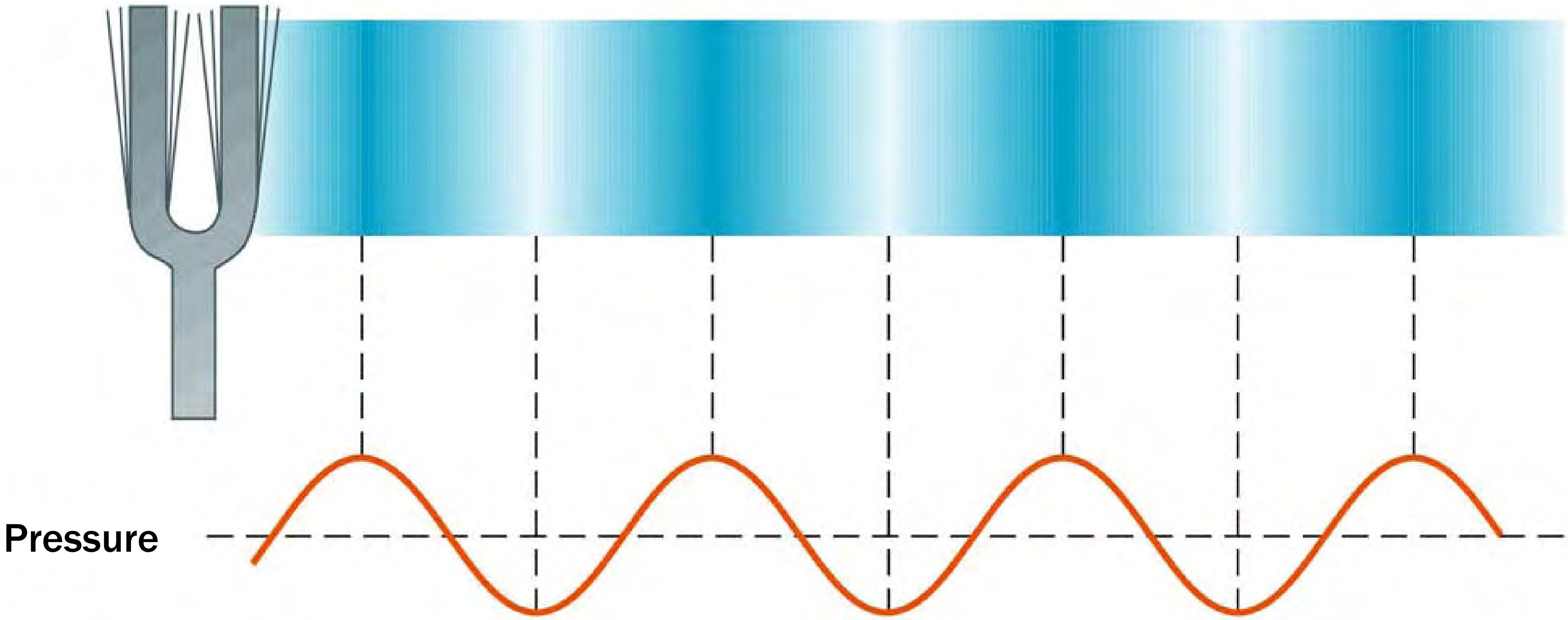
SOUND


Pressure

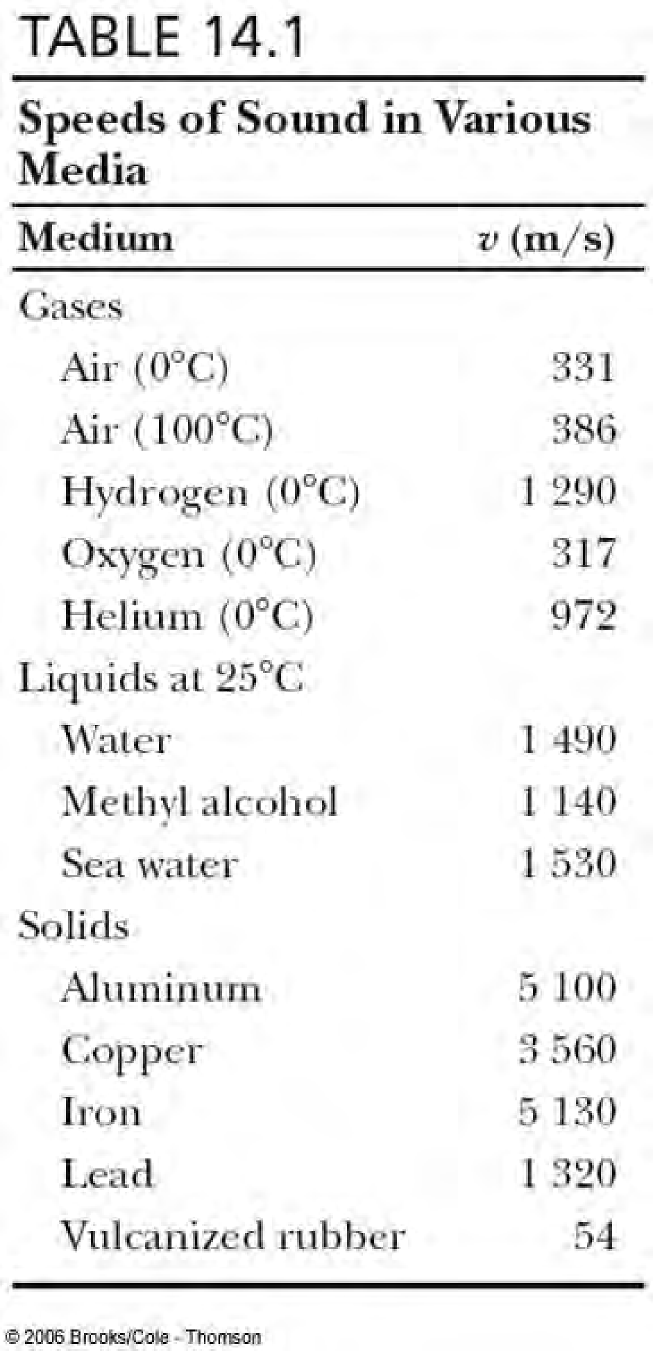
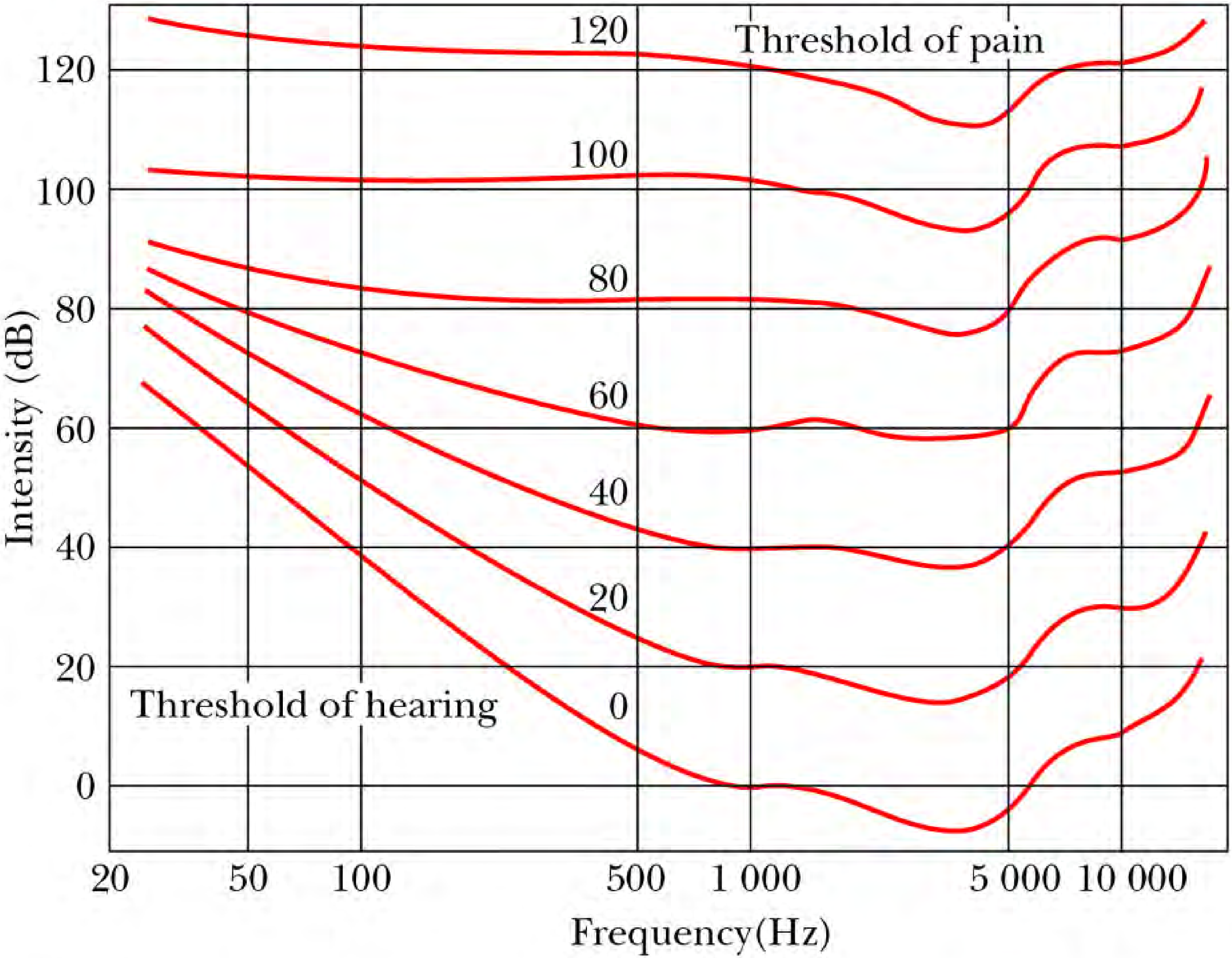


