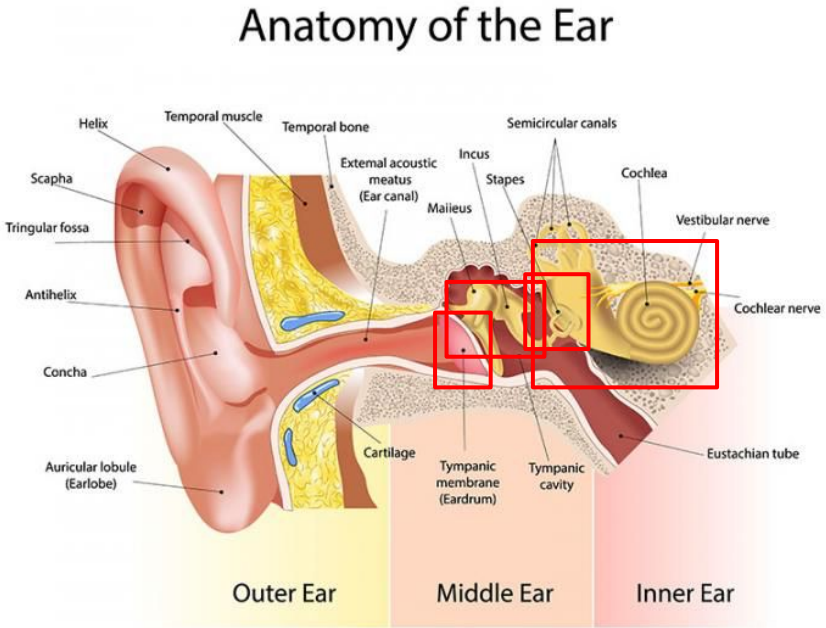
COGS 17 Week 5

Winter 2024, A04

Slides Adapted From Previous Quarter

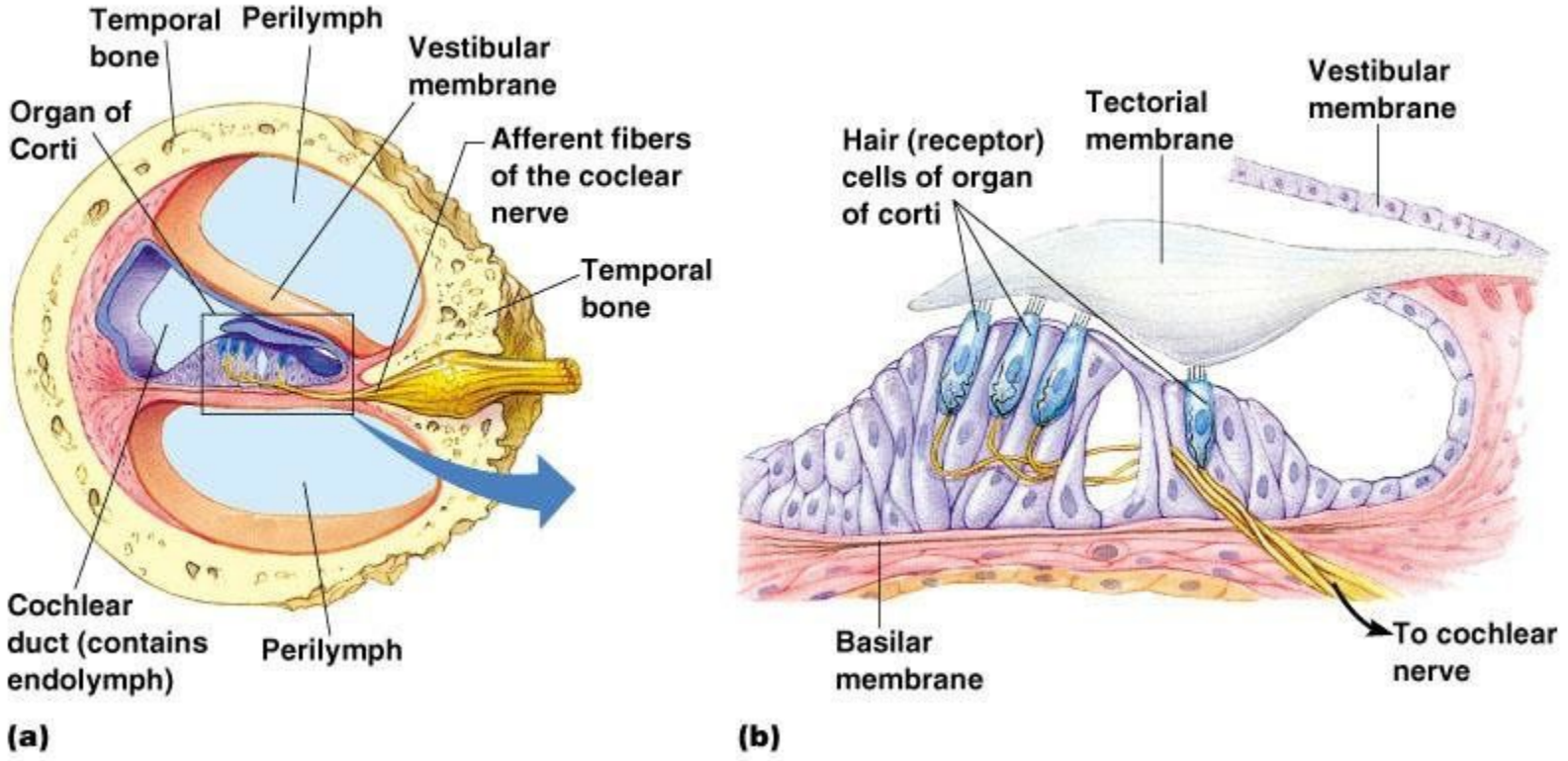
By: Jason Chen

Anatomy of the Ear

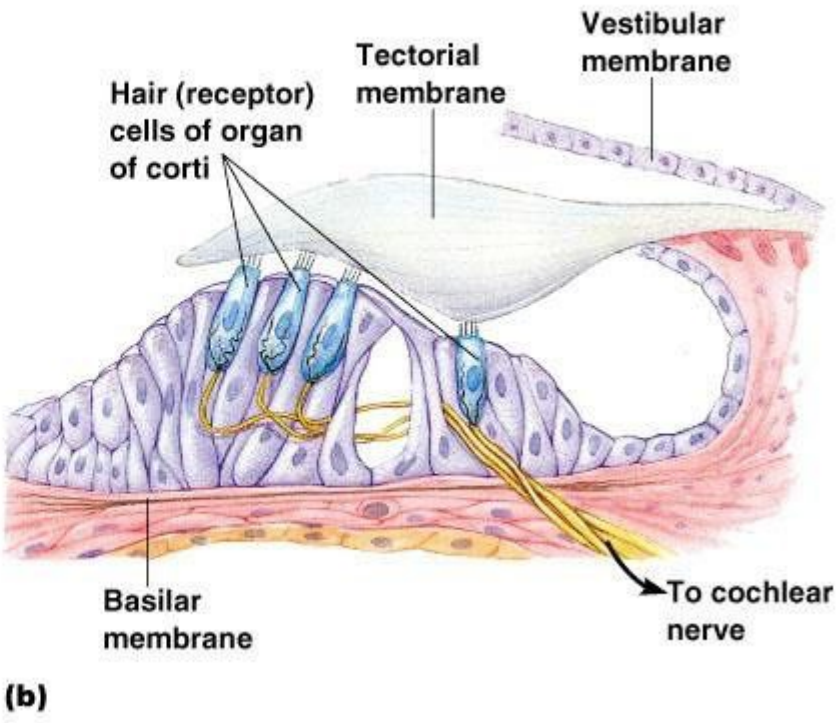


- Pinna -- Outer ear
- Tympanic Membrane -- eardrum, which transfers vibrations to >>
- Ossicles -- 3 smallest bones in body, which transfer vibrations to >>
- Oval window -- a membrane at the base of the upper chamber of >>
- Cochlea -- snail-shaped (coiled) tube with 3 fluid-filled chambers

Organ of Corti

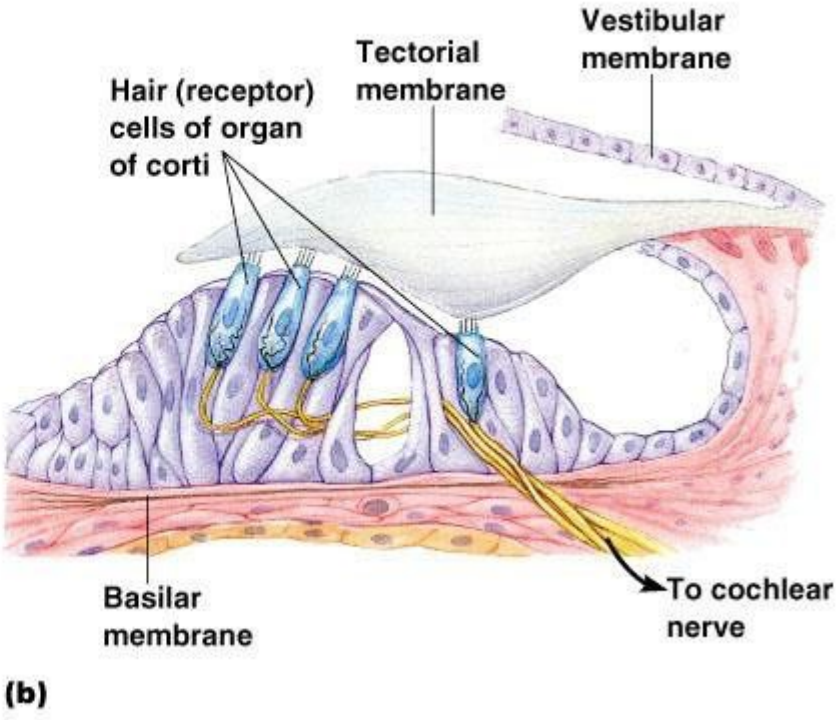


Organ of Corti



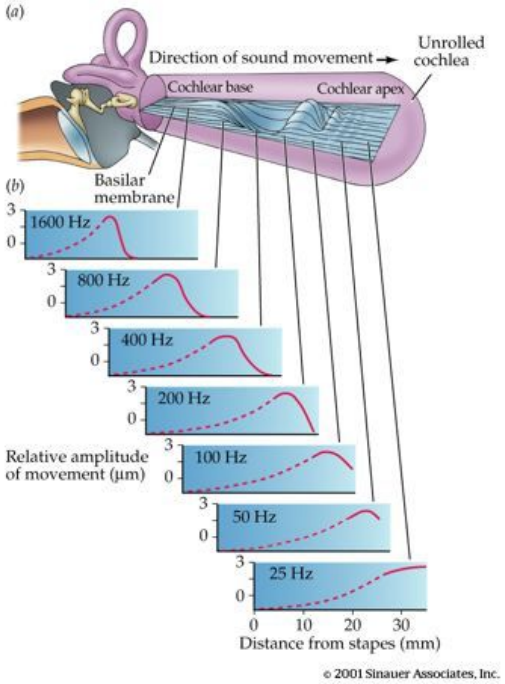
- A structure in the cochlea of the inner ear which produces nerve impulses in response to sound vibrations
- The floor is Basilar Membrane, the ceiling is Tectorial membrane
- The auditory receptor cells, hair cells, are located between these two membranes
