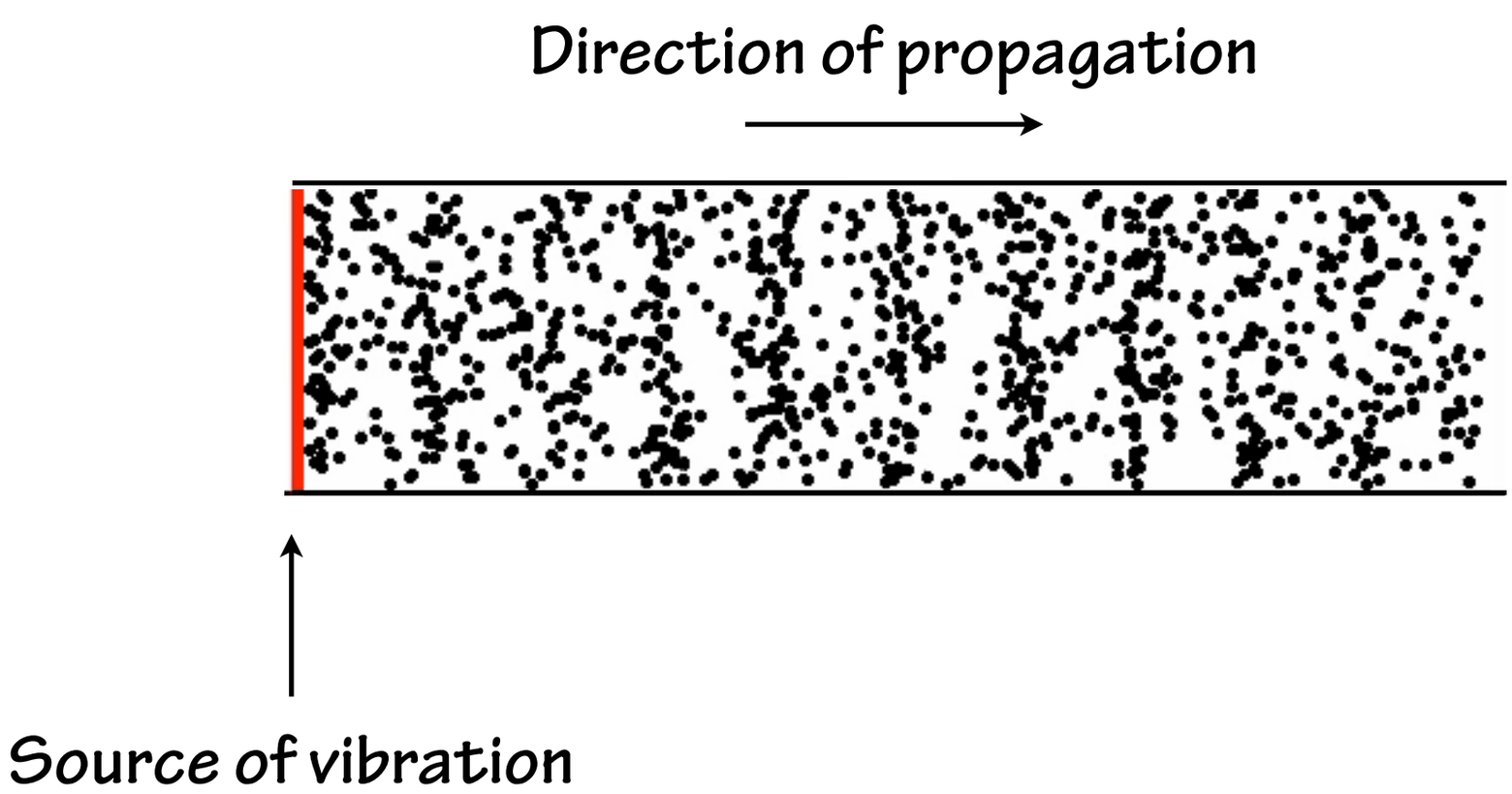