TABLE 14.1

Speeds of Sound in Various Media

Medium	v (m/s)
Gases	
Air (0°C)	331
Air (100°C)	386
Hydrogen (0°C)	1 290
Oxygen (0°C)	317
Helium (0°C)	972
Liquids at 25°C	
Water	1 490
Methyl alcohol	1 140
Sea water	1 530
Solids	
Aluminum	5 100
Copper	3 560
Iron	5 130
Lead	1 320
Vulcanized rubber	54

At normal air temperature, v_{sound} ~ 340 m/s

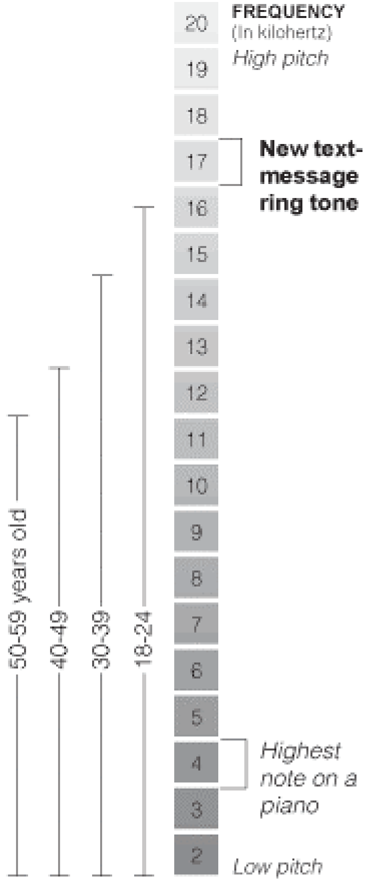

120
Threshold of pain
100
80
60
40
20
0
Threshold of hearing
120
100
80
60
40
20
0
Intensity (dB)
20
50
100
500
1 000
5 000
10 000
Frequency(Hz)

Hearing High Tones

New York area teenagers have begun using a text-message ring tone with a frequency too high for most adults to hear.

Range by age group

Audible frequencies for sound at 60 decibels SPL (sound pressure level)



Sources: "Extended High-frequency Audiometry" by Petter Hallmo, Arne Sundby and Iain WS Mair; Andy Vermiglio, House Ear Institute; Compound Security Systems

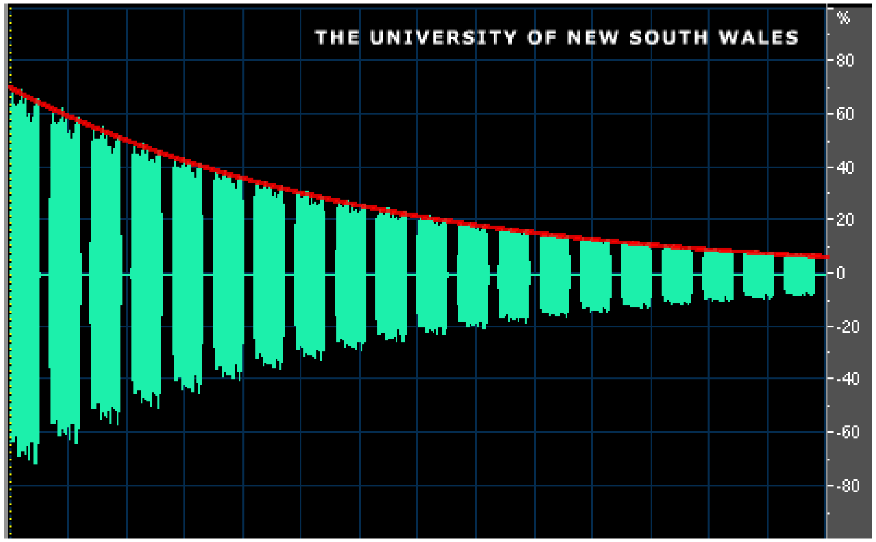
The New York Times

TABLE 14.2

Intensity Levels in Decibels for Different Sources

Source of Sound	**β(dB)**
Nearby jet airplane	150
Jackhammer, machine gun	130
Siren, rock concert	120
Subway, power mower	100
Busy traffic	80
Vacuum cleaner	70
Normal conversation	50
Mosquito buzzing	40
Whisper	30
Rustling leaves	10
Threshold of hearing	0

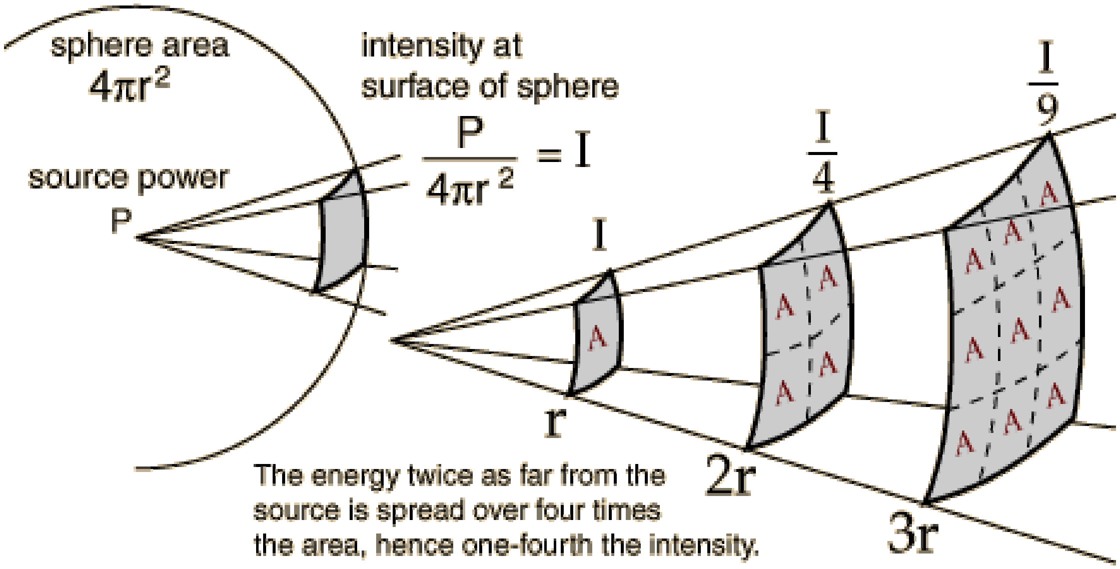
How big is a decibel? In the next series, successive samples are reduced by just one decibel.



One decibel is close to the Just Noticeable Difference (JND) for sound level. As you listen to these files, you will notice that the last is quieter than the first, but it is rather less clear to the ear that the second of any pair is quieter than its predecessor. $10*\log_{10}(1.26) = 1$, so to increase the sound level by 1 dB, the power must be increased by 26%, or the voltage by 12%.

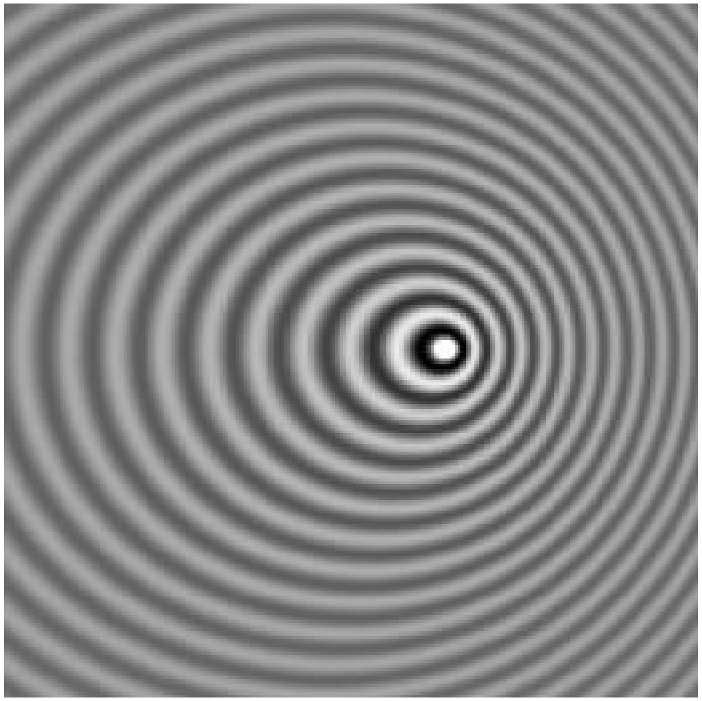
▶ Broadband noise decreasing by 1 dB steps.

