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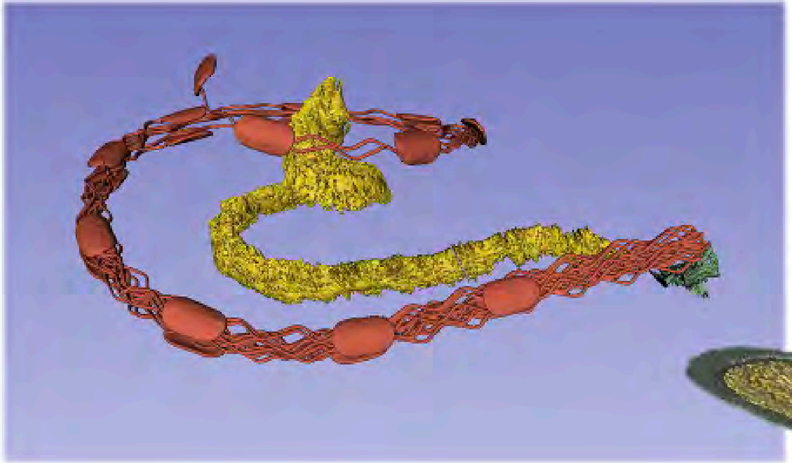
Move over Mickey Mouse™

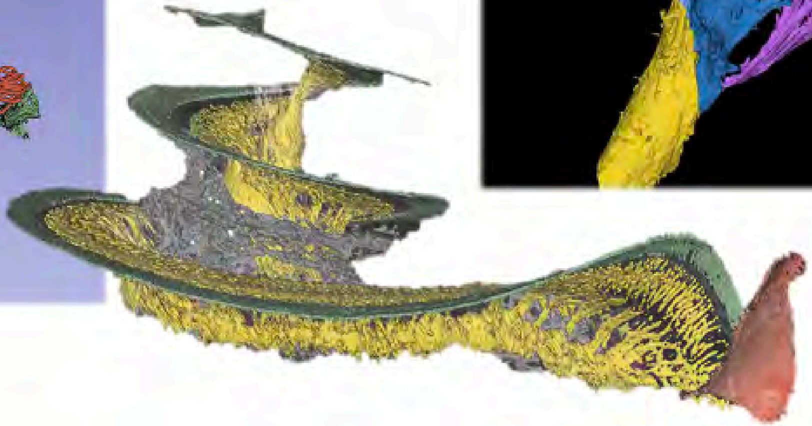
Turning the tables on what you know about CI sound quality

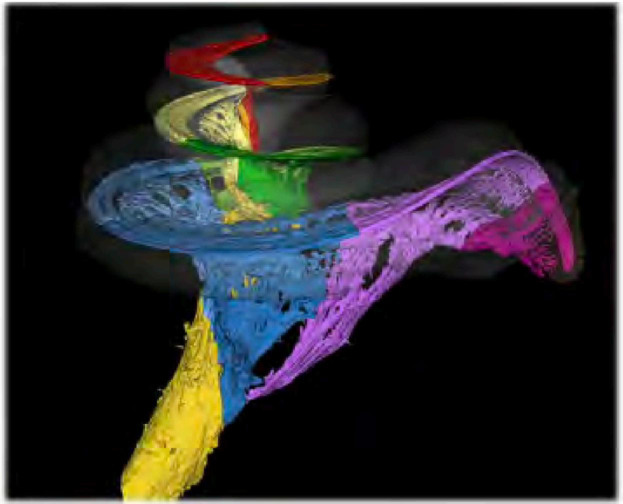
Josh Stohl, PhD

Director – North American Research Laboratory

MED-EL's key design principles

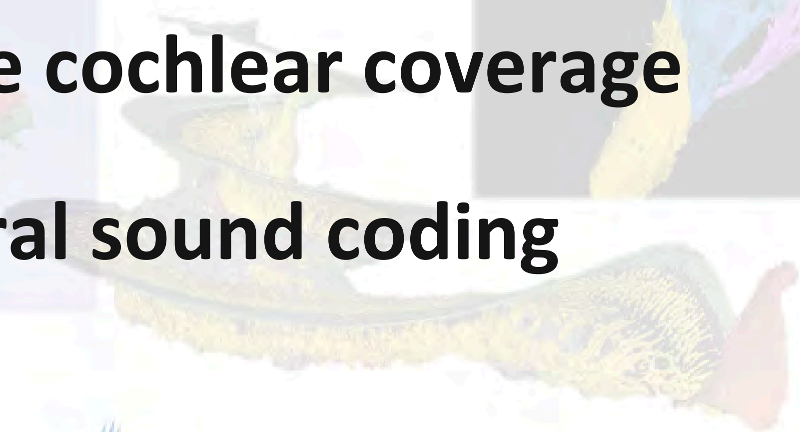






Images provided by Hanif Ladak and Luke Helpard

MED-EL’s key design principles



Atraumatic electrode arrays

Complete cochlear coverage

Natural sound coding

Images provided by Hanif Ladak and Luke Helpard

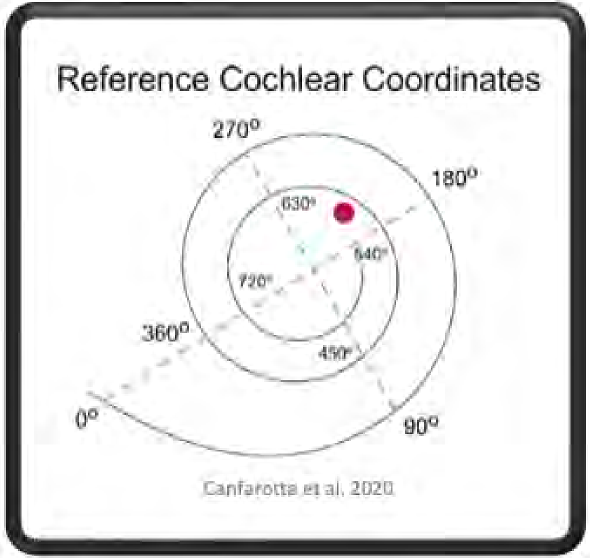
Voice of the CI

Learning from SSD CI users

- Dorman et al. had single-sided deaf (SSD) cochlear implant (CI) users listen to acoustic simulations of CIs to better understand device sound quality

- 17-year-old patient with 2 years device experience
- FLEX28 with angular insertion depth of 580 degrees
- Programmed with FS4-p

- Electrode 1 deactivated to simulate an angular insertion depth of 461 degrees



Original → 580 degrees 10/10 match → 461 degrees 10/10 match

Voice of the CI

Learning from SSD CI users

TABLE 1 | Selected biographical data for patients.

Subject ID	Age at time of test 1 (years)	Duration deaf (years)	Insertion Depth (degrees)
1	38	1.7	409
2	26	2.7	387
3	49	3.5	419
4	40	0.22	395
5	52	8.2	340

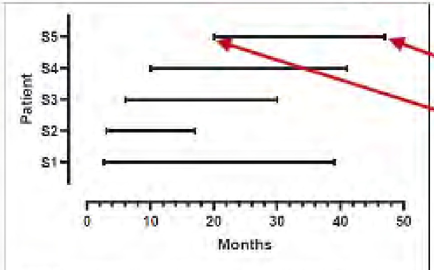
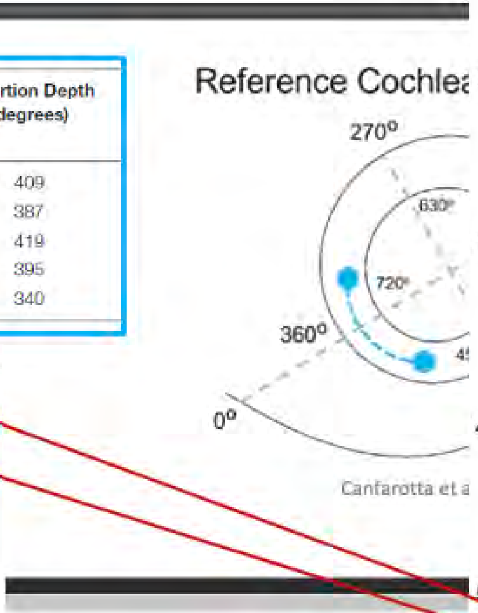
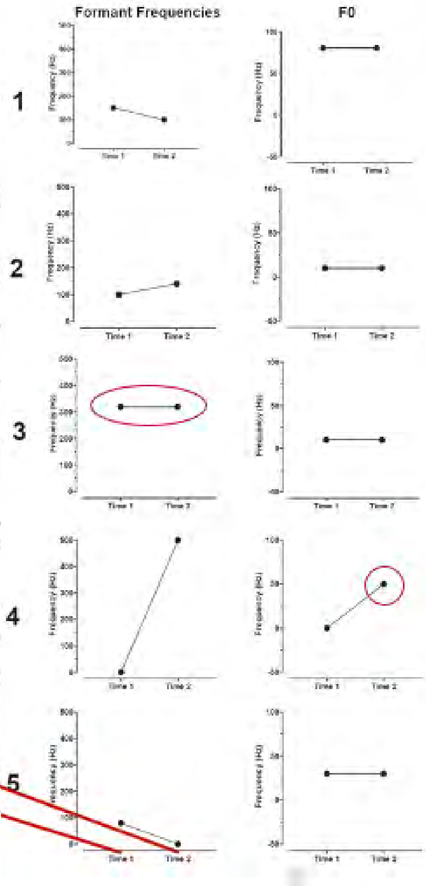


FIGURE 1 | Duration of CI listening experience at first and second test points for each patient. The beginning and endpoint of each line indicates the first and second test times, respectively.





