HST.722 Brain Mechanisms of Speech and Hearing
Fall 2005

Dorsal Cochlear Nucleus
September 14, 2005

Ken Hancock

Dorsal Cochlear Nucleus (DCN)

- Overview of the cochlear nucleus and its subdivisions
- Anatomy of the DCN
- Physiology of the DCN
- Functional considerations

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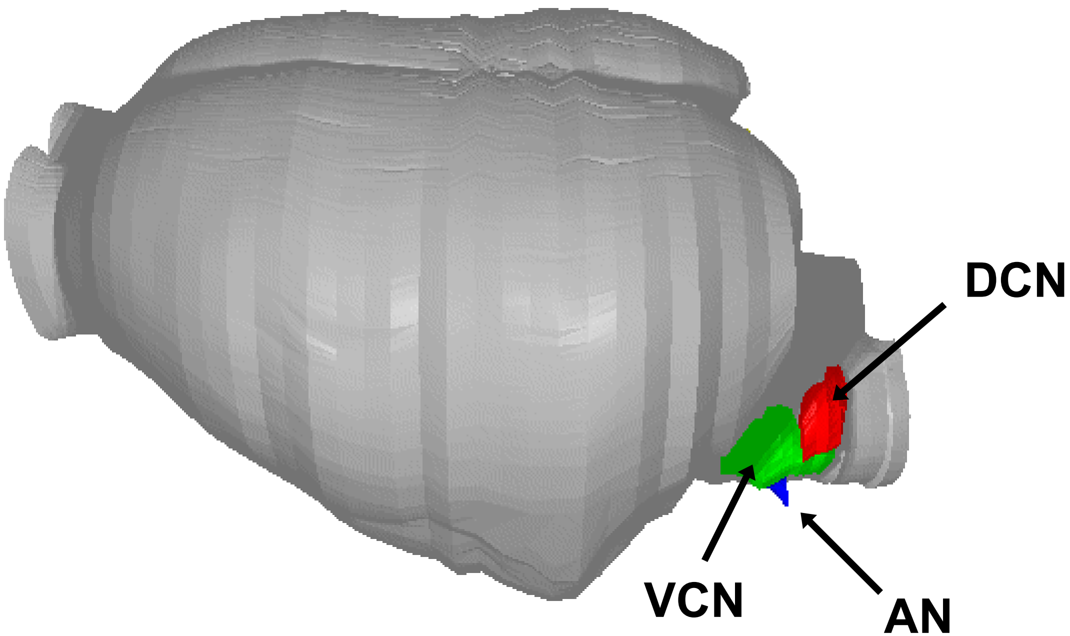
The cochlear nucleus



AN fibers terminate in a "tonotopic" or "cochleotopic" pattern

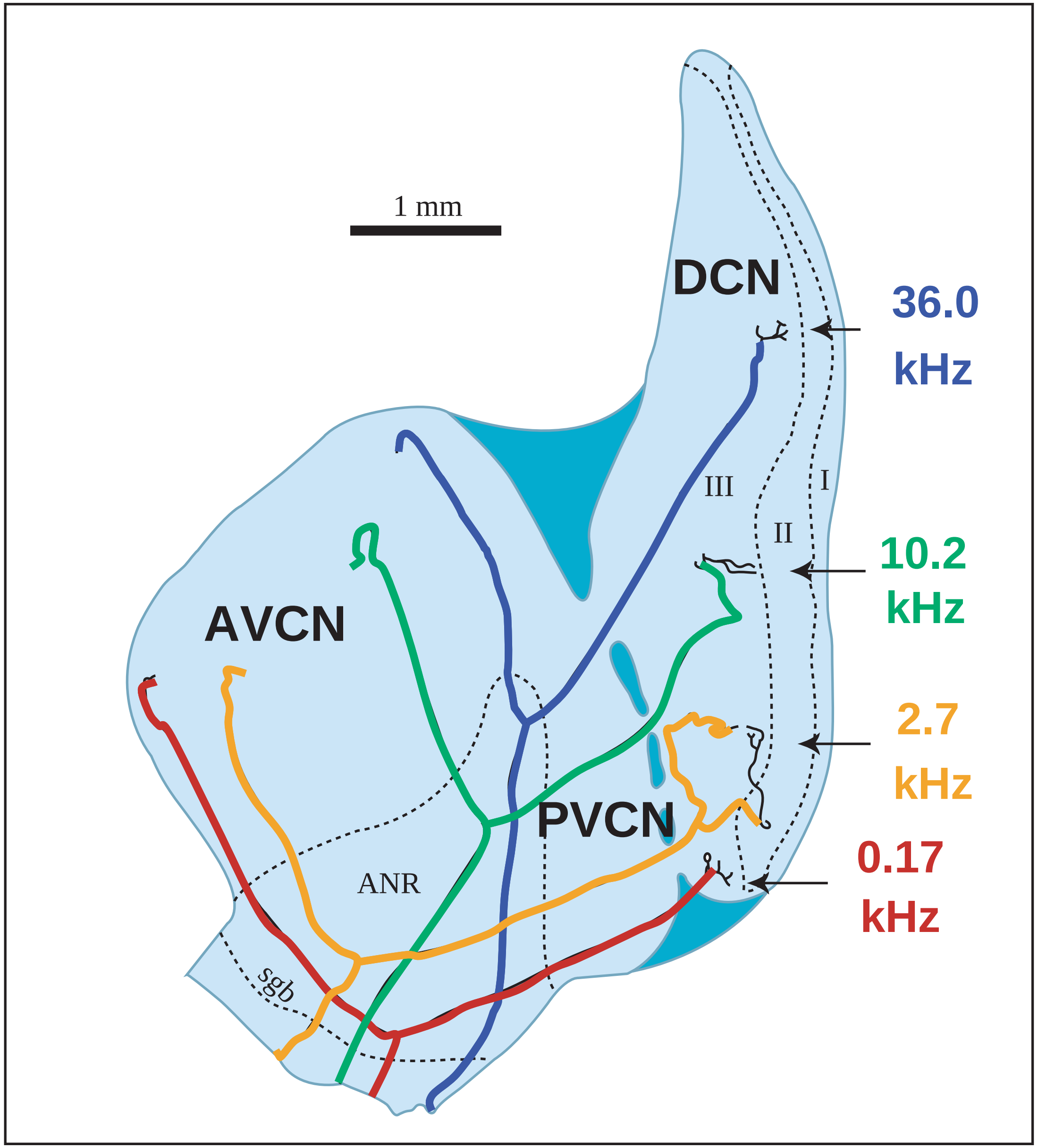
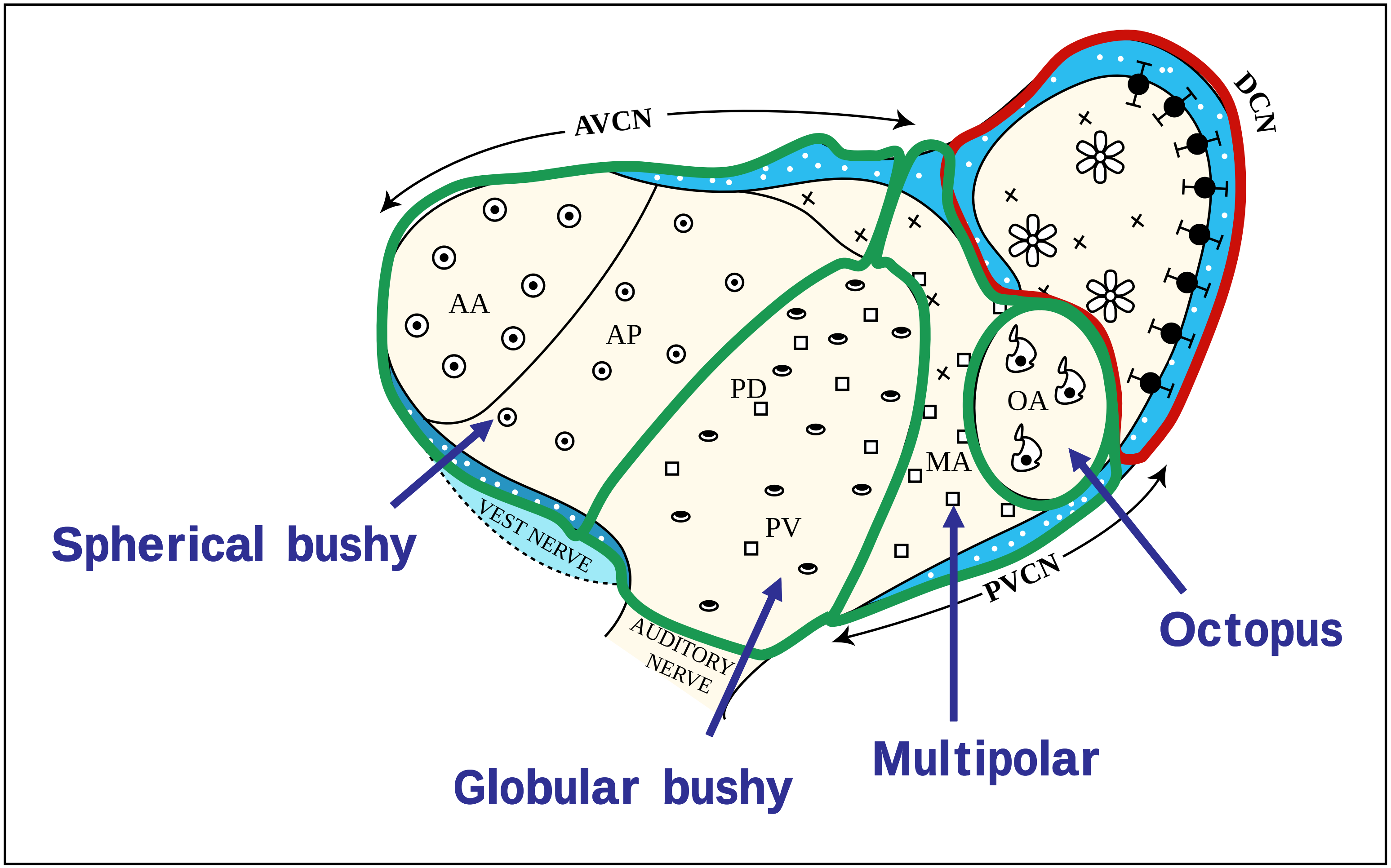


Figure by MIT OCW.

