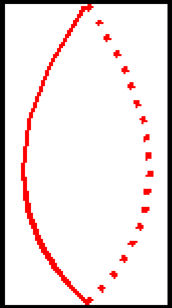
# Hearing: auditory coding mechanisms

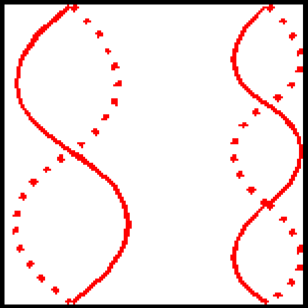
# Harmonics/ Fundamentals

- Recall: most tones are complex tones, consisting of multiple pure tones
- The lowest frequency tone in a sound is called the *fundamental frequency*; other tones are called *harmonics* or *overtones*.
- The fundamental frequency is the greatest common denominator of the other frequencies.

- Harmonics, fundamentals (cont.)
  - Here's a stringed instrument, plucking out a fundamental tone:



  - And here's the same stringed instrument, showing some of the harmonics:



- Harmonics, fundamentals (cont.)
- The fundamental is (generally) the greatest common denominator of the harmonic tones.

100, 200, 300 hz?

200, 400, 600 hz?

In the following, the true fundamental is missing:

200,300,400,500 hz?

250,300,400 hz?

2000,2400hz ?

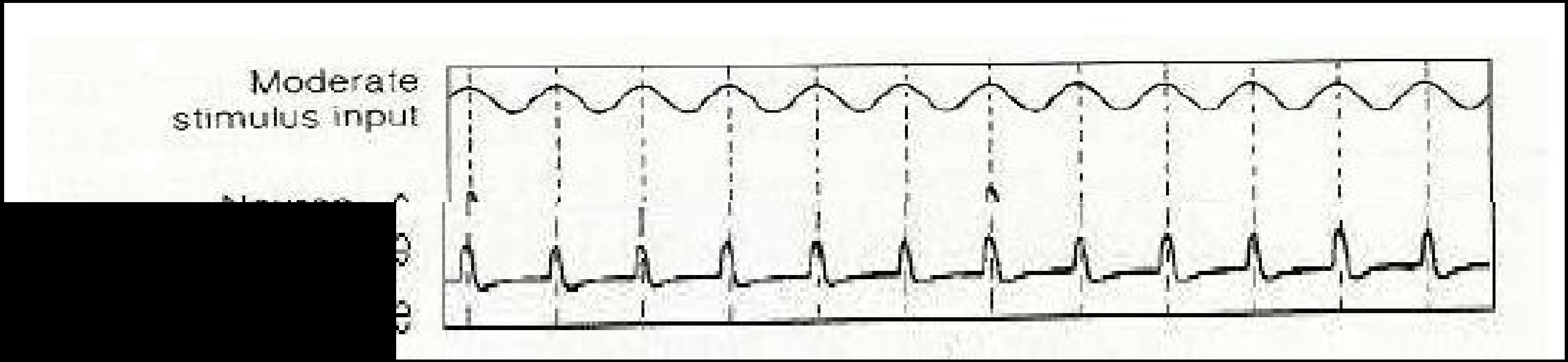
- Harmonics, fundamentals (cont.)
  - The problem of the missing fundamental
    - When the fundamental frequency is ***missing*** from a complex tone, people report that they hear it.

      ex: men on (older) phones

      ex: bad stereo in a noisy car
  - So?
    - A problem for traditional explanations of hearing – the region on the basilar membrane that codes the fundamental is NOT moving

- Harmonics, fundamentals (cont.)
    - The problem of the missing fundamental(cont.)
        - So if the basilar membrane isn't moving in the *place* that represents the fundamental, how can you still hear it?
        - *Place theory* vs. *frequency theory*
            - Place theory is the same basilar membrane theory we talked about before.
            - *Frequency theory* contends that, if sound is a vibration, then if neurons fire in response, they should replicate the frequency.

