Hearing in the Environment

(Chapter 10)

Lecture 17

Jonathan Pillow
Sensation & Perception (PSY 345 / NEU 325)
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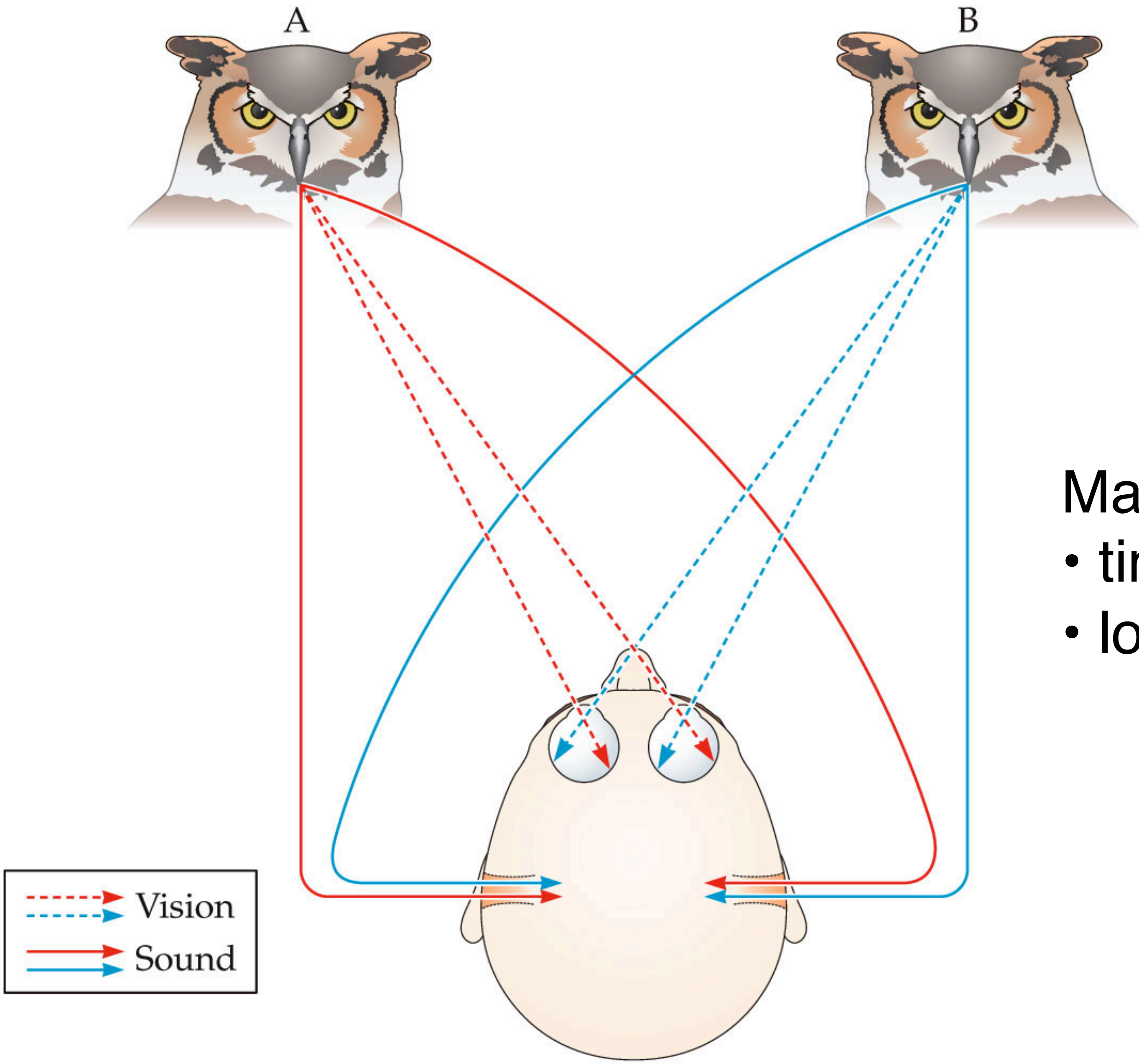
Q: How do you detect the location of a sound?



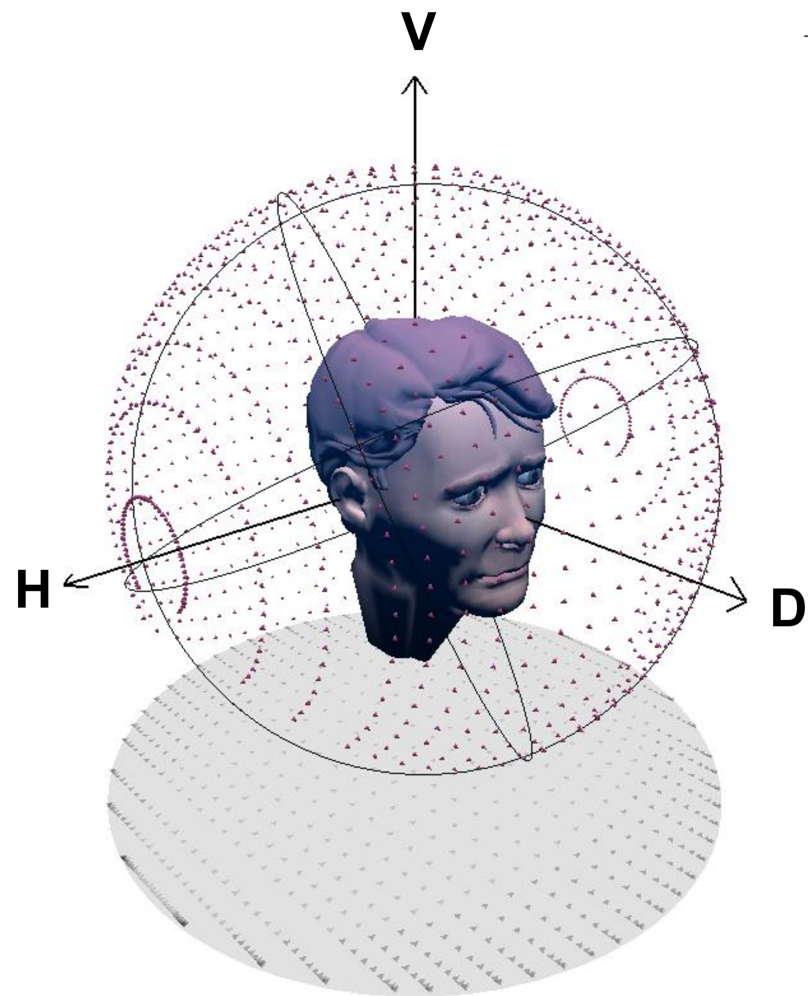
Position detection by the visual and auditory systems

Main answer:

- timing differences
- loudness differences

3 coordinates:

- Horizontal (azimuth)
- Vertical (elevation)
- Distance



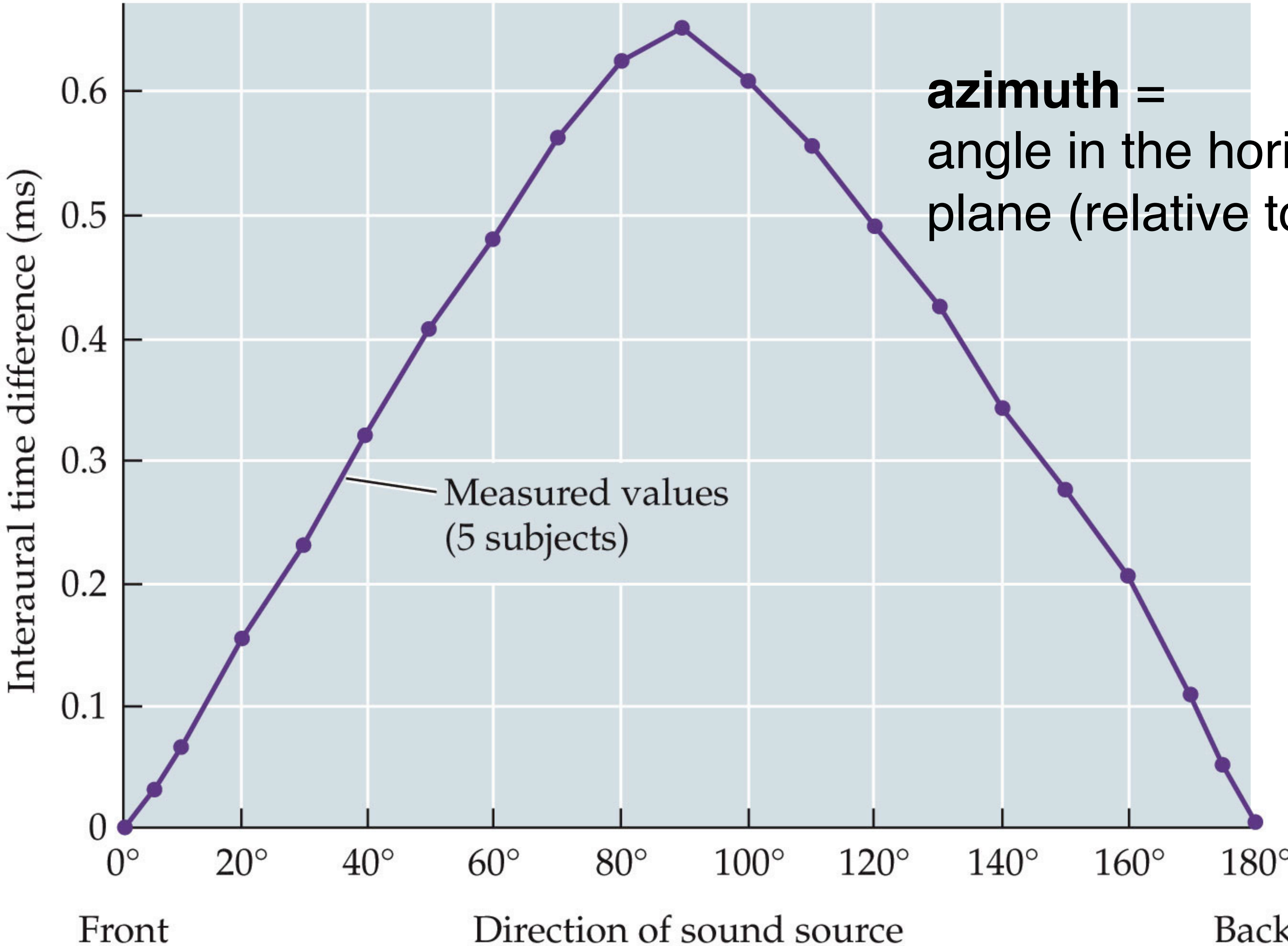
The sound at microphone #1 will:
-be ***more intense***
-arrive ***sooner***

Sound Localization

First Cue: timing

Interaural time differences (ITD): The difference in time between a sound arriving at one ear versus the other