Major subdivisions of the cochlear nucleus



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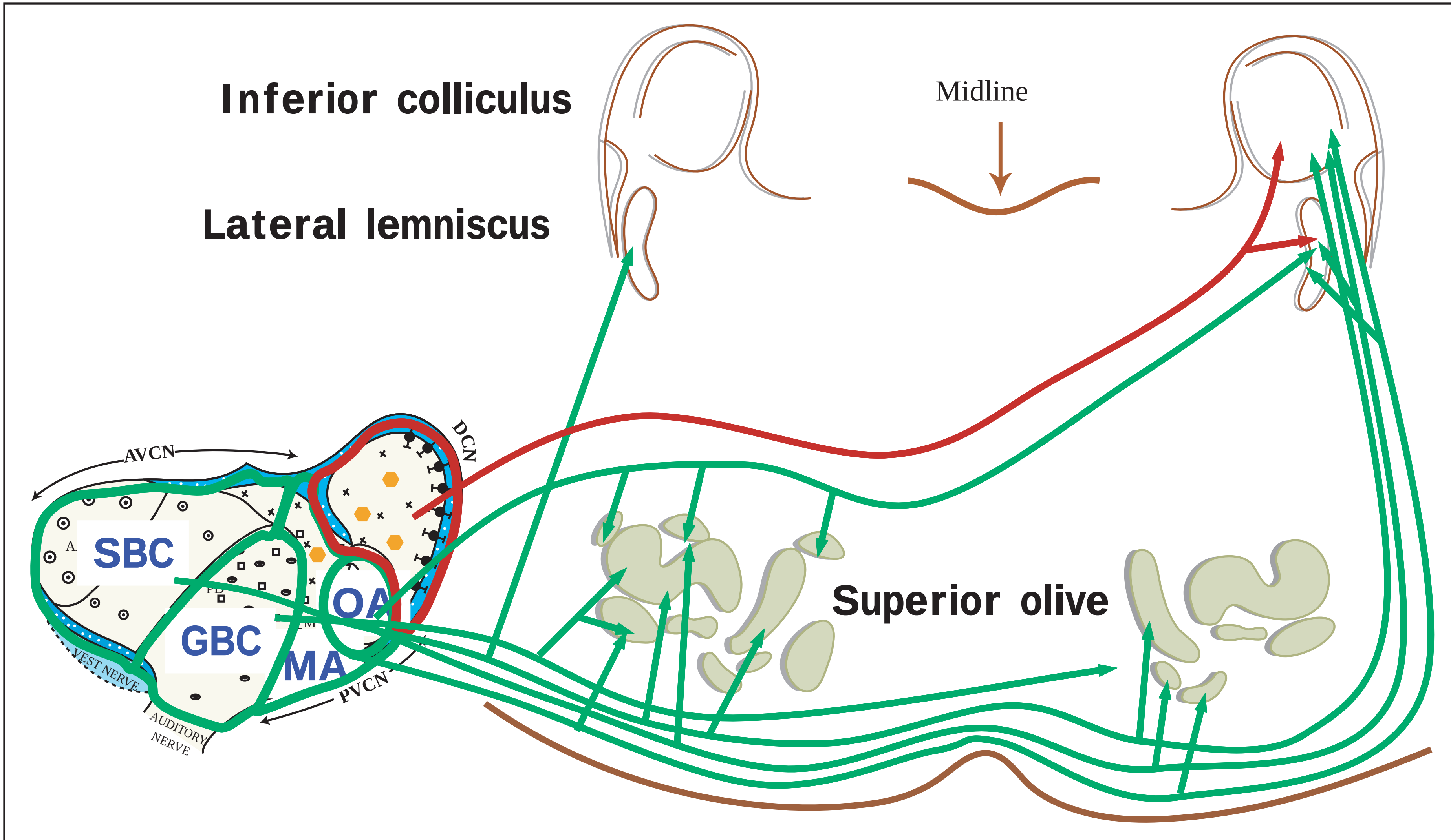
Summary of pathways originating in the cochlear nucleus



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Projections suggest DCN is a different animal than VCN

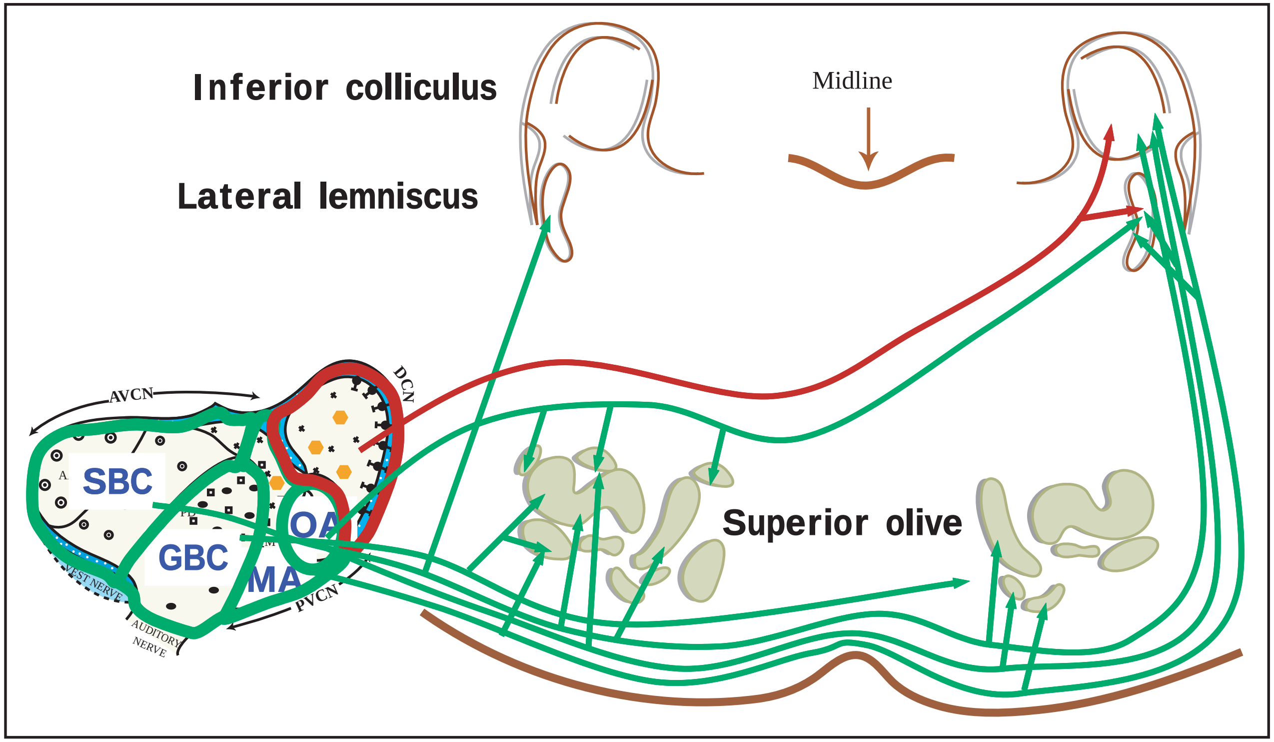

Figure by MIT OCW.

- (All roads lead to the inferior colliculus)
- VCN projects directly to structures dealing with binaural hearing and olivocochlear feedback
- DCN ???

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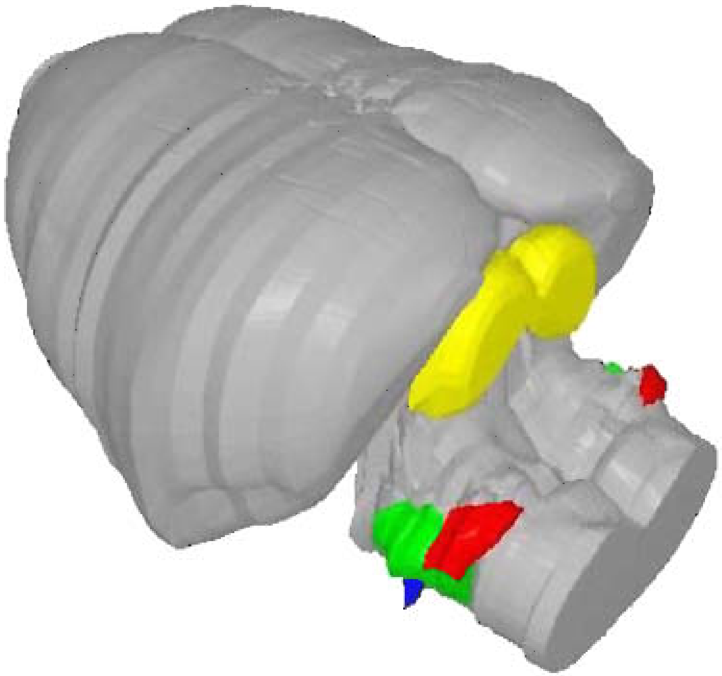

