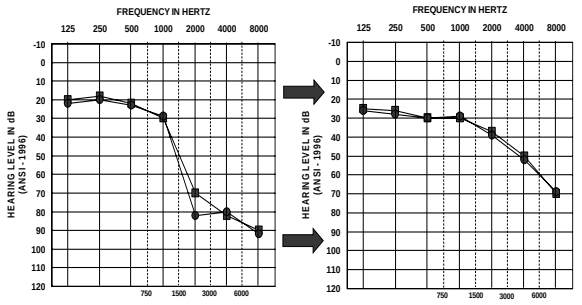


Slide from Pat Leake, UCSF

Why Research Cochlear Implant Alternatives?

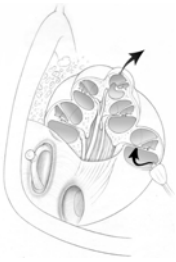
- Outcomes with a cochlear implant are good… but not as good as normal hearing
- Cochlear implants can not be used for mild or moderate levels of hearing loss

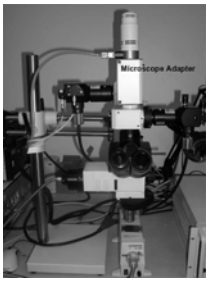
Pie in the Sky?



Modulation of Cochlear Mechanics

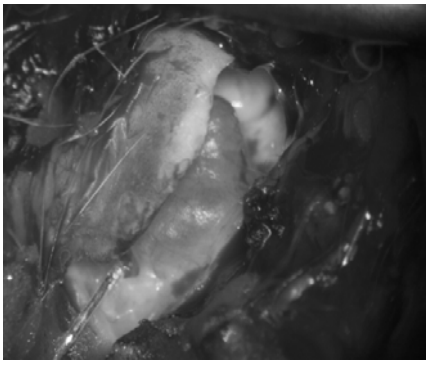
- Drug therapy
- Gene therapy
- Physical manipulations



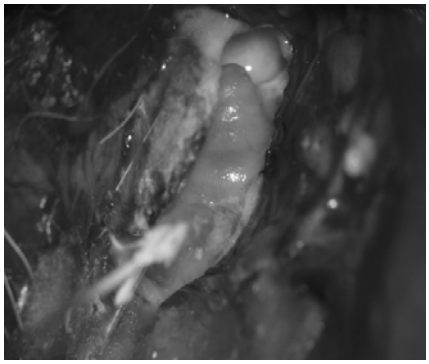


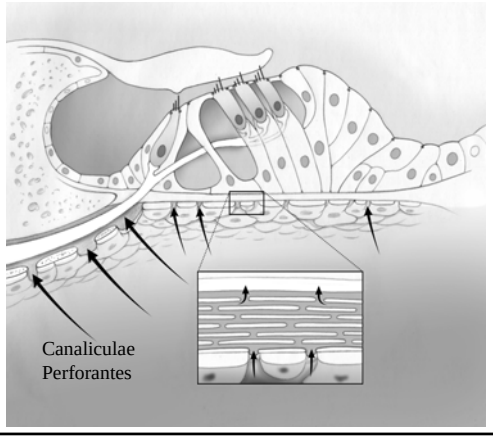
1) Measure *hearing* with various cochlear potentials (CAP, DPOAES, CM, & EP)
2) Measure *basilar membrane motion* using laser doppler vibrometer (2 picometer sensitivity)

Ventral Exposure of the Guinea Pig Cochlea



Perfusion Technique





Research Implications:

Developing a Treatment for Cochlear Hearing Loss

- Techniques for performing surgery of the inner ear
- Potential surgical objectives:
  - **Change mass, stiffness, or damping of organ of Corti**
    - **Laser**
    - **Physical manipulations**
  - **Drug therapy**
    - **Modulate outer hair cell electromotility**
    - **Modulate stereociliary transduction**
  - **Genetic manipulations:**
    - **Insert exogenous motor proteins (prestin)**
    - **Modulate tectorial membrane passive mechanics**
  - **Electronic device implantation (bionic OHC's)**

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