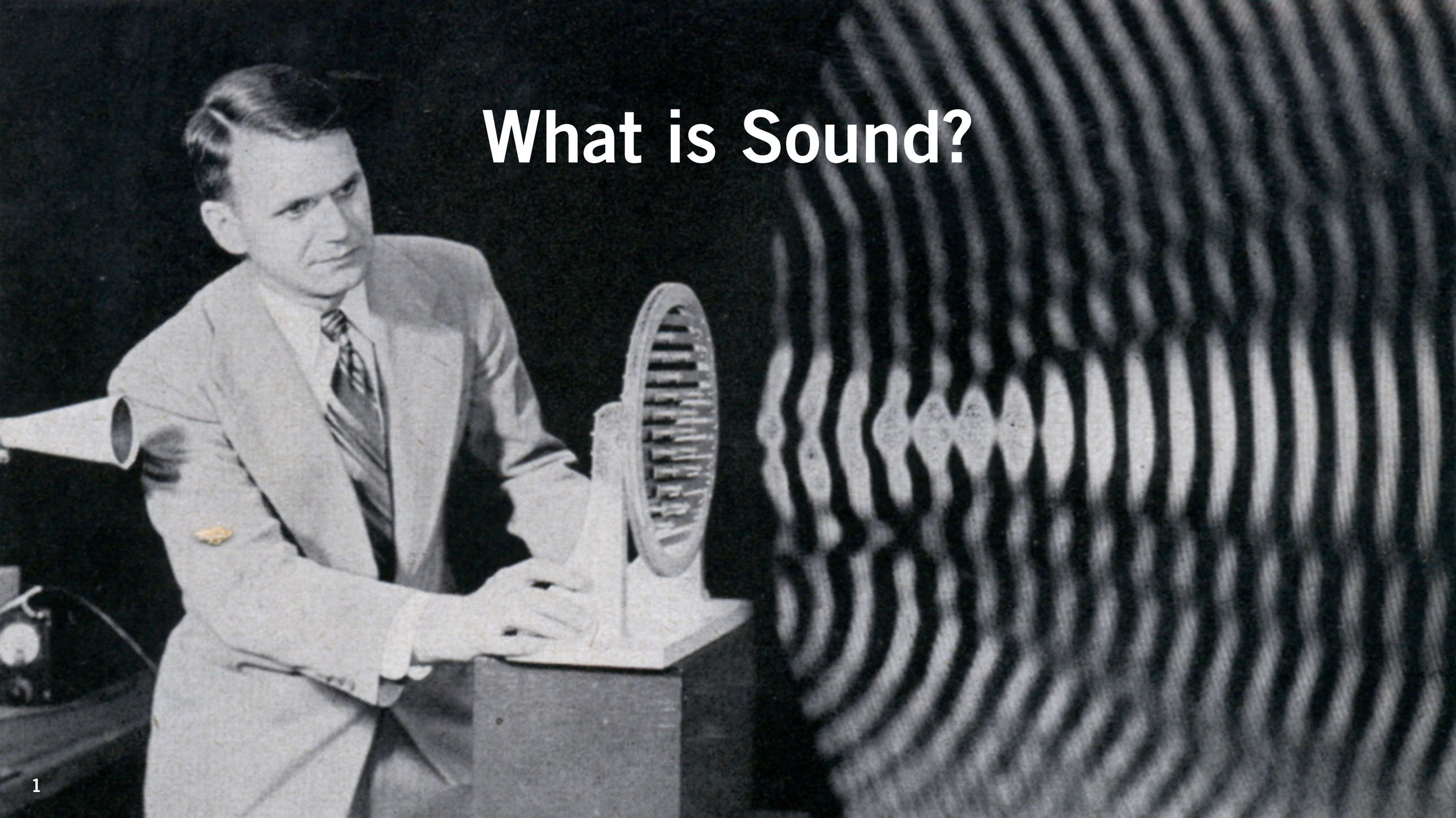
What is Sound?



SOUND & SOUND

Sound refers to both what is perceived (a sensation) and to the stimulus that suggests the sensation (a physical phenomenon involving vibrations and energy)

Subjective & Objective

Psychoacoustics & Acoustics

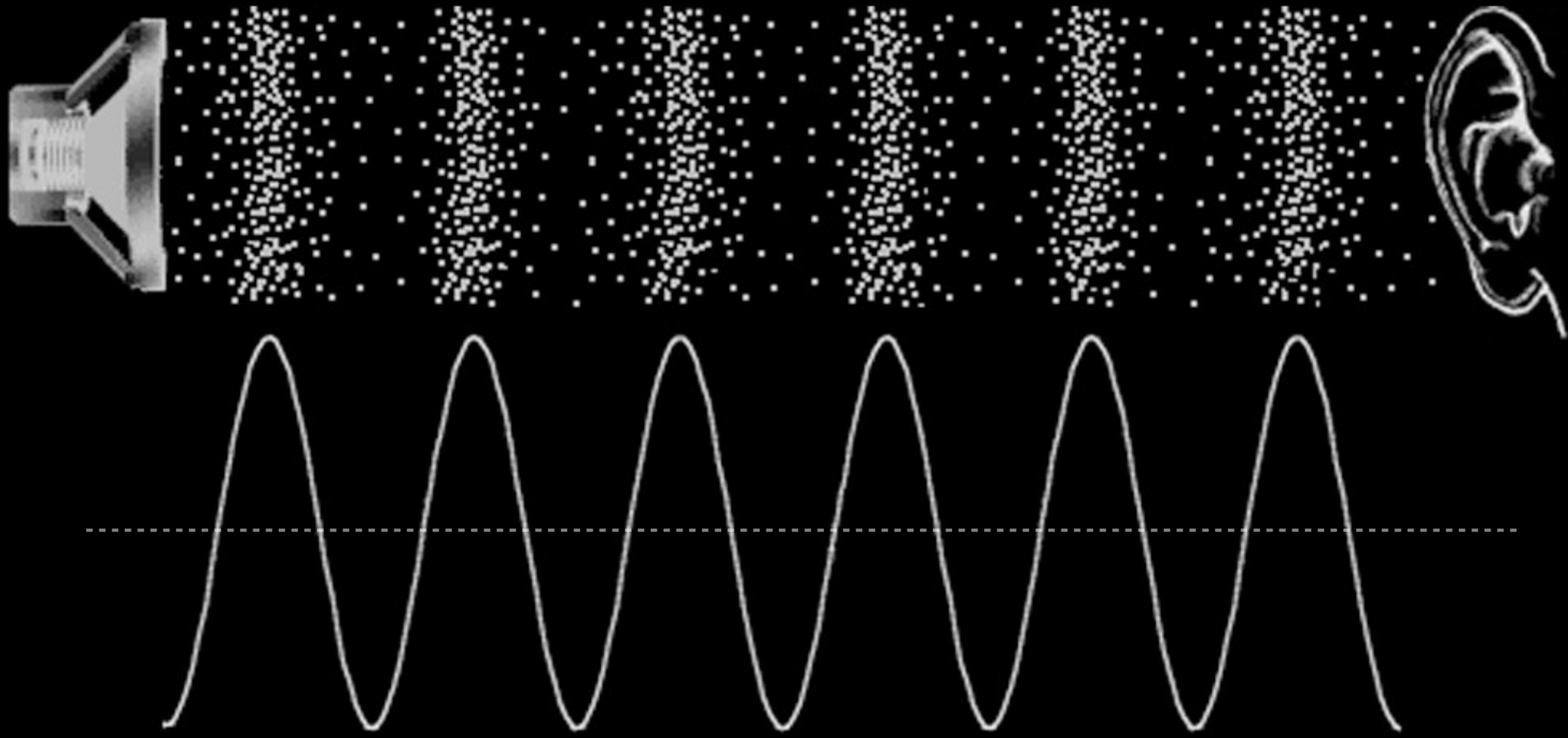
Examining the Phenomenon of Sound

What is it physically?

How do we quantify or measure it?