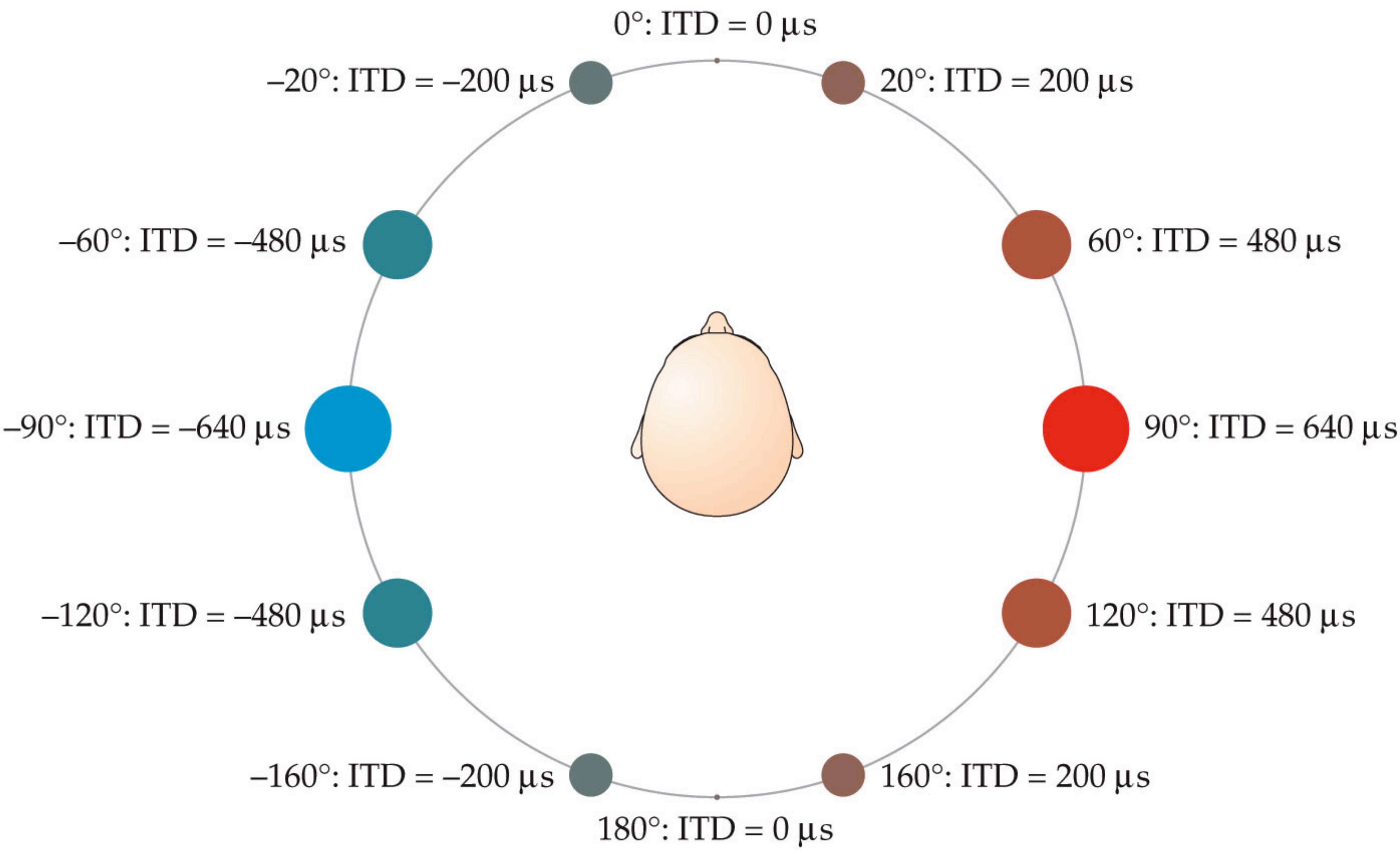
Interaural time differences for sound sources varying in azimuth



azimuth =
angle in the horizontal plane (relative to head)

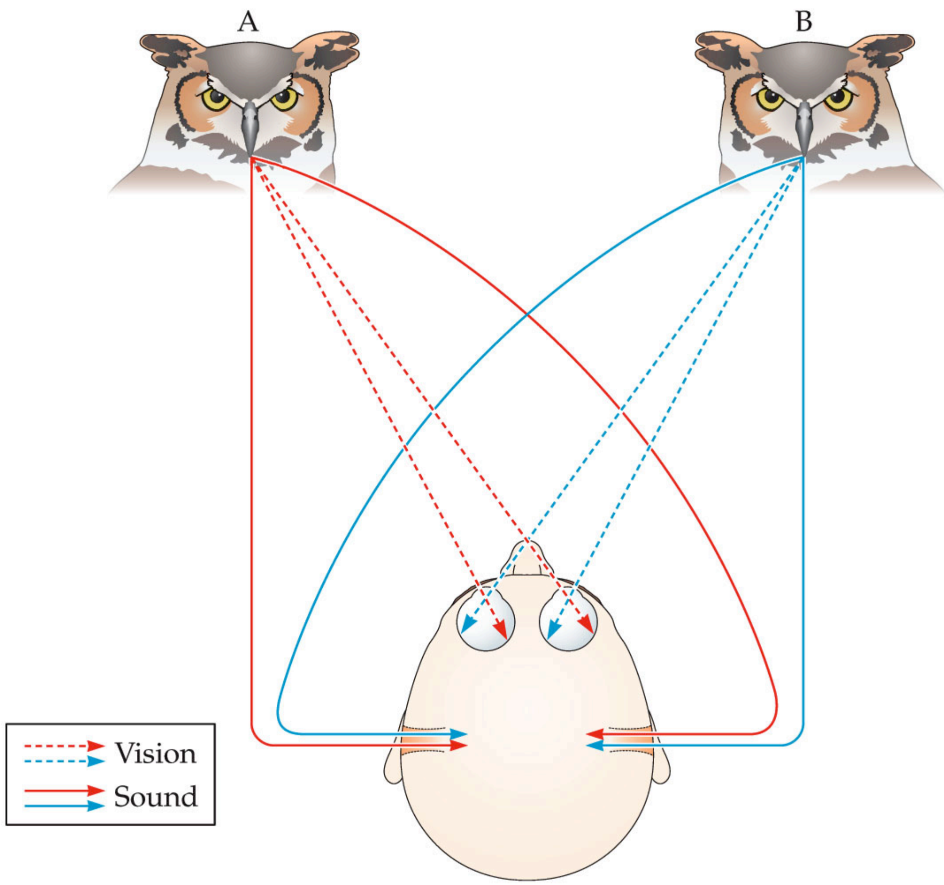
azimuthal angle

Interaural time differences for different positions around the head



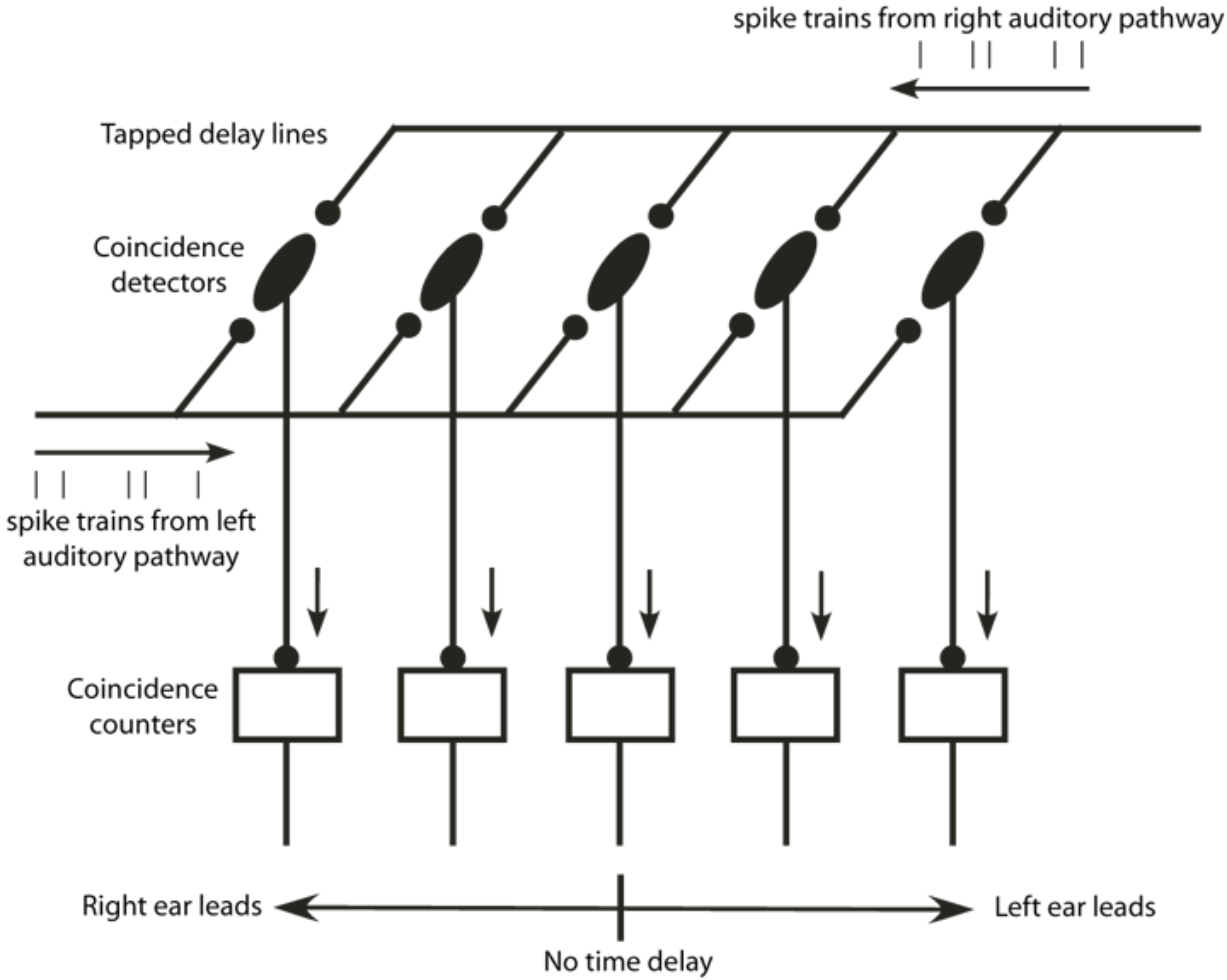
Q: how would you design a system to detect inter-aural time differences?

(Think back to Reichardt detector)



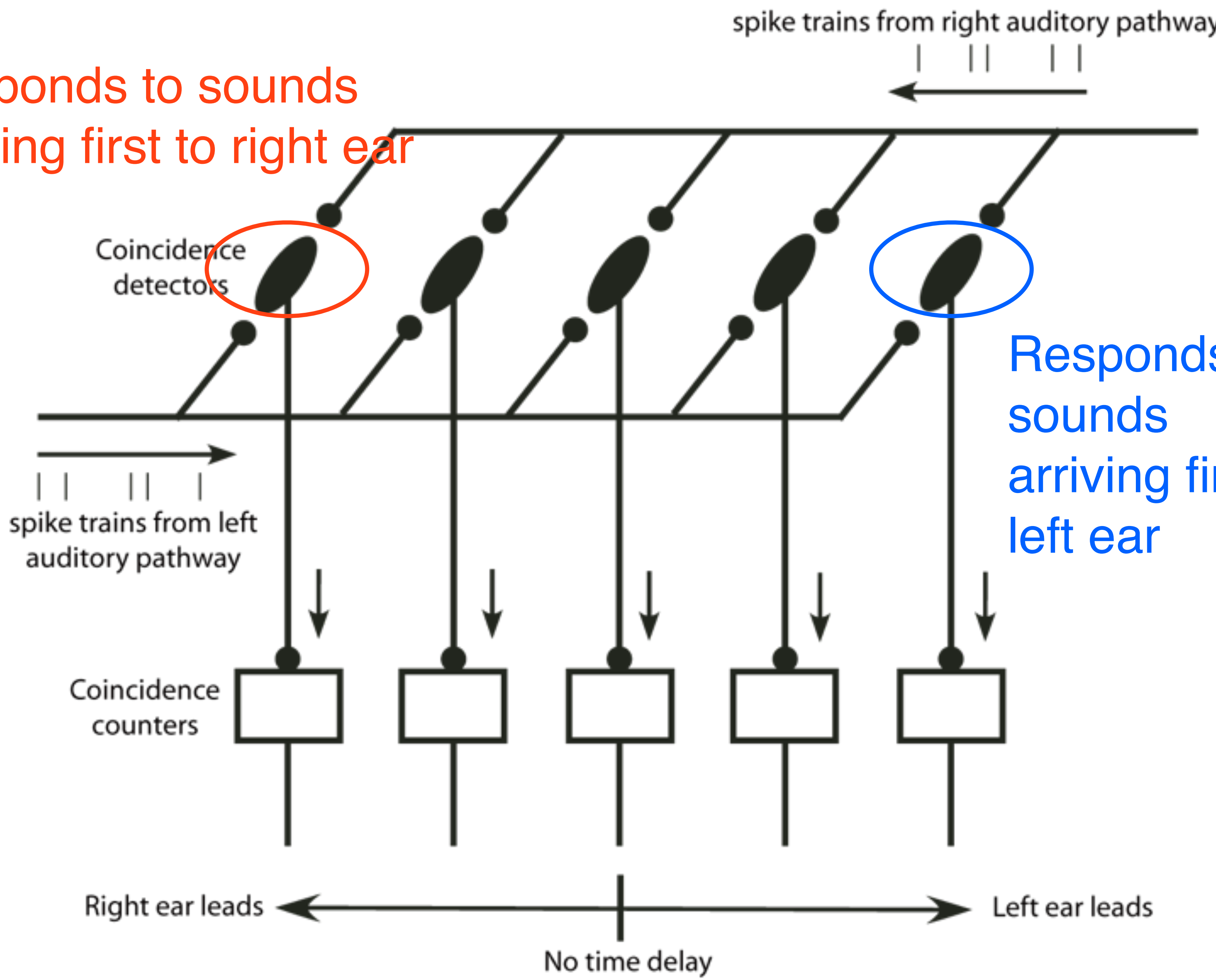
Hint: “delay lines”

Jeffress Model



Jeffress Model

Responds to sounds arriving first to right ear



Responds to sounds arriving first to left ear

Physioloy of ITD processing

- **Medial superior olive (MSO)**:
- ITDs processed (first place where binaural information combined)
- form connections during the first few months of life
- interpretation of ITD changes with age (as head grows, ears get further apart!)

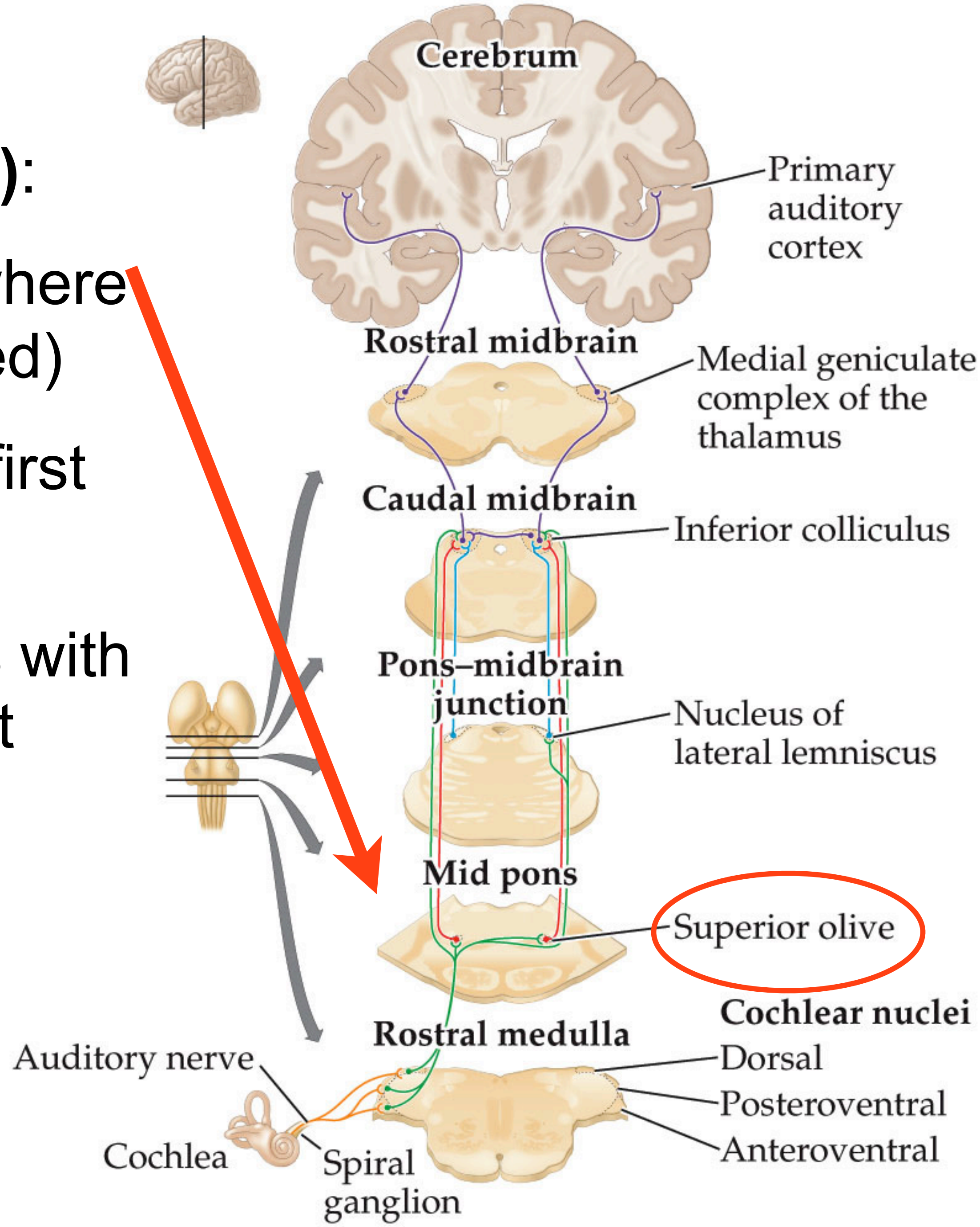
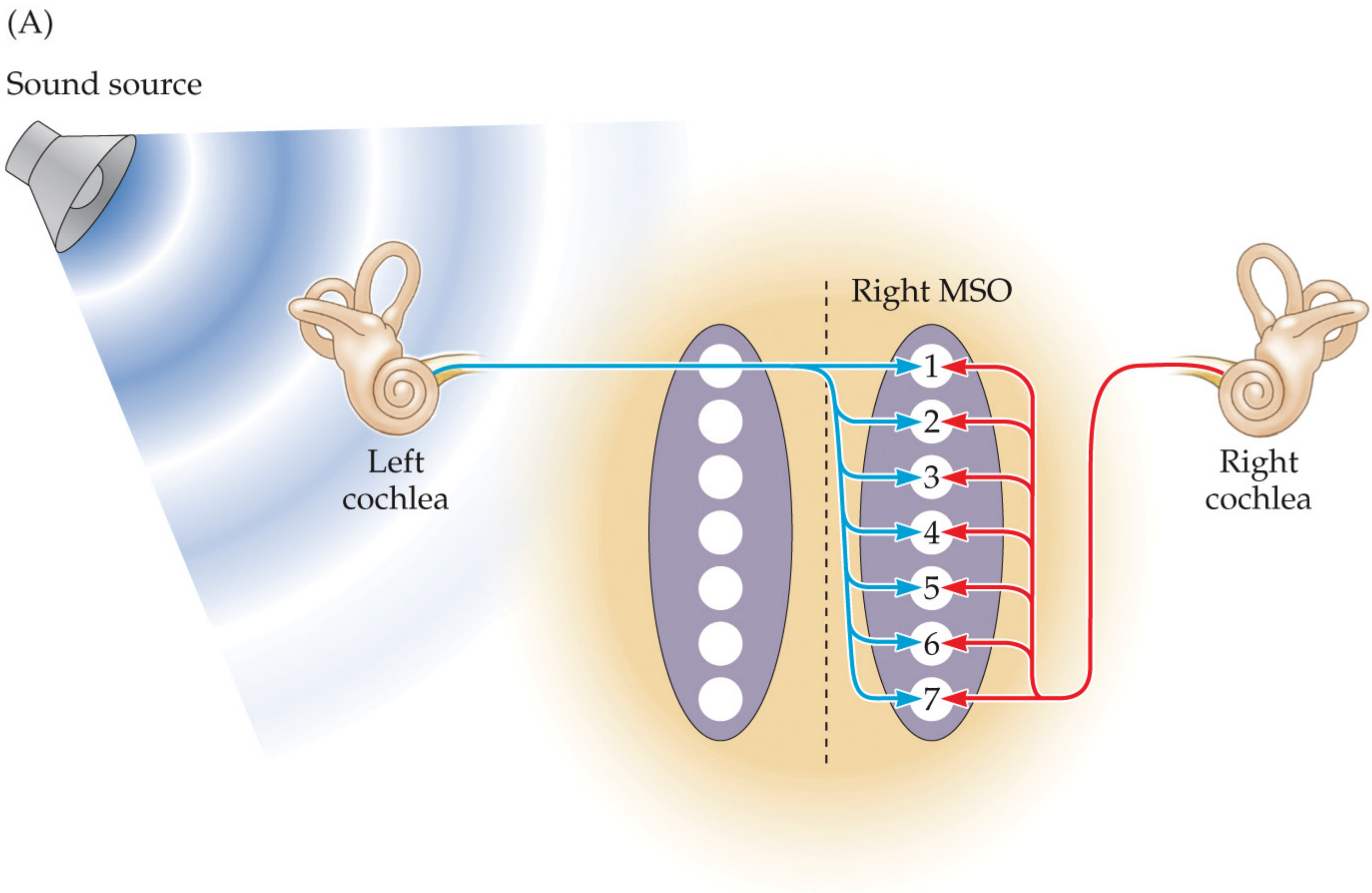
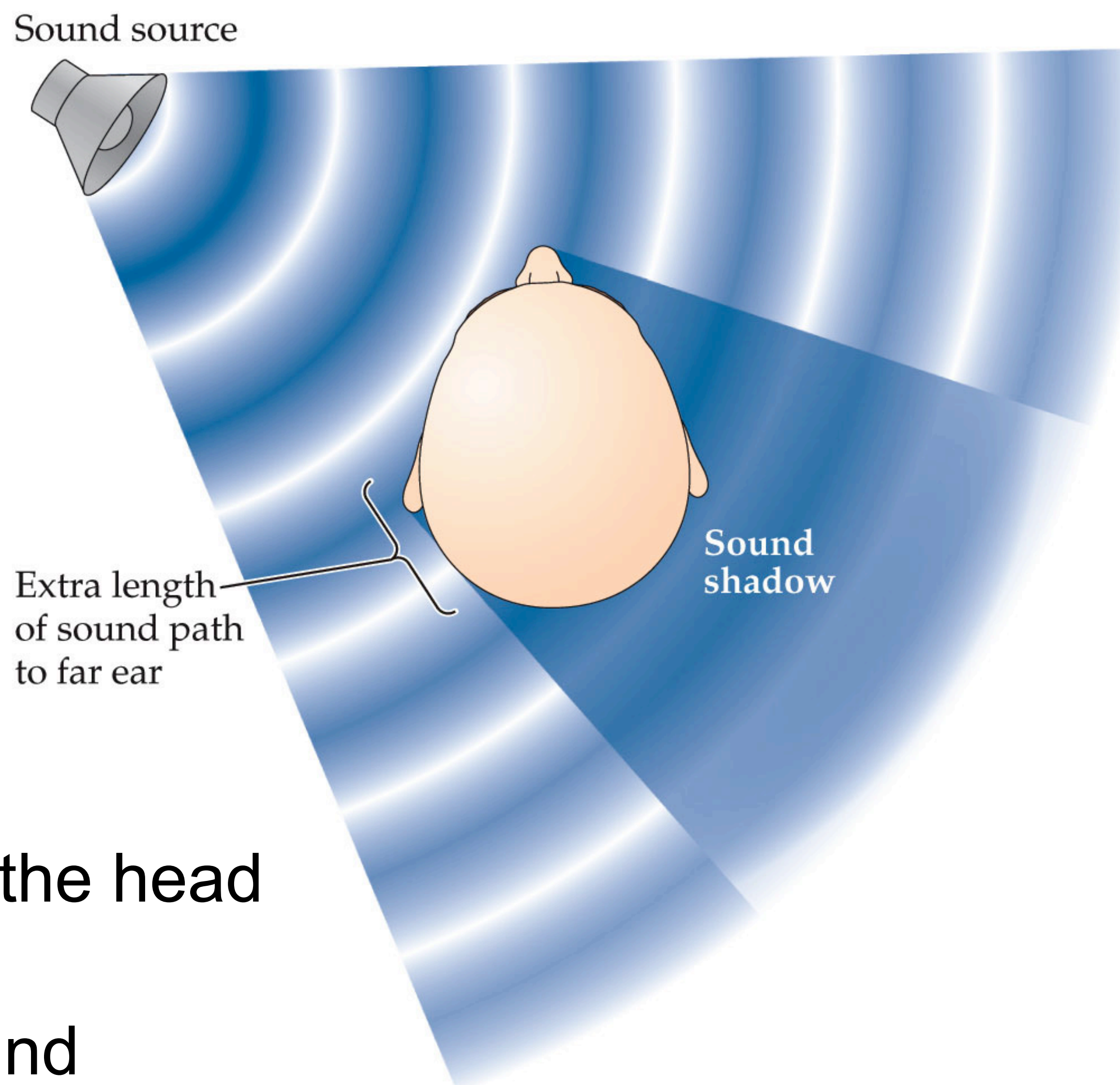