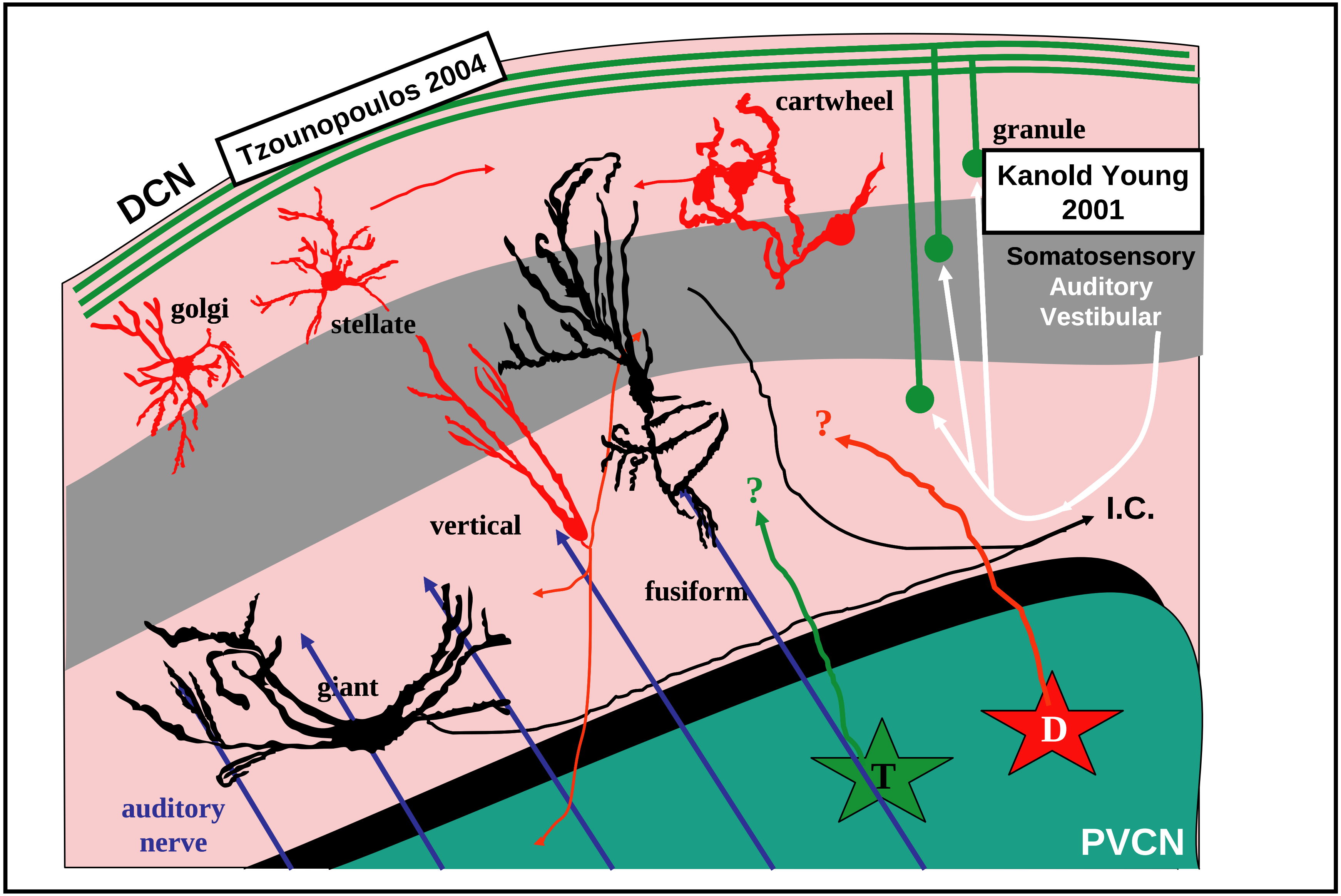

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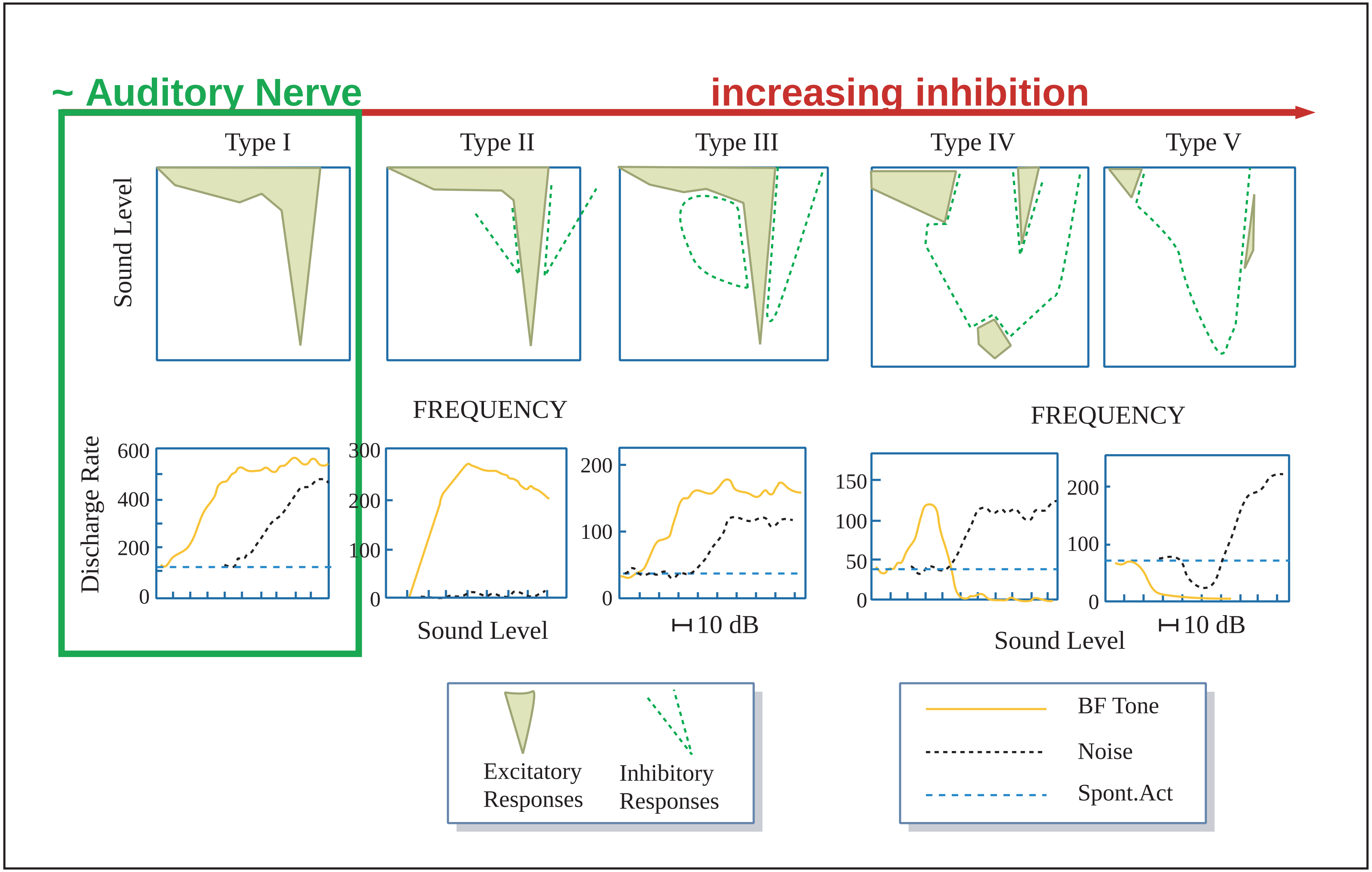
Eric Young

Response Map classification scheme



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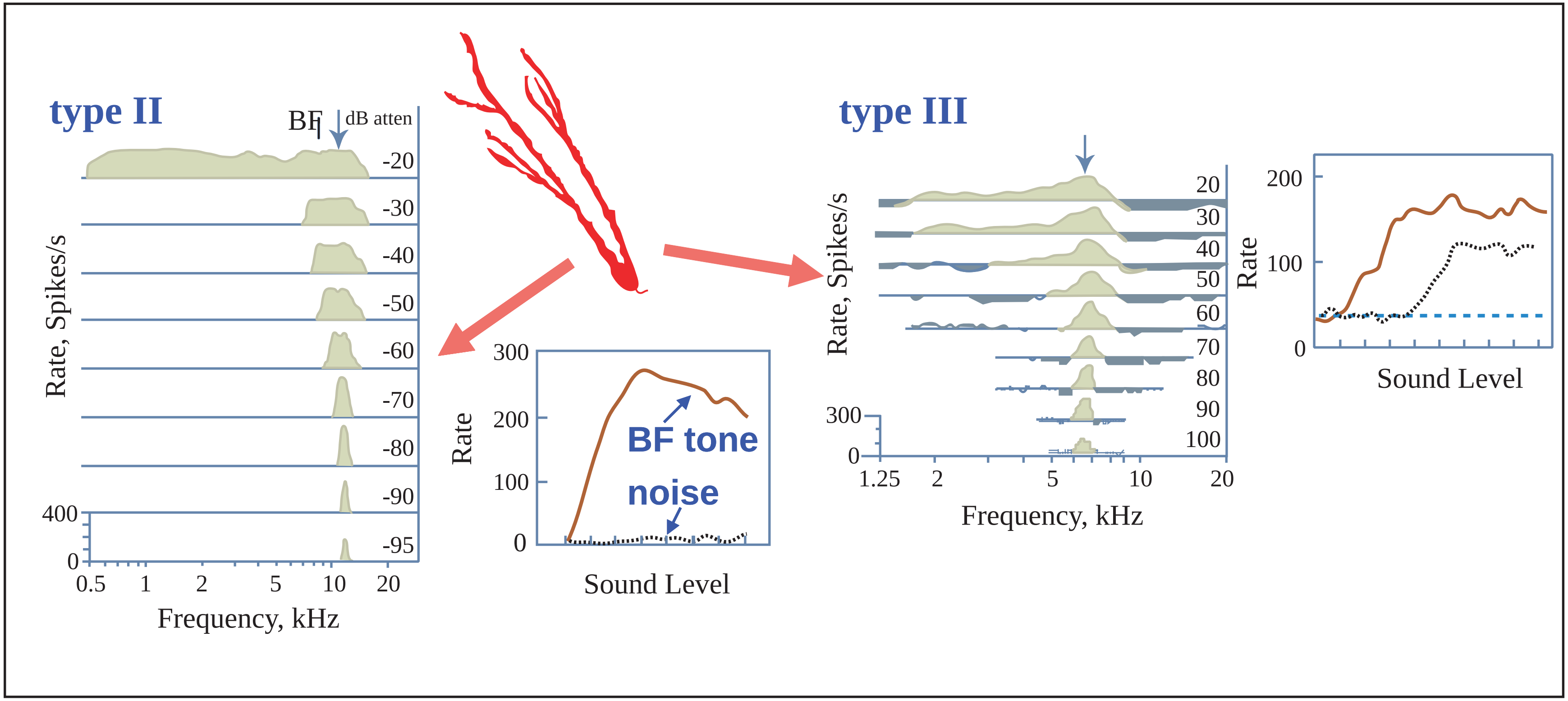
DCN: Vertical cells are type II and type III units



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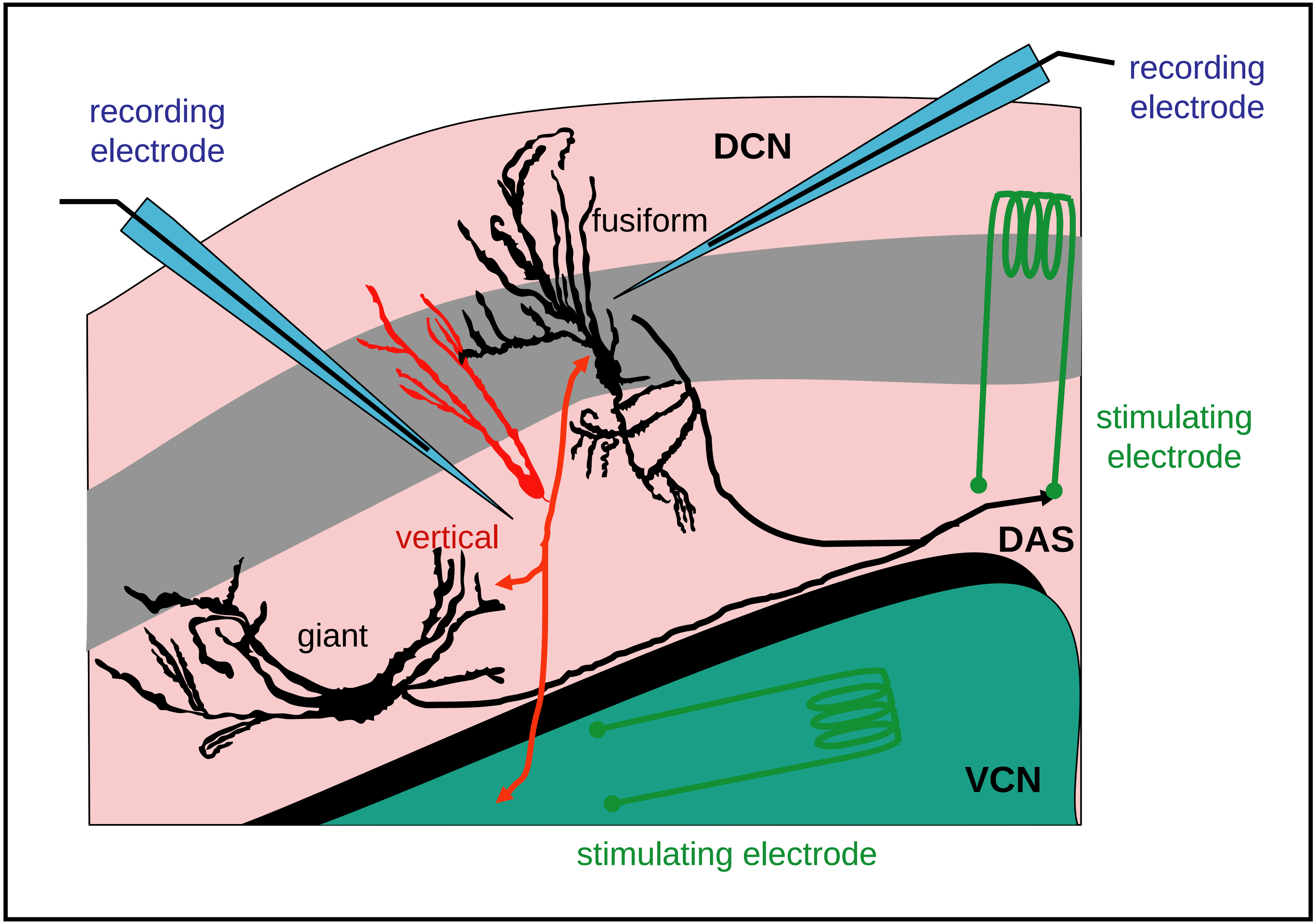
- Narrow V-shaped region of excitation
- No spontaneous activity
- Tone response >> noise response

