

Chapter 12: Sound Localization and the Auditory Scene

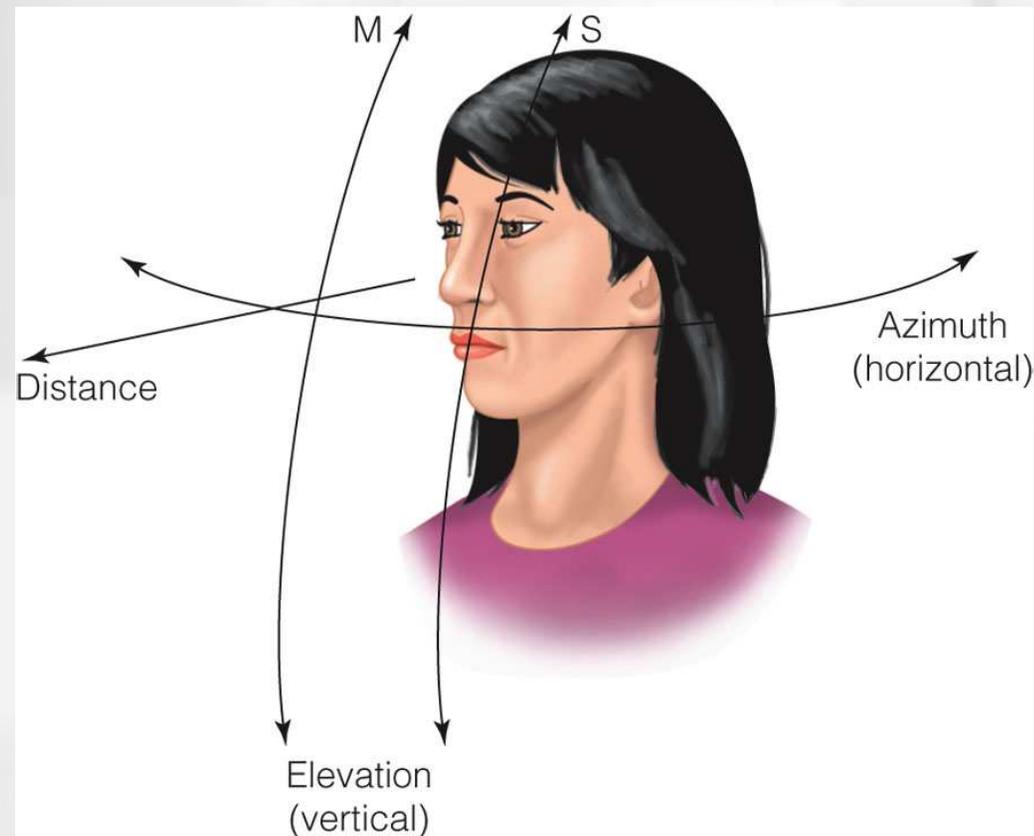
- What makes it possible to tell where a sound is coming from in space?
- When we are listening to a number of musical instruments playing at the same time, how can we perceptually separate the sounds coming from the different instruments?
- Why does music sound better in some concert halls than in others?

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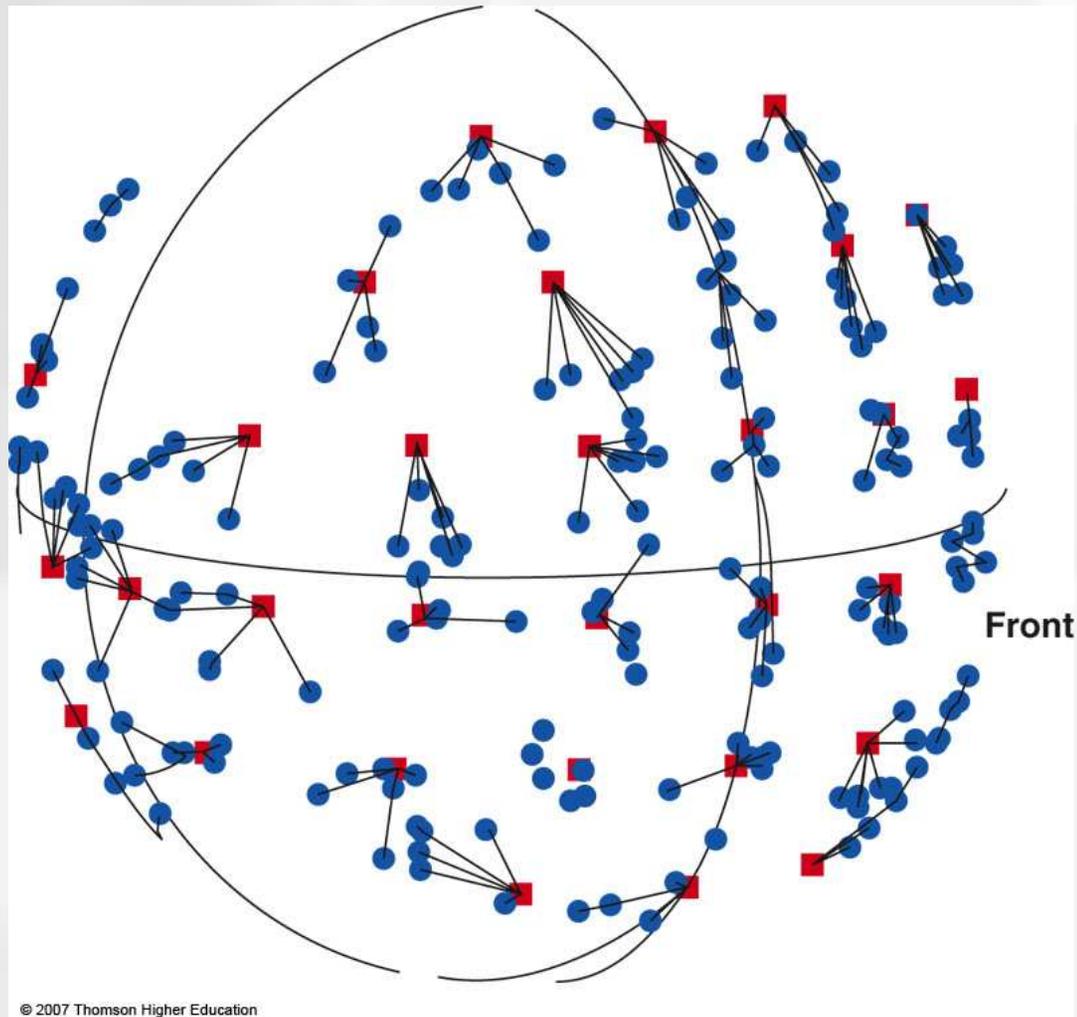
Auditory Localization; the 'Where' pathway for the auditory system