- Filled with a viscous, non-compressible, K+ rich fluid called endolymph

Organ of Corti



- Vibration causes Basilar Membrane to move up and down and Tectorial Membrane to move left and right
- Cilia of Hair Cells bend, when toward longest cilium, **K+ GATES OPEN**
- Na+ **NOT** involved
- K+ in >> Ca ++ in, NT out
- **Graded** response

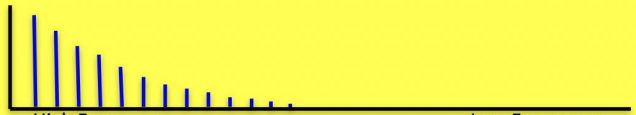
Place Coding



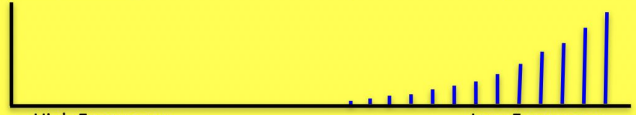
- The **BASE** of the basilar membrane is narrow and stiff >> resonates to **HIGH** frequencies
- The **APEX** of the basilar membrane is wide and floppy >> resonates to **LOW** frequencies
- The more the Basilar Membrane resonates, the farther it moves >> the farther the Cilia will bend >> more NT release
- The **DISTRIBUTION** of NT release along Basilar Membrane that codes for Frequency

Place Coding

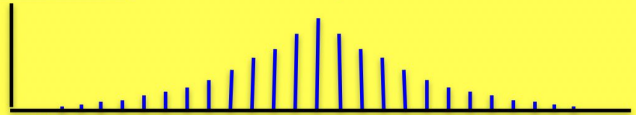
High frequency sound = more response from Base than Apex