- V-shaped region of excitation
- Inhibitory sidebands

Evidence: Antidromic stimulation (Young 1980)

Antidromic stimulation

- record from neuron
- shock its axon



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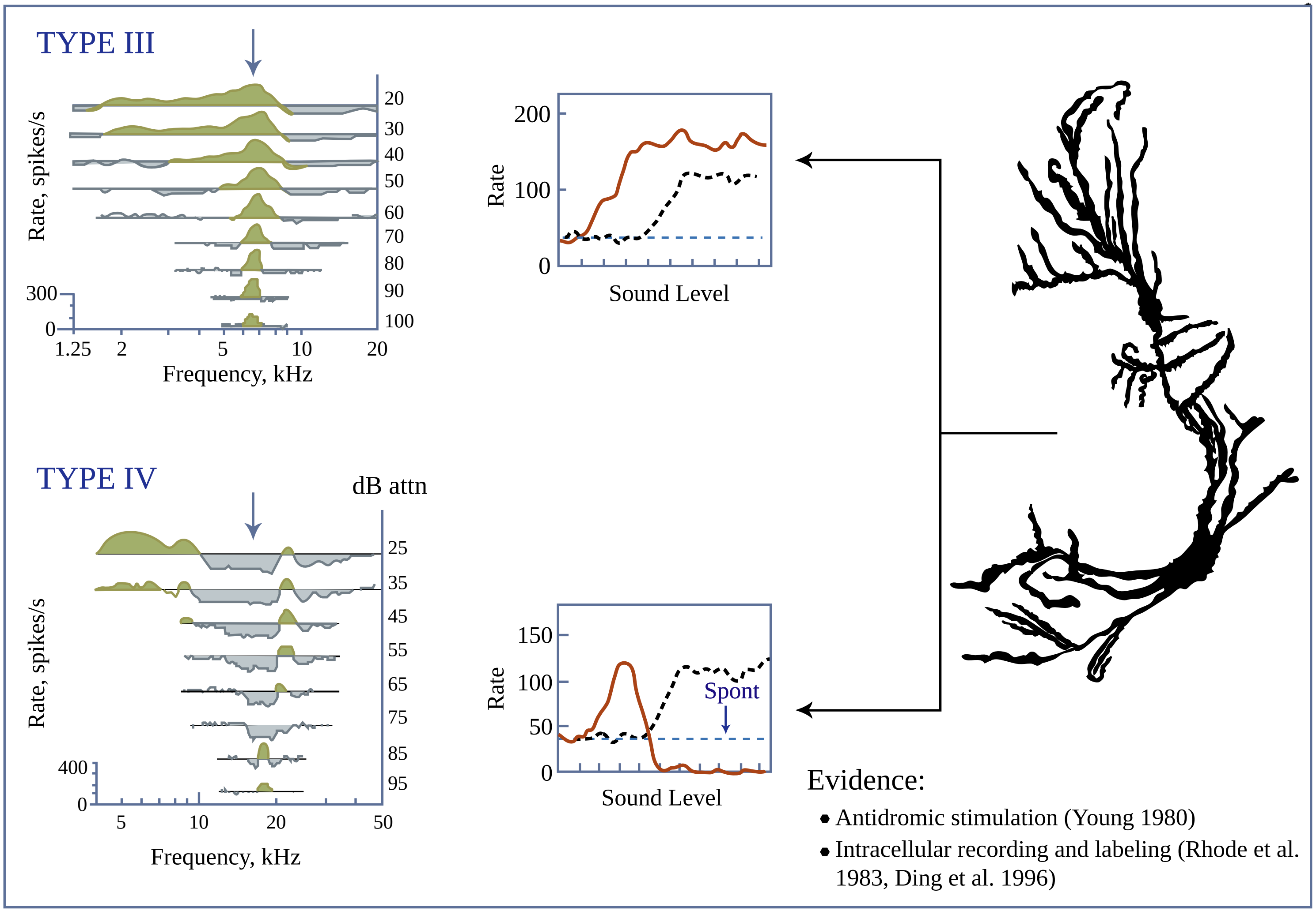
DCN: "Principal" cells are type III and type IV units



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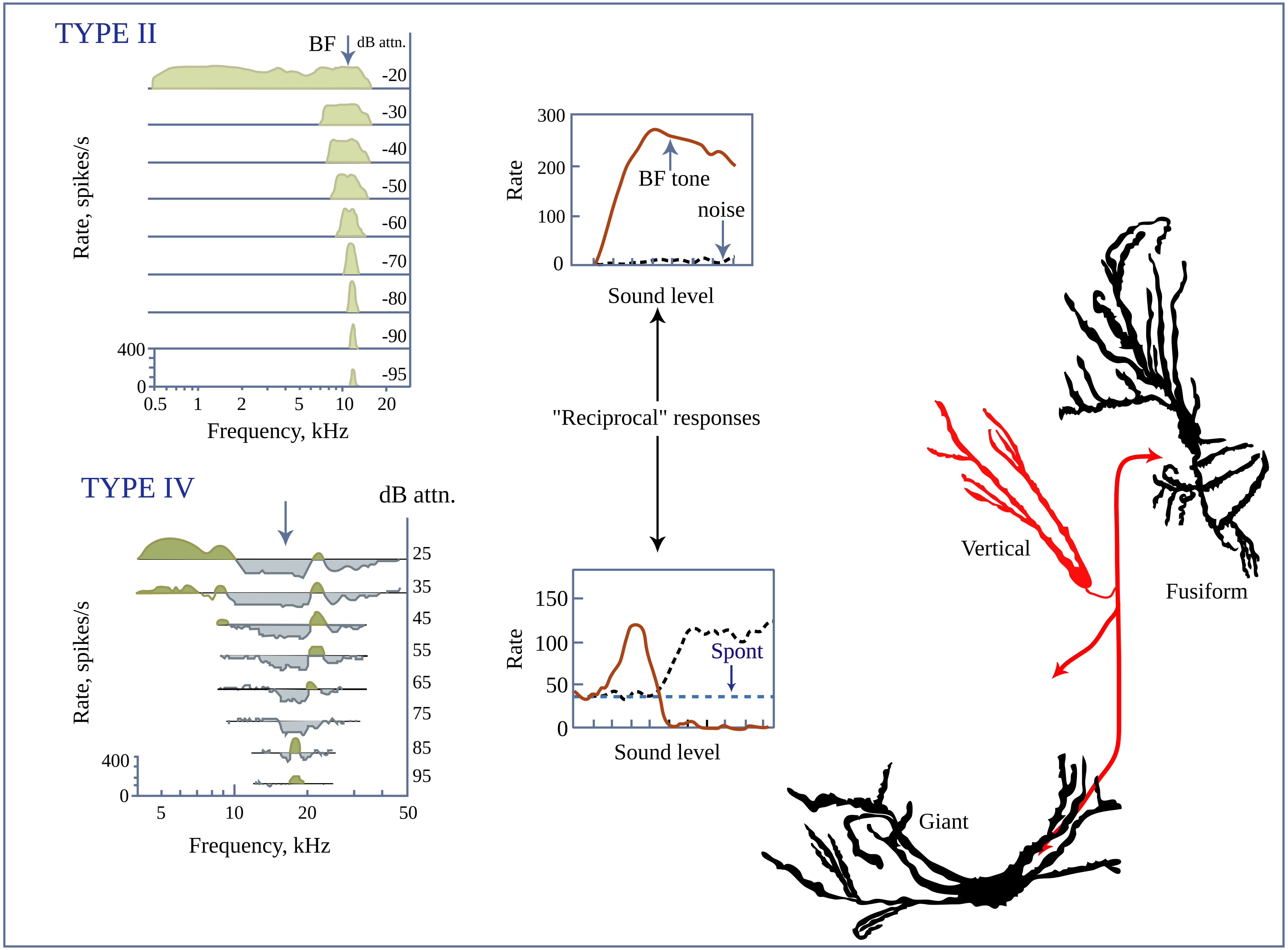
- "Island of excitation" & "Sea of inhibition"
- BF rate-level curve inhibited at high levels
- Noise rate-level curve ~ monotonic