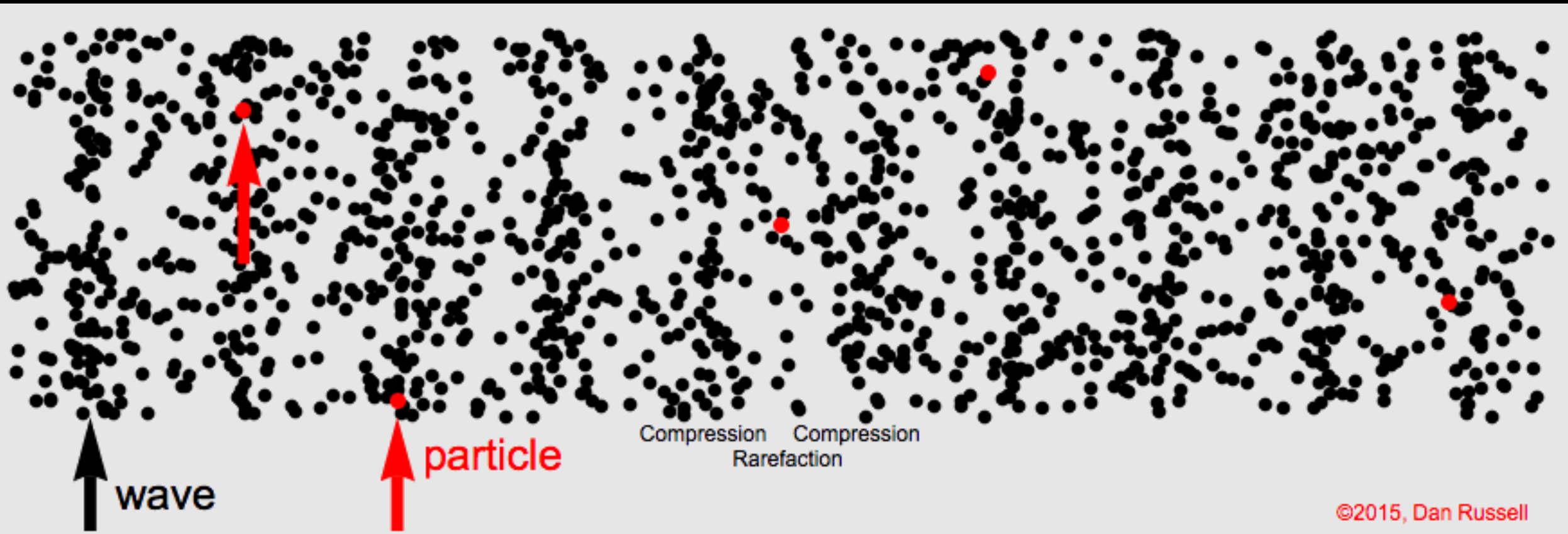
How is it interpreted as sensations?

longitudinal waves of acoustical energy caused by air compression and rarefaction