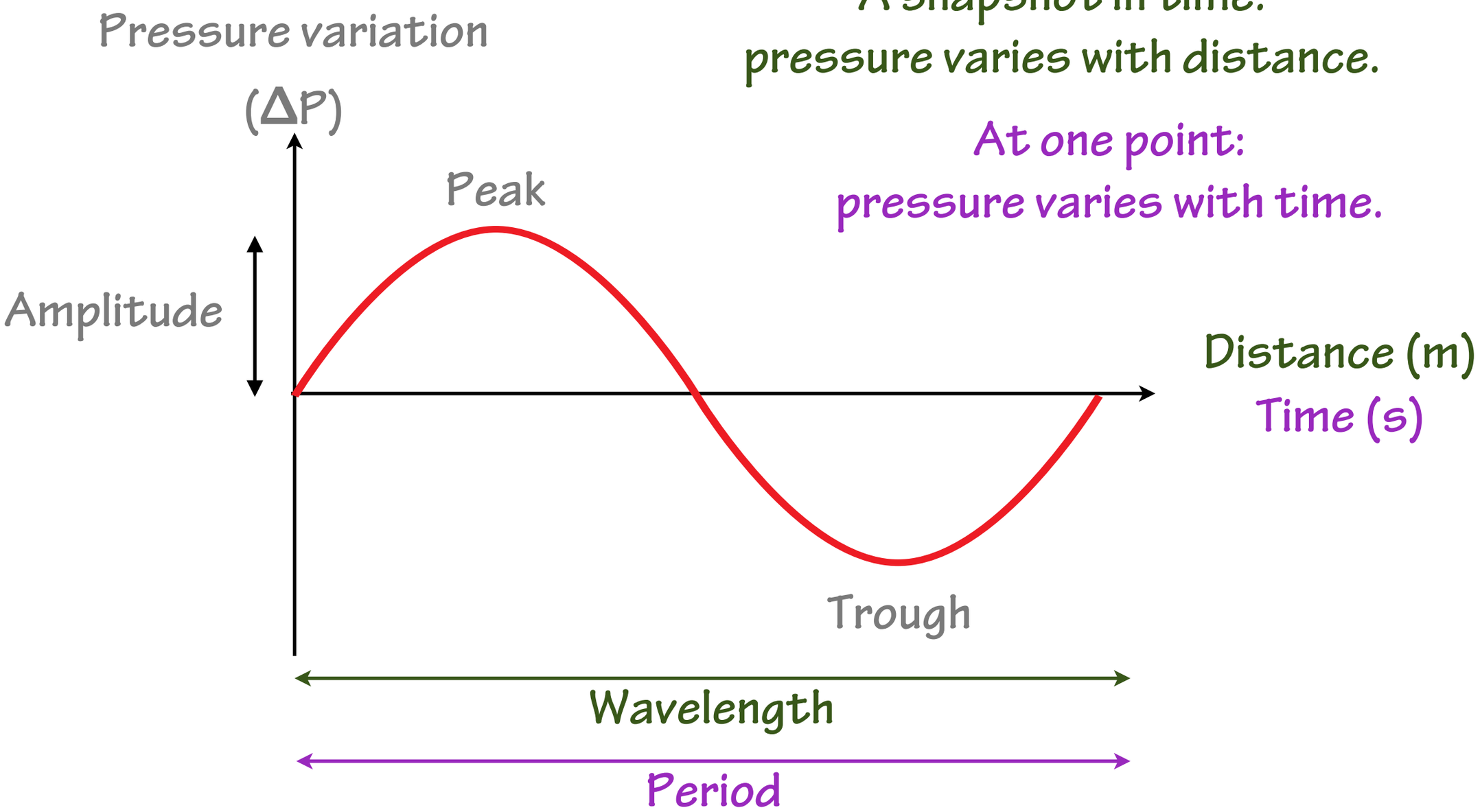
Sound waves