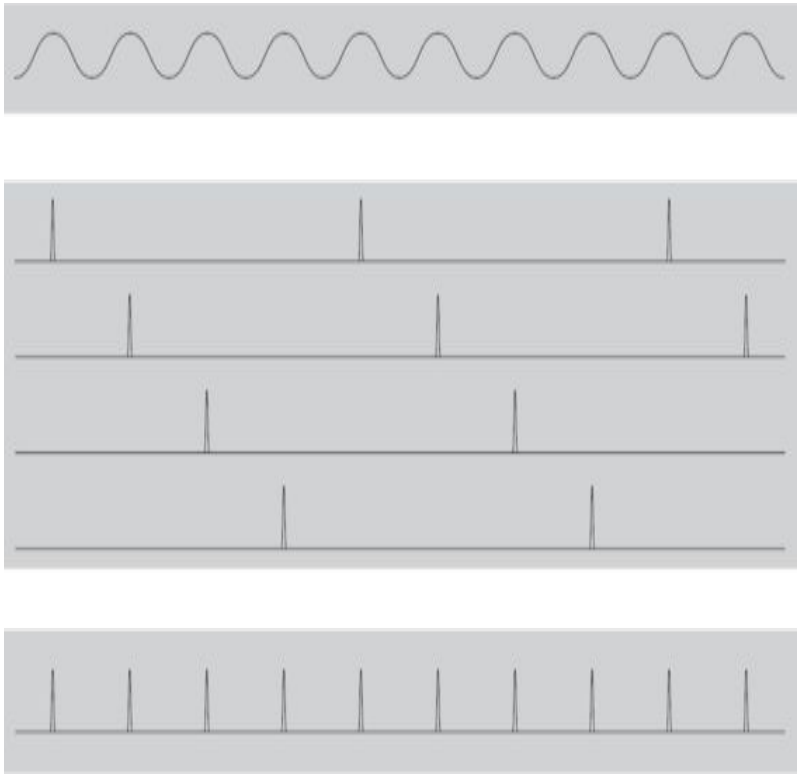
Low frequency sound = more response from Apex than Base



Mid frequency sound = more response from Mid-Membrane

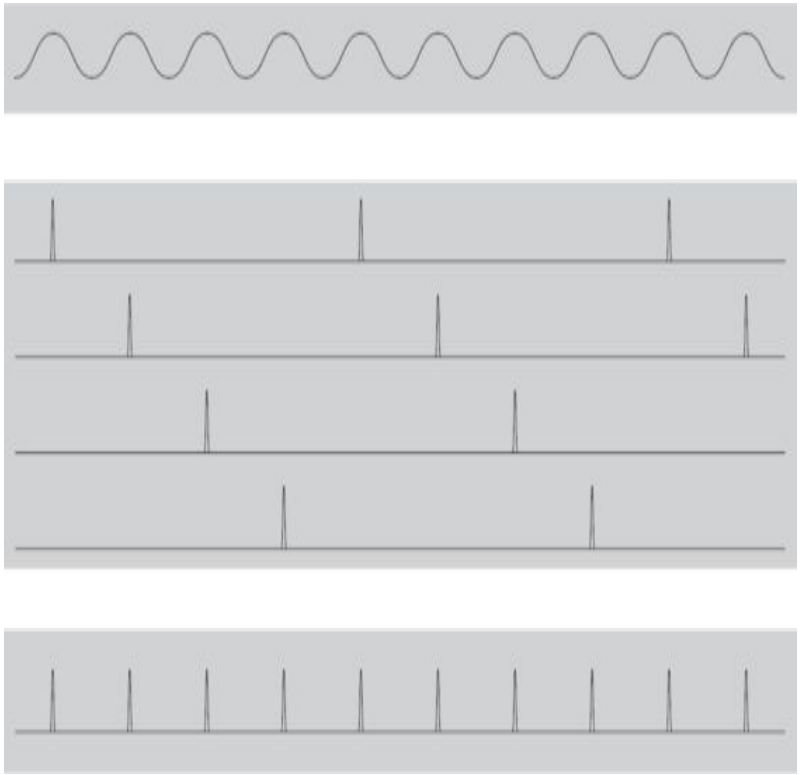


Temporal Coding



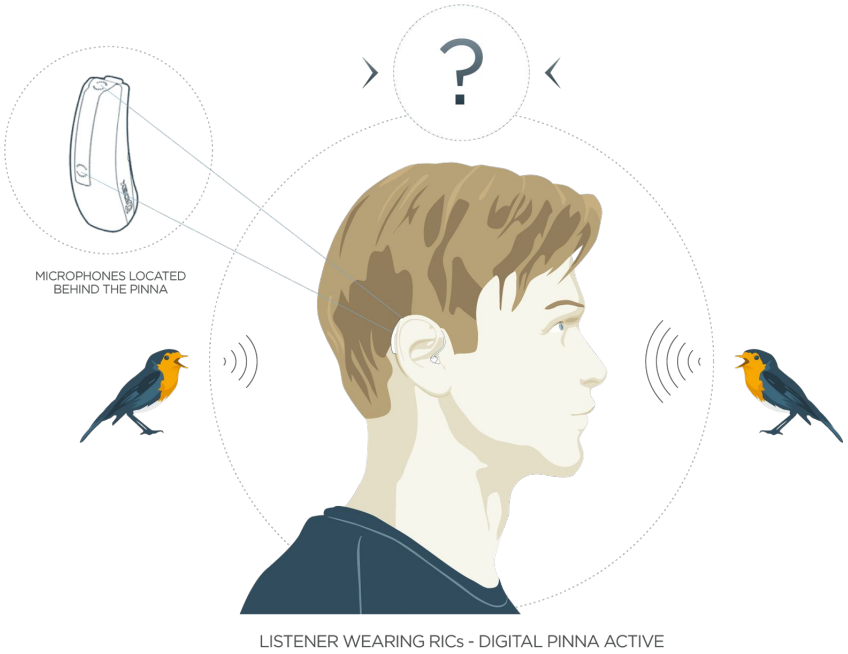
- The whole basilar membrane will vibrate at the rate of input
- However, Hair Cells communicate to Spiral Ganglions, which fire **ACTION POTENTIAL**, which limits the rate spiral ganglions can fire
- Maximum frequency ~1000 Hz
- Solution: Volley Principle -- No single Ganglion cell can code for a high rate, but a group of them working together can