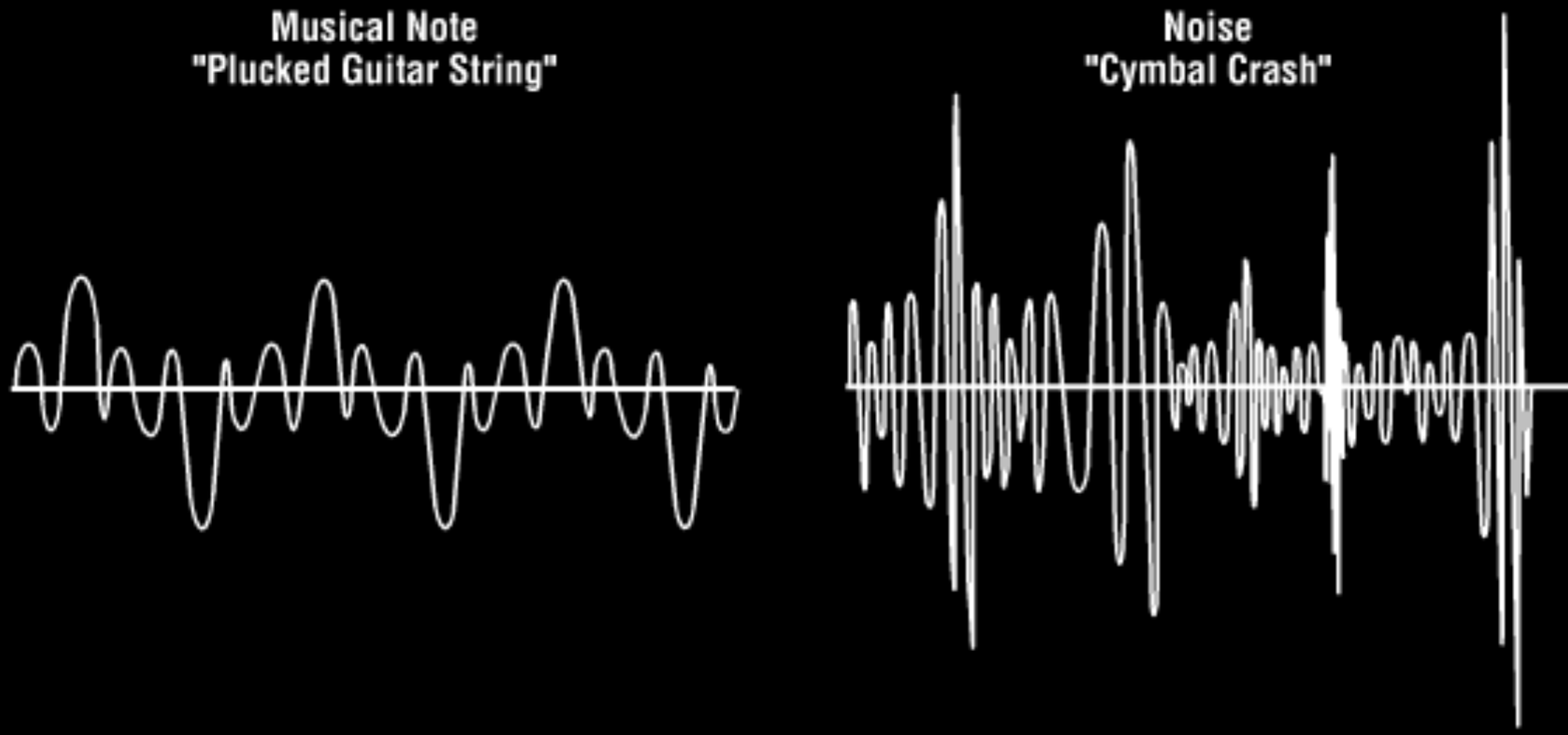


Transverse Wave

Longitudinal Wave

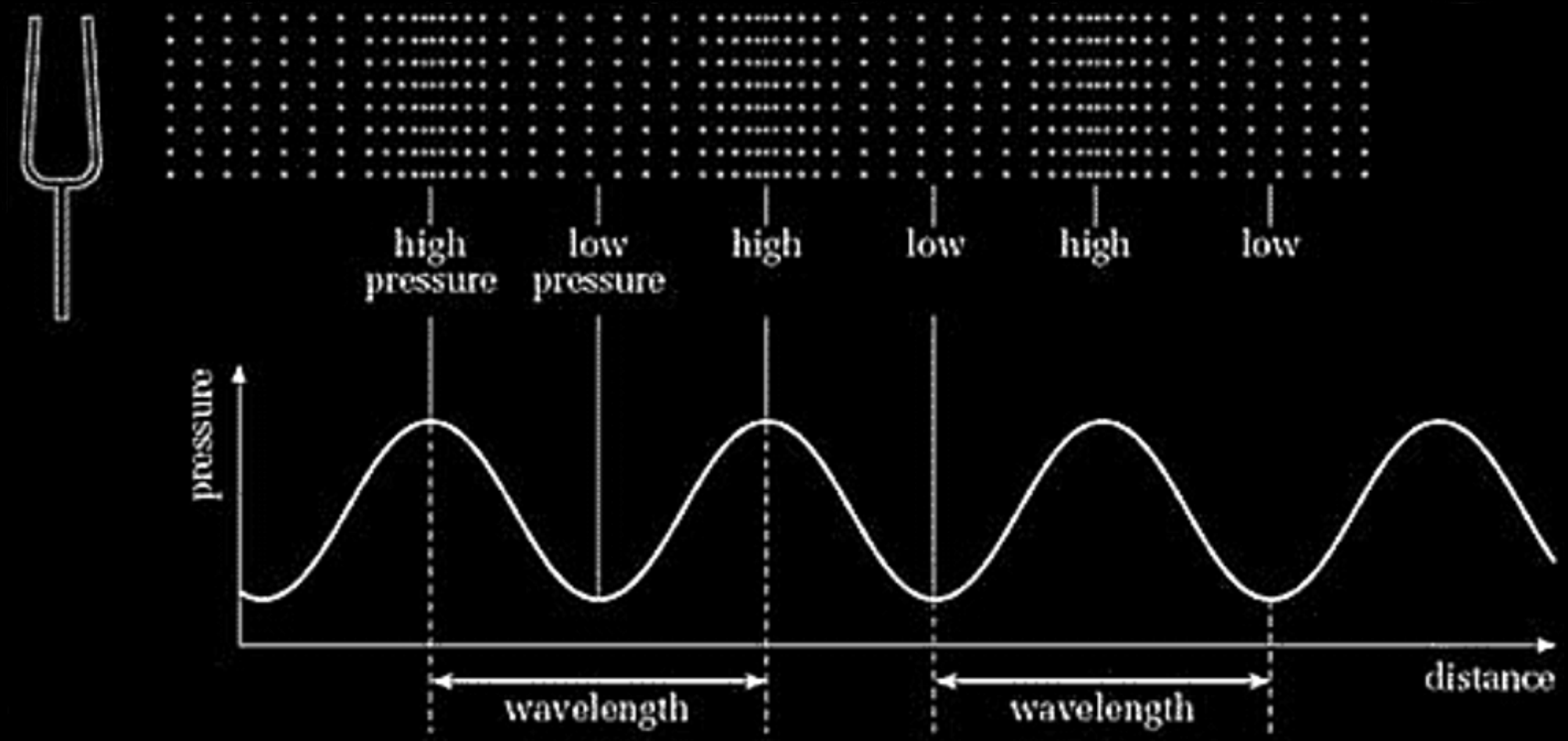

wave
particle
Compression
Rarefaction
Compression
©2015, Dan Russell

Periodic vs Aperiodic



PSYCHOACOUSTICS		ACOUSTICS
LOUDNESS	⟷	AMPLITUDE
PITCH	⟷	FREQUENCY
QUALITY	⟷	TIMBRE

Graphing a Periodic Sound Wave

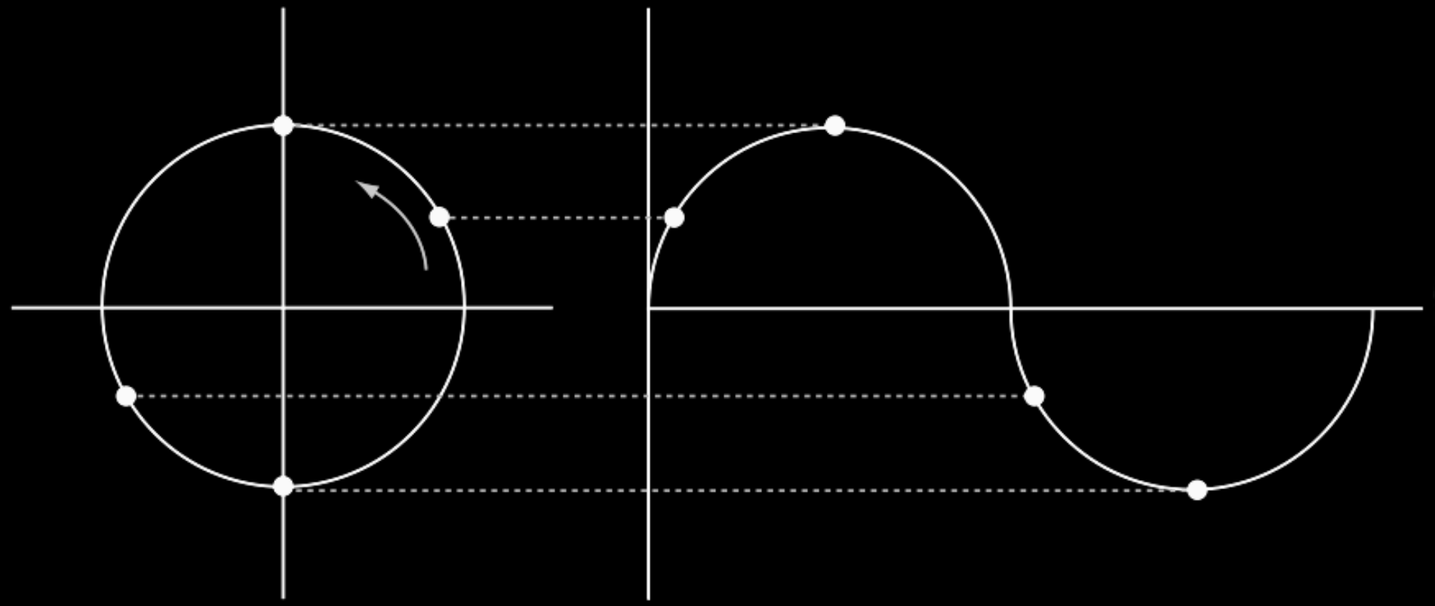


Sinusoidal Waves

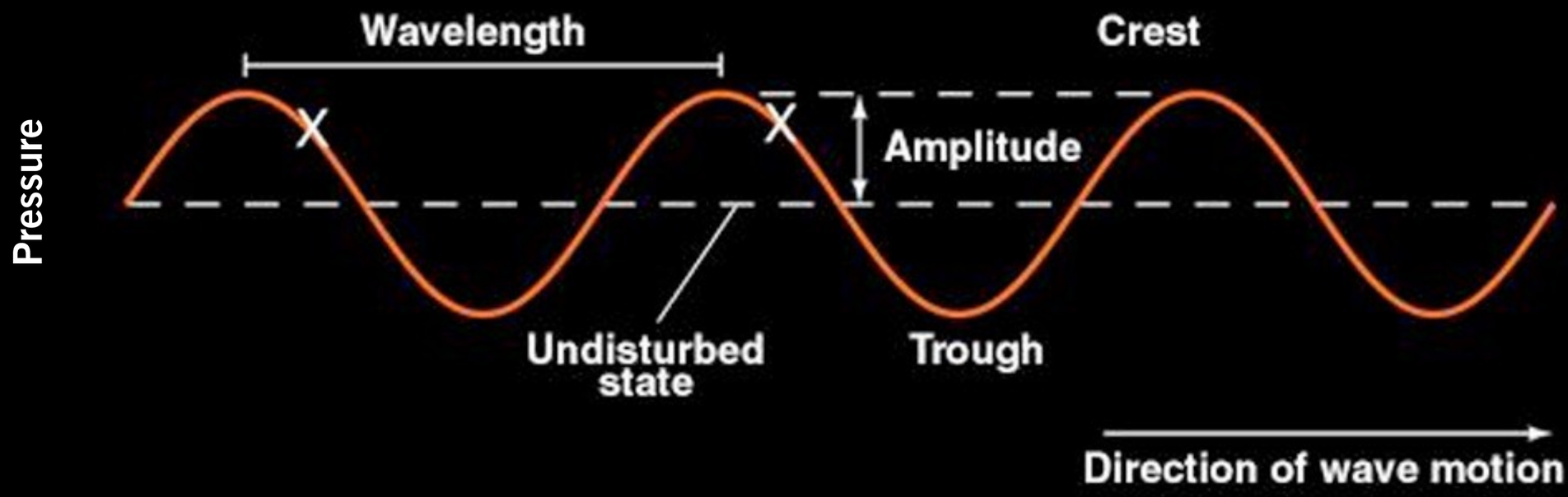
Sine wave: a circular/smooth oscillation

makes for a good oscillation (frequency) reference

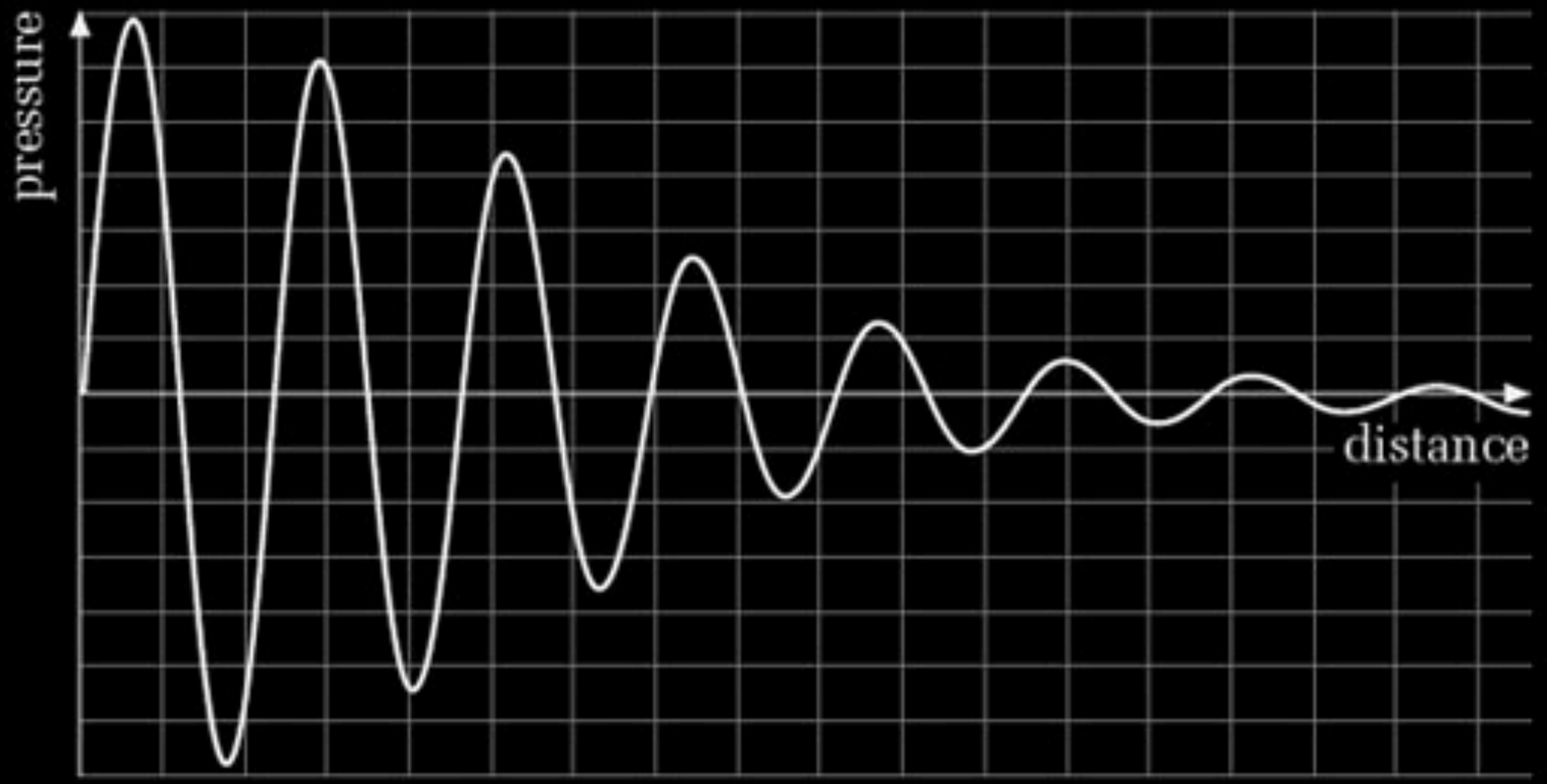
pure sine waves are rarely found in nature



