

Intro to Audition & Hearing

(+ Chap 8 leftovers)



Lecture 15

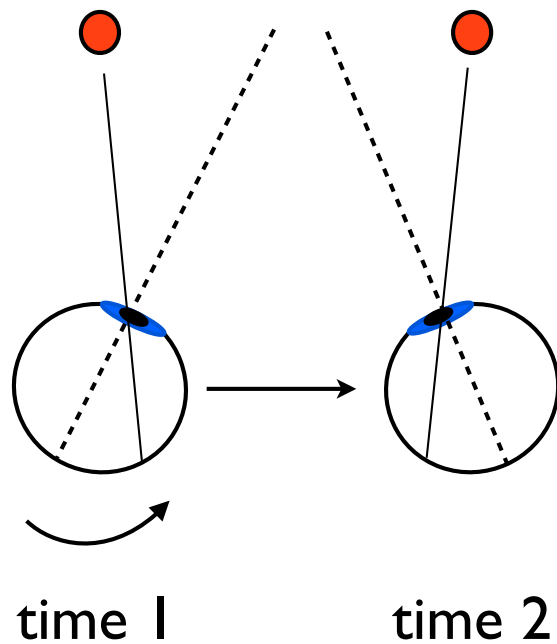
Chapter 9

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Sensation & Perception (PSY 345 / NEU 325)
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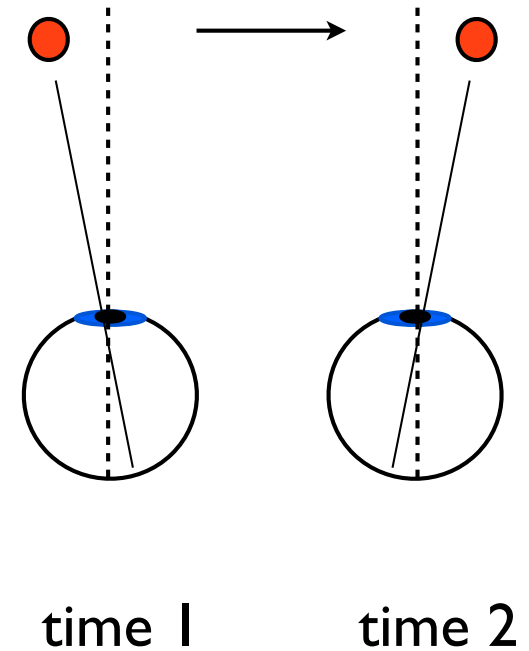
Eye movements: also give rise to retinal motion.

- important to distinguish motion due to eye movements from motion due to moving objects!

two scenarios with same retinal motion



eye moves



object moves

Eye Movements

- **Smooth pursuit** - eyes smoothly follow a moving target
- **Saccade** - rapid movement of the eyes that changes fixation from one location to another
- **Vergence** - two eyes move in opposite directions, as when both eyes turn towards the nose
- **Reflexive** - automatic / involuntary (e.g., vestibular-ocular-reflex)

Smooth pursuit vs. saccadic eye movements

in-class experiment

Partner up!

Experiment:

1) Moves their finger from left to right, following it with with their eyes

or

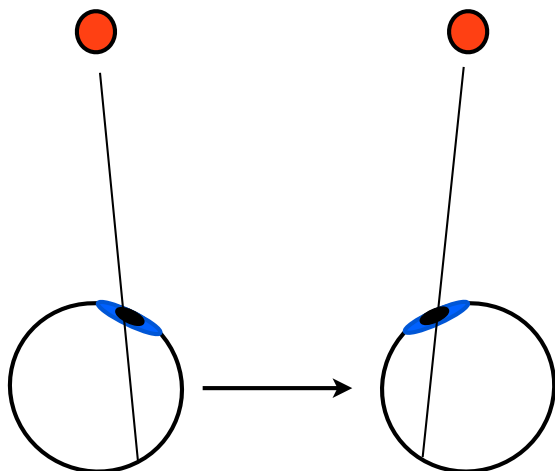
2) Attempts to move their eyes from left to right in the scene, as smoothly as possible, but without tracking a moving object.

How to discriminate motion from eye movements vs. object movement?

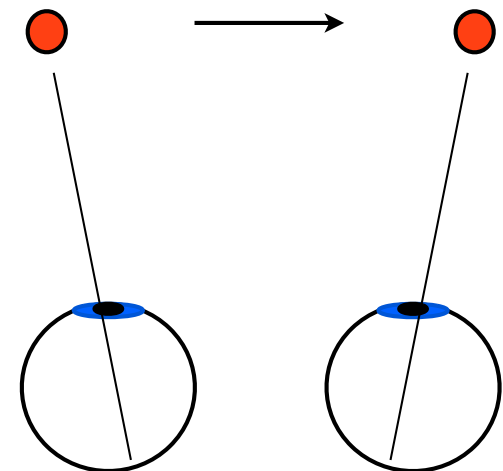
Comparator: compensates for retinal motion due to eye movement

- receives a copy of the order issued by the motor system to the eyes
- subtracts the *expected motion* from the retinal motion

object motion = retinal motion - eye motion



Two scenarios with same retinal motion



Saccadic suppression - reduction of visual sensitivity during a saccade

Test it out yourself:

- In a mirror, and look from one eye to the other.
- You will never see yours eyes moving

(But you will see the motion if you watch a friend.)

Motion Illusions:

- **wagon wheel illusion** - wheels in movies appear to spin backwards due to the multiple solutions to the correspondence problem ('aliasing').

http://www.michaelbach.de/ot/mot_wagonWheel/index.html



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- spinning wheel
- apparent motion
- sampled at: 24 frames /sec

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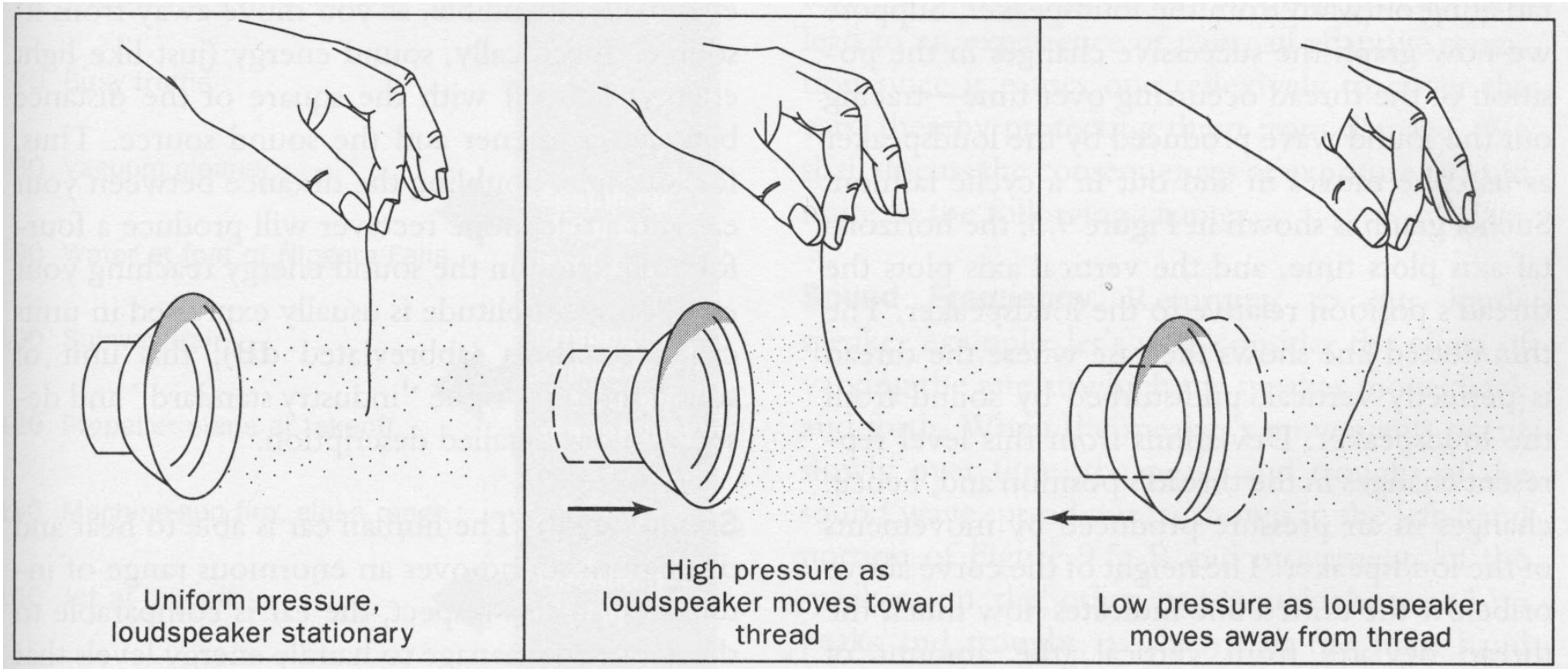


Chapter 9

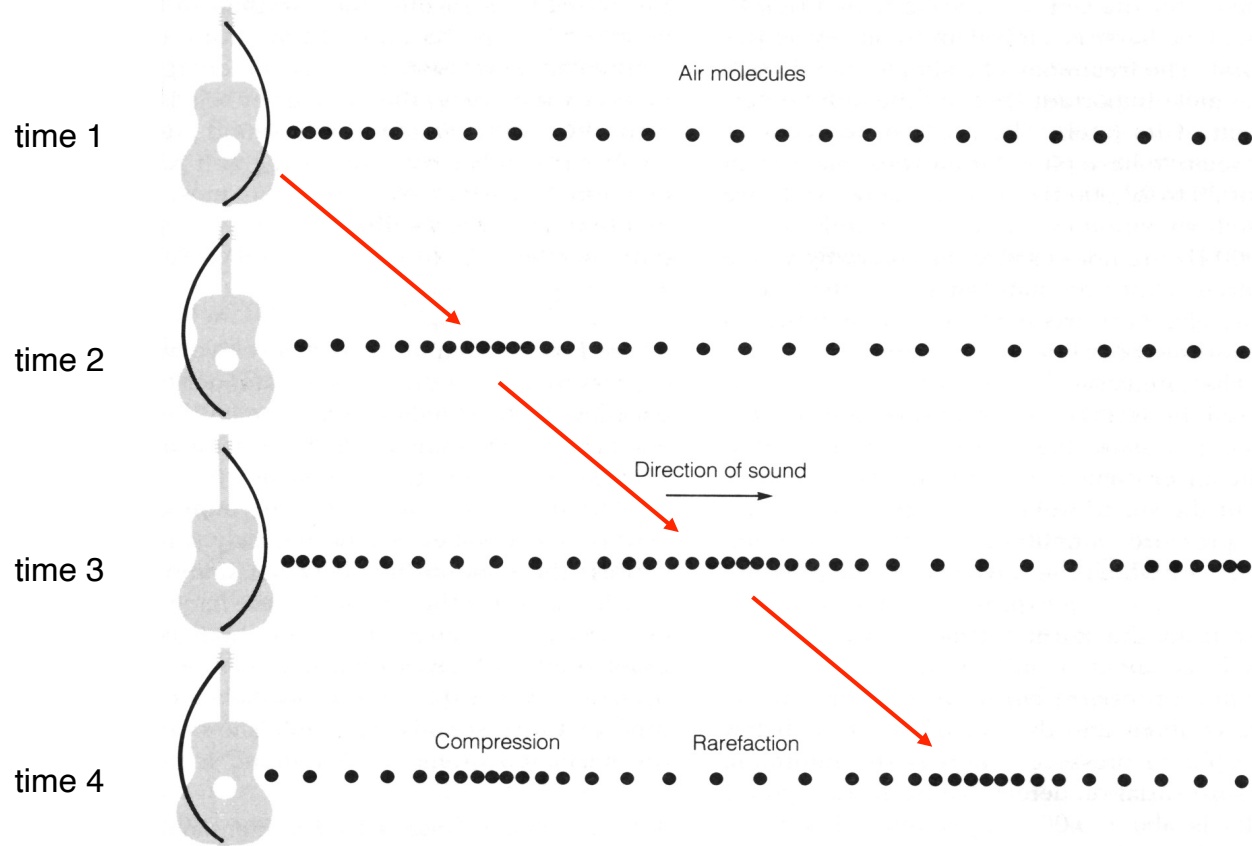
Part 1: The Physics of Sound

What is sound?

- collisions, created when objects vibrate
- in a gas (air), it is changes in pressure (compression and rarefaction)



These collisions travel as *sine waves of pressure*.



Snapshot of the pressure at time 4

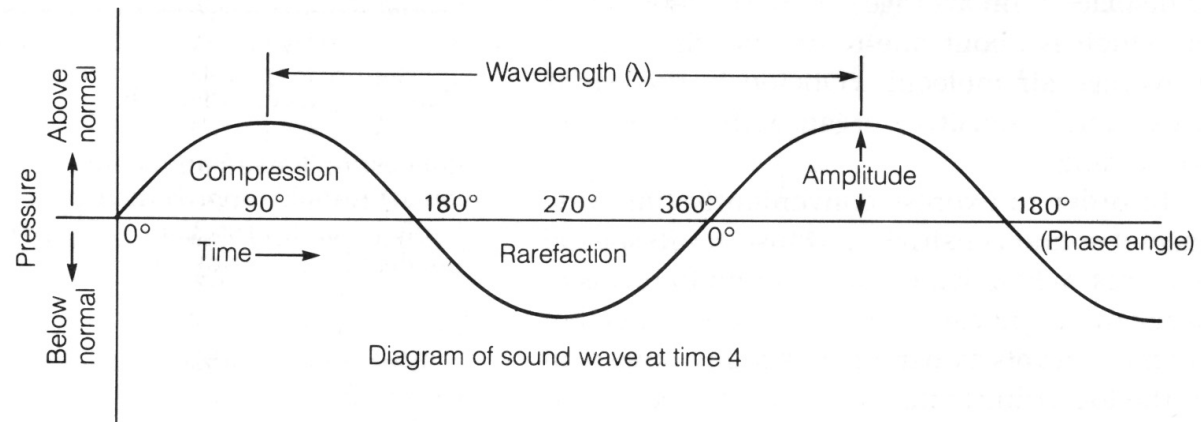
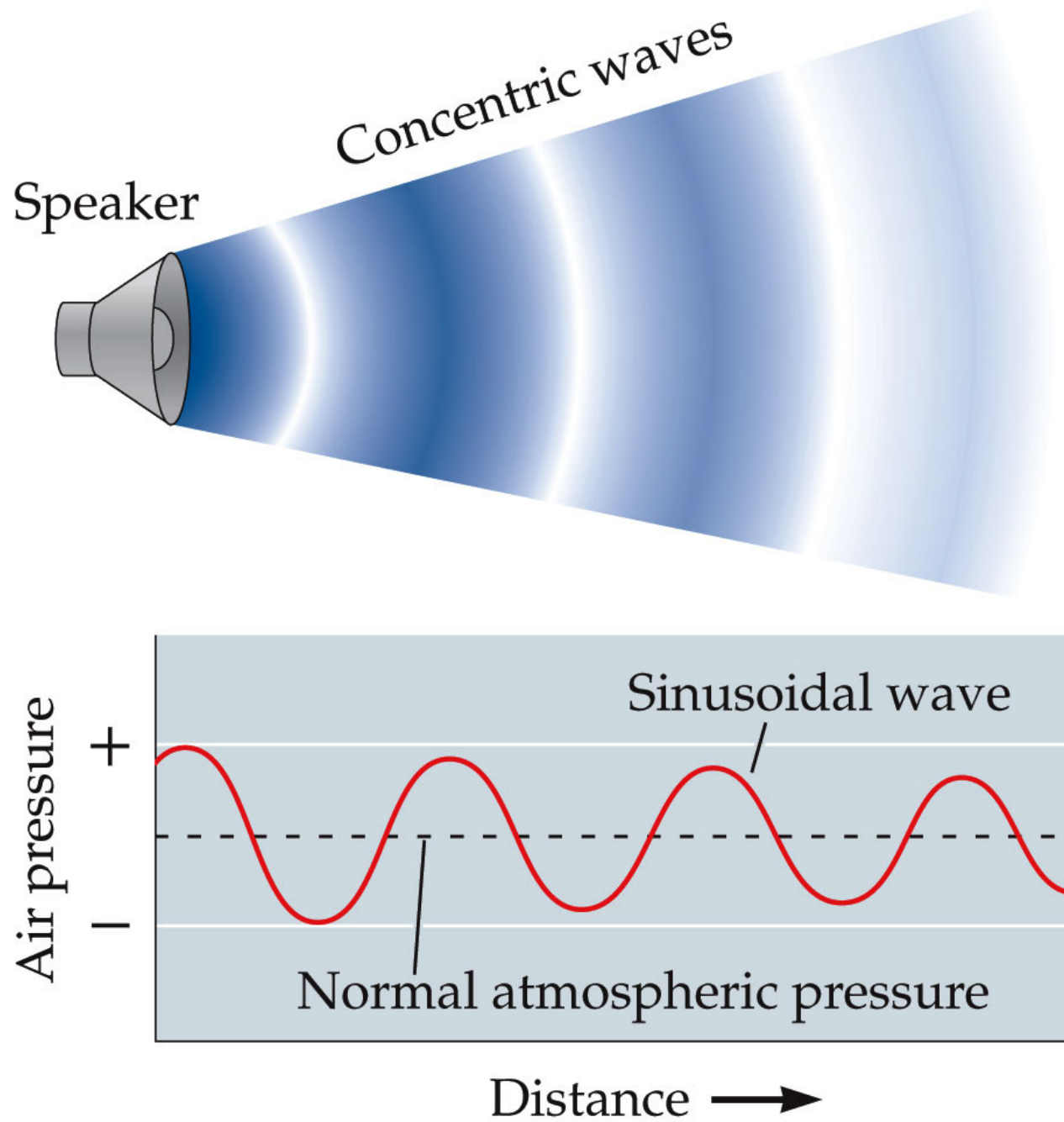


Figure 9.1 The pattern of pressure fluctuations of a sound stays the same as the sound wave moves away from the source, but the amount of pressure change decreases with distance



What Is Sound?

Sound waves travel at a particular speed

- Depends on the medium
- through air: 340 meters/second
- through water: 1500 meters/second

- (vs. 3,000,000 m/s for light!)

What Is Sound?

Physical qualities of sound waves:

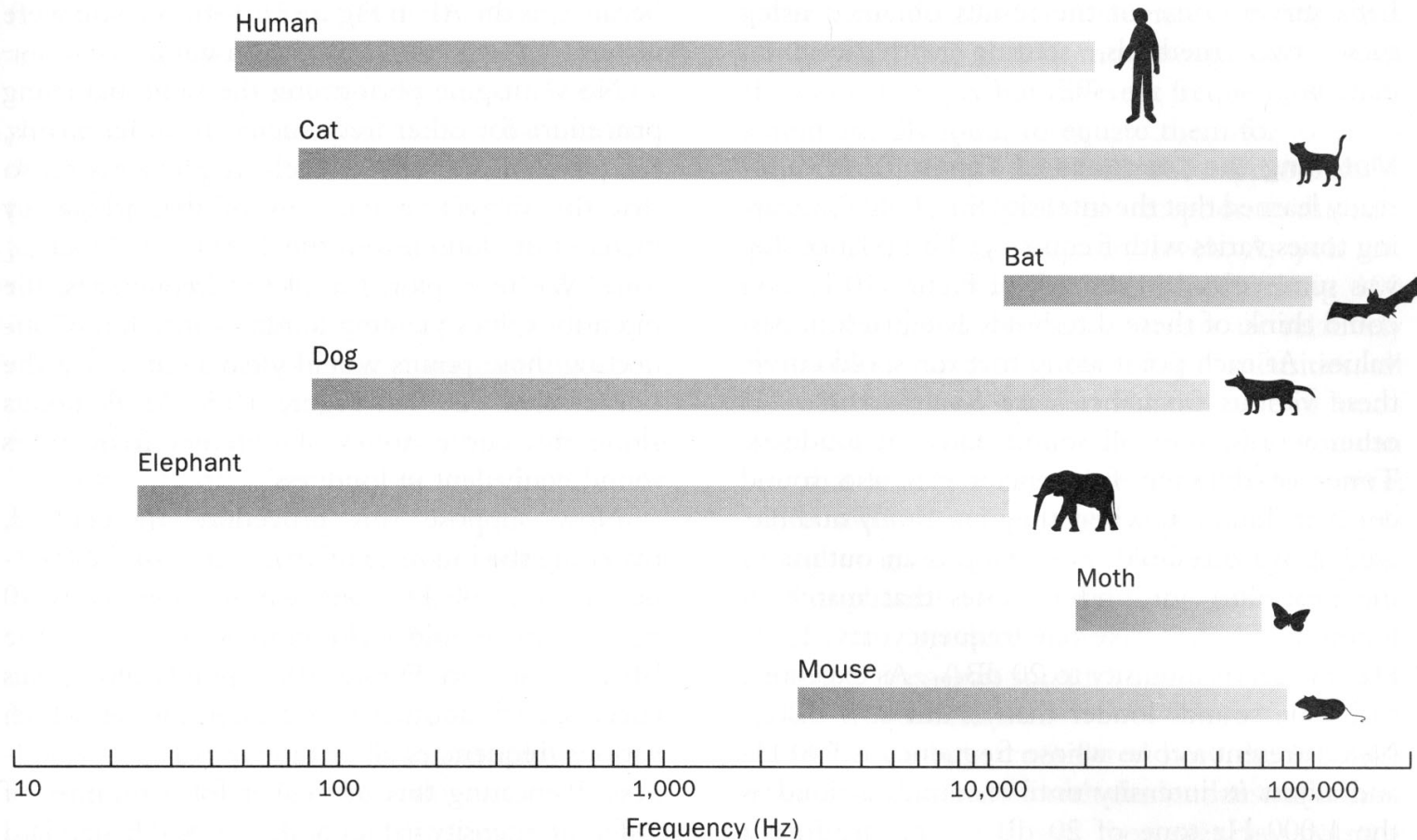
- **Frequency**: the number of times per second that a pattern of pressure repeats
 - related to **pitch** - psychological quality of how “high” or “low” a sound is.
- **Amplitude**: the magnitude of displacement of a sound pressure waves
 - related to **loudness** - the perceived intensity of a sound

Psychological properties of sound

Units for measuring frequency:

- **Hertz (Hz):** A unit of measure for frequency. One Hz equals one cycle per second

Perceivable Frequencies:



Units for measuring loudness:

Decibel (dB): unit for the physical intensity of sound

- the ratio of sound pressure level (SPL) of a sound to that of a “barely detectable” sound.
 - 0 dB = threshold of hearing (by definition)
 - each increment of 20dB represents an increase in SPL by a factor of 10:1
 - thus, +40 dB means SPL increases by 100

Psychological qualities of sound waves:

- **Loudness:** The psychological aspect of sound related to perceived intensity or magnitude

Q: One sound is 50 dB, while another is 110 dB. How much greater SPL is the second?

Human hearing uses a limited range of frequencies (Hz) and sound pressure levels (dB)

- Loudness is measured by Sound Pressure Level (SPL), which has units of decibels (dB)

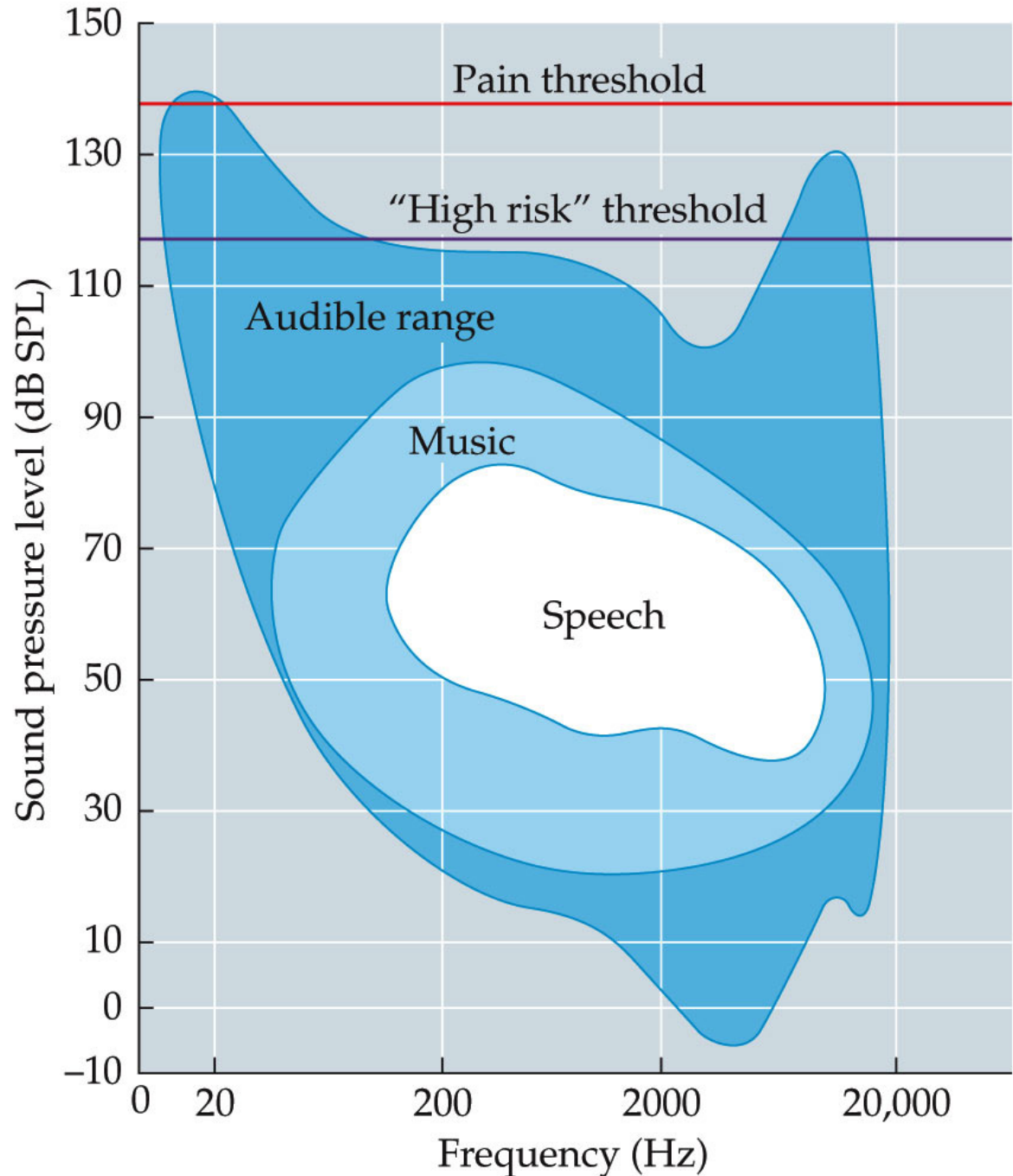
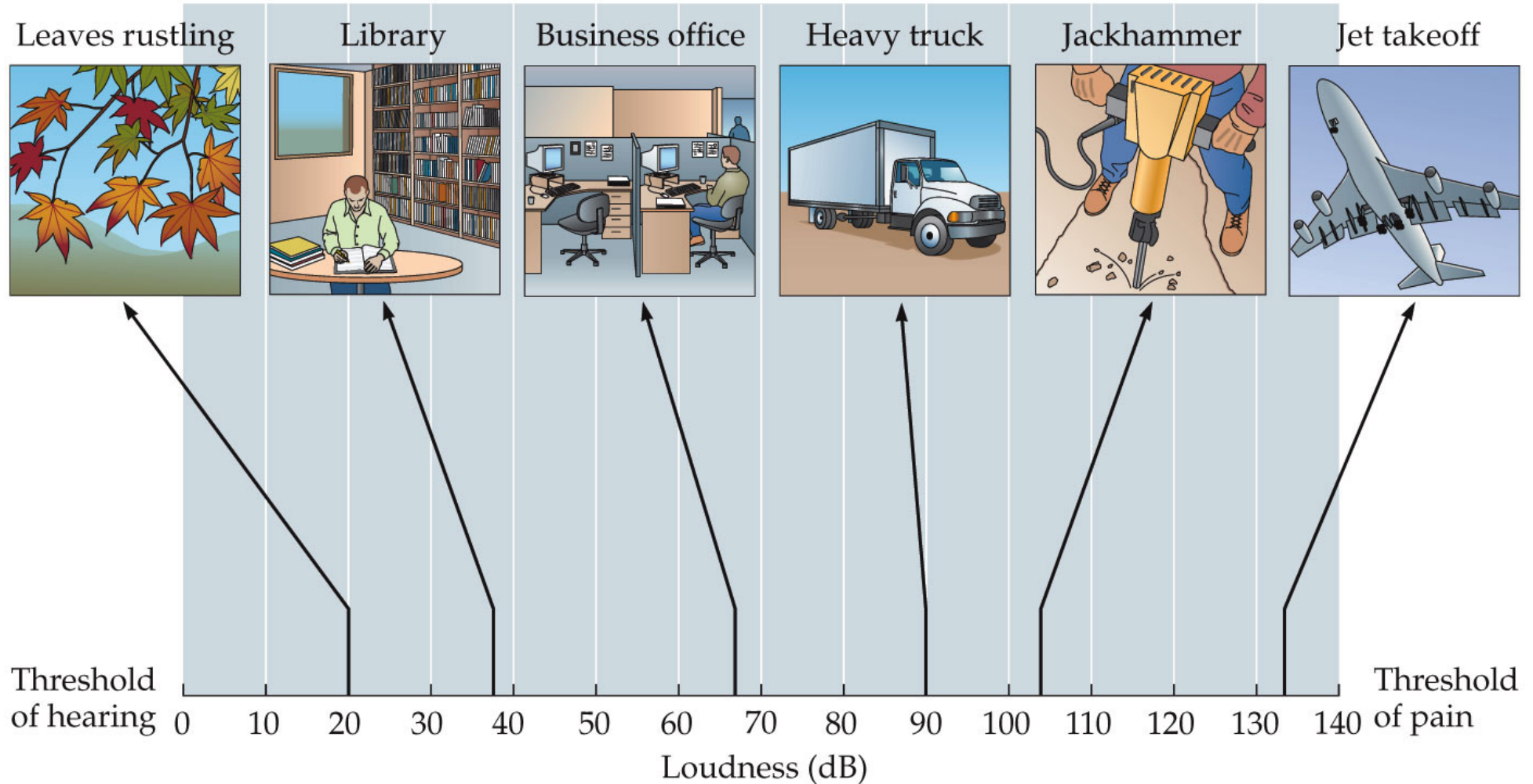


Figure 9.4 Sounds that we hear in our daily environments vary greatly in intensity

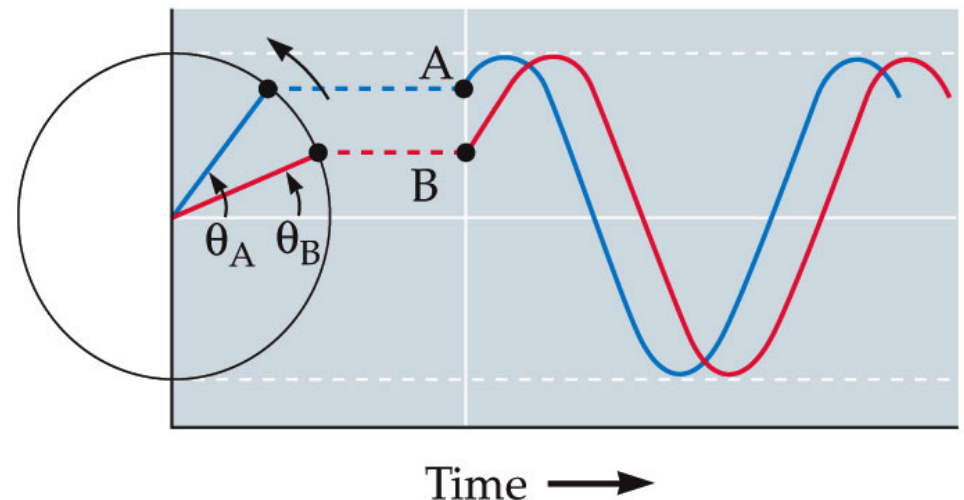
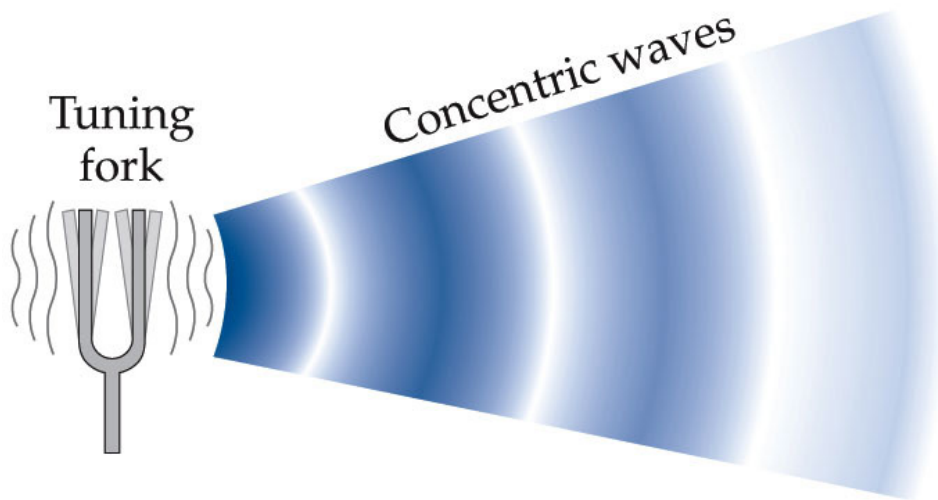


Wikipedia: "Loudest band in the world"

The heavy metal band [Manowar](#) is one claimant of the title of "loudest band in the world", citing a measurement of 129.5 [dB](#) in 1994 in [Hanover](#). However, [Guinness Book of World Records](#) listed Manowar as the record holder for the *loudest musical performance* for an earlier performance in 1984. Guinness does not recognize Manowar's later claim, because it no longer includes a category of loudest band, reportedly because it does not want to encourage [hearing damage](#).

Sine wave: one of the simplest kinds of sounds: sound for which pressure as a function of time is a sine function

- **Period:** The time required for one cycle of a repeating waveform (frequency = $1 / \text{period}$)
- **Phase:** The relative position of two or more sine waves
 - There are 360 degrees of phase across one period



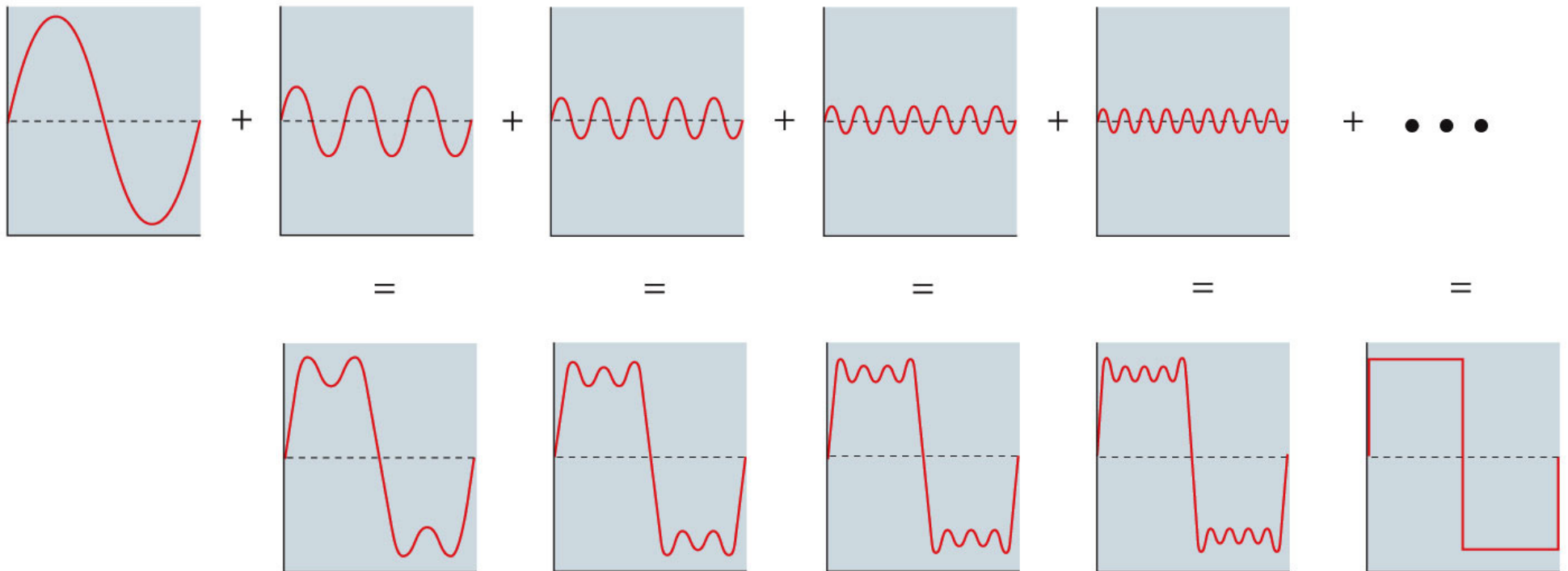
But: sine waves are a very *unnatural* kind of sound

- complex natural sounds can be broken down into a sum of sine waves

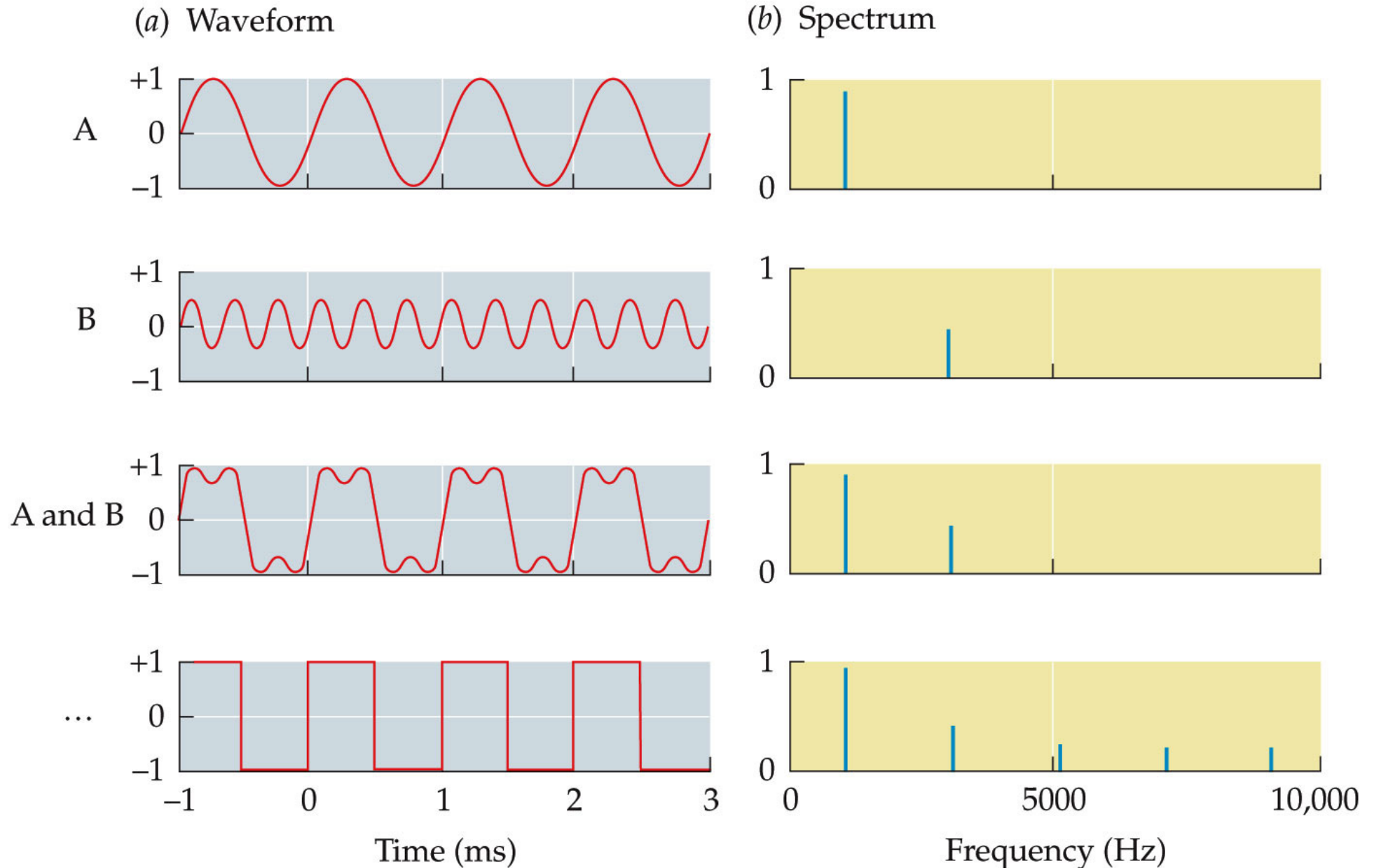
Complex sounds can be described by Fourier analysis

- **Fourier analysis:** mathematical theory by which any sound can be divided into a sum of sine waves

example: generating a square wave from a sum of sine waves

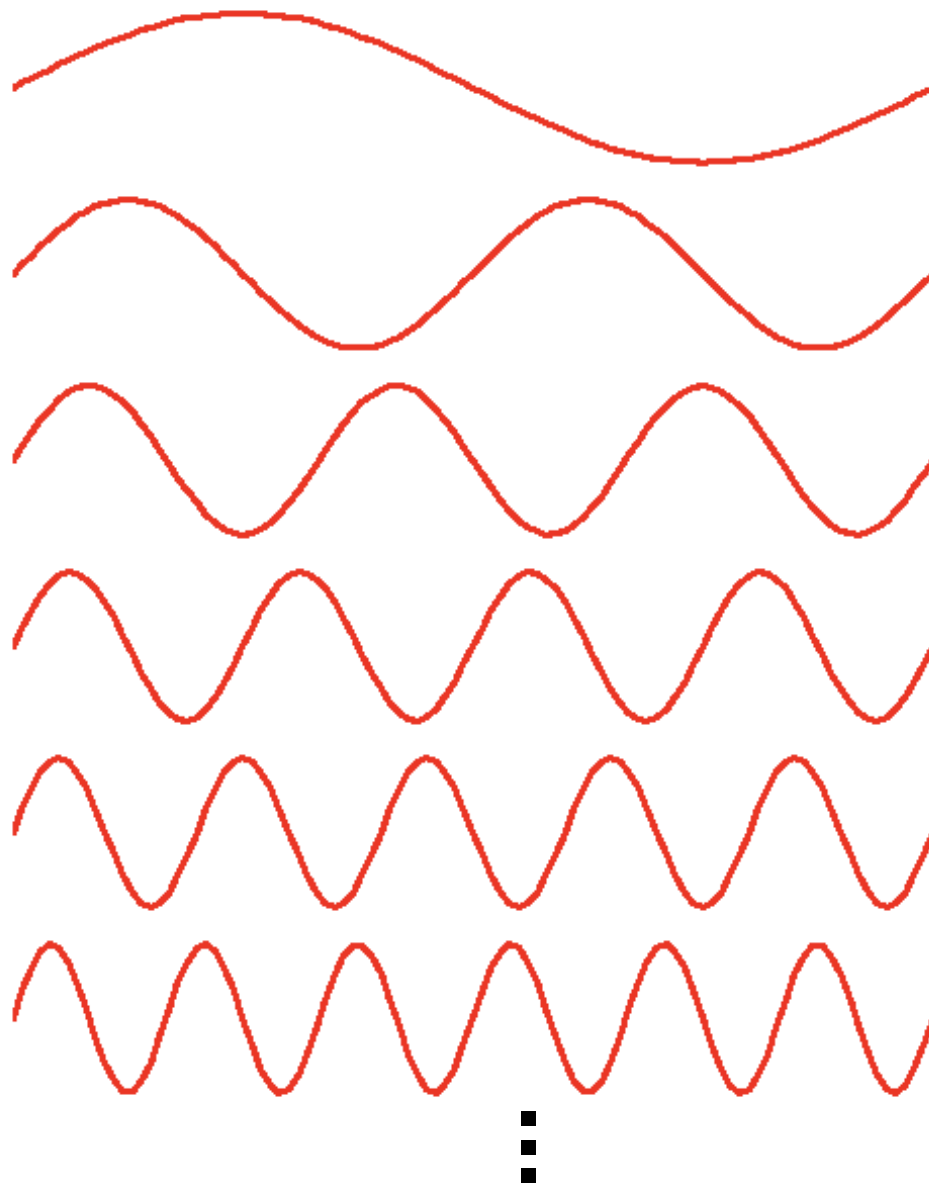


Fourier spectrum: shows the amplitude for each sine wave frequency present in a complex sound



Harmonic spectrum: Typically caused by a simple vibrating source (e.g., guitar string, saxophone reed)

- Also referred to as a “**harmonic stack**”



• **Fundamental frequency**

x 2

x 3

x 4

x 5

x 6

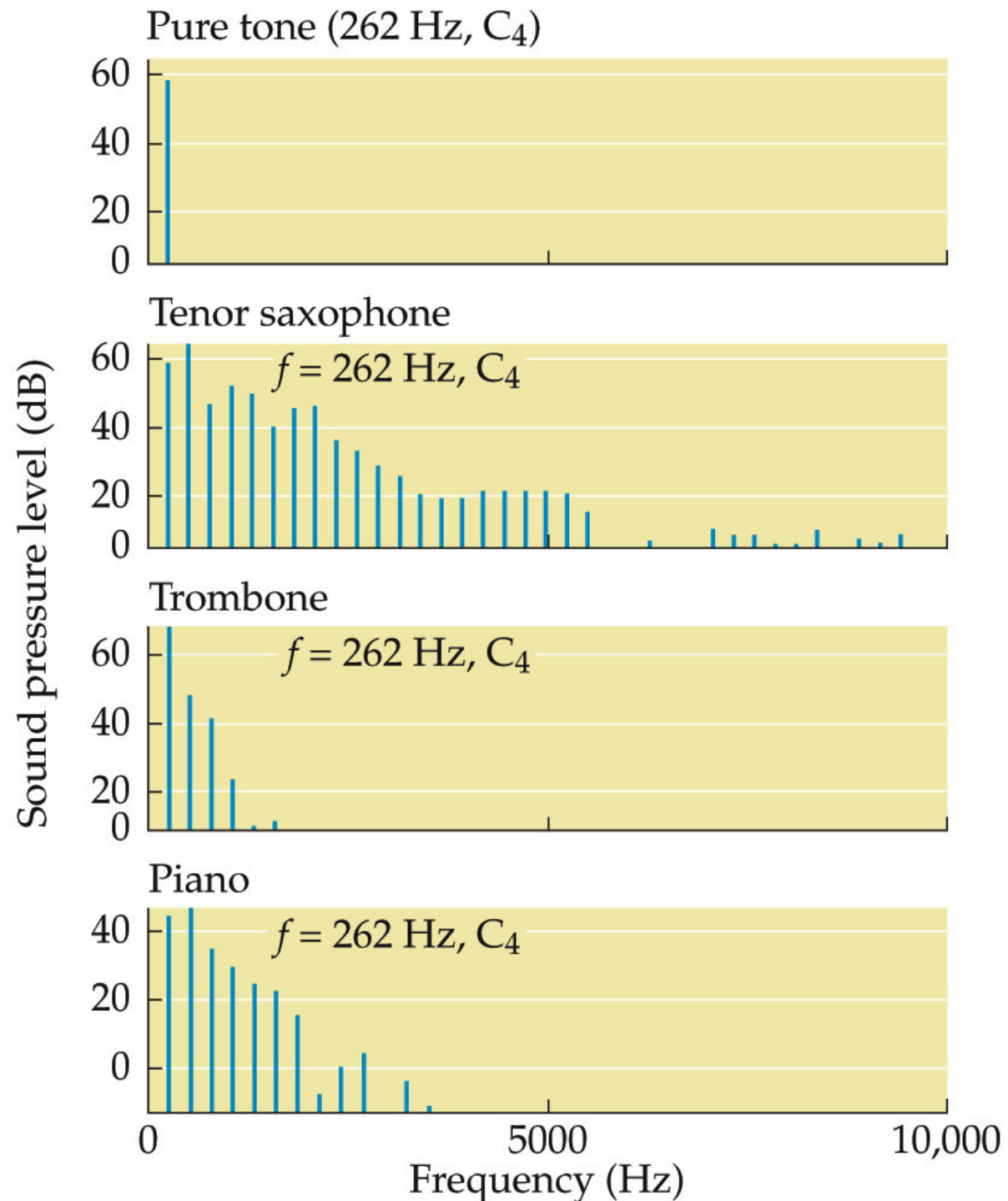
↑
determines
the perceived
pitch

Timbre: psychological sensation by which a listener can judge that two sounds with the same loudness and pitch are dissimilar

- timbre quality is conveyed by harmonics and other high frequencies

(more on this when we get to “music”)

Harmonic sounds with the same fundamental frequency can sound different (i.e. have different timbre) due to differences in high harmonics



Summary

- sound = pressure waves caused by movement, vibration
- amplitude / intensity (related loudness)
- frequency (related to pitch)
- Sound Pressure Level (SPL) and decibels (dB)
- pure & complex tones
- Fourier analysis - breaking sound into sum of sine waves
- power spectrum - sound energy at each frequency
- timbre - quality of sound
- harmonics (integer multiples of a “fundamental” frequency sine wave)
- harmonic stack