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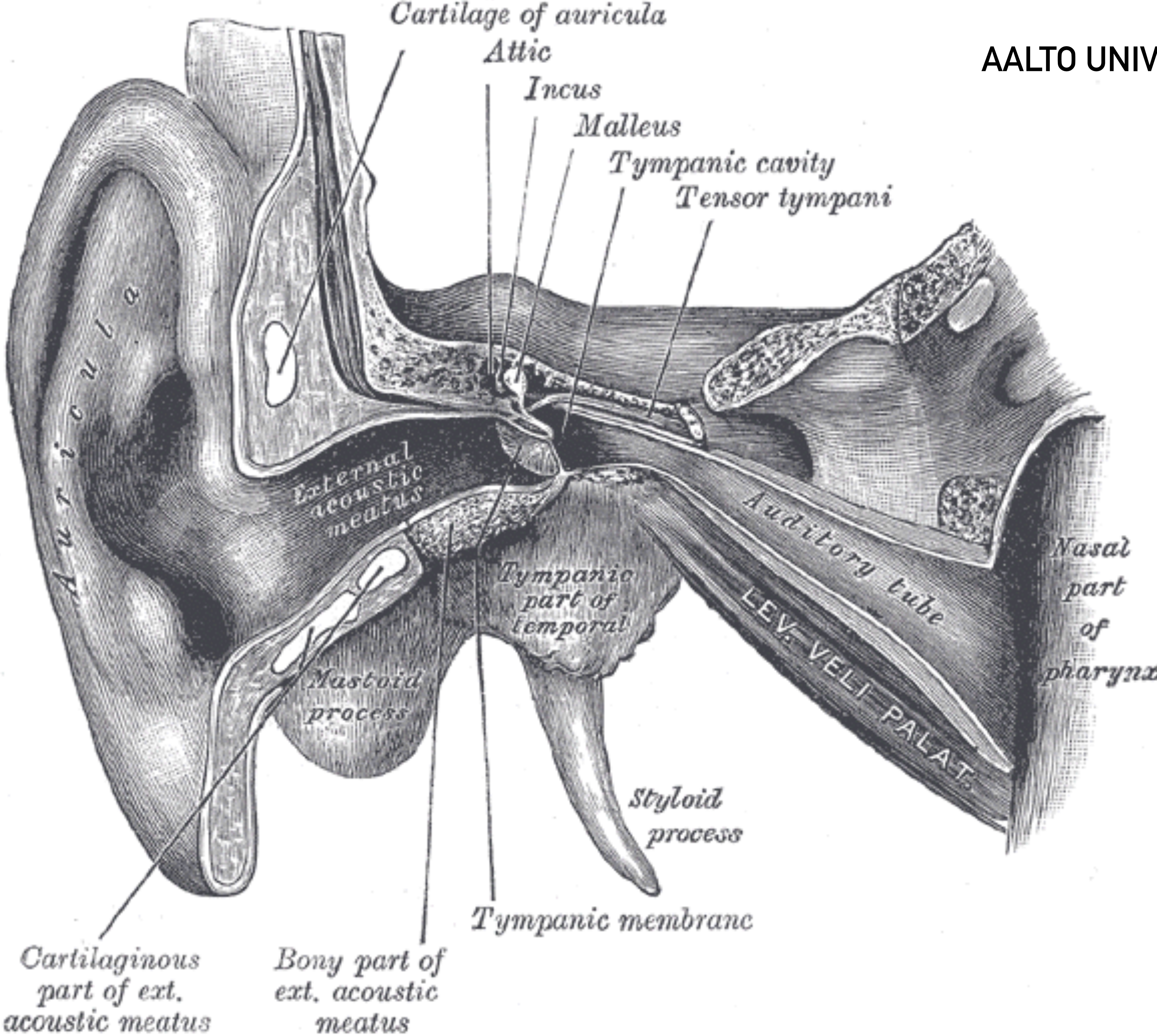

TIME TURNED INTO SPACE - 2019

A BIT OF SOUND LOCALISATION SCIENCE

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SOUND: WHAT IS IT THAT WE HEAR?

- **Sound** is the victim of a definition's confusion; it is often described confusing two very different points of view:

1. Sound is an oscillation in pressure that propagates through a transmission medium such as a gas, liquid or solid. So a physical phenomenon.

BUT

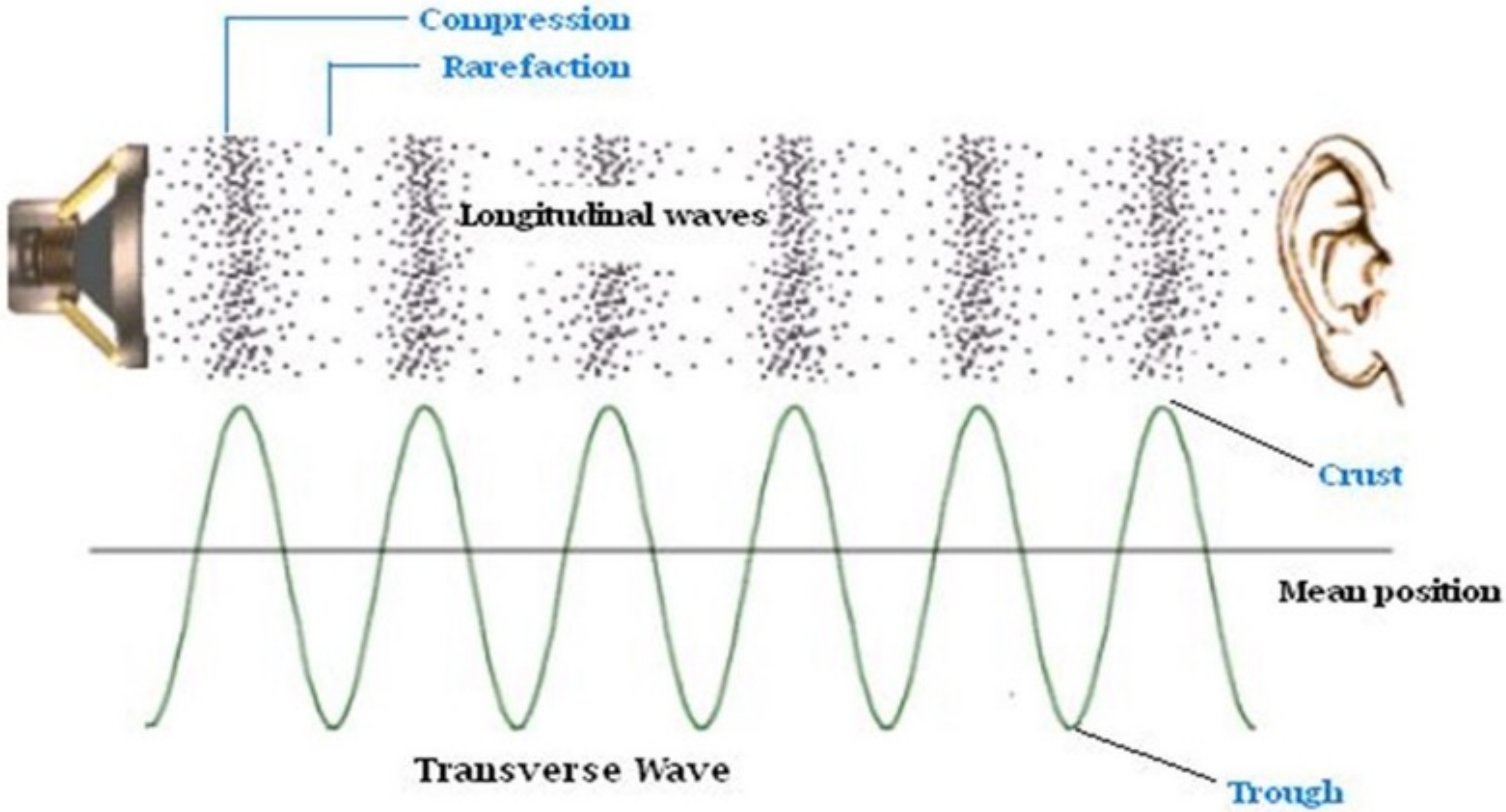
2. Sound can also be viewed as an excitation of the hearing mechanism, caused by the same oscillation, that results in an auditory sensation.

- It is an ambiguous definition: confusing the physical phenomenon and the perceptual one. The stimuli and its interpretation.
- It would be the same as confusing **vision** and **light**.

BUT WHAT DOES IT MEAN, REALLY?

- The vibrating phenomenon has obviously **no sound** *per se* no more than light **would be** equivalent to an image in our brain.
- On the other hand, anyway, sound is the name we give only to a limited portion of all those undulatory phenomena happening in air: the part that we CAN "hear".
- Lastly what we CAN hear, doesn't necessary coincide with what we actually hear. What we hear is not just the apprehension of a change in the status of things.
- Sound is in fact a complex phenomenon, intersecting physical, biological and cultural aspects. Sound is the active product of this intersection. But what does it mean that we hear it?
- Let's start from the stimuli…

THE STIMULI – SOUND WAVE



- Frequency (Hz): the number of peaks per unity of time.
- Intensity [~Volume] (dB SPL): a measure of the energy of the wave

SOUND PROPAGATION

- Although we are used to consider sound as a phenomenon mainly related to air pressure variation, in fact sound travels faster through matter than through air.

- In 20 °C air at sea level, the speed of sound is approximately 343 m/s

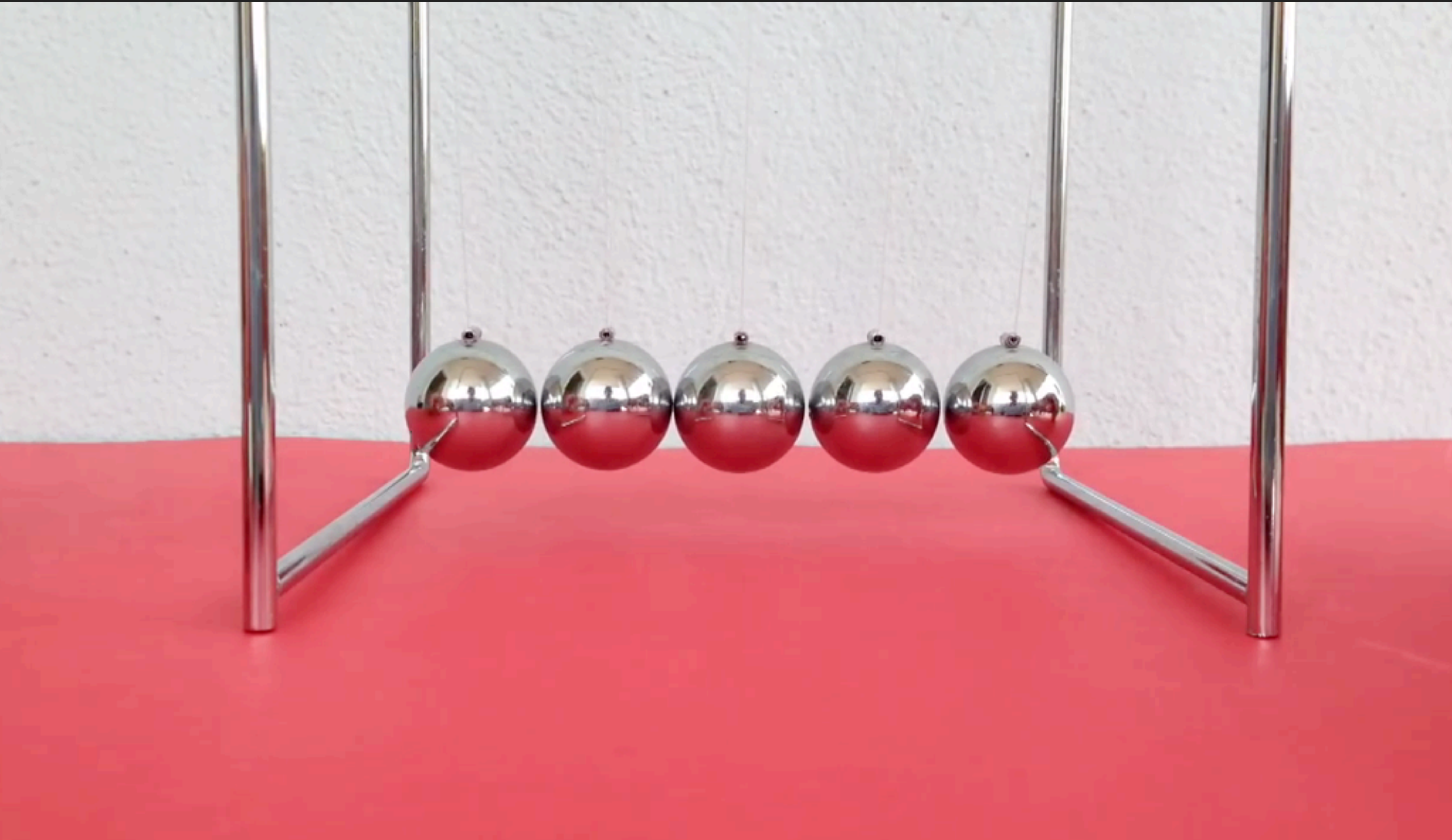
- In water the speed of sound is approximately 1,482 m/s (5,335 km/h).

- In steel, the speed of sound is about 5,960 m/s

- The closer the molecules of the carrier material are to each other and the tighter their bonds, the less time it takes for them to pass the sound to each other –> the faster sound can travel.

- Also if a material is more dense (i.e. its molecules are larger), it will transmit sound slower because it takes more energy to make large molecules vibrate than it does to make smaller molecules vibrate.

A VISUAL ALTERNATIVE TO SOUND PROPAGATION