- Auditory space - surrounds an observer and exists wherever there is sound
- Researchers study how sounds are localized in space by using
 - Azimuth coordinates - position left to right
 - Elevation coordinates - position up and down
 - Distance coordinates - position from observer

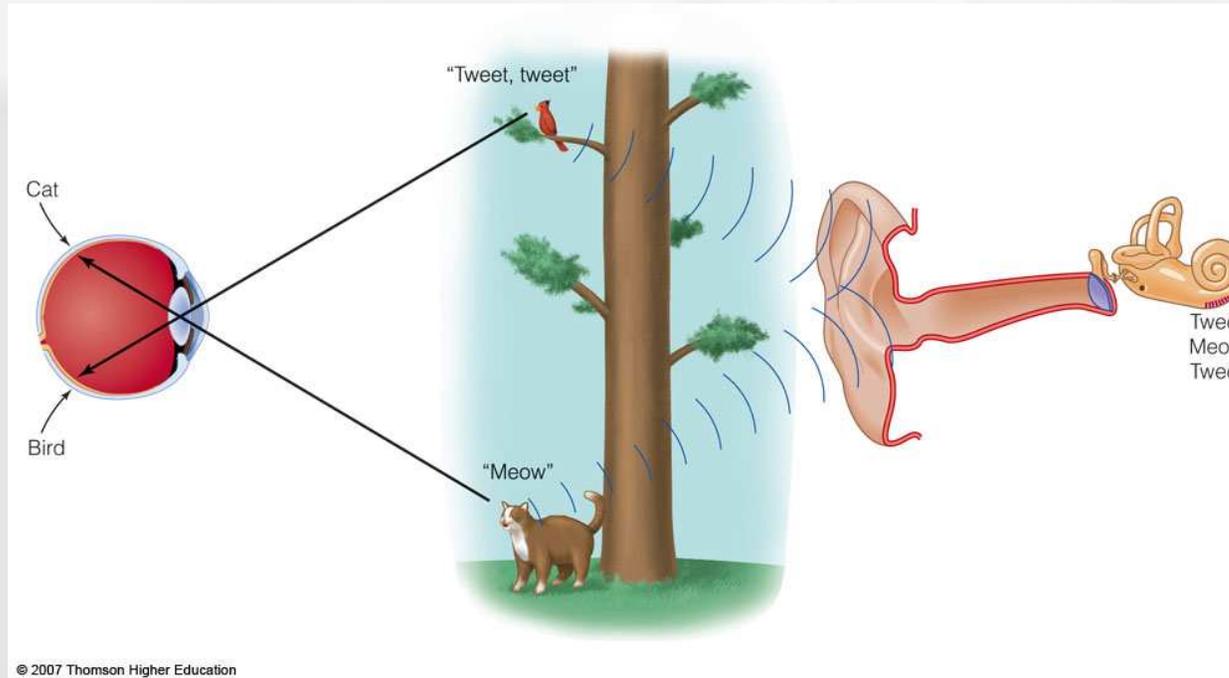


Auditory Localization

- On average, people can localize sounds
 - Directly in front of them most accurately
 - To the sides and behind their heads least accurately



Location cues are not contained in the receptor cells like on the retina in vision; location for sounds must be calculated through other cues.



3 primary cues for auditory localization:

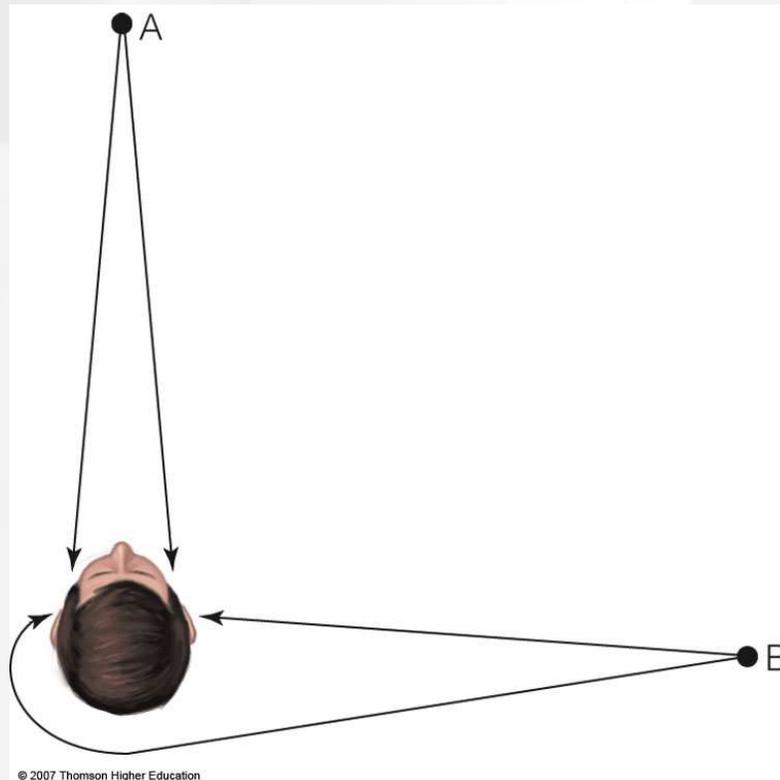
1. Interaural time difference (ITD)
2. Interaural level difference (ILD)
3. Head-related transfer function (HRTF)

Cues for Auditory Location

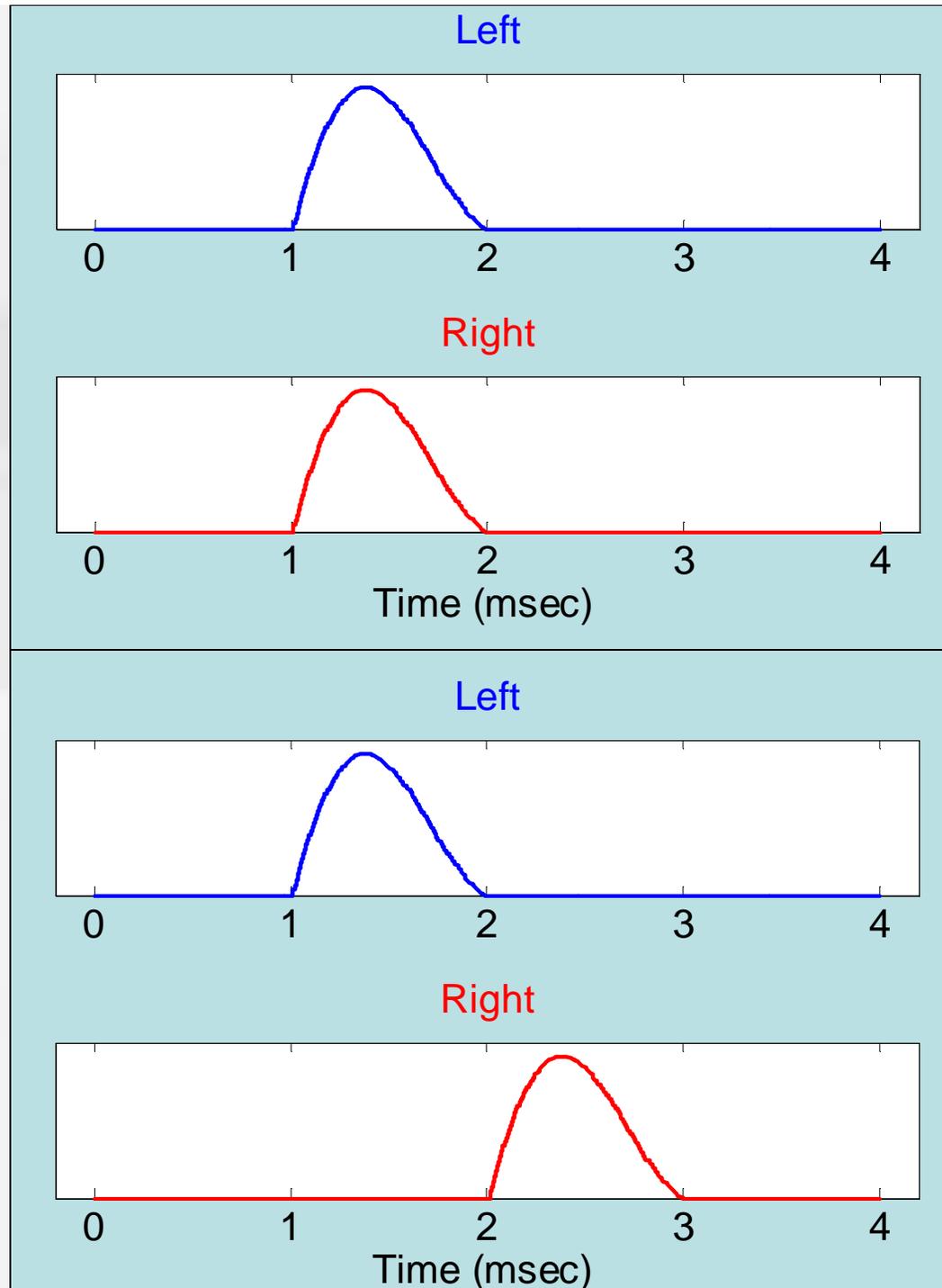
- Binaural cues - location cues based on the comparison of the signals received by the left and right ears

Cue 1: Interaural *time* difference (ITD) - difference between the times sounds reach the two ears

- When distance to each ear is the same, there are no differences in time
- When the source is to the side of the observer, the times will differ



Interaural time difference (ITD)

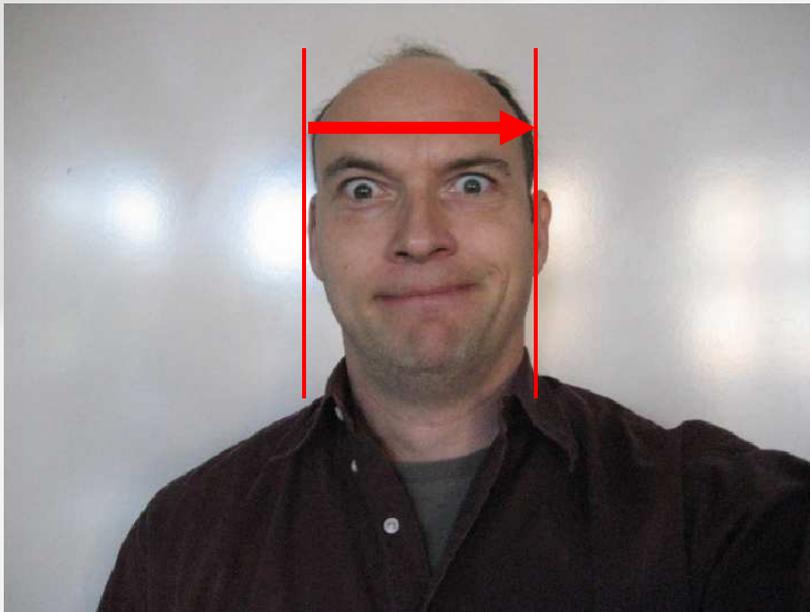


Interaural time difference (ITD)

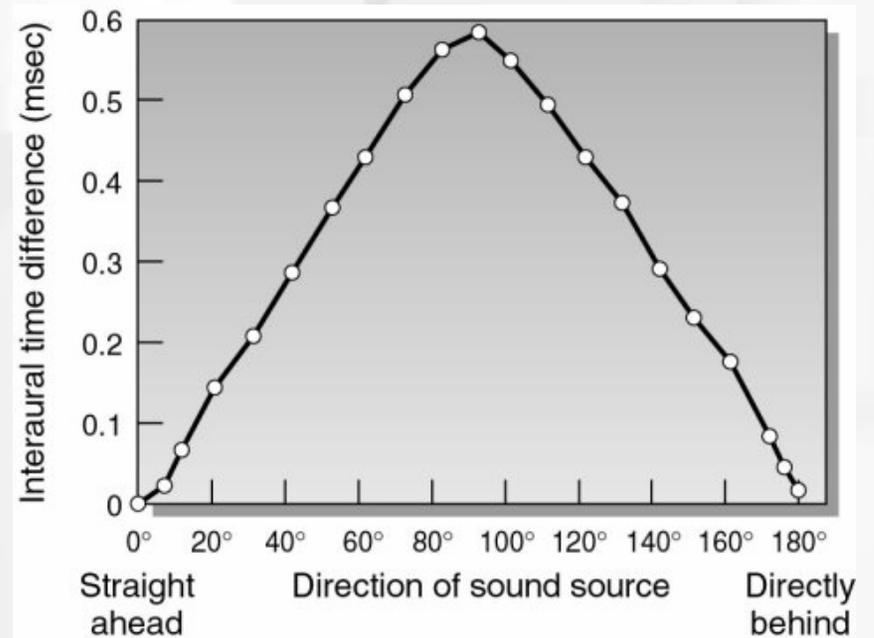


Speed of sound at sea level: 761 mph = 6.22 inches/millisecond

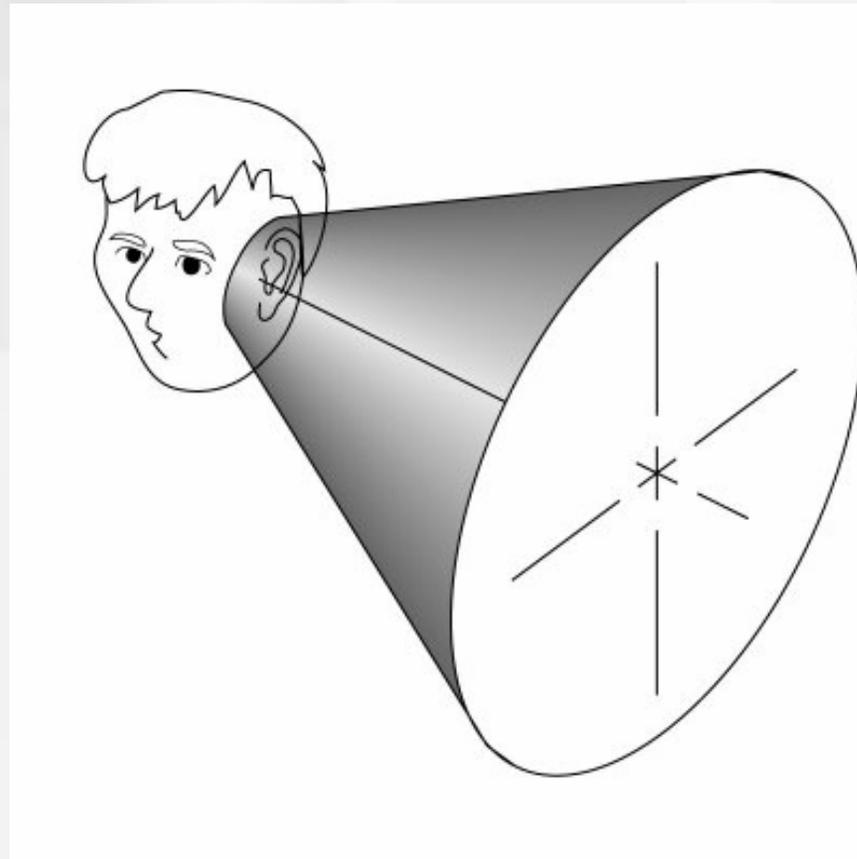
It should take about 0.6 msec for sound to travel the width of the average head.



ITD for different directions:



The '**Cone of Confusion**': Set of locations that have the same interaural time differences (ITD)



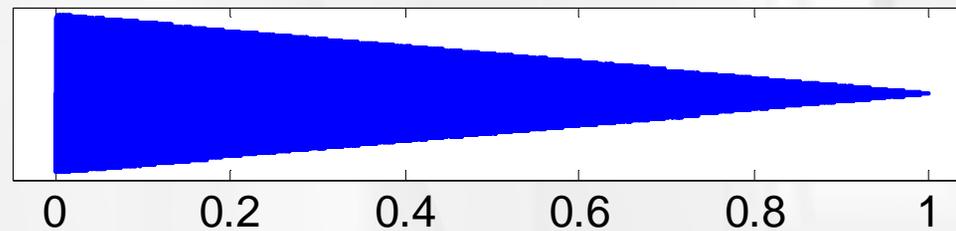
Cue 2: Interaural *level* difference ILD - difference in sound pressure level reaching the two ears

Reduction in sound level occurs for high frequency sounds for the far ear
The head casts an *acoustic shadow*

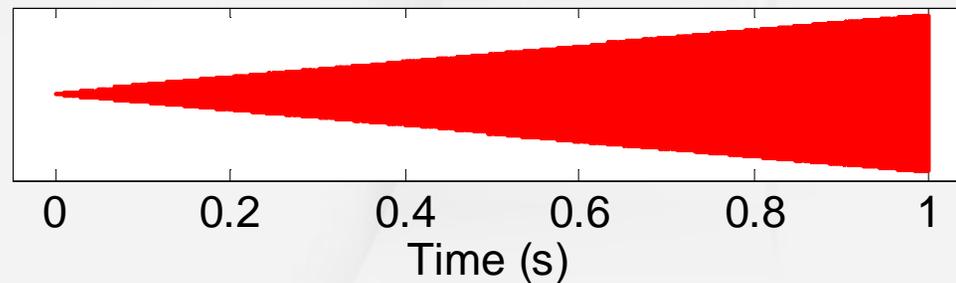
Demonstration of interaural level difference (ILD):

intensity sweep from left to right ear.

Left

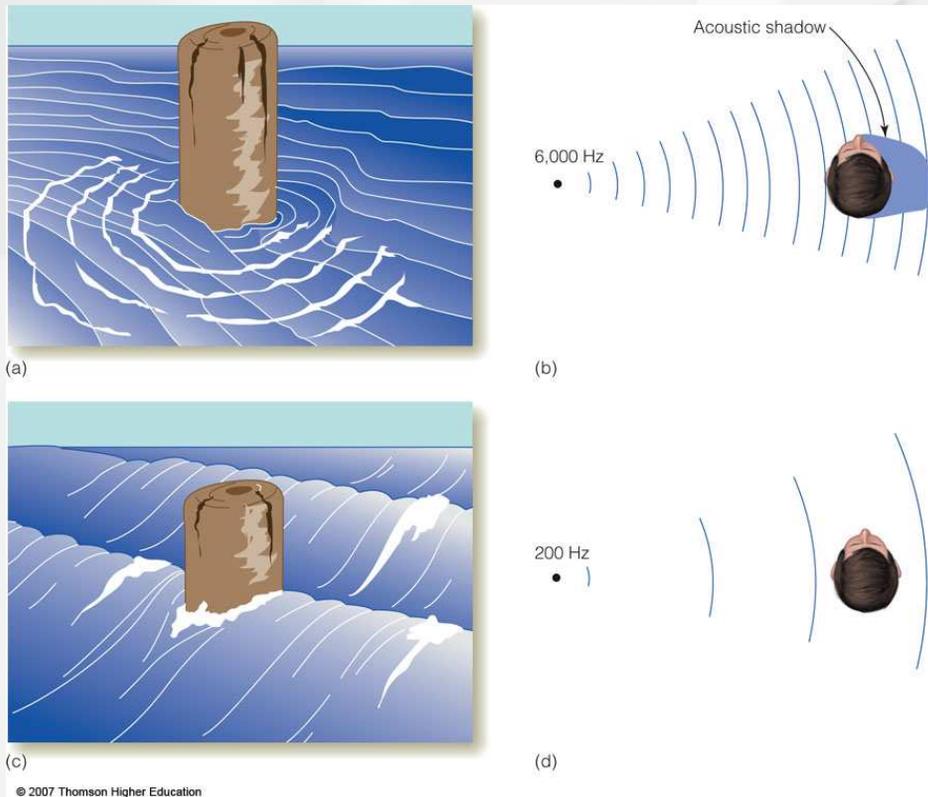


Right

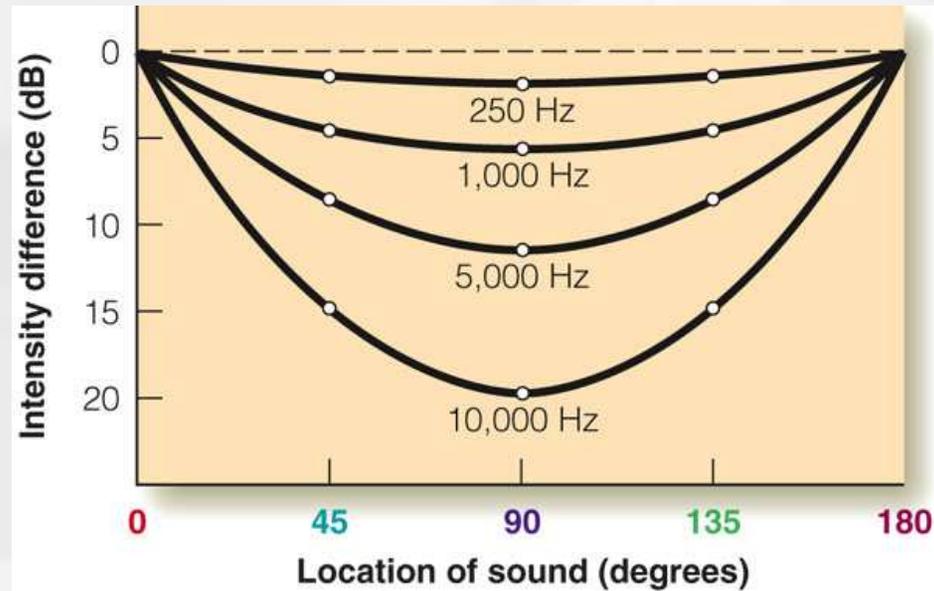


Interaural level difference (ILD) is best for high frequency sounds because low frequency sounds are not attenuated much by the head.

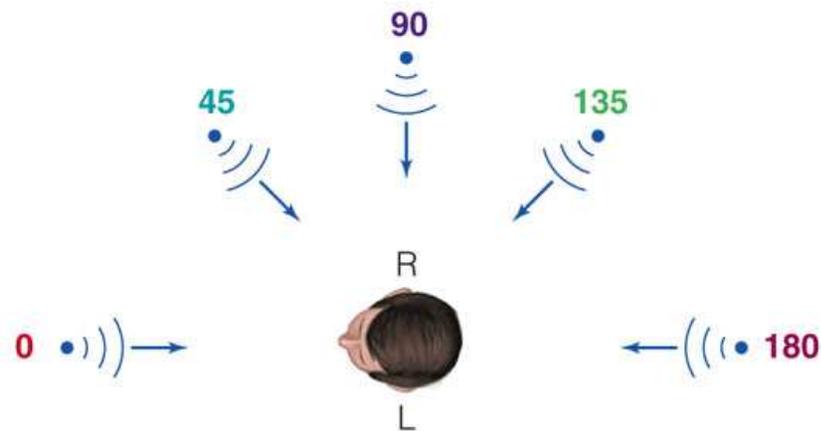
(think of how low frequency sounds pass through the wall from your neighbor next door)



Interaural level difference (ILD) is best for high frequency sounds.



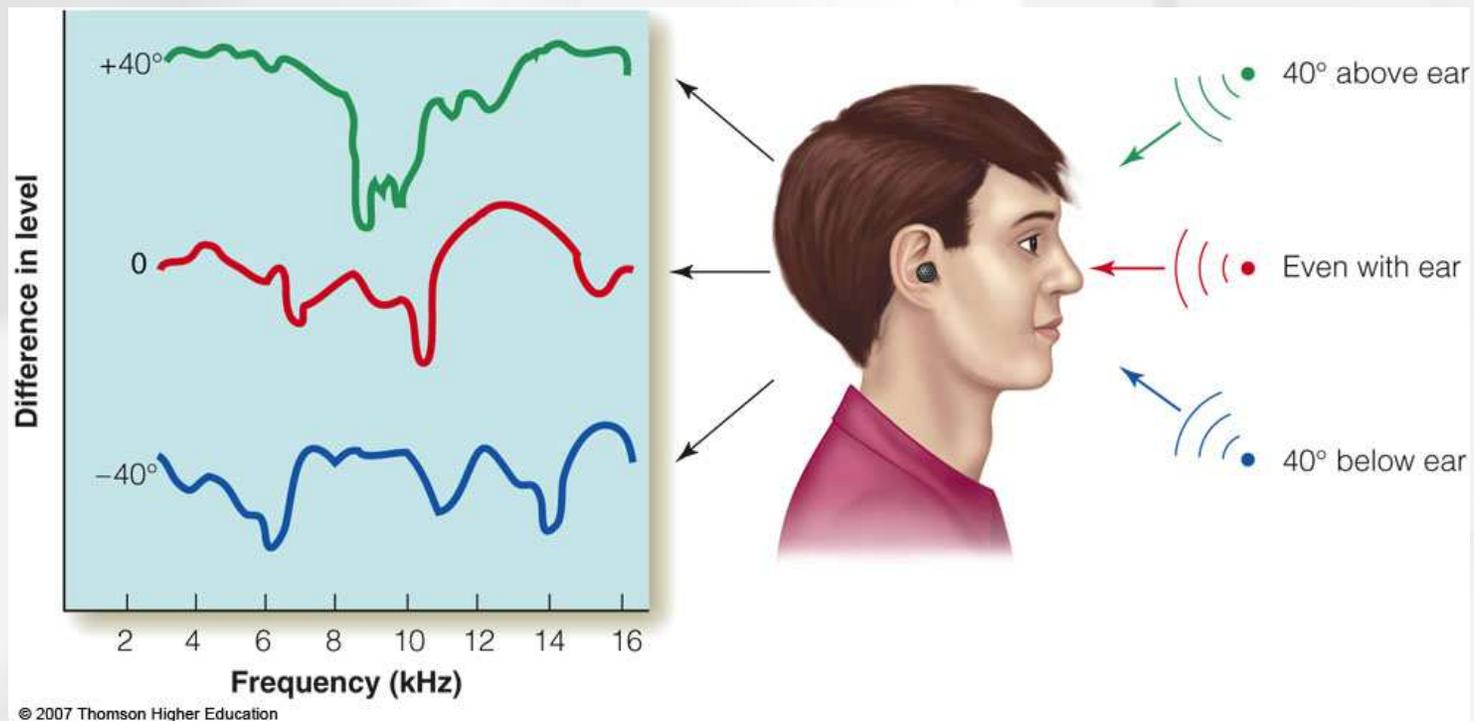
(a)



(b)

Cue 3: the head-related transfer function (HRTF)

- The pinna and head affect the intensities of frequencies
- Measurements have been performed by placing small microphones in ears and comparing the intensities of frequencies with those at the sound source
 - The difference is called the head-related transfer function (HRTF)
 - This is a spectral cue since the information for location comes from the spectrum of frequencies



Two ways to present sounds to subjects:

- 1) Free-field presentation - sounds are presented by speakers located around the listener's head in a dark room

Listener can indicate location by pointing or by giving azimuth and elevation coordinates

