Hearing & Deafness (3)

Auditory Localisation

http://www.aip.org/pt/nov99/locsound.html

Demo class

- 1pm this Thursday 27th Chichester LT
- Going through Frequencies, Filters, Excitation patterns etc
- Using Excel spreadsheet that you can download.

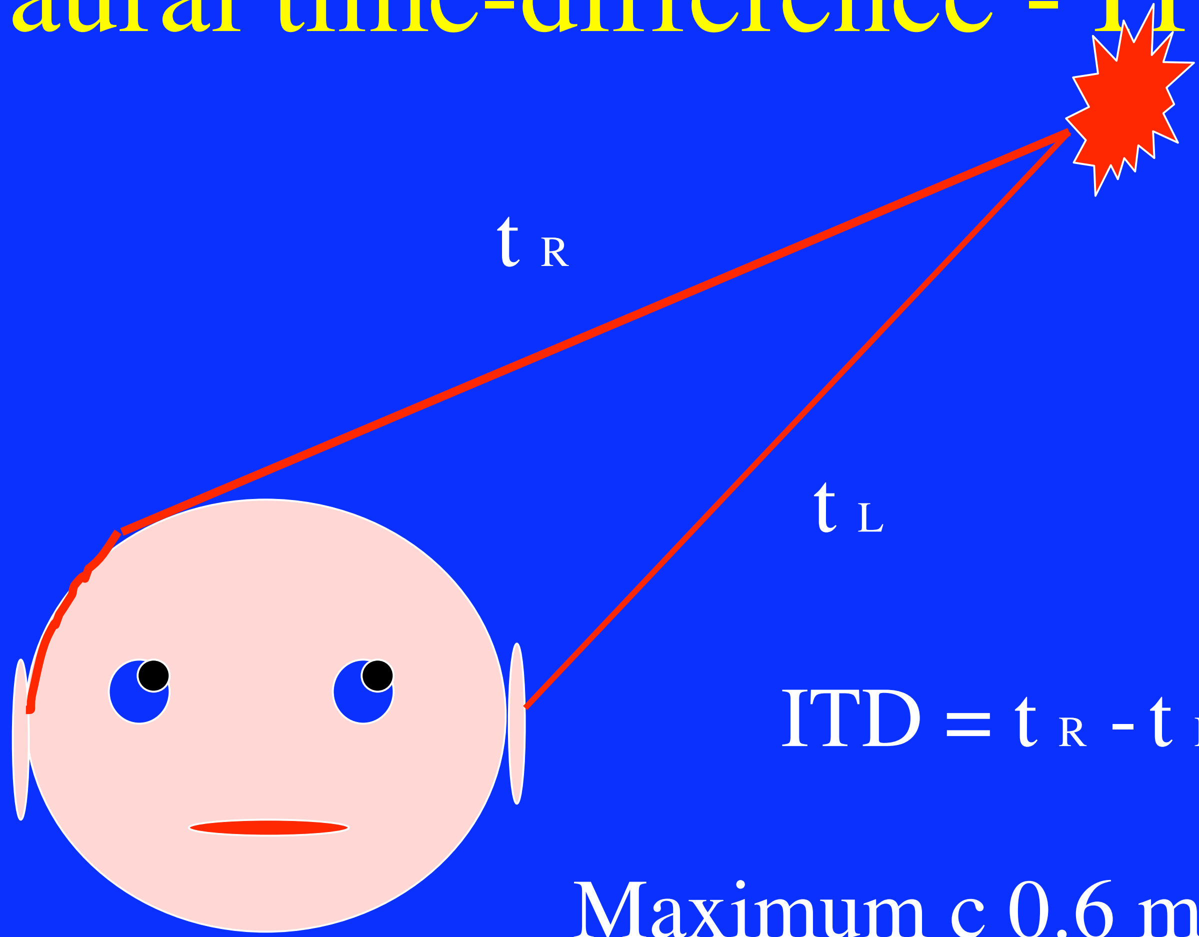
Localisation in 3 dimensions

- Azimuth (left/right)

  (Arab. *as-sumut*, i.e. *as* = *al* the + *sumut*, pl of *samt* way)

  – Binaural cues: ITD and ILD
- Median-plane (front, up, back, down)
  – Pinna-induced spectral cues
  – Head movements
- Distance
  – Absolute level, excess IID (inverse-square law), spectral balance, reverberation

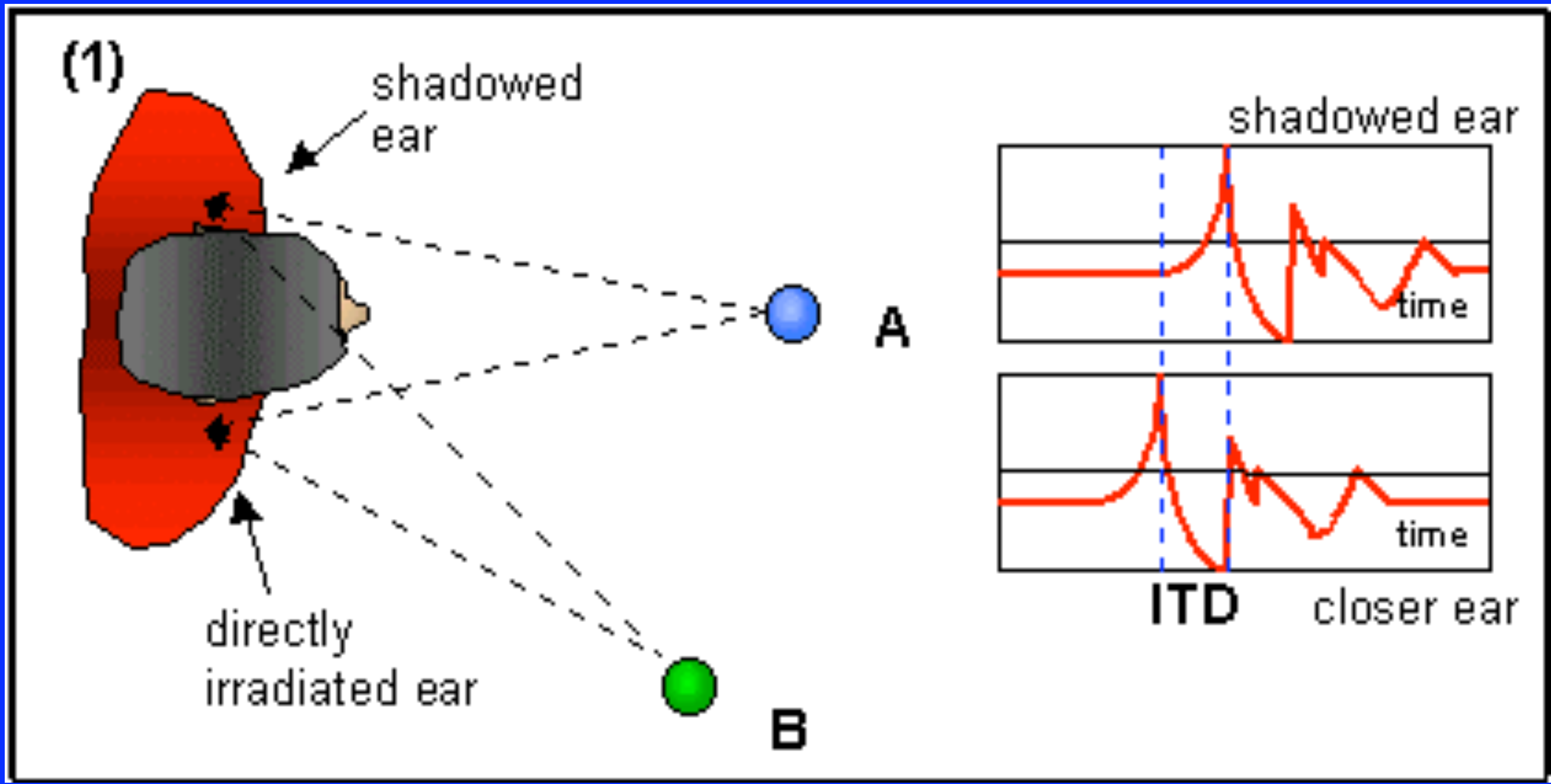
Interaural time-difference - ITD



$ITD = t_R - t_L$

Maximum c 0.6 ms

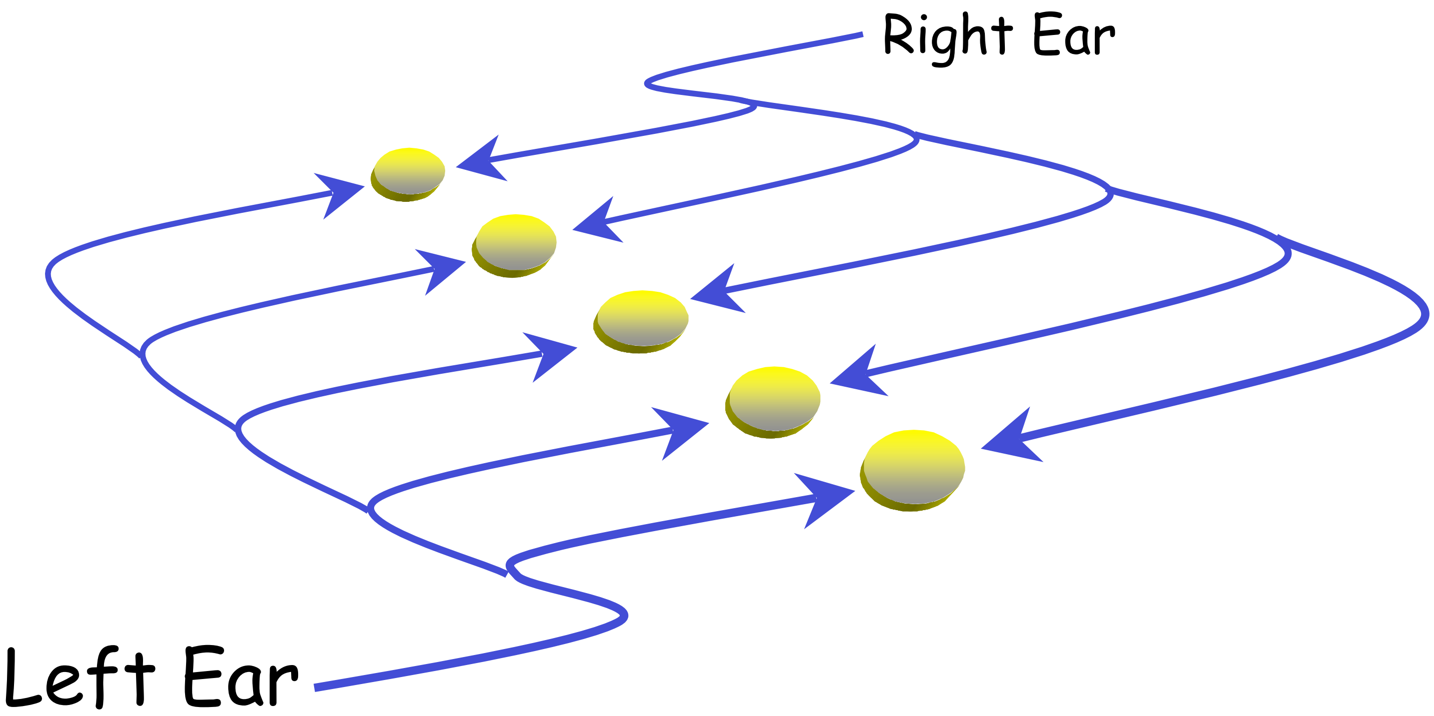
Interaural Time Difference (ITD)



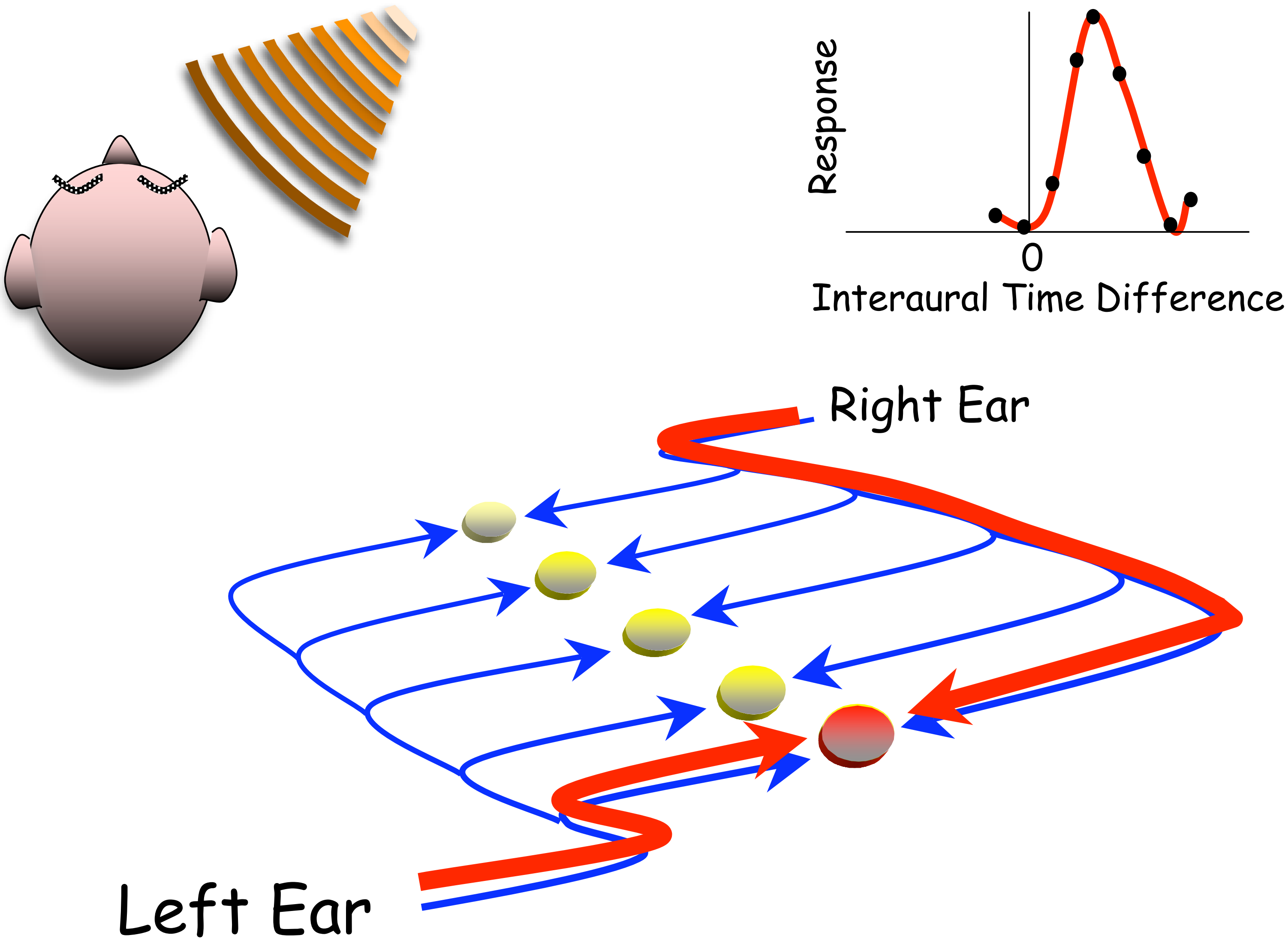
From David McAlpine

Processed in Medial Superior Olive

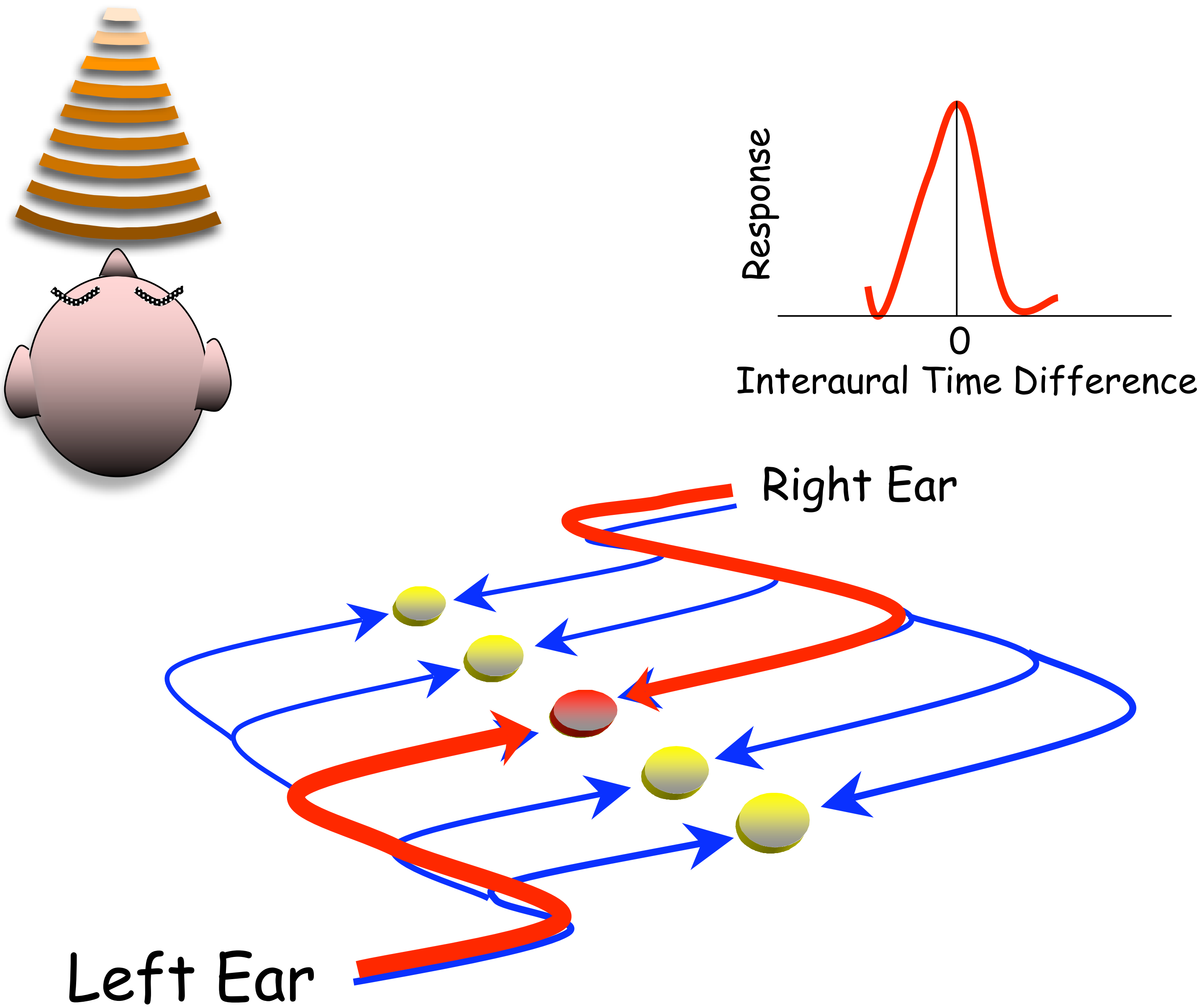
The coincidence detection model of Jeffress (1948) is the widely accepted model for low-frequency sound localisation



From David McAlpine



From David McAlpine

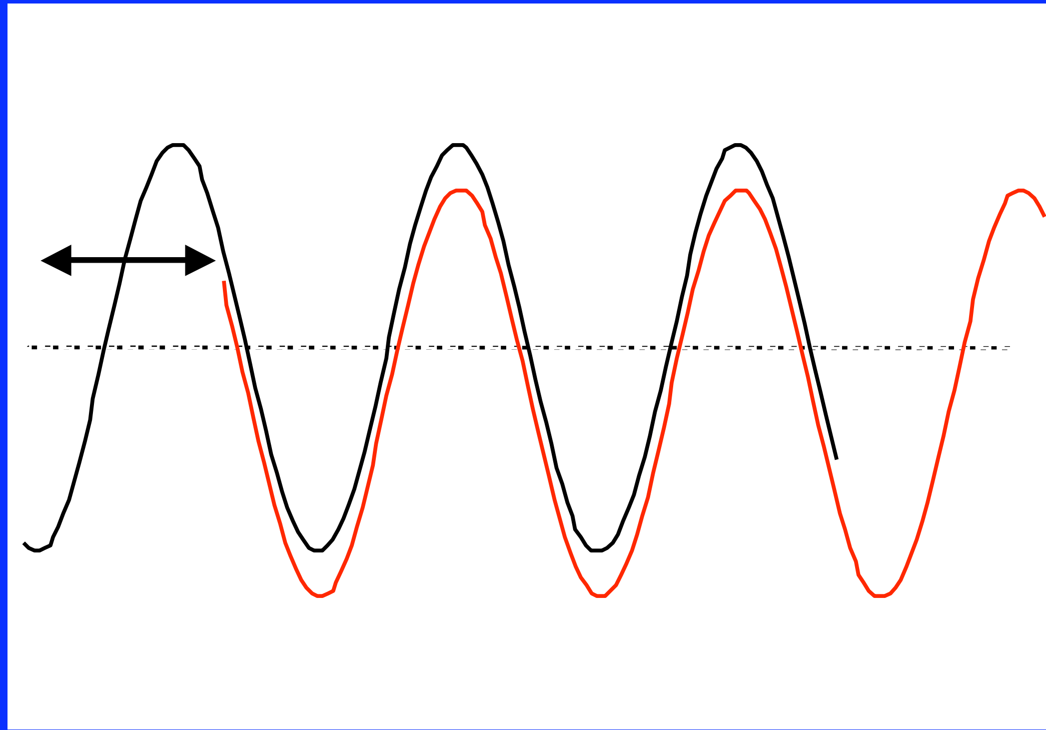


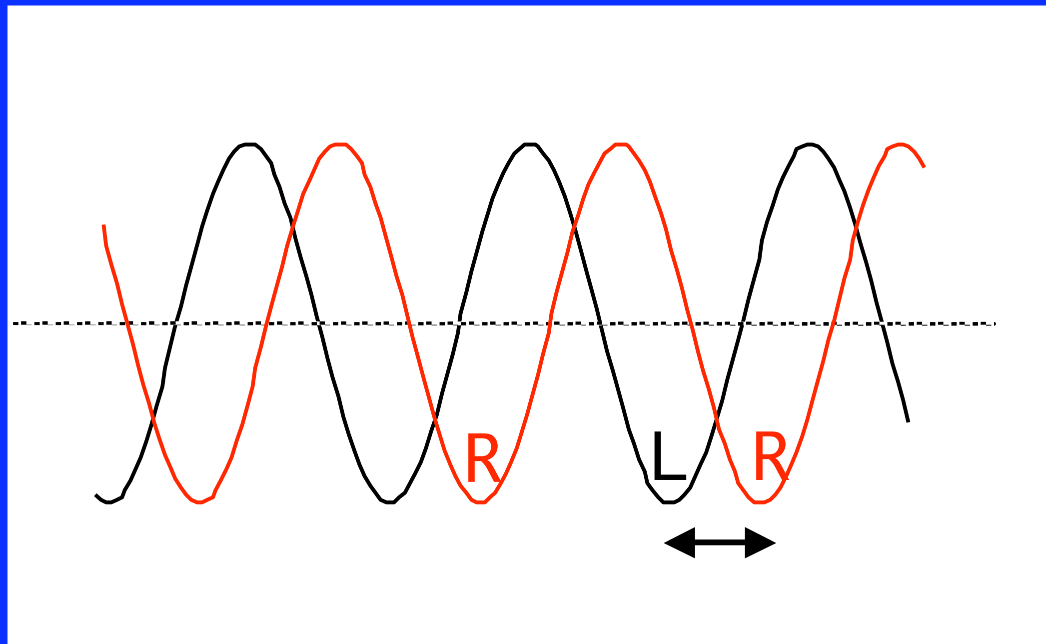
From David McAlpine

Onset-time

versus

ongoing phase differences

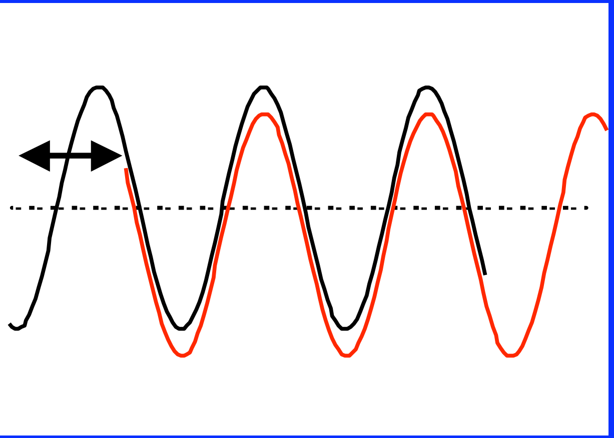




Natural sounds have both

Onset-time

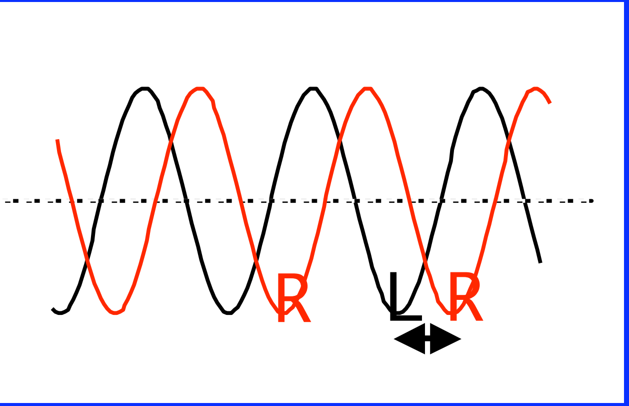
Works for high-
and
low-frequency sounds



versus

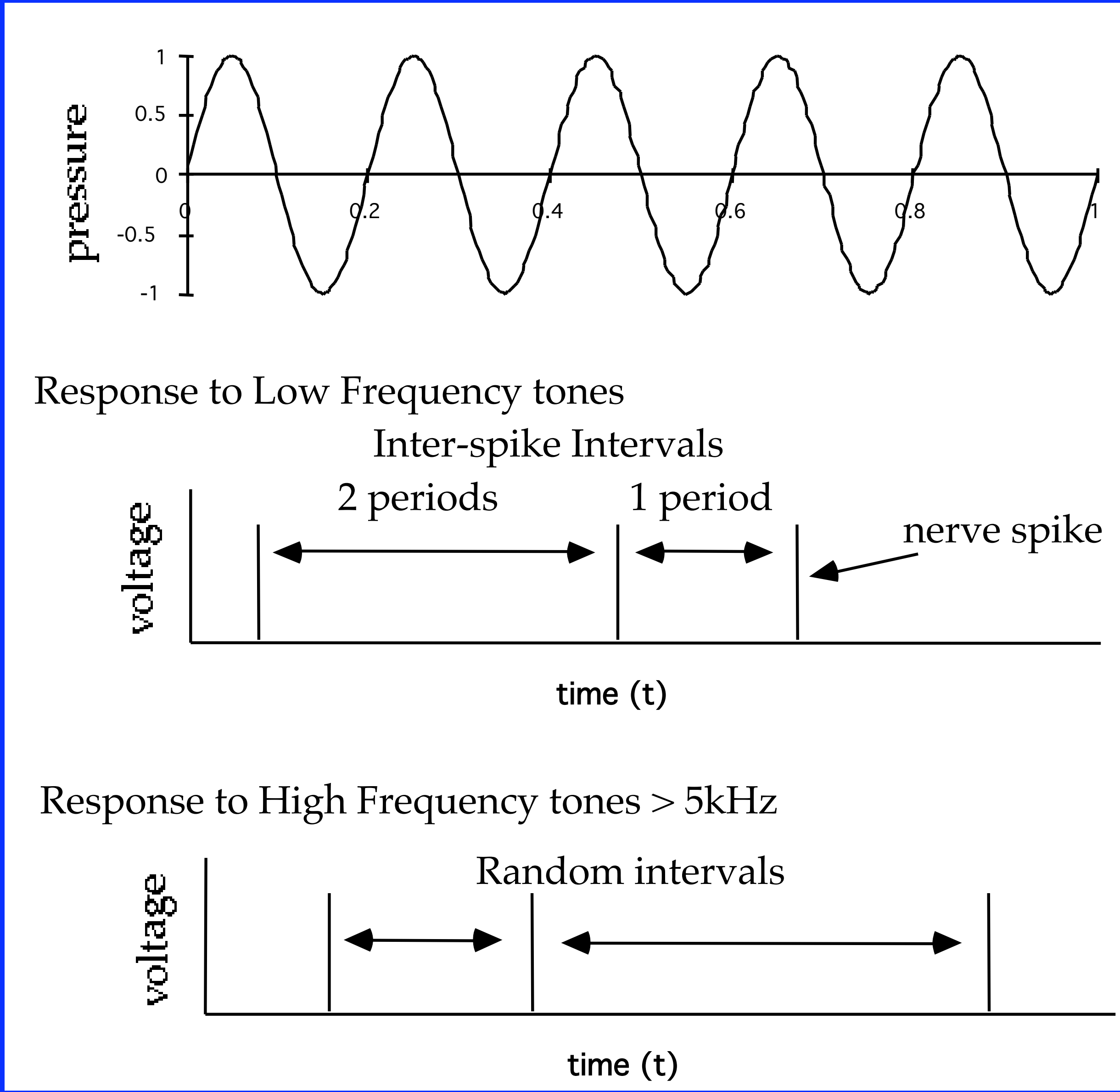
ongoing phase differences

Does not work for high-frequency pure tones:
- no phase locking above 4kHz
- phase ambiguity above 1.5 kHz

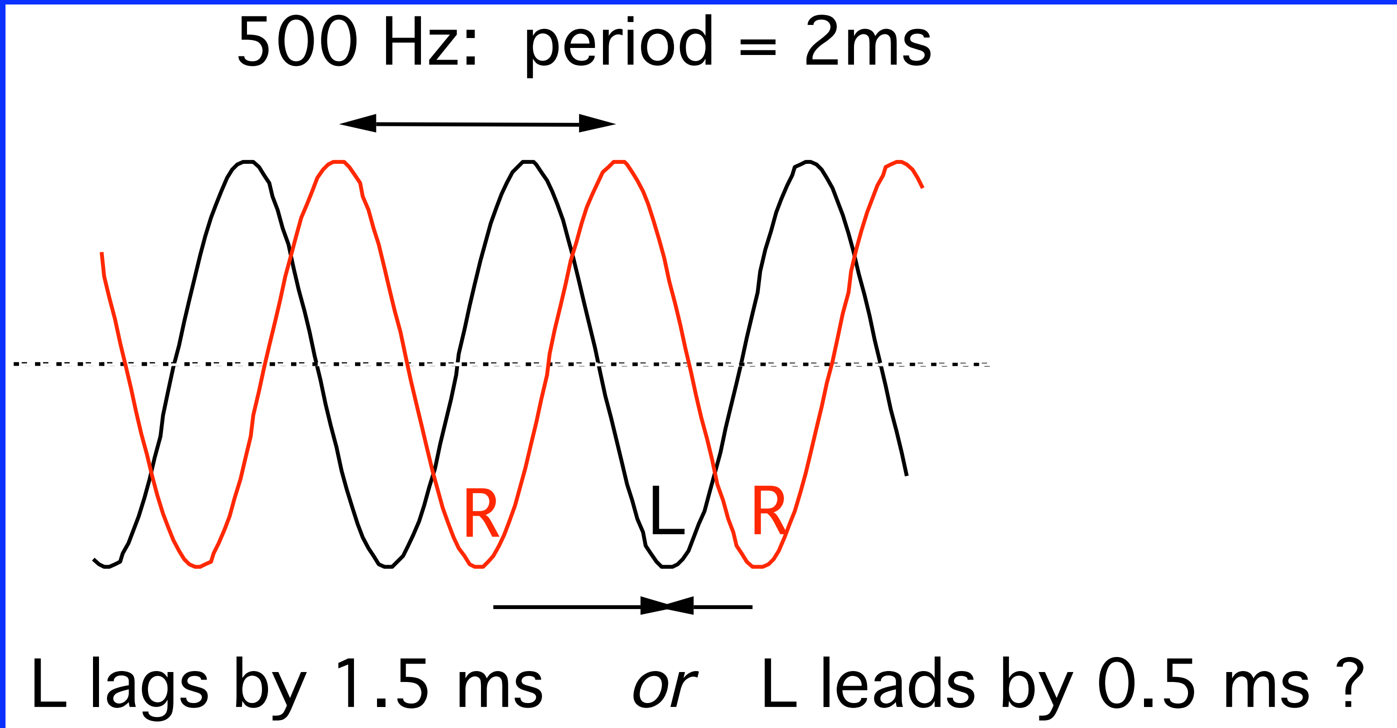


Natural sounds have both

Phase-locking



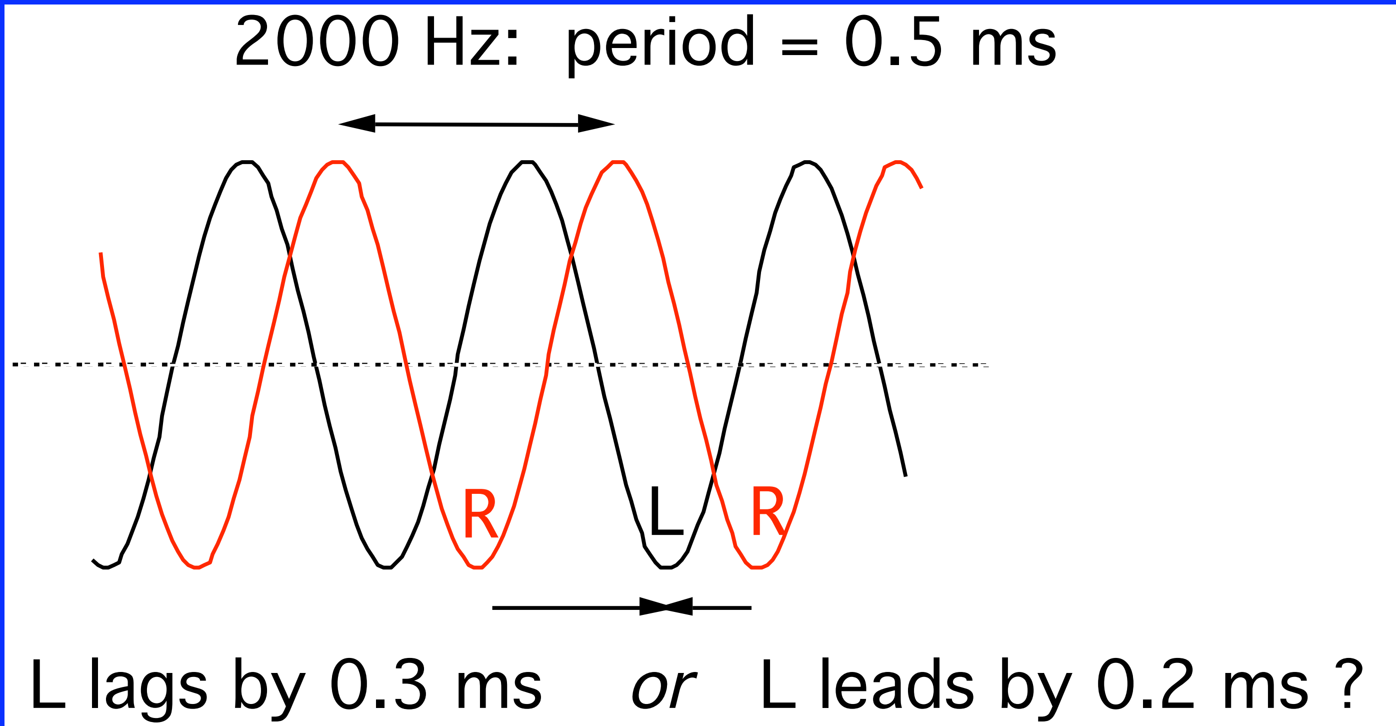
Phase Ambiguity



This particular case is not a problem since max ITD = 0.6 ms

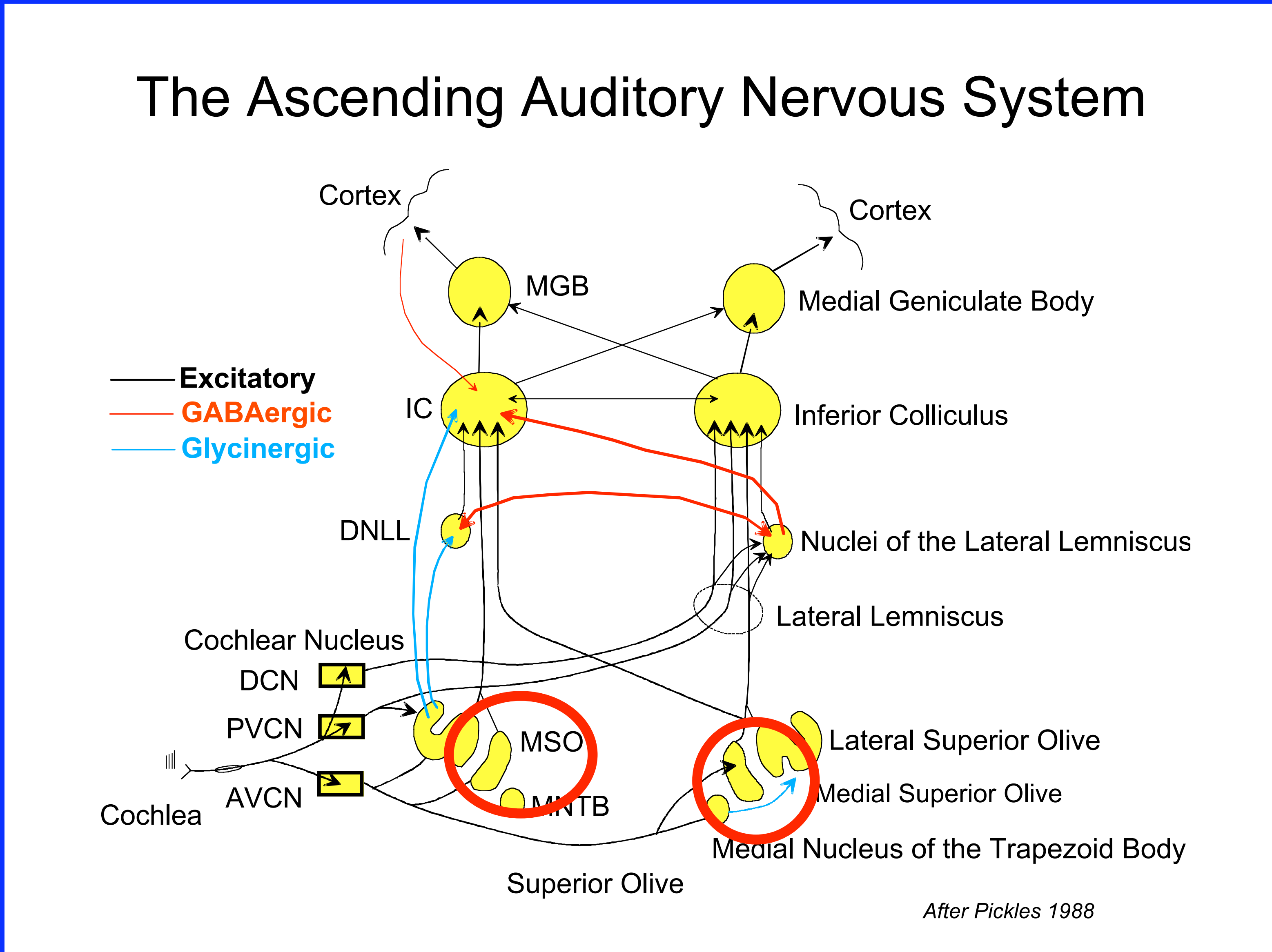
But for frequencies above 1500 Hz it IS a problem

Phase Ambiguity

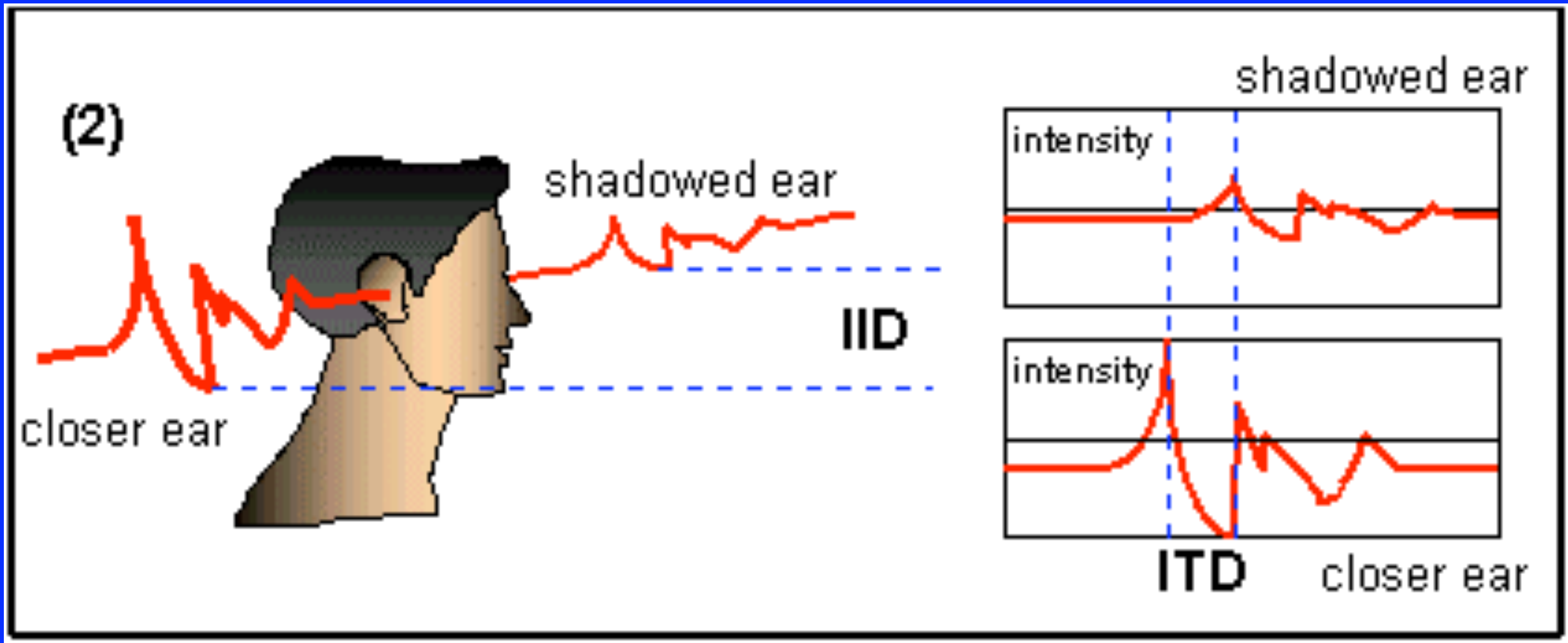


Both possible times are less than the maximum ITD of 0.6 ms

Anatomy of the auditory system



Interaural Level Difference (ILD)



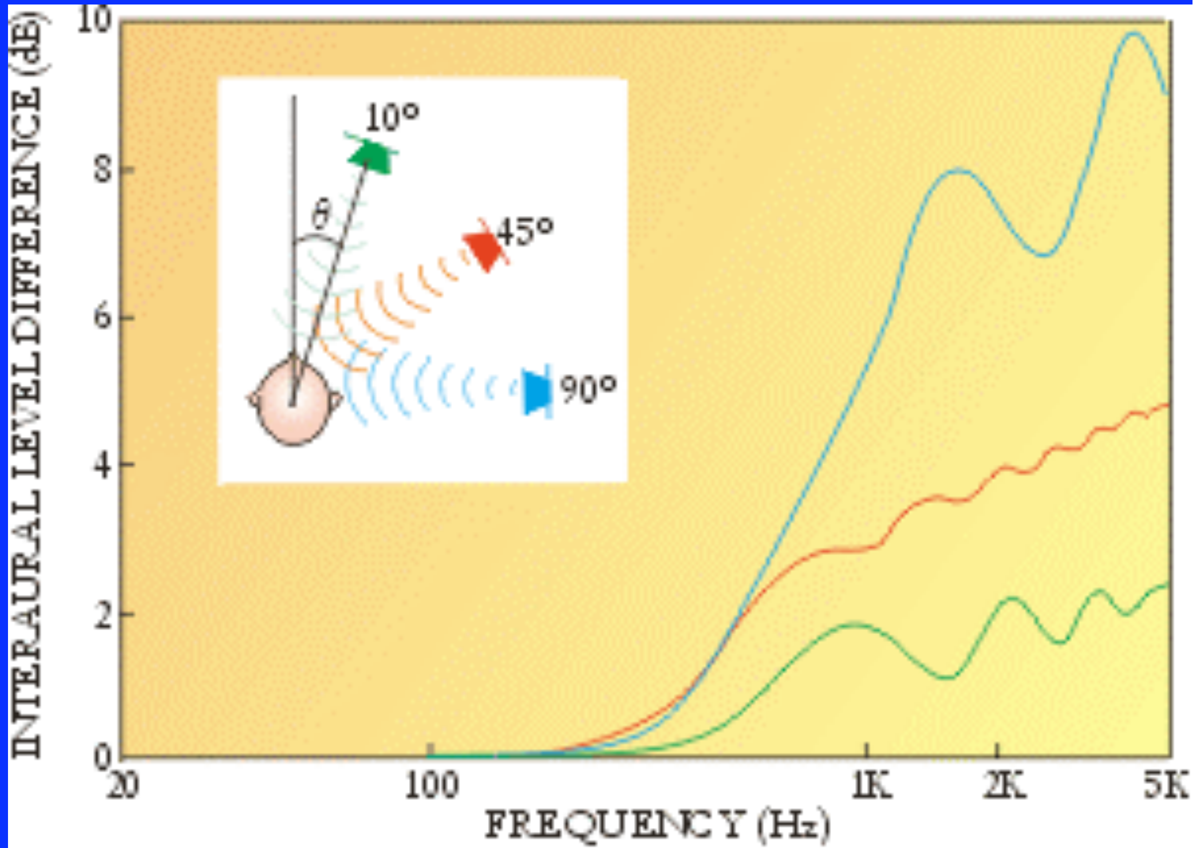
From David McAlpine

Processed in Lateral Superior Olive

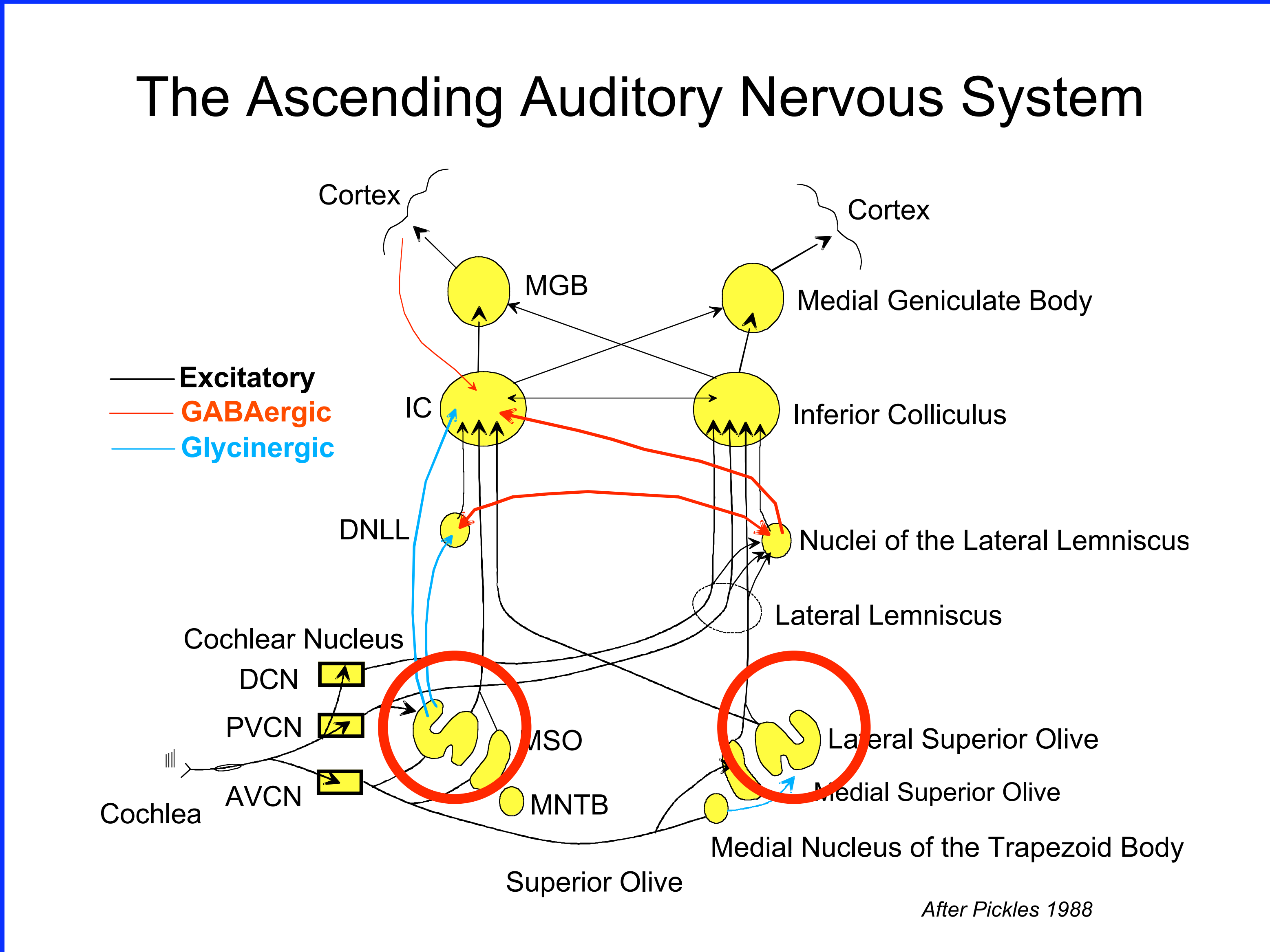
ILD is greater for higher frequencies

Interaural level differences calculated for a source in the horizontal plane. The source is at an azimuth θ of 10° (green curve), 45° (red), or 90° (blue) relative to straight ahead.

The calculations assume that the ears are at opposite poles of a rigid sphere.



Anatomy of the auditory system



Raleigh's Duplex theory for pure tones

- Low frequency pure tones (<1500 Hz) localised by interaural time differences

- High frequency pure tones localised by intensity differences

Raleigh’s Duplex theory for pure tones (2)

1. Low frequency tones (<1500 Hz) localised by phase differences:

- Very small interaural intensity difference for low-frequency tones.

- Phase locking present for low frequency tones (<4kHz).

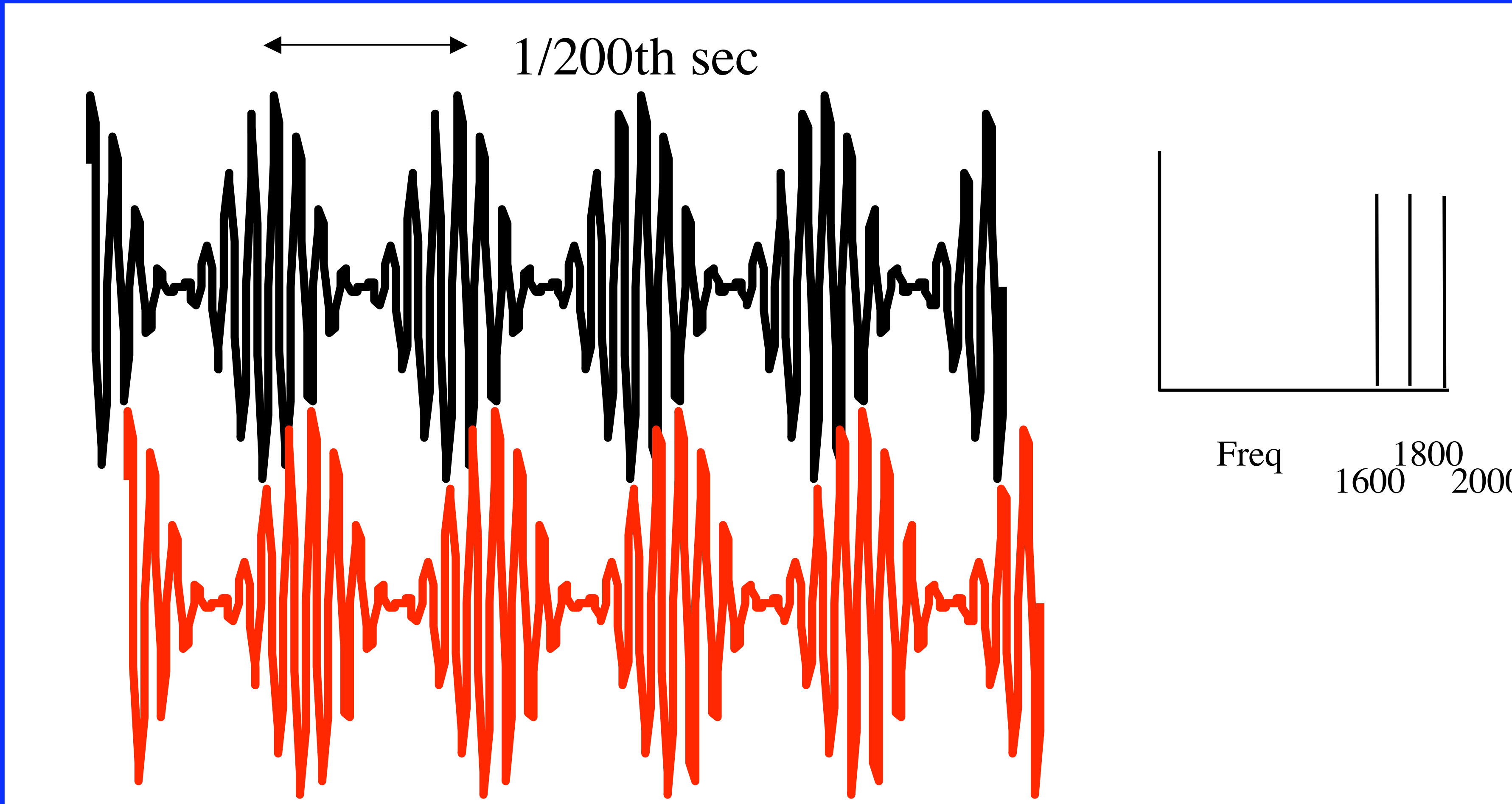
Raleigh's Duplex theory for pure tones (2)

1. Low frequency tones (<1500 Hz) localised by phase differences:

- Phase locking present for low frequency tones (<4kHz).

- Limited by phase ambiguity: Maximum ITD= 670 μs corresponding to a whole cycle at 1500 Hz (the upper limit for binaural phase sensitivity)

Phase ambiguity not a problem for complex high-frequency tones



Raleigh's Duplex theory for pure tones (3)

High (and close low) frequency tones localised by intensity differences

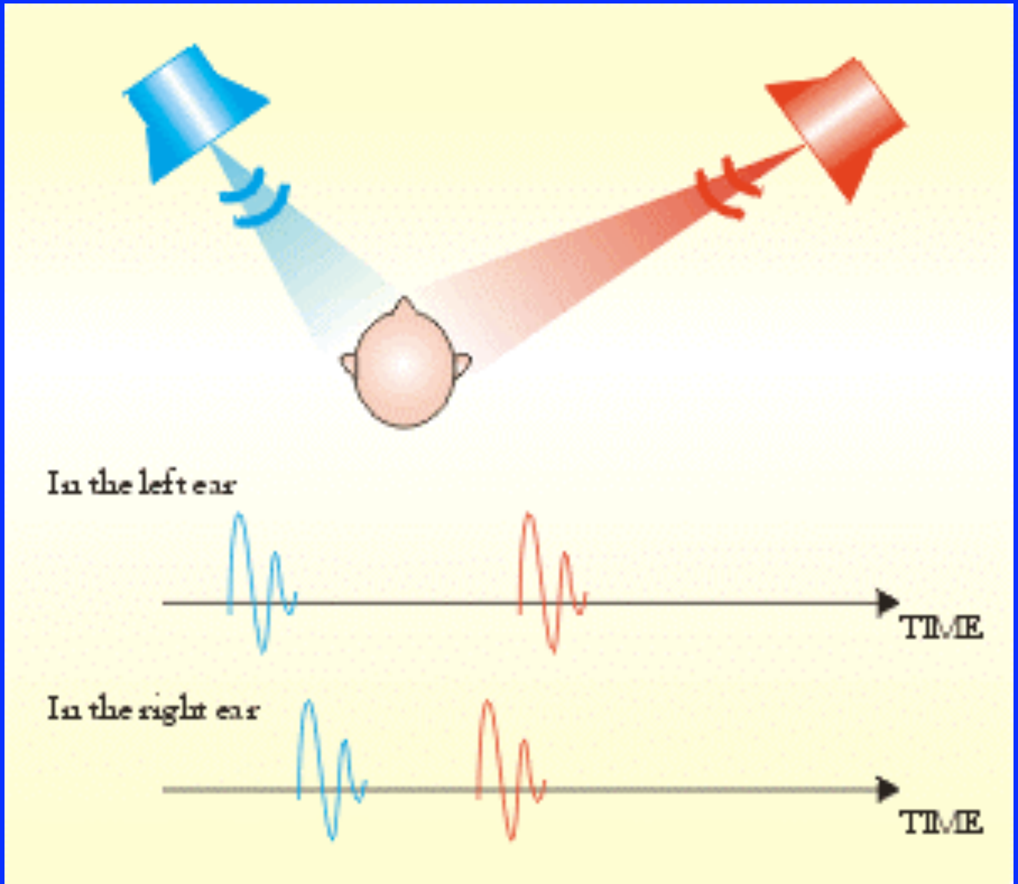
- Shadow cast by head greater at high (20 dB at 6 kHz) than low frequencies (3 dB at 500 Hz) i.e. head acts as a lowpass filter.

- For close sounds (<1.5m) the inverse square law gives intensity differences between the ears for all frequencies. These differences vary with azimuth independently of any head-shadow effect. Beyond 1.5m the difference in level between the ears due to this factor is less than 1 dB.

Azimuth for complex sounds

- Complex sounds contain both low and high frequencies
- But the dominant azimuth information is the ITDs of the low frequencies

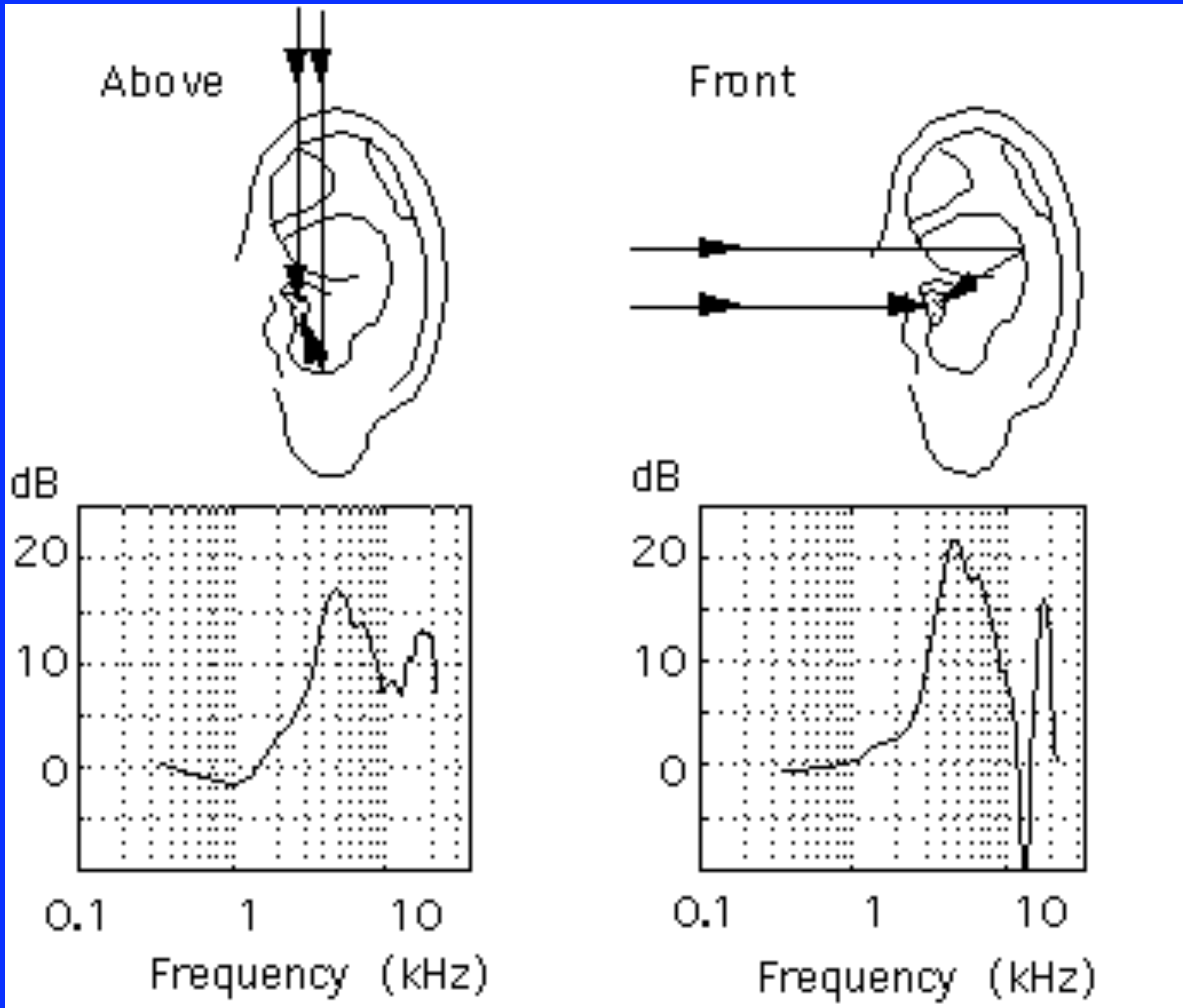
Precedence (or Haas) effect



Titrate blue ITD vs red ITD to center the single sound

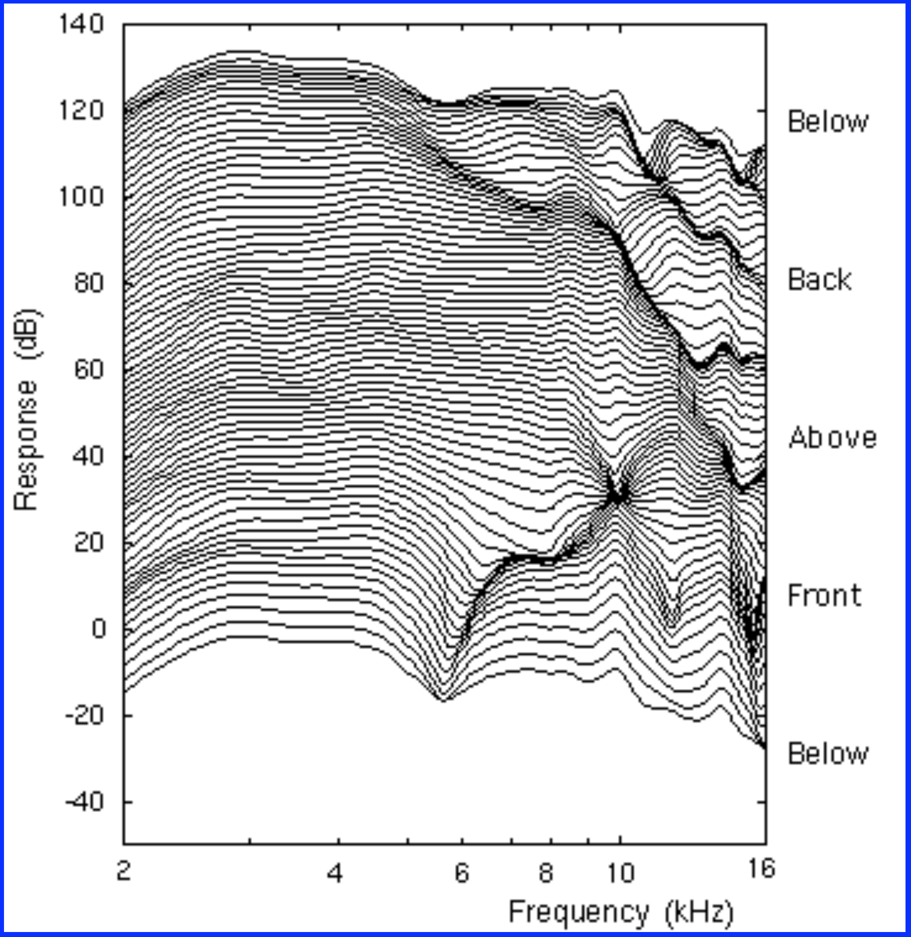
Lots of red ITD needed to offset a little blue