Reading a Periodic Waveform



Amplitude



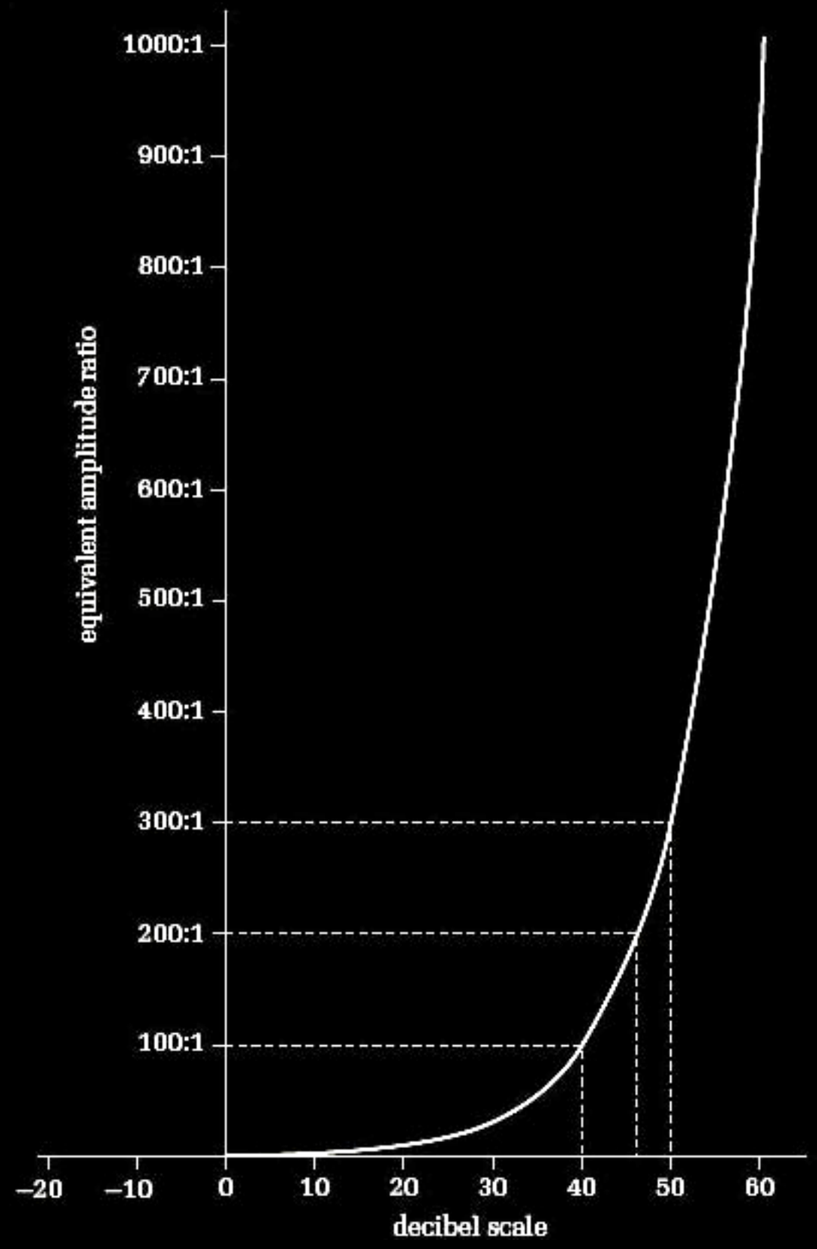
commonly measured in decibels (dB) - logarithmic units

Decibels

Decibels (dB) - logarithmic scale

Our perception of loudness is not linear, but exponential.

Logarithmic perception means that it takes more of a change in the amplitude to produce the same perceived change in loudness as the amplitude increases.



Amplitude

0 dB - silence

30 dB - whisper. all day long

60 dB - typical conversation. safe.

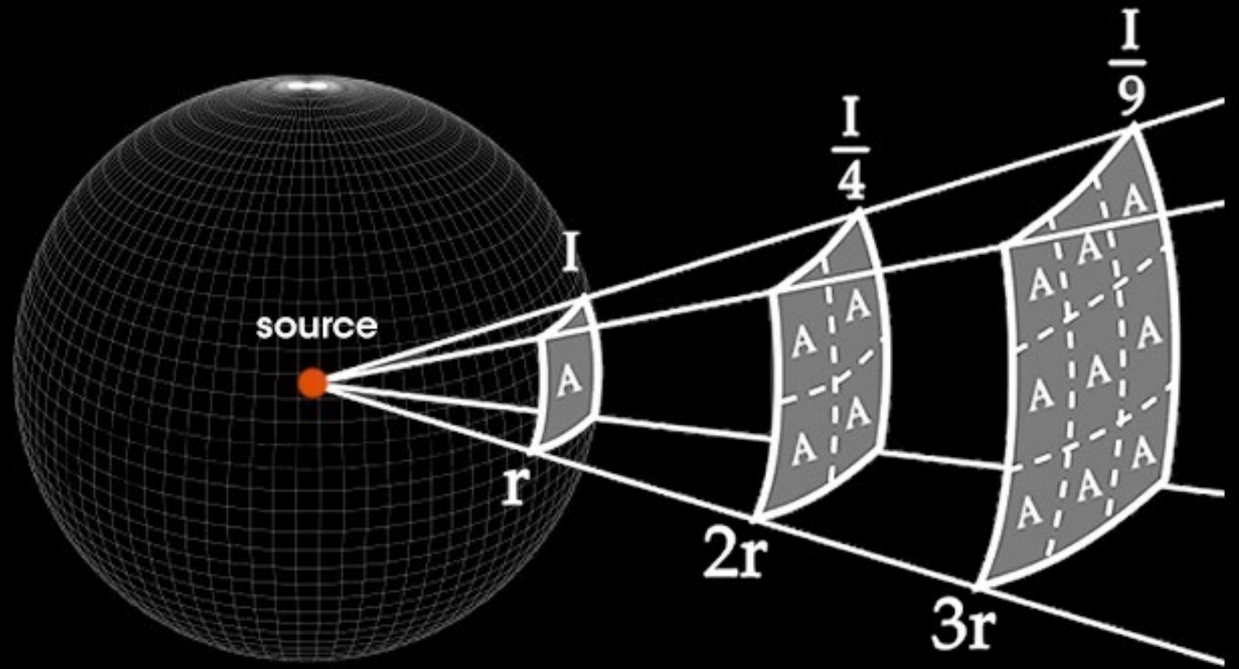
85 dB - bulldozer. permanent damage after 8 hours.

105 dB - headphones at max volume. chainsaw. hearing damage after 2 hours.

120 dB - the threshold of pain :(

Amplitude - inverse square law

sound intensity is inversely proportional to the square of the distance from the source

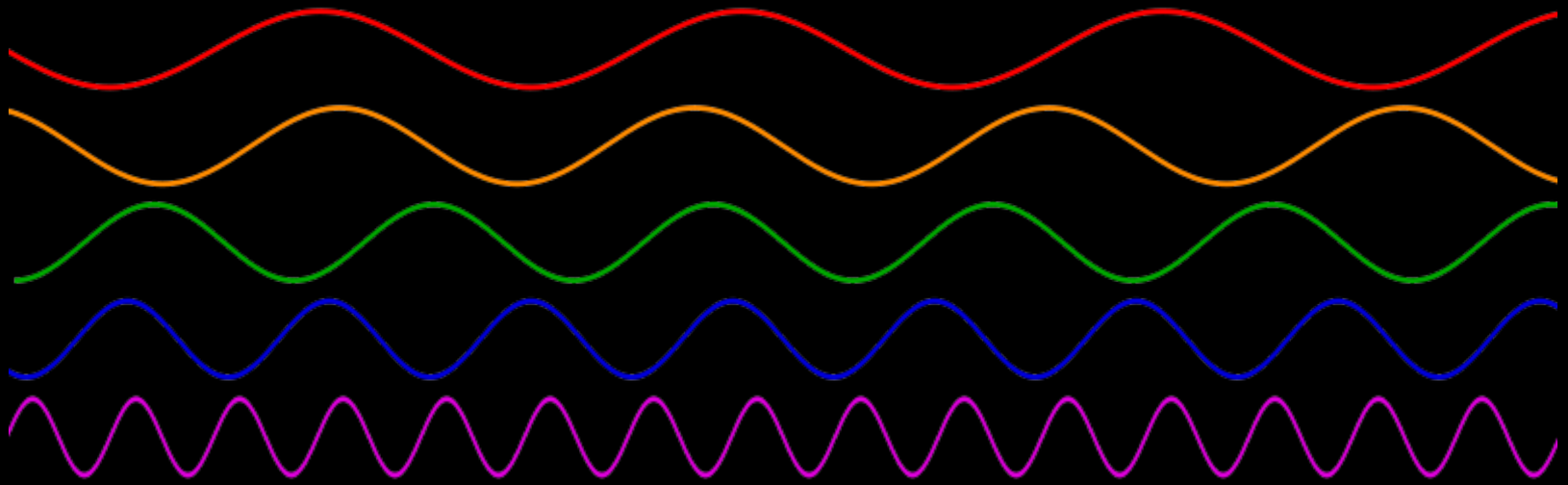


$$I \sim 1/r^2$$

Frequency

rate at which the air pressure fluctuates is the frequency of the sound wave

Cycles per second, Hertz (Hz)