Dorman, M. F., et al. "Upward Shifts in the Internal Representation of Frequency Can Persist Over a 3-Year Period for Cochlear Implant Patients Fit With a Relatively Short Electrode Array." Front. Hum. Neurosci. (2022)

Voice of the CI

Learning from SSD CI users

Insertion angles between 340˚ and 419˚

- Upshift in F0 pitch and speech frequencies
- Can persist for years

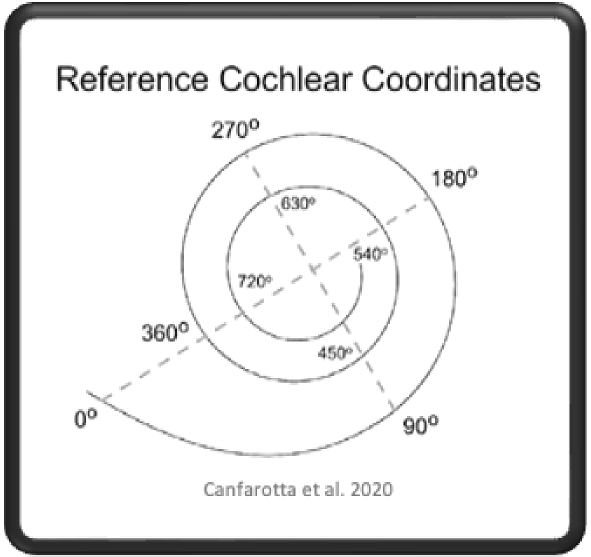
Insertion angles shallower than ~450˚

- Upshift in F0 pitch
- Upshifted speech frequency spectrum

Insertion angles greater than ~450˚

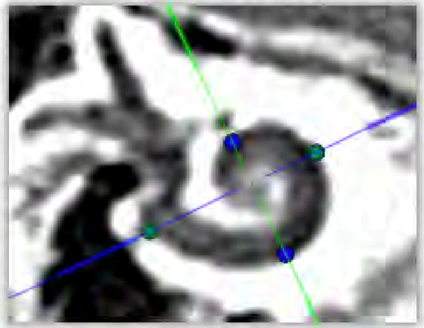
- No upshift in pitch
- No upshift in speech frequencies

Dorman et al.

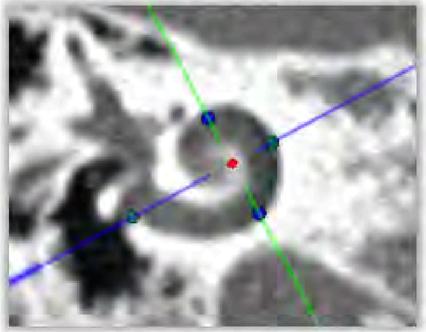


Electrode array + Cochlear duct length

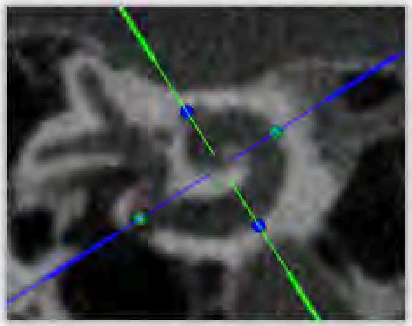
Short CDL
29.79 mm

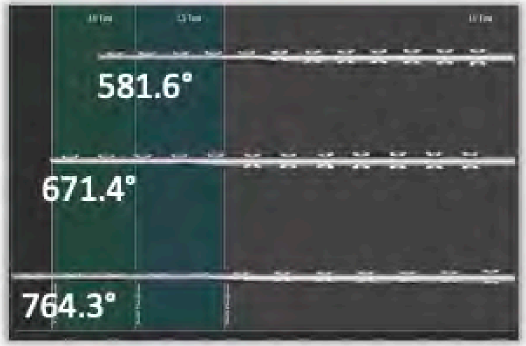


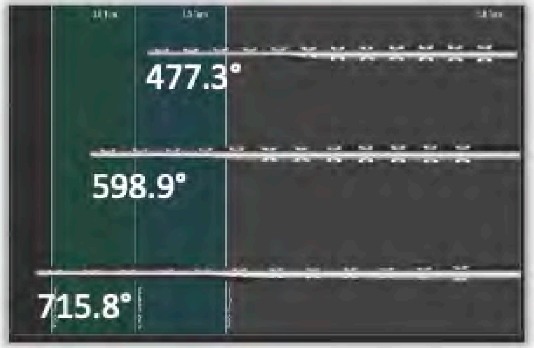
Average CDL
33.84 mm

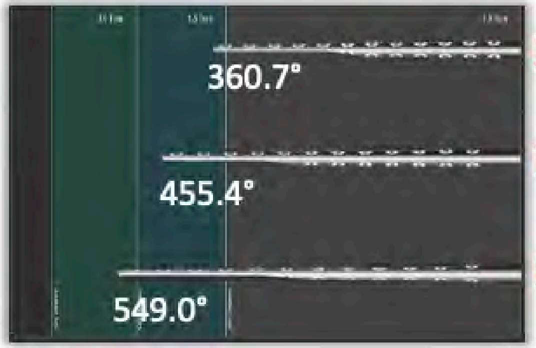


Long CDL
40.27 mm





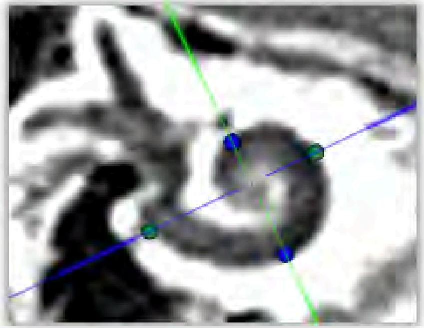


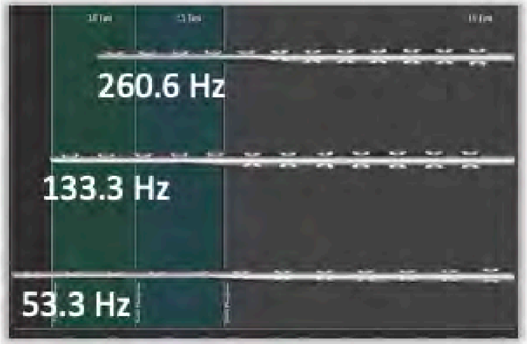


FLEX24
FLEX28
FLEXSoft

Electrode array + Cochlear duct length

Short CDL
29.79 mm





Average CDL
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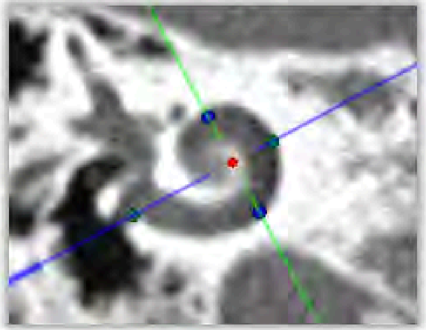

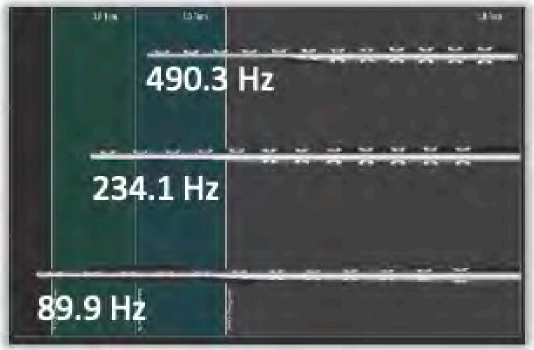

Long CDL
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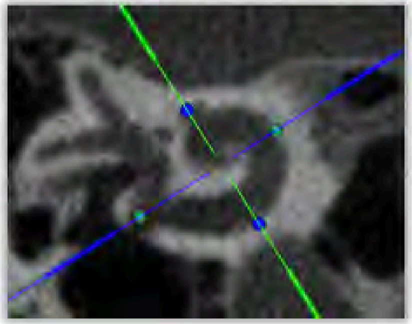
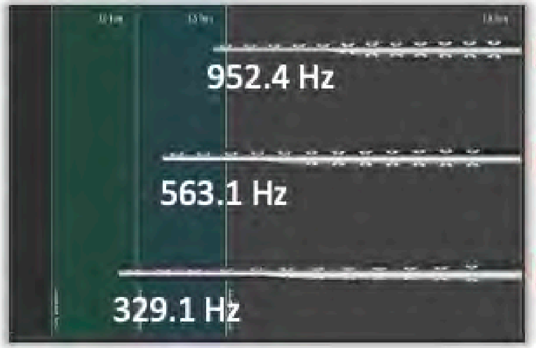