Temporal Coding



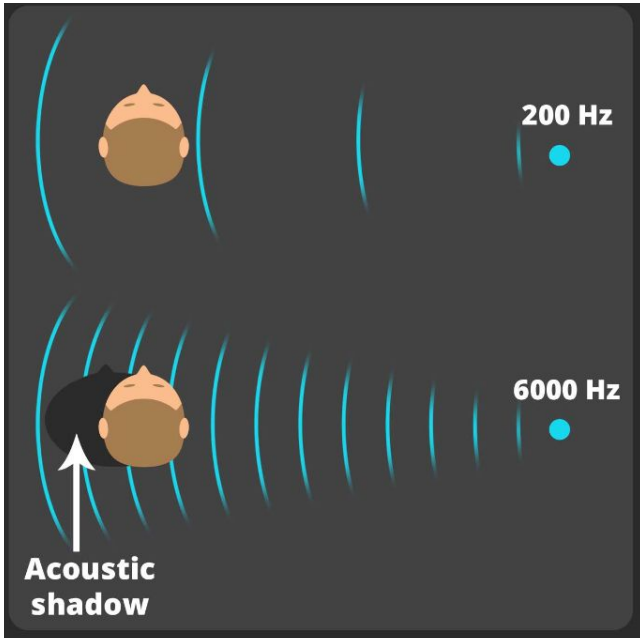
- Depends on Ganglions being **Phase Locked**
- The Ganglions can only fire at the same phase (e.g. peak) of the input frequency even when it is ready to fire
- These volleys occur at a rate that corresponds to the rate of the input
  frequency

Localization



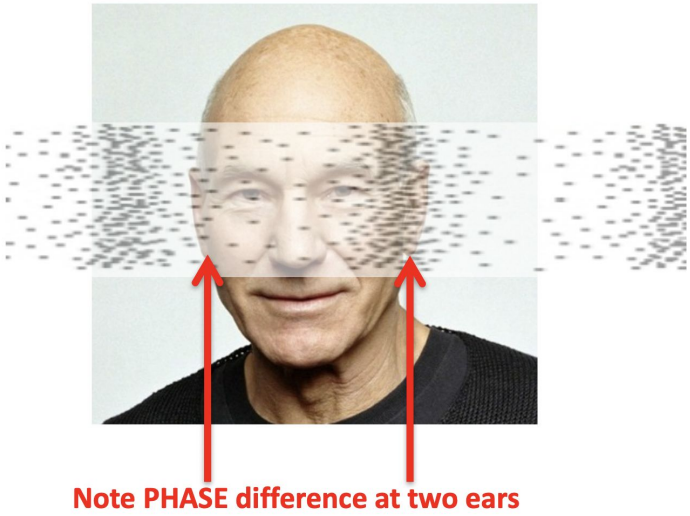
- Localization can use **Intensity** differences, **phase** differences, or **timing** differences to the two ears

Localization via Intensity differences



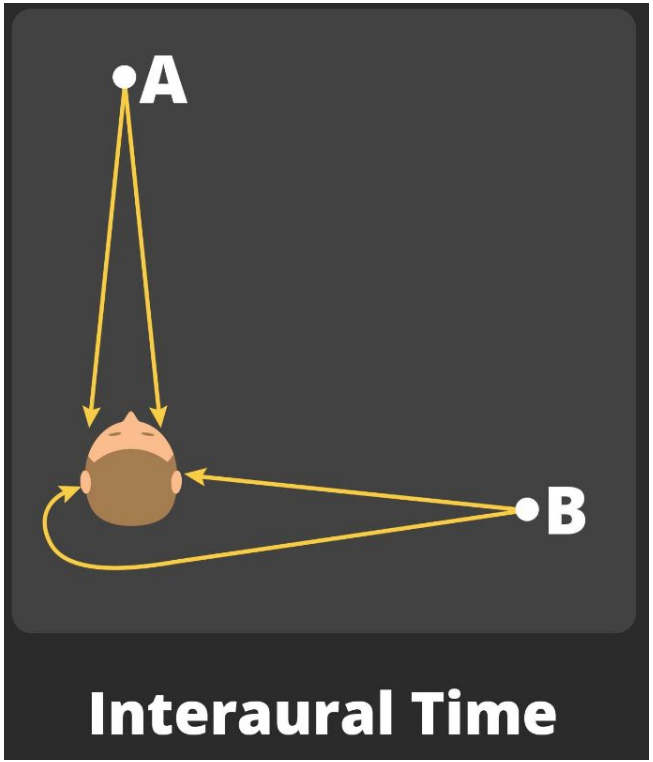
- Sound at ear closer to source is slightly more intense than at other ear, because of the head shadow
- Works best for **higher** frequencies, since these most likely to be absorbed by head

Localization via phase differences



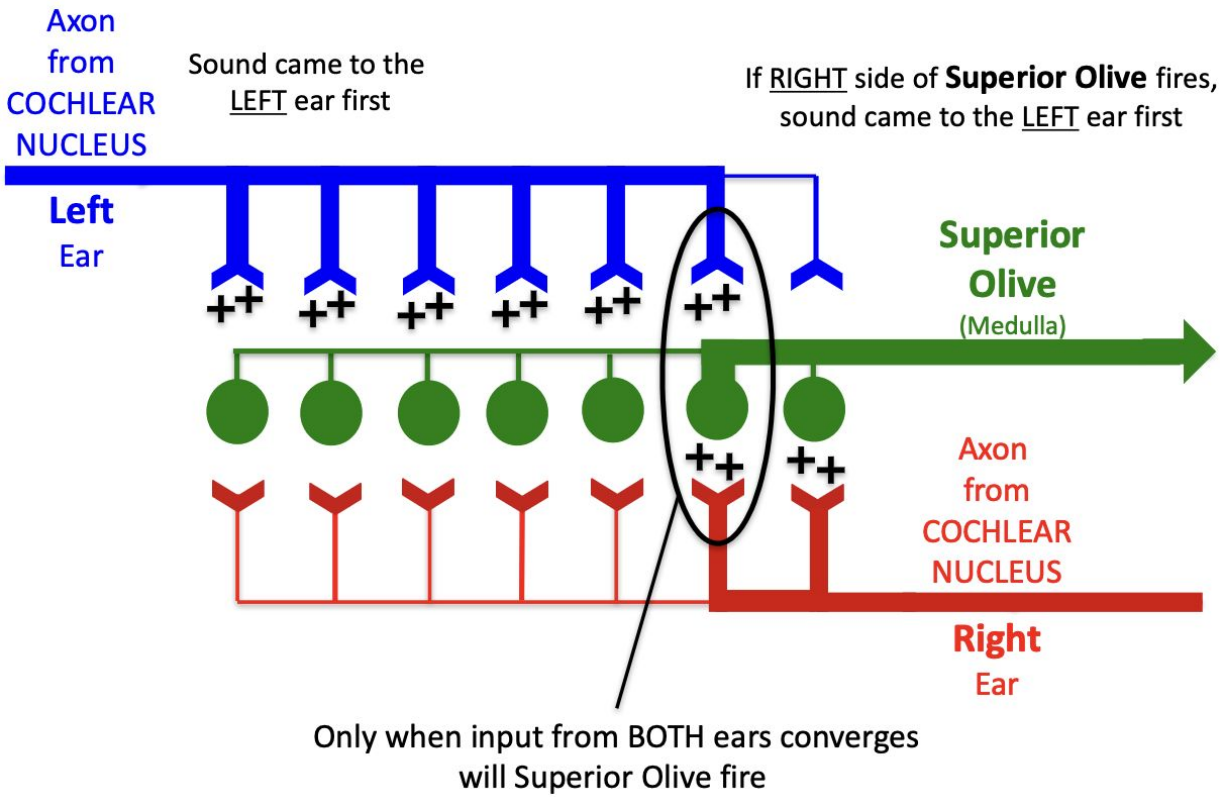
- For **lower** frequencies (longer wavelength), can detect difference in peak vs. trough of wave reaching two ears