Sound waves

- Sound waves are variations in pressure (above & below the background).
- A series of **compressions** and **rarefactions**.
- Particles are moving forward & back (~1mm), but the wave as a whole moves forward at the speed of sound (340 m/s in air).
- This is known as a **longitudinal** wave.



Sound waves



A snapshot in time:
pressure varies with distance.

At one point:
pressure varies with time.

Distance (m)
Time (s)

Standing longitudinal waves

Wave equations

$$v = f\lambda$$

v = speed of sound (m/s)
(dependent on material)

f = frequency (Hz)

λ = wavelength (m)

$$f = \frac{1}{T}$$

T ← period (s)

$$v = \frac{\lambda}{T}$$

Wave equations

- Human ears can hear from ~20 Hz to 20kHz.
- What is the range of wavelengths?

$$v = f\lambda \longrightarrow \lambda = \frac{v}{f}$$

$$\lambda = \frac{340m/s}{20Hz} = 17m$$

$$\lambda = \frac{340m/s}{20{,}000Hz} = 0.017m\ (17mm)$$

Speed of sound

- The speed of sound is a property of the material: it depends upon the elasticity and density of the material
- c ≈ 340m/s in air at room temp
- c ≈1400m/s in water
- c ≈ 5000m/s in steel

More dense, but much more resistant to compression: waves travel faster.