Neural circuitry underlying DCN physiology: type II units inhibit type IV units



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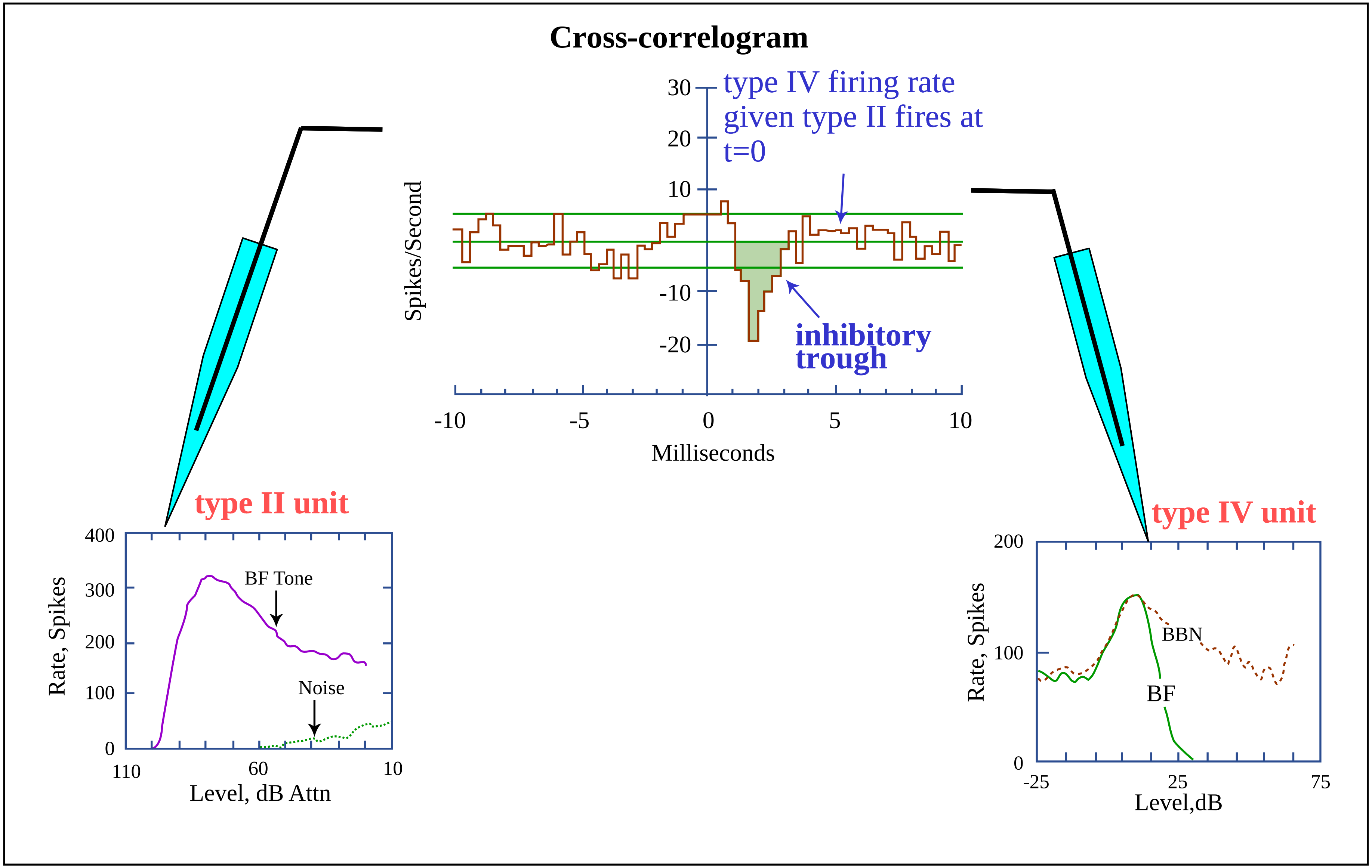
Classic experiment: type II units inhibit type IV units



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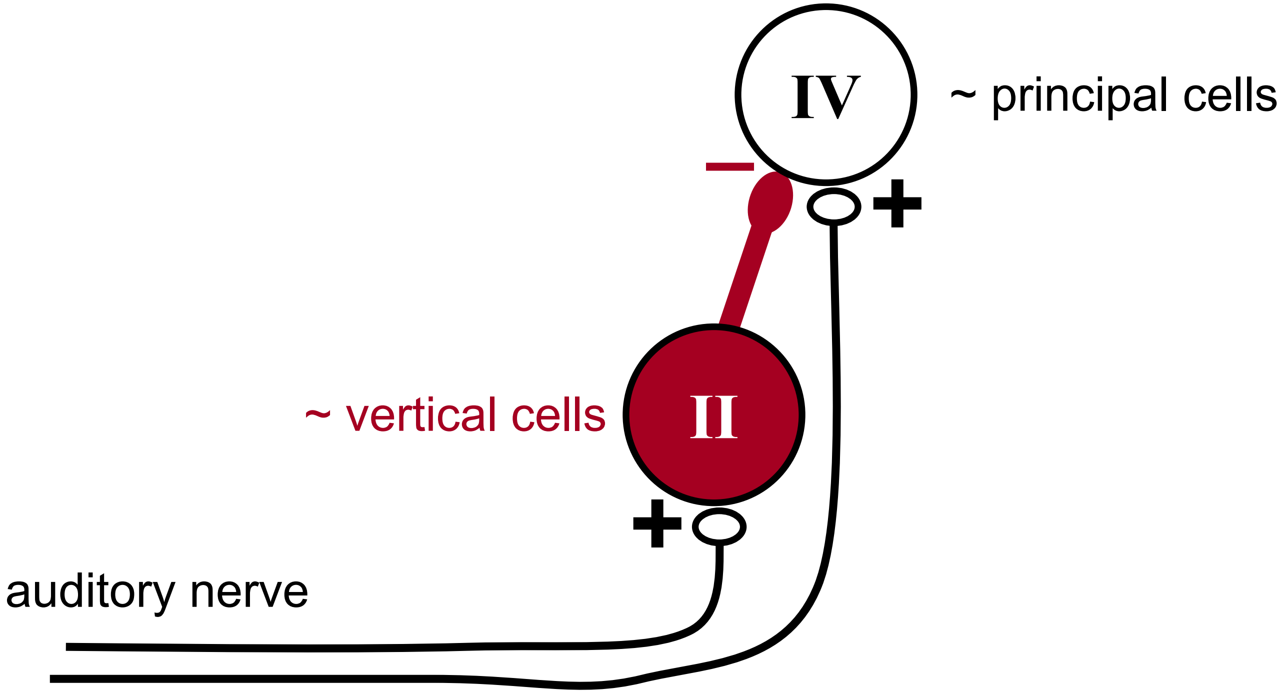
DCN physiology so far…



- type II units inhibit type IV units
- ***BUT*** this analysis based on pure-tone responses

$\Rightarrow$ what happens with more general stimuli???

Inhibition from type II units doesn't account for everything

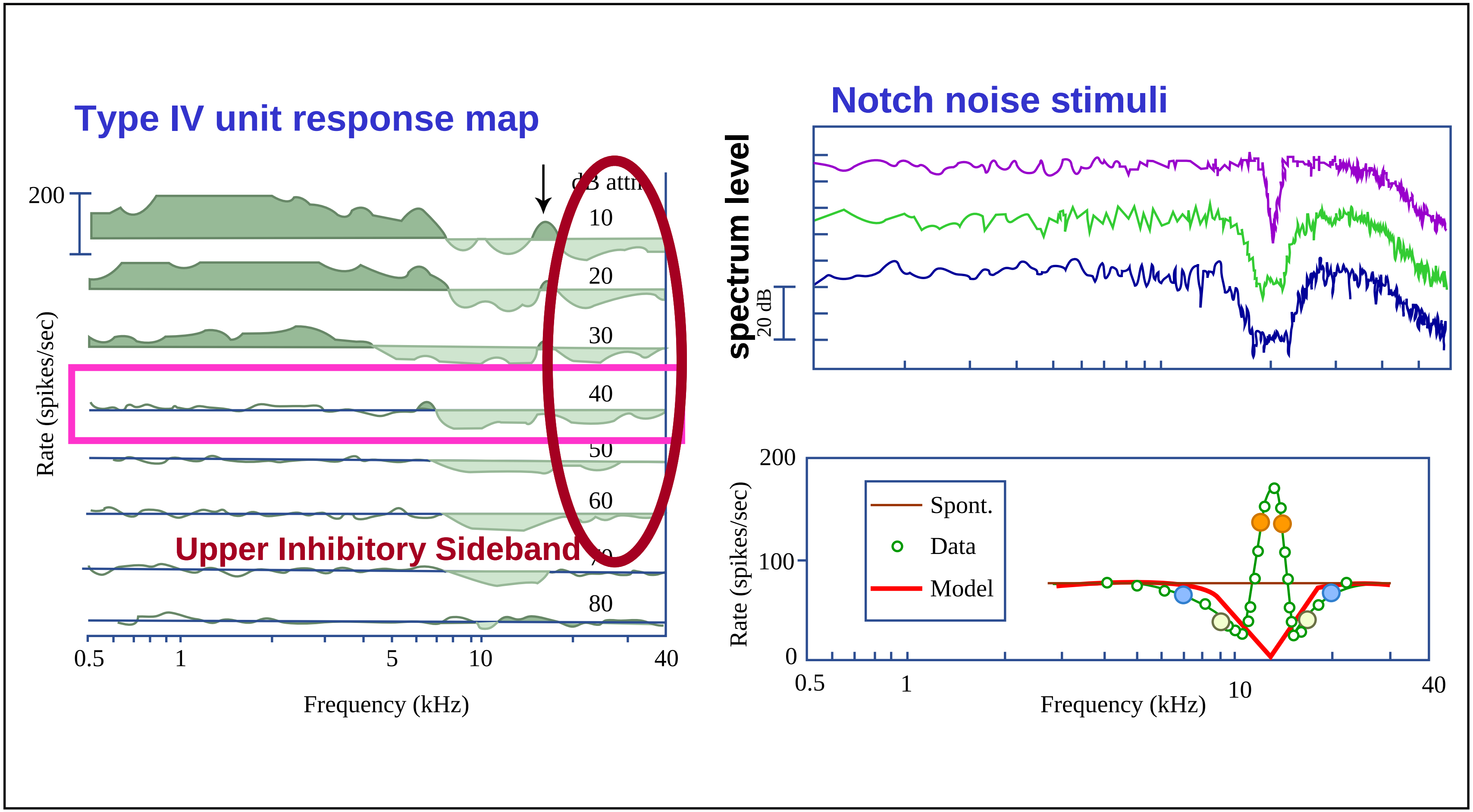
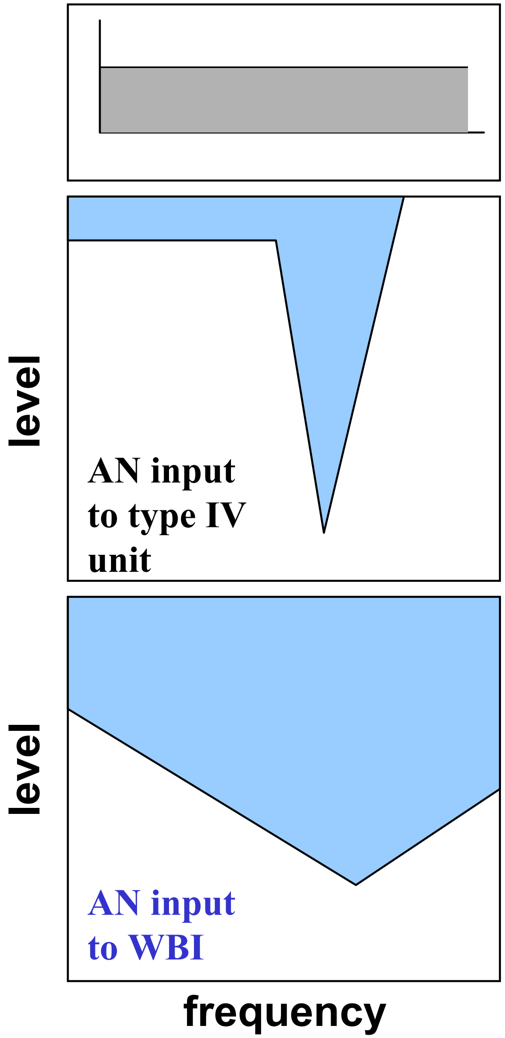


Figure by MIT OCW.

- (DCN responses to broadband stimuli cannot be predicted from responses to tones: *nonlinear)*
- Type II units do not respond to notch noise—whither the inhibition?
- Response map has two inhibitory regions?

DCN notch noise sensitivity due to *wideband inhibition*

Broadband noise



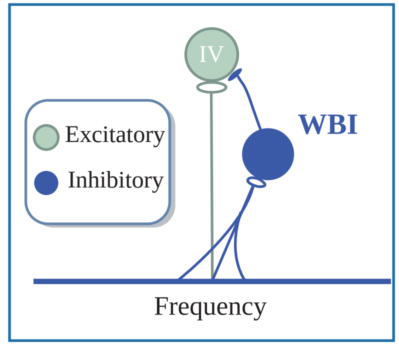
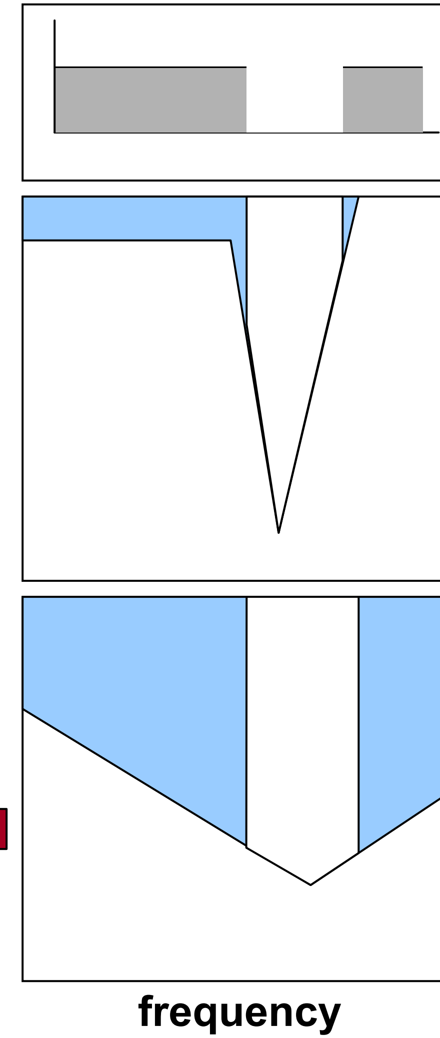


Figure by MIT OCW.

- strong AN input dominates
- type IV response is ***excitatory***

Notch noise



- type IV loses greater portion of its excitatory input
- WBI input dominates
- type IV response is ***inhibitory***

Nelken & Young 1994

PVCN: is the D-stellate cell the wideband inhibitor?

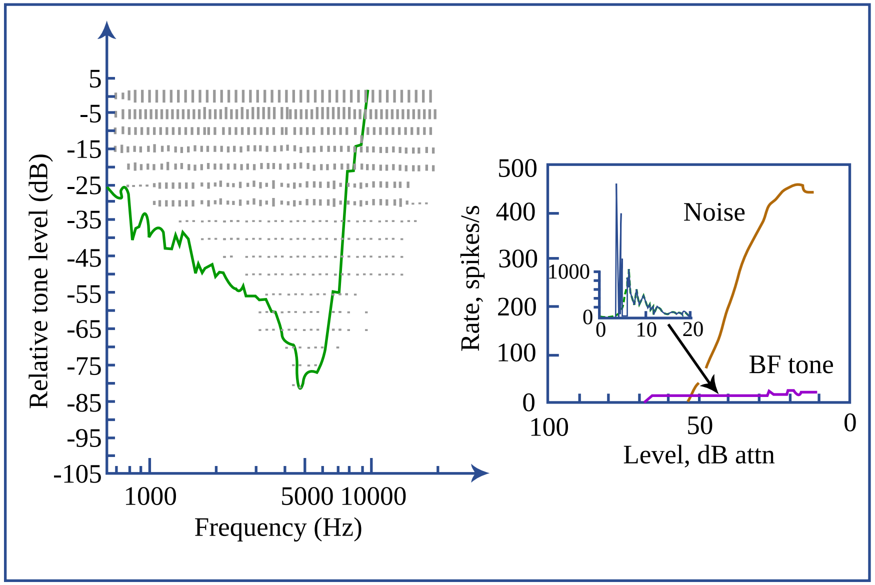
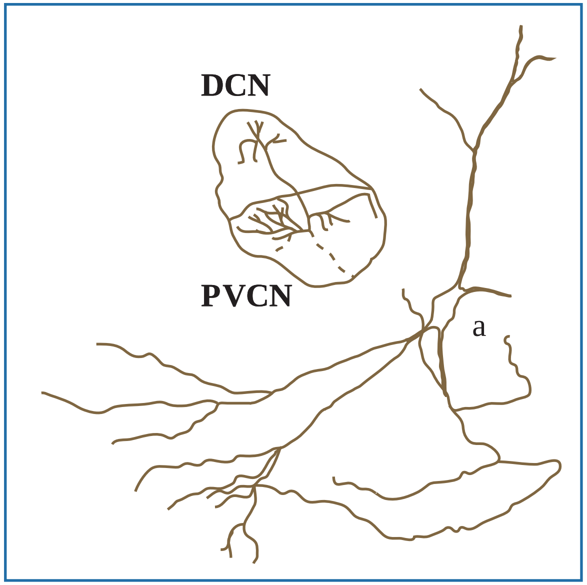


Figure by MIT OCW.

- broadly-tuned, onset-chopper units are found in the PVCN (Winter & Palmer 1995)
- typically respond better to broadband noise than to tones

- such responses arise from radiate or stellate neurons (Smith & Rhode 1989)
- stellate cells send axons *d*orsally into the DCN, thus called "D-stellate cells" (Oertel et al. 1990)
- D-stellate cells are inhibitory (Doucet & Ryugo 1997)



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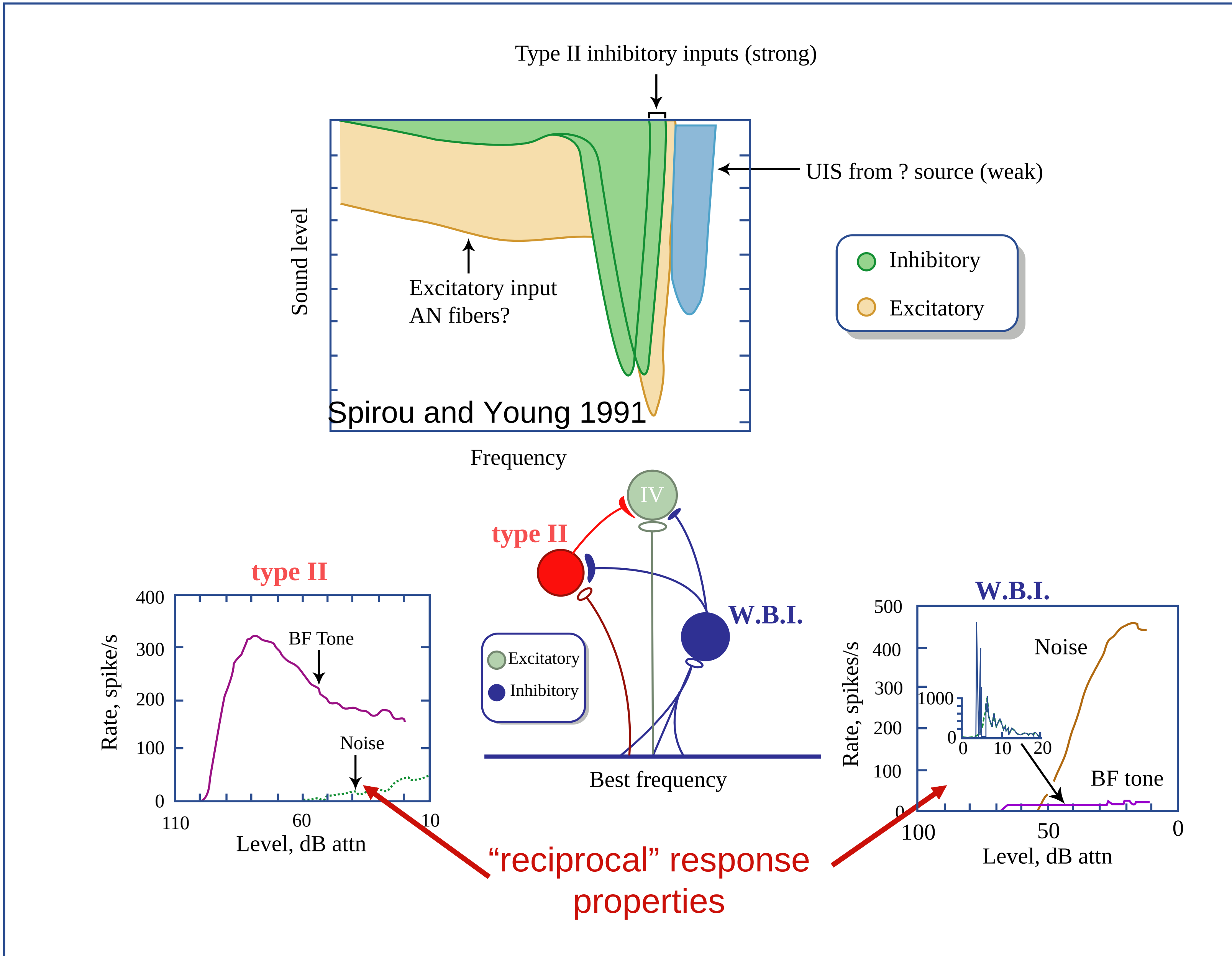
Summary: Circuitry of DCN deep layer