Localization via Timing Differences

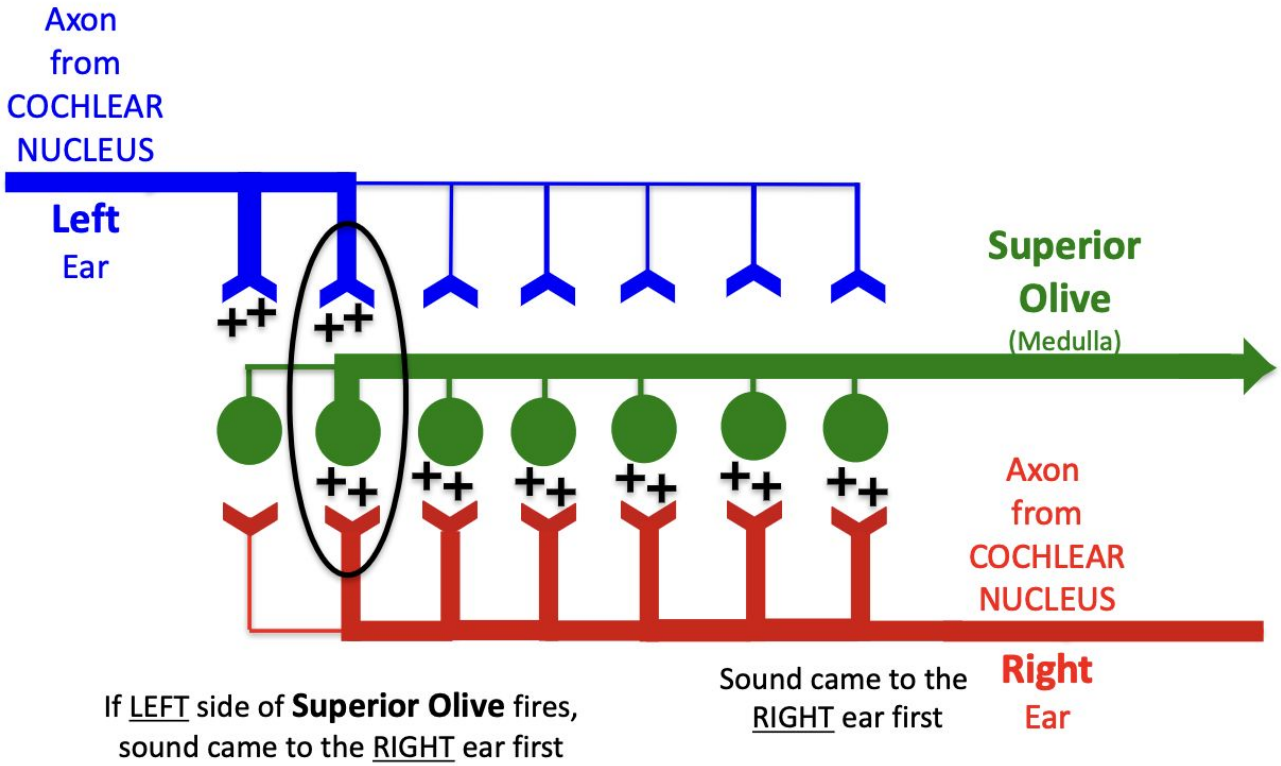


- Onset signals race to same Superior Olive nucleus; Signal travels on axon with a branch to each Superior Olive cell in array