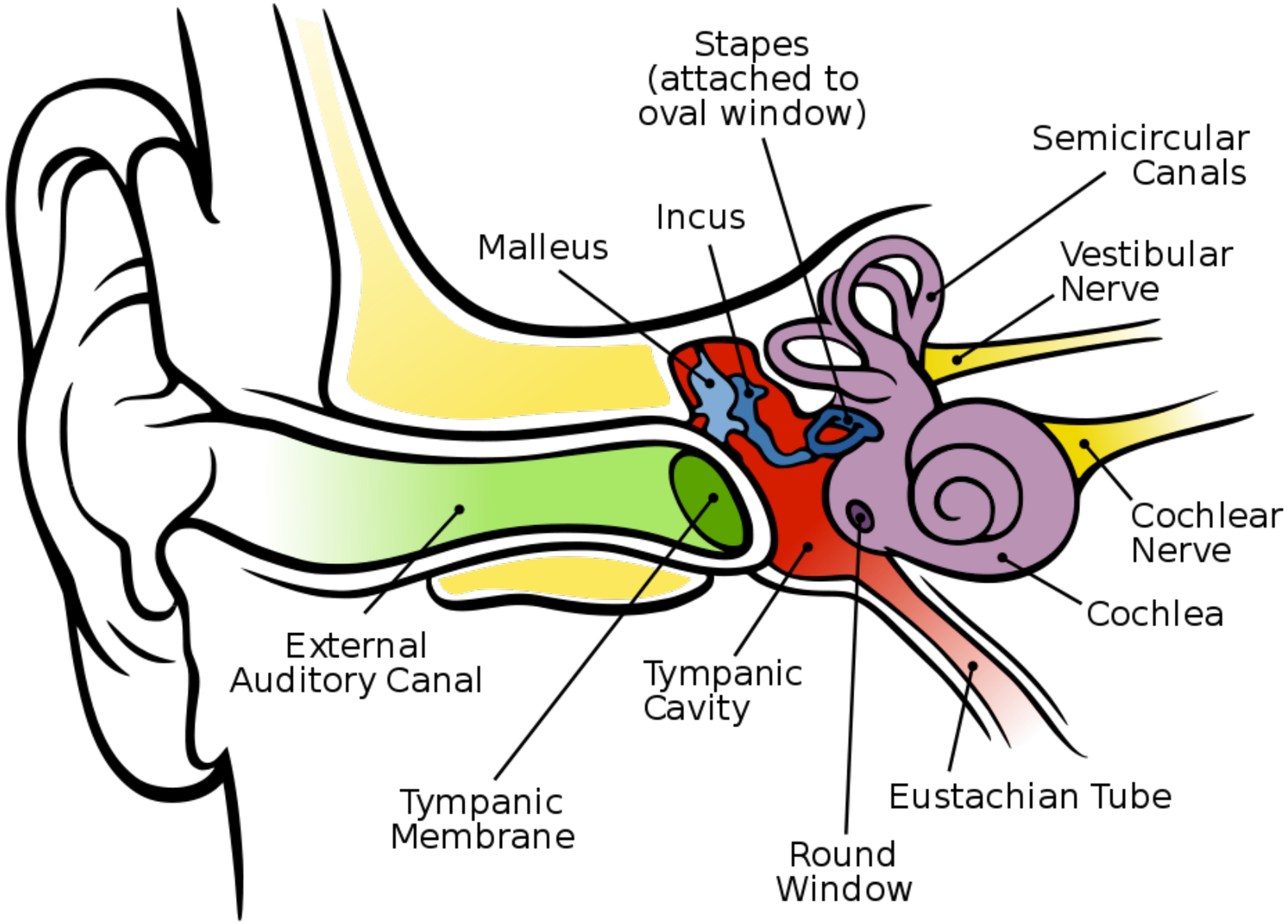
$$v = \sqrt{\frac{C}{\rho}}$$

Co-efficient of stiffness (solids) or modulus of elasticity (gases)

Density (mass / volume)

The human ear

- The ear changes sound pressure waves from the outside world into nerve impulses sent to the brain.
- The sound is amplified through the middle portion of the ear and passed from of air into a liquid.
- The hollow channels of the inner ear are filled with liquid, and contain microscopic "hairs" that project out into the fluid. The hair cells are receptors that release a chemical signal when stimulated.