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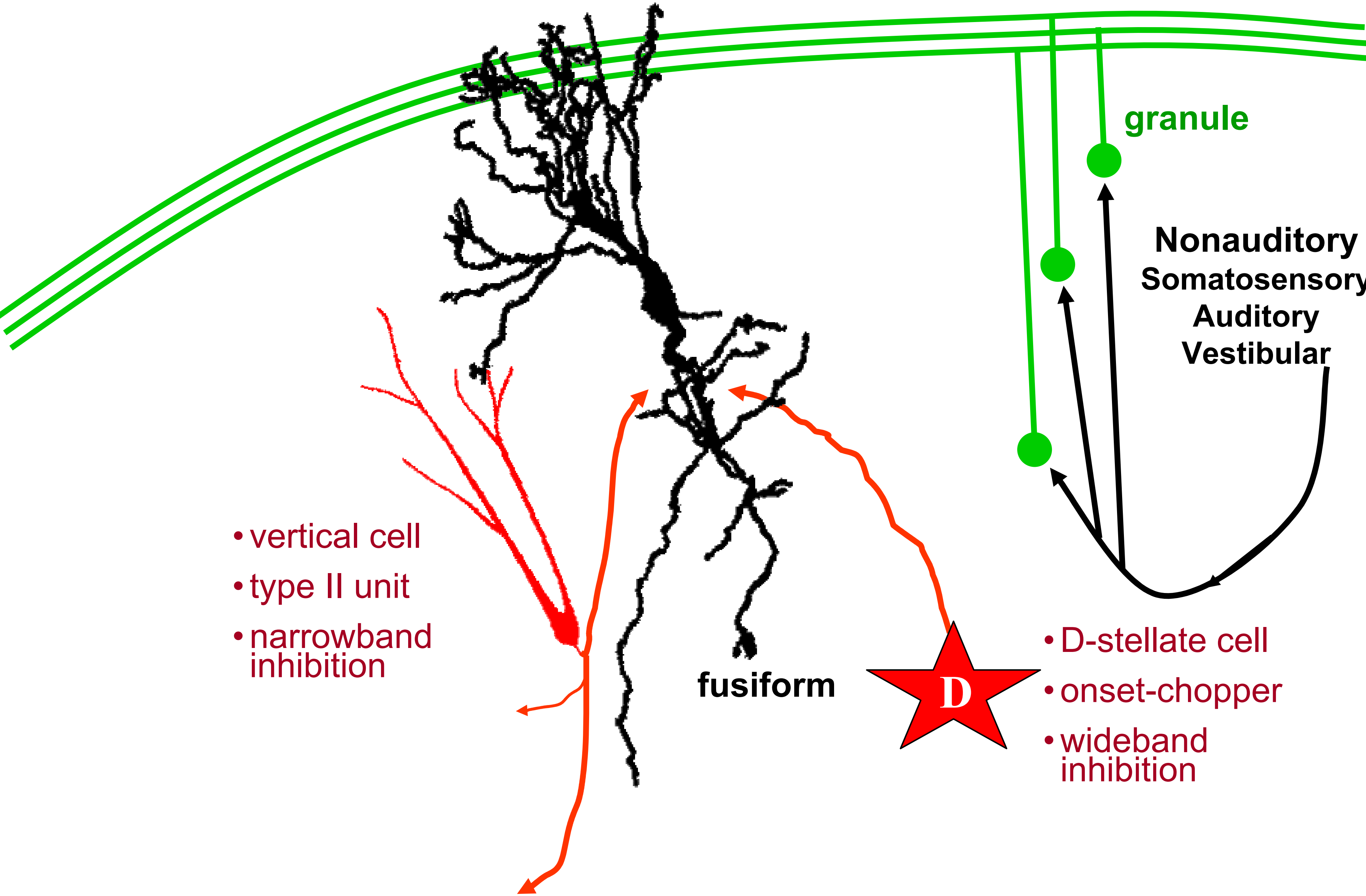
Summary of DCN anatomy and physiology



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  - highly nonlinear
- Functional considerations

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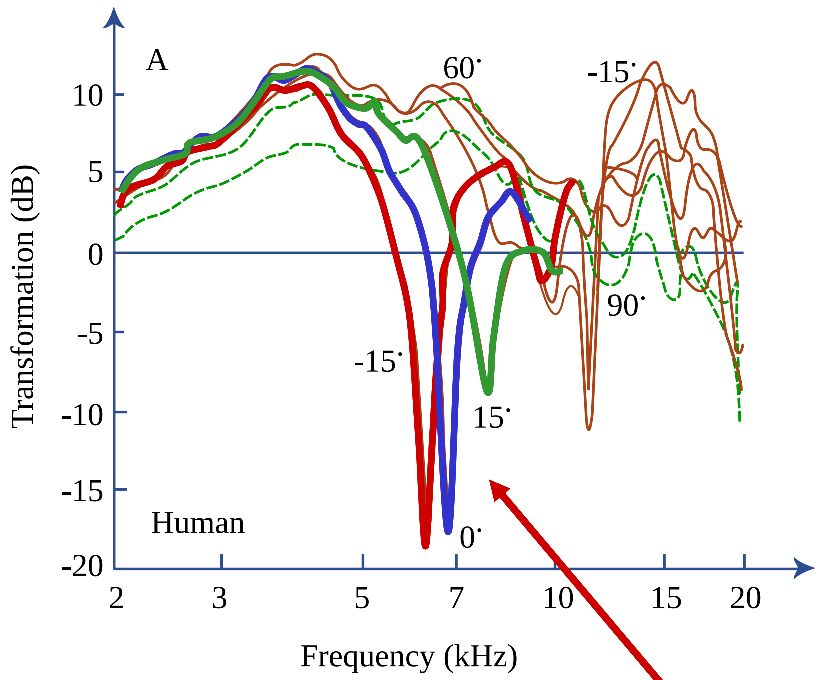
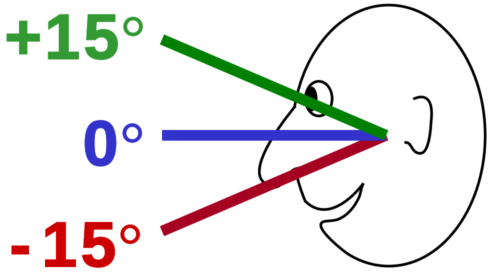
Filering by the pinna provides cues to sound source location

“Head Related Transfer Function” (HRTF)

Outer ear gain

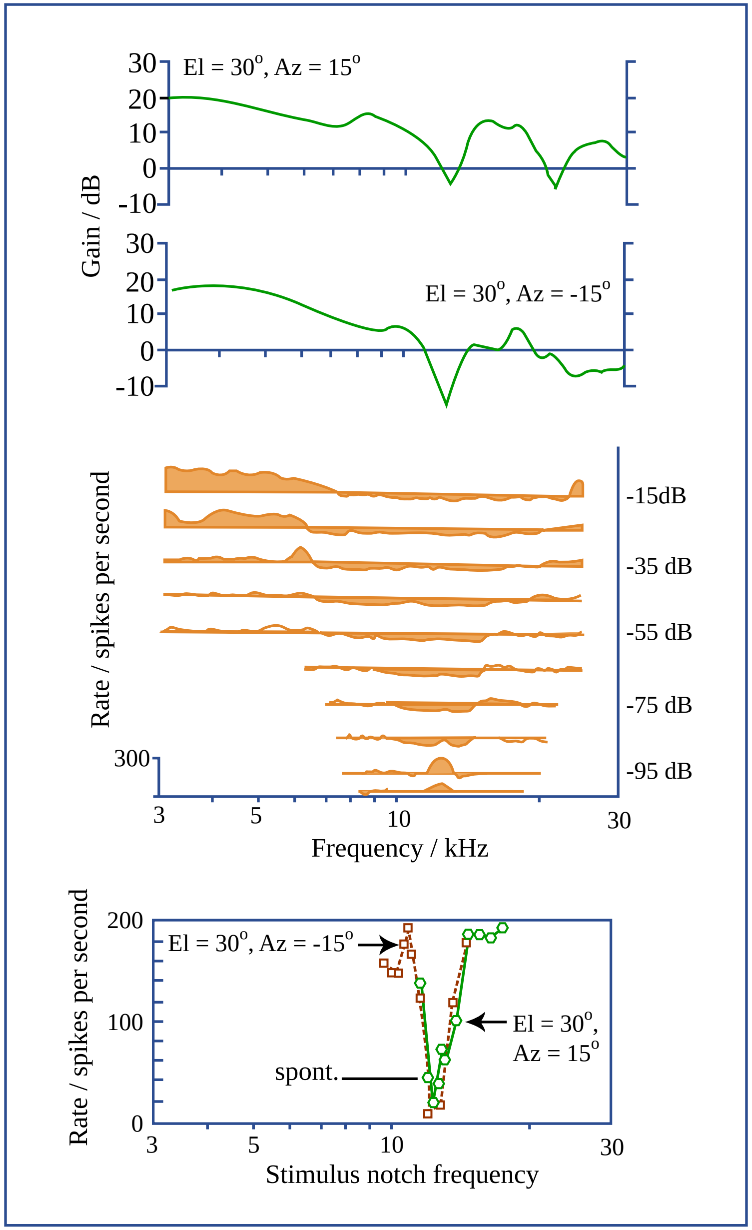




“first notch” frequency changes with elevation

Figures by MIT OCW.

Type IV units are sensitive to HRTF first notch



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- type IV units are ***inhibited*** by notches centered on BF
- ***null*** in DCN population response may code for sound source location

Physiology ⇒

Reiss & Young 2005

Behavior ⇒

May 2000

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  - coding sound source location based on pinna cues

DCN is a "cerebellum-like structure"

