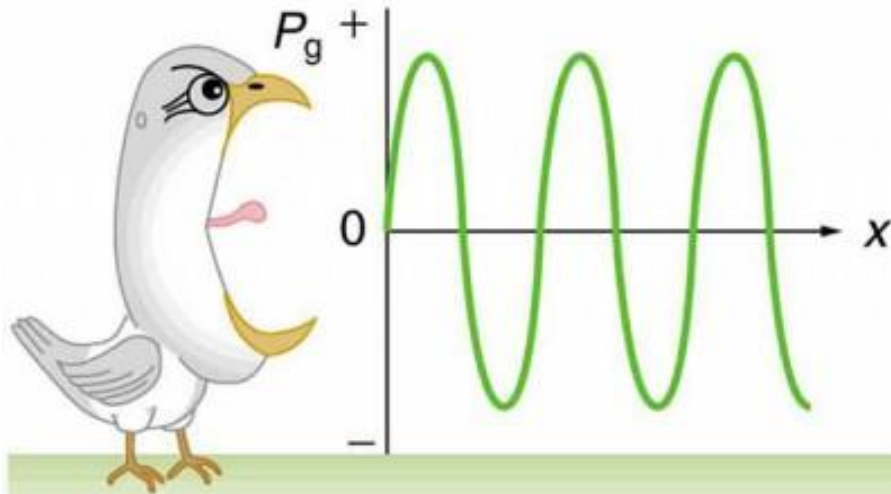
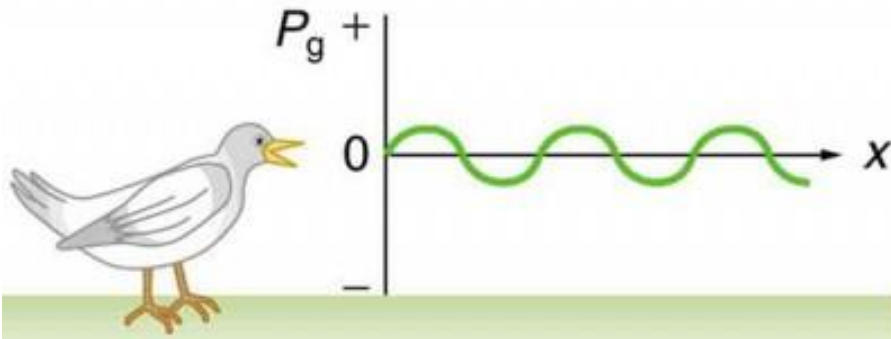


Sound waves: Intensity

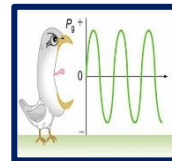
“How loud?”

Low **Amplitude** = Soft



High **Amplitude** = Loud

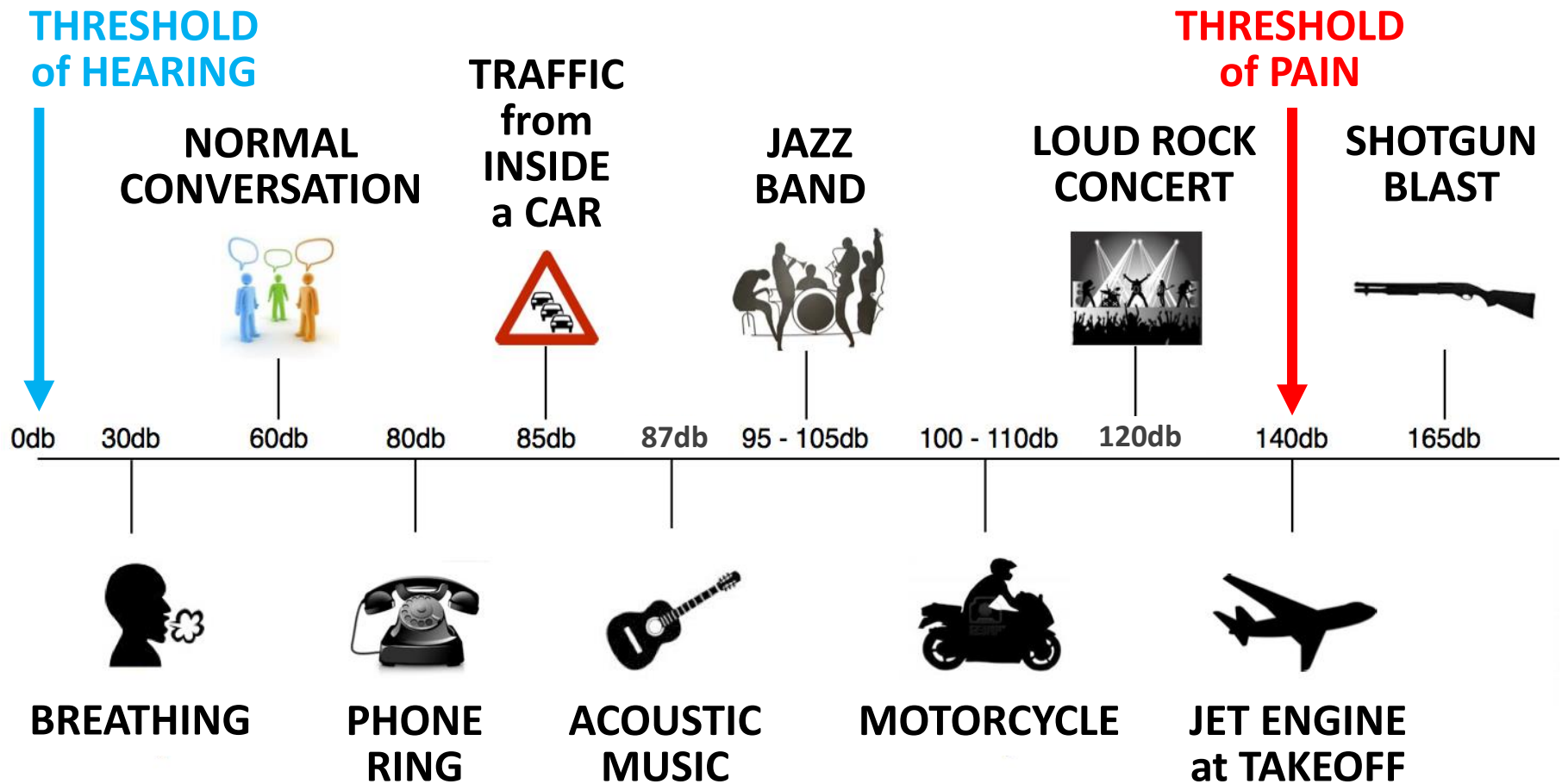
- Sound intensity is a measure of **the amount of energy** in sound waves.
- Intensity results from two factors:
 - ✓ the **amplitude** of the sound waves
 - ✓ and **how far they have traveled from the source of the sound**.



- The **unit** of intensity is the **decibel (dB)**.

Typical sound levels

The decibel scale is *non-linear*: for every 10-decibel *increase* in the intensity of sound, *energy is 10 times greater*.



1. Compare the *intensity* of sound you hear during a jazz band performance and a rock concert.

- Jazz band is about 100 dB
- Rock concert is about 120 dB

Sound level at a rock concert is 20 dB greater.

2. What is the corresponding difference in sound *energy*?

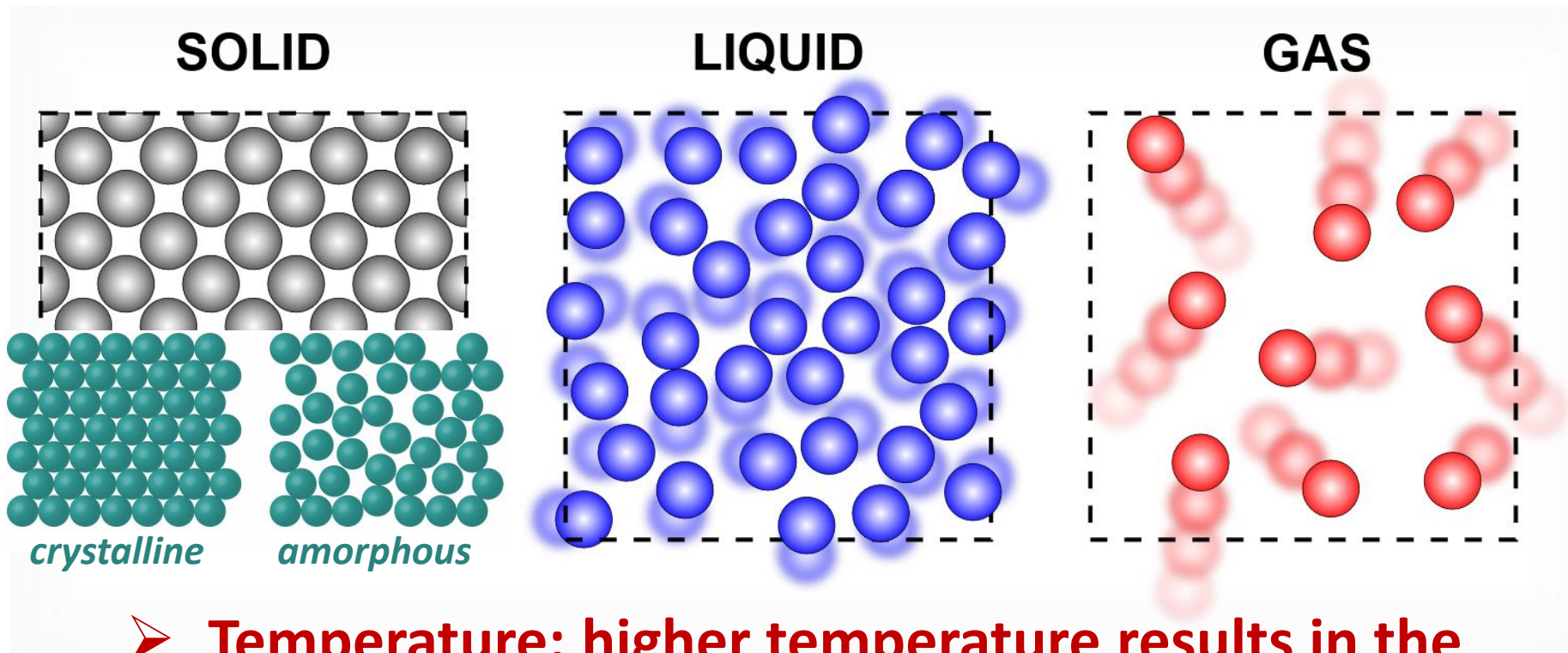
- for every 10-decibel *increase* in the intensity of sound, energy is 10 *times* greater
- 20-decibel increase means $10 \cdot 10$ times energy increase

Sound energy at a rock concert is 100 times greater.

How does sound travel?

Vibrations are passed between neighboring particles of a substance, so the following properties are important:

- Particle arrangement: different states of matter, particular structure (*crystalline or amorphous*)

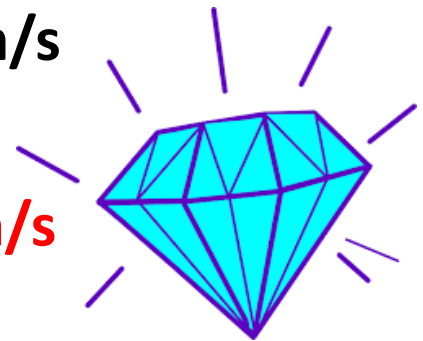


- Temperature: higher temperature results in the increased rate of interaction between particles

Speed of sound

varies from substance to substance

- sound travels **most slowly in gases**:
 - ✓ speed of sound **in air** at room temperature is **343 m/s**
- it travels **faster in liquids**:
 - ✓ speed of sound **in water** is about **1,400 m/s**
(about 4 times as fast as in air)
- and faster still in solids:
 - ✓ speed of sound in concrete is about 3,700 m/s
 - ✓ speed of sound in hardwood is about 4,000 m/s
 - ✓ speed of sound in iron is about 5,000 m/s
 - ✓ speed of sound **in diamond** is about **12,000 m/s**
(about **35 times as fast as in air** which is around the **maximum** speed of sound possible...)



The ultimate speed limit of sound

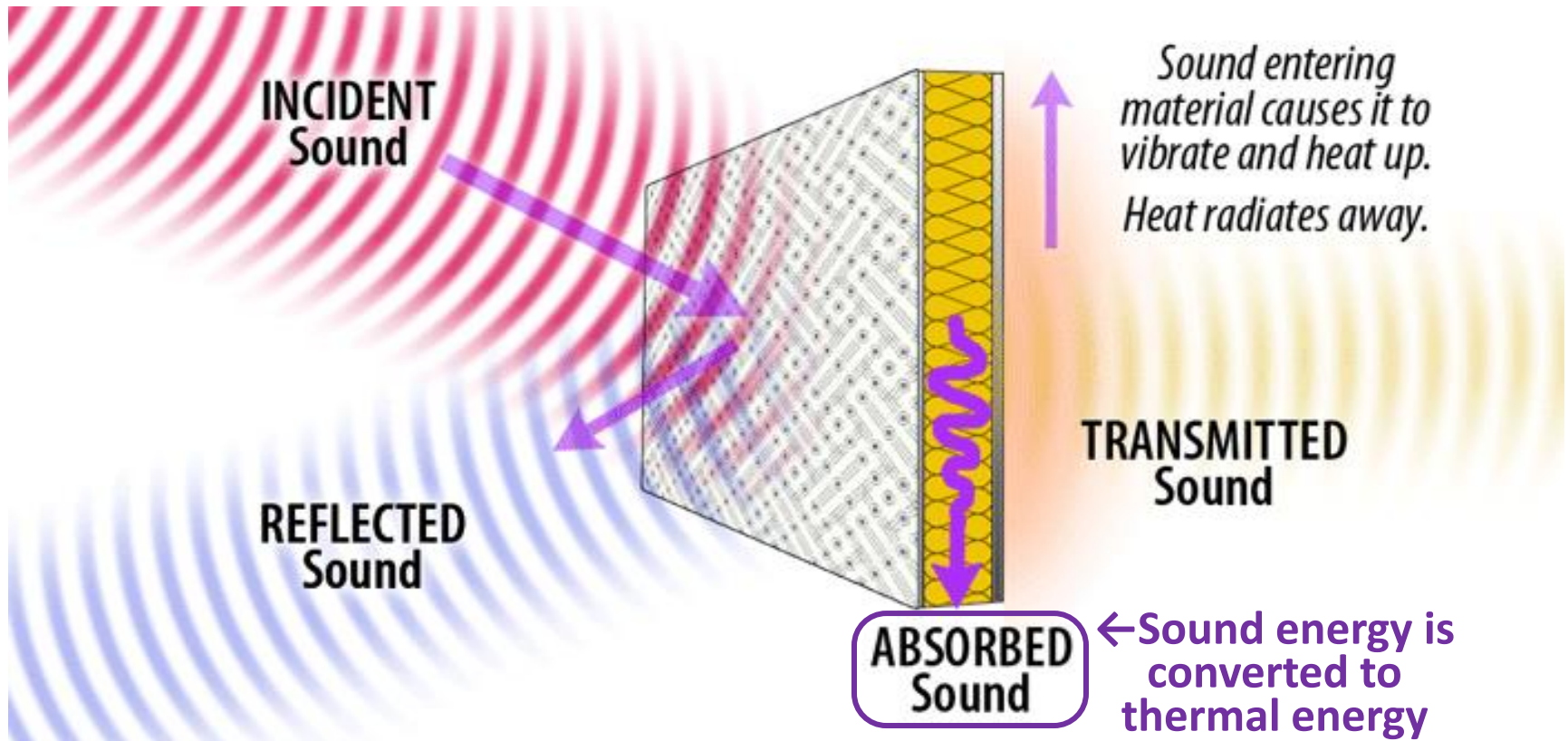
36
km/s

is determined by the maximum density of a material and how the atoms within it are bound together.

- Scientists have found that **the lighter the material - the faster the atomic motion**, which implies that the fastest sound can travel must occur in the lightest of all elements, **hydrogen**.
- In 2020, scientists predicted that **solid metallic hydrogen** – a material that *theoretically exists at the center of giant planets* like Jupiter – should have the **highest speed of sound, calculated to be ~36,000 m/s**.
- It's not possible to test this theoretical top speed in the real world!



Reflection, Transmission, Absorption



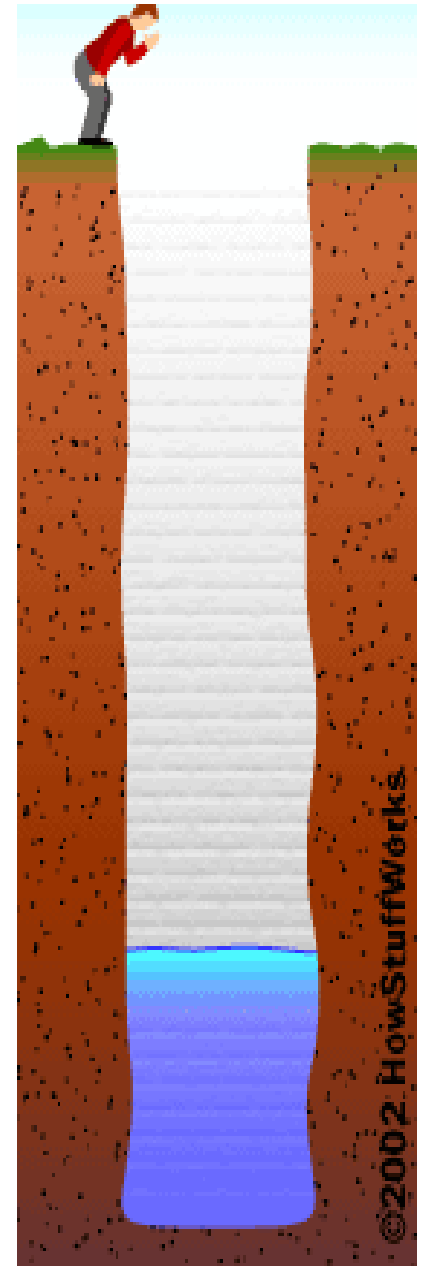
- Sound is **reflected best from hard and/or smooth surfaces** (like walls in a large hall, mountain cliffs, surface of water in a well).
- **Soft and/or rough surfaces tend to absorb most of the sound.**

What is Echo?



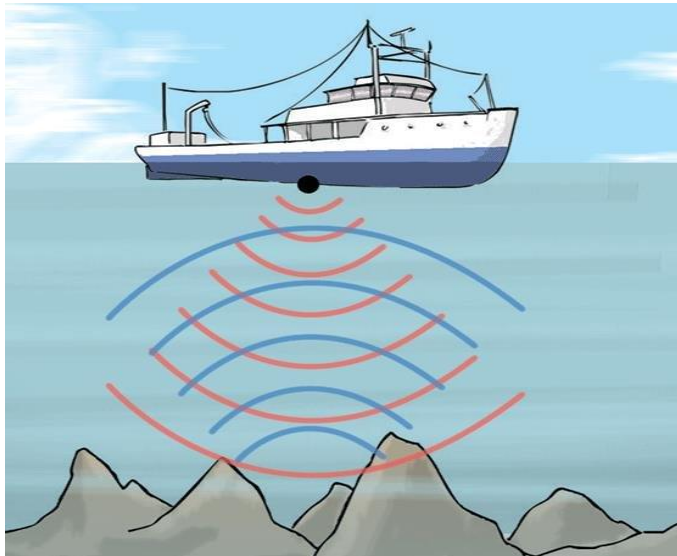
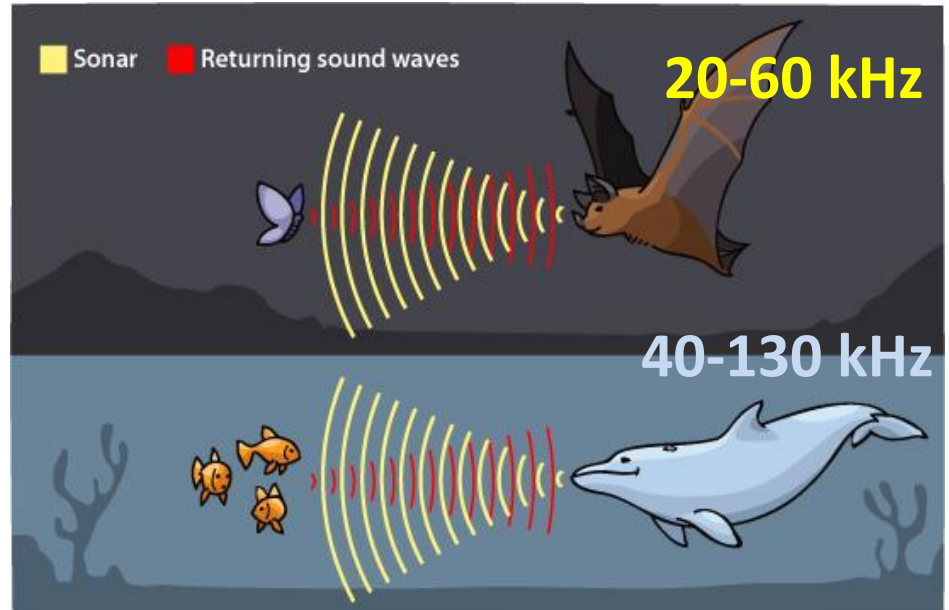
An echo is a reflected sound wave.

- For a human to hear the echo clearly, the delay in time between the original sound and reflected one must be at least 0.1 seconds (our ears can detect two separate sounds if they are at least this much apart).
- The **repeated reflection** (multiple overlapping echoes) of sound in closed quarters perceived as *persistence* of sound is called **reverberation**.



Echolocation and SONAR

- Echolocation: animals such as bats and dolphins send out **ultrasound** waves and use their echoes to identify the locations of objects they cannot see. Animals use echolocation to find prey and avoid running into objects in the dark.



- SONAR (**s**ound **n**avigation **r**anging) is a technique that uses sound to navigate, communicate with or detect objects on or under the surface of the water. Sonars use a wide range of frequencies from **infrasonic** (provides longer range) to **ultrasonic above a megahertz** (provides high detail).