Figure 10.7 Models for the way neurons in the medial superior olive (MSO) can detect time difference between two ears (Part 1)



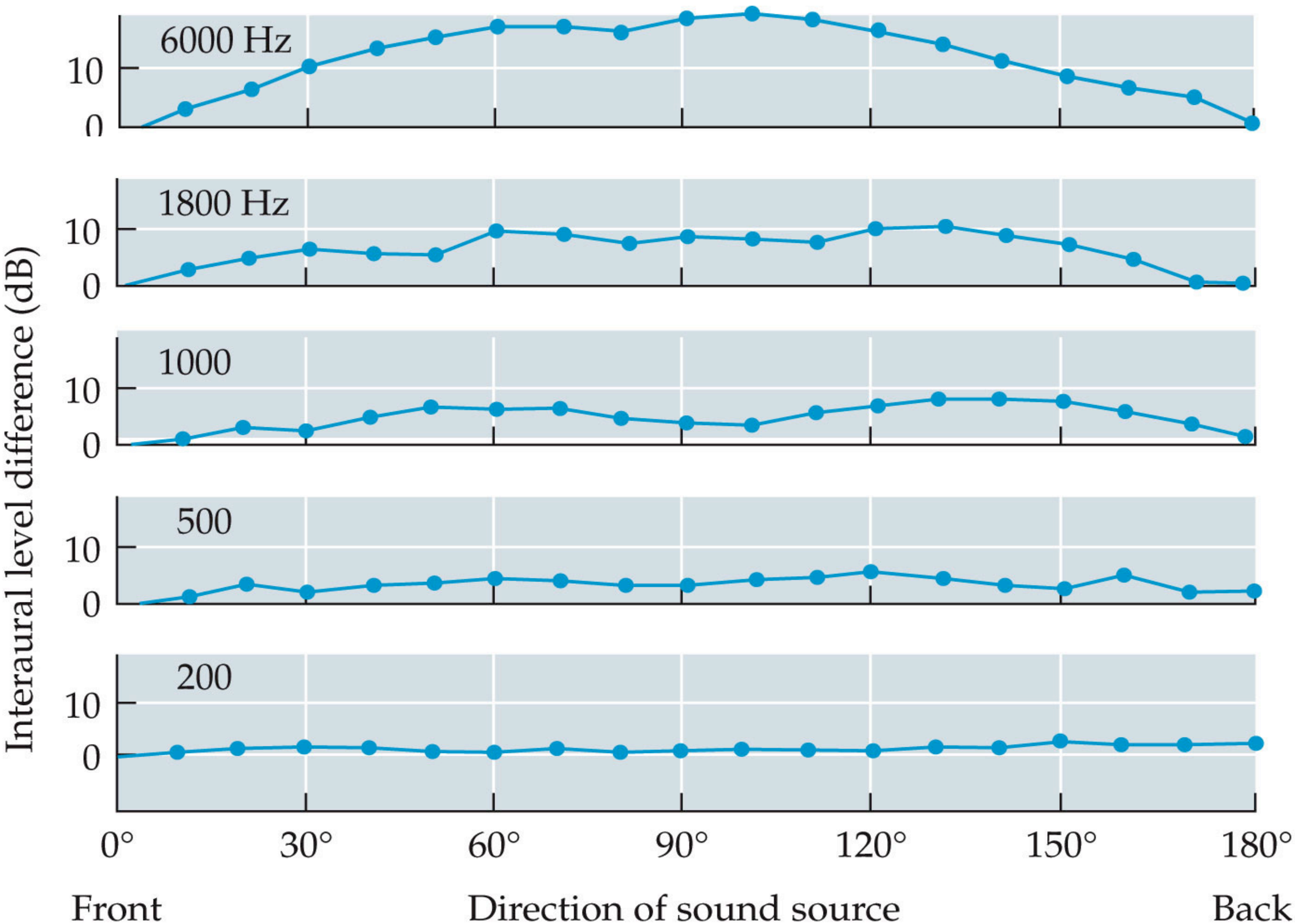
Second cue: Loudness (or "level") differences (ILDs)

ILD: difference in level (intensity) between a sound arriving at one ear versus the other

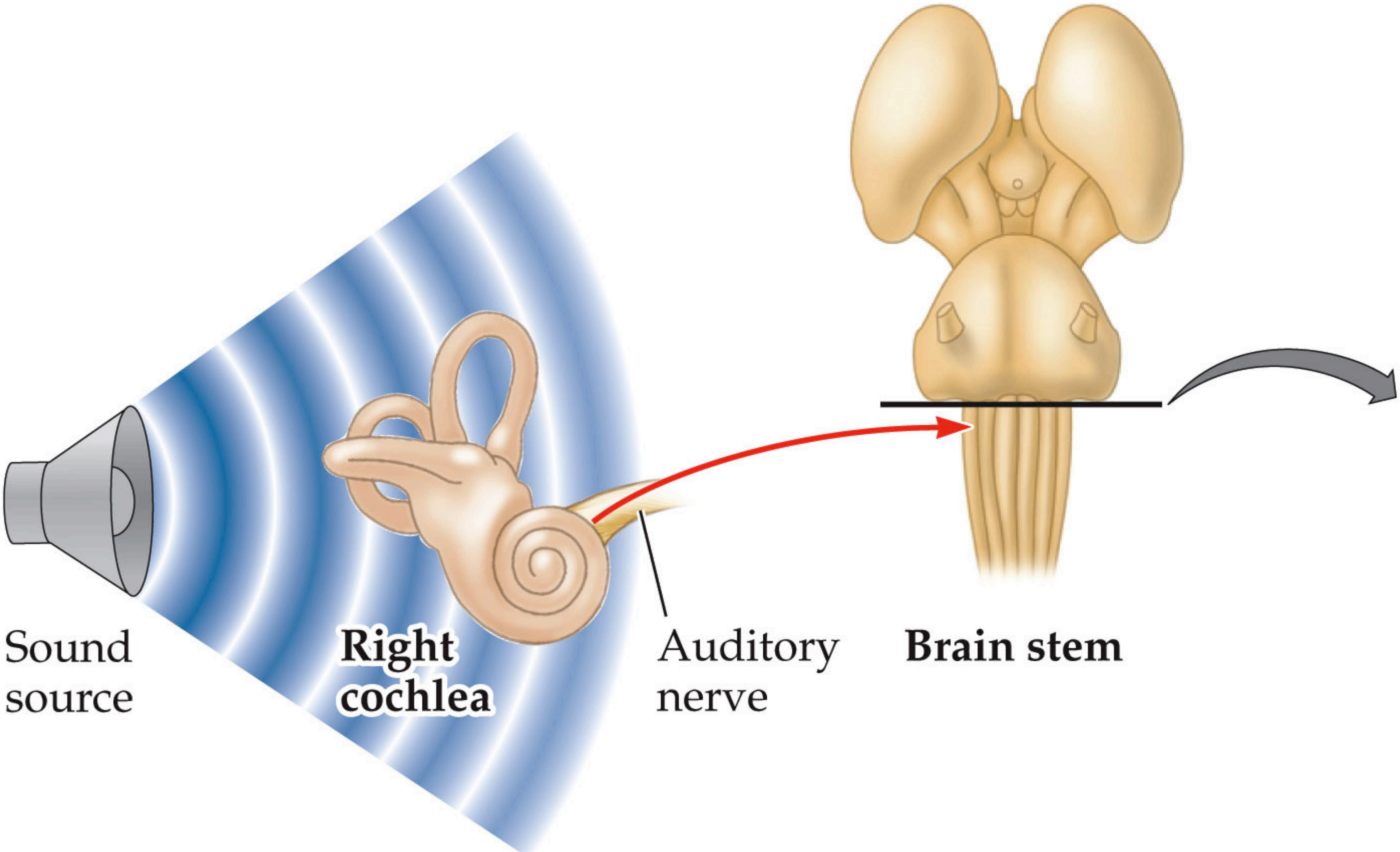


- For frequencies >1000Hz, the head blocks some energy
- correlates with angle of sound source, but not quite as reliable as with ITDs