Period & Wavelength

Frequency	**number of cycles per second (f)**
Period	**time it takes for one cycle to occur (T)**
Wavelength	**distance travelled in one cycle (λ)**

frequency is inversely related to period

$$f = 1 / T \quad \text{or} \quad T = 1 / f$$

wavelength is equal to the speed of sound divided by the frequency

$$\lambda = v / f$$

v = the speed of sound is constant, ~1,125 feet per second (one mile in 5 seconds)

Frequency

LISTEN: Hearing range 20 Hz to 20,000 Hz (0-20Hz frequencies are infrasonic)

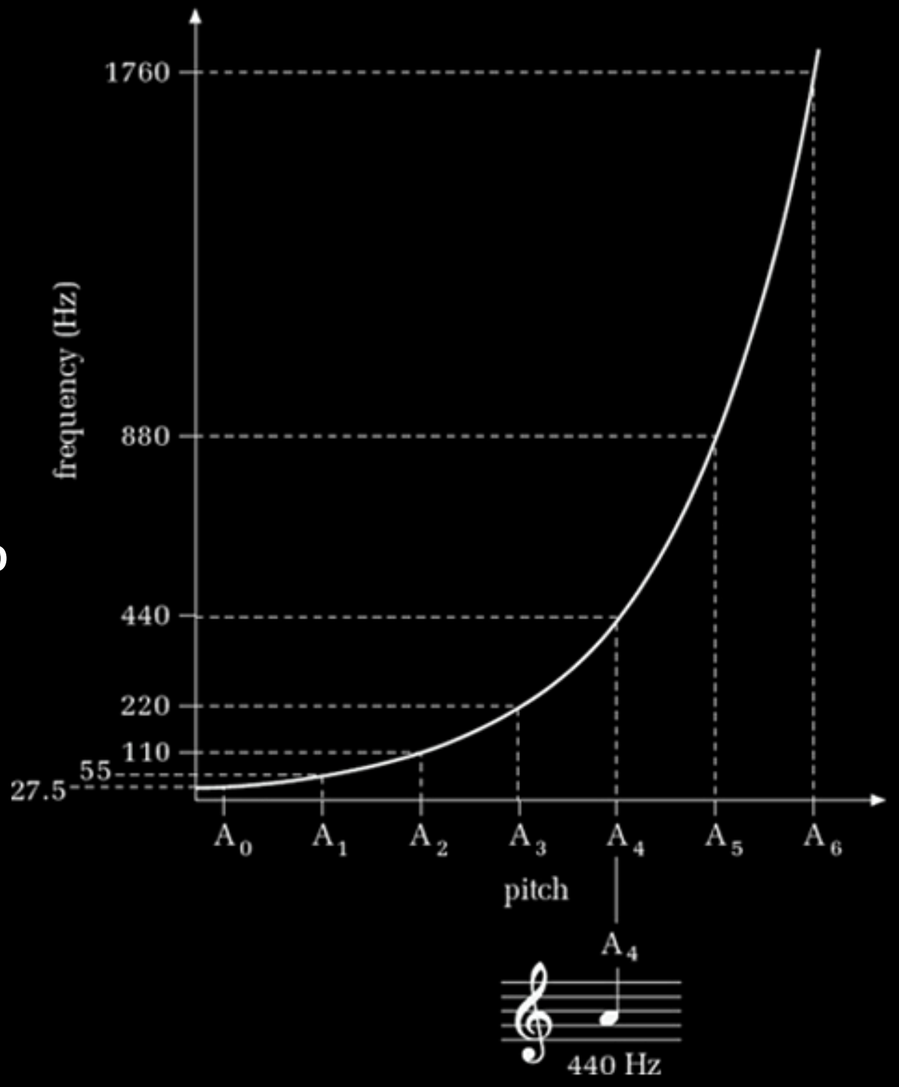
Frequency Ranges (fundamental)

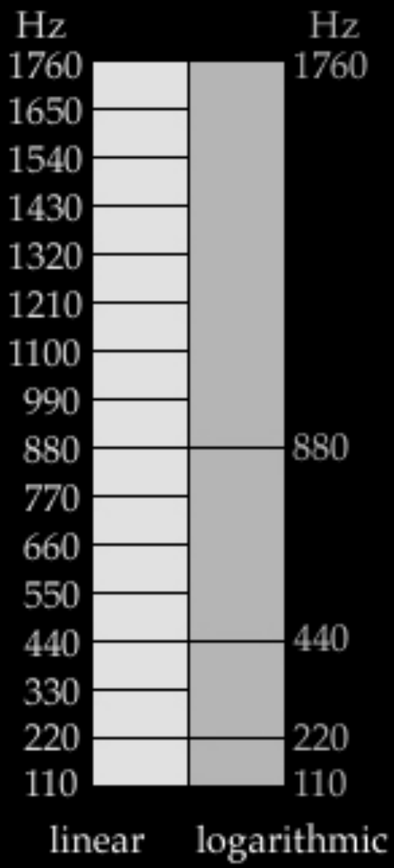
	Low (Hz)	High (Hz)
Piano	27.5	4186
Speech	80	500
Standard Digital Audio	0	22,050
Human hearing	20	20,000
Dog hearing	20	45,000
Seal hearing	1000	123,000

Frequency & Pitch

We experience pitch logarithmically as well

Octave - 2:1 frequency ratio





Frequency

The interval between two notes can be measured by the ratio of their frequencies.

(just intonation)

1:1 (unison)

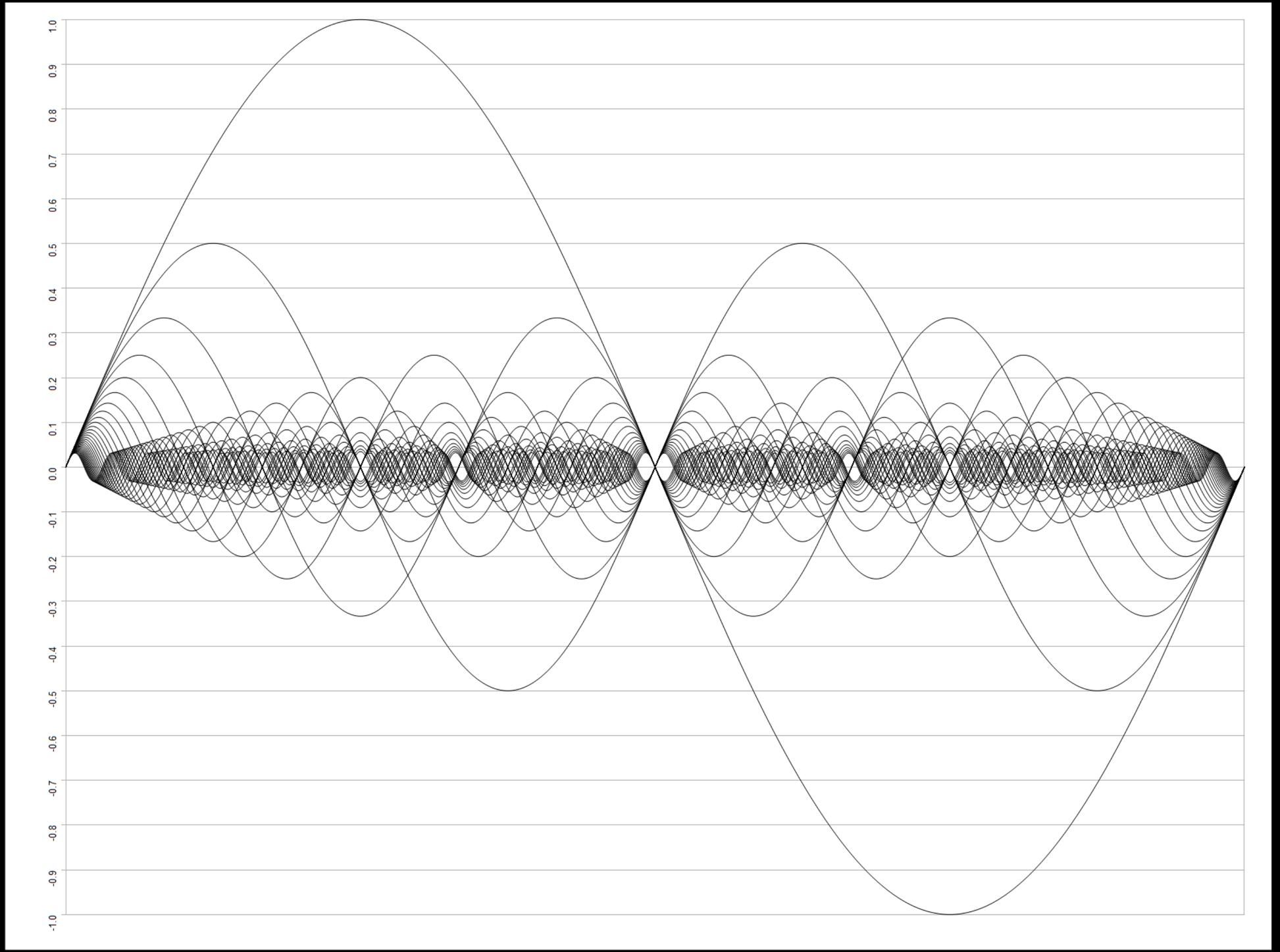
2:1 (octave)