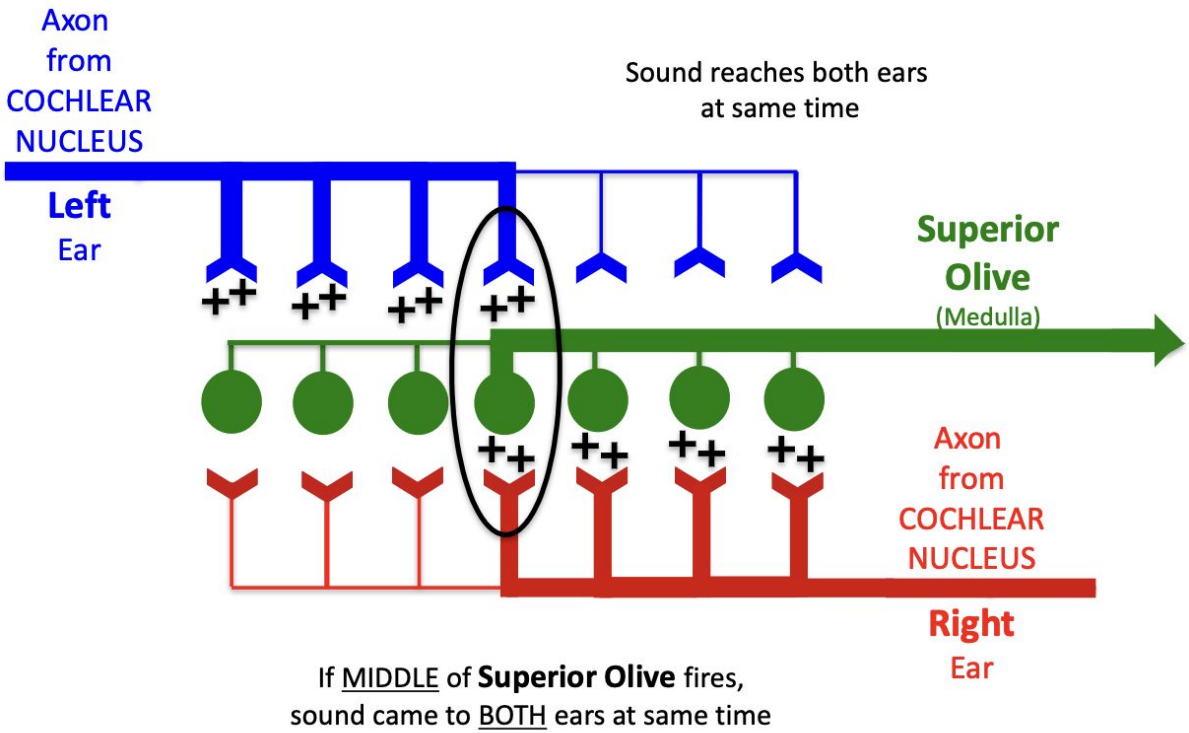
Localization via Timing Differences



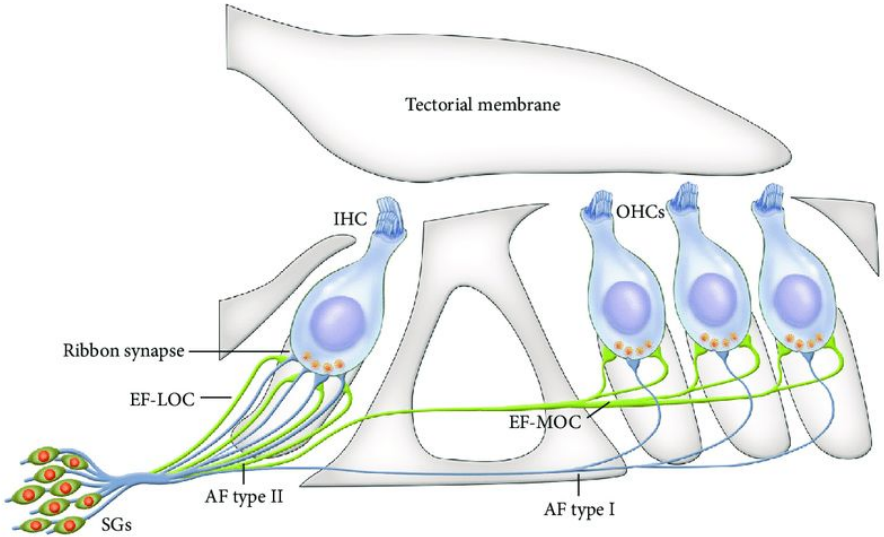
Localization via Timing Differences



Localization via Timing Differences

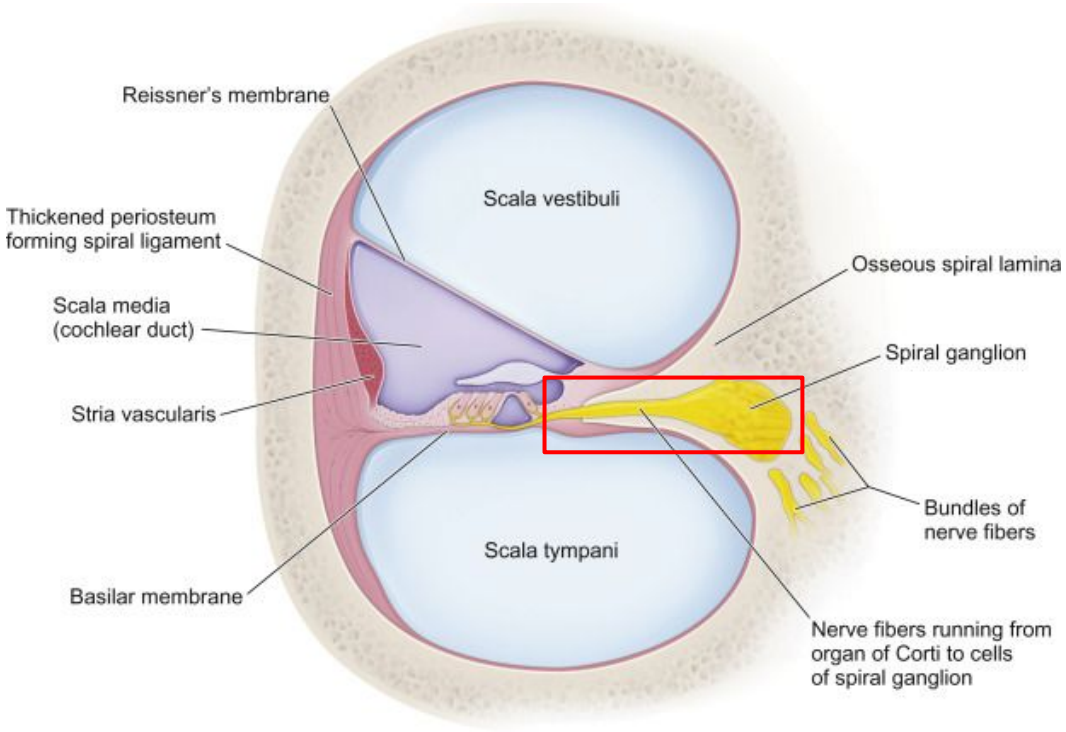


Auditory Pathways -- Hair Cells



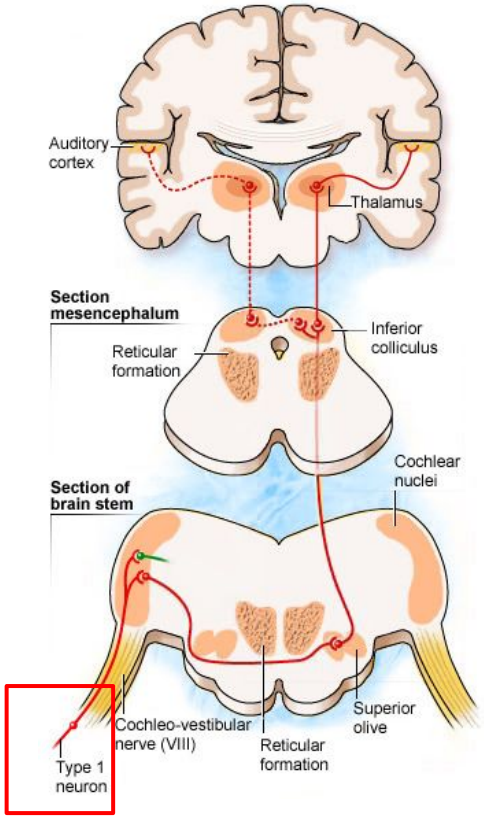
- Two types of hair cells
- Inner hair cells -- divergent connectivity, better for details
- Outer hair cells -- convergent connectivity, better for amplitude
- >> Spiral Ganglions

