We have to put energy in by doing work. The wave motion transports energy, not matter. This allows them to sense objects roughly as small as the wavelength.

Audible range is about 20 to 20,000 Hz. Dolphins emit high frequency sound waves at ~100,000 Hz for guidance and hunting. The speed of sound in water is ~1500 m/s, so the wavelength is:

\[ \lambda = \frac{v}{f} = \frac{1500 \text{ m/s}}{100,000 \text{ Hz}} = 0.015 \text{ m} = 1.5 \text{ cm} \]

This allows them to sense objects roughly as small as the wavelength. Ultrasound imaging uses high frequency (short wavelength) sound to generate ‘echoes’ from internal organs to create an image.

With an ultrasound frequency of 5 MHz, the wavelength in water (the main constituent of the body) is ~0.3 mm and feature as small as this can be seen in the images.
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- Unlike musical tones, noise is a combination of all frequencies, not just harmonics of a fundamental.

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### Sound intensity - Loudness

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### Perception of Sound

- For a given frequency, the greater the pressure amplitude, the greater the loudness - the ear is not equally sensitive to all frequencies.
- High frequency sensitivity decreases with age and exposure.
- Pitch (high or low) is primarily determined by frequency, although amplitude also has a small affect (louder sounds are usually perceived as slightly lower pitch).

### Harmonic content

- Musical sounds are more complex than a simple wave. The pressure fluctuations illustrated below are complex because the column of air in the wind instruments vibrates at a fundamental frequency and many harmonics (multiples of the fundamental frequency) at once.

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