http://www.phys.unsw.edu.au/jw/dB.html

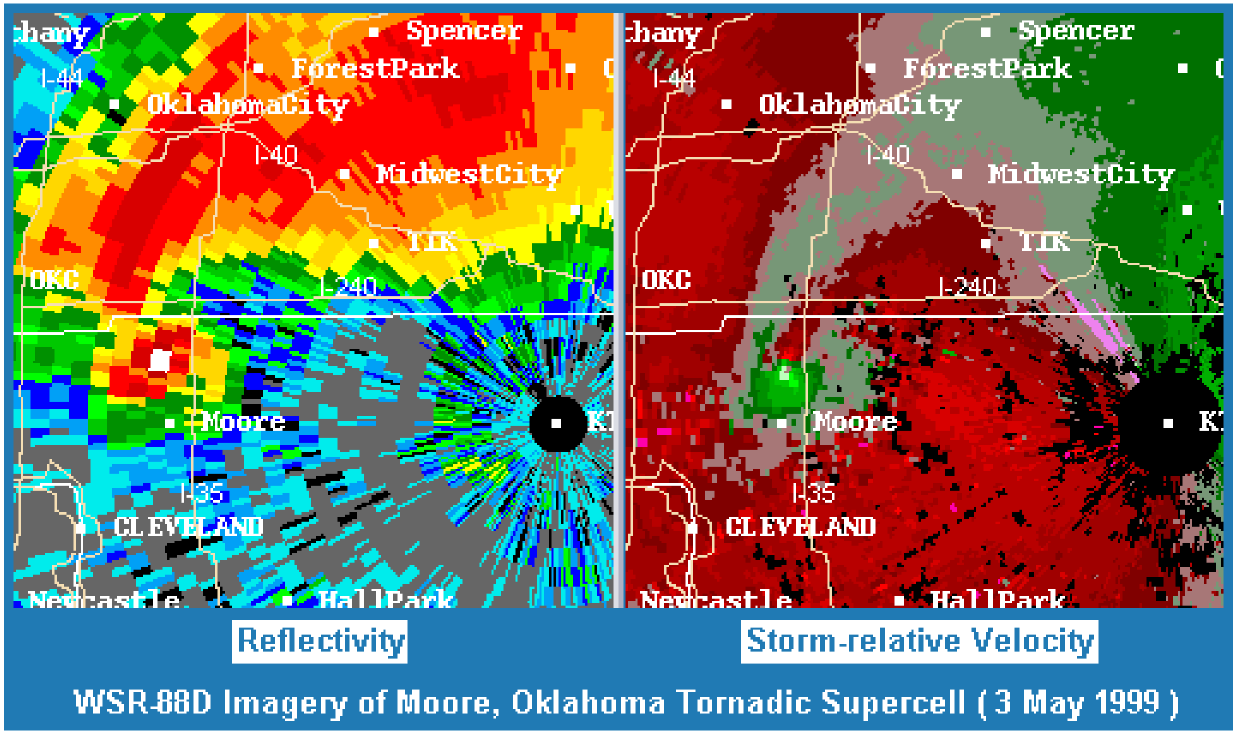


The energy twice as far from the source is spread over four times the area, hence one-fourth the intensity.

•Animation courtesy of Dr. Dan Russell, Kettering University



- Animation courtesy of Dr. Dan Russell, Kettering University

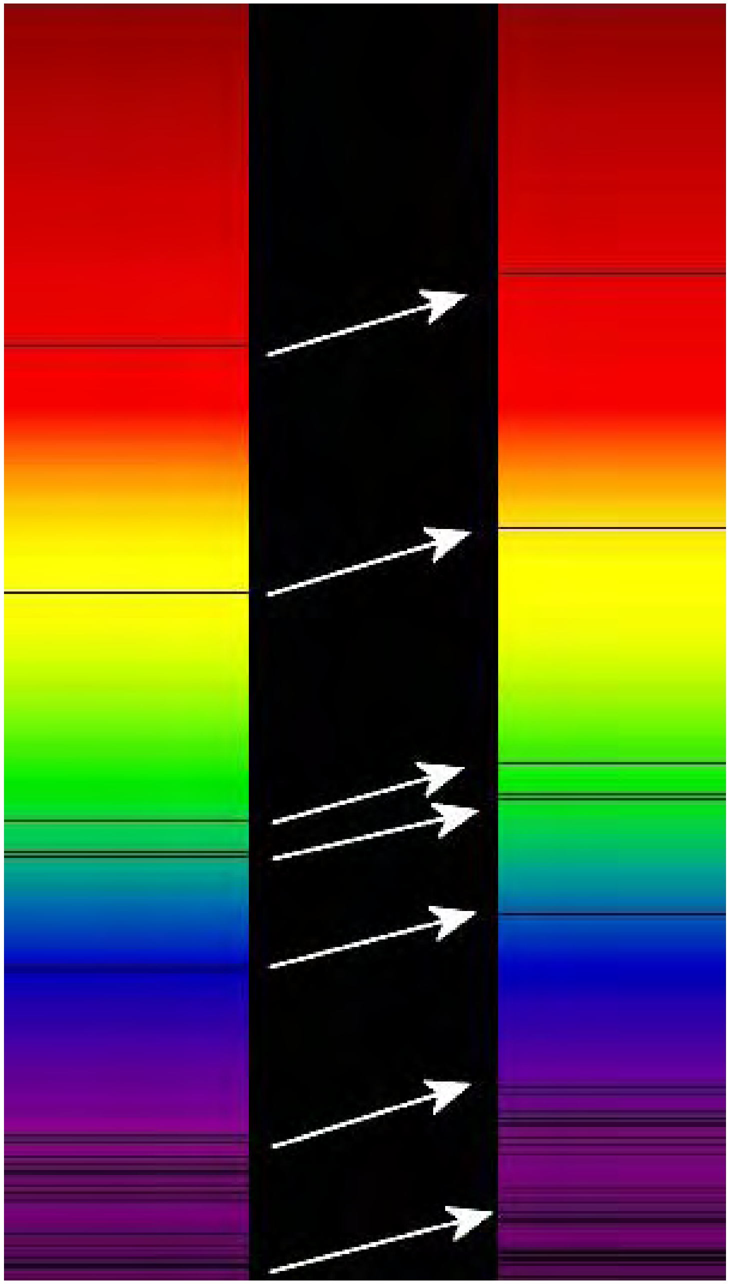


Reflectivity

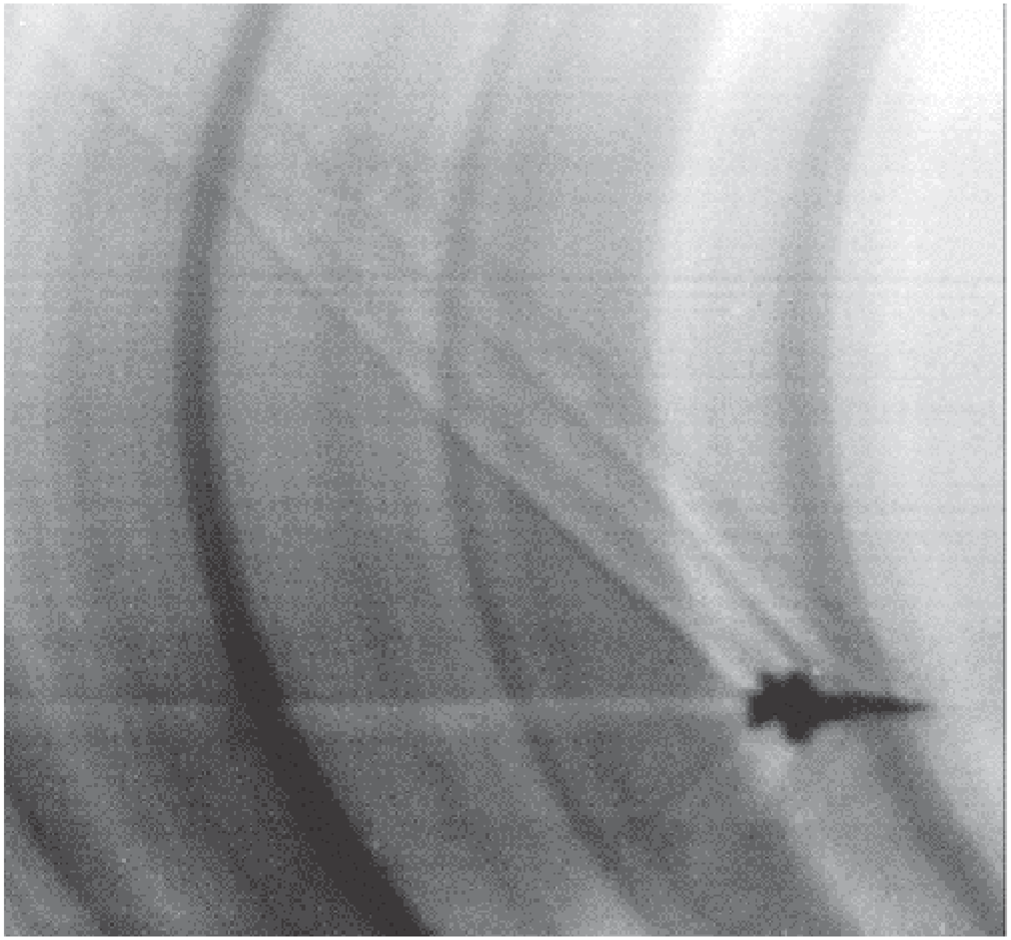
Storm-relative Velocity

WSR-88D Imagery of Moore, Oklahoma Tornadic Supercell (3 May 1999)