ILDs for tones of different frequencies



Lateral superior olive (LSO): relay station in the brainstem where inputs from both ears contribute to detection of ILDs



After a single synapse, information travels to medial and lateral superior olive

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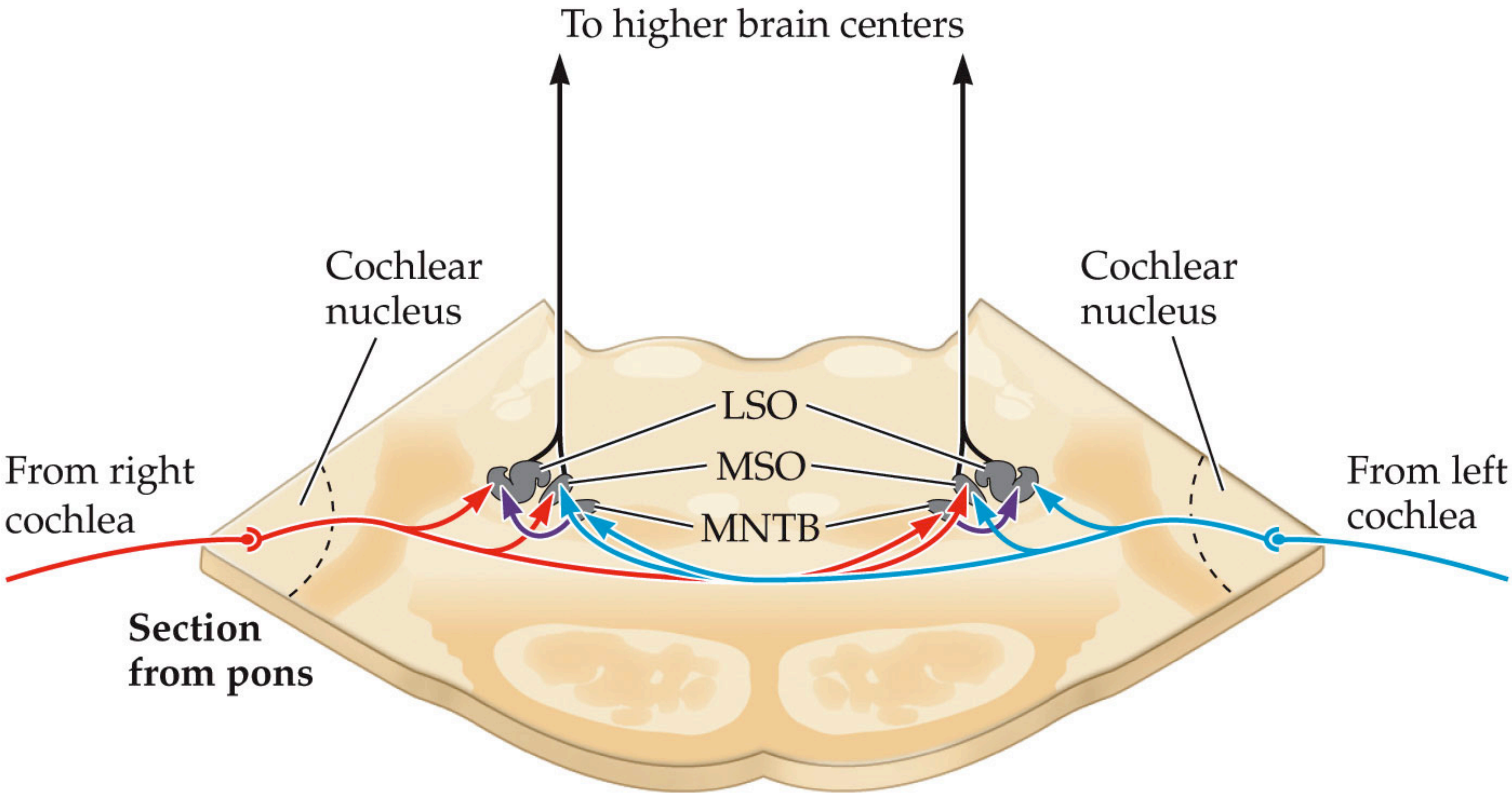
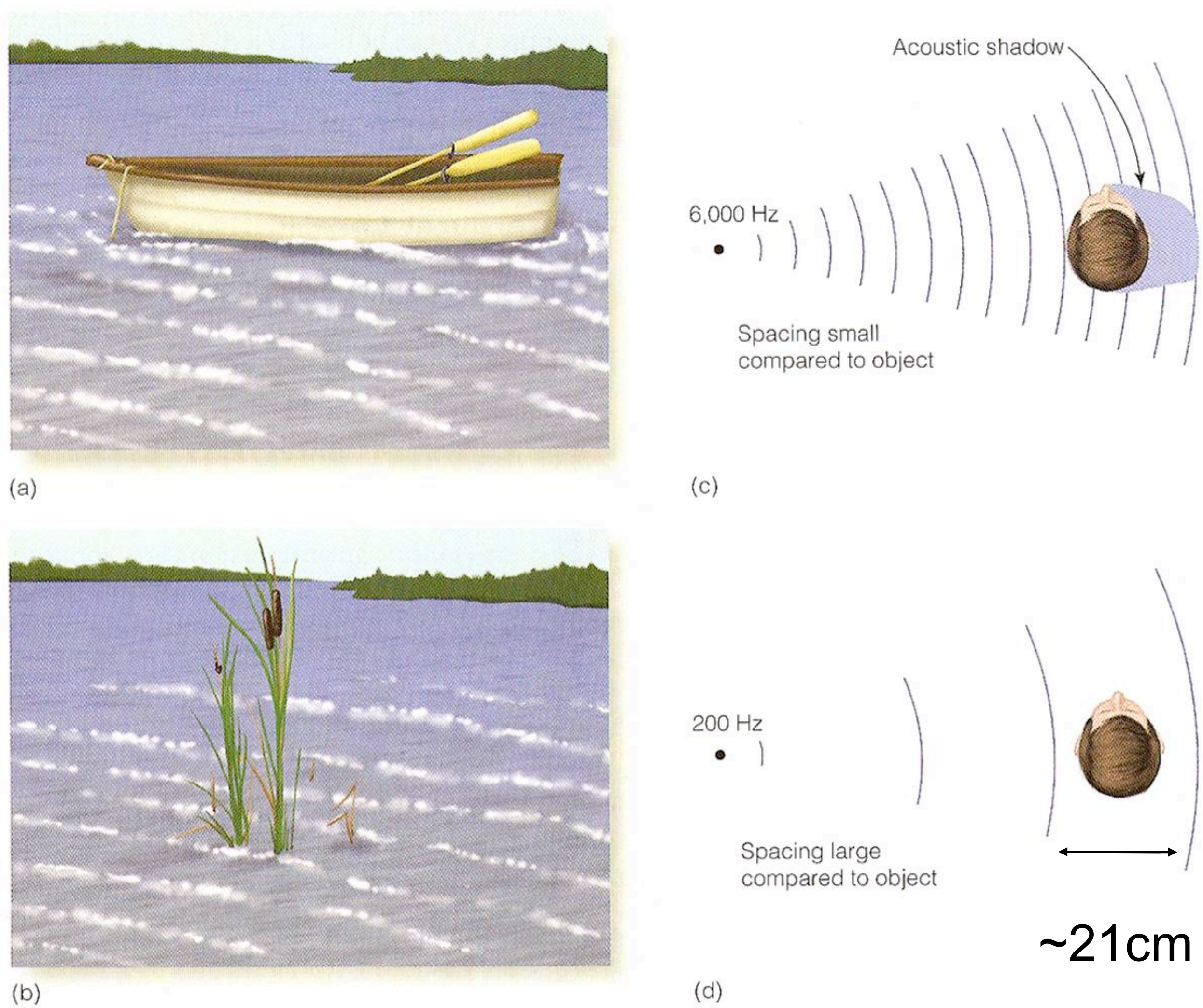


Auditory Localization Demo
(try with headphones)

https://oup-arc.com/access/content/sensation-and-perception-5e-student-resources/sensation-and-perception-5e-activity-10-1?previousFilter=tag_chapter-10

Why 2 cues?



High frequencies

>1600 Hz

Low frequencies

<800 Hz

Both cues contribute for 800-1600 Hz

Summary of ITD and ILD

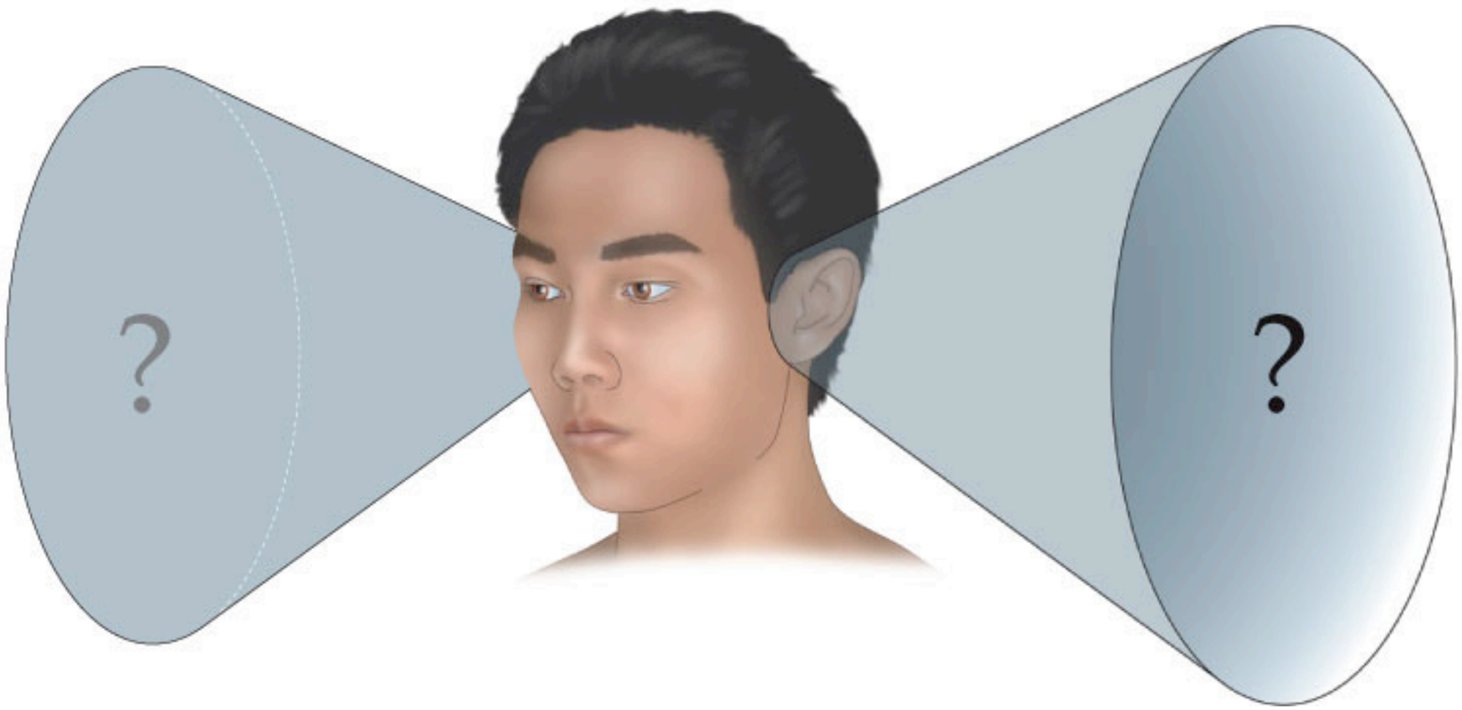
ITD: good for low frequencies (processed in MSO)

ILD: good for high frequencies (processed in LSO)

Problem with using ITDs and ILDs for sound localization:

- **Cone of confusion**: A region of positions in space where all sounds produce the same ITDs and ILDs

(a)

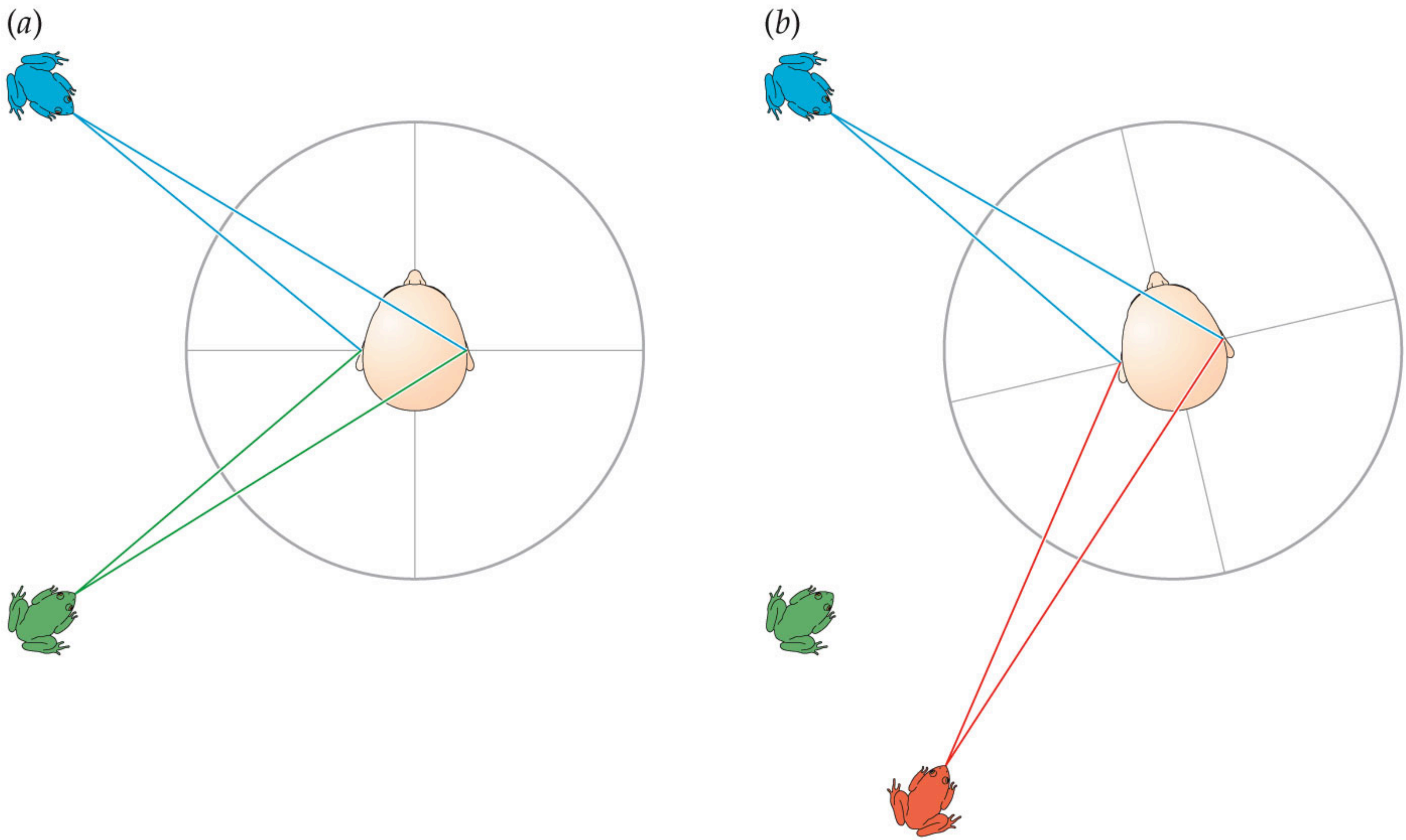


Q: where is the cone of confusion for a point directly in front of your head?

Sound Localization

Overcoming the cone of confusion

- Turning the head can disambiguate ILD/ITD similarity

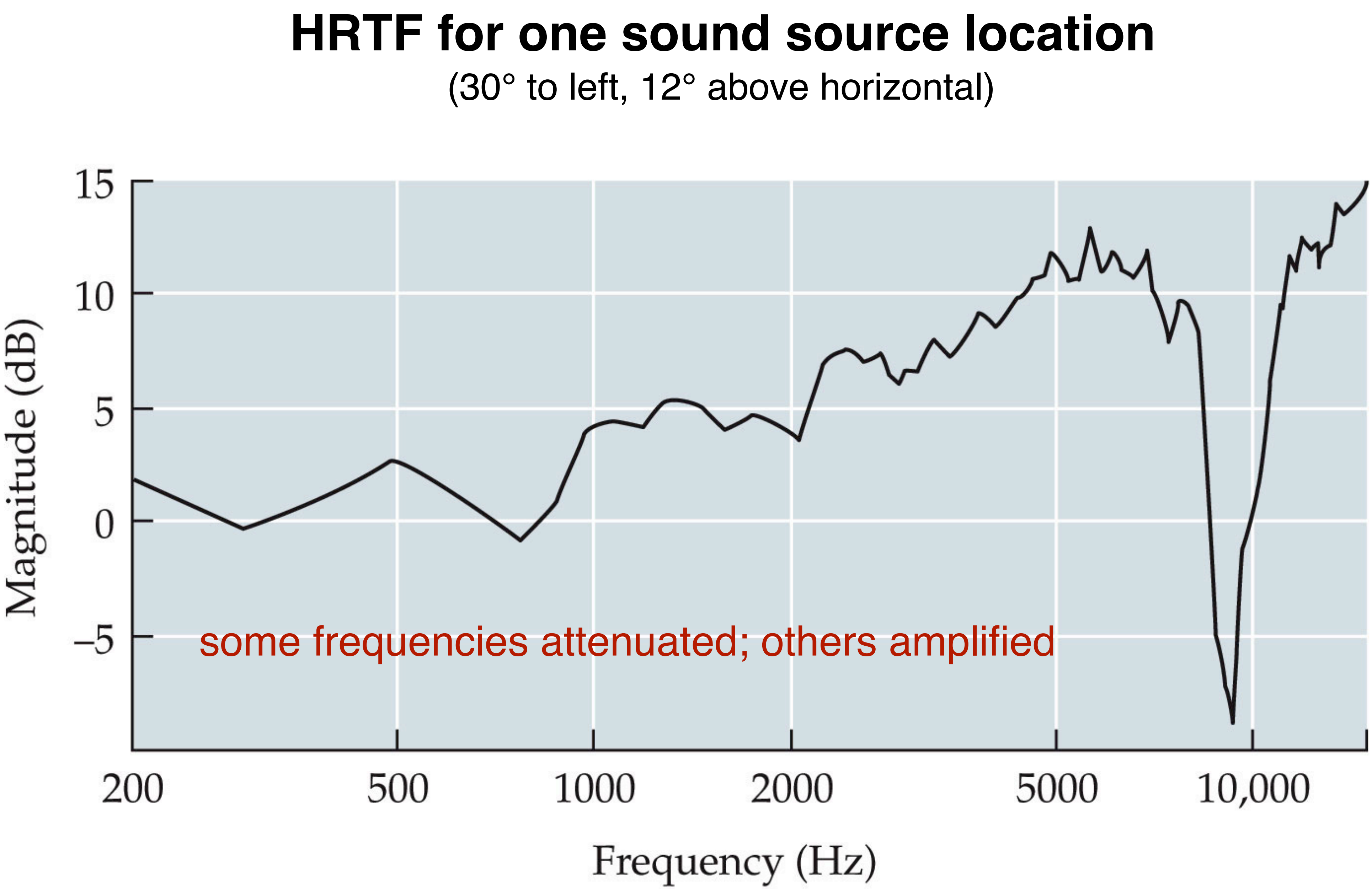


Head-related transfer function (HRTF)

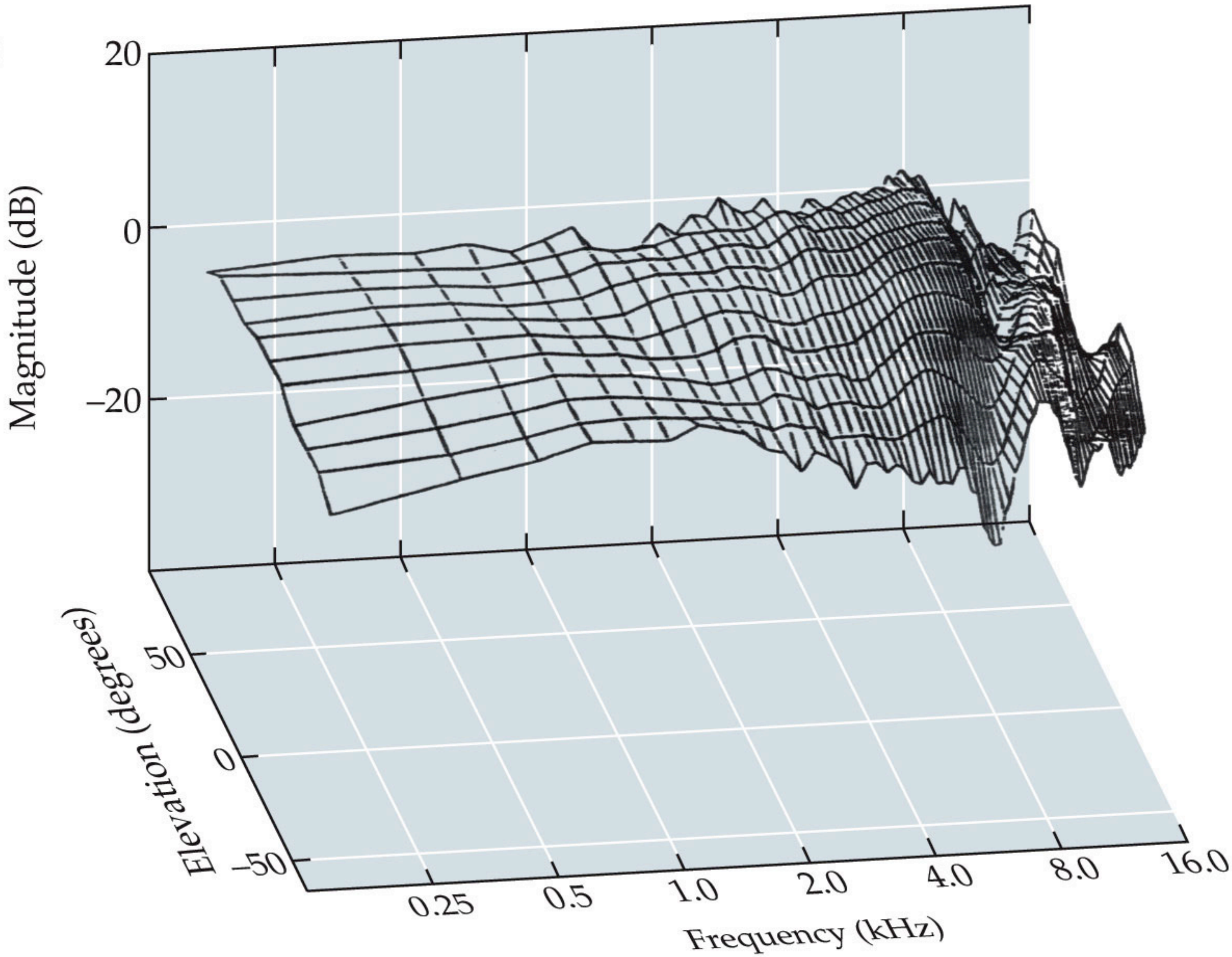
- describes how pinnae, ear canals, head, and torso change the intensity of sounds with different frequencies as the sound location changes

- Each person has his/her own HRTF (based on his/her own body) and uses it to help locate sounds

HRTF: can be measured with microphone in ear canal



HRTF varies with sound source elevation (& azimuth)



- provides information about source location in 3D

Head-related transfer function (HRTF)

- Hofman et al 1998: inserted plastic molds into pinnae, altering subjects' HRTFs
- sound localization performance abruptly degraded

Findings:

- Can learn a new HRTF in about 6 weeks (shown experimentally using inserted artificial pinna)
- Old HRTF is stored (can return to old one instantaneously)

Auditory distance perception

<u>Several Cues:</u>

- **Loudness** (“inverse square law”) - Intensity decreases as square of the distance: (quieter = farther away) (duh.)
- **Spectral composition** - Higher frequencies decrease in energy more than lower frequencies as sound waves travel

  Example: distant vs. nearby thunder.

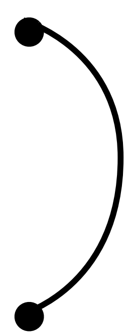
  - This cue only works for long distances (d > 1000m)

Auditory properties of complex sounds

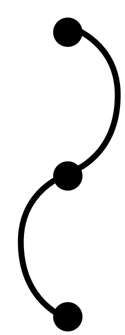
Harmonics

- Objects tend to vibrate at multiple “resonant frequencies” (integer multiples of some fundamental frequency)
- most vibrations die down, but some persist because their wavelength is reinforced by the object’s physical properties
- Auditory system acutely sensitive to harmonics

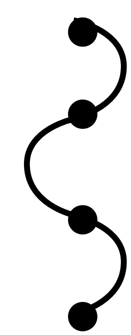
Example: guitar string



Fundamental F1
(1st harmonic)

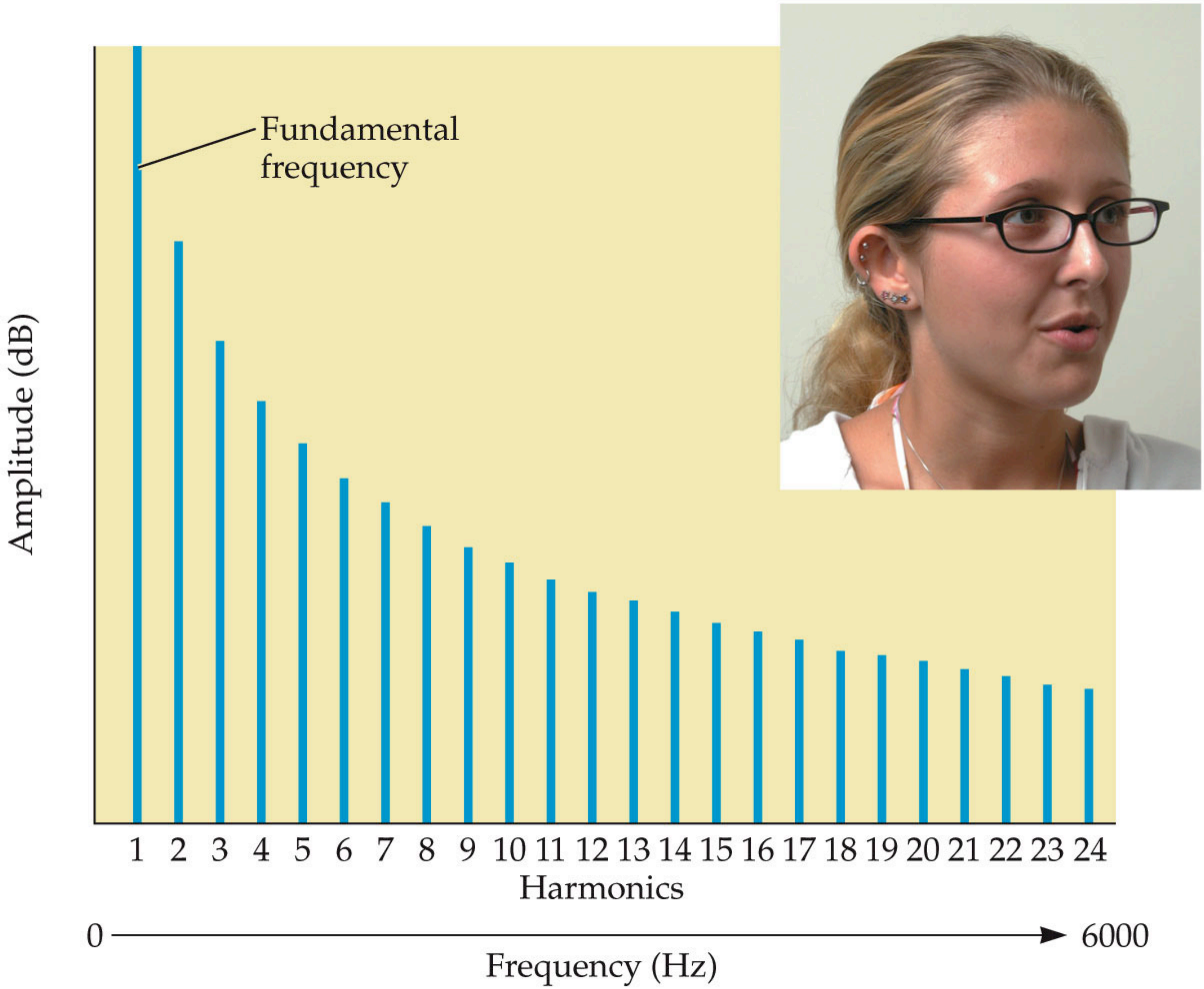


2nd harmonic F2
(2 x F1)

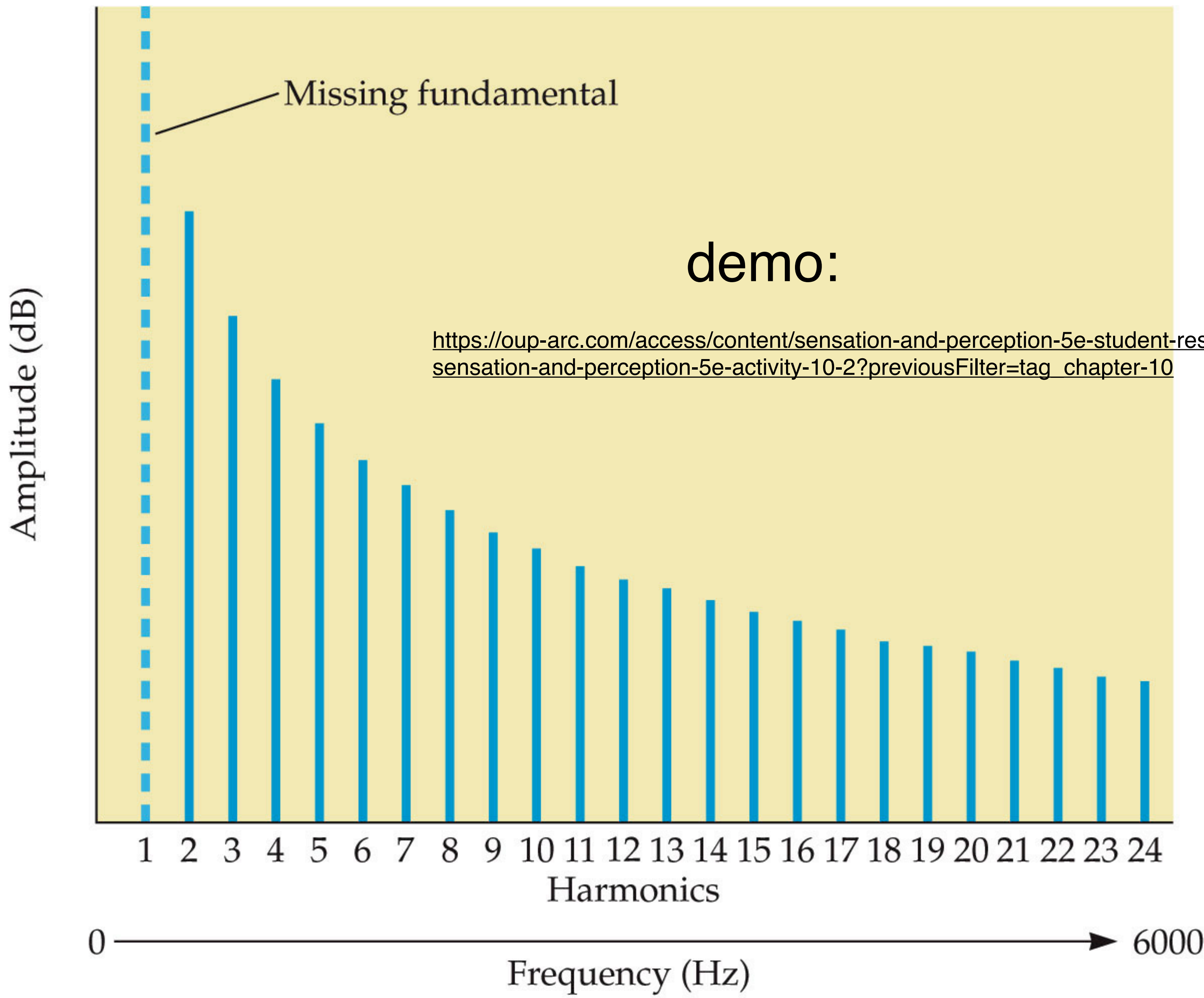


3rd harmonic F3
(3 x F1)

