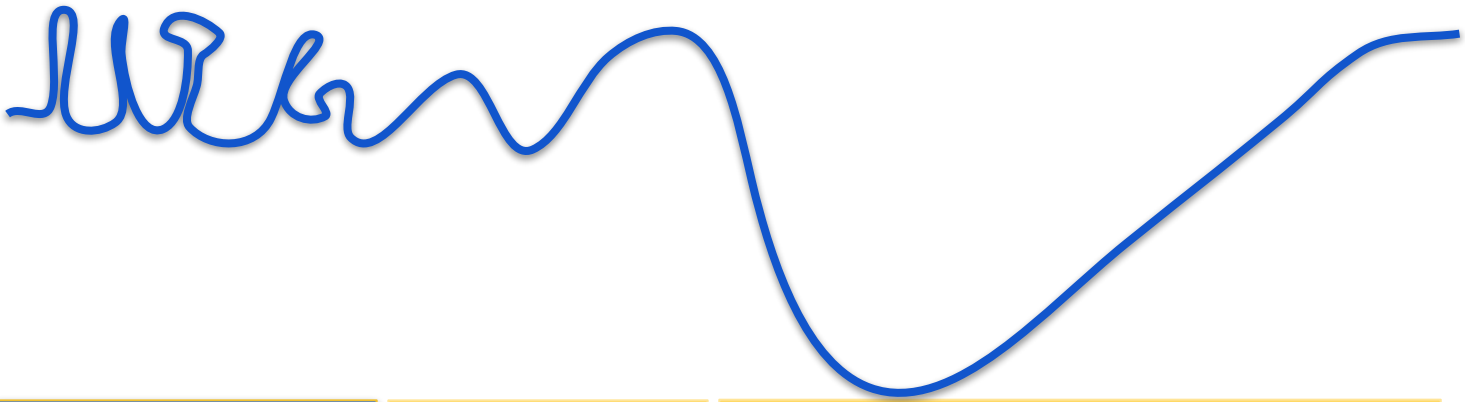
Computing with Signals



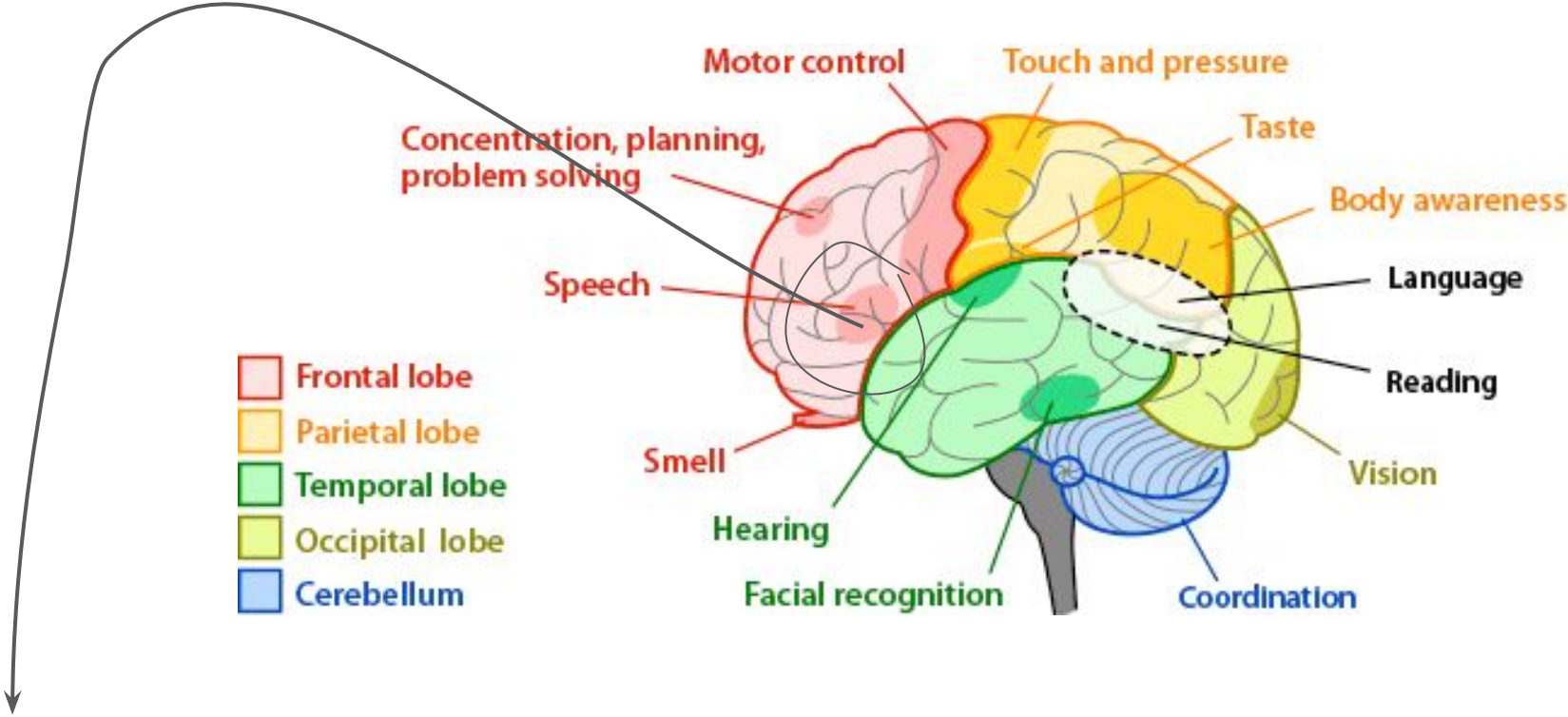
DA 623

Jan - May 2024

IIT Guwahati

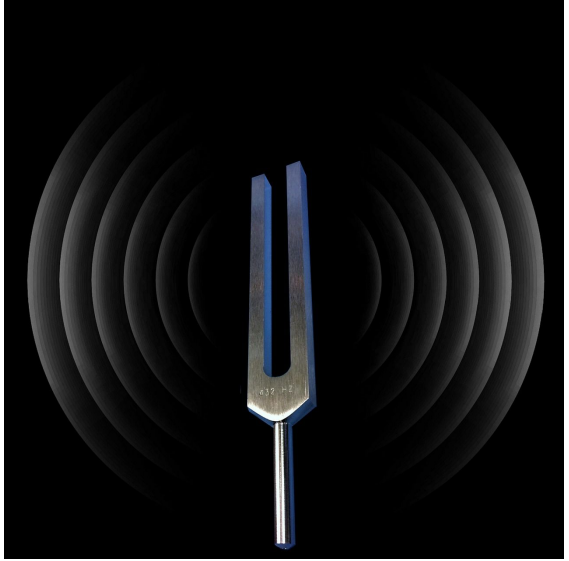
Instructors: Neeraj Sharma

Lecture-20



Speech - what kind of signal is that?

Sound



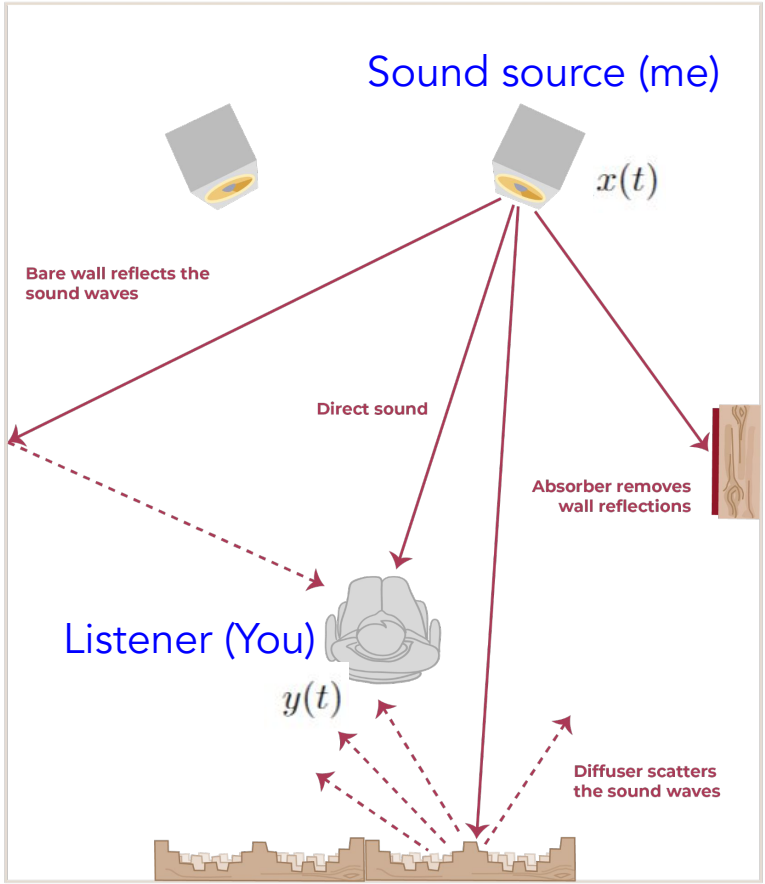
Tuning Fork?

- A disturbance in the pressure
- Travels through a medium
- Disturbance propagates as a longitudinal pressure wave
  - Example, through a stone into a pond, you feel see the ripples hitting the shore
- Sound waves hit your eardrums
  - From where are these waves coming
    - direct sound waves from the source
    - reflected sound waves

Sound

- Sound waves hit your eardrums
  - From where are these waves coming?
    - direct sound waves from the source
    - reflected sound waves (from walls, furniture etc.)
    - received signal (y(t)) can be expressed as follows:

$$y(t) = \alpha_1 x(t) + \alpha_2 x(t - t_2) + \alpha_3 x(t - t_3) + \cdots + \alpha_n x(t - t_n)$$
$$= \sum_{k=1}^{n} \alpha_k x(t - t_k)$$



https://www.ekustik.eu/tips-and-tricks-blog/basics-of-room-acoustics

Sound

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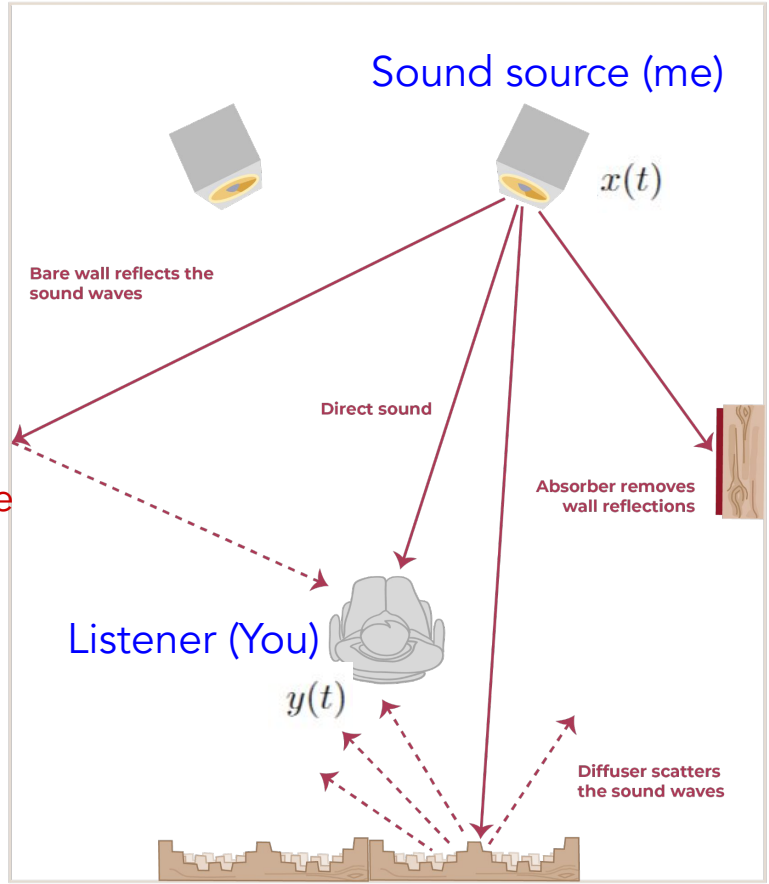


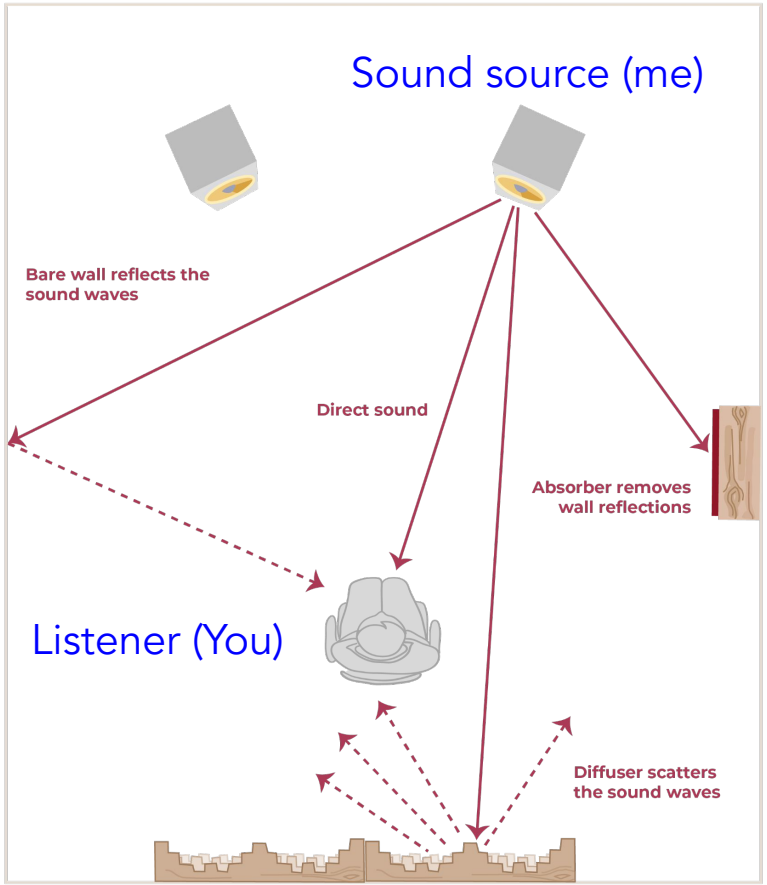
https://www.ekustik.eu/tips-and-tricks-blog/basics-of-room-acoustics

- y(t) is expressed as a weighted combination of delayed copies of the source signal x(t)
- y(t) is perceived to contain echoes and reverberation)

Sound

- Sound waves hit your eardrums
  - From where are these waves coming
    - direct sound waves from the source
    - reflected sound waves

Can we have a setup which has ZERO wall, furniture reflections?

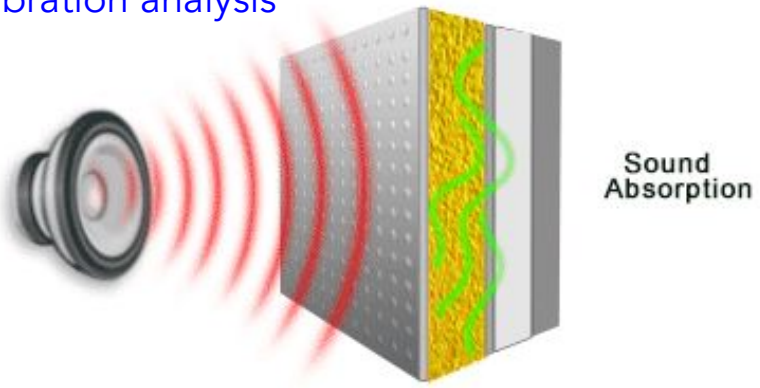


https://www.ekustik.eu/tips-and-tricks-blog/basics-of-room-acoustics

Sound

Can we have a setup which has ZERO wall, furniture reflections?

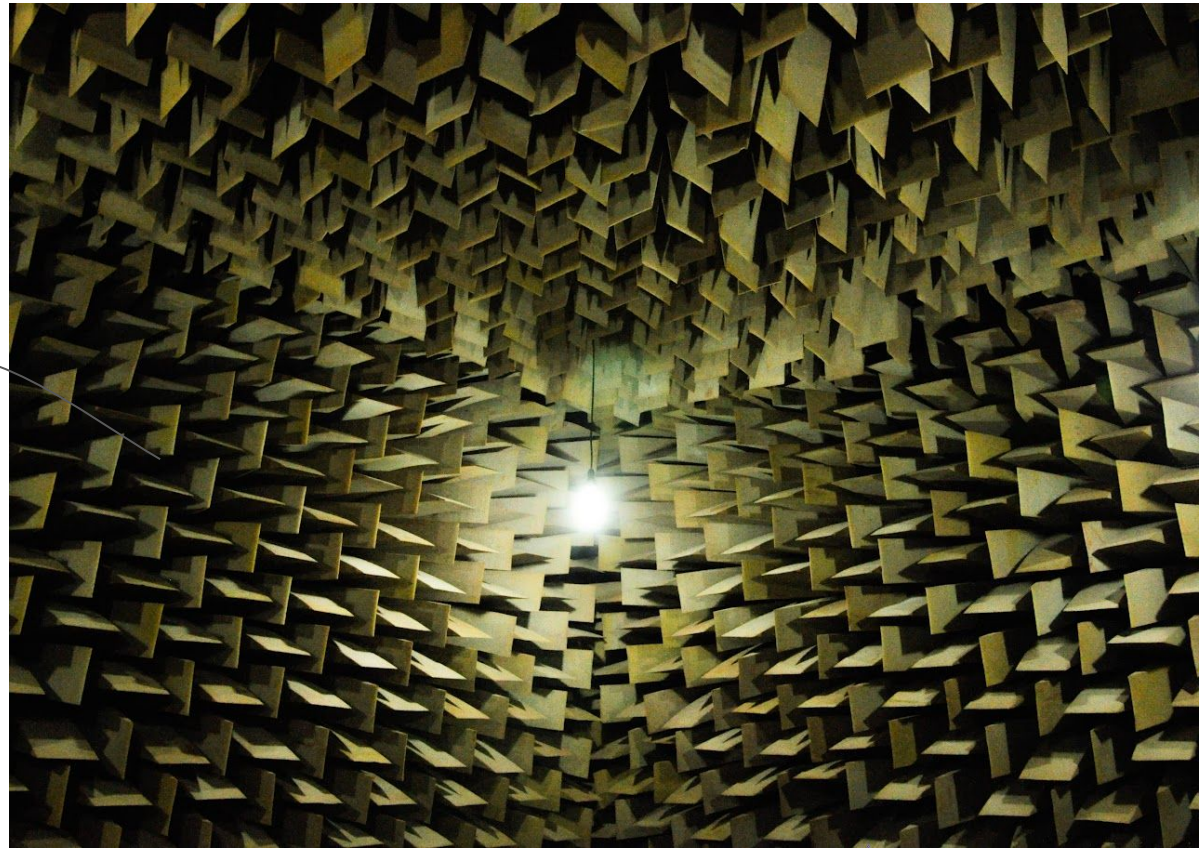
- Use case
  - record only the direct sound of the source
  - clean music/song/speech recording
  - capturing feeble sound - machine vibration analysis



Sound

Can we have a setup which has ZERO wall, furniture reflections?

Foam

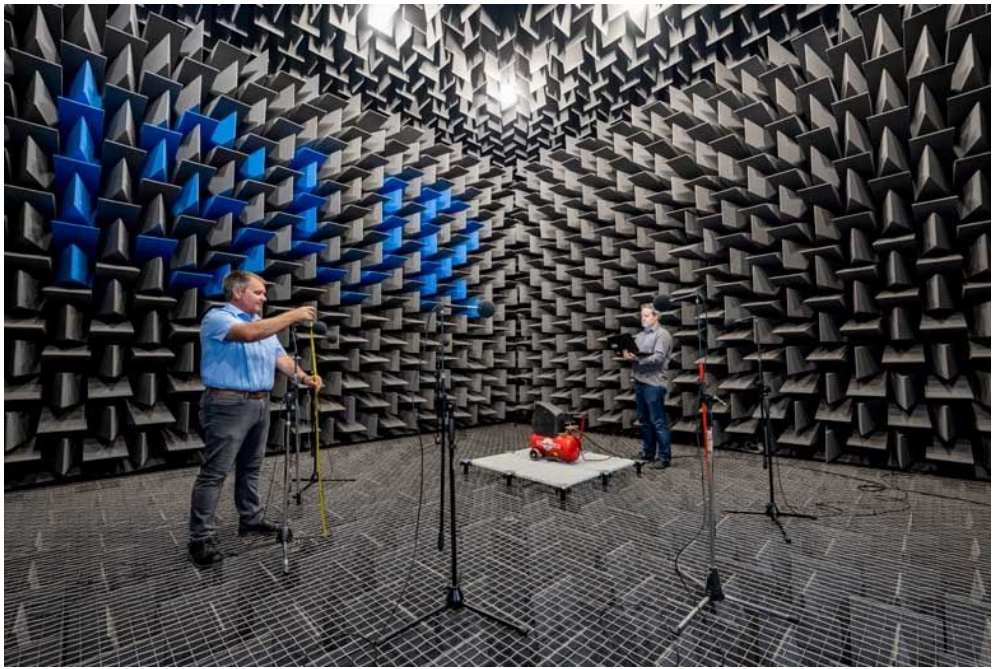


Indian Institute of Science, Bangalore

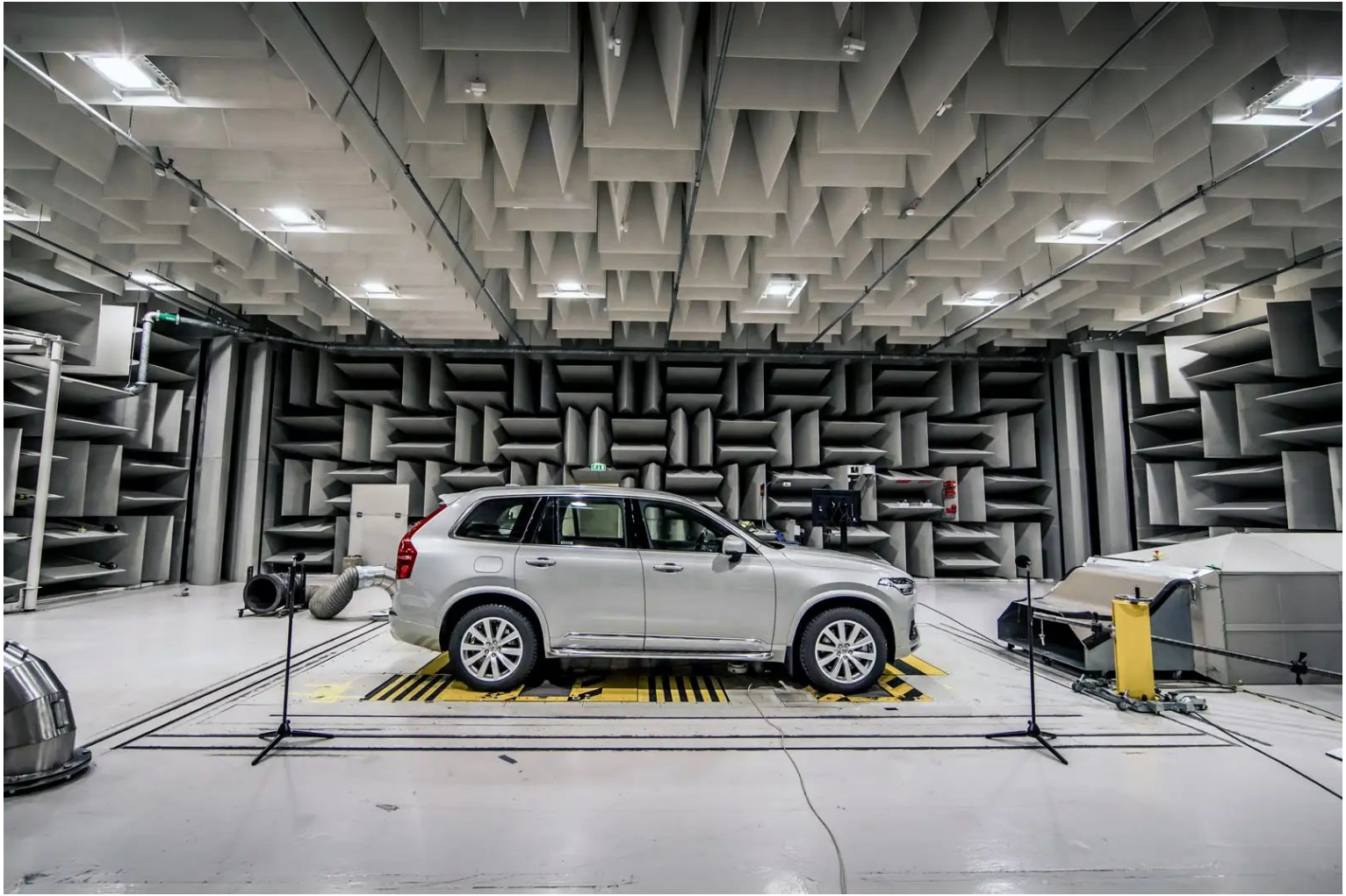
Sound

Can we have a setup which has ZERO wall, furniture reflections?

Anechoic Chamber: no echo and reflections



Institute of Sound and Vibration Research, Univ. Southampton, UK



Recording Sound

Recording Sound - microphones

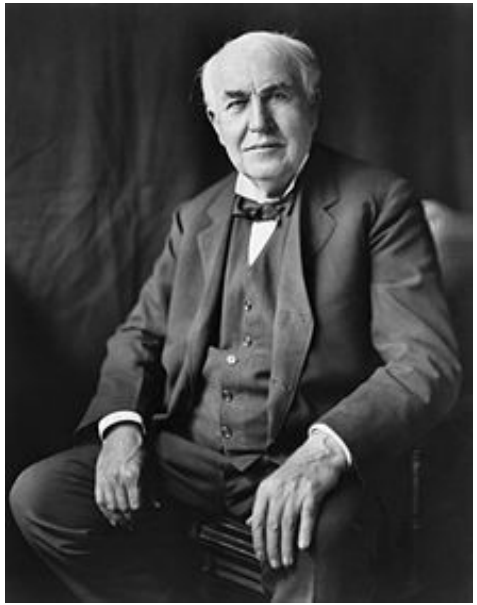
"In December, 1877, a young man came into the office of the *Scientific American*, and placed before the editors a small, simple machine about which very few preliminary remarks were offered.

The visitor without any ceremony whatever turned the crank, and to the astonishment of all present the machine said: *'Good morning. How do you do? How do you like the phonograph?'*

The machine thus spoke for itself, and made known the fact that it was the phonograph…" Scientific American Magazine

Recording Sound - microphones

"In December, 1877, a young man, Thomas Edison …



Recording Sound - microphones

"I was never so taken aback in my life--I was always afraid of things that worked the first time."

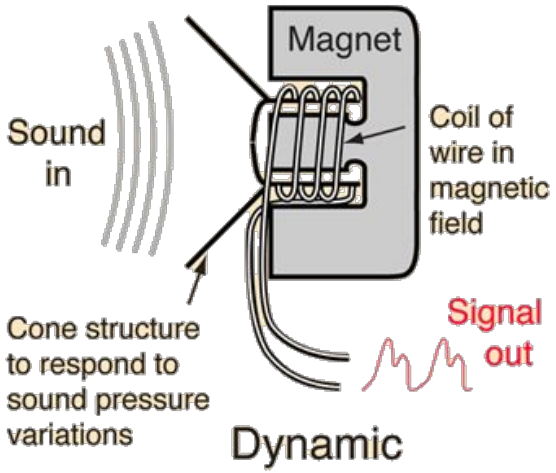
- Thomas A. Edison on hearing his voice play back to him from his first tin foil phonograph (1877)

Recording Sound - microphones

- Dynamic Microphones
  - Moving-Coil Dynamic Microphones

Sound waves cause the diaphragm to vibrate, and this vibration, in turn, sets the attached coil of wire in motion within the magnetic field.

Movement generates a voltage, effectively mirroring the variations in sound pressure, thus classifying it as a pressure microphone.



http://hyperphysics.phy-astr.gsu.edu/hbase/Audio/mic.html

Recording Sound - microphones

- Dynamic Microphones
  - Moving-Coil Dynamic Microphones
  - Ribbon Dynamic Microphones
- Condenser Microphones (Capacitor Microphones)
  - Electret Condenser Microphones
  - True Condenser Microphones
- Carbon Microphones
- Piezoelectric Microphones
- Fiber-Optic Microphones
- MEMS (Micro-Electro-Mechanical Systems) Microphones
- Laser Microphones

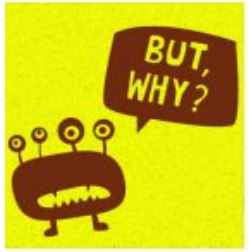
Recording Sound - microphones

- Dynamic Microphones
  - Moving-Coil Dynamic Microphones
  - Ribbon Dynamic Microphones
- Condenser Microphones (Capacitor Microphones)
  - Electret Condenser Microphones (in computer/cellphone)
  - True Condenser Microphones
- Carbon Microphones
- Piezoelectric Microphones
- Fiber-Optic Microphones
- MEMS (Micro-Electro-Mechanical Systems) Microphones
- Laser Microphones

Check this out!

How do we hear sound

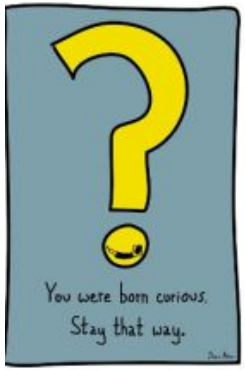
- Insects
- Animals
  - Vertebrates
    - Humans
    - Other animals



😱

generation is “easy”

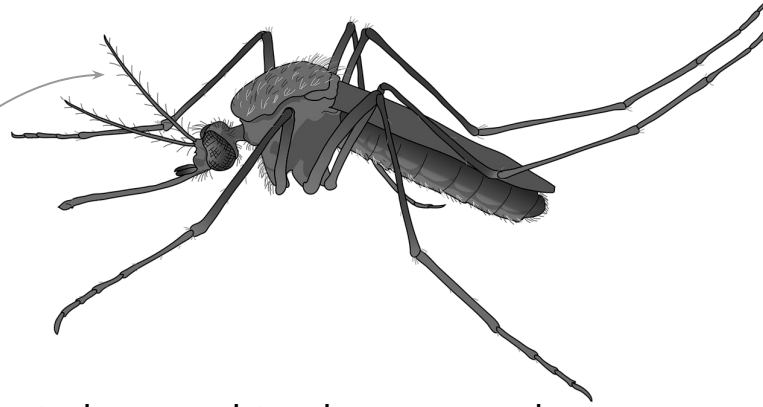
“bio-acoustic sound space”



“even within species interference”

staring simple

Mosquitoes hearing mechanism



Organ

Johnston's organ or the antennal ear. This organ is located in the second segment of their antennae.

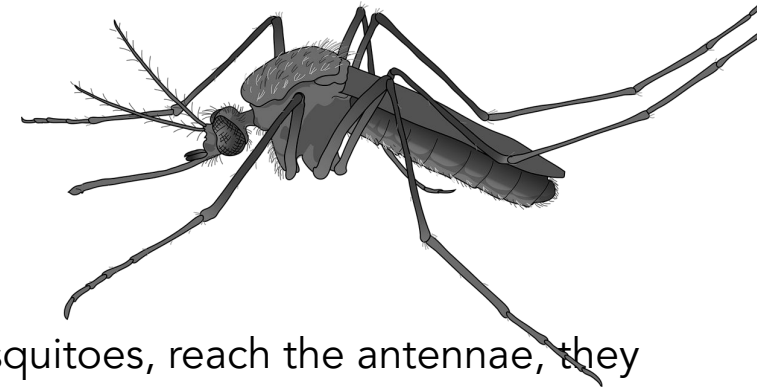
Sensitivity to Sound

Mosquitoes are highly sensitive to sound vibrations (300-3000 Hz, narrowband and tone-like in this range).

This sensitivity allows them to detect the wingbeat frequencies of other mosquitoes, which is important for mate selection.

staring simple

Mosquitoes hearing mechanism



Sound Detection

When sound waves, such as the wingbeats of other mosquitoes, reach the antennae, they cause the antennal segments to vibrate.

Neural Signaling

These vibrations are then transmitted to the sensory neurons within the Johnston's organ. The sensory neurons convert the mechanical vibrations into electrical signals

Processing in the Brain

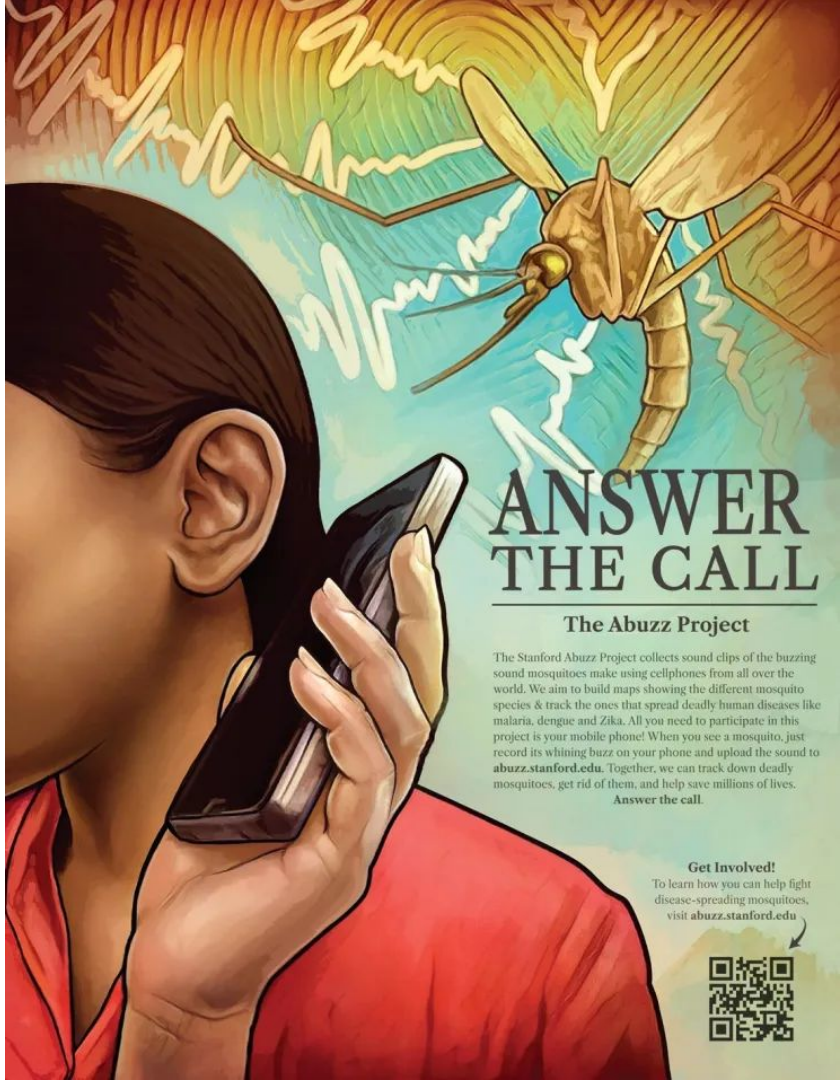
The electrical signals generated by the Johnston's organ are transmitted to the mosquito's brain for processing. This allows the mosquito to perceive and interpret the sounds it detects.

staring simple

Data analysis of mosquito sound signals

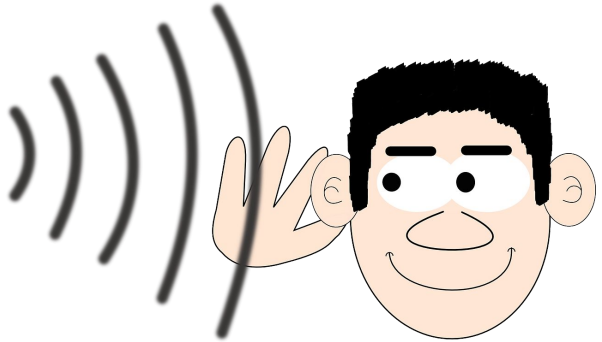
Check this out!

https://web.stanford.edu/group/prakash-lab/cgi-bin/mosquitofreq/the-science/figures-2/



Going further

Human hearing mechanism



Complex Ear Structure

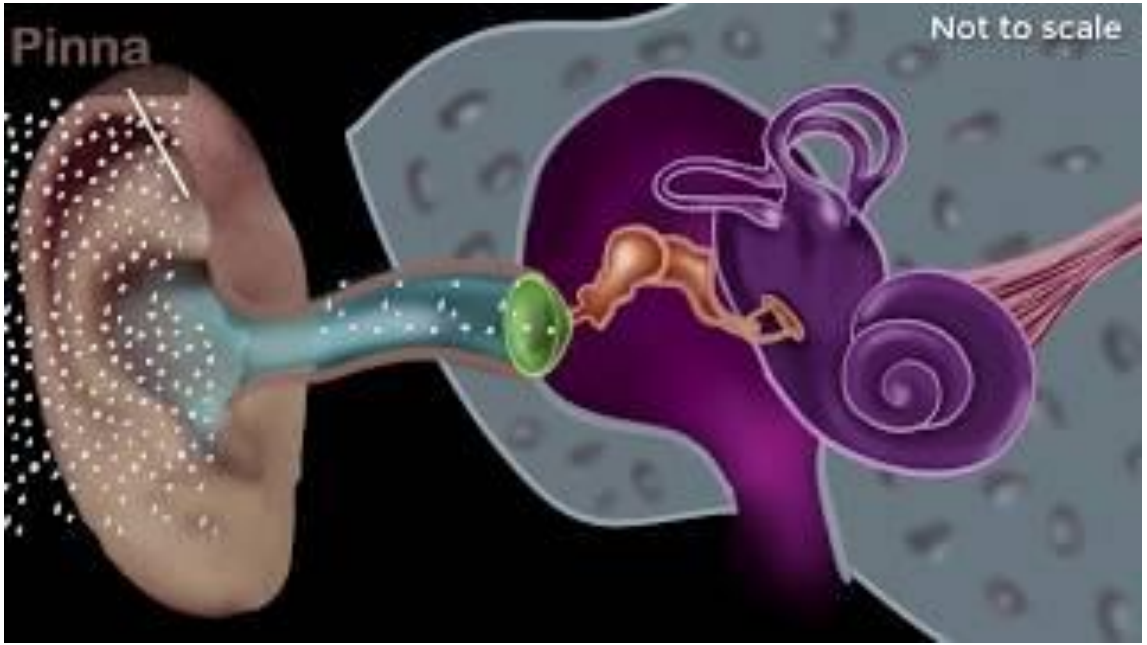
Humans have a highly complex ear structure, including the outer, middle, and inner ear, each with distinct functions. In contrast, mosquitoes primarily rely on a single auditory organ, the Johnston's organ in their antennae

Sound Amplification

The human middle ear contains three tiny bones (ossicles) that amplify sound vibrations, allowing us to hear a wide range of frequencies with precision. Mosquitoes lack such an amplification system.

Human hearing mechanism

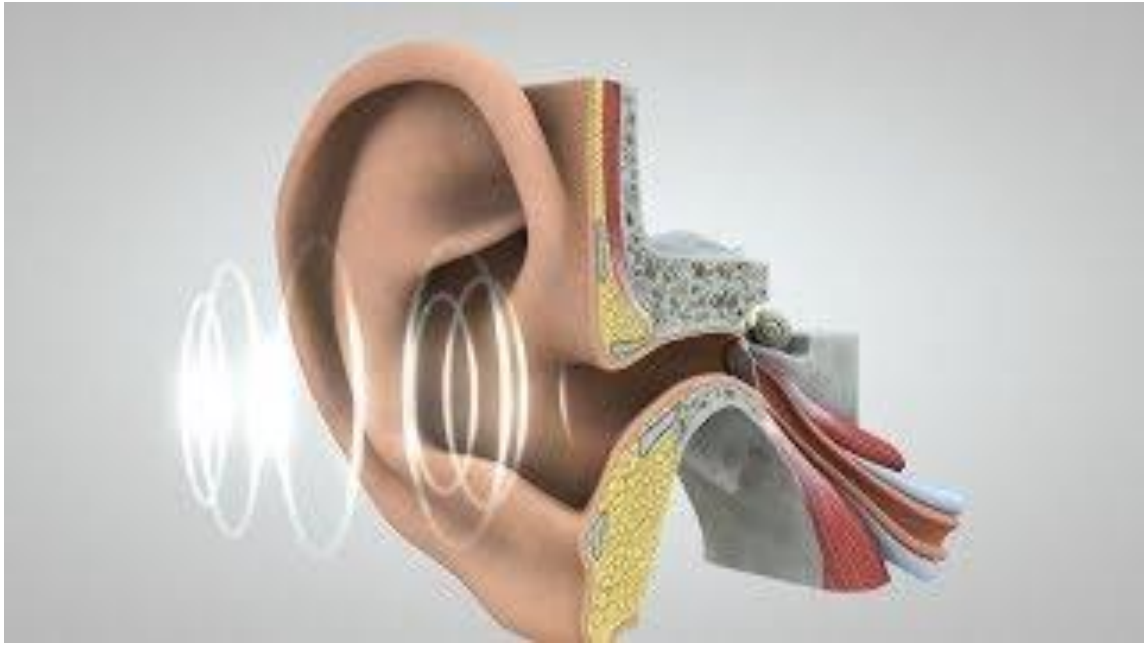
Check this out!



Video in Youtube: Human ear - structure & working | Sound | Physics | Khan Academy

Human hearing mechanism

Check this out!



Video in Youtube: Journey of Sound to the Brain National Institutes of Health (NIH)

Next class … further into audio analysis

Thank you!