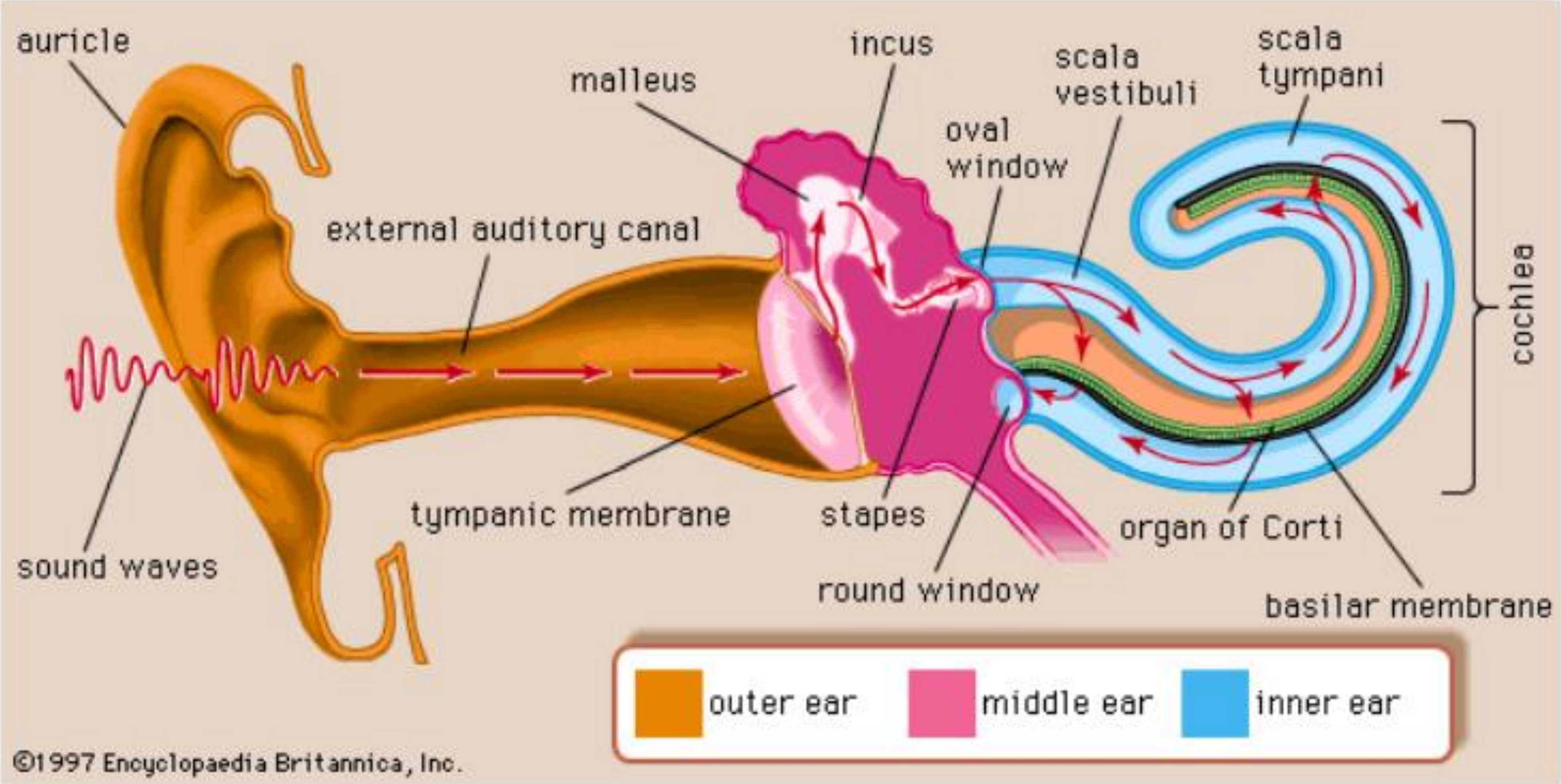