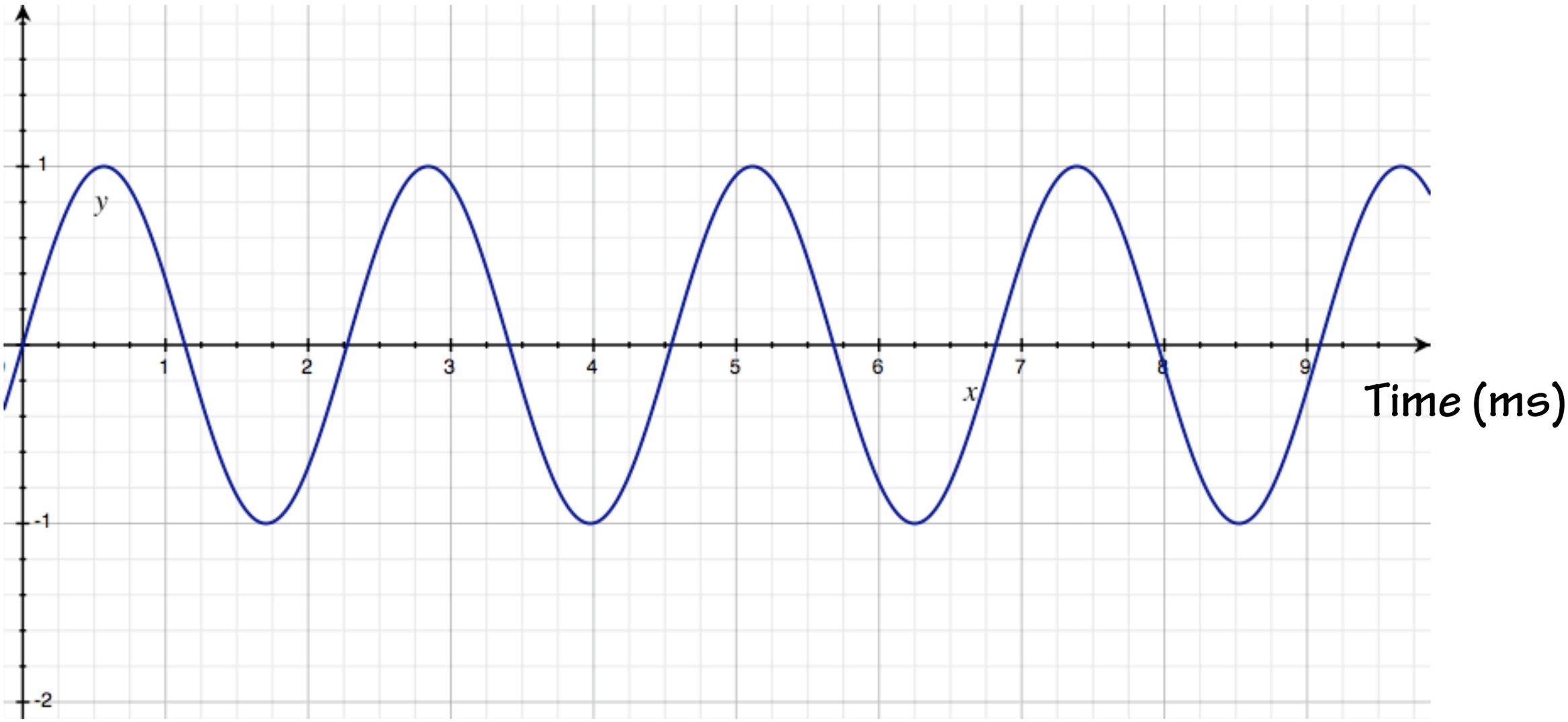


Wikipedia: Ear

Sounds are waves

- A 440 Hz pure tone is often used as a reference.
- This wave has a period of 2.27 ms.

