Theoretical Bases of Audiology

BHPI

hearing for all 2024

Nature of Sound

Sound is generated by vibration and is carried through the air around us by pressure waves. It is only when these pressure waves strike the ear that hearing occurs.

Nature of Sound

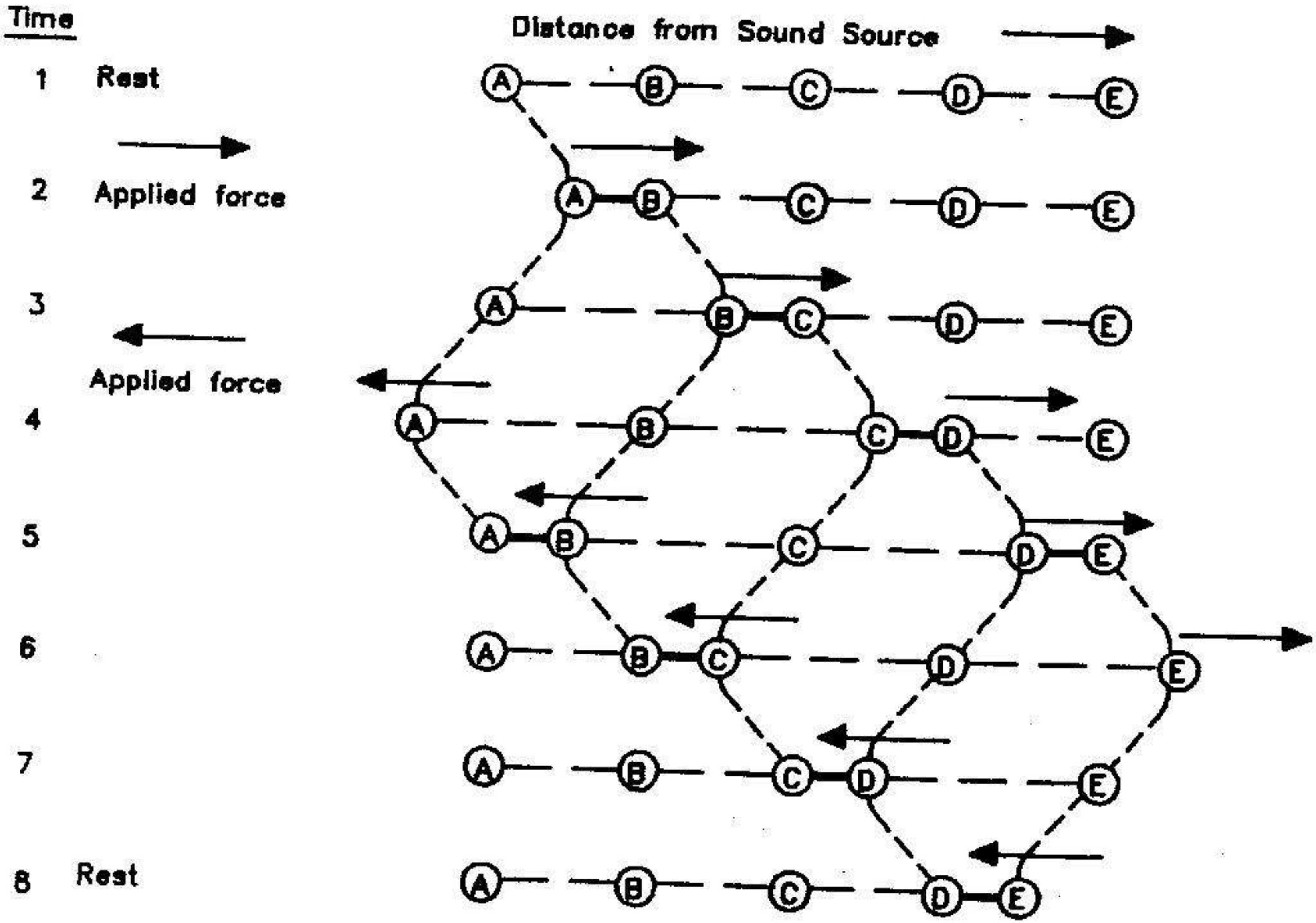
- Air around us is composed of billions of air particles
- Air particles are randomly moving around but for our discussion, we will assume they have an average resting position
- When an object vibrates, the air particles around it also vibrate