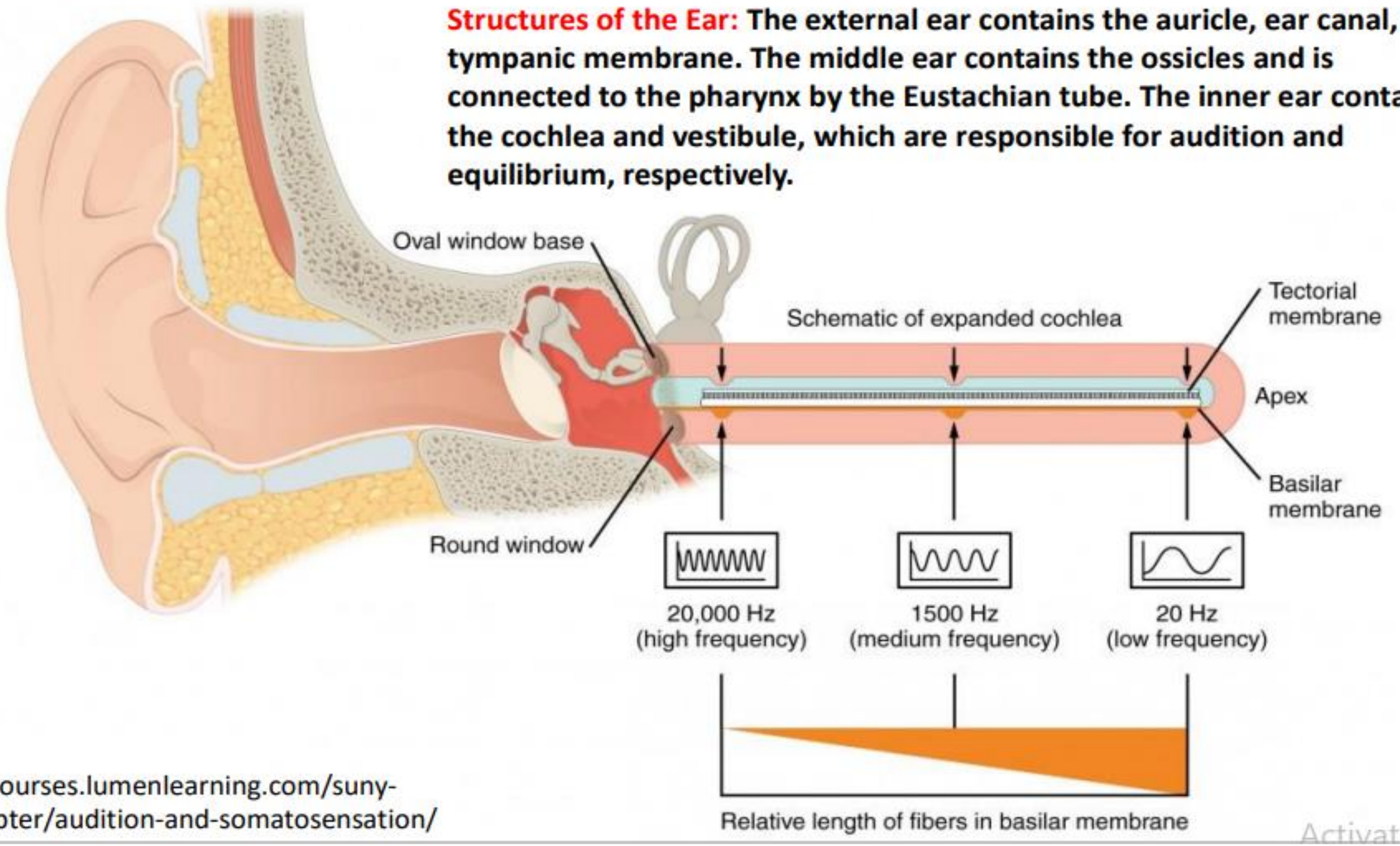


In human hearing, sound waves enter the outer ear and travel through the external auditory canal. When the waves reach the tympanic membrane, they cause the membrane and the attached chain of auditory ossicles to vibrate. The motion of the stapes against the oval window sets up waves in the fluids of the cochlea, causing the basilar membrane to vibrate. This stimulates the sensory cells of the organ of Corti, atop the basilar membrane, to send nerve impulses to the brain.

https://www.britannica.com/science/stapes

Structures of the Ear: The external ear contains the auricle, ear canal, and tympanic membrane. The middle ear contains the ossicles and is connected to the pharynx by the Eustachian tube. The inner ear contains the cochlea and vestibule, which are responsible for audition and equilibrium, respectively.

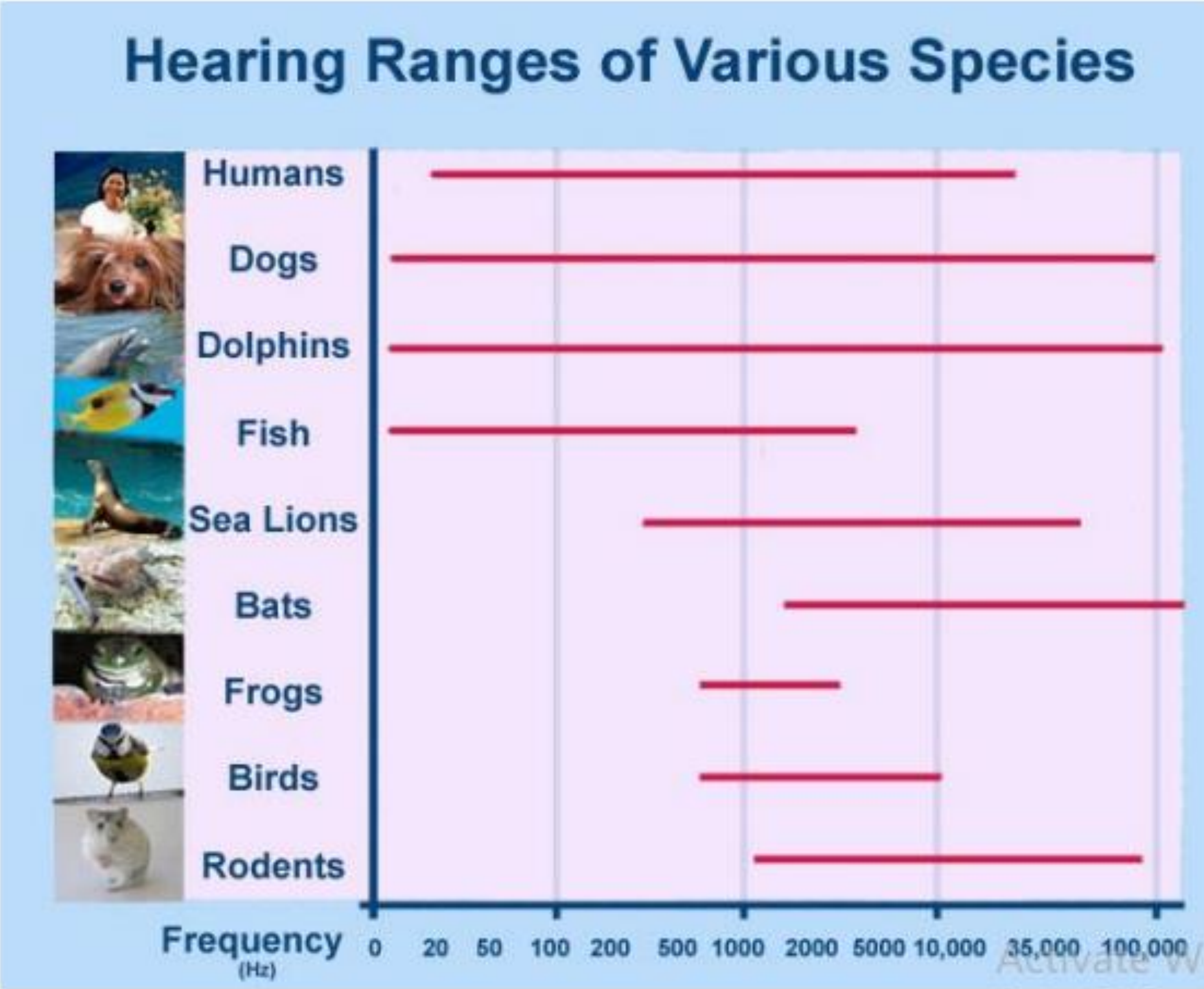


https://courses.lumenlearning.com/suny-ap1/chapter/audition-and-somatosensation/

Hearing range

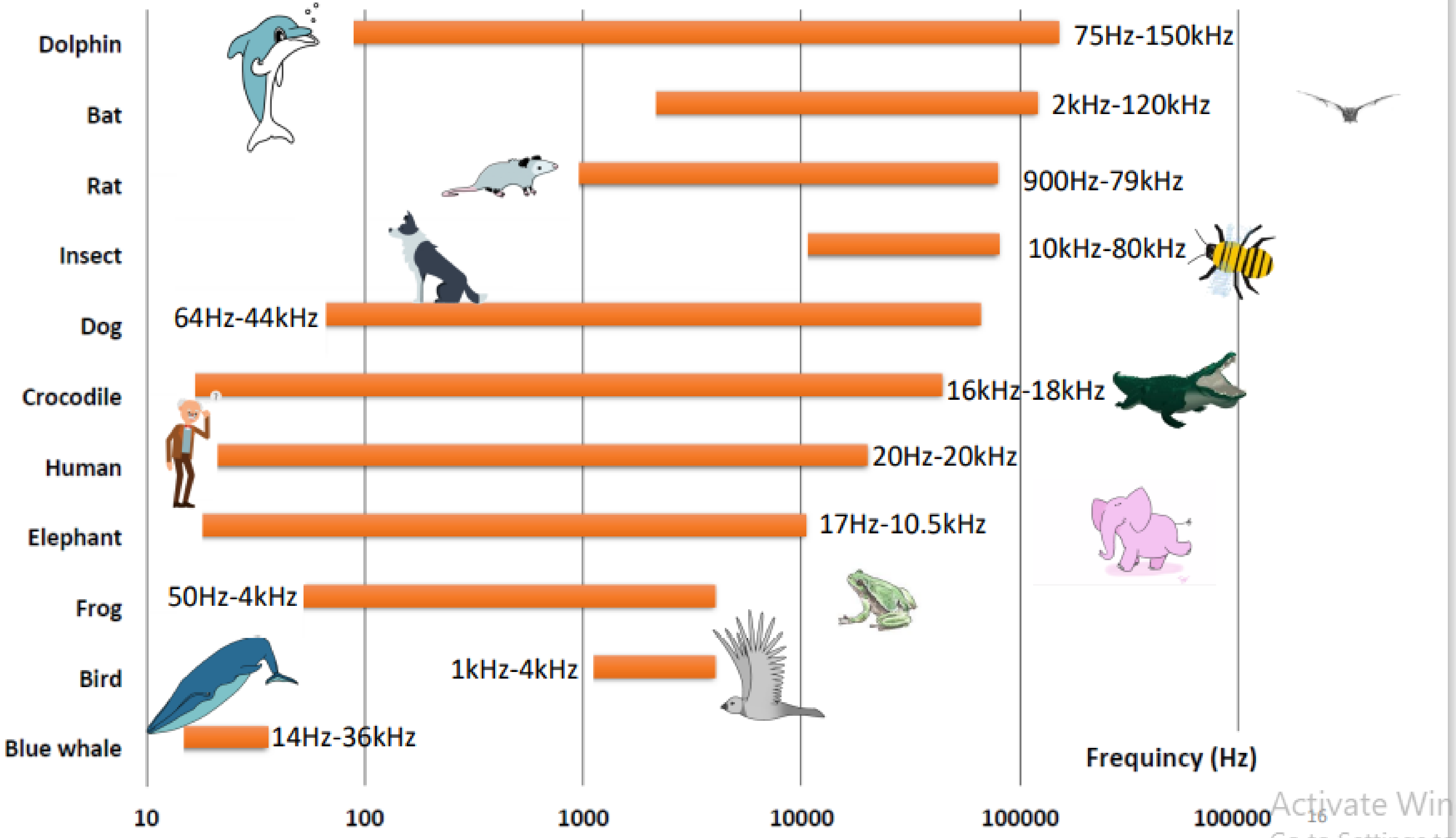
Hearing range describes the range of frequencies that can be heard by humans or other animals, though it can also refer to the range of levels.

Several animal species are able to hear frequencies well beyond the human hearing range. Some dolphins and bats, for example, can hear frequencies up to 100,000 Hz. Elephants can hear sounds at 14–16 Hz, while some whales can hear infrasonic sounds as low as 7 Hz (in water).



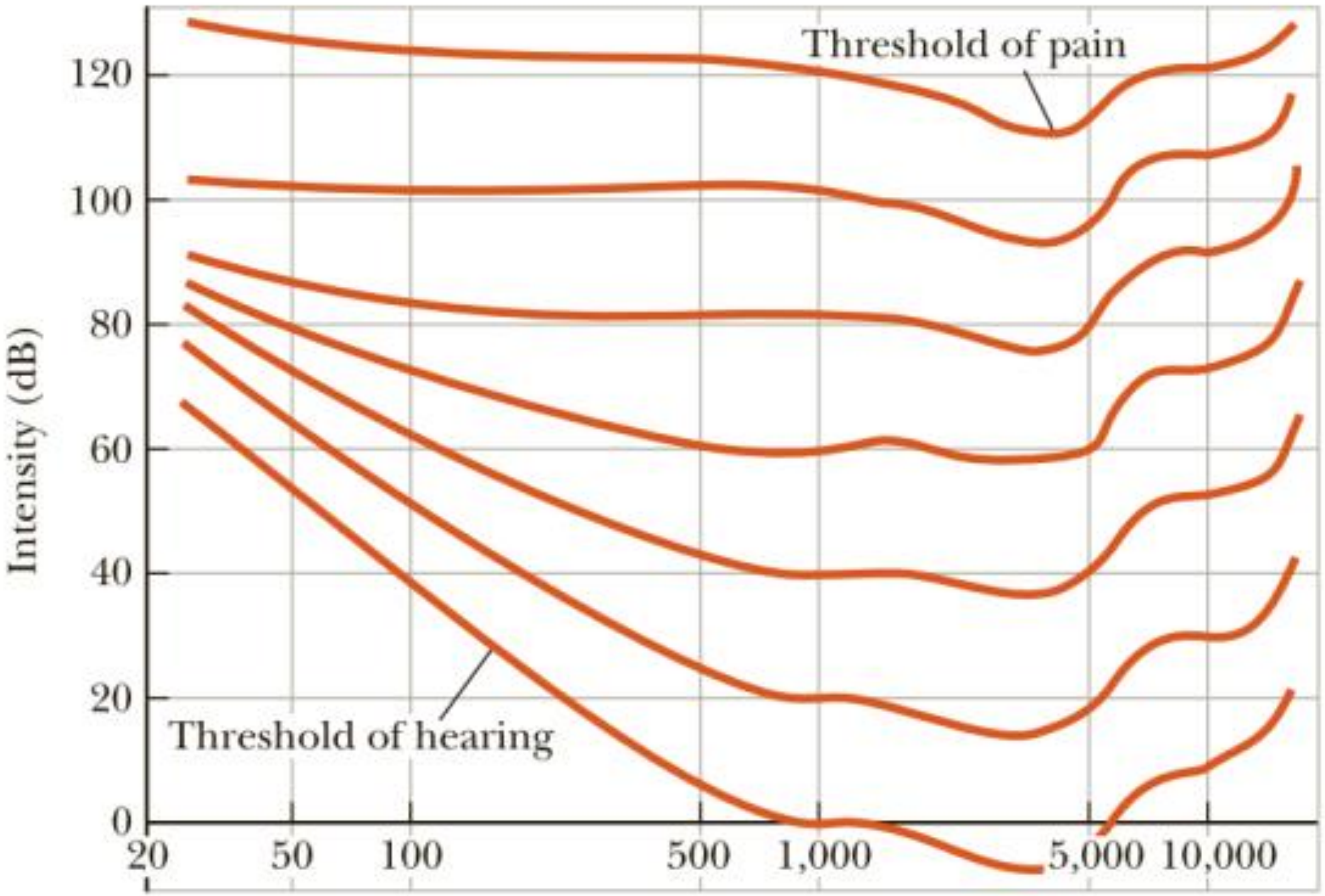
https://www.lsu.edu/deafness/HearingRange.html

The hearing range of different animals



The frequency response curves of an average human ear for sounds of equal loudness

Curves of intensity level versus frequency for sounds that are perceived to be of equal loudness. Note that **the ear is most sensitive at a frequency of about 3300 Hz**. The lowest curve corresponds to the threshold of hearing for only about 1% of the population.



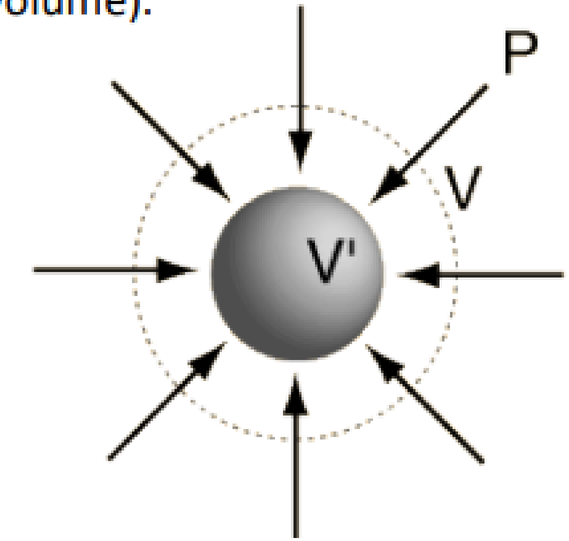
Loudness is related to the amplitude of sound waves.

Book: College Physics, Serway, 2018, P:486

4) Velocity of Sound in Gas (Newton's formula)

Bulk modulus

Bulk modulus is a modulus associated with a volume strain, when a volume is compressed.
The formula for bulk modulus is bulk modulus = - (pressure applied / fractional change in volume).

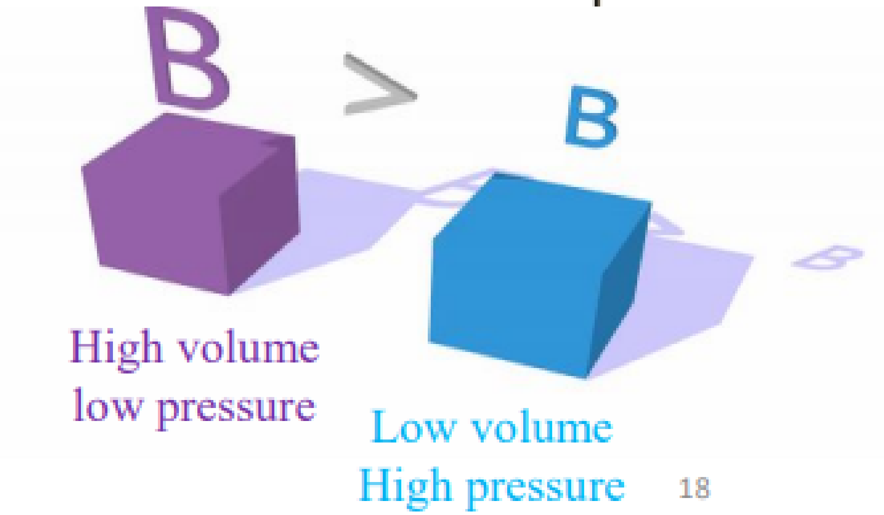


Bulk modulus tells us the **compressibility** of a fluid or solid

- If something is highly compressible it has a low bulk modulus
- If something has low compressibility it has a high bulk modulus

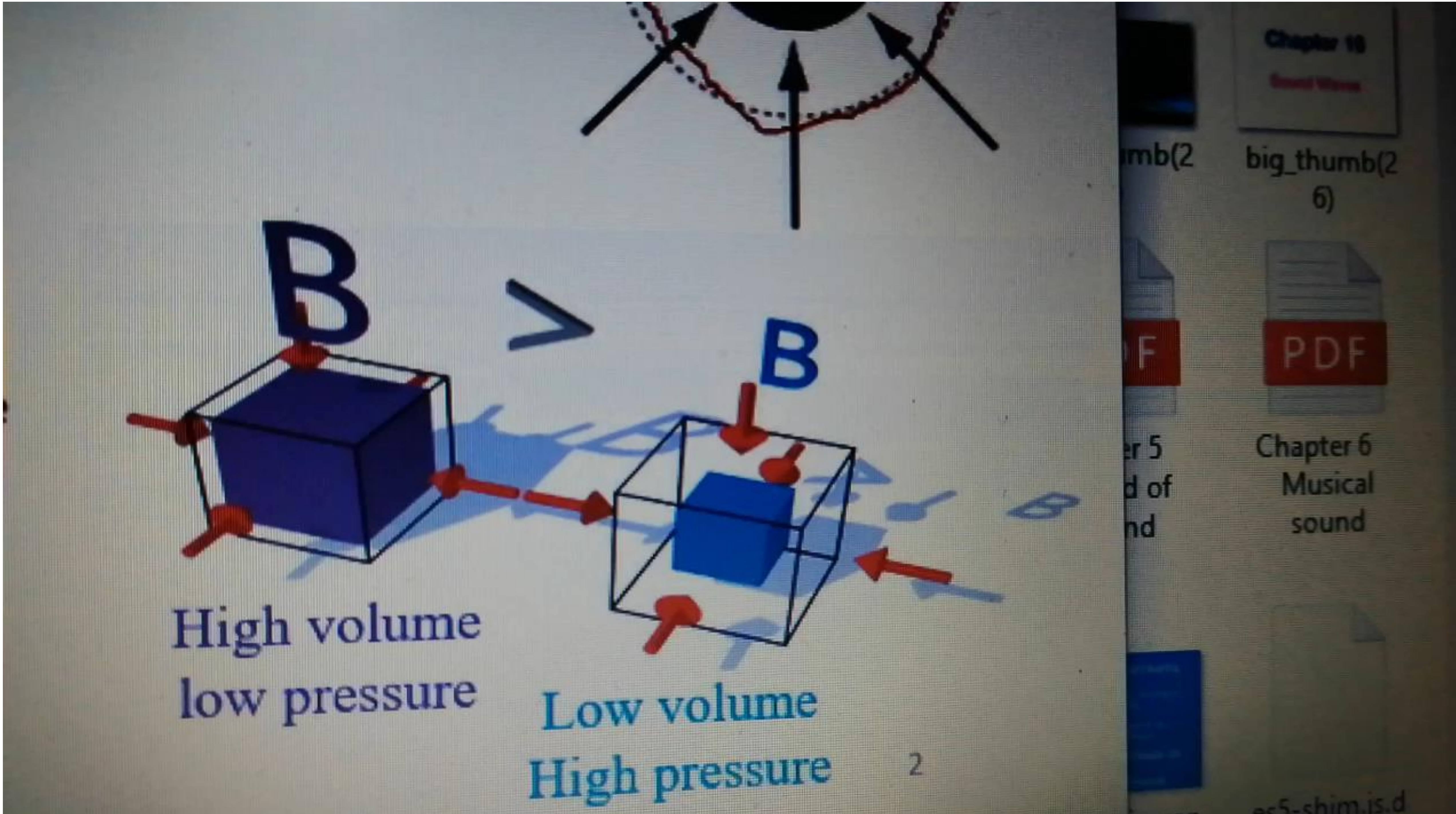
$$B = -\frac{\Delta P}{\frac{\Delta V}{V}} \quad \ldots\ldots\ldots\ldots 5.1$$

V: the volume of the object
ΔP: the change in pressure exerted on the material
ΔV: the change in the volume of the object due to the pressure change
The "-" is due to the fact that the change in volume is **ALWAYS** opposite the sign of the change in pressure.



The higher the bulk modulus, the faster the speed of sound (m/s).

Book: University Physics With Modern Physics by Hugh D. **Young**, Roger A. **Freedman**, 2008, P:533


B
>
B
High volume
low pressure
Low volume
High pressure
2
big_thumb(2 6)
Chapter 6 Musical sound

According to Newton, when sound waves propagate in air, compression and rarefaction are formed. He assumed that the process is very slow and the heat produced during compression is given to surrounding and heat loss during compression is gained from surrounding. So the temperature remains constant and sound waves propagate through an isothermal process.