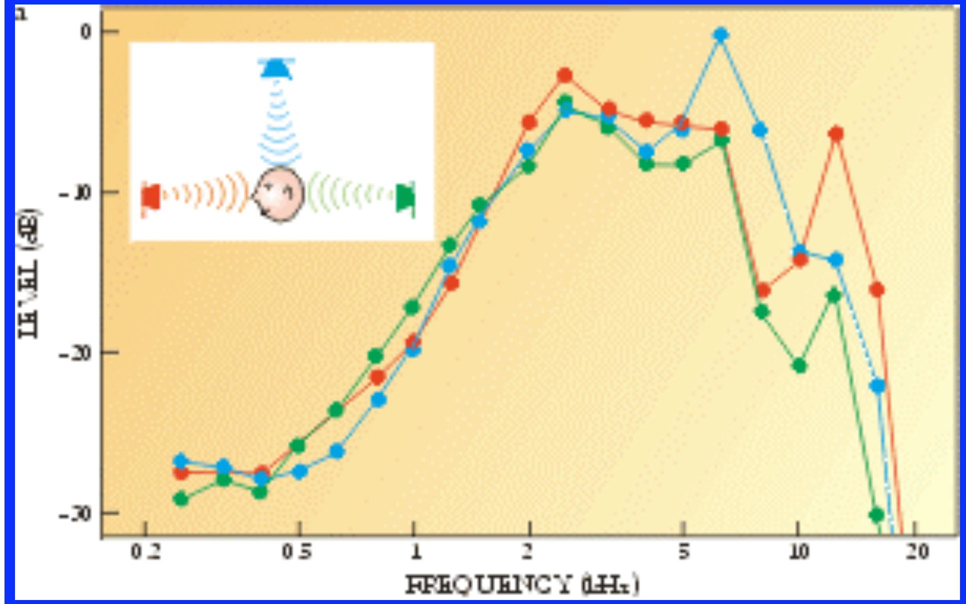
Pinna notch



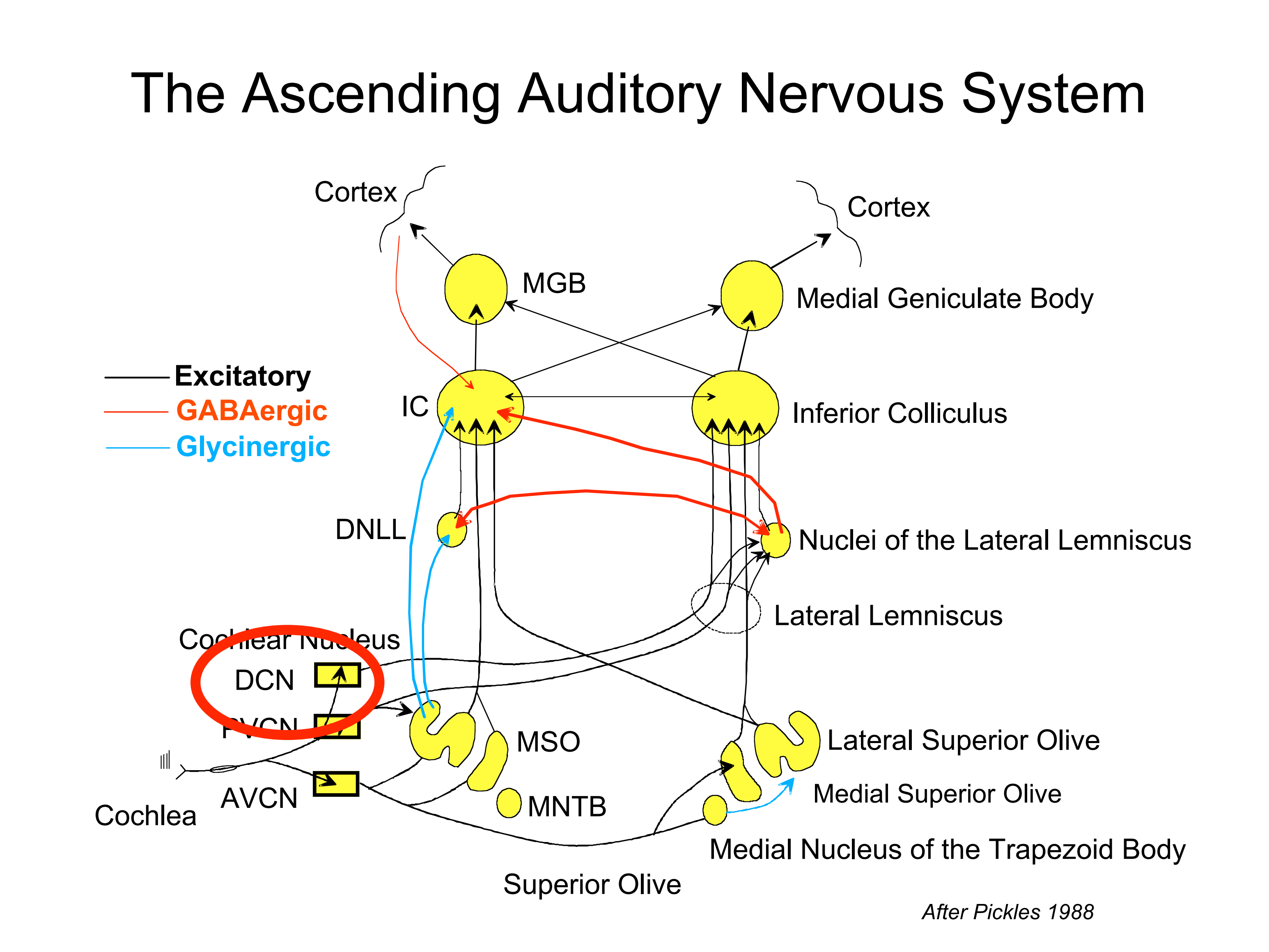
Above
Front
dB
20
10
0
0.1
1
10
Frequency (kHz)
dB
20
10
0
0.1
1
10
Frequency (kHz)

Head-Related Transfer Function: Median Plane





Anatomy of the auditory system



Distance

More distant sounds are:

- Quieter (inverse-square law)
- More muffled (high frequencies don’t travel so well)
- More reverberant (direct is quieter relative to reflected)

For very close sounds, the difference in distance from the source to the two ears becomes significant -> excess IID from inverse-square law.

Binaural masking level difference

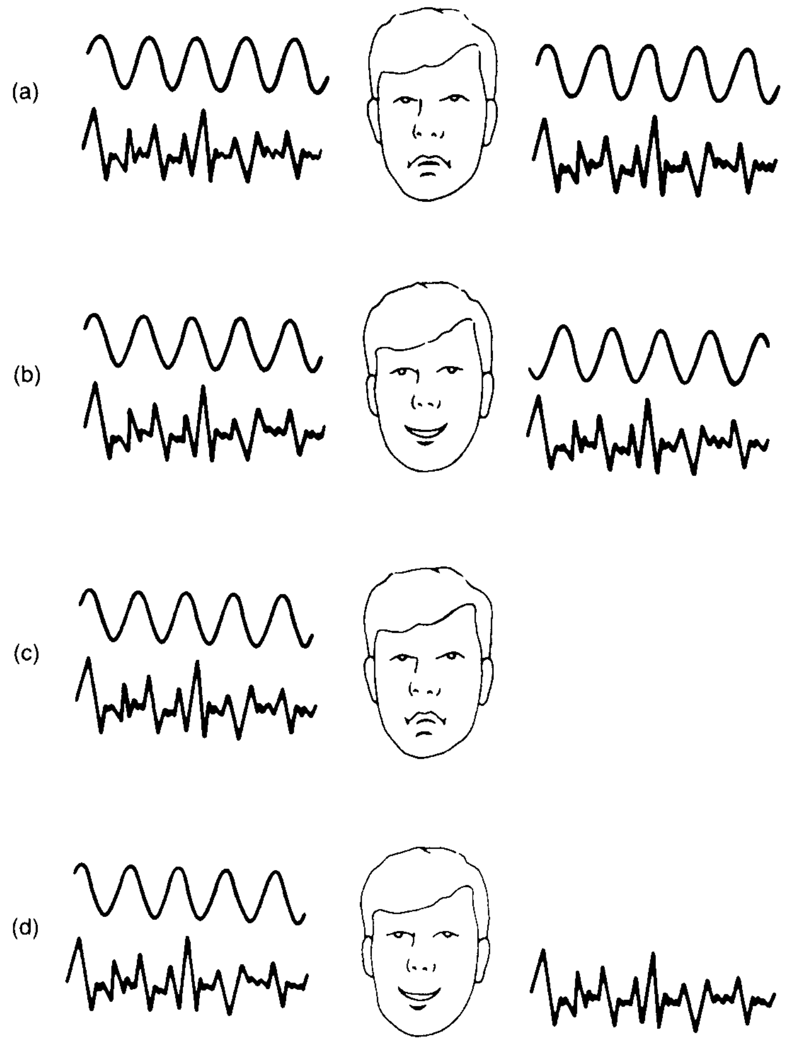


FIG. 6.9 Illustration of two situations in which binaural masking level differences (MLDs) occur. In conditions (a) and (c) detectability is poor, while conditions (b) and (d), where the interaural relations of the signal and masker are different, detectability is good (hence the smiling faces).

Explain by simply
Adding or subtracting
the signals at the two ears
(after adjusting their
levels)

(Durlach's Equalisation
and Cancellation model)