Nature of Sound

- When sufficient force is applied to air molecules around a moving object, the air particles will be moved in the direction of the force
- Once the force is removed, the displaced particle returns to its resting position

Nature of Sound

- The displaced air particles collide with particles next to them, displacing them also
- The vibration of air particles is passed from one particle to another through a sequential series of collisions
- Each particle has moved only a small distance, but the vibration can be transferred a long distance


Time
Distance from Sound Source
1 Rest
2 Applied force
3
Applied force
4
5
6
7
8 Rest
A
B
C
D
E

Sound Waves

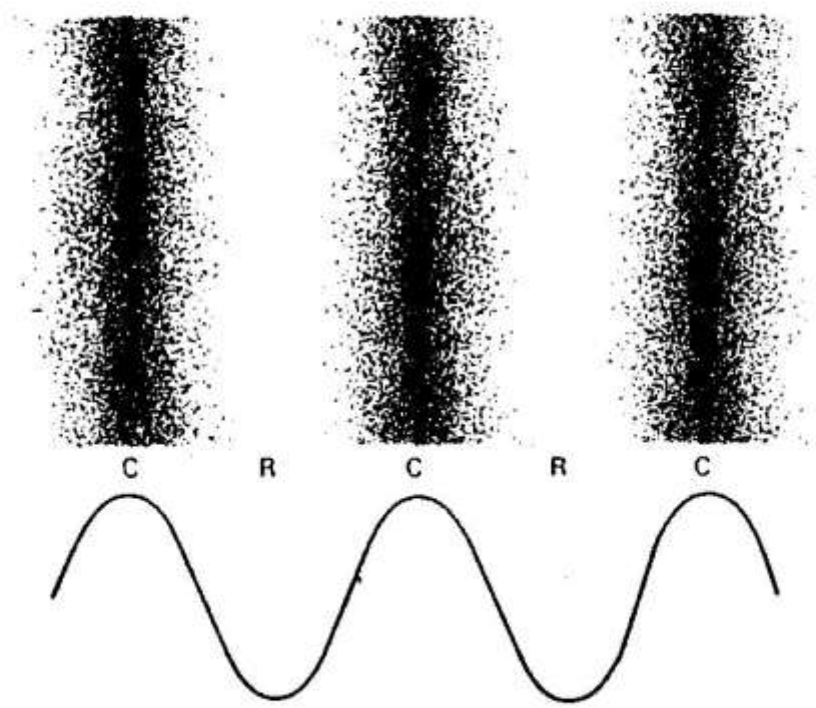
- A movement or propagation of a disturbance (the vibration) through a medium, such as air, without the permanent displacement of particles
- Any solid, liquid, or gas can act as a medium for sound