Auditory Pathways -- Spiral Ganglion



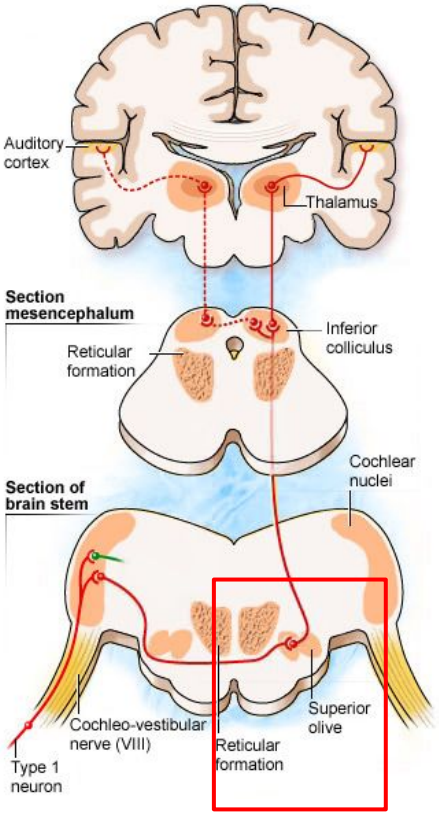
- Axons of which form Auditory Nerve
- >> Cochlear Nucleus

Auditory Pathways -- Cochlear Nucleus



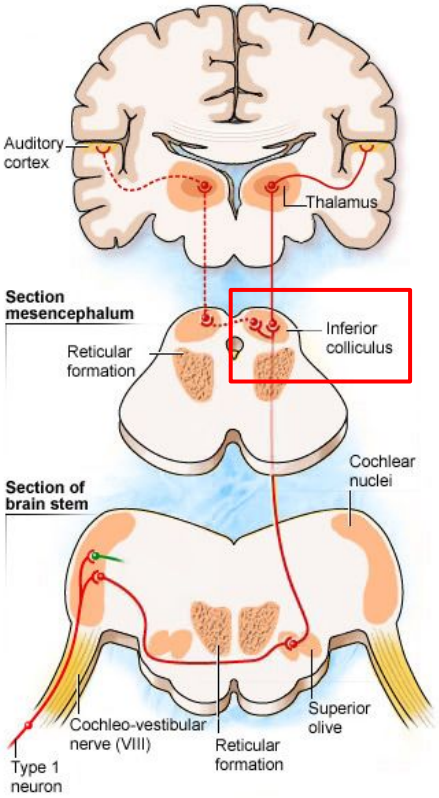
- In medulla
- Monaural site (Left Cochlear Nucleus receives from left ear only, right from right only)
- Each Spiral Ganglion synapses on multiple cochlear nucleus cells
- Different types of cochlear nucleus cells: primary-like, build-up, onset, phaser
- >> Superior Olive

Auditory Pathways -- Superior Olive



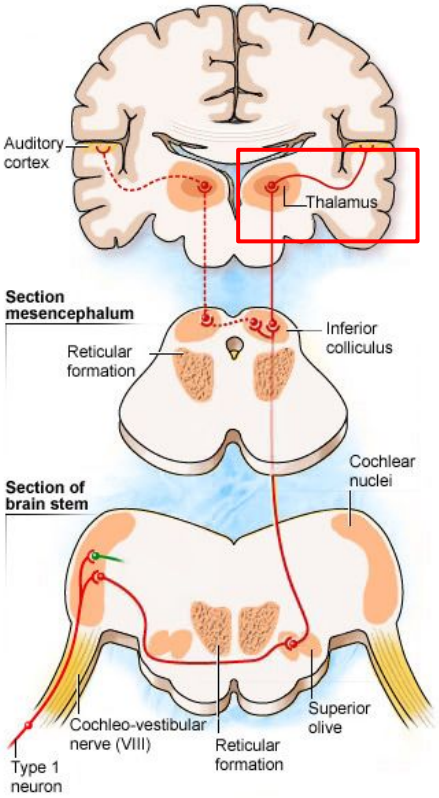
- In medulla
- Some Cochlear Nucleus axons cross-over to contralateral Superior Olive, others to ipsilateral
- First **binaural** site along pathway
- Critical for localization
- >> Inferior Colliculus

Auditory Pathways -- Inferior Colliculus



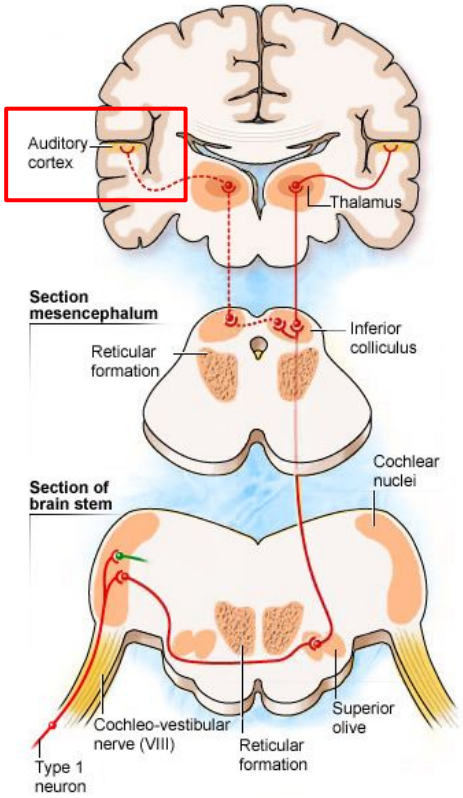
- In tectum of midbrain
- Integrates with visual info in Superior Colliculus, help map source of sight/sound
- >> Thalamus