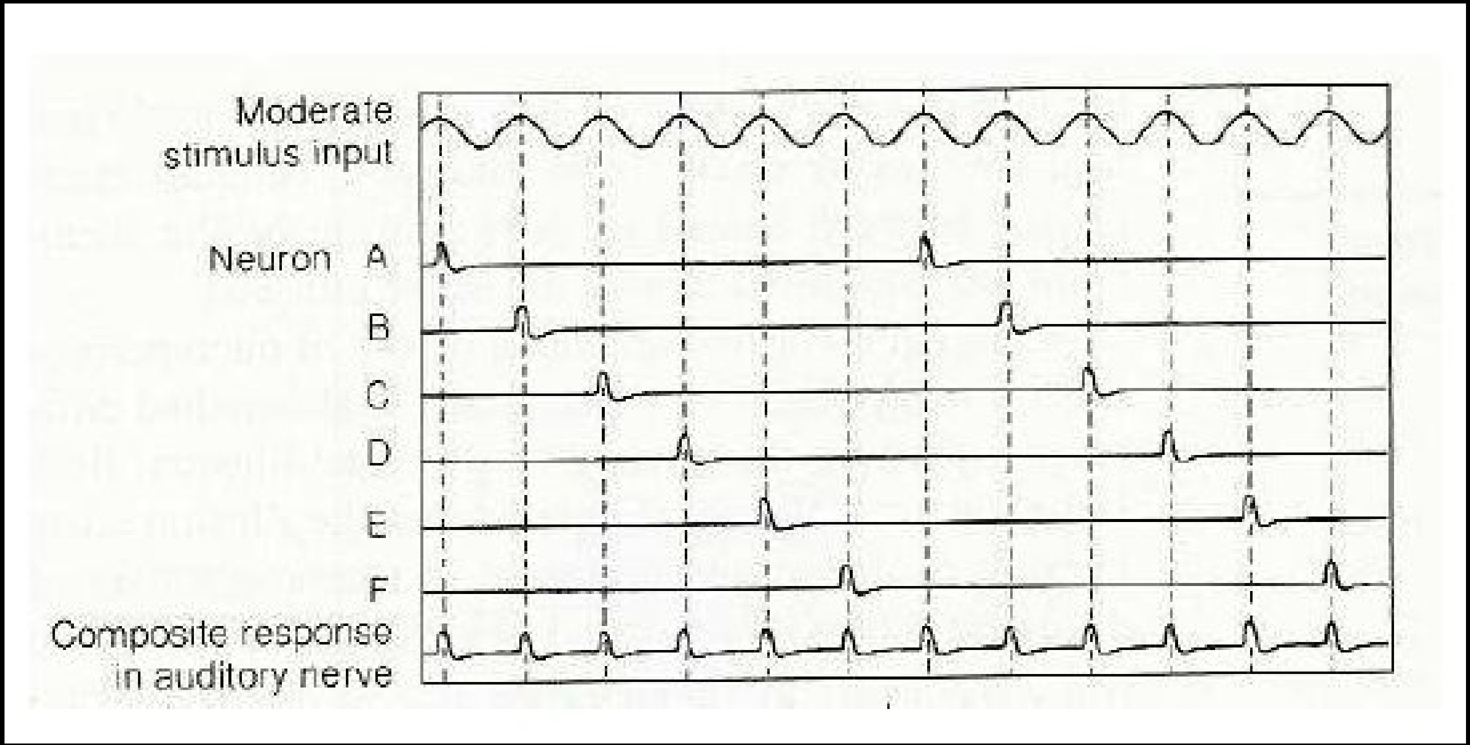
- Harmonics, fundamentals (cont.)
  - The problem of the missing fundamental(cont.)
    - Place theory vs. frequency theory(cont.)
      - Here, a particular frequency's signal is reproduced in the auditory nerve:




      - Does it work?

- Harmonics, fundamentals (cont.)
  - The problem of the missing fundamental(cont.)
    - Place theory vs. frequency theory(cont.)
      - Only sort of.
      - problem: neurons can't fire fast enough to match tones at higher frequencies than about 1000 Hz – but we know we can hear lower frequencies than that (even when they aren't actually there, if they're a missing fundamental – freaky!)

• Harmonics, fundamentals (cont.)
  • The problem of the missing fundamental(cont.)
    • Place theory vs. frequency theory(cont.)
      • *volley principle*: while one neuron is resting, another is firing. (helps for coding loudness as well!)



- Harmonics, fundamentals (cont.)
  - The problem of the missing fundamental(cont.)
    - Place theory vs. frequency theory(cont.)
      - So even though we know place theory works, frequency theory seems to work too (thanks to the volley principle), and helps account for TPOTMF

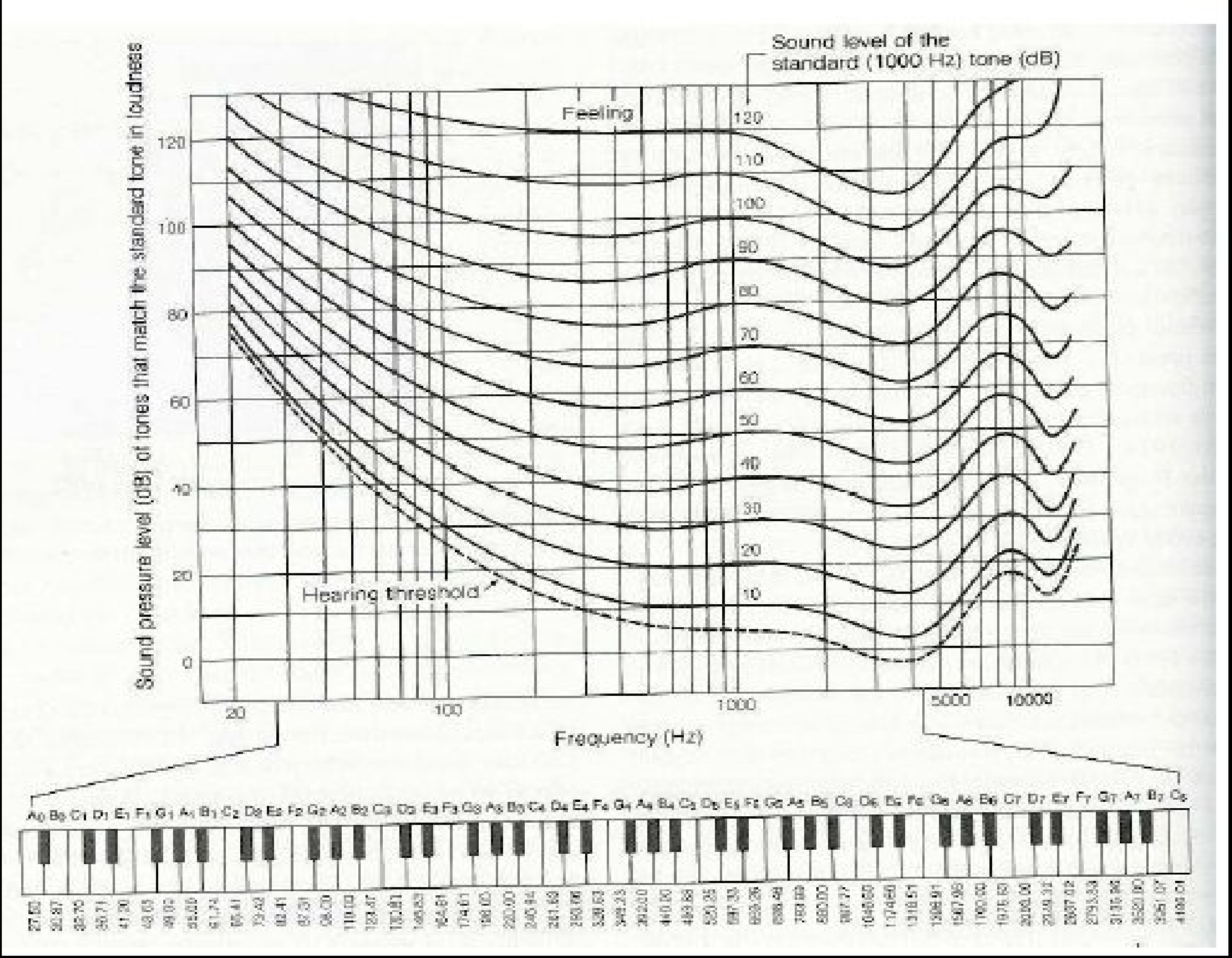
loudness is psychological reaction to amplitude.

- determined by # of neurons firing at a time (similar to volley principle).
- 4 factors influence loudness perception:

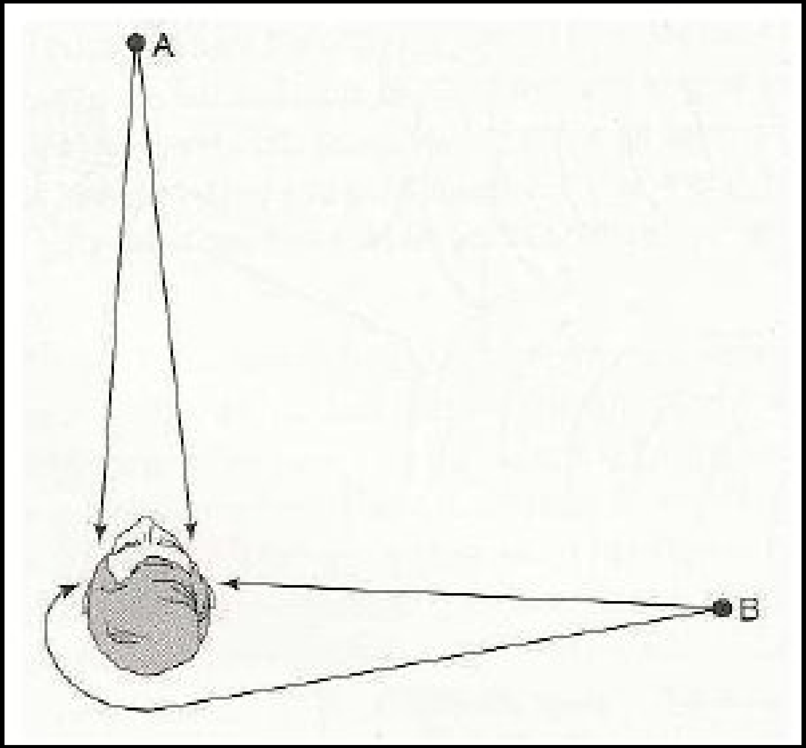
1. duration: brief tones are perceived as quieter.
2. context: tones presented with a background of noise (static) are perceived as quieter.

- loudness is psychological reaction to amplitude.(cont.)
  - 4 factors influence loudness perception(cont.)
    3. observer state:
       - attention to tones can make them seem louder
       - adaptation: fresh ears perceive sounds as louder than ears that have been adapted to noise.

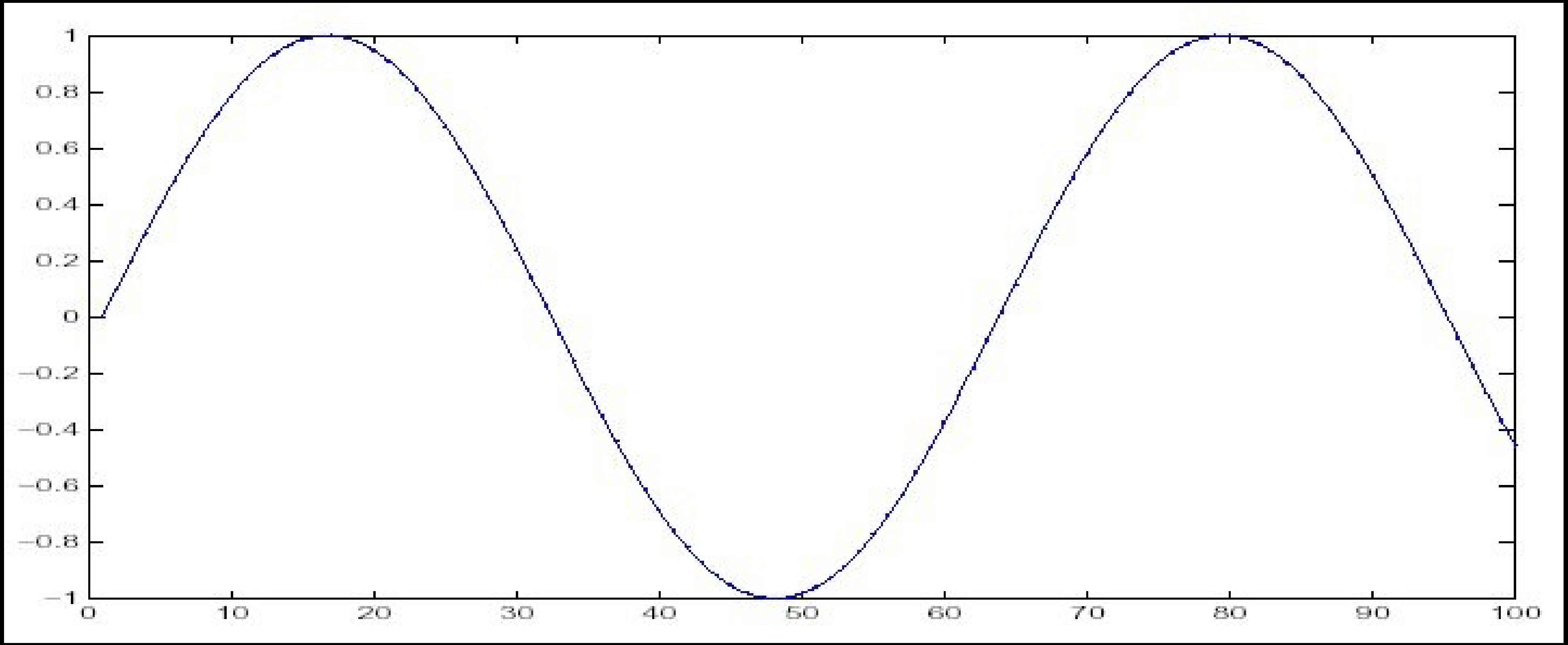
- loudness is psychological reaction to amplitude.
  - 4 factors influence loudness perception(cont.)
    - 4. frequency: same amplitude sounds louder at 1000Hz than at 100 Hz. Equal loudness contours:



- Localization: How do we know where a sound is coming from?
  - most factors are *binaural*
    1. interaural onset difference. How long did it take the sound to hit your left ear after your right?

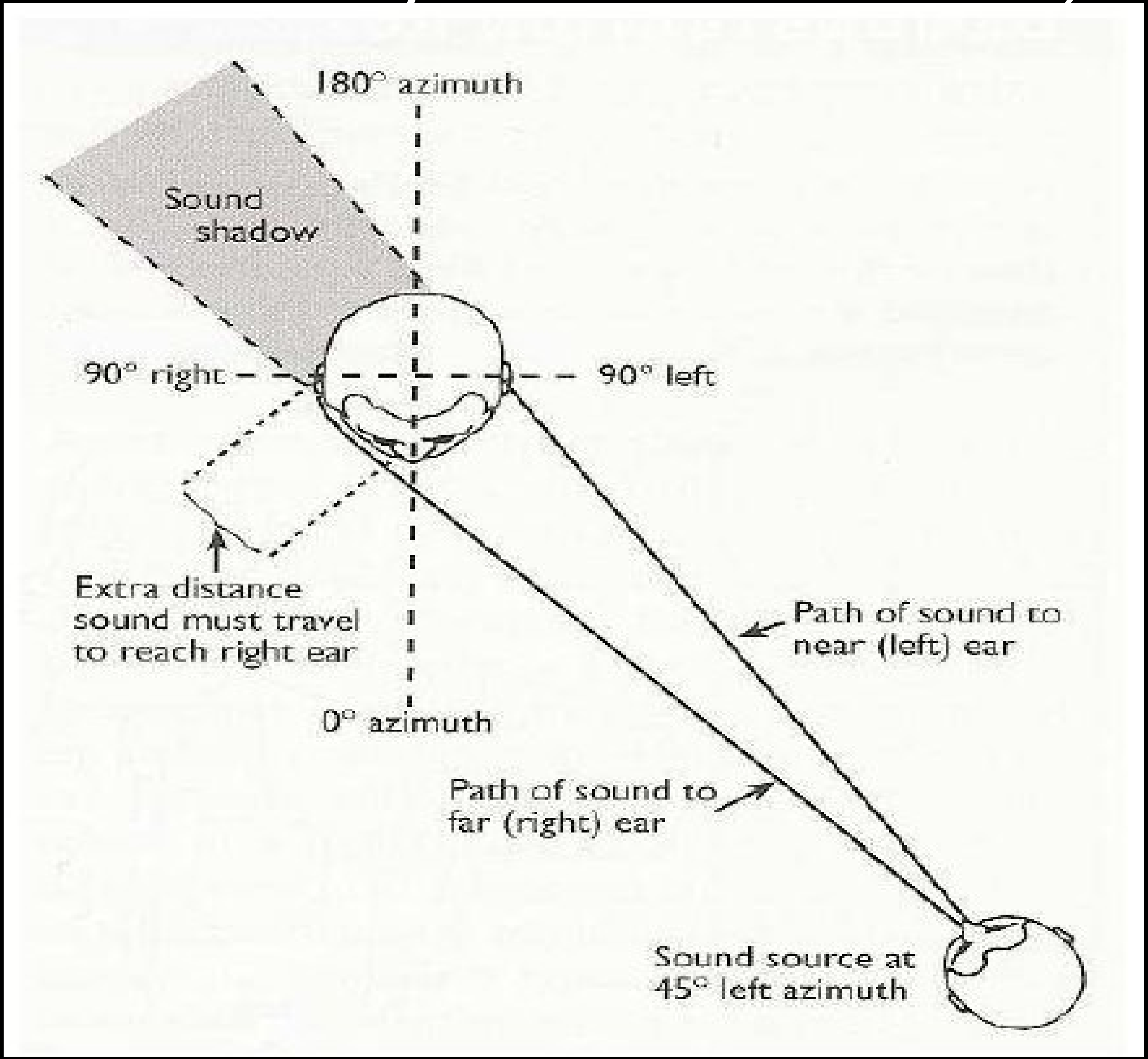


- Binaural localization (cont.)
  2.interaural phase difference.  compare where in the cycle a tone is when it hits the ear.



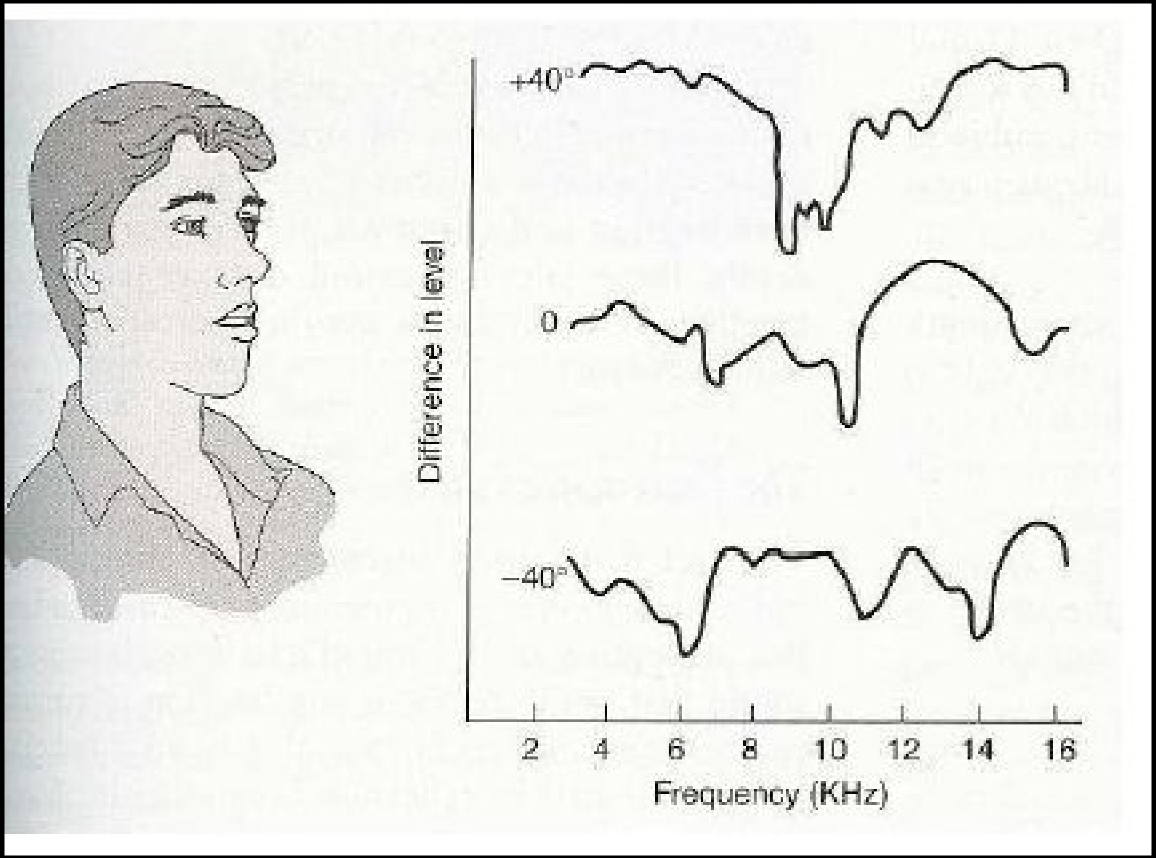
•Binaural localization (cont.)

3.interaural intensity difference. (sound shadow lowers intensity of some sounds).



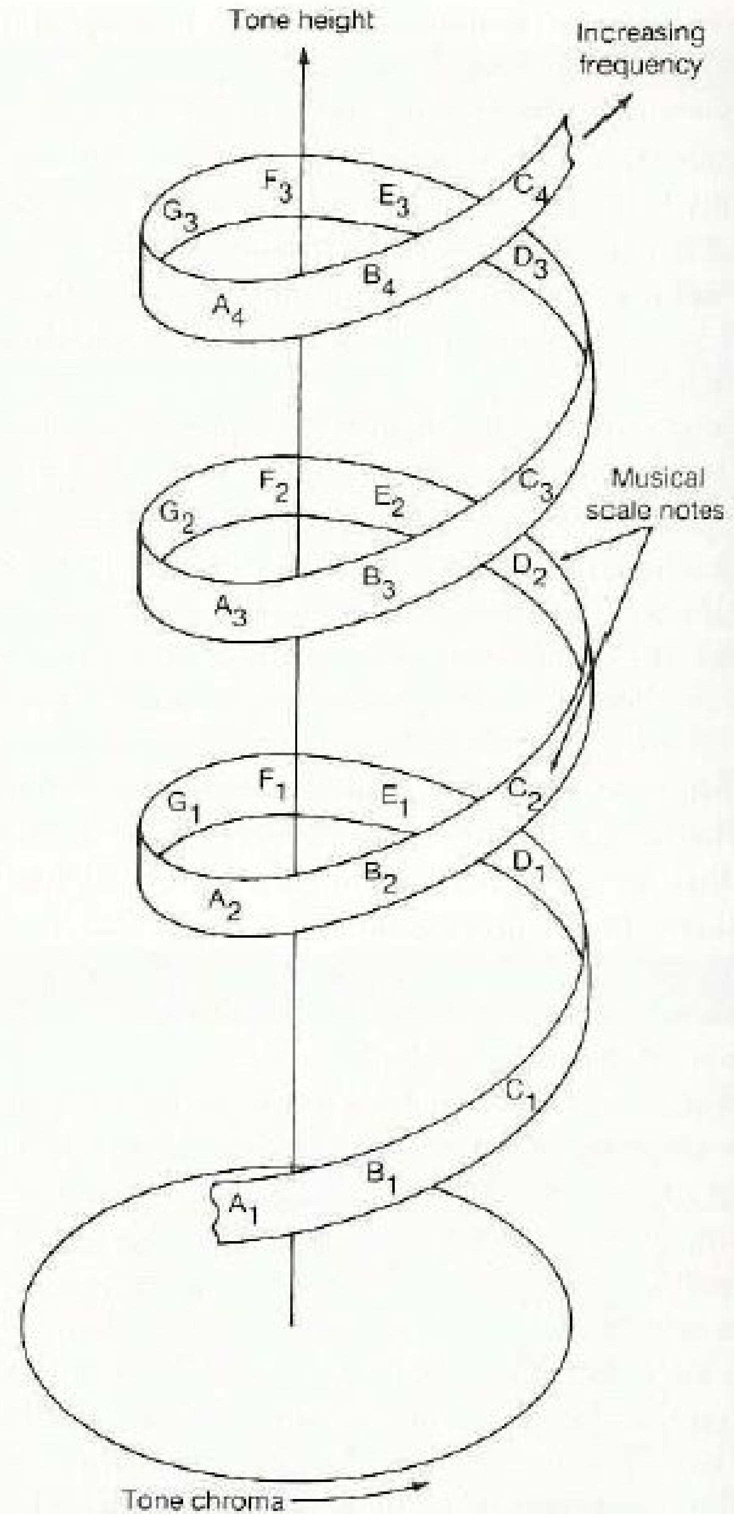
- monaural factors
  1. movement parallax: nearby sounds change their location faster than distant sounds.
  2. doppler shift: sounds coming towards you have a higher pitch than sounds moving away from you.

- binaural factors help left-right location discrimination- What about up-down?
  - Pinna plays a role here: sounds bounce off folds of pinna, enhancing some frequencies & decreasing others - called a . . .