Sound Waves

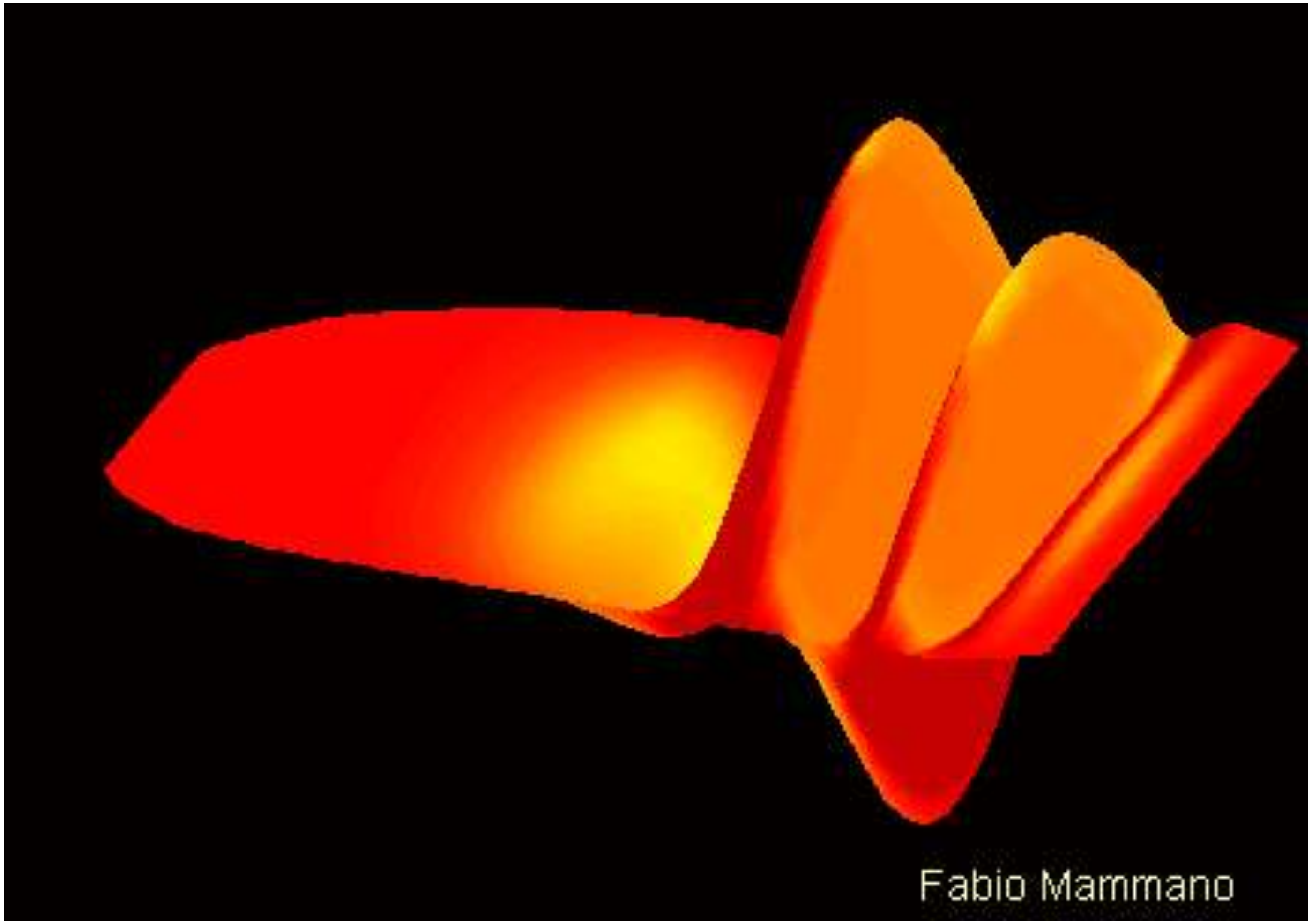
- When molecules are pushed close together, they are compressed
- Gaps between compressions are rarefactions
- Sound waves are successive compressions and rarefactions

Sound Waves

- Continual vibration sets up chains of compressions and rarefactions
- These chains may be translated into a waveform