3:2 (perfect fifth)

4:3 (perfect fourth)

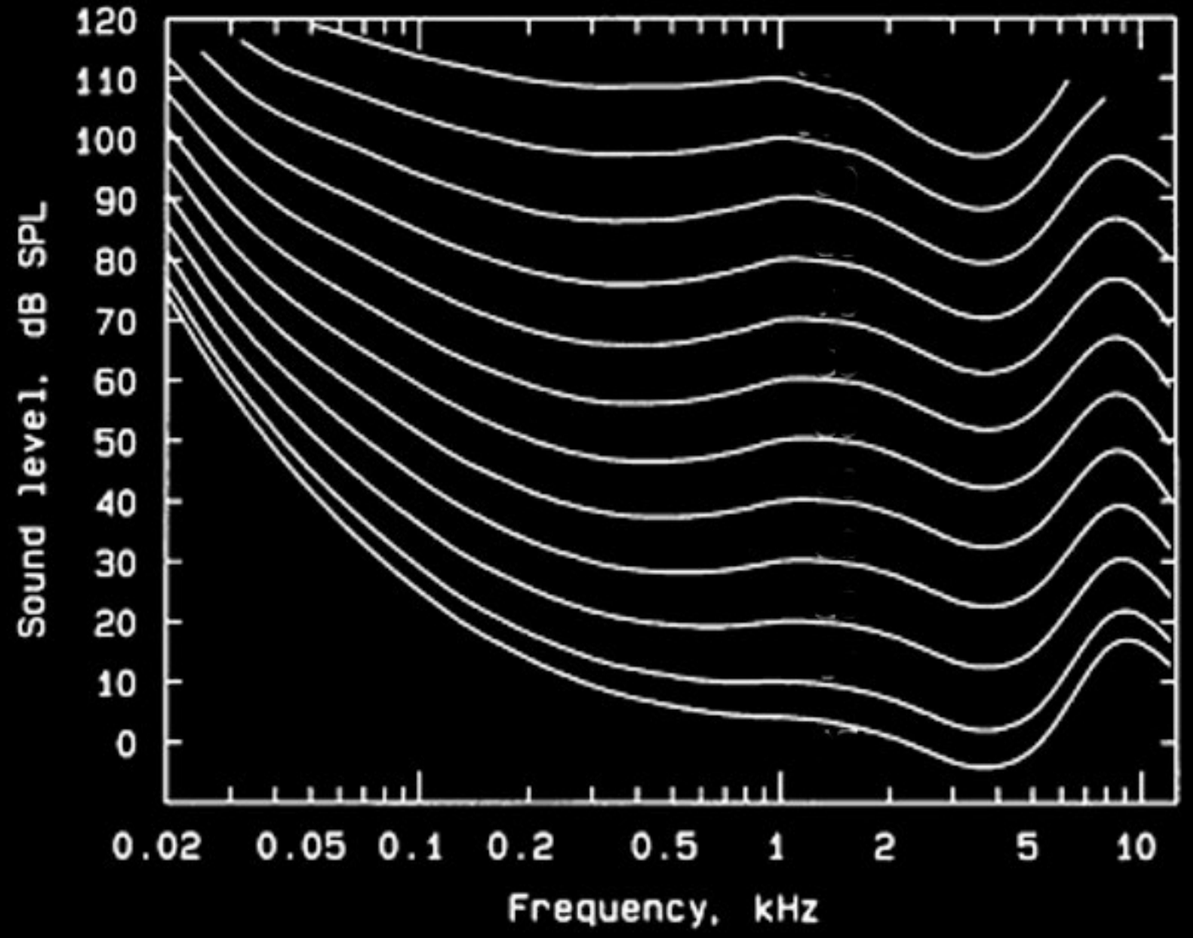
5:4 (major third)

6:5 (minor third)


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0

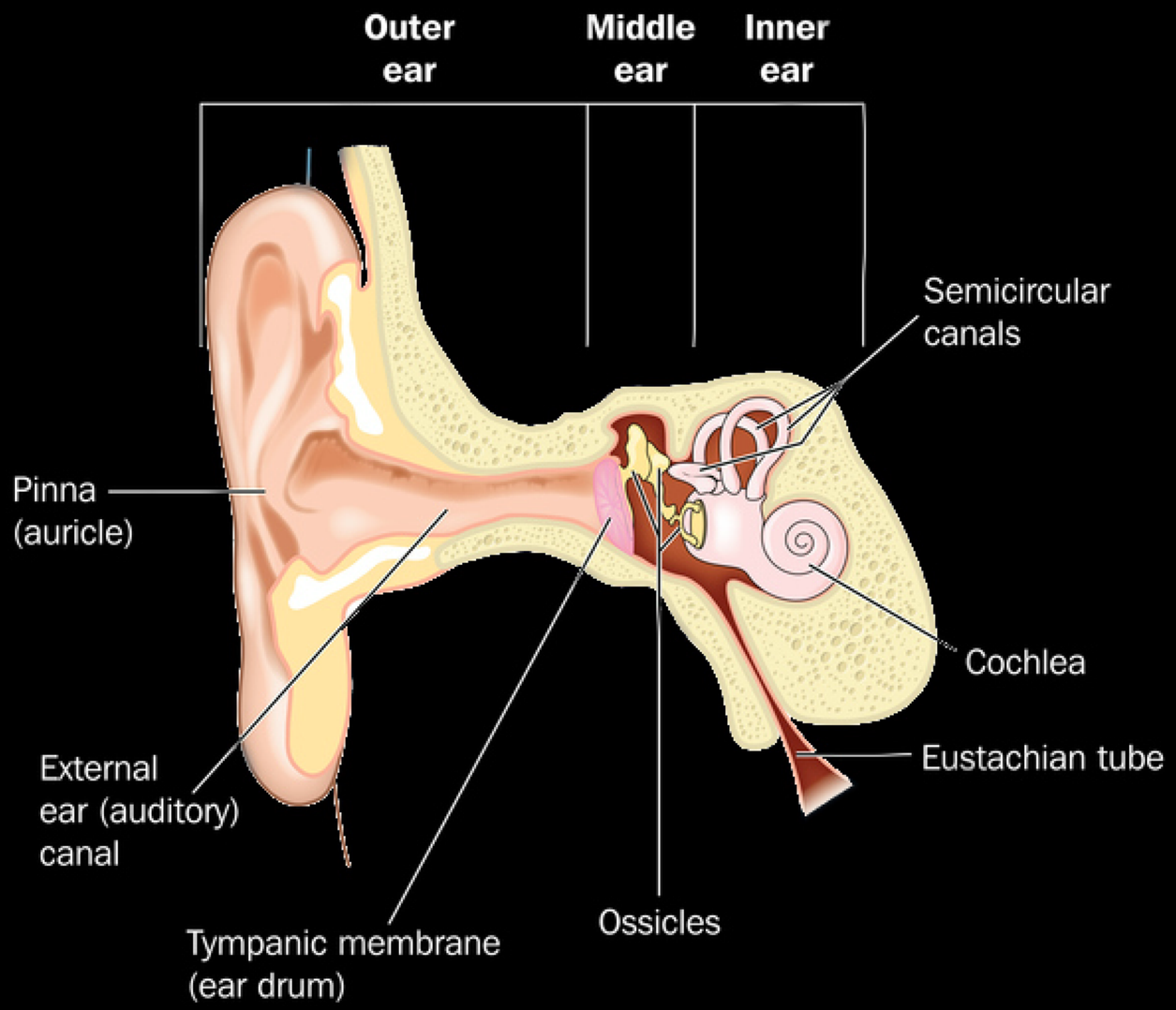
Equal Loudness Contours

(Fletcher-Munson Curves)