According to gas law (Boyle's law):

$$PV = \text{constant}, \quad T = \text{constant}$$

where, P = pressure, V = volume of air, T=Temperature

Differentiating above equation, we get:

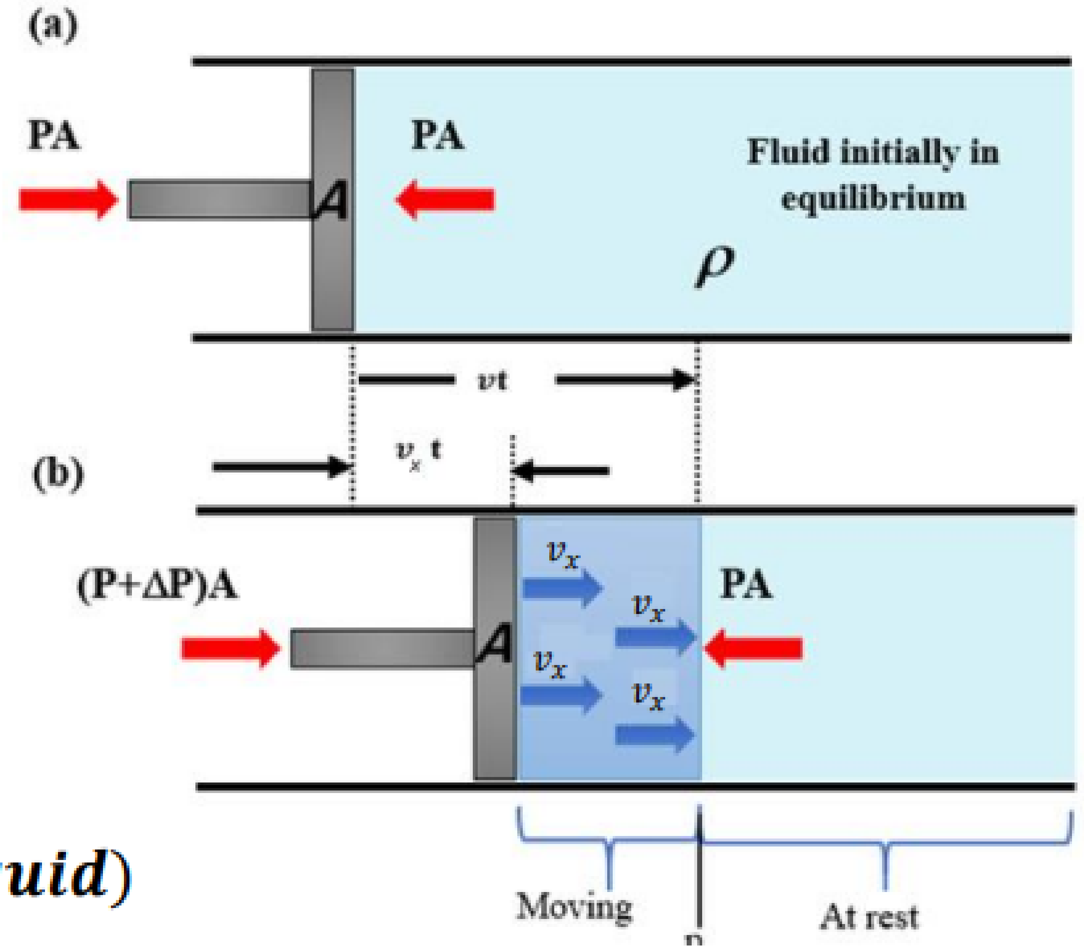
$P\,dV + V\,dP = 0$, So $P\,dV = -V\,dP$

$$P = -\frac{V\,dP}{dV} = -\frac{dP}{\frac{dV}{V}} = B \;\rightarrow\; \therefore P(gas) = B(Liquid)$$

$$\therefore B = -\frac{Pressure\ change}{Fractional\ volume\ change} = -\frac{\Delta P}{\frac{\Delta V}{V}} = \frac{-\Delta P}{-\frac{Av_xt}{Avt}} = \frac{-\Delta P}{-\frac{v_x}{v}}$$

$$\therefore \Delta P = B\frac{v_y}{v}$$

B=Compressibility of the liquid= 2.18×10^9 Pa (for water)



A sound wave propagating in a fluid confined to a tube. (a) Fluid in equilibrium. (b) A time t after the piston begins moving to the right at speed v_y , the fluid between the piston and point P is in motion. The speed of sound waves is v.