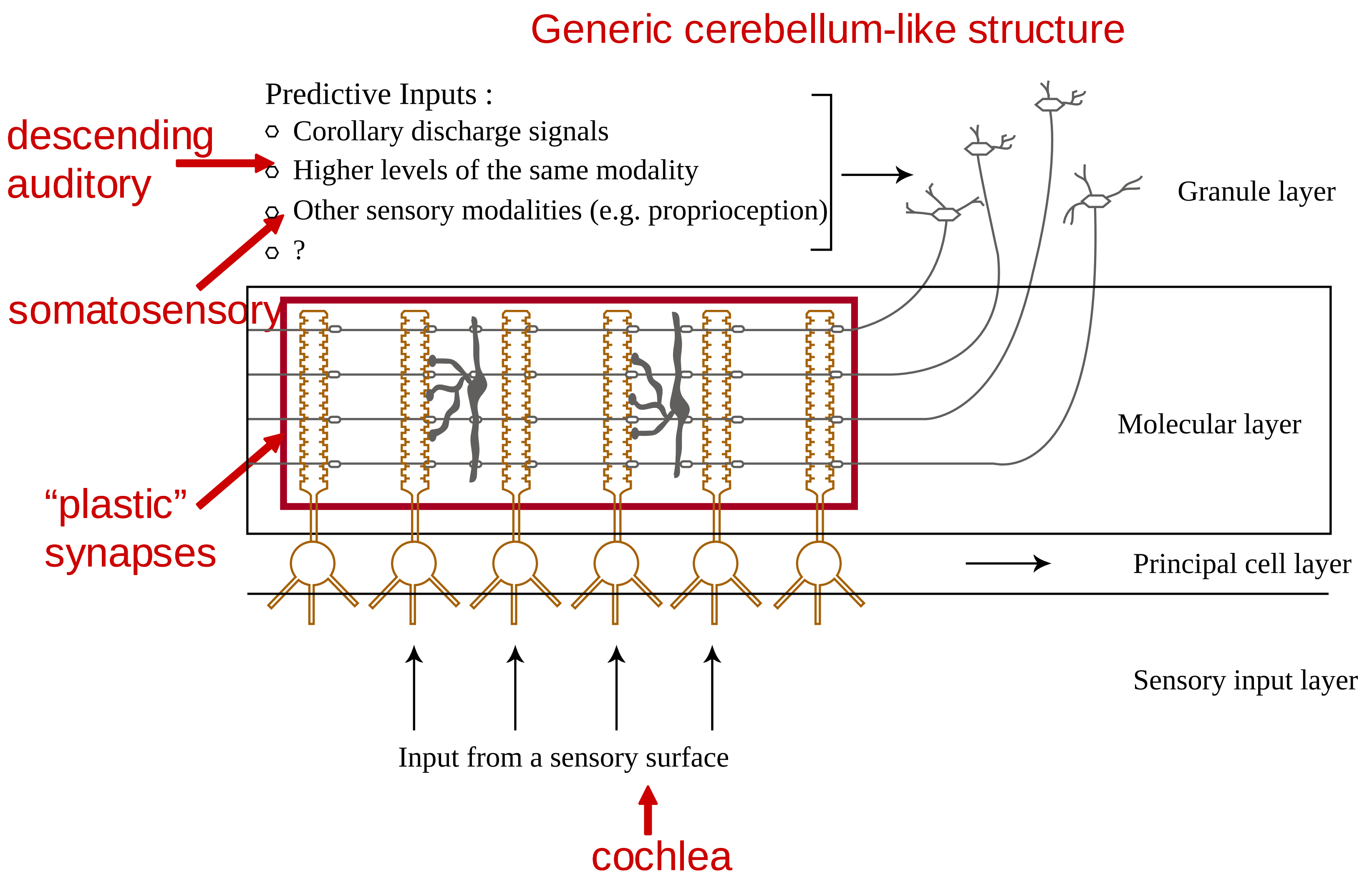
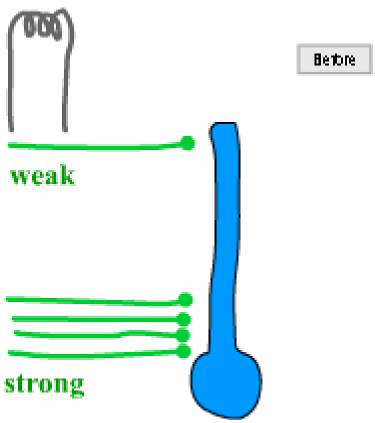
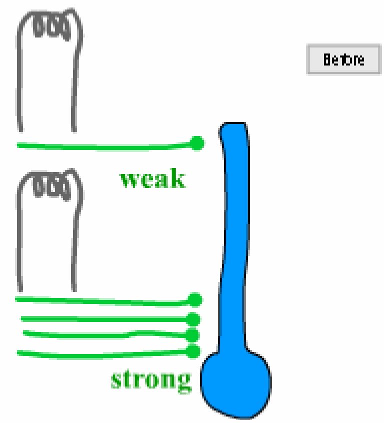


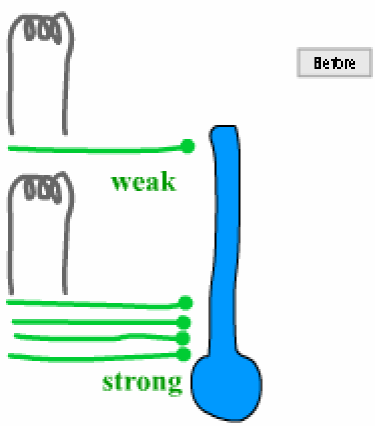
Figure by MIT OCW.

Synaptic plasticity: Long-Term Potentiation (LTP)

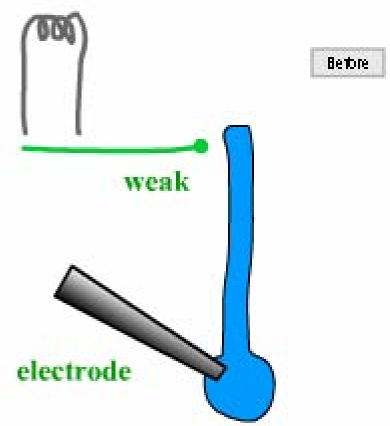
- “Classical” LTP demonstration at the hippocampal CA3-CA1 synapse
- LTP evoked by *tetanic* stimulation (mechanism involves NMDA receptors)







Tzounopoulos 2004



Electric fish provide clues to cerebellum-like function

black ghost knifefish
(*Apteronotus albifrons*)

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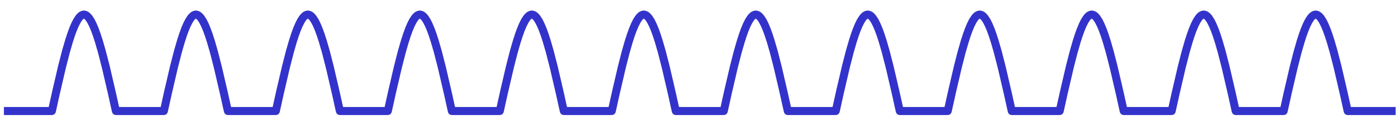
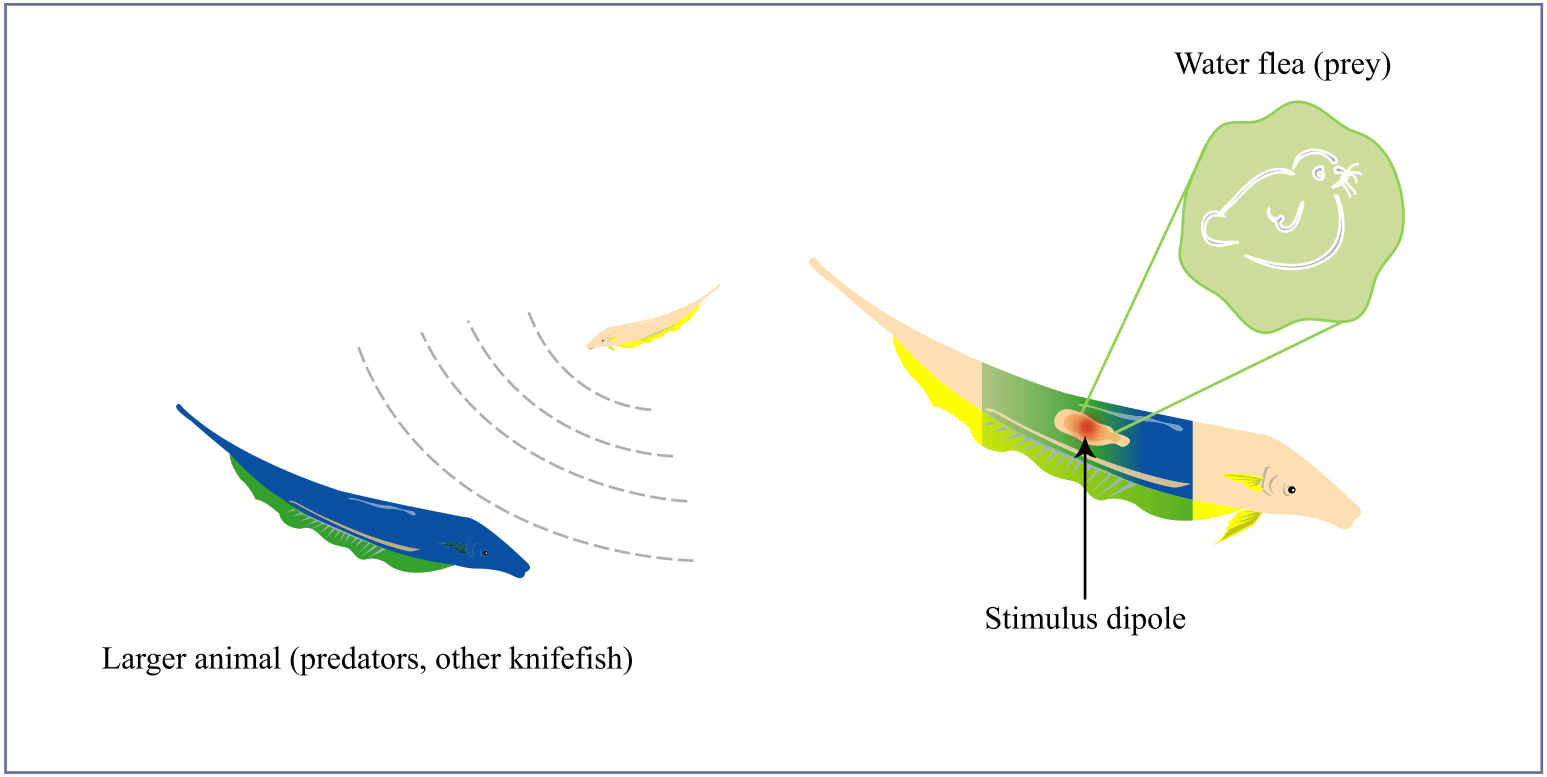
Please see the Nelson Lab home page:
http://nelson.beckman.uiuc.edu

electric organ
discharge
(EOD)



- electrical activity detected by ***electric lateral line***
- afferent activity transmitted to electric lateral line lobe (ELL), analogous to DCN

Electric fields provide information about nearby objects



Figures by MIT OCW.

- ***BUT*** the fish generates its *own* electric fields:
  - tail movements
  - ventilation

⇒ cerebellum-like ELL helps solve this problem

Bell 2001

What do cerebellum-like structures do???

- Subtract the *expected* input pattern from the *actual* input pattern to reveal unexpected or **novel** features of a stimulus.
  - DCN: pinna movement is *expected* to shift the first notch, independent of what the sound source is doing

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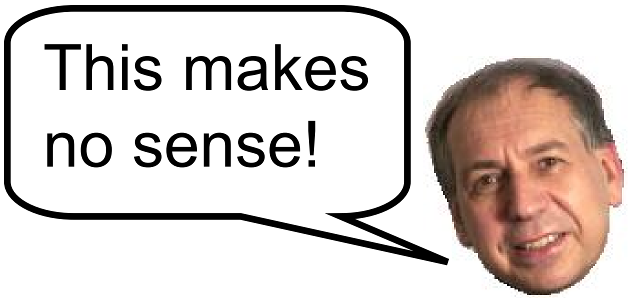
  - extract novel components of response

DCN may play a role in tinnitus



- percept of noise, ringing, buzzing, etc.
- affects up to 80% of the population
- 1 in 200 are debilitated

- (not voices in the head)

So why DCN? Because tinnitus…

- involves plasticity
- may involve somatosensory effects

↓

Levine 1999

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  - extract novel components of response
  - contribute to tinnitus

Slide 5:

Ryugo DK, May SK (1993) The projections of intracellularly labeled auditory nerve fibers to the dorsal cochlear nucleus of cats. J Comp Neurol 329:20-35.

Slide 6:

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Slide 7:

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Spirou GA, Young ED (1991) Organization of dorsal cochlear nucleus type IV unit response maps and their relationship to activation by band-limited noise. J Neurophysiol 66:1750-1768.

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