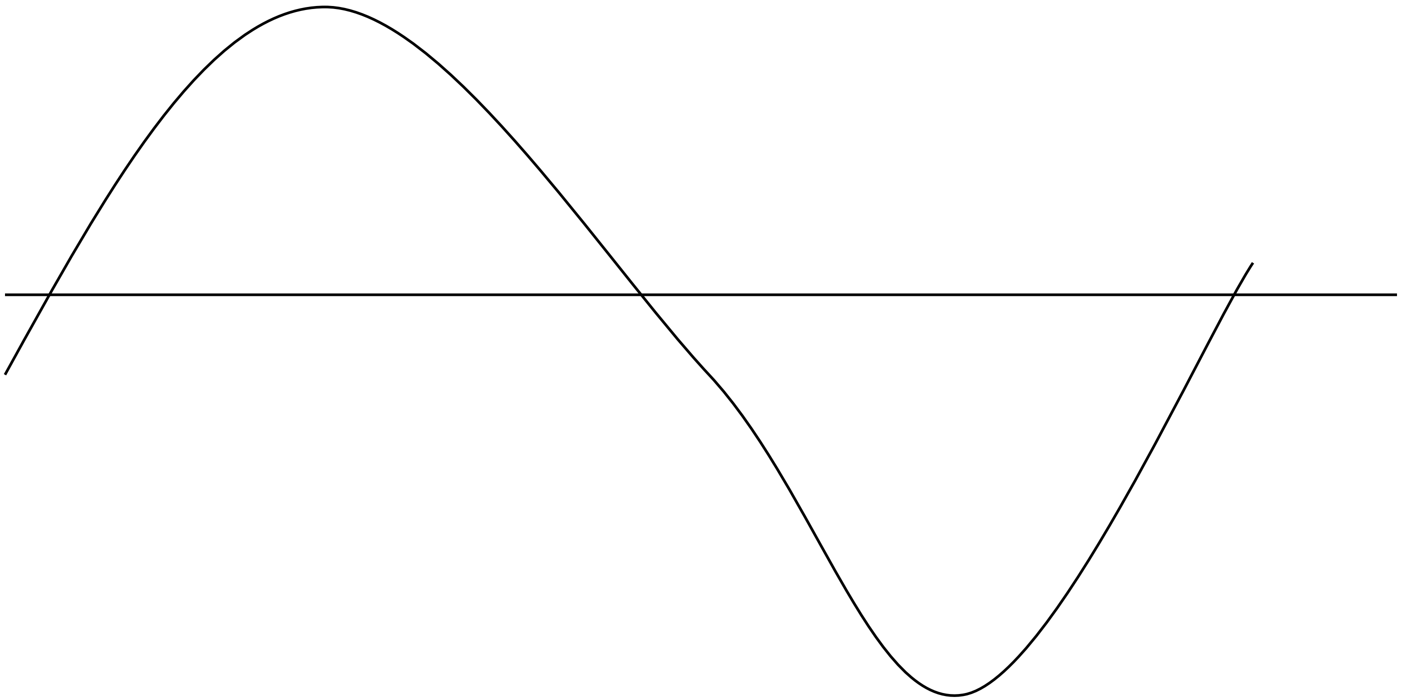
Sound Waves



Frequency

- Imagine a weight on a string or a pendulum to represent a vibrating air particle
- It swings from original position at left, through to the right and back to the left
- If we plot the displacement of the pendulum over time, a waveform known as a sine wave results

Sine Wave



Frequency

- Any time the pendulum swings from its original position at the left, to the right and back again it has completed one cycle
- Similarly any point on the sine wave to the same point on the next wave is one cycle
- When a body vibrates like this, showing only one frequency of vibration it is said to be a Pure Tone

Frequency

- The number of cycles per second is the FREQUENCY of the pendulum
- Similarly, the number of vibratory cycles of air particles is said to be the FREQUENCY of the sound pressure wave set up
- Frequency is measured in Hertz (Hz)

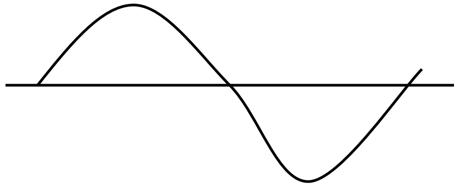
Frequency

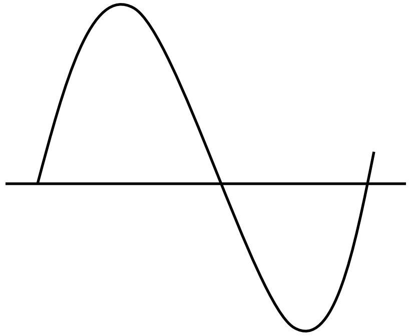
- The human ear can detect frequencies over the range of 20Hz to 20,000Hz
- The audiogram is scaled along the frequency axis in octaves
- For any frequency, the octave which is one octave above is equal to twice that frequency

Intensity

- When an object vibrates, it exerts a certain force on adjacent air particles
- The greater the force applied to air particles by a vibrating object, the further the particles move from point of rest
- The amount of force per unit area is referred to as the INTENSITY of the sound wave

Intensity





- The sine waves have the same frequency
- The lower sine wave is moving farther in each cycle because it has had more force exerted on it

Intensity

- Common measure of pressure is Pascal
- Human ear detects very small pressure fluctuations
- Need to use microPascals or one millionth of a Pascal
- Range of human ear:

just audible	20μP
pain threshold	200,000,000 μP

Intensity

- Using μP as measurement unit results in very large numbers
- More convenient to use logarithm scale
- Decibel scale is used (dB)
- Reduces range of sound to more manageable one

just audible	0dB
Pain threshold	120dB

Decibel Scale

- Points to note about the decibel scale

  - It is a relative scale of measure

  - Decibels cannot be added, subtracted etc. in the usual manner

  - Must be expressed in terms of reference

  - 0dB does not mean silence, rather that the sound is 0dB above the reference point

Decibel Scale

- Common points of reference for decibel scales

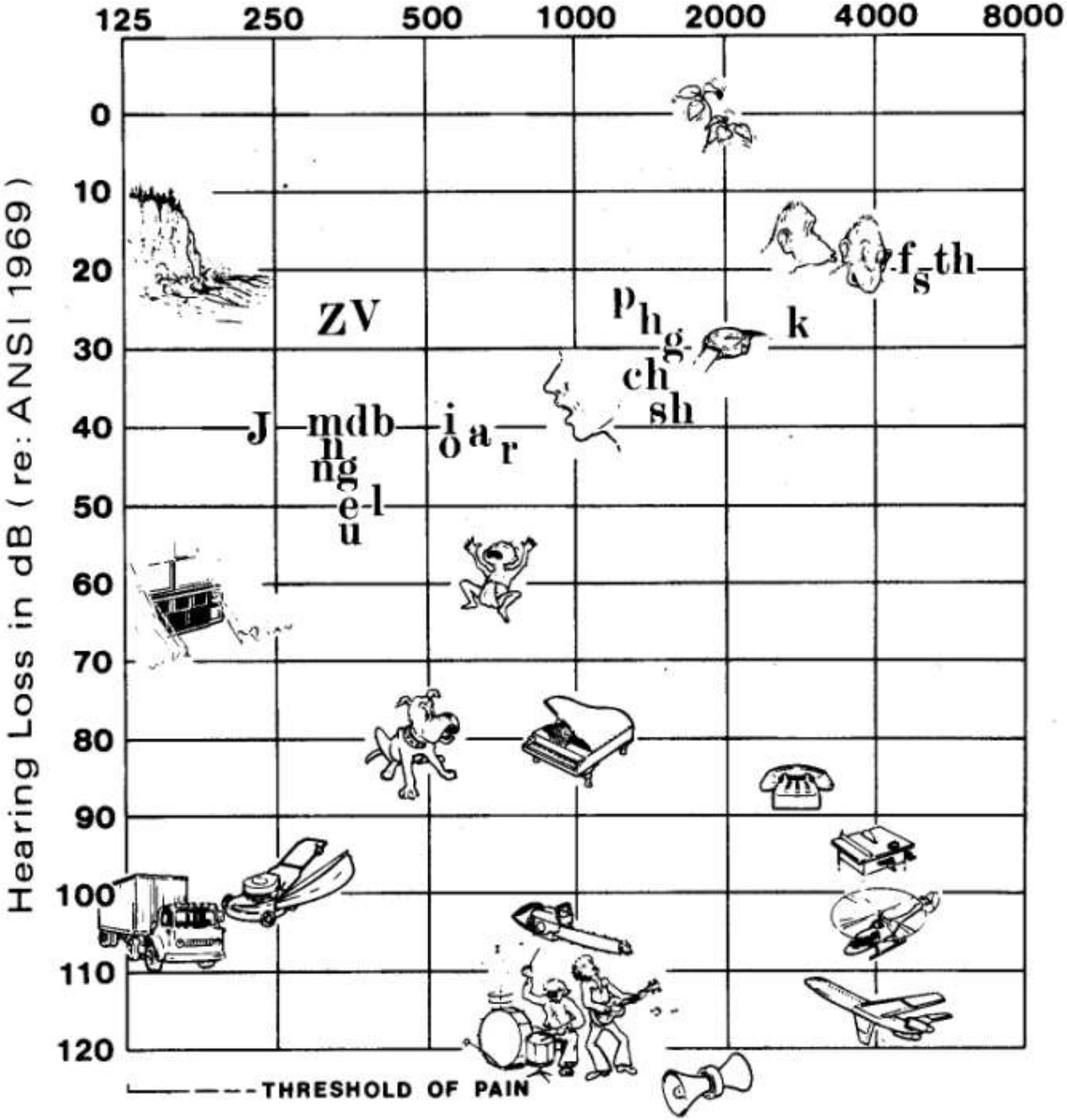
  - Sound Pressure Level (dBSPL)
  - Hearing Level (dBHL)
  - Sensation Level (dBSPL)

Sound Pressure Level

- dBSPL
- Used in free-field testing, speech testing, and measurement of environmental sounds
- Uses a reference point determined to be the average threshold of audibility for the human ear (i.e. microPascal)

Sound Levels of Some Environmental Sounds

0dB	Softest Sound Human can Hear
10dB	Normal Breathing
20dB	Leaves Rustling in a Breeze
30dB	Very Soft Whisper
60dB	Average Speaking Voice
90dB	City Traffic
110dB	Loud Thunder



125
250
500
1000
2000
4000
8000
Hearing Loss in dB (re: ANSI 1969)
0
10
20
30
40
50
60
70
80
90
100
110
120
ZV
J
m d b
n
ng
e l
u
i
o a r
p h g
ch
sh
k
f s th
THRESHOLD OF PAIN

Hearing Level

- dB HL
- Used when testing under headphones
- Audiometers are calibrated to this scale
- The lowest intensity level that stimulates hearing is termed zero hearing level
- The ear shows different sensitivity to different frequencies

Hearing Level

- Ear is most sensitive in 1000Hz to 4000Hz range
- Different amounts of pressure are required for zero HL at different frequencies
- Scale created so that average pressure level just audible was 0dB HL
- Easier for comparison to normal when testing hearing

Sensation Level

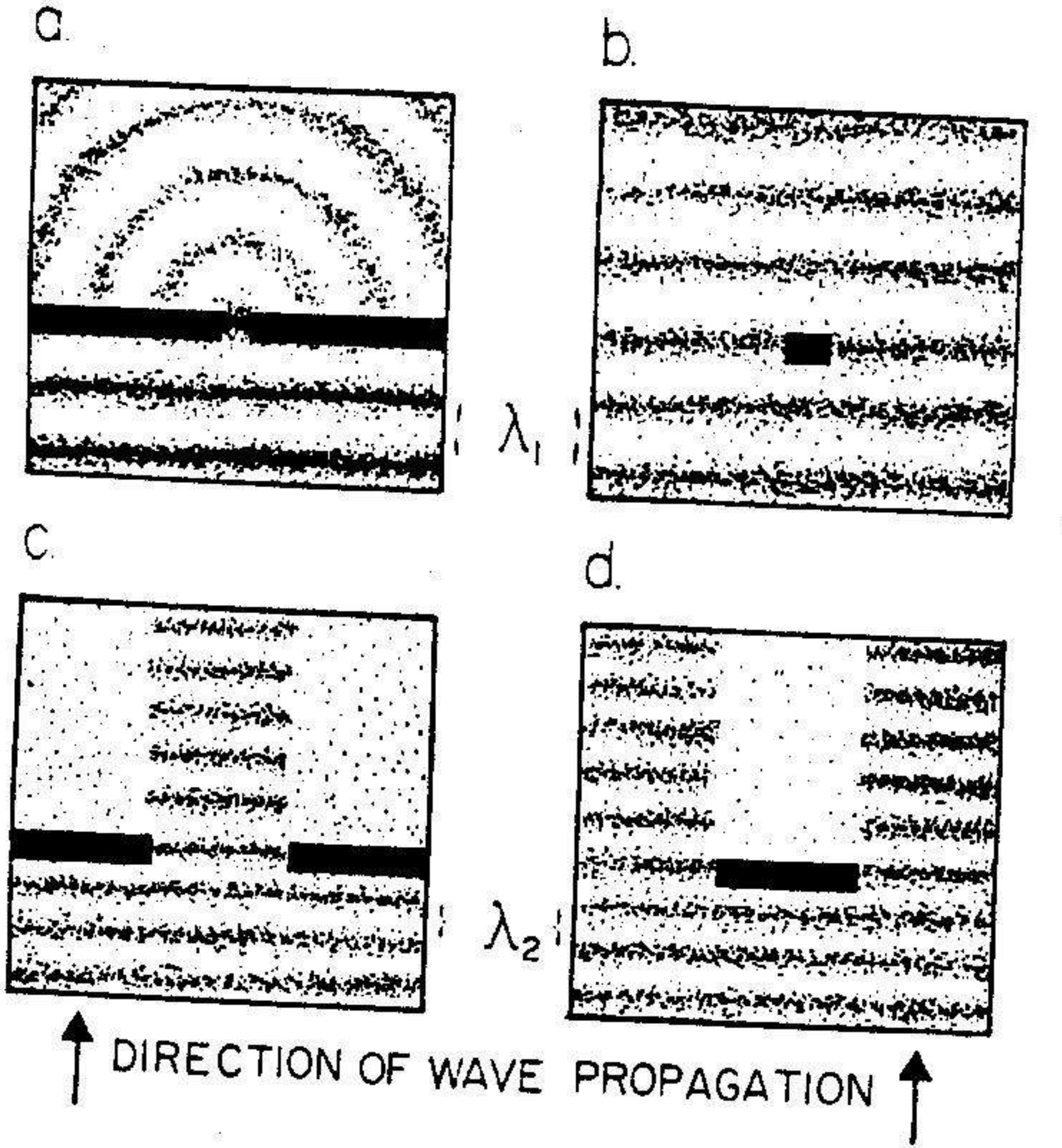
- dB SL
- Uses specific individual's auditory threshold as point of reference
- If threshold of individual is 20 dB HL and tone is presented at 50 dB HL then tone is at 30 dB SL

Phase

- The phase of a point on a sine wave is the location compared to a standard
- Allows description of relationships between corresponding points on different waves

Wave Interaction

- When more than one tone is introduced, there are interactions among sound waves
- Waves may add together to increase intensities
- Waves may cancel each other depending on phase


a.
b.
c.
d.
λ_1
λ_2
DIRECTION OF WAVE PROPAGATION

Complex Sounds

- Tones of different frequencies may add together to form complex sounds
- Composed of a number of different frequencies, intensities, and phase relationships