FLEX24

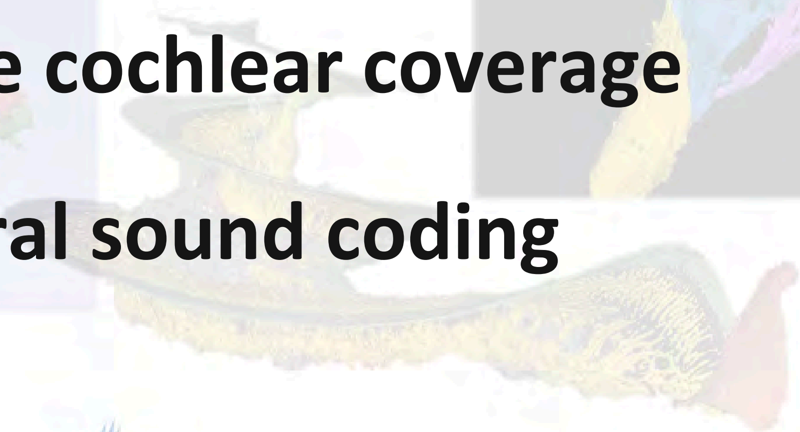
FLEX28

FLEXSoft

OTOPLAN ON DEMAND

Preoperatively assists in choosing the optimal array length based on an individual's unique cochlear duct length (CDL)

MED-EL's key design principles



Atraumatic electrode arrays

Complete cochlear coverage

Natural sound coding

Images provided by Hanif Ladak and Luke Helpard

Natural Sound Coding

MED-EL's broad design goal is to mimic the natural auditory system

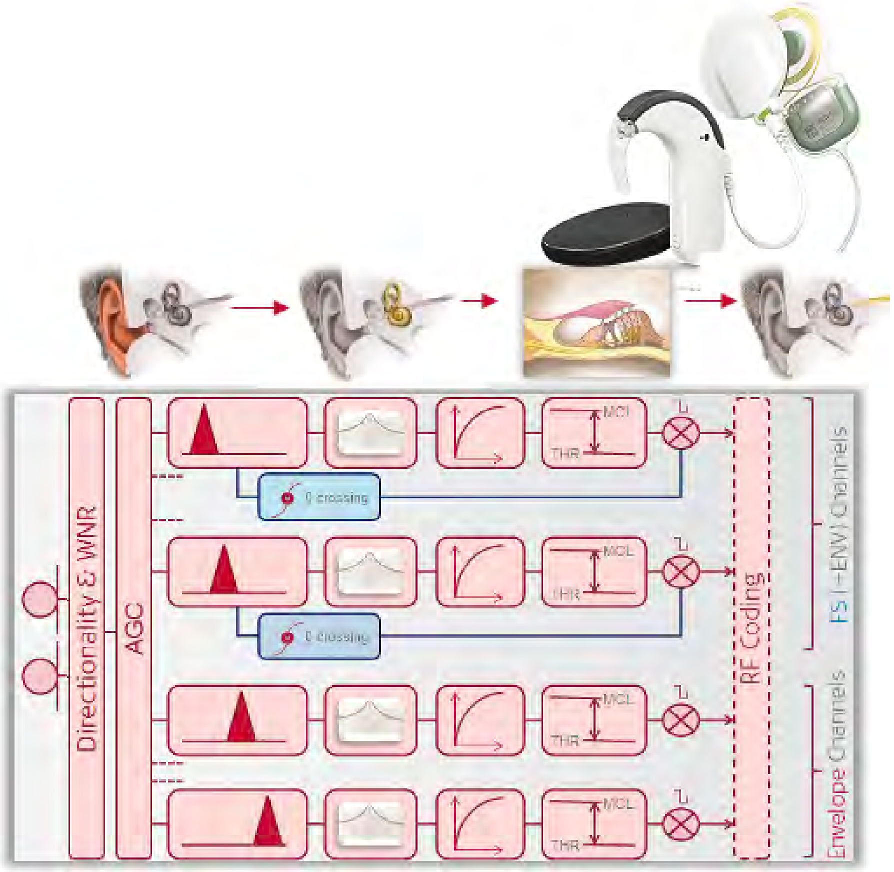
Sound to stimulation

Natural sound coding

Sound →

- Microphone(s)
- Directionality, WNR
- Automatic gain control (AGC)
- Bell-shaped bandpass filters
- Envelope extraction
- Noise reduction
- Zero-crossing detection
- Maplaw compression
- Patient-specific fitting

→ Stimulation



Sound to stimulation

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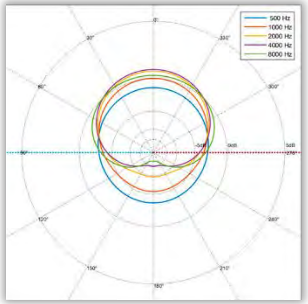
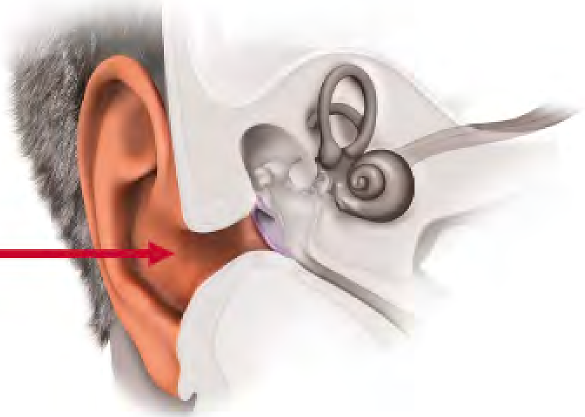
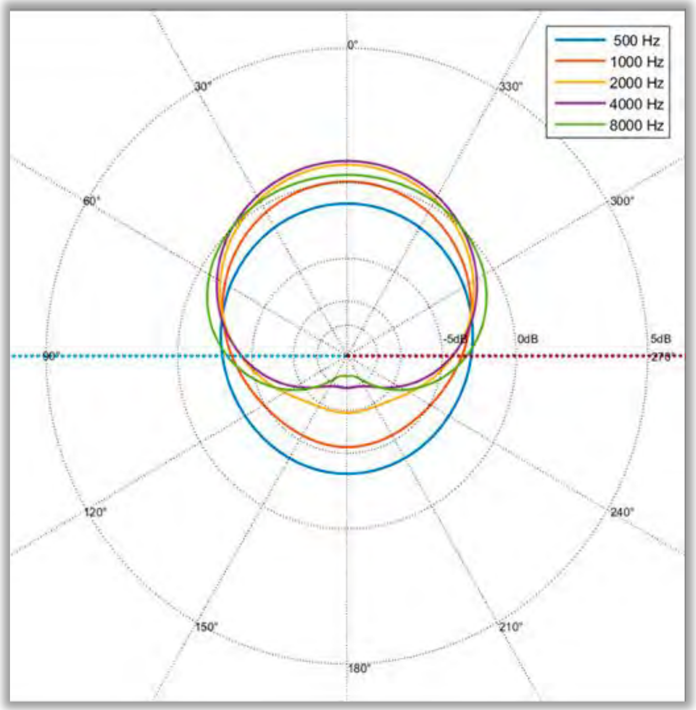
Dorman et al. (2018)





Sound to stimulation

Natural sound coding

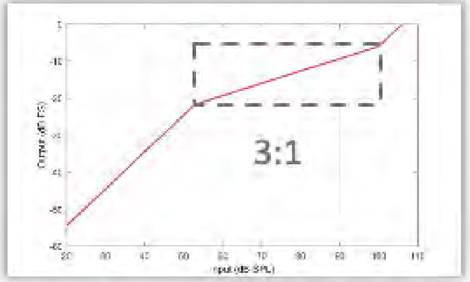


Dorman et al. (2018)