Auditory Pathways -- Thalamus



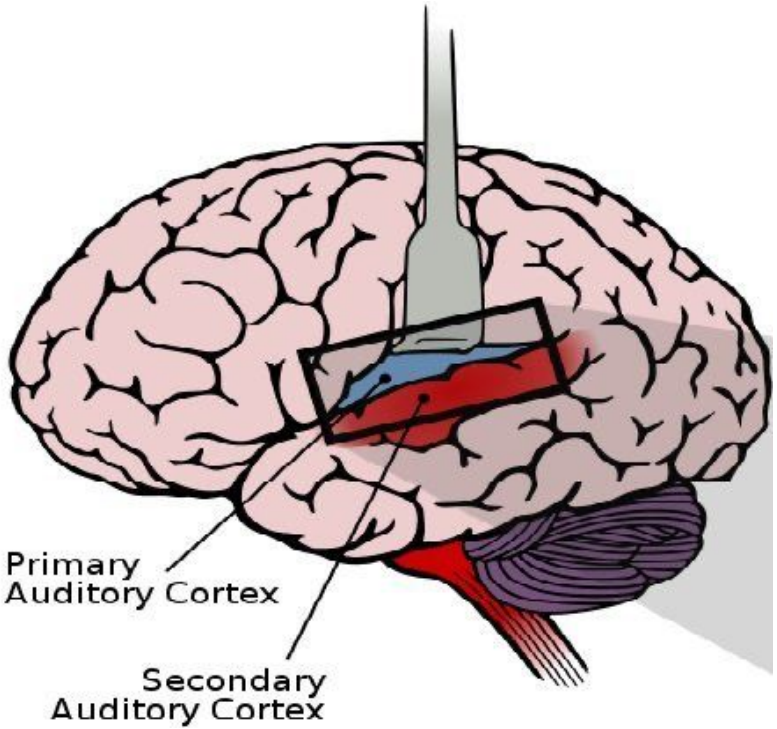
- Medial Geniculate Nucleus (MGN)
- Includes Topological Maps
- Topological Maps -- Cells that respond to highest frequencies next to cells that respond to medium-high, next to medium, etc.
- >> Auditory Cortex

Auditory Pathways -- Auditory Cortex

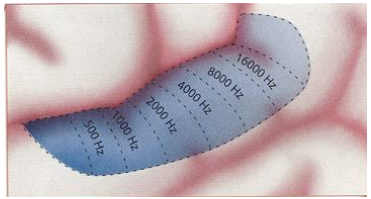


- A1 (Primary Auditory Cortex, along Lateral Sulcus of Temporal Cortex)
- A2 (Secondary Auditory Cortex, also in Temporal Lobe)

A1 (Primary Auditory Cortex)

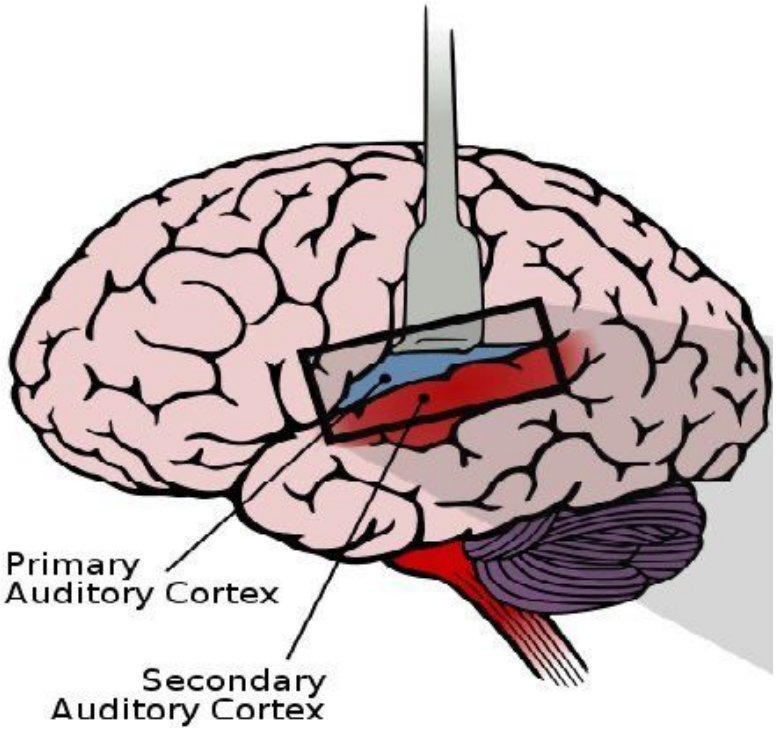


- In **MEDIAL** temporal cortex
- Responsible for Tonotopic/Amplitude Map



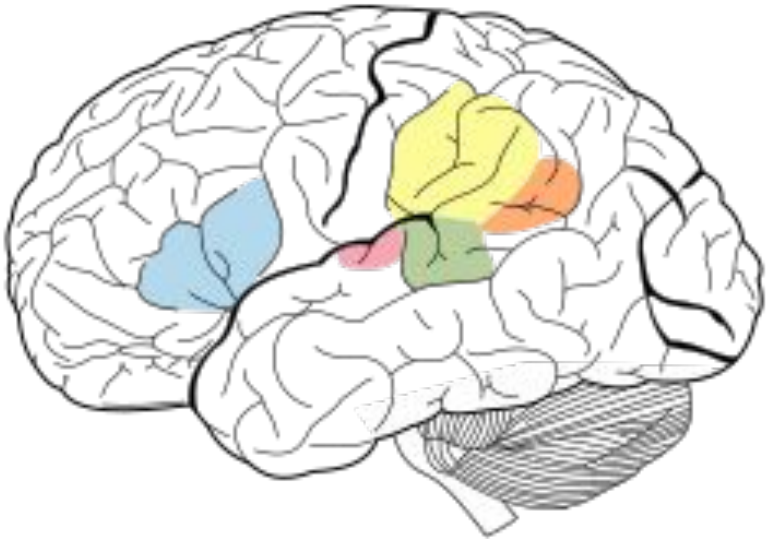
- Some cells respond best to simple (sine-wave) tones, others to more complex sounds (e.g. sounds that change frq)
- Other A1 areas respond per location

A2 (Secondary Auditory Cortex)



- In **MEDIAL** temporal cortex
- Most respond best to complex sounds (familiar noises, speech sounds)
- >> Higher Auditory

Auditory Pathways -- Higher Auditory



- Processes complex patterns; Integrates auditory input with other perceptual and cognitive activity
- Example: Wernicke’s Area - Specialized for comprehending SPEECH
- Damage to Wernicke’s area -- Wernicke’s aphasia

Questions?

Office Hours: Mon 5-6 pm

To get the section slides:
https://github.com/JasonC1217/COGS17_A04_Wi24

OR: