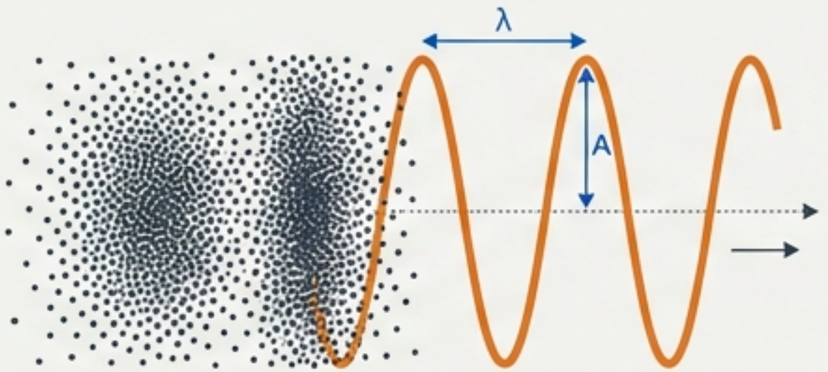
The Physics of Sound

From Vibration to Perception

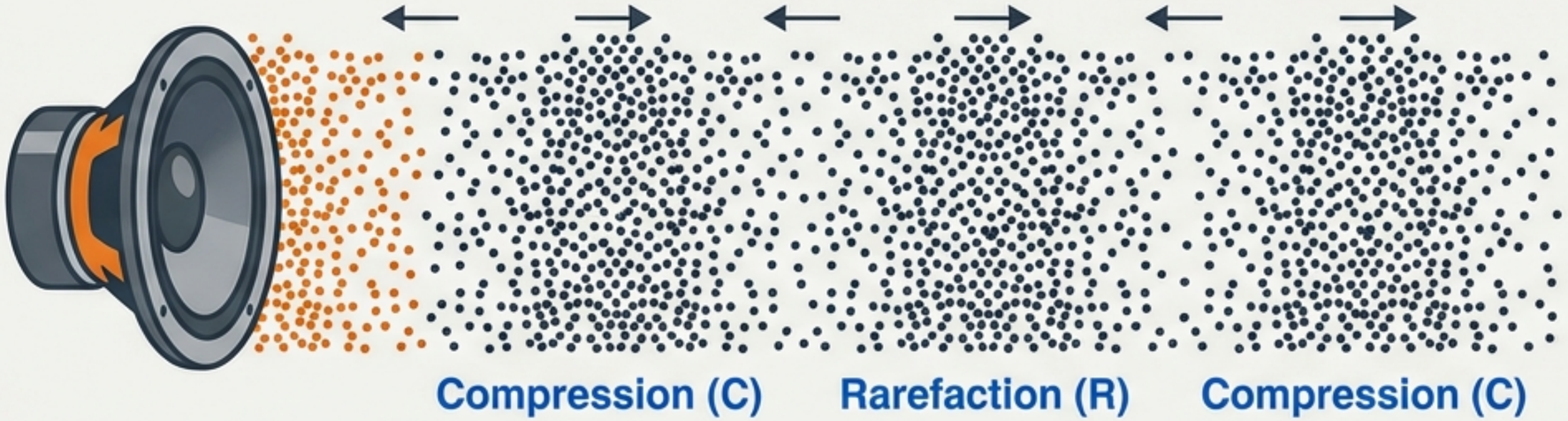
A visual exploration of wave theory, velocity, and application



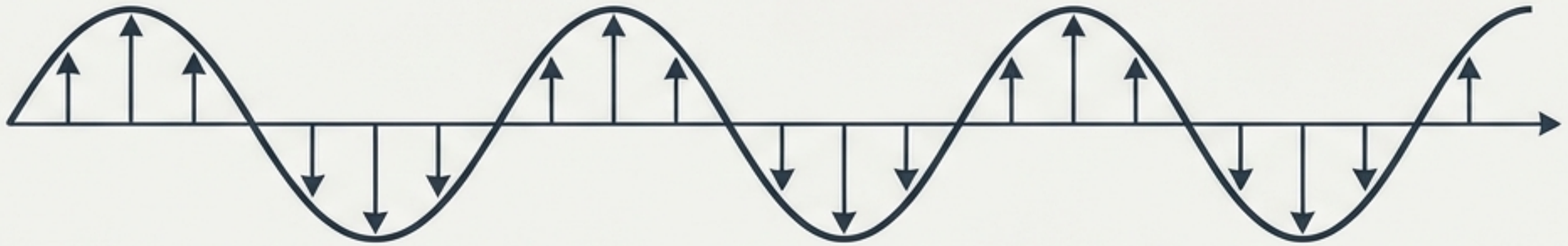
Presenter Name

The Nature of Sound

Longitudinal Wave



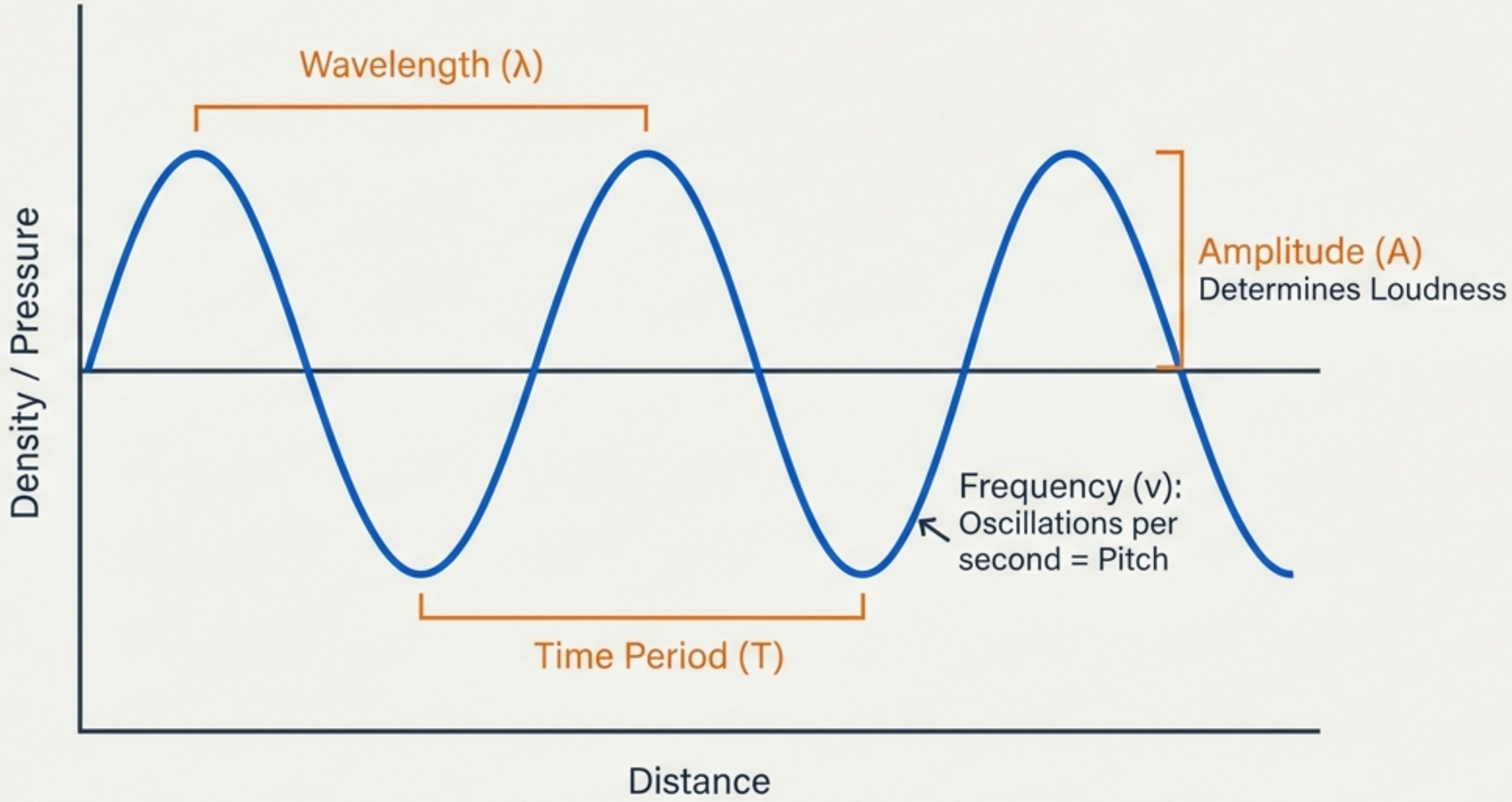
Transverse Wave



Sound is energy requiring a medium. Unlike light, it physically moves particles.

Longitudinal waves consist of Compressions (high pressure) and Rarefactions (low pressure).

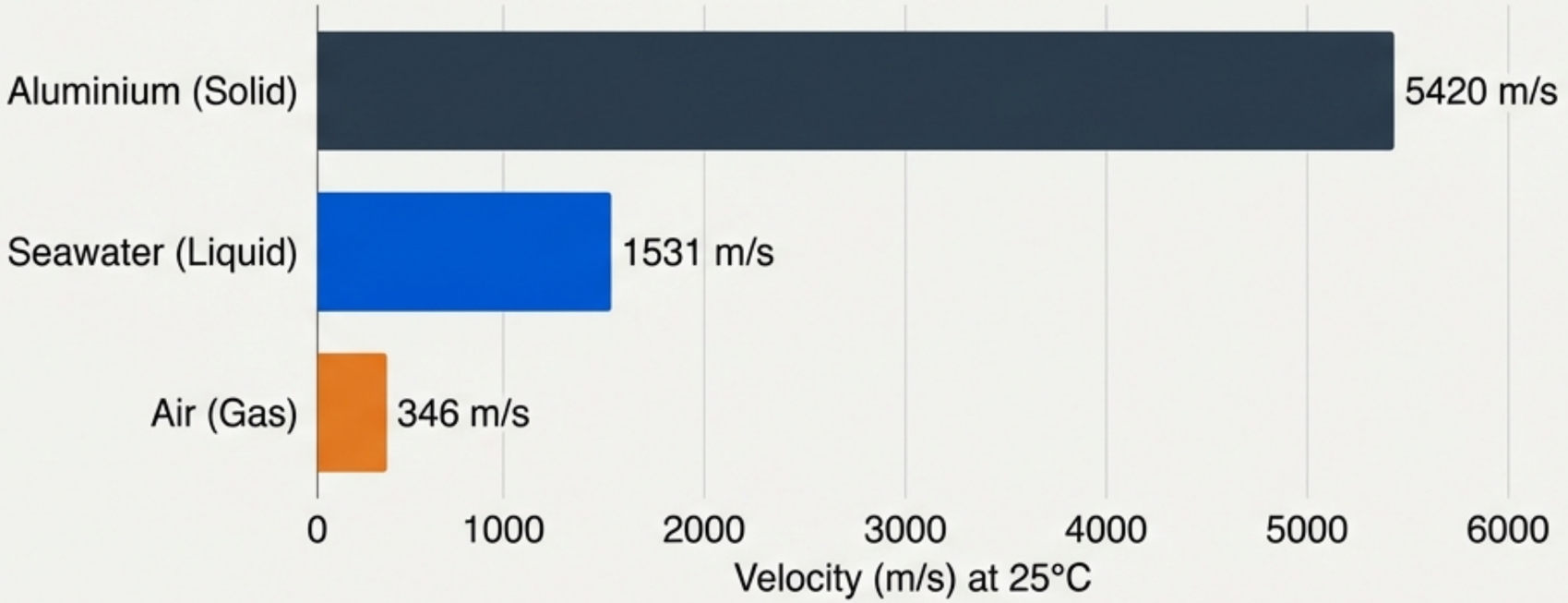
The Anatomy of a Wave Signature



The Velocity of Sound

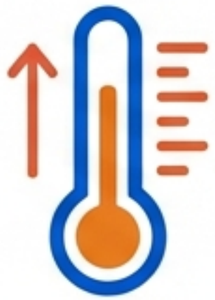
Velocity (v) = Wavelength (λ) × Frequency (v)

Speed of Sound in Different Media at 25°C



Sound travels fastest in solids and slowest in gases. You would hear a tap on an iron pipe through the metal long before hearing it through the air.

Factors Influencing Velocity in Gases

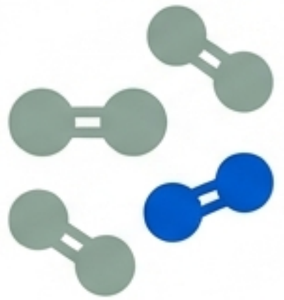


Temperature (T)

Directly proportional to $\sqrt{T}$. Increasing temperature 4x doubles the velocity.

Density (ρ)

Inversely proportional to $1/\sqrt{\rho}$. Increasing density 4x halves the velocity.



Molecular Weight (M)

Inversely proportional to $1/\sqrt{M}$. Sound travels 4x faster in Hydrogen (M=2) than Oxygen (M=32).

The Sonic Spectrum

Infrasound (< 20 Hz)

Pendulums, Earthquakes, Elephants

Audible Range

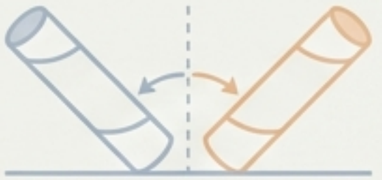
20 Hz — 20 kHz

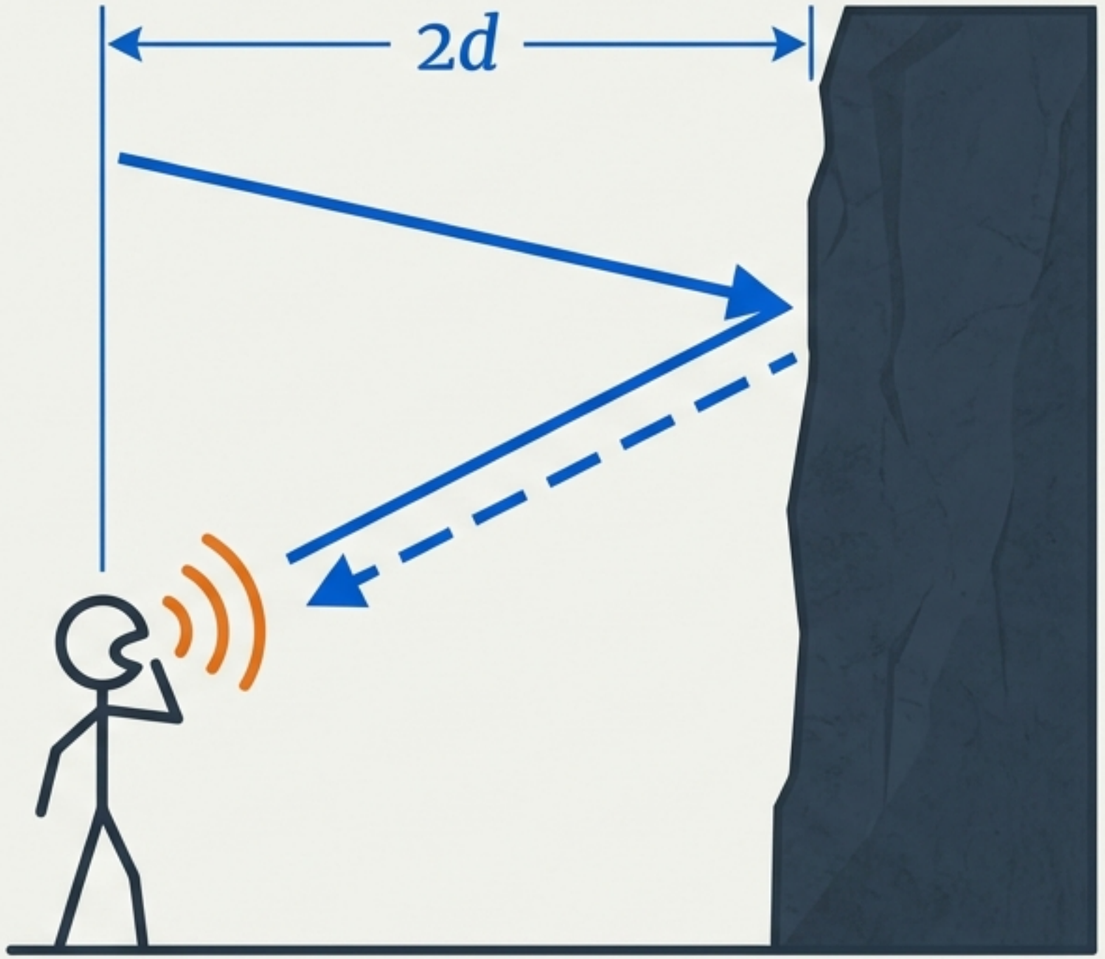
Ultrasound (> 20 kHz)

Bats, Dolphins, Medical Imaging

Children < 5 years and dogs can hear up to 25 kHz

Reflection and Echoes





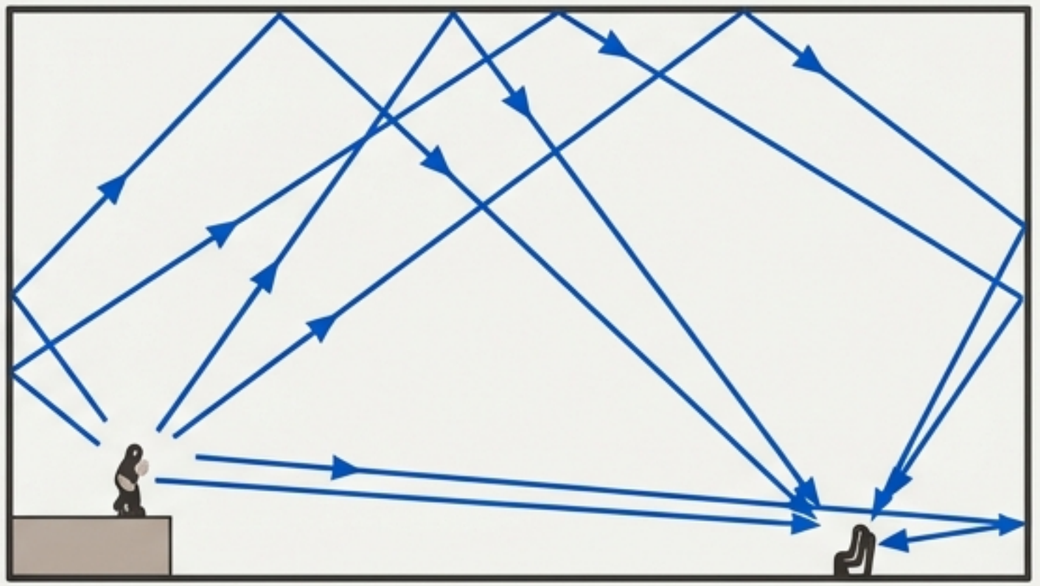
Helvetica Now Display Bold

Law of Reflection: Angle of Incidence = Angle of Reflection.

The Echo Threshold:

- Brain retains sound for: **0.1 seconds**.
- Speed of sound (22°C): **344 m/s**.
- Distance travelled in 0.1s: **34.4 metres**.
- Minimum distance for echo: **17.2 metres** (Half of 34.4).

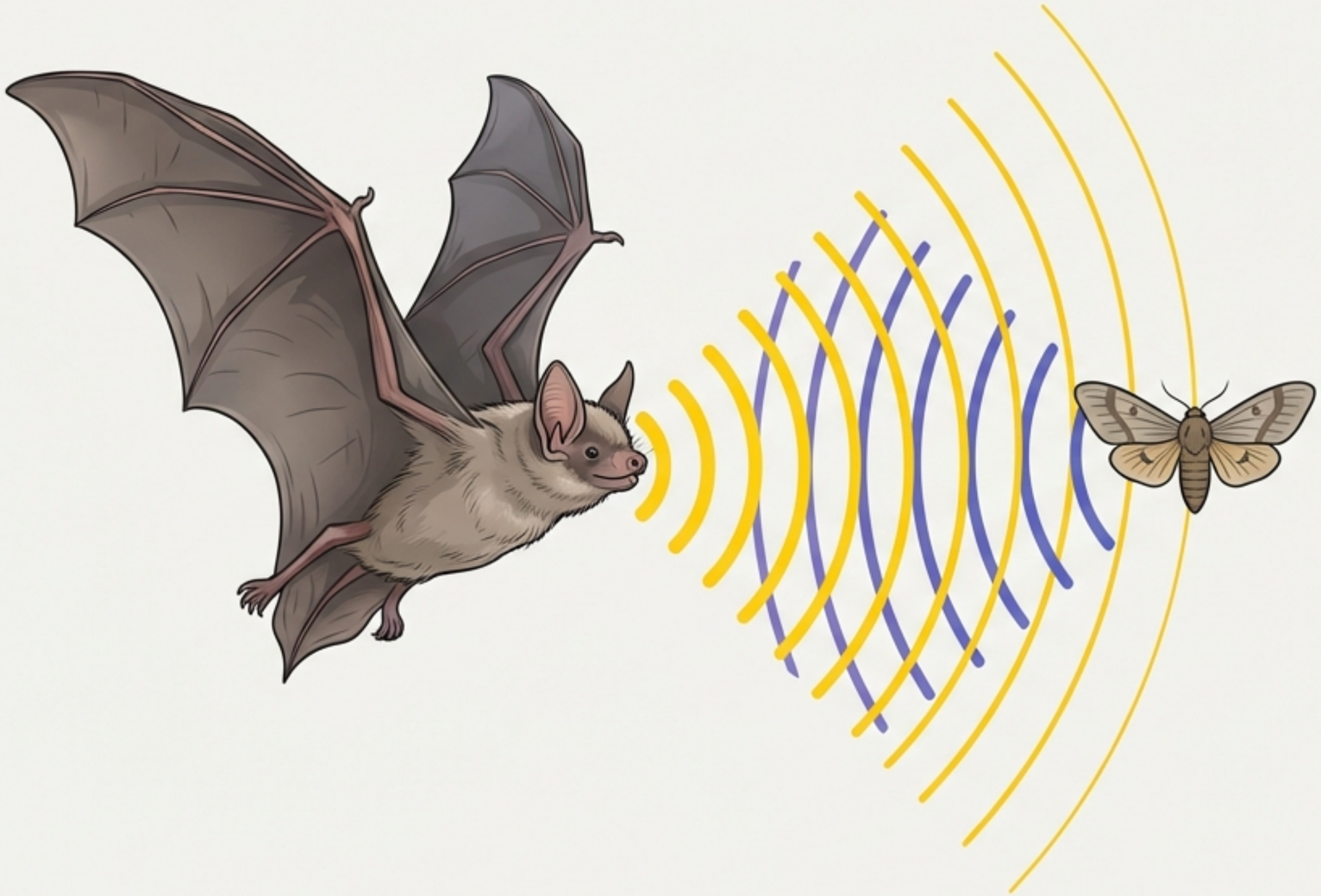
Reverberation: Architectural Acoustics



Reverberation is the persistence of sound due to multiple reflections. In auditoriums, this causes signals to overlap.

Solution:
Sound-absorbing materials (compressed fibreboard, curtains).

Nature’s Navigation: Echolocation



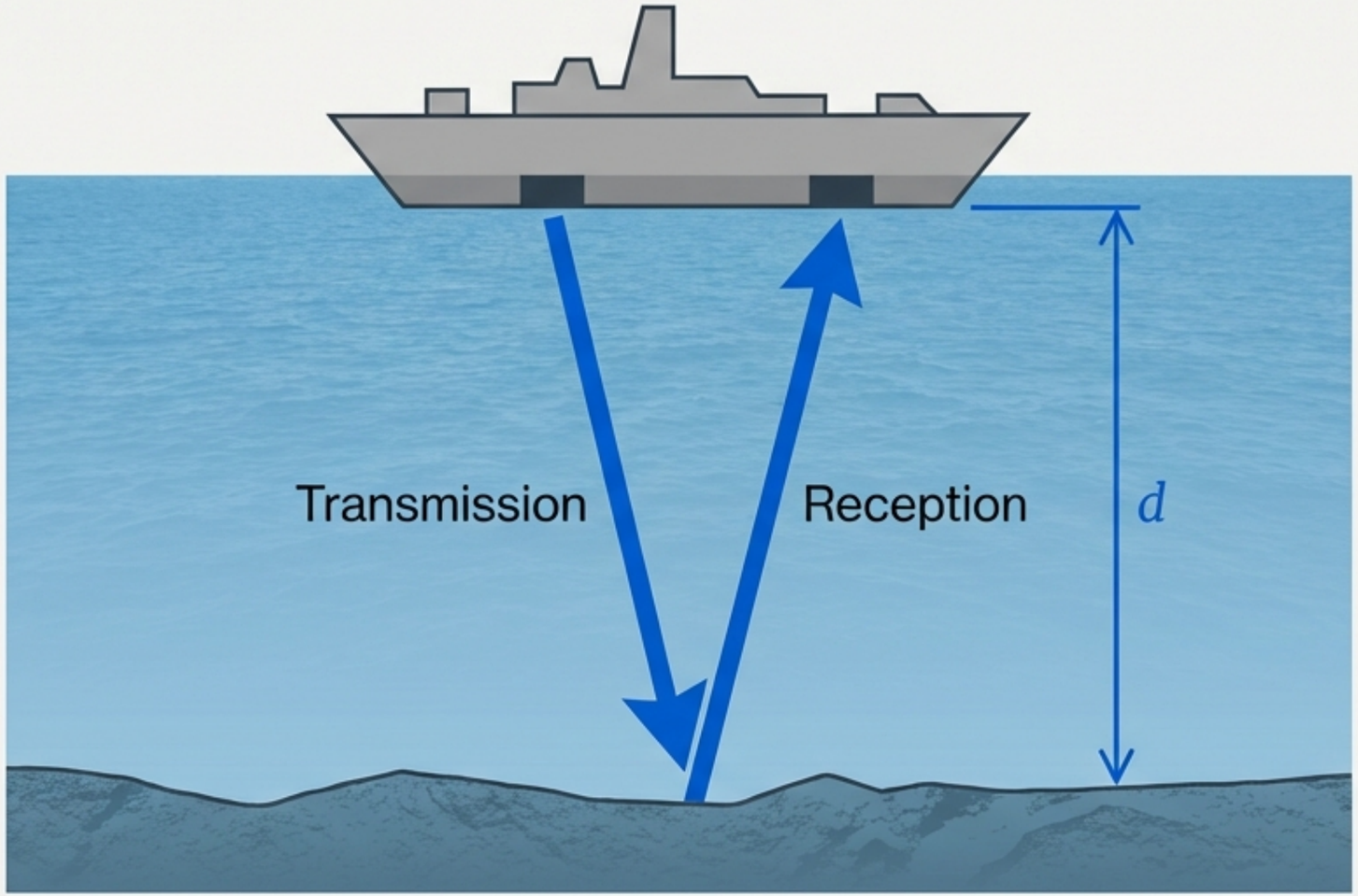
Echolocation: Determining distance and direction via reflected ultrasound.

Bats emit high-frequency sounds that bounce off objects. By analyzing the echoes, they build a sonic map of their surroundings.

Spallanzani’s Discovery:

Experiments revealed that bats navigate using their ears, not eyes. They emit **ultrasound** that **reflects** off obstacles.

SONAR: Sound Navigation and Ranging

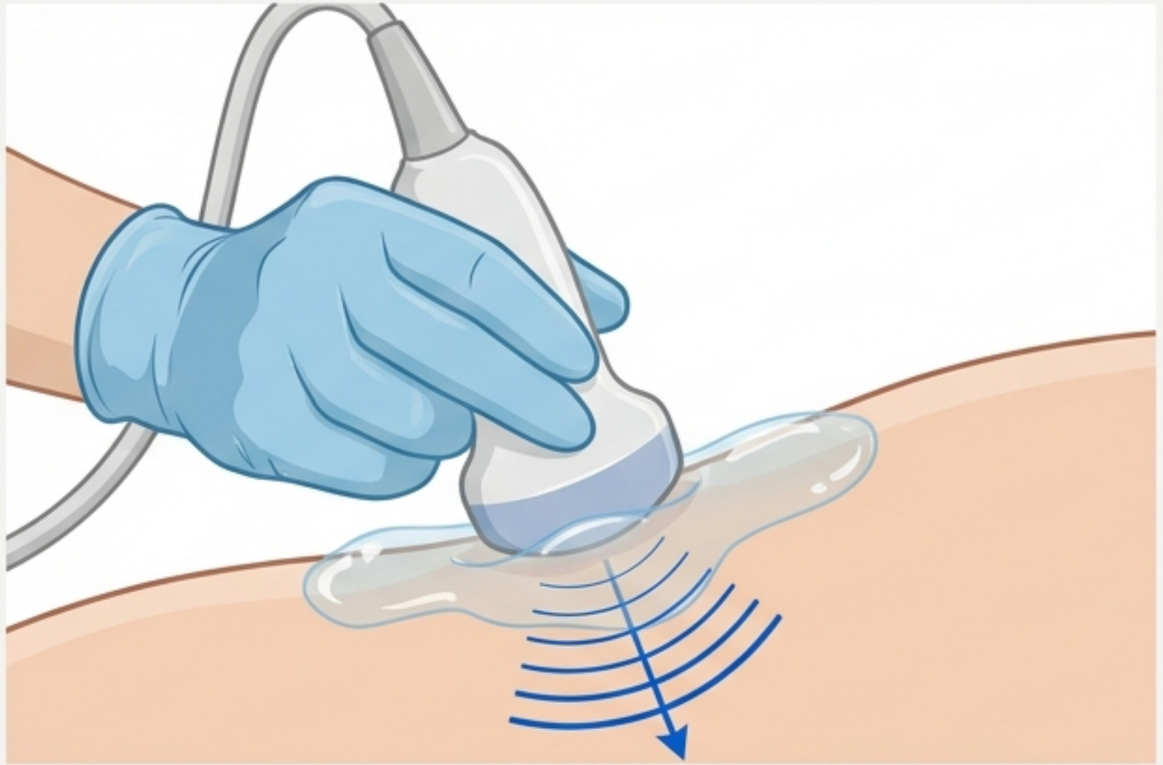


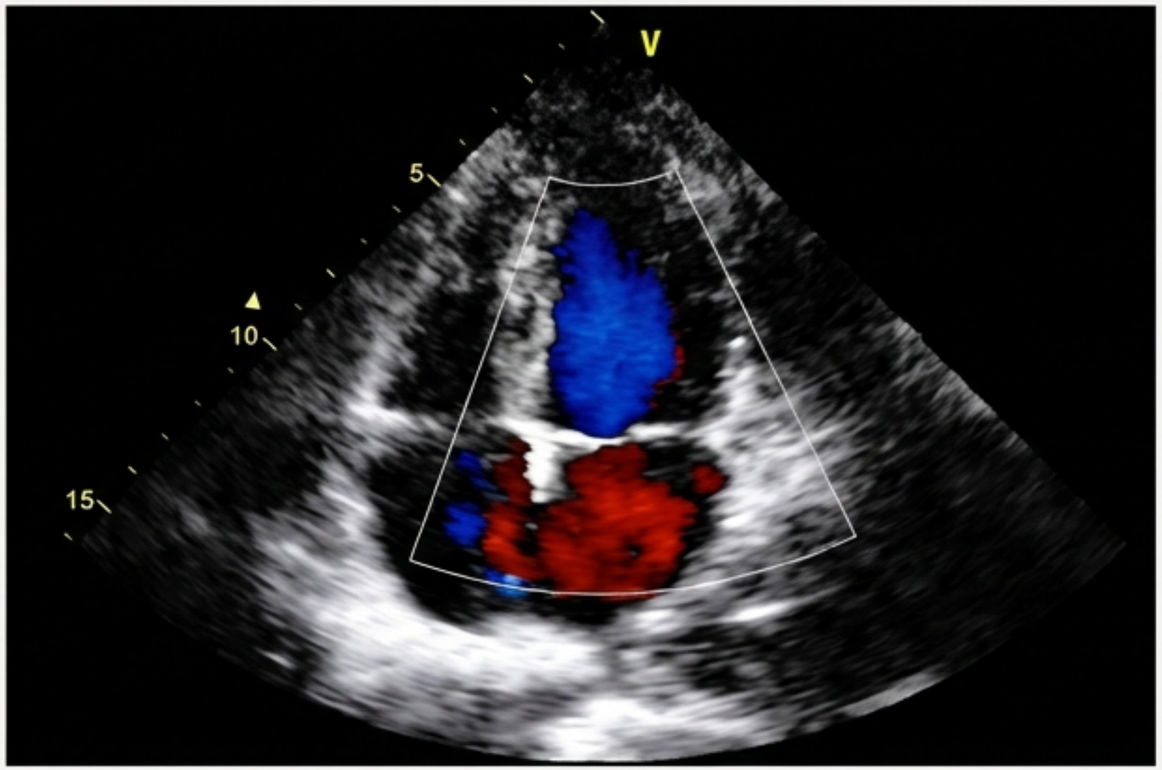
Transmitter sends ultrasound → Reflection off seabed → Receiver detects echo.

Formula: $2d = v \times t$

Applications:
Measuring sea depth, locating submarines and icebergs.

Medical Imaging: Sonography





High-frequency **ultrasound** reflects off internal organs to generate images. Gel is used to ensure acoustic contact.

Uses: Echocardiography, infection diagnosis, and foetal monitoring.

Technology & Ethics: A Dual-Edged Sword

The Benefit

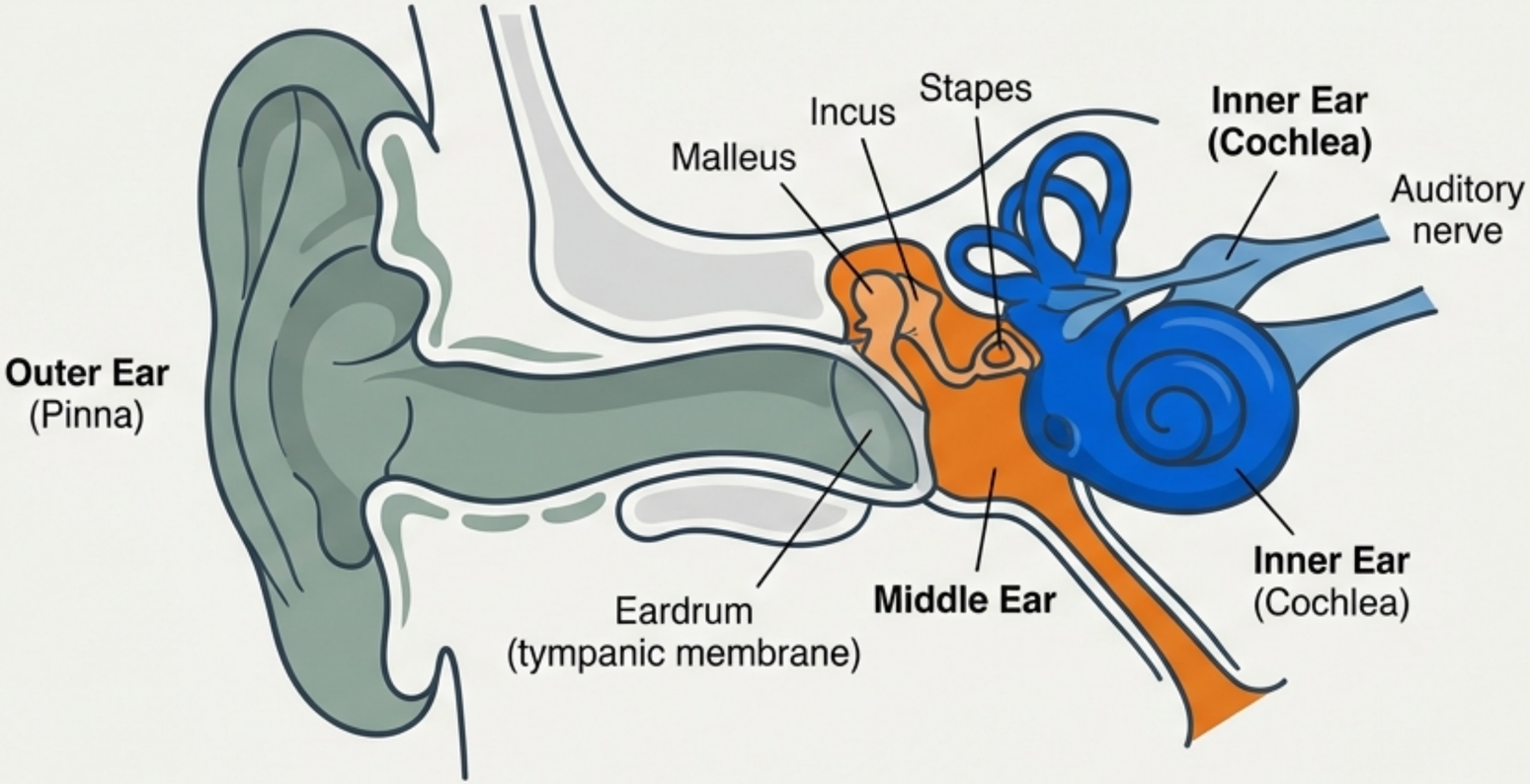
Essential monitoring of foetal health and development.

The Misuse

Illegal sex determination leading to female foeticide.

Under the PNDT Act, sex determination is a cognizable offence. Technology must be used responsibly.

The Biological Receiver: The Human Ear



Vibrations are collected by the **Pinna**, amplified by the **Middle Ear** bones, and converted to electrical signals in the **Cochlea** for the brain.

Summary & Key Formulas

Velocity

$$v = \nu\lambda$$

$v \propto \sqrt{T}$ (Temp) $v \propto \frac{1}{\sqrt{\rho}}$ (Density)

Audible Range

20 Hz — 20,000 Hz

Echoes

Minimum distance: 17.2 m (at 22°C)

SONAR

$$\text{Depth} = \frac{v \times t}{2}$$