Many sounds, including voices, are harmonic



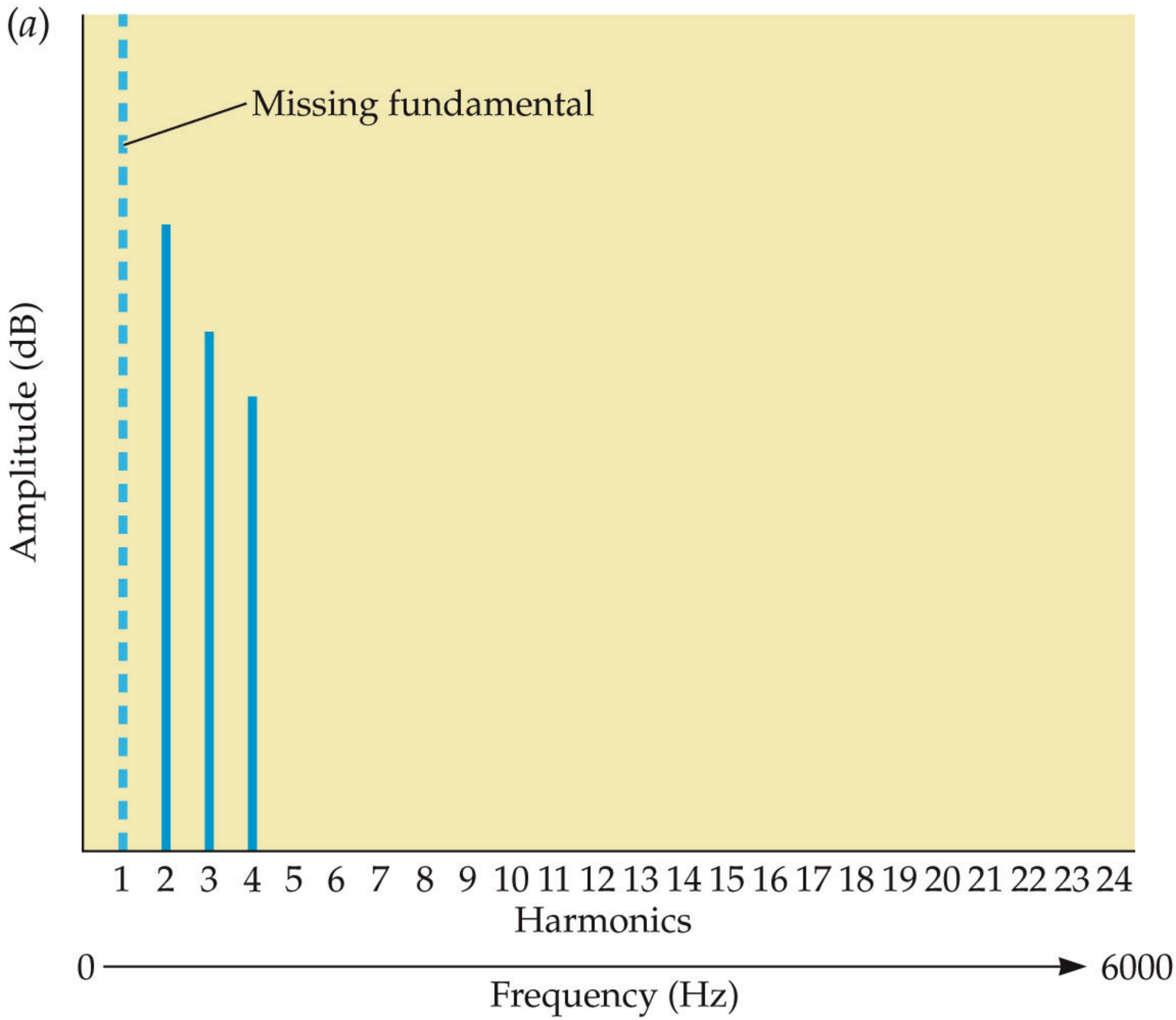
If the fundamental of a harmonic sound is removed, listeners will still hear its pitch



demo:

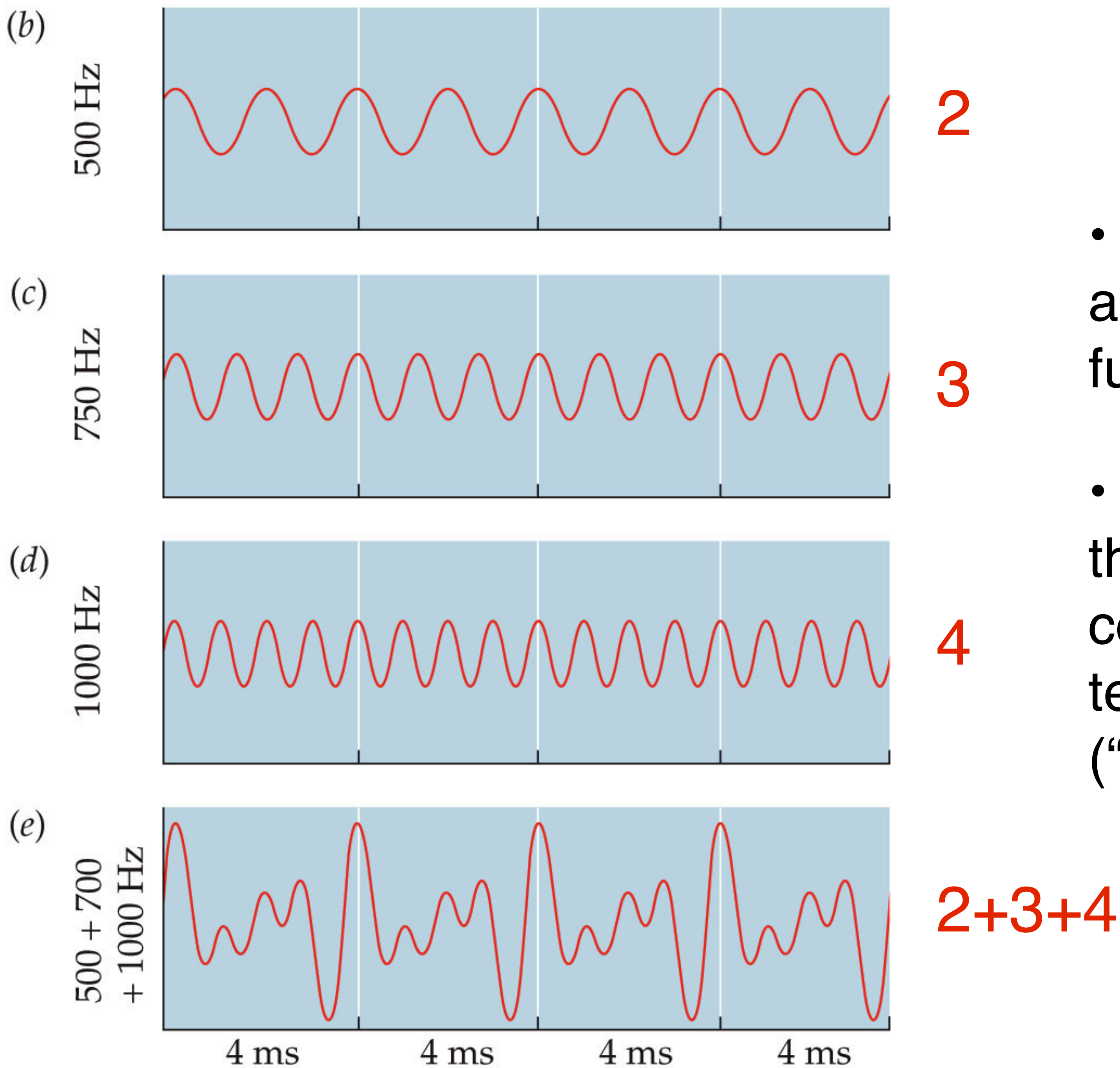
https://oup-arc.com/access/content/sensation-and-perception-5e-student-resources/sensation-and-perception-5e-activity-10-2?previousFilter=tag_chapter-10

Missing Fundamental



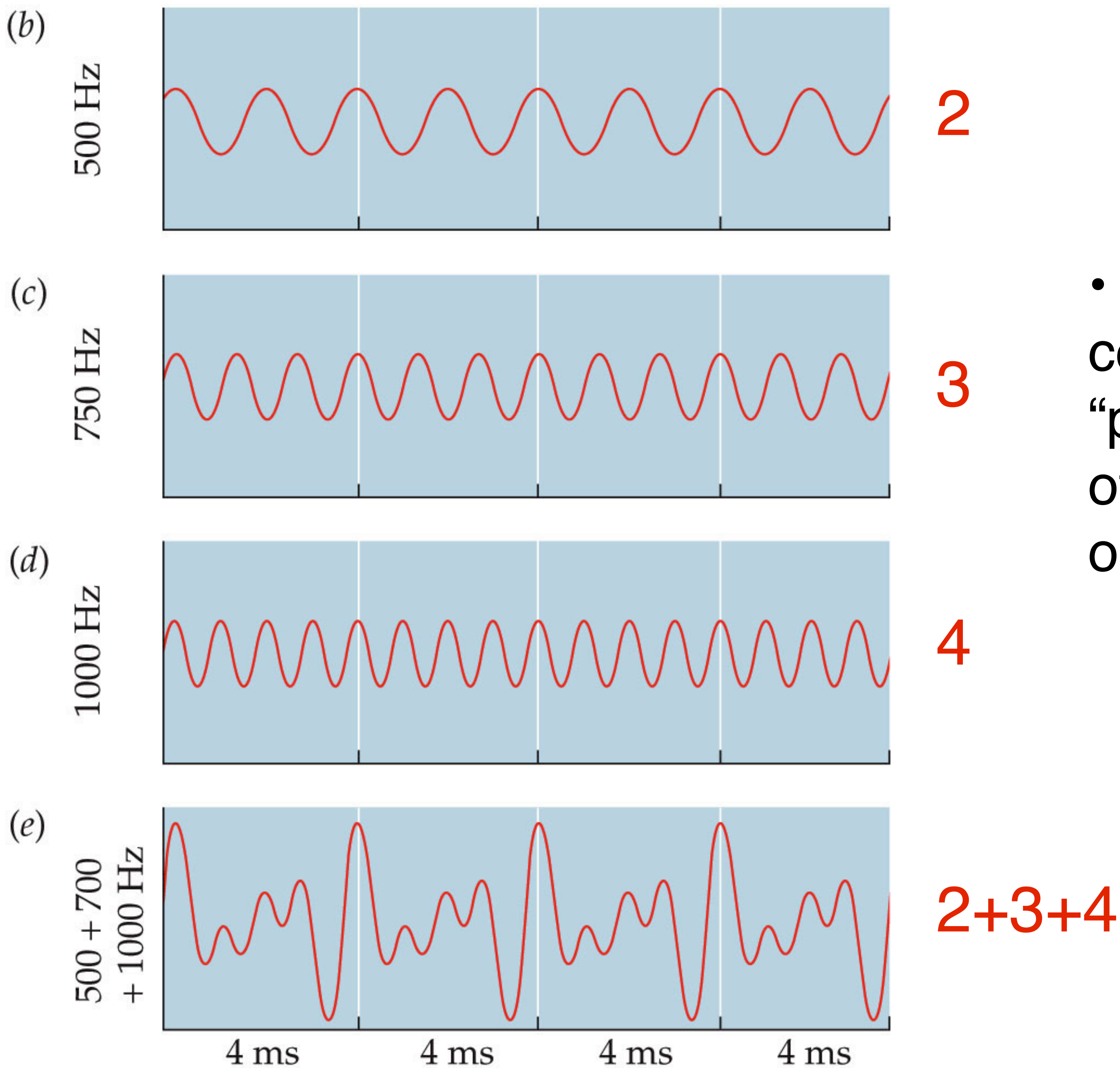
- only 3 harmonics are needed

Only three harmonics are needed to hear a missing fundamental



- all harmonics are aligned at the fundamental freq.
- fundamental could therefore be conveyed by temporal code ("phase locking")

Only three harmonics are needed to hear a missing fundamental



- Could also be conveyed by "pattern matching" of the place code on the cochlea