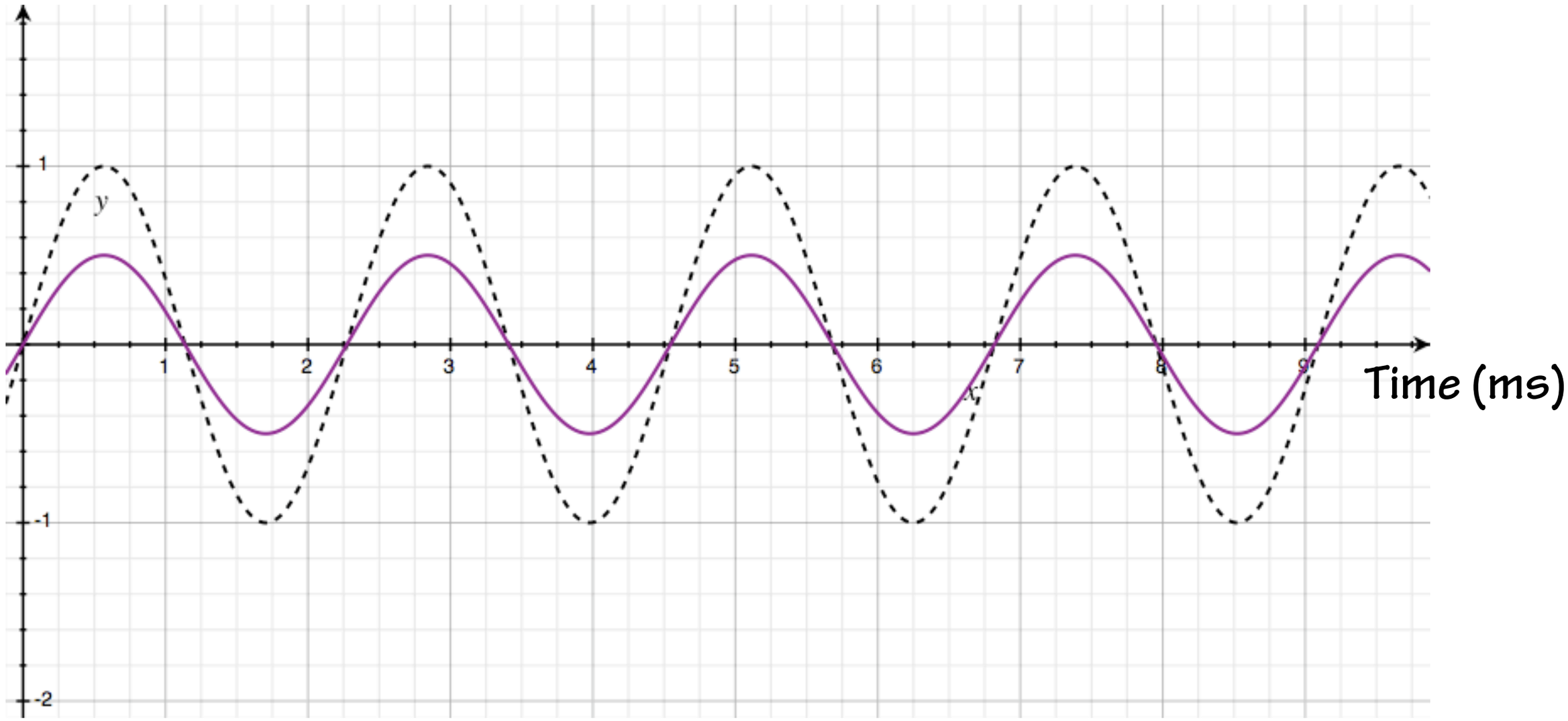
Intensity



Intensity

- **Loudness / intensity** is related to amplitude. (Higher pressure variations → higher intensity.)
- This tone has the half the intensity of the reference.

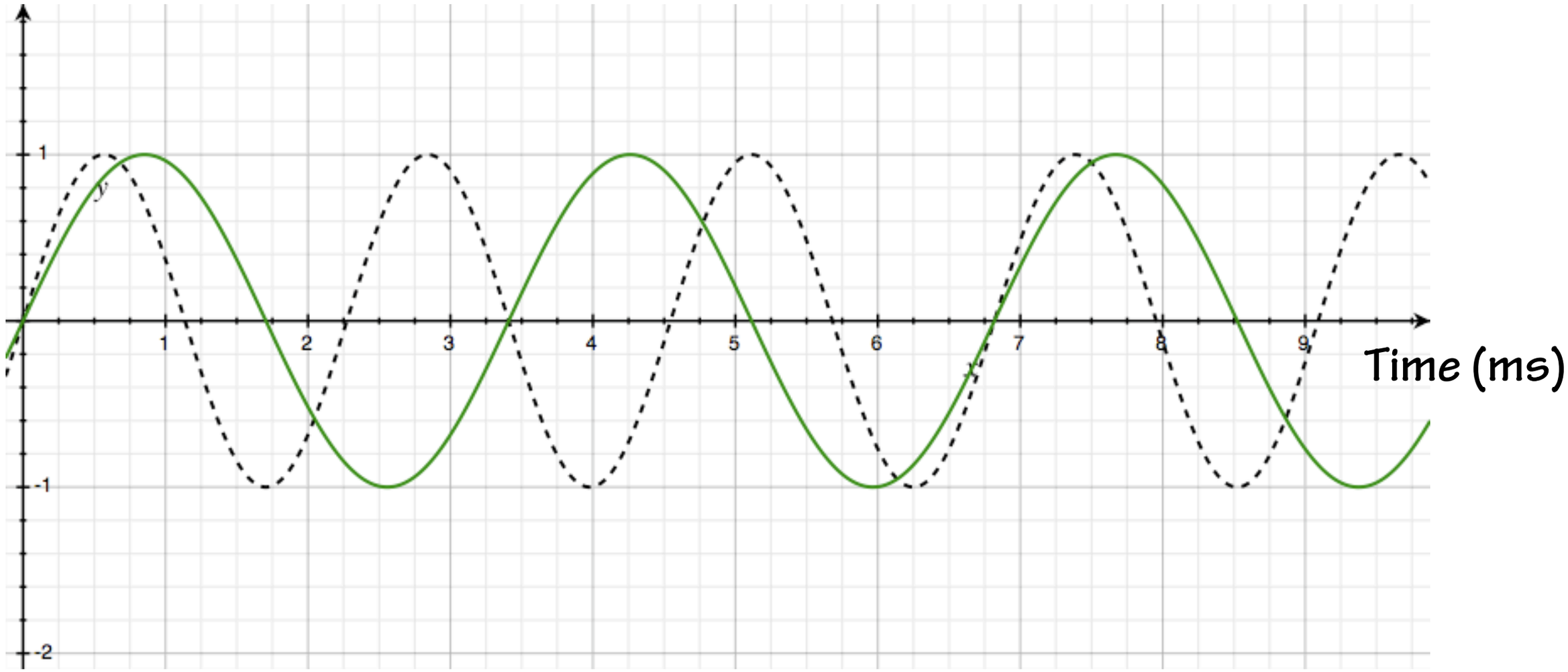
Intensity



Pitch

- **Pitch** is related to frequency. (Lower frequency → lower pitch.)
- 330 Hz has a period of 3.4 ms.

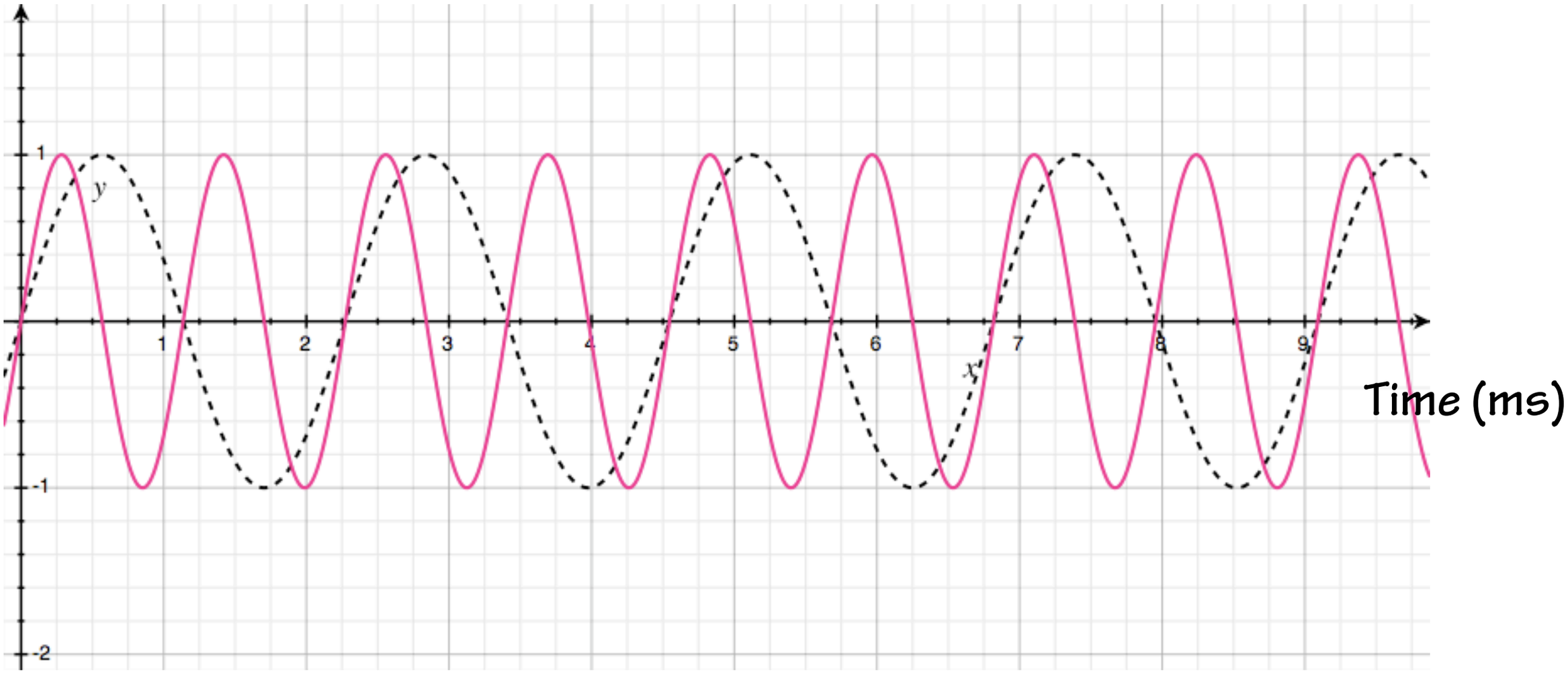
Intensity



Pitch

- **Pitch** is related to frequency. (Higher frequency → higher pitch.)
- 880 Hz has a period of 1.14 ms

Intensity



Tone

- **Timbre / tone** is related to the shape of the wave. (Single sin wave→ pure tone.)
- This tone combines 440 Hz & 880 Hz.

Intensity