Doppler Radar

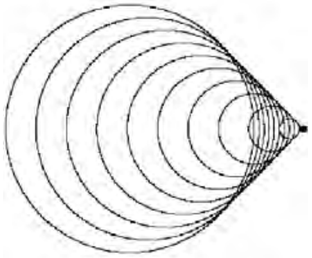


Red Shift

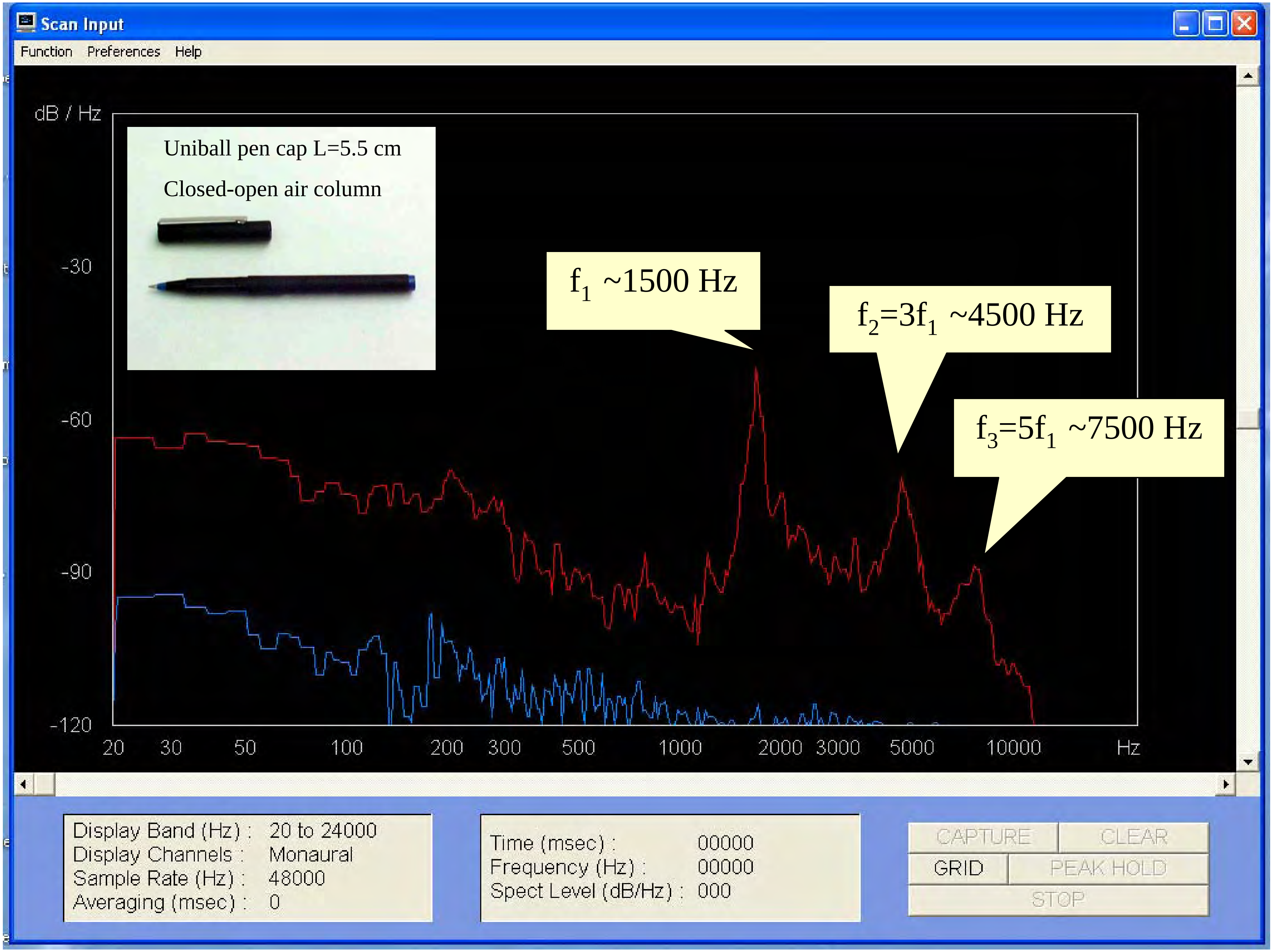


F-18 at Mach = 1.4, altitude = 35,000 ft

http://www.nasa.gov/centers/dryden/news/FactSheets/FS-033-DFRC.html



- Animation courtesy of Dr. Dan Russell, Kettering University



Uniball pen cap L=5.5 cm

Closed-open air column

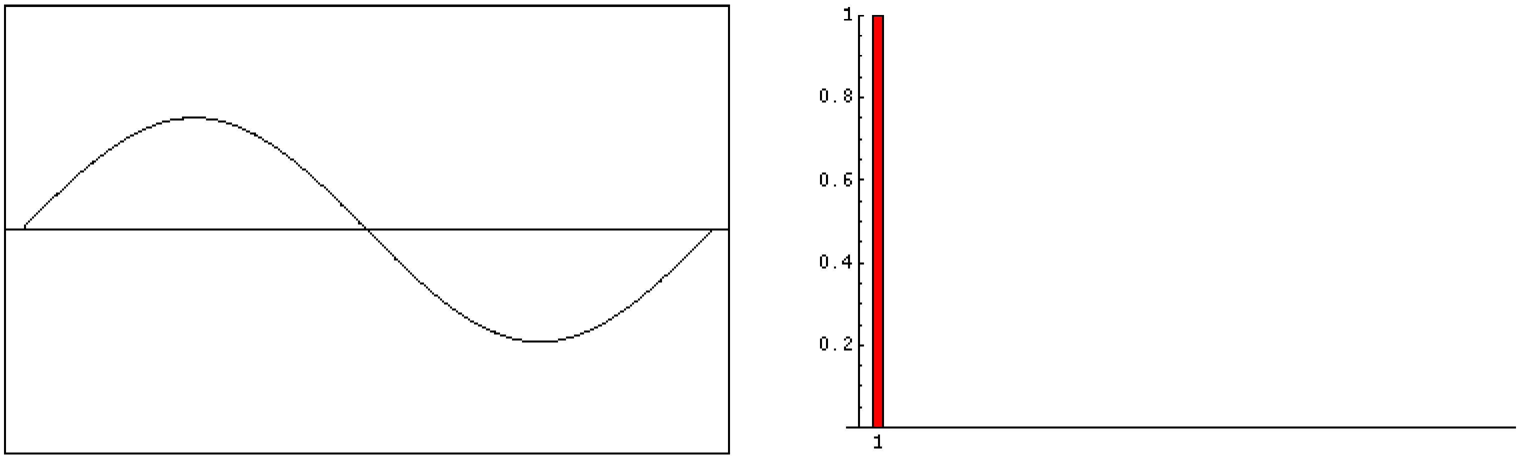
f_1 ~1500 Hz

$f_2=3f_1$ ~4500 Hz

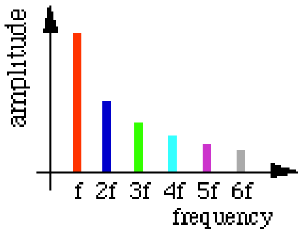
$f_3=5f_1$ ~7500 Hz

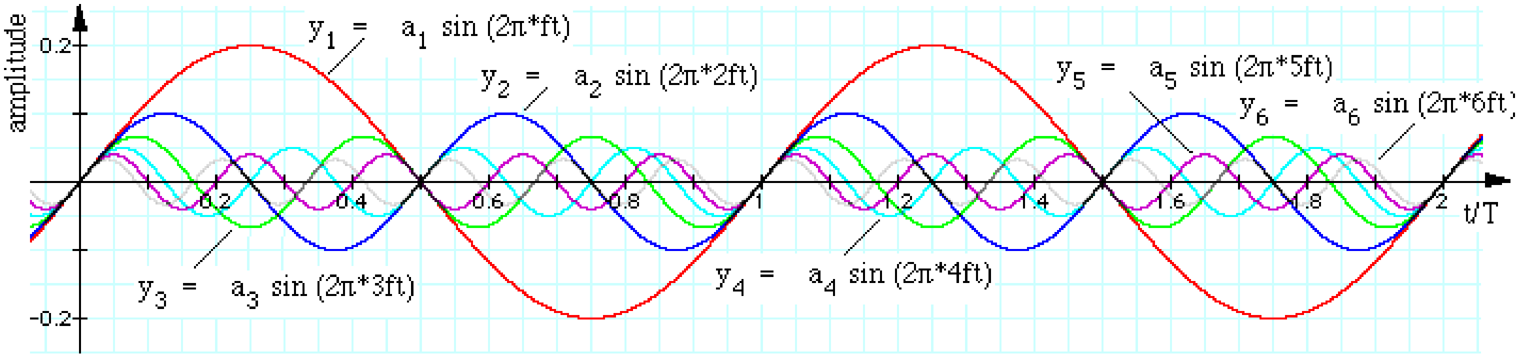
Display Band (Hz) : 20 to 24000
Display Channels : Monaural
Sample Rate (Hz) : 48000
Averaging (msec) : 0

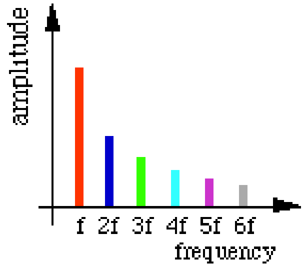
Time (msec) : 00000
Frequency (Hz) : 00000
Spect Level (dB/Hz) : 000