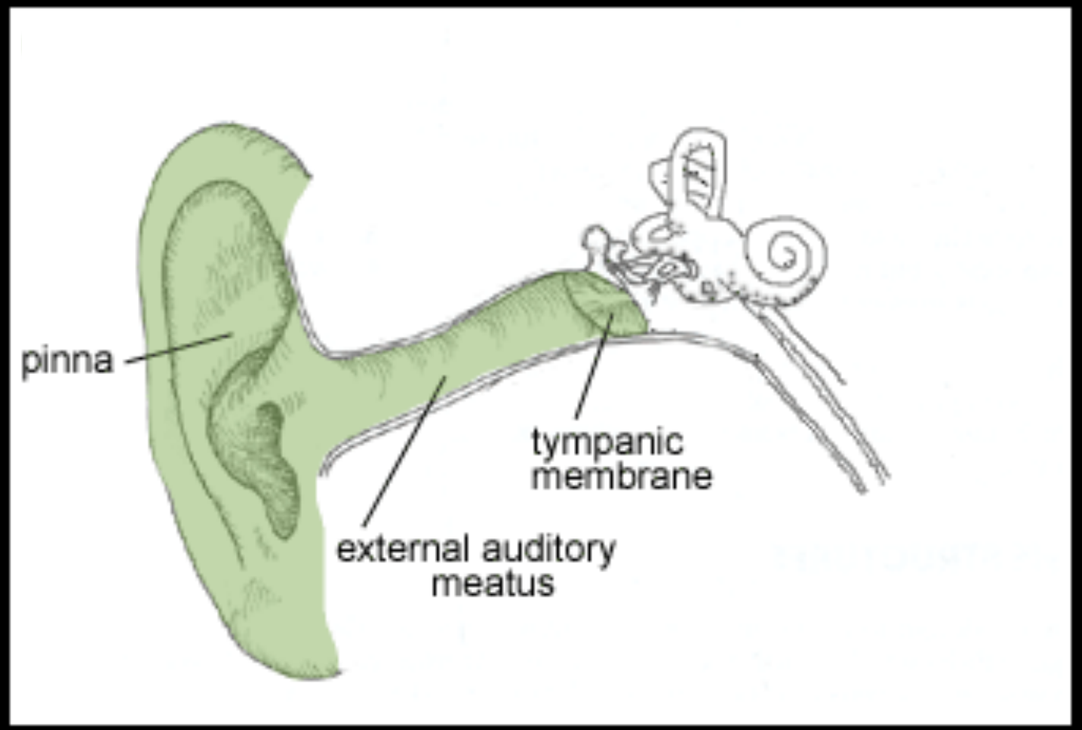


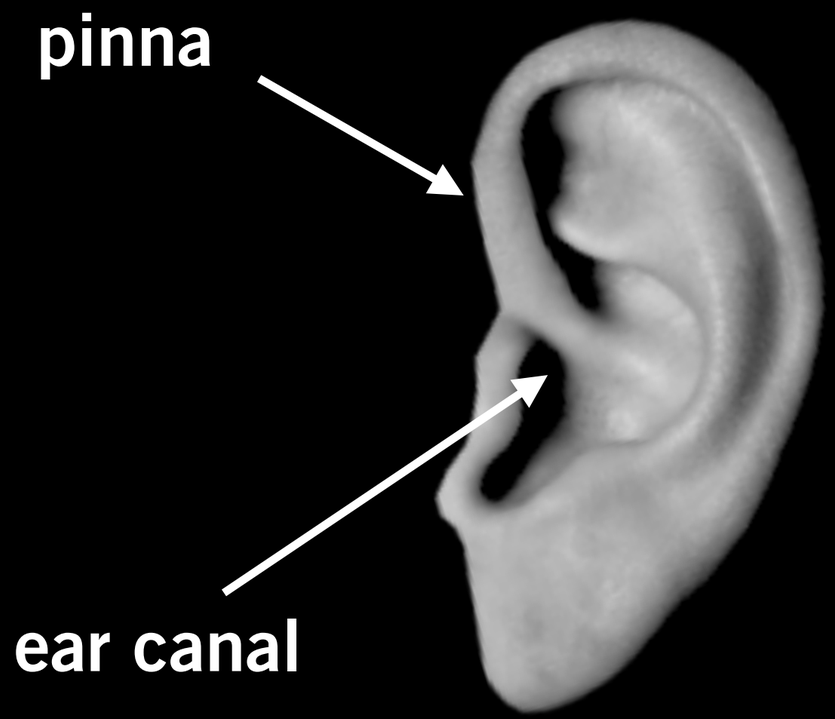
Physical (Acoustics)	Perceptual (psychoacoustics)	Units
amplitude	loudness	decibels (dB)
frequency	pitch	hertz (Hz)
duration	time	seconds (s)
timbre	quality / tone / spectral content	

How do we sense and perceive sound?