Emphasizes sounds in front of the listener

Sound to stimulation

Natural sound coding



Sound →

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- Directionality, WNR
- **Automatic gain control (AGC)**
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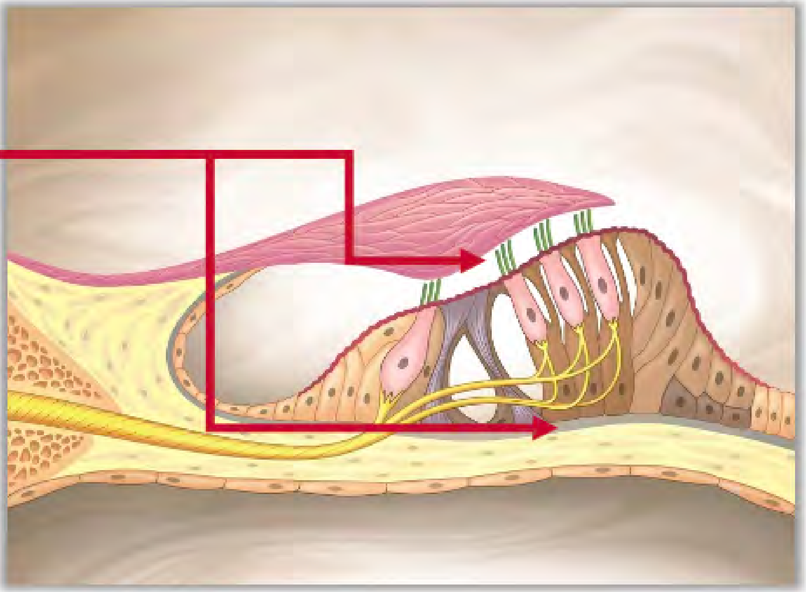
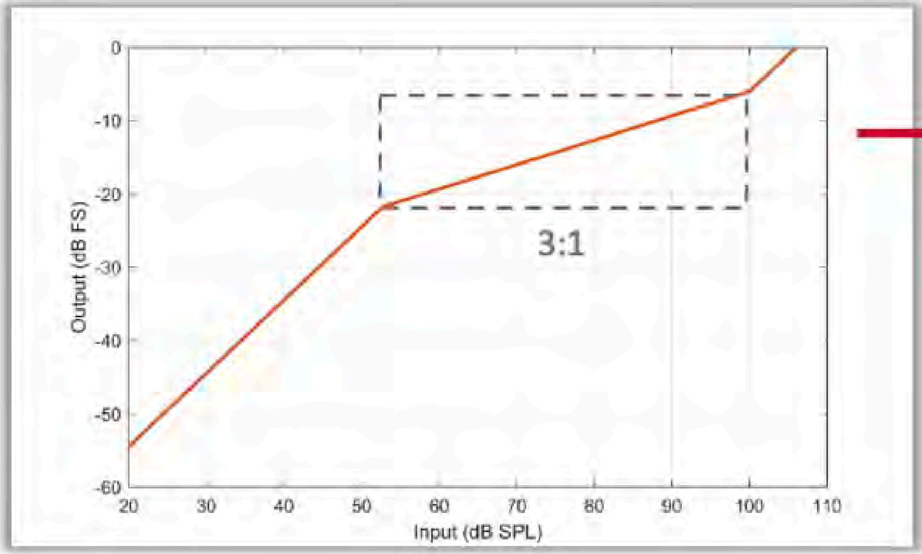
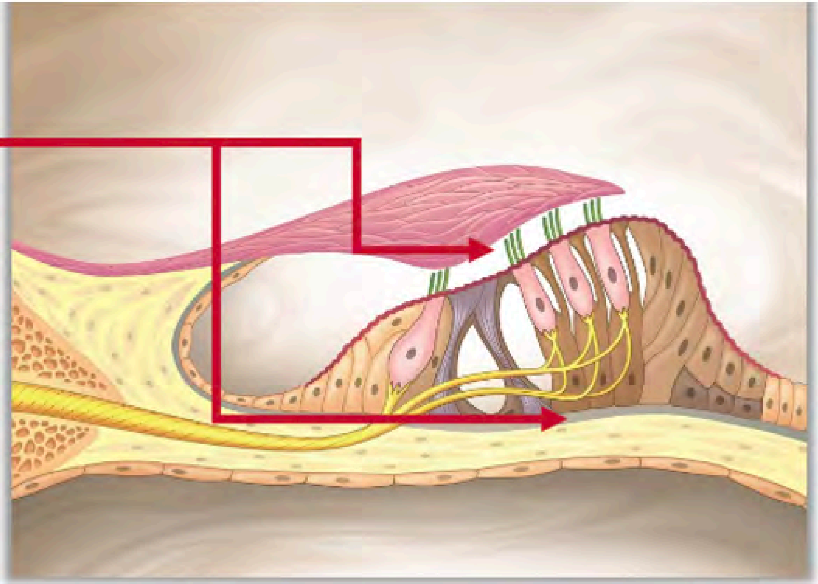


Sound to stimulation

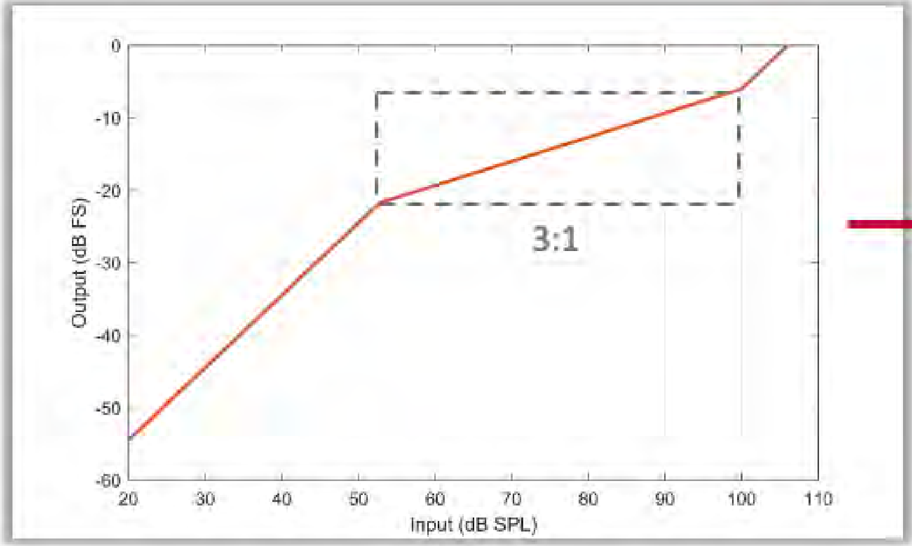
Natural sound coding

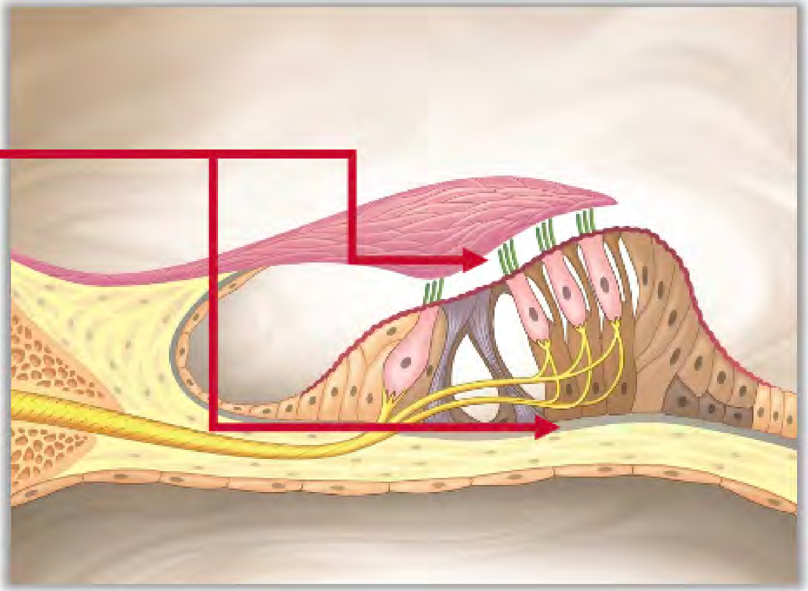




Sound to stimulation

Natural sound coding



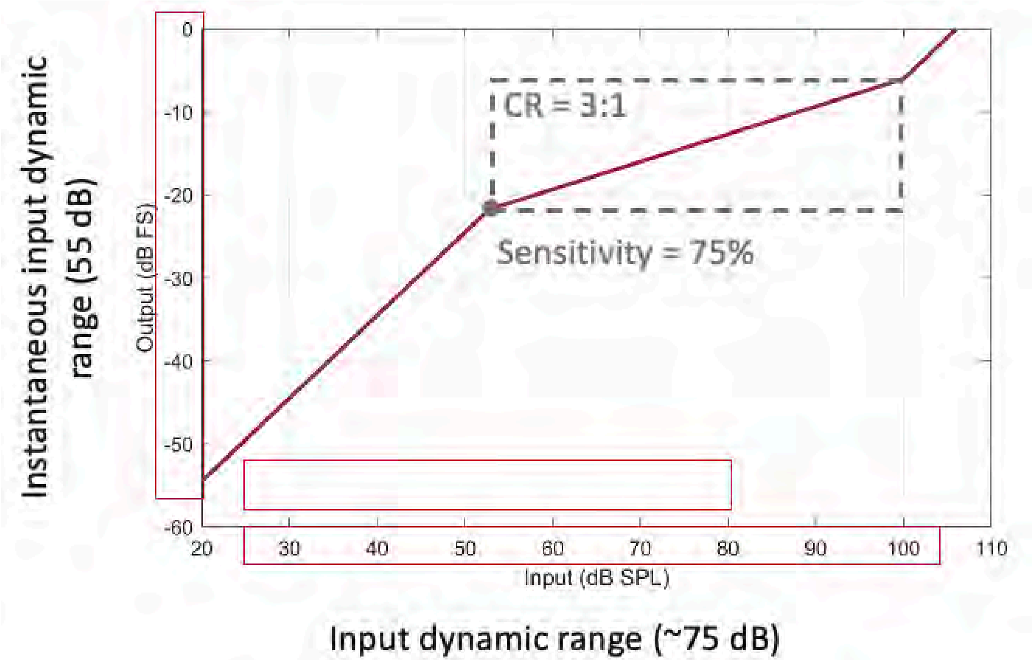


	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Compression ratio (dB/dB)	1.32	2.00	2.91	3.10	2.83	2.44

Basilar membrane compression (Plack and Oxenham, 2000)

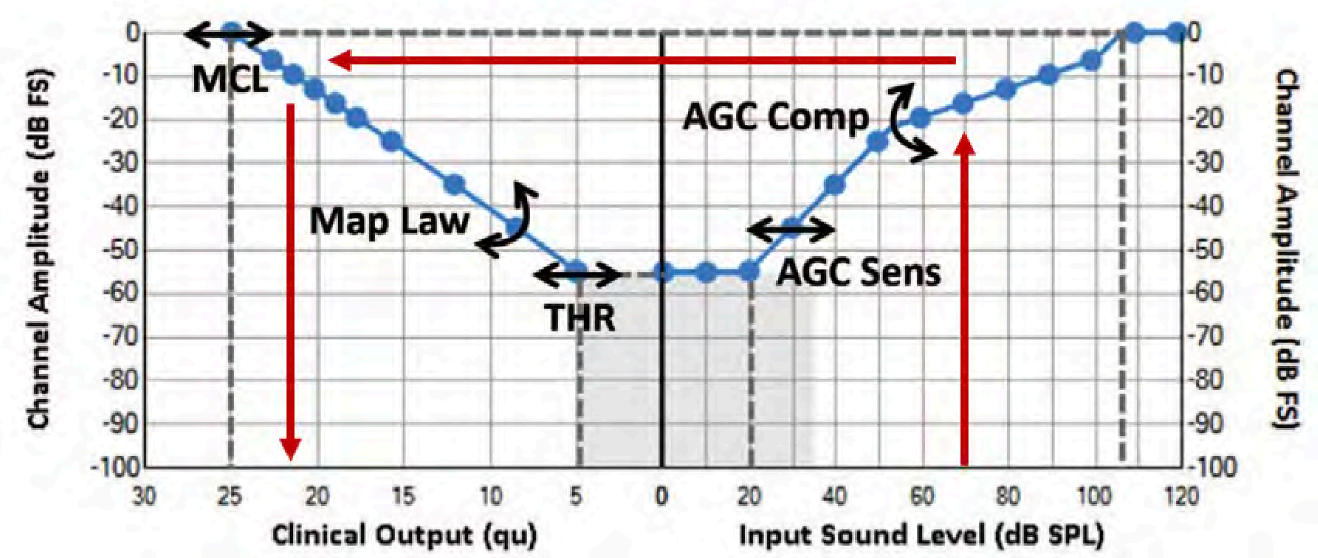
Automatic gain control (AGC)

Wide input dynamic range



Automatic gain control (AGC)

Comparing CI systems



Vaerenberg B, Govaerts PJ, Stainsby T, Nopp P, Gault A, and Gnansia D,
“A uniform graphical representation of intensity coding in current-generation cochlear implant systems,”
Ear and Hearing, vol. 35, no. 5, pp. 533–543, 2014.

Automatic gain control (AGC)

Comparing CI systems

MED-EL

- Linear up to kneepoint (Sensitivity)
- Natural compression above kneepoint (3:1)

Cochlear

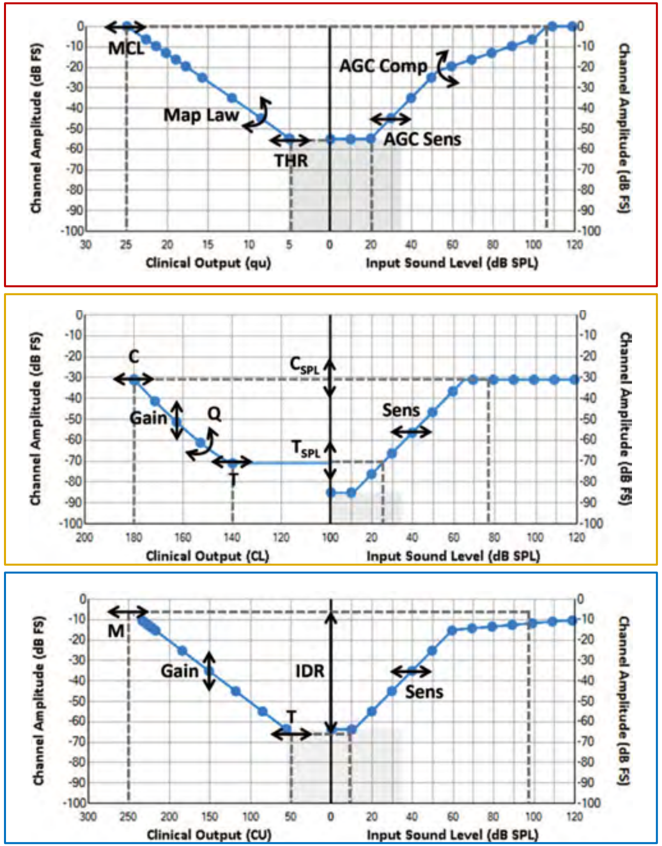
- Linear up to C-SPL
- Infinite compression/limiter at C-SPL (65 dB SPL)

Advanced Bionics

- Linear up to kneepoint (sensitivity)
- Limiting above kneepoint (12:1)

Limiting at medium levels by competitors

- Suggests focus on conversational speech
- May create asymmetric loudness growth when paired with hearing aid, (near-)normal hearing



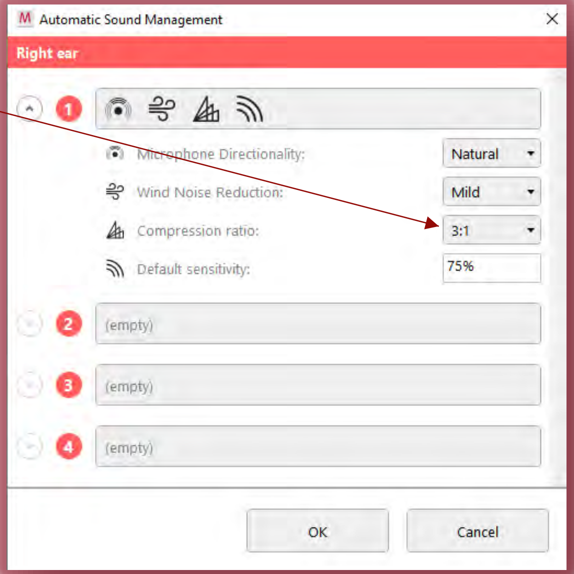
Vaerenberg et al. (2014)

Automatic Gain Control

Compression ratio can be adjusted to match hearing aid

Allows for preferred amplification solution

Matches natural compression by default (SSD)



Sound to stimulation

Natural sound coding

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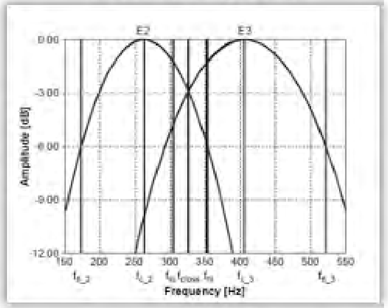
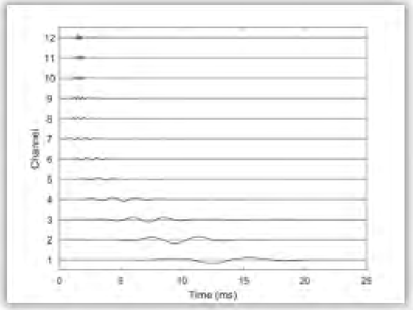
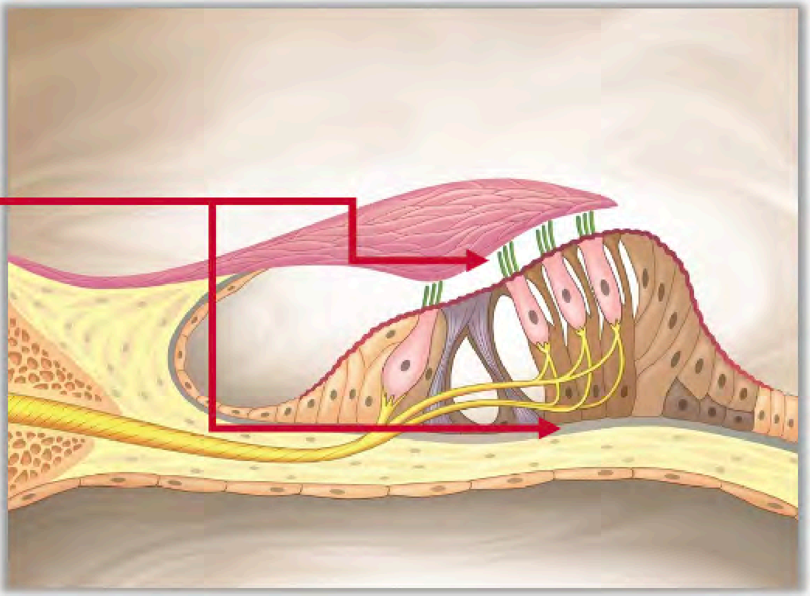
- Patient-specific fitting

→ Stimulation

Nobbe et al. (2007)



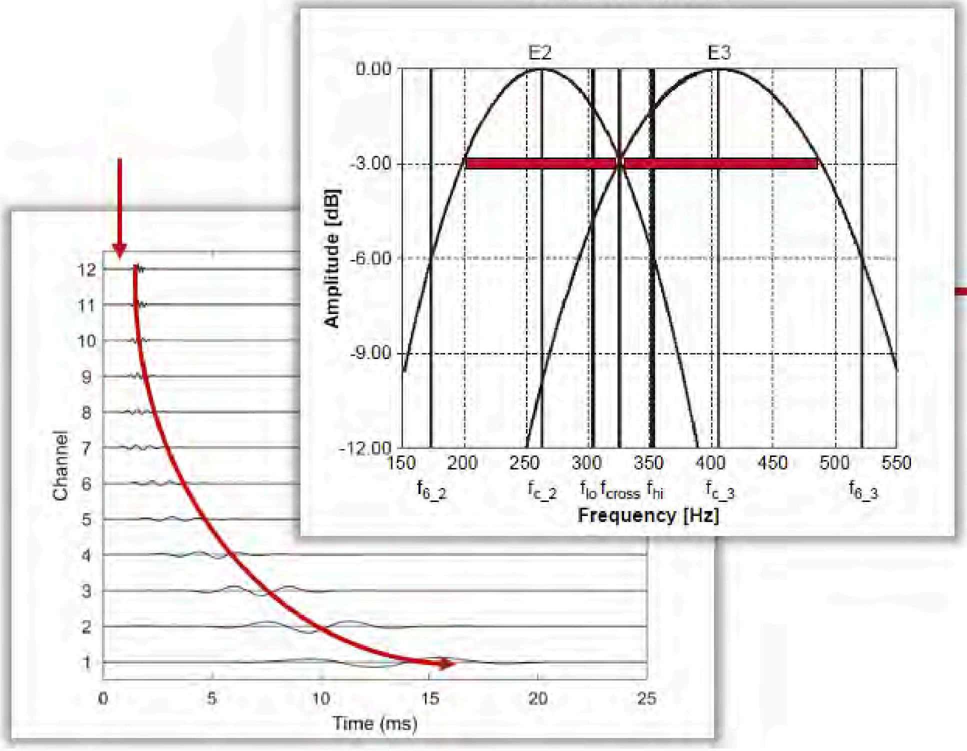




Sound to stimulation

Natural sound coding

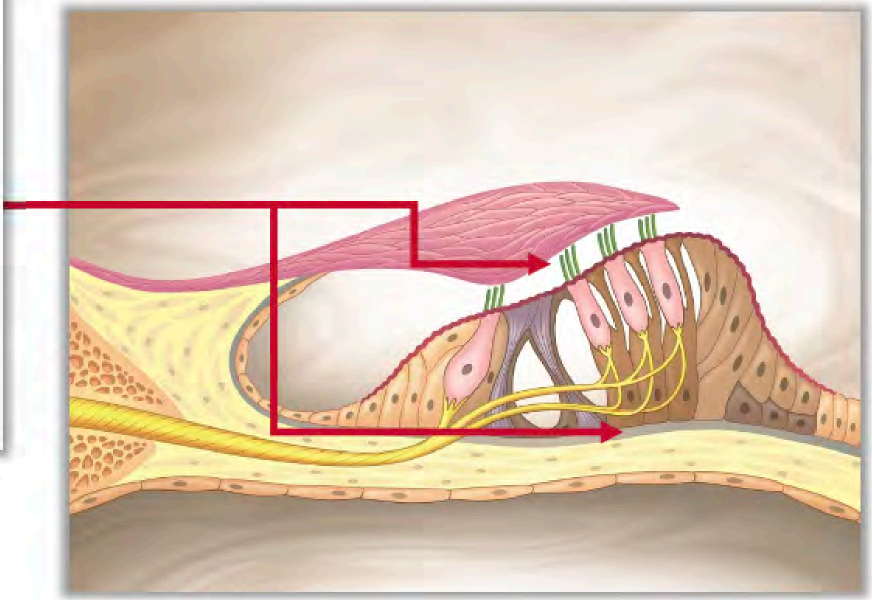
Nobbe et al. (2007)



Intermediate pitches

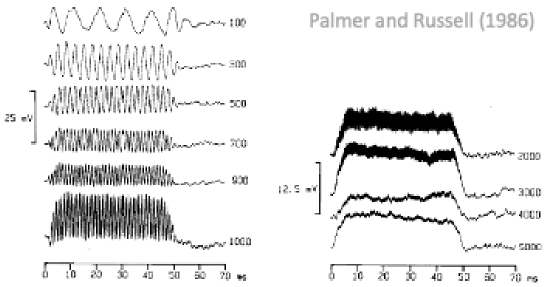
Short processing delay

Mimic traveling wave delays



Sound to stimulation

Natural sound coding



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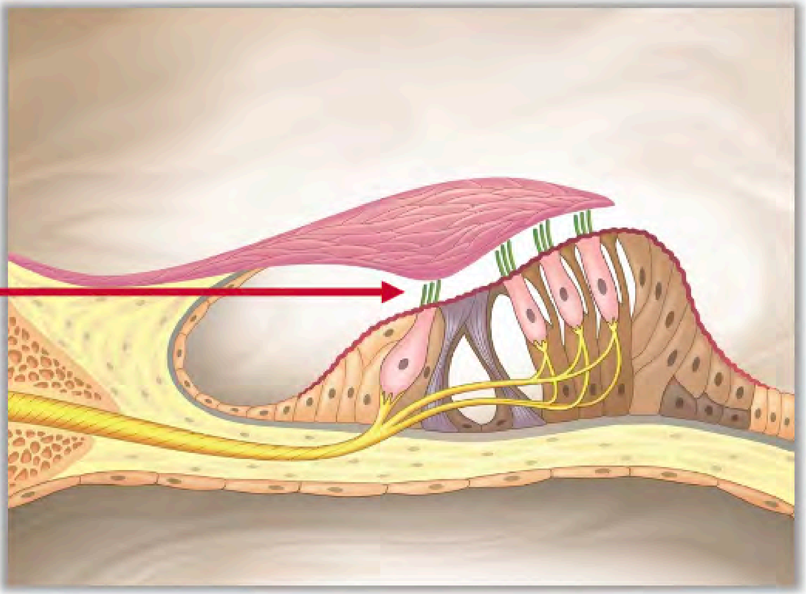
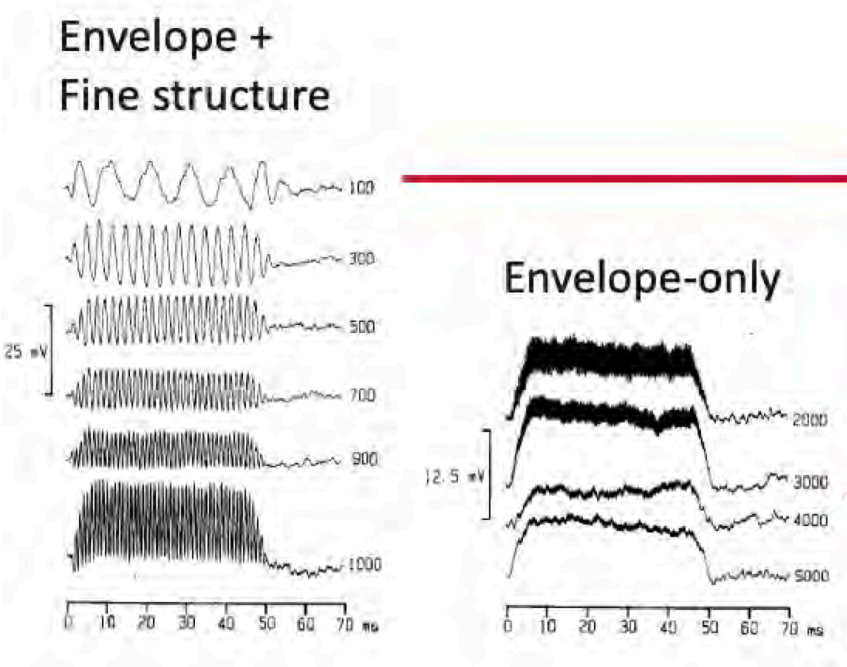
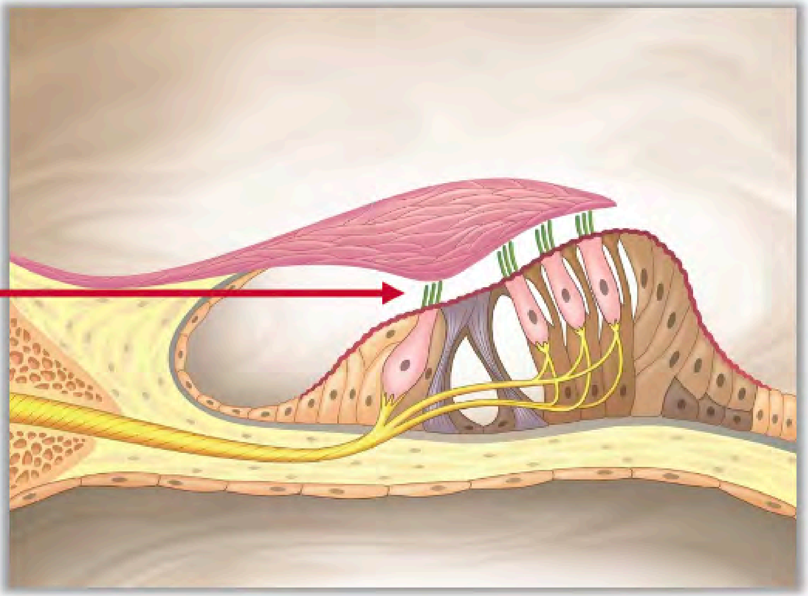


Sound to stimulation

Natural sound coding





Palmer and Russell (1986)

Sound to stimulation

Natural sound coding

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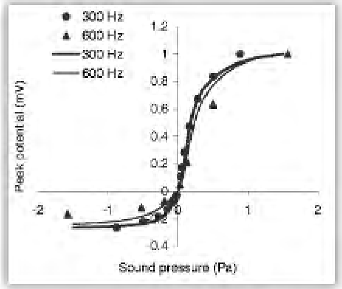
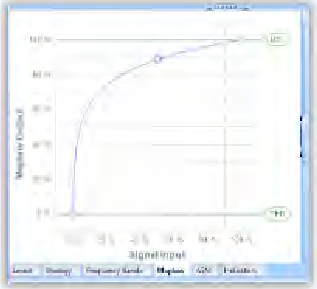
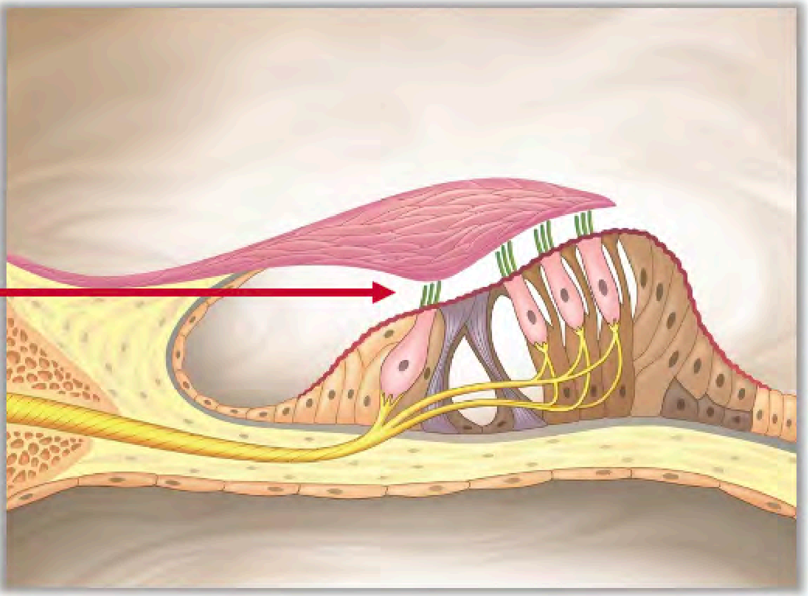




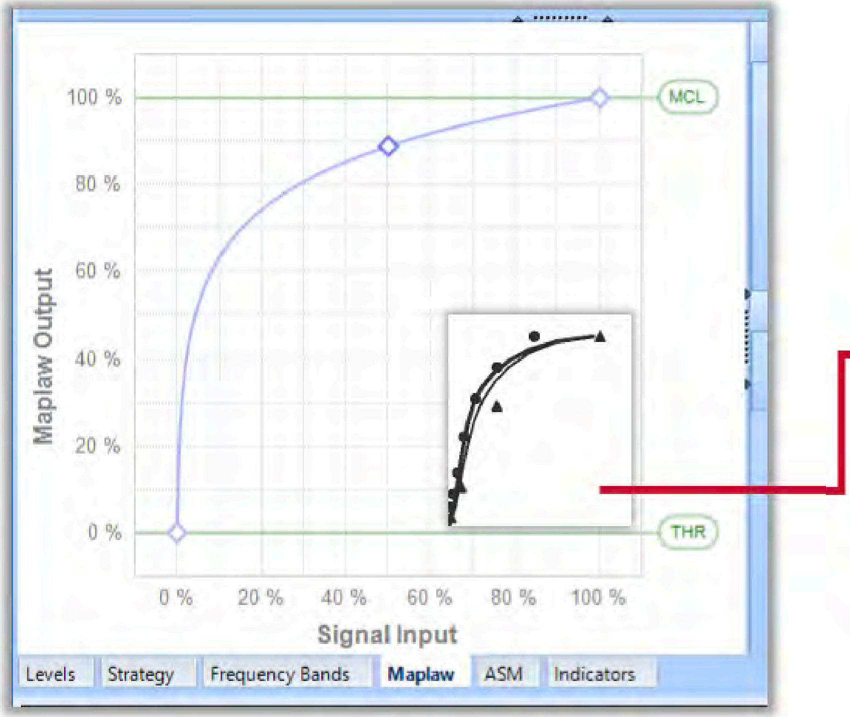
Russell et al. (1986); Lopez-Poveda and Eustaquio-Martin (2006)



Sound to stimulation

Natural sound coding

Maplaw compression mimics inner hair cell compression



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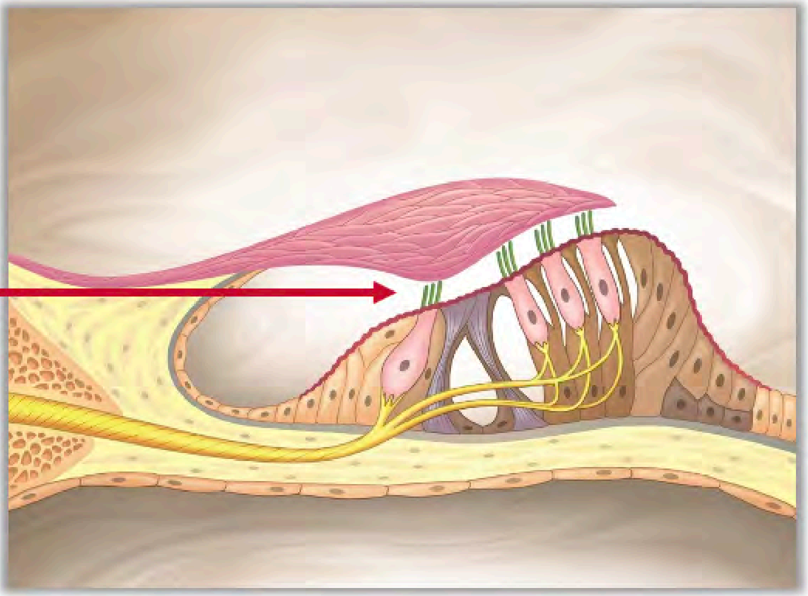
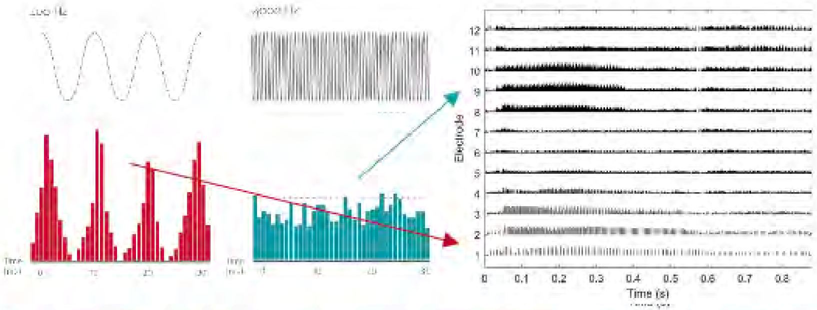


Sound to stimulation

Natural sound coding



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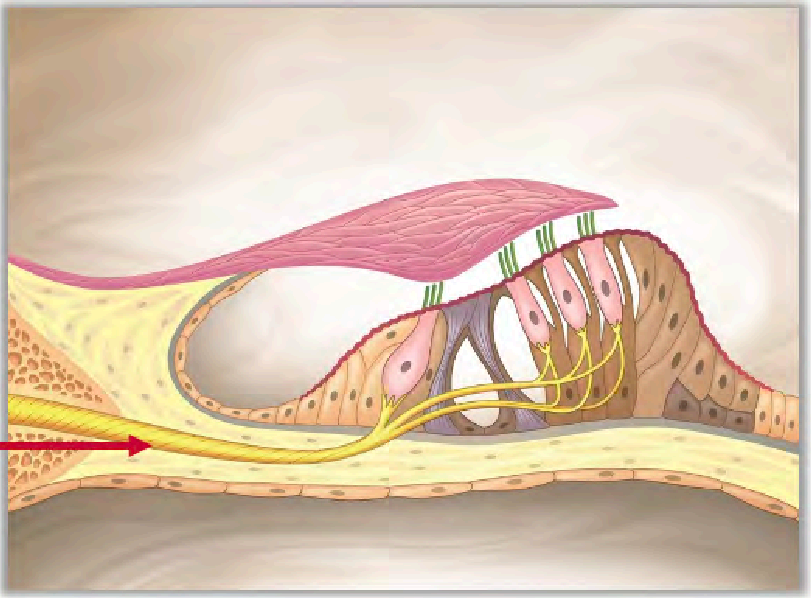
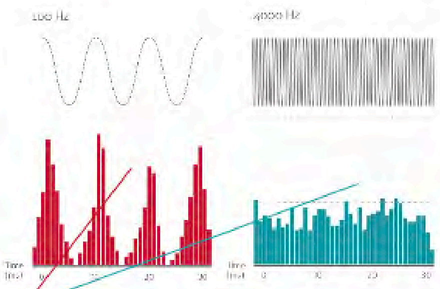
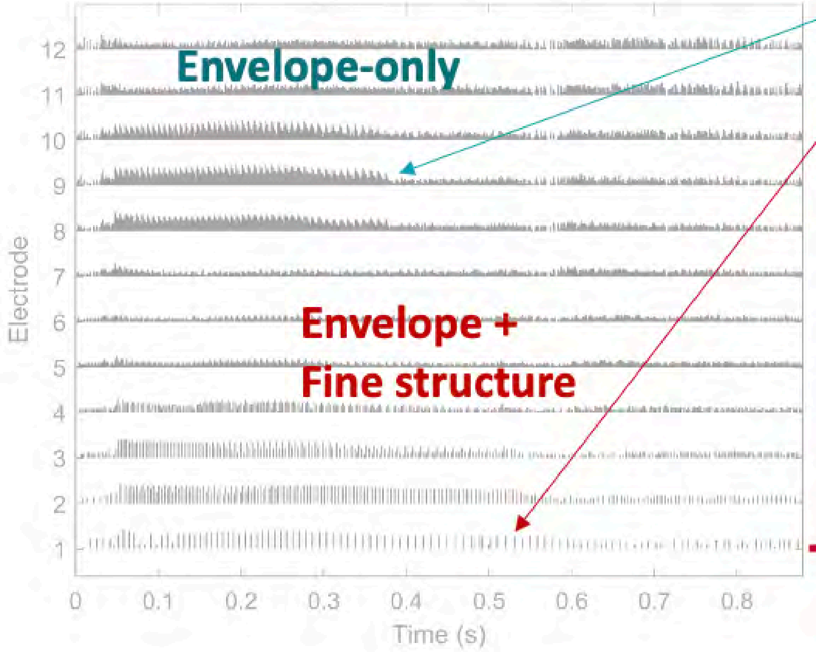
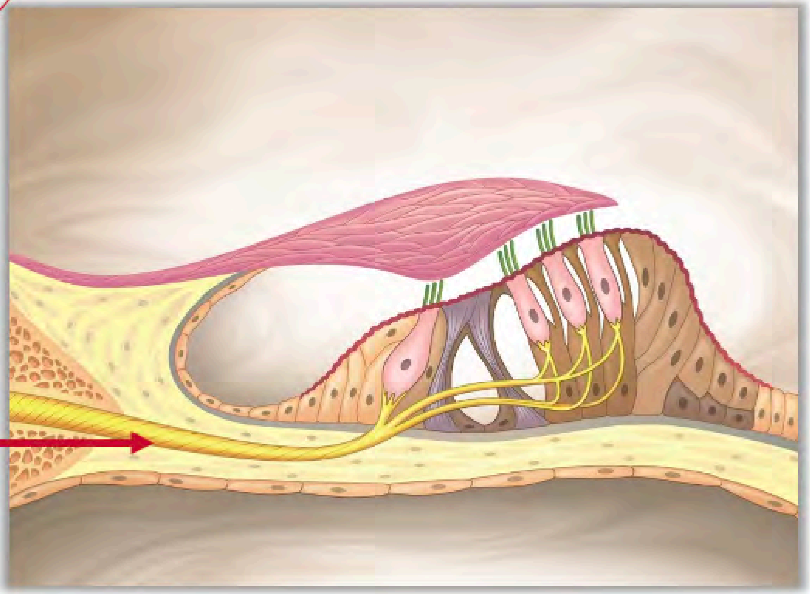
→ Stimulation



Sound to stimulation
Natural sound coding



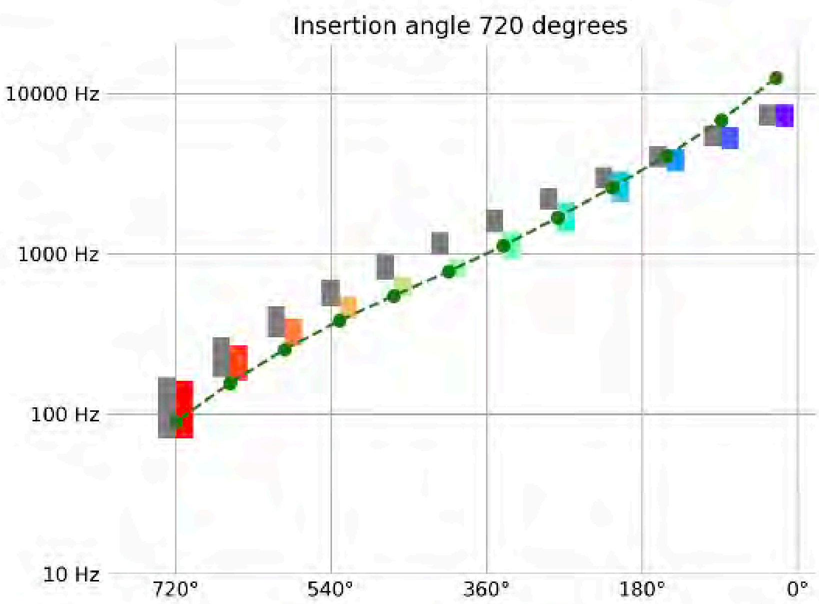


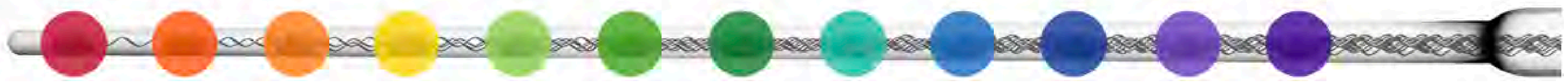


Anatomy-Based Fitting (ABF)

ABF is MED-EL's new frequency allocation option that utilizes information from OTOPLAN

ABF has a goal of aligning processor frequency bands with anatomy-based frequencies associated with electrode contacts to better match natural sound coding





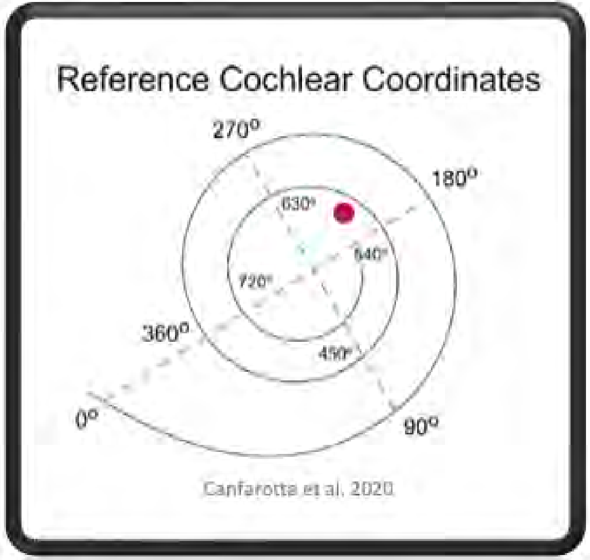
Voice of the CI

Learning from SSD CI users

- Dorman et al. had single-sided deaf (SSD) cochlear implant (CI) users listen to acoustic simulations of CIs to better understand device sound quality

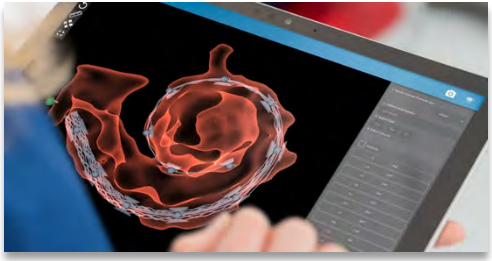
- 17-year-old patient with 2 years device experience
- FLEX28 with angular insertion depth of 580 degrees
- Programmed with FS4-p

- Electrode 1 deactivated to simulate an angular insertion depth of 461 degrees



Original → 580 degrees 10/10 match → 461 degrees 10/10 match

Summary



Long-standing key design principles:

Atraumatic electrode arrays

Complete cochlear coverage

Natural sound coding

Individualized cochlear implantation:

Pre-planning with OTOPLAN

Post-op frequency fitting with Anatomy-Based Fitting

Closest to Natural Hearing

Move over Mickey Mouse™!

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Thank you for listening!