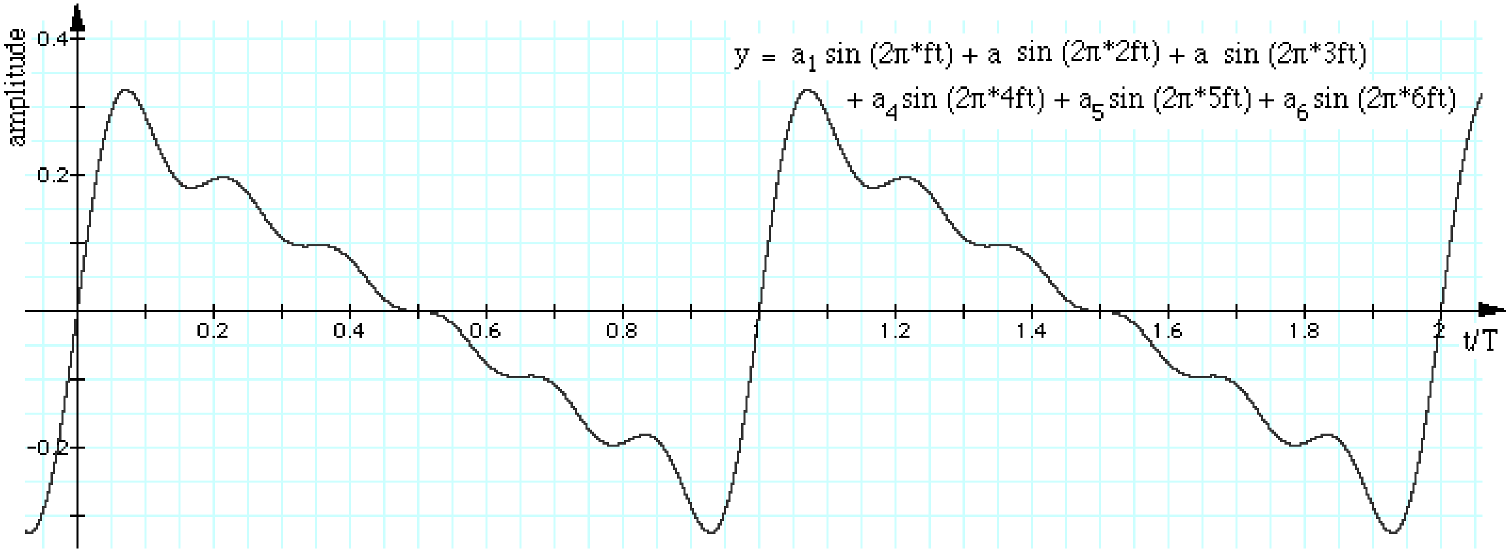


•Animation courtesy of Dr. Dan Russell, Kettering University

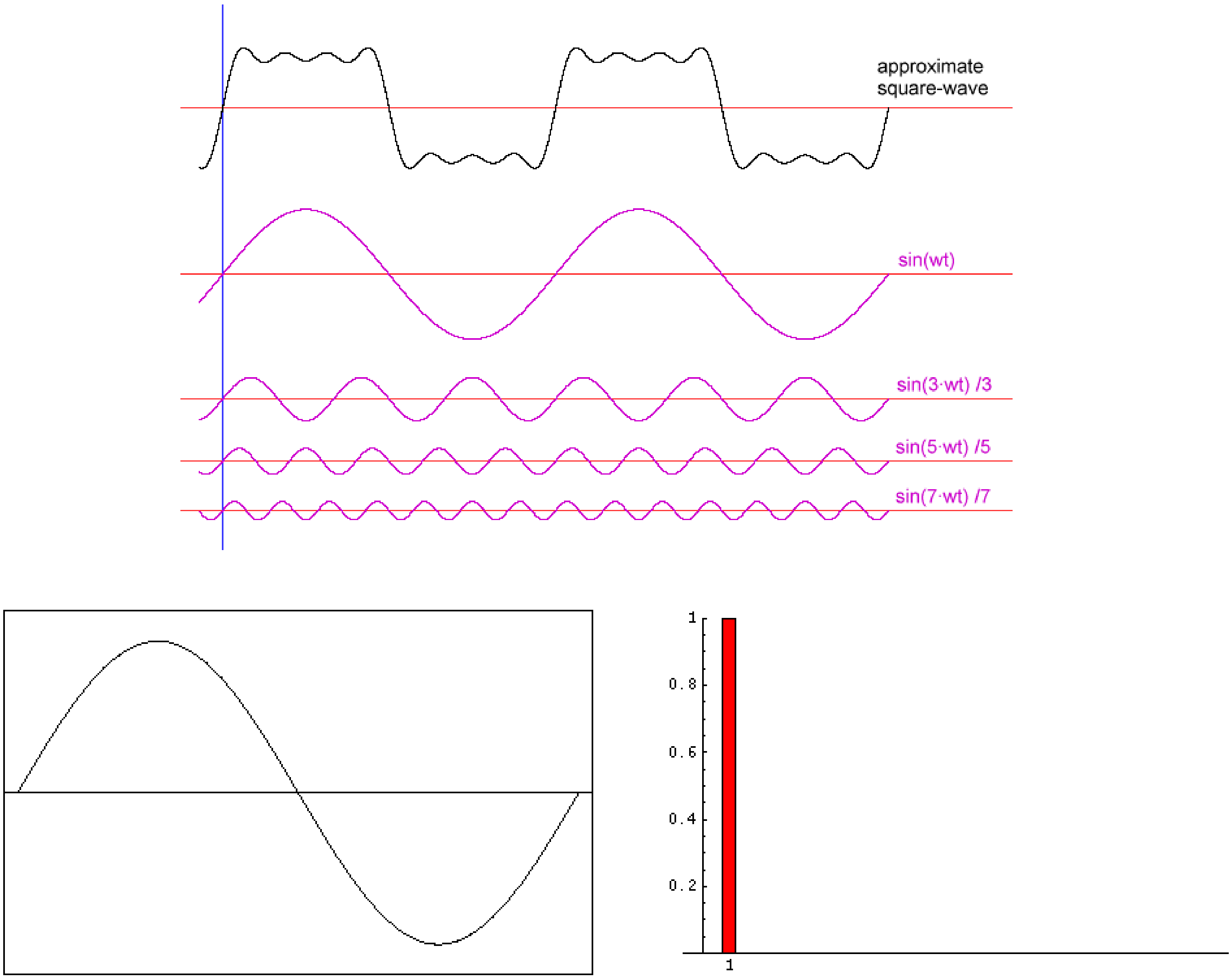








http://www.phys.unsw.edu.au/jw/sound.spectrum.html



•Animation courtesy of Dr. Dan Russell, Kettering University

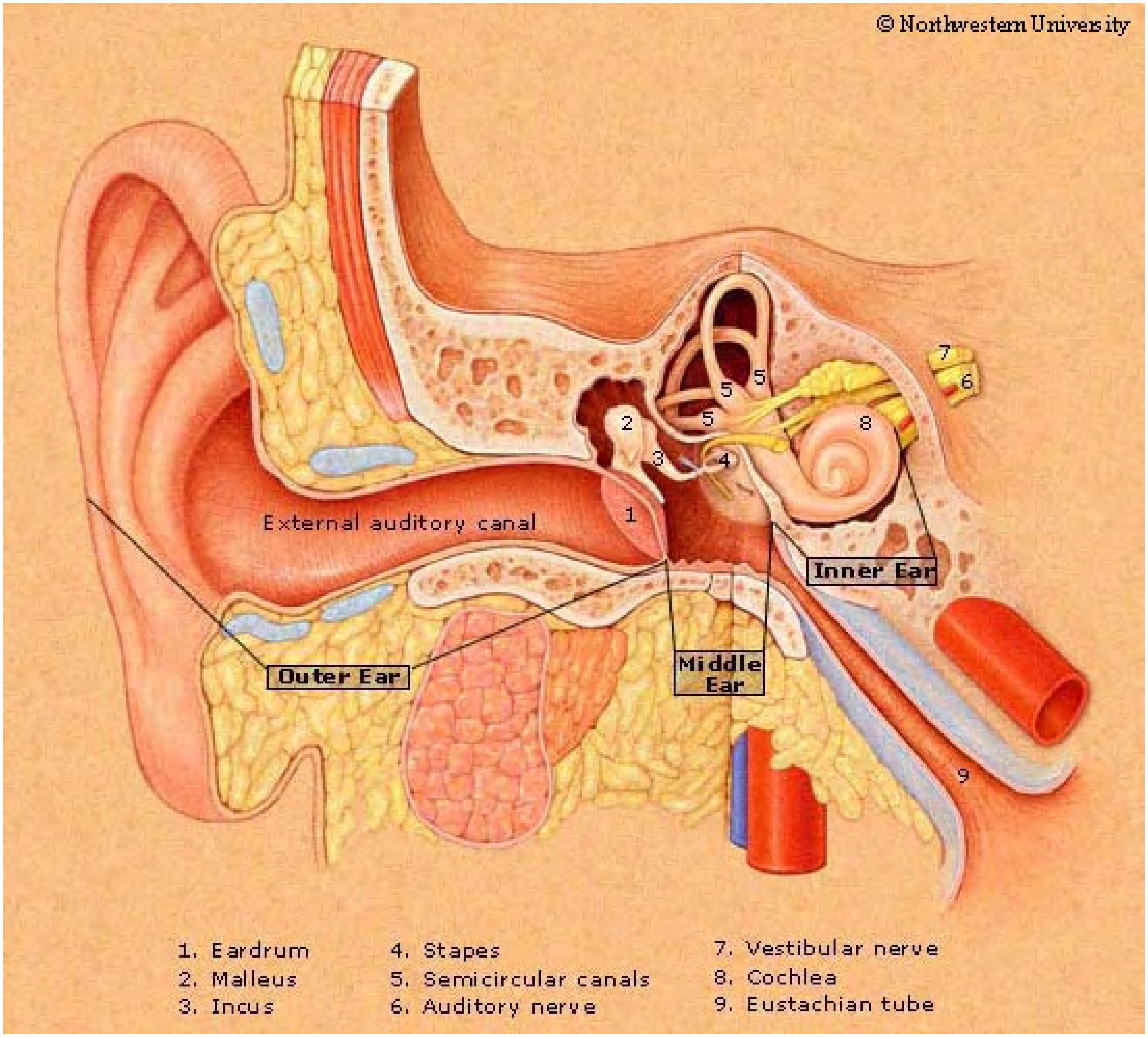
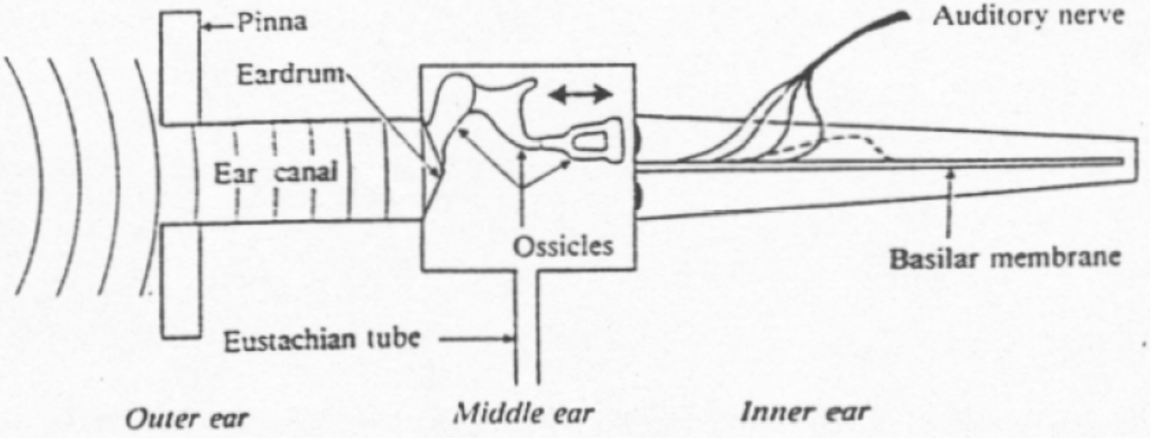
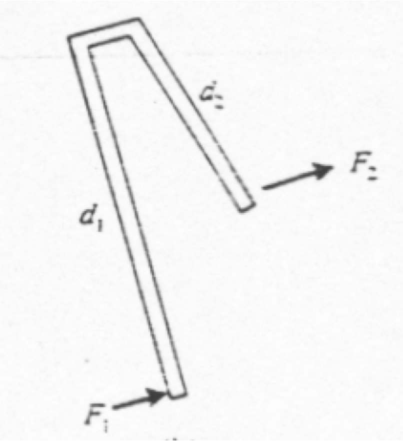

© Northwestern University
External auditory canal
Outer Ear
Middle Ear
Inner Ear
1
2
3
4
5
5
5
6
7
8
9
1. Eardrum
2. Malleus
3. Incus
4. Stapes
5. Semicircular canals
6. Auditory nerve
7. Vestibular nerve
8. Cochlea
9. Eustachian tube

FIG. 5.6

A schematic representation of the ear, illustrating the overall hearing mechanism. Sound waves in the outer ear cause mechanical vibrations in the middle ear, and eventually nerve impulses that travel to the brain to be interpreted as sound.

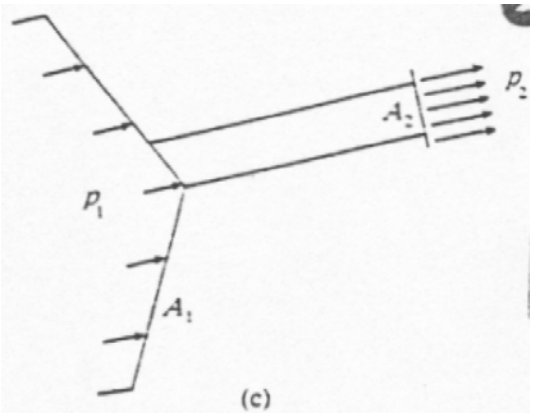


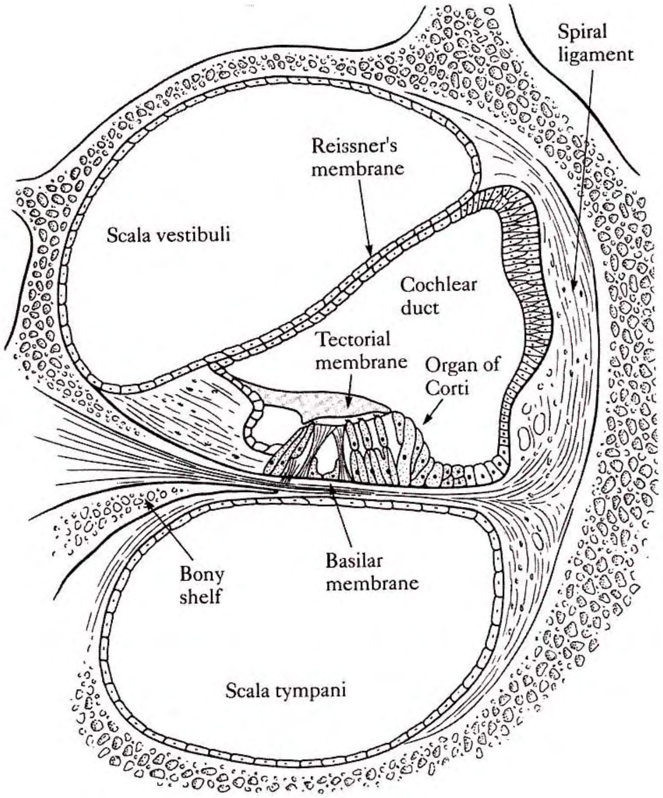
Lever: $F_1 d_1 = F_2 d_2$

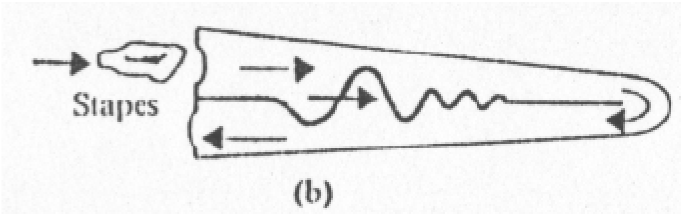


Area: $F_1 = P_1 \times A_1$

$P_2 = F_2 / A_2$







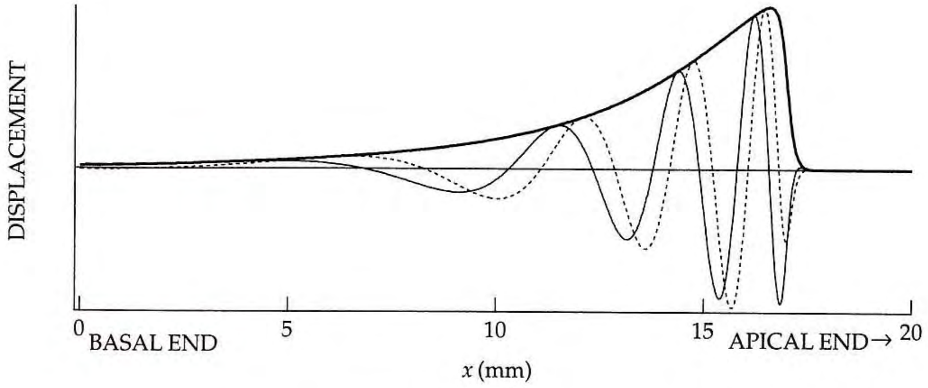
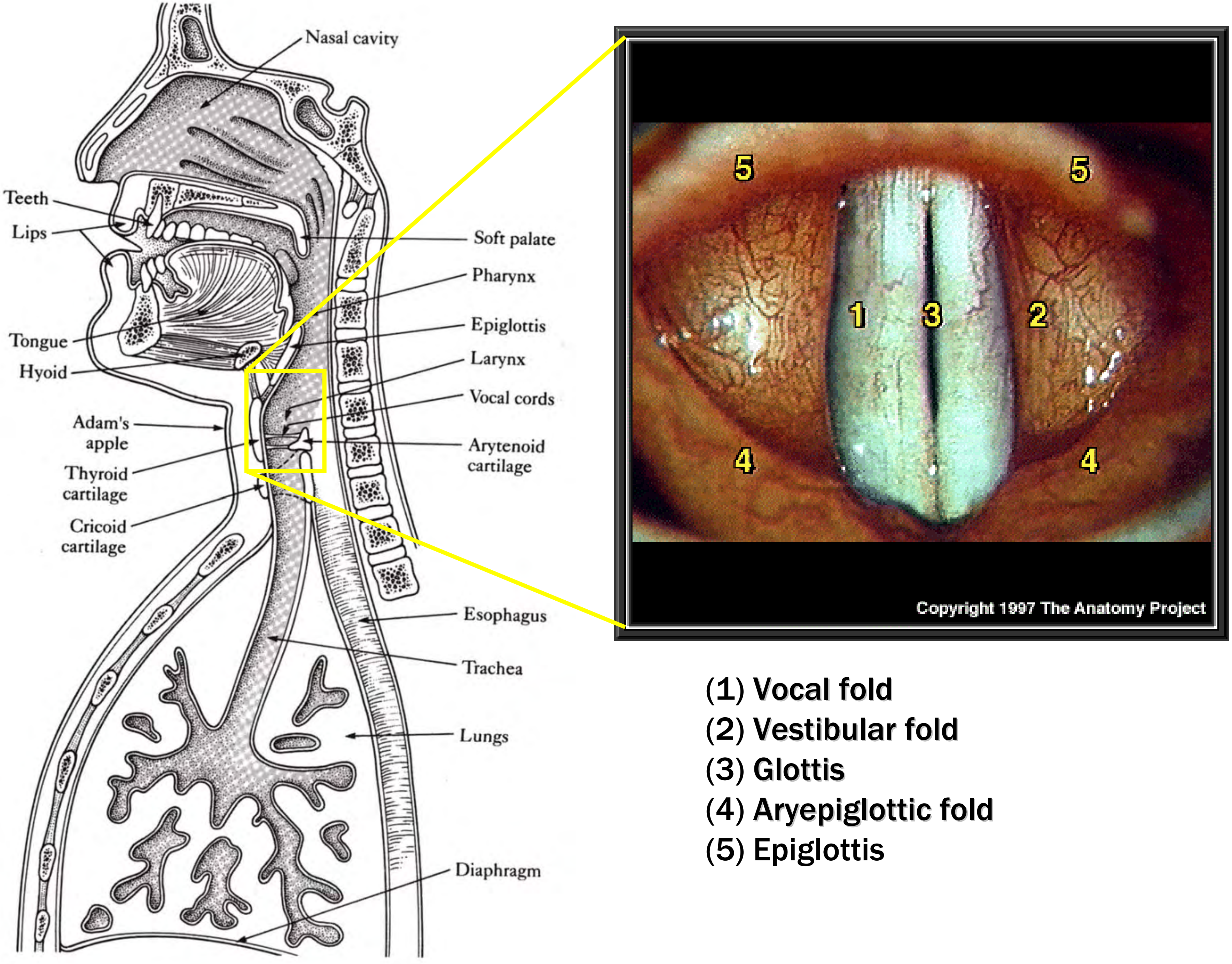


FIGURE 12-10 Displacement of the basilar membrane by a traveling wave set up when the stapes vibrates sinusoidally. The distance from the basal end is denoted as x, measured in millimeters. The entire basilar membrane is about 35 mm long. The light solid line is a snapshot of a wave. The dotted line is the same wave at a slightly later time, so that it is displaced to the right. The propagation velocity and wavelength decrease as the wave moves to the right onto less stiff parts of the basilar membrane. The main peak occurs at the region of the membrane that is in resonance at the frequency of the impressed wave. The amplitude diminishes rapidly to the right of that point. The heavy solid line is the envelope of the wave—that is, it traces out the positions that the maxima of the traveling wave sweep out. The figure is only qualitatively accurate. See the Web site for an animated version. ❁



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(1) **Vocal fold**
(2) **Vestibular fold**
(3) **Glottis**
(4) **Aryepiglottic fold**
(5) **Epiglottis**

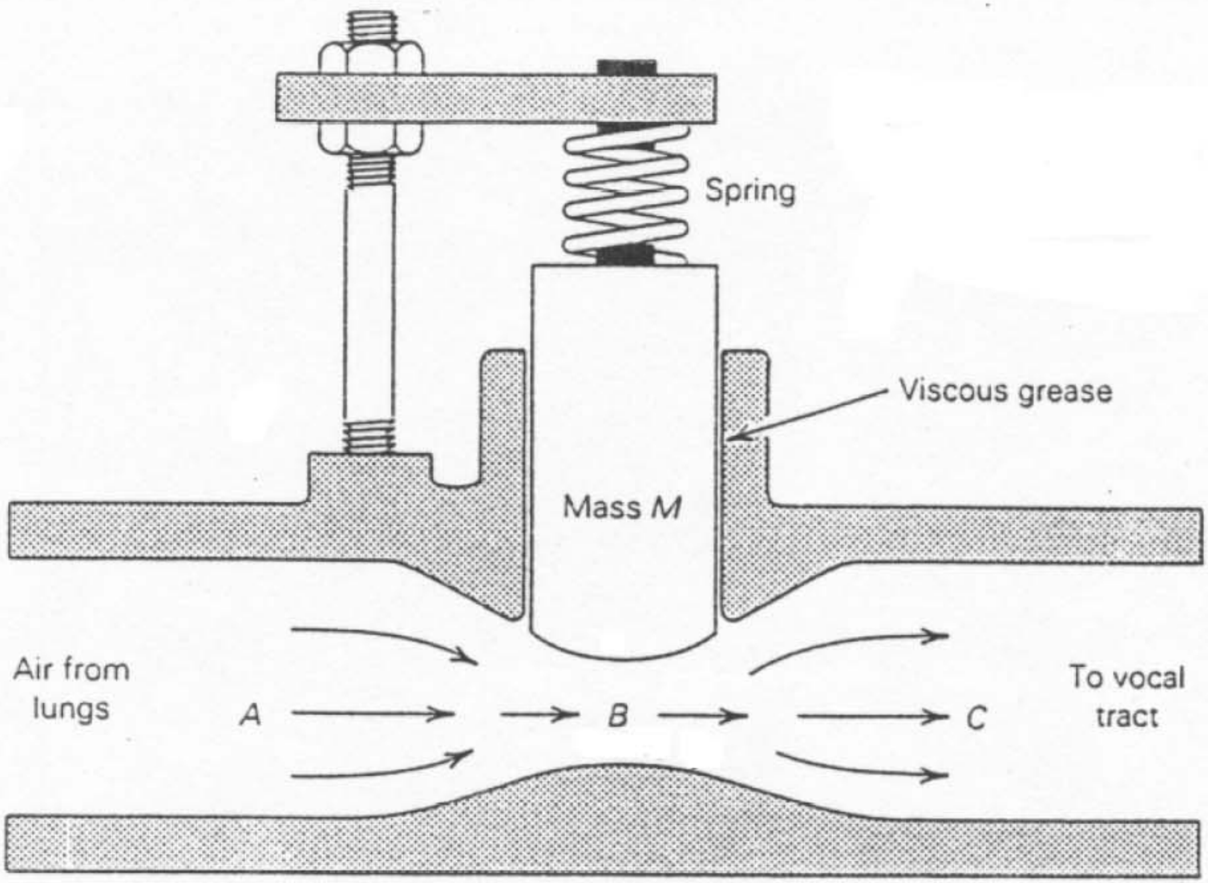
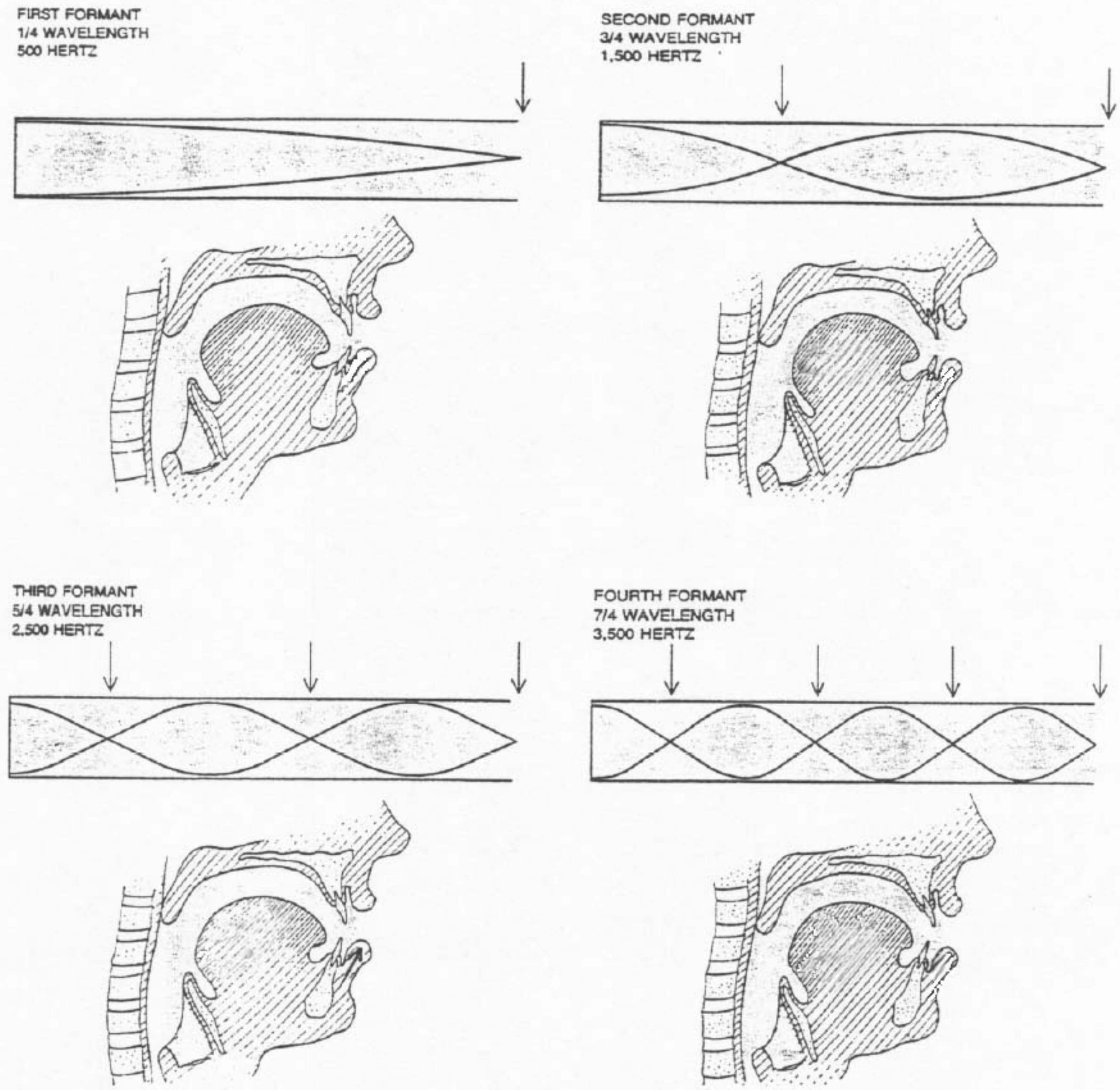
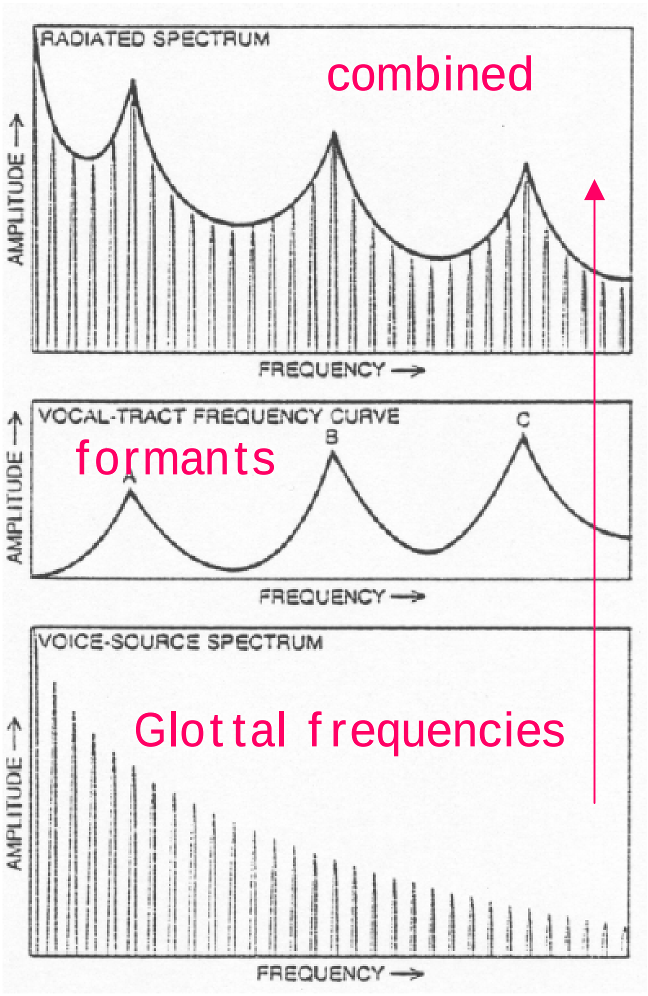


FIGURE 14.5 The mass M is a physicist's analogy to a vocal cord; it is merely a minor detail that it is not a pair. For sufficiently large airflow, M will undergo steady oscillations, thus periodically changing the flow; that is, creating sound waves. (From *Fundamentals of Musical Acoustics* by Arthur H. Benade. Copyright © 1976 by Oxford University Press, Inc. Reprinted by permission.)



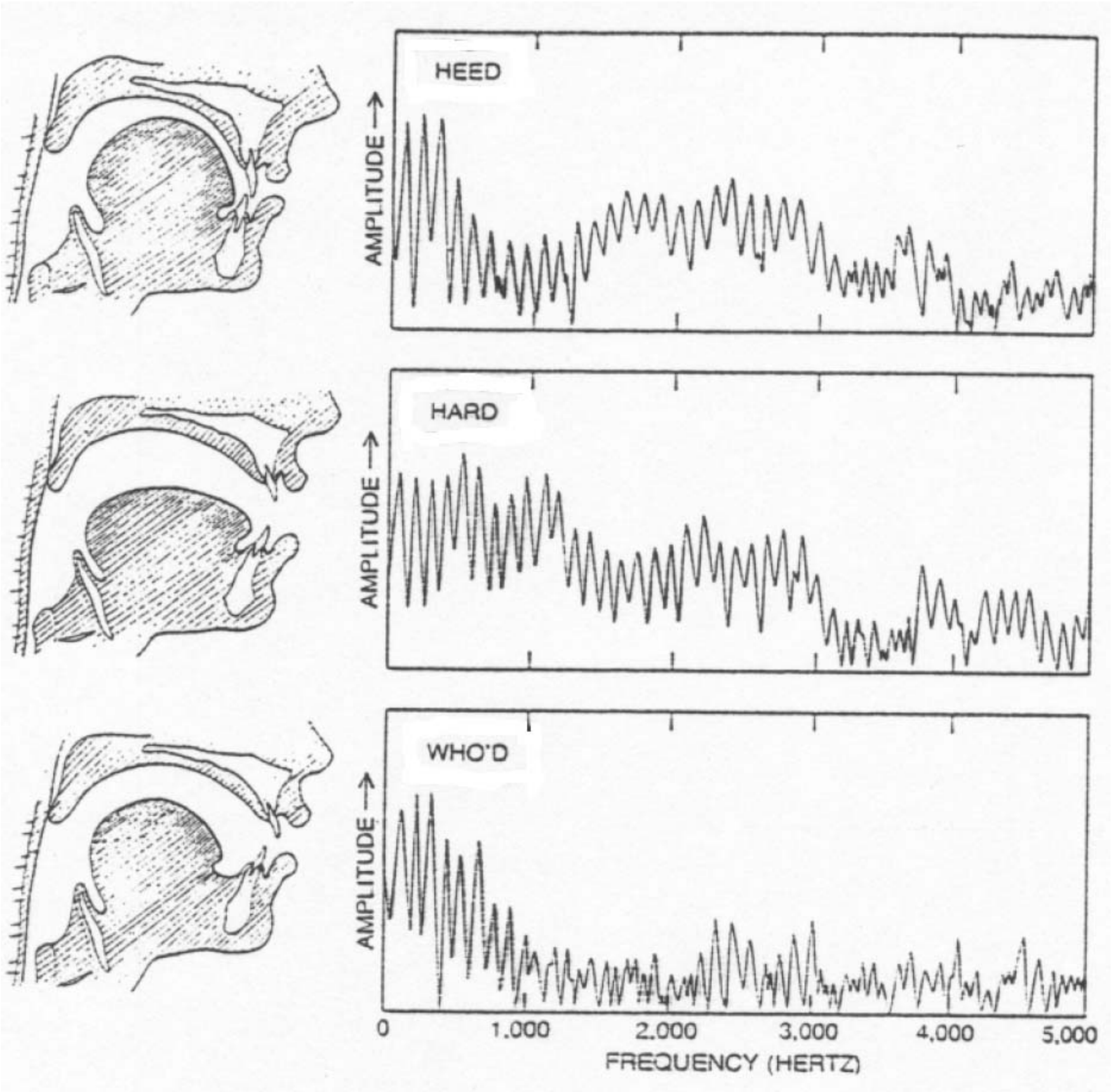
FORMANTS correspond to standing waves, or static patterns of air-pressure oscillations, in the vocal tract. Here the first four formants are shown as standing waves in cylindrical tubes, the schematic equivalent of the vocal tract (*colored areas in drawings*). The sine waves represent the amplitude of the pressure differential, which is always maximal at the glottal end and minimal at the lips. For the lowest formant a quarter of a wavelength is within the vocal tract and, if the tract is 17.5 centimeters long, the formant's frequency is about 500 hertz (cycles per second). The second, third and fourth formants are 3/4, 5/4 and 7/4 of a wavelength, and their frequencies vary accordingly. If the area of the vocal tract is decreased or increased at a place where the formant's pressure amplitude is at a minimum (*arrows*), that formant's frequency is respectively lowered or raised; the same change in area has the opposite effect if it is at a pressure maximum.

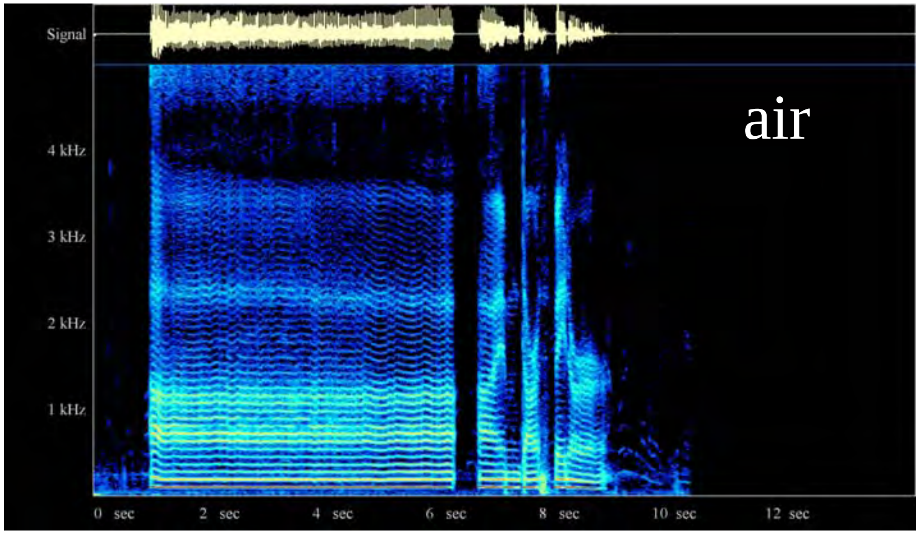


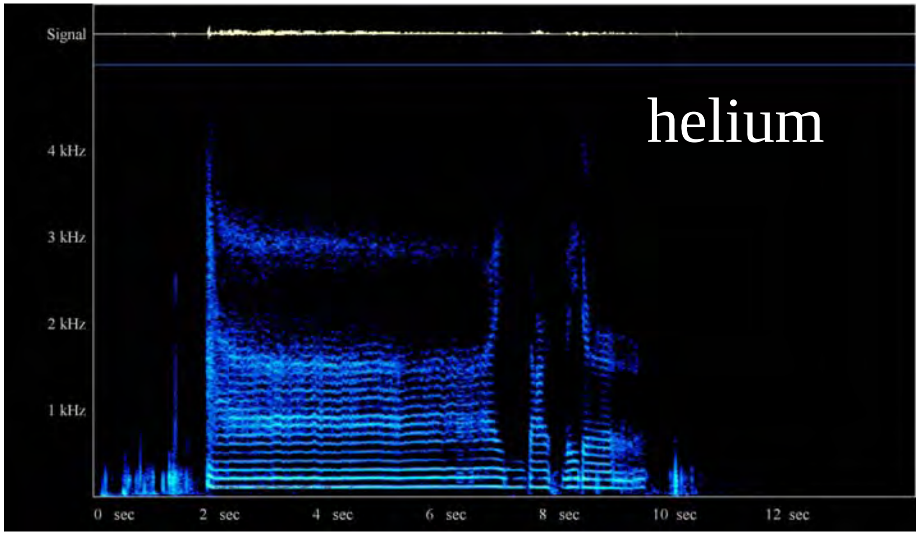
combined

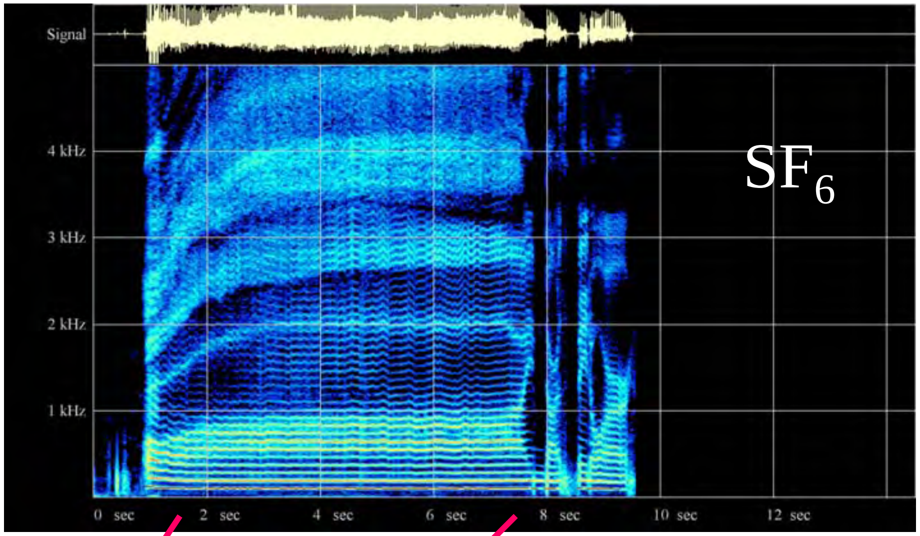
formants

Glottal frequencies









Aaaaahhhhhh - I'm Darth Vader