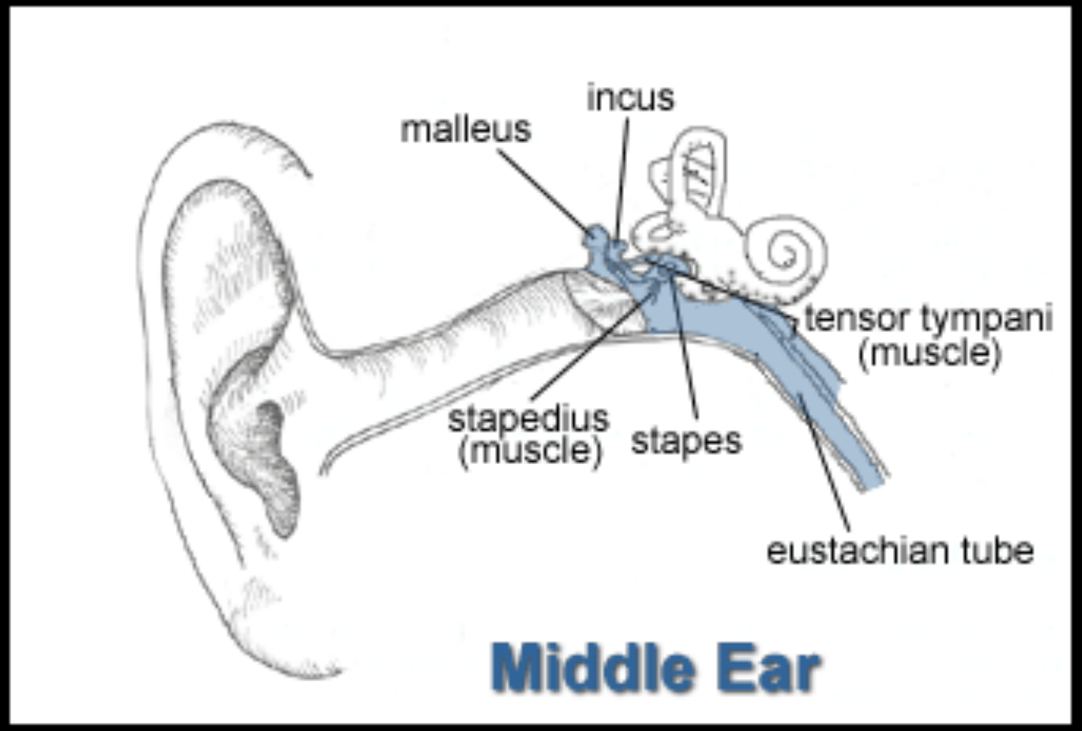


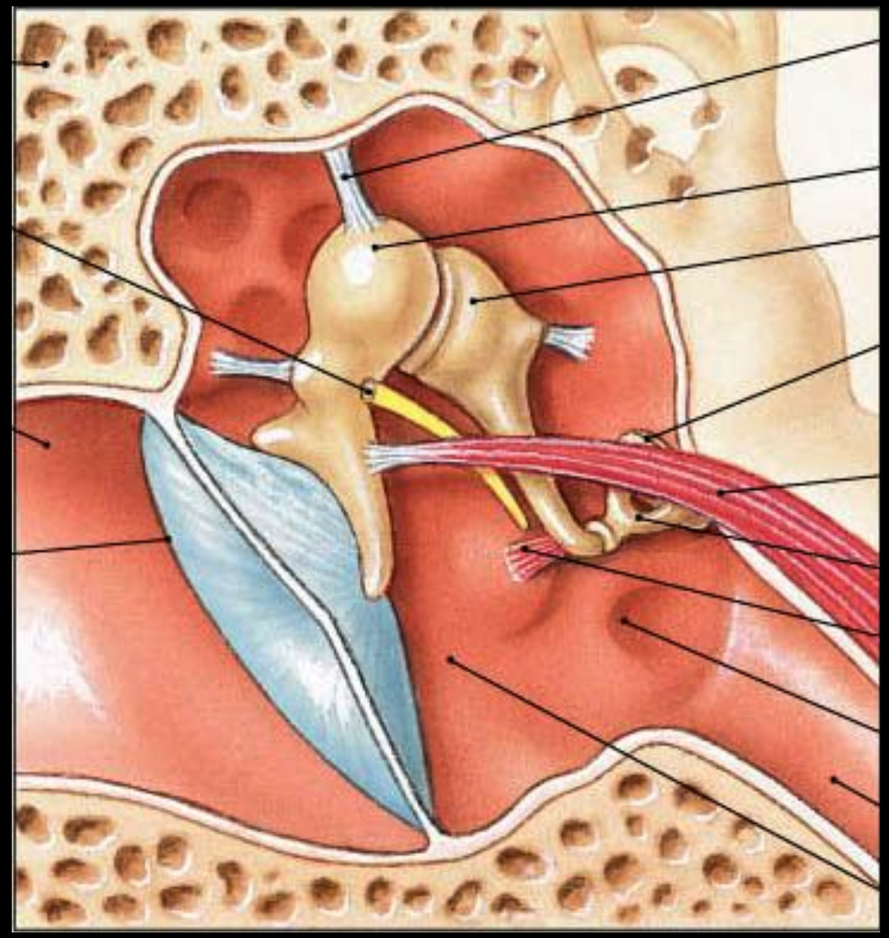
Outer Ear


pinna
tympanic membrane
external auditory meatus

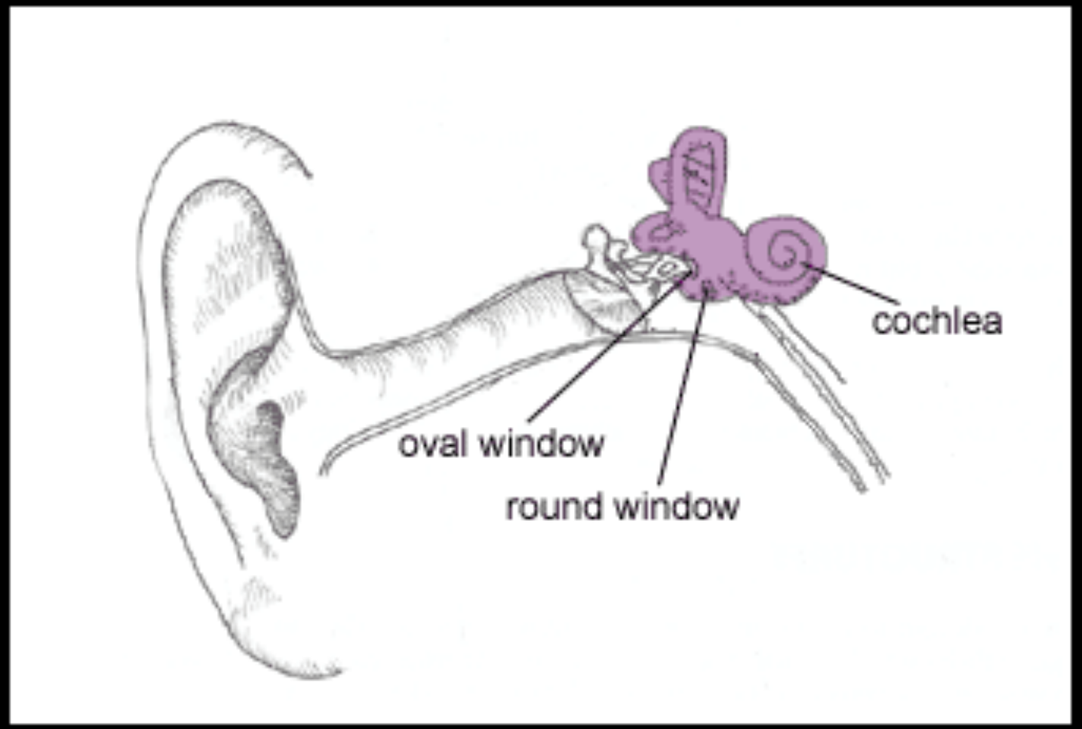

pinna
ear canal

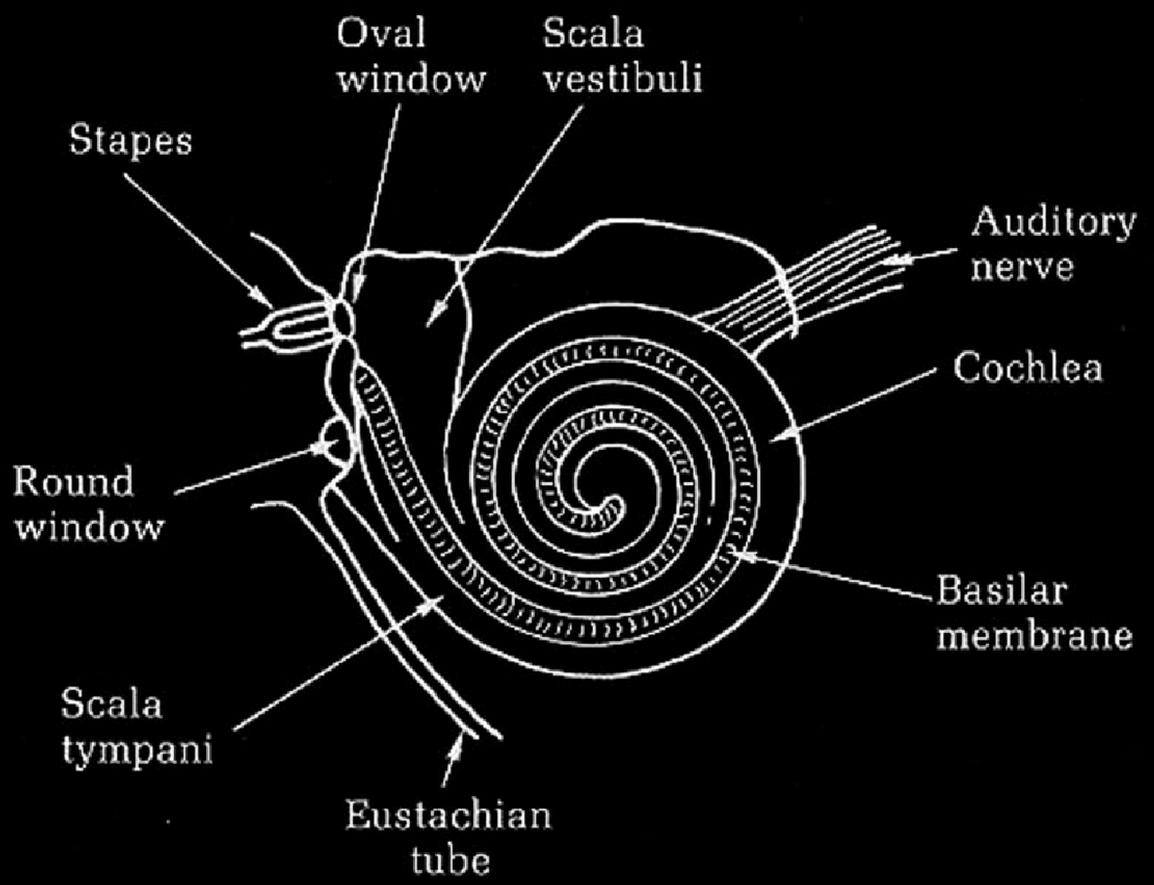
Middle Ear


malleus
incus
tensor tympani
(muscle)
stapedius
(muscle)
stapes
eustachian tube
Middle Ear



Inner Ear

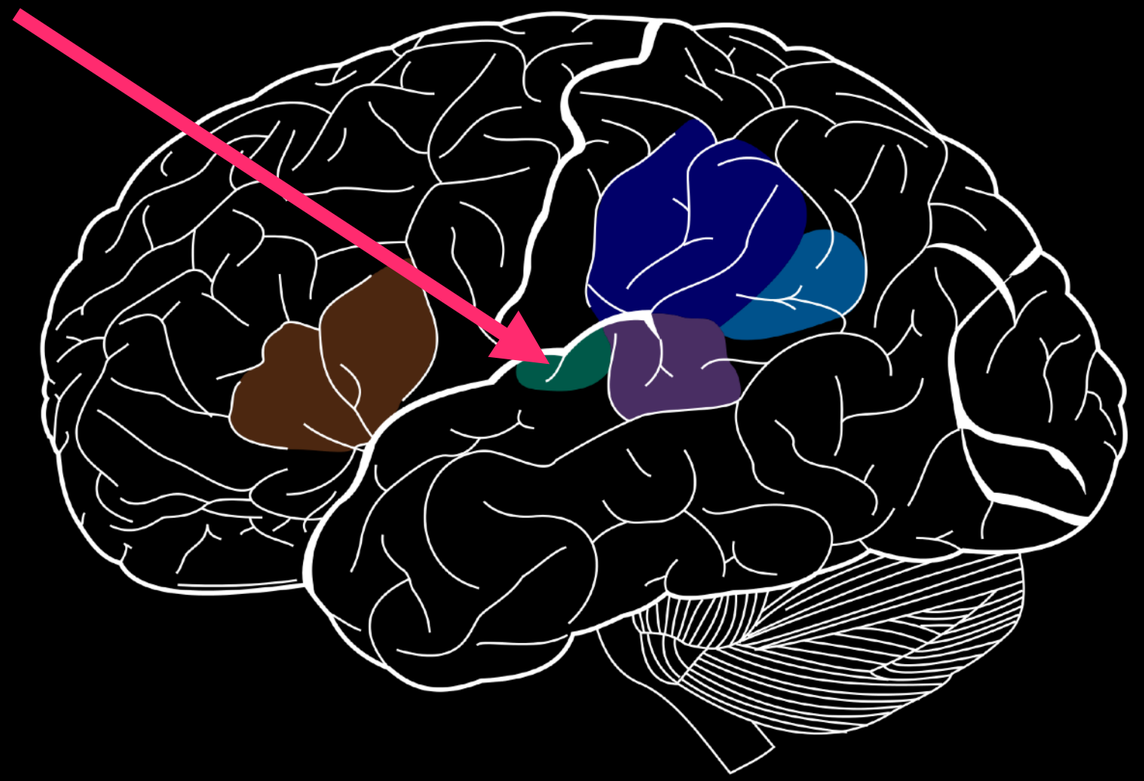




The inner ear.

Brains

auditory cortex



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