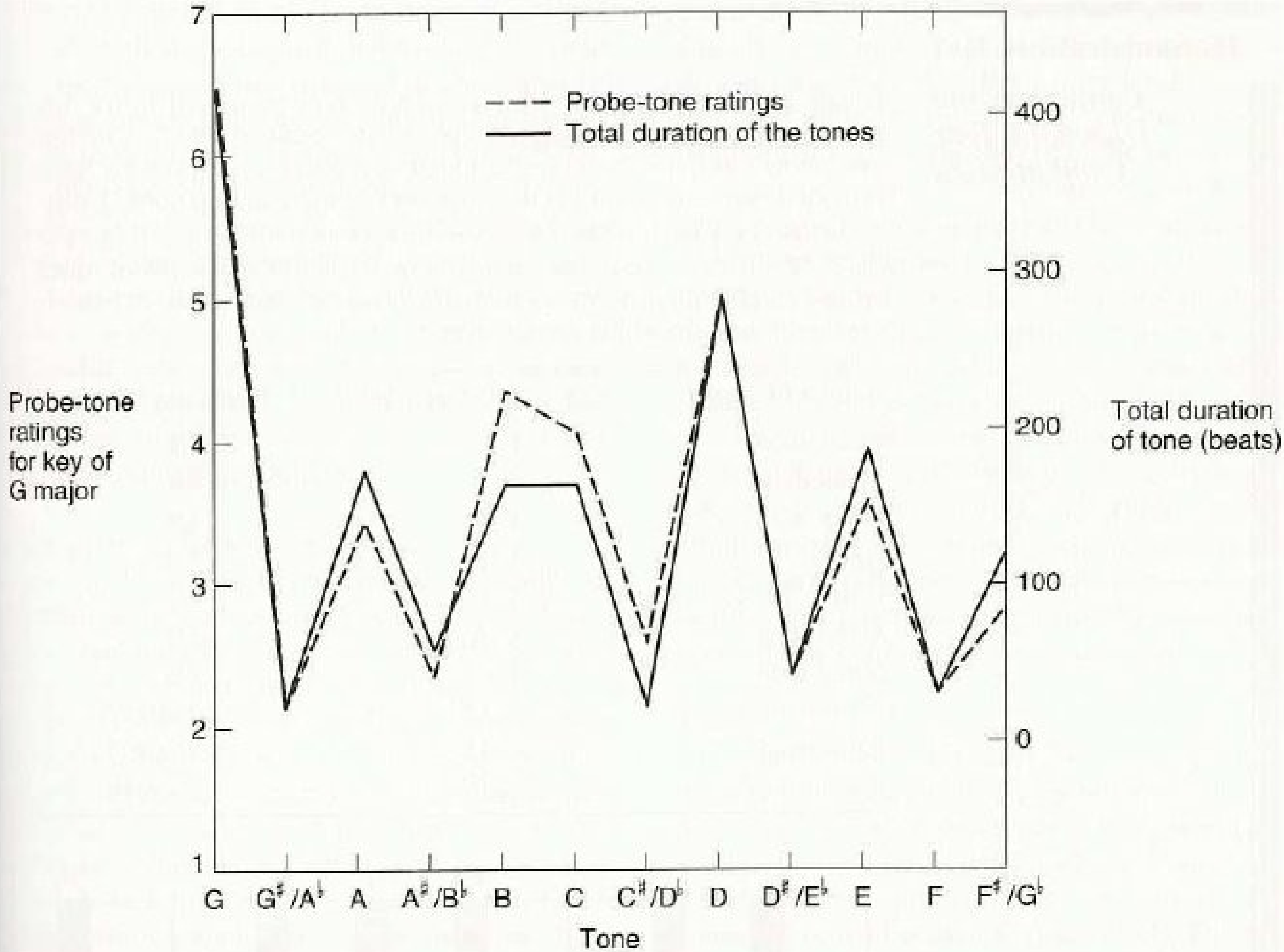


- . . .directional transfer function:
  - Gardner & Gardner (1973): inserted modelling compound into peoples pinnae, & measured ability to localize sounds.
  - result: as pinnae were made smoother & smoother, localization became worse & worse.

- Music, speech
  - Musical tones have two values: *height* and *chroma*.
  - *octave*: sounds that live directly above one another on the tone helix represent successive doubling of frequencies.



- Music, speech (cont.)
  - Krumhansl (1983): probe-tone experiment. Play a chord (to establish a key), then a tone – one of the 12 found within the octave of the key.
    - participants rate goodness" of probe tone. goodness ratings correlate with use of tones in classical music.



Probe-tone ratings
Total duration of the tones
Probe-tone ratings for key of G major
Total duration of tone (beats)
7
6
5
4
3
2
1
400
300
200
100
0
G
G♯/A♭
A
A♯/B♭
B
C
C♯/D♭
D
D♯/E♭
E
F
F♯/G♭
Tone

- Music, speech (cont.)
  - music can impact emotional states: Evers & Suhr (2000) showed music can affect seratonin release in the brain.
  - *perfect pitch*: ability to identify a musical note even in isolation from others.
    - harmonics important for this ability; when presented with pure tones, accuracy drops to about 50%.

- Music, speech (cont.)
  - nonmusicians have good memory for pitch: Schellenburg & Trehub (2003) played TV themes in a new key: people did better than expected.
  - auditory cortex larger in musicians with perfect pitch.
  - *amusia*: inability to recognize melodies and tunes; other auditory perception (speech, events) unaffected.

# List of terms, section 4

- Harmonic
- Fundamental
- Place theory
- Frequency theory
- Missing fundamental
- Volley principle
- Loudness
- Duration
- Context
- Observer state
- Attention
- Adaptation
- Frequency
- Equal loudness contours
- Binaural factors
- Interaural phase difference
- Interaural onset difference
- Interaural intensity difference
- Movement parallax
- Doppler shift
- Directional transfer function
- Gardner & Gardner experiment
- Tone height, chroma
- Octave
- Krumhansl experiment
- Evers & Suhr result
- Perfect pitch
- Schellenburg & Trehub result
- Amusia