- 2) Headphone presentation of sounds

Advantage - experimenter has precise control over sounds

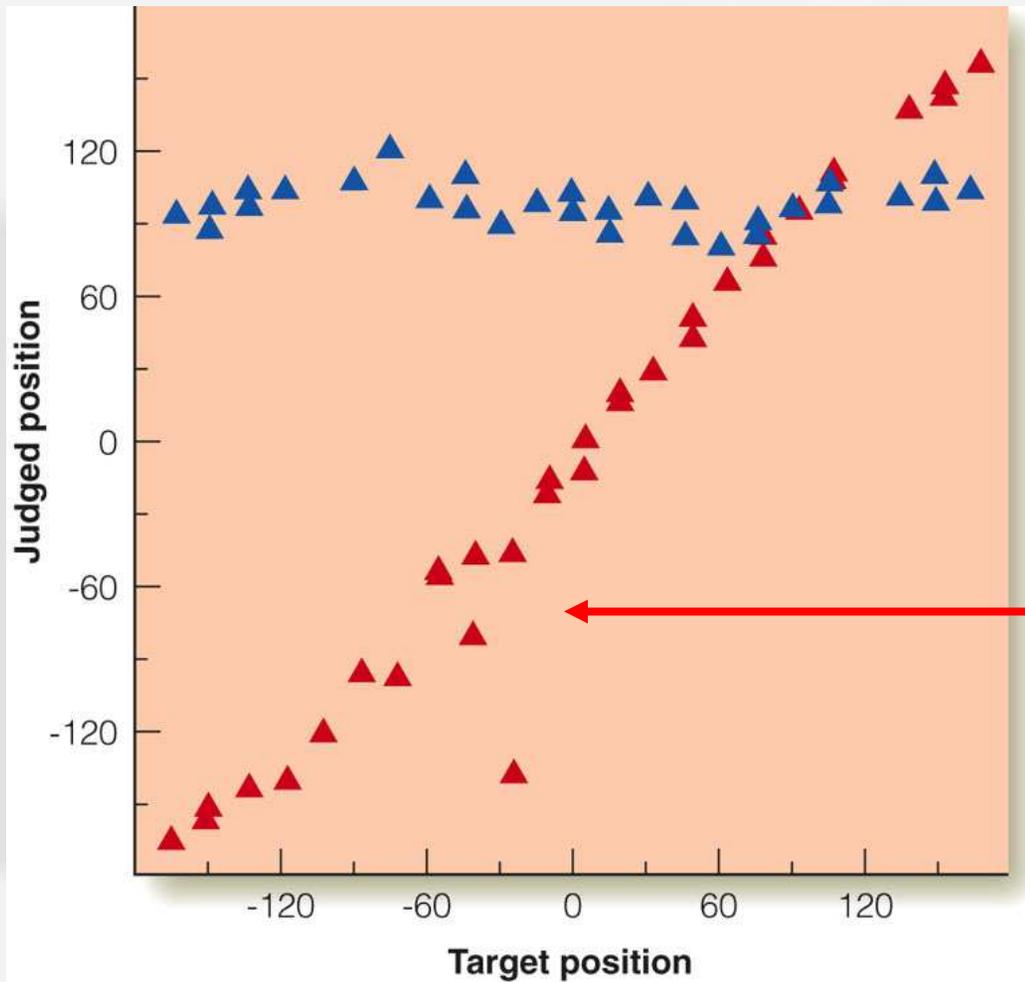
Disadvantage - cues from the pinna are eliminated, which results in the sound being *internalized*

- Sound can be *externalized* by using HTRFs to create a virtual auditory space

Which cues for sound localization do we actually use?

- Experiments by Wight and Kistler
 - Experiment 1 - used virtual auditory space
 - HRTFs, ITDs, & ILDs were used to indicate locations that varied from left to right
 - Listeners were fairly accurate

Low frequency tone:



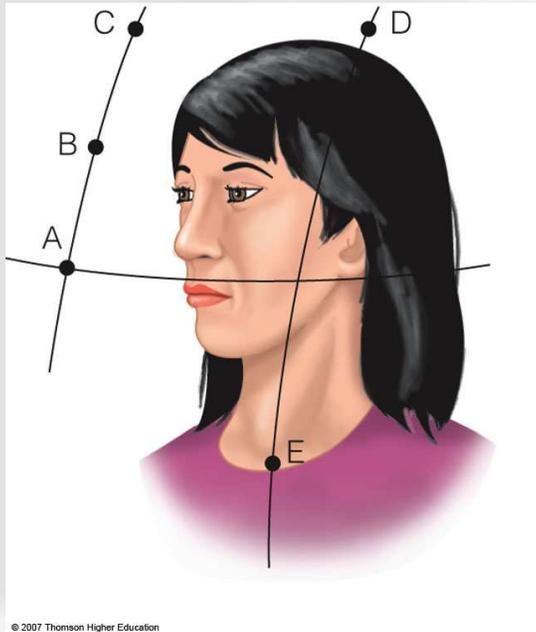
ITD kept constant at 90 degrees:
Subjects don't use ILD cue and
ITD dominates judgment

Both ITD and ILD cues:
Accurate judgment of azimuth

For low frequencies, ITD dominates judgment
For high frequencies, ILD dominates judgment

Judging Elevation

- ILD and ITD are not effective for judgments on elevation since in many locations they may be zero



You can turn elevation to azimuth by tilting your head.