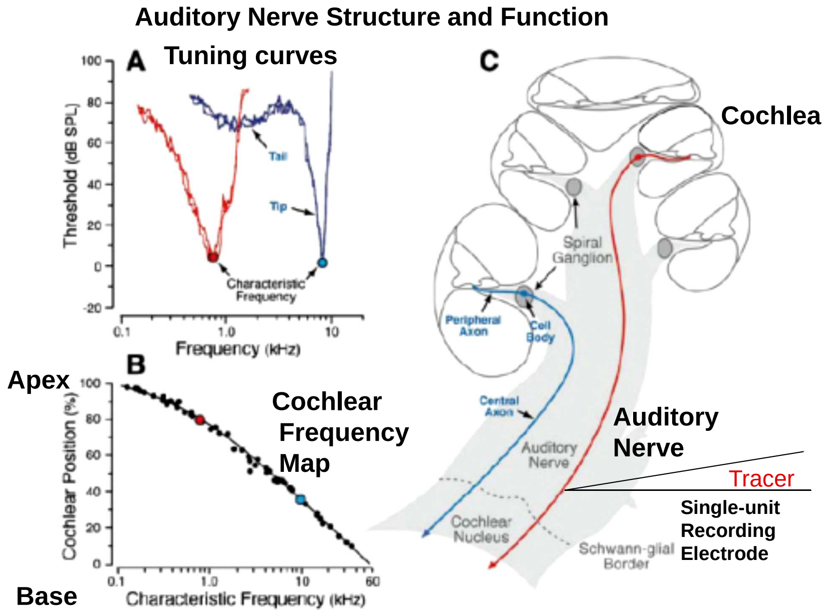
# Psychoacoustics of hearing impairment

# What do we know about physiological reflections of sensori-neural hearing loss?

- focus on hair cell damage






slide courtesy of Chris Brown, Mass Eye & Ear

Liberman (1982)

# Outer Hair Cells are relatively vulnerable to damage, leading to ...

- Decreases in basilar membrane movement and hence increased thresholds to sound
  –
- A loss of cochlear compression (a *linearised* input/output function)
  –
  –
- Loss of frequency tuning (analogous to widened filters in an auditory filter bank).
  –



# Input/ Output functions on the basilar membrane near CF in an impaired ear

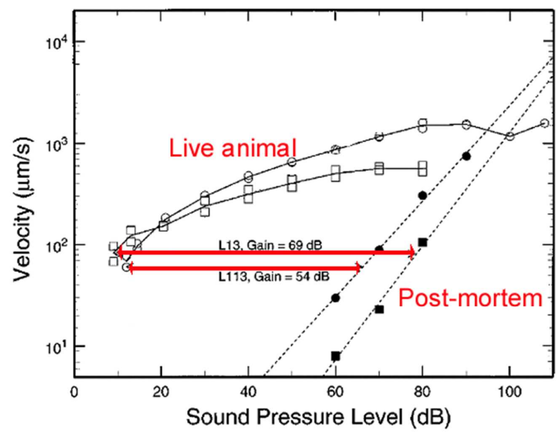
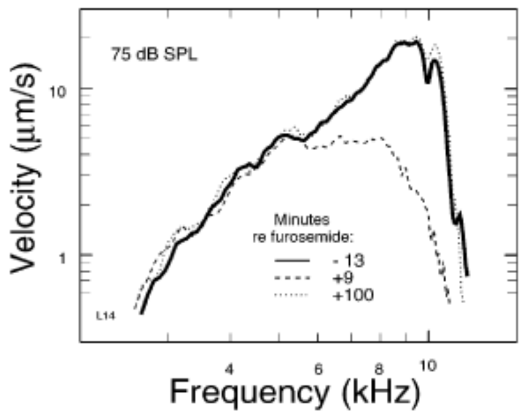



FIG. 16. Stability and vulnerability of responses to CF and near-CF tones. The open symbols depict the peak velocities of responses to CF tones (L13: squares; L113: circles) recorded in the sensitive cochleae of two live chinchillas. The filled symbols represent the CF responses recorded immediately after (within minutes of) death. Responses to CF tones in both cochleae were measured both early in the experiment and 160–240 min later.

# Frequency response of a single place on the BM in an impaired ear (furosemide)




Ruggero and Rich (1991)



# Inner Hair Cell (IHC) damage ...

- Leads to a more sparse representation of *all* auditory information passed on to higher auditory centres.
- There are possibly even regions of the cochlea without any IHCs — so-called *dead regions*.
- Hence, there may be a degradation of a wide variety of auditory abilities *(e.g*. temporal resolution).



# Relation of Hair Cell loss to audiogram

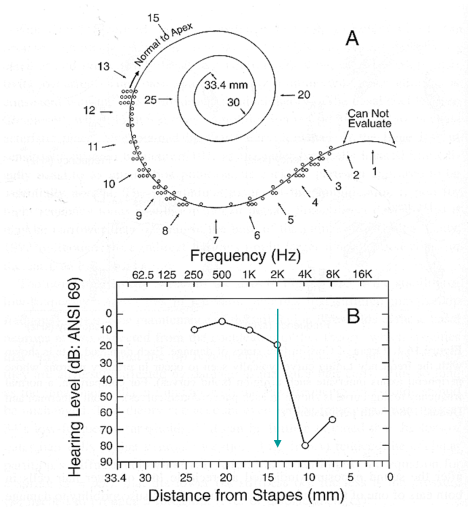
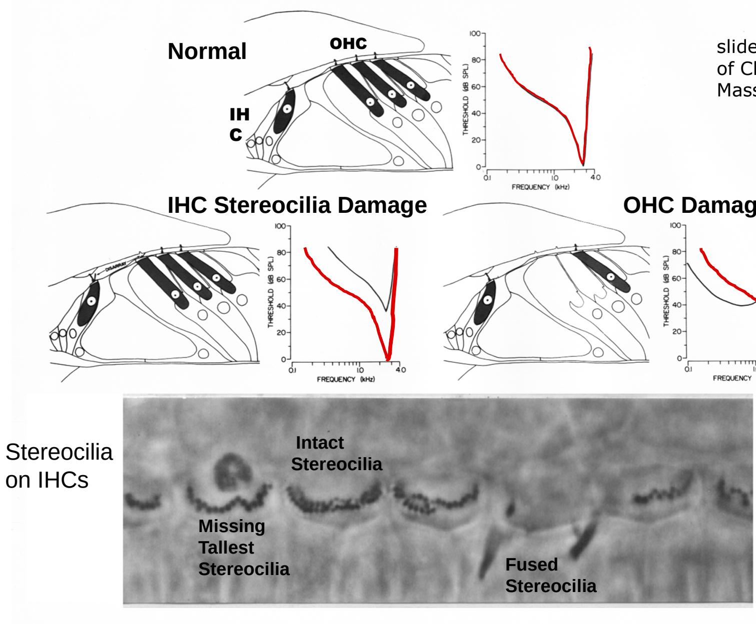



**Figure 16.5.** Comparison of cochlear pathology with the audiogram of a human patient. *A.* Patient's cytocochleogram, showing in pictorial form the hair cells (circles) remaining in each of the four rows of hair cells, regardless of their condition, plotted as a function of distance from the stapes. Note the extensive hair cell loss in the most basal 12 mm. *B.* Patient's audiogram, showing a profound hearing loss above 2 kHz (top scale of abscissa). The apical border of the extensive hair cell loss corresponds well with the 3 kHz place on the characteristic-frequency/location map for primary auditory neurons in humans (bottom scale of abscissa). (From Schuknect, 1993, with permission.*)



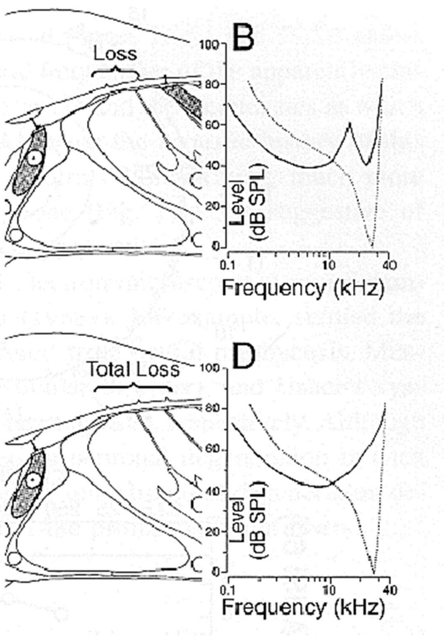
## Auditory Nerve Fiber Responses From Damaged Cochleas



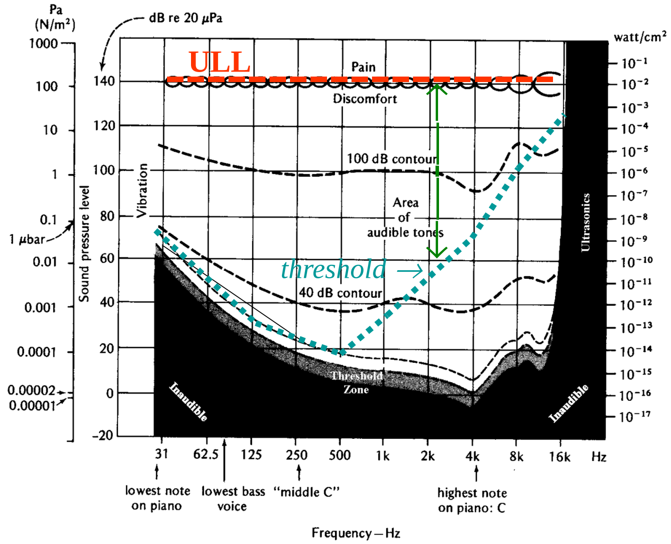

slide courtesy of Chris Brown, Mass Eye & Ear

Liberman and Kiang (1978)
Liberman and Beil (1979)
Liberman and Dodds (1984)

Effects of OHC damage and total loss on tuning in the auditory nerve




# An *auditory area* in sensori-neural loss






Recruitment requires compression as well as amplification to maximize audibility

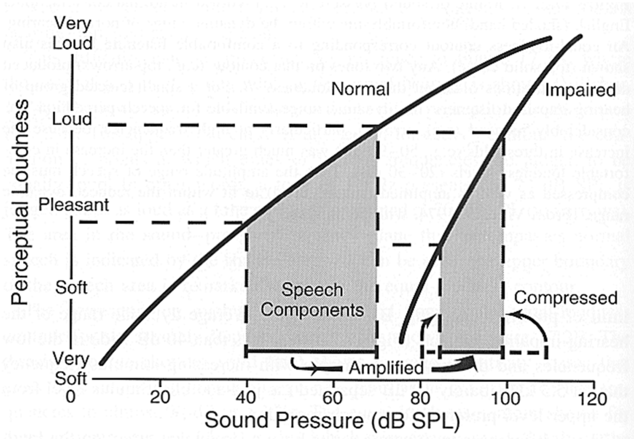
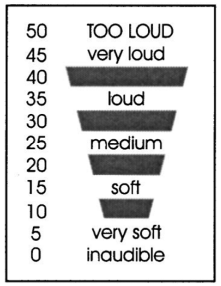



**Figure 17.3.** Idealized relations between sound pressure and perceptual loudness for subjects with normal hearing (left curve) and those with severely impaired hearing (right curve) for a representative band of frequencies (e.g., around 2 kHz). To produce the same levels of subjective loudness as those experienced by normally hearing listeners, speech for the hearing impaired must be both amplified *and* compressed. (Adapted from Pluvinage, 1994.)



# Categorical scaling of loudness ACALOS (adaptive categorical loudness scaling)




ACALOS category scale. Subjects do not see the numbers.
Brand and Hohmann (2002) JASA 112, 1597-1604

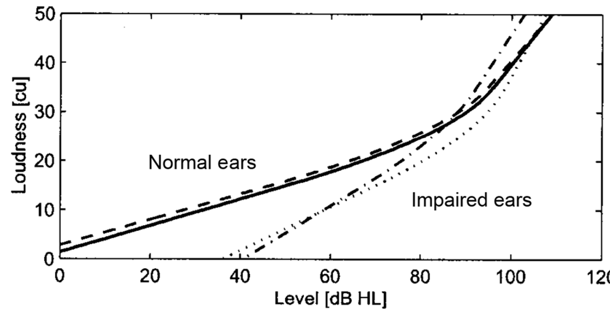
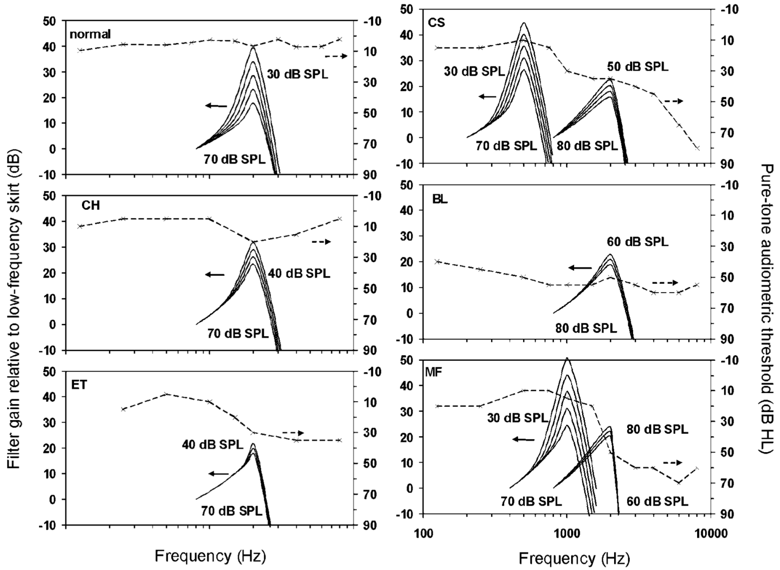



FIG. 5. Loudness functions with the median parameters displayed in Table I. Normal-hearing subjects with adaptive procedure (solid), normal-hearing subjects with constant stimuli procedure (dashed), subjects with hearing impairment with adaptive procedure (dotted), subjects with hearing impairment with constant stimuli procedure (dash-dotted).

## Changes in frequency selectivity reflect loss of nonlinearity
Rosen & Baker (2002)



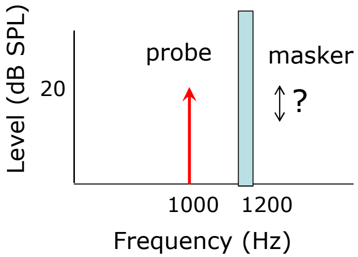


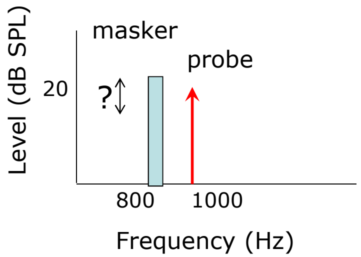

# ‘Dead’ regions

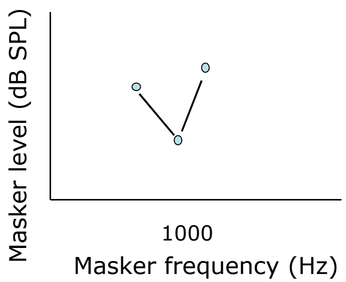
- Regions in the inner ear with absent or non-functioning inner hair cells (IHCs)
- No BM vibrations in such regions are directly sensed
- But spread of BM vibration means that tones can be detected ‘off-place’
  - by auditory nerve fibres typically sensitive to a different frequency region
- Most clearly seen when measuring PTCs
  - directly interpretable



# Psychophysical tuning curves (PTCs)

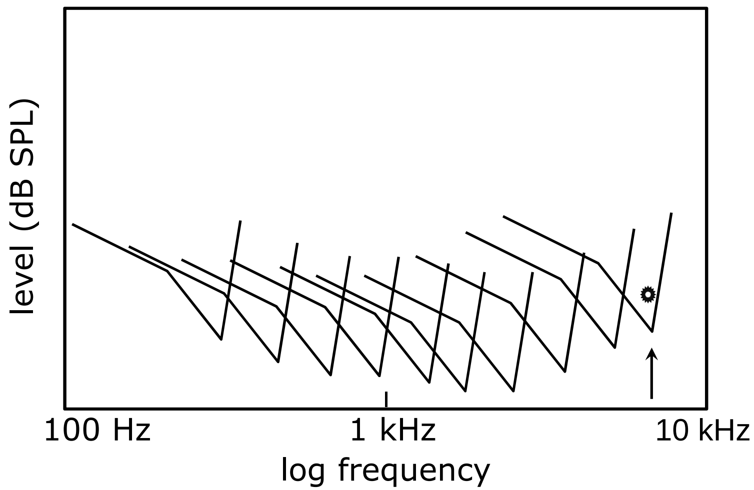


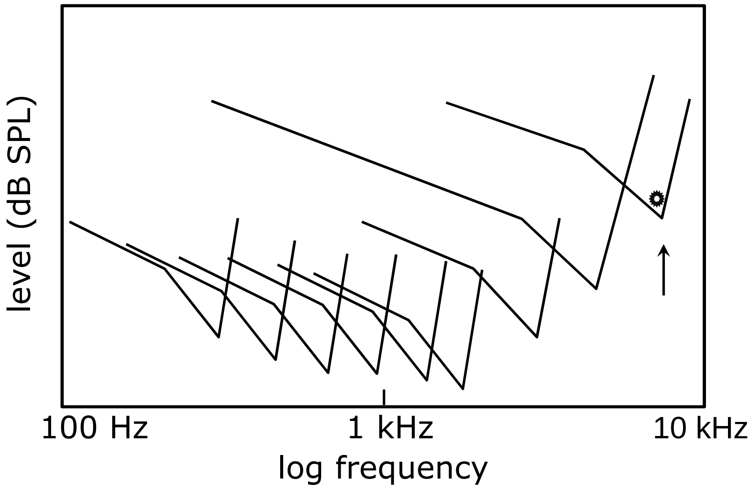




*Determine the minimum level of a narrow-band masker at a wide variety of frequencies that will just mask a fixed **low-level** sinusoidal probe.*

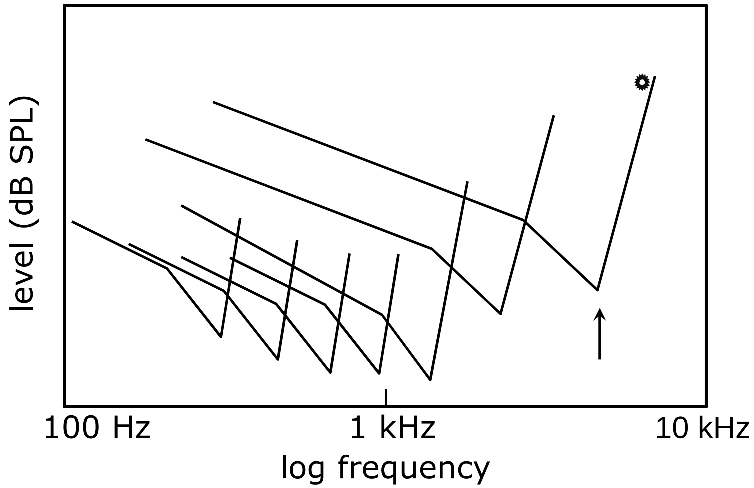
# Physiological TCs for a range of auditory nerve fibres: Normal hearing

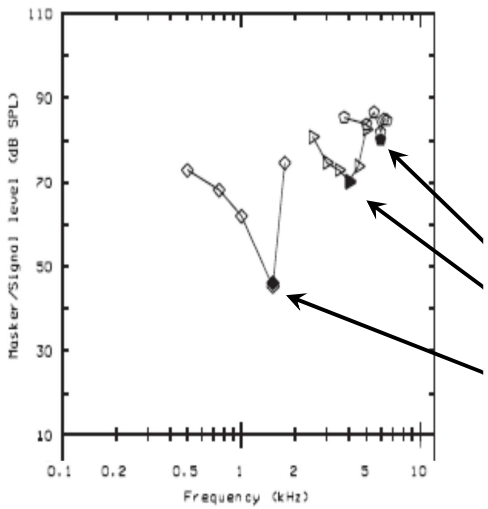


# Hearing loss *without* a dead region

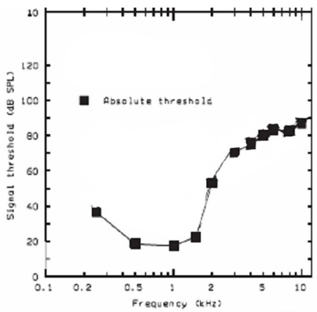



# Hearing loss *with* a dead region

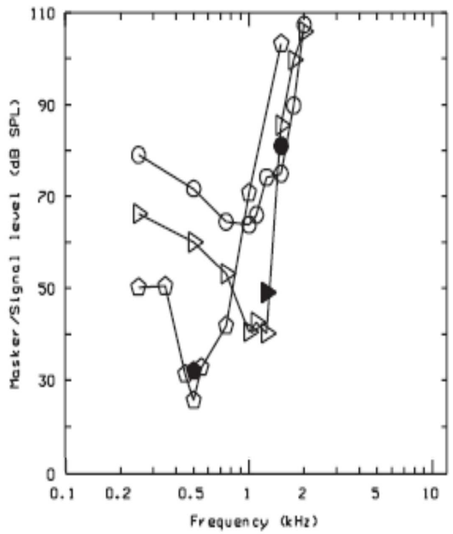


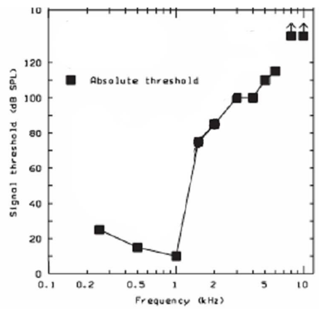

SNHL without dead region: PTCs





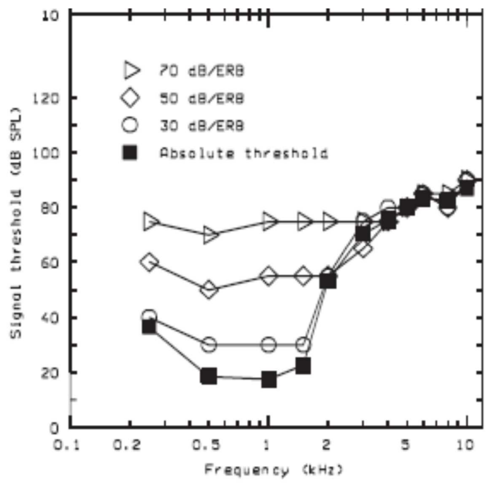

SNHL with dead region: PTCs



# Diagnosing dead regions

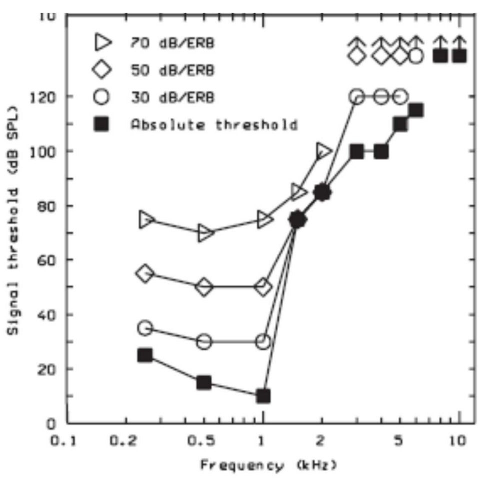
- PTCs perhaps clinically impractical
- TEN test (threshold equalizing noise)
  - a broad band noise designed to produce approximately equal masked thresholds over a wide frequency range
- Rationale
  - a tone within a dead region is detected with neurons whose CF is remote from the tone frequency …
  - so amplitude of BM in the remote region smaller than in the dead region …
  - so broad-band noise more effective, as it need only mask the reduced response at the remote place






SNHL without dead region: TEN test






SNHL with dead region: TEN test



# What can current hearing aids do for ...

- Hearing loss
  - 
- Reduced dynamic range & loudness recruitment
  - 
- Degraded frequency selectivity
  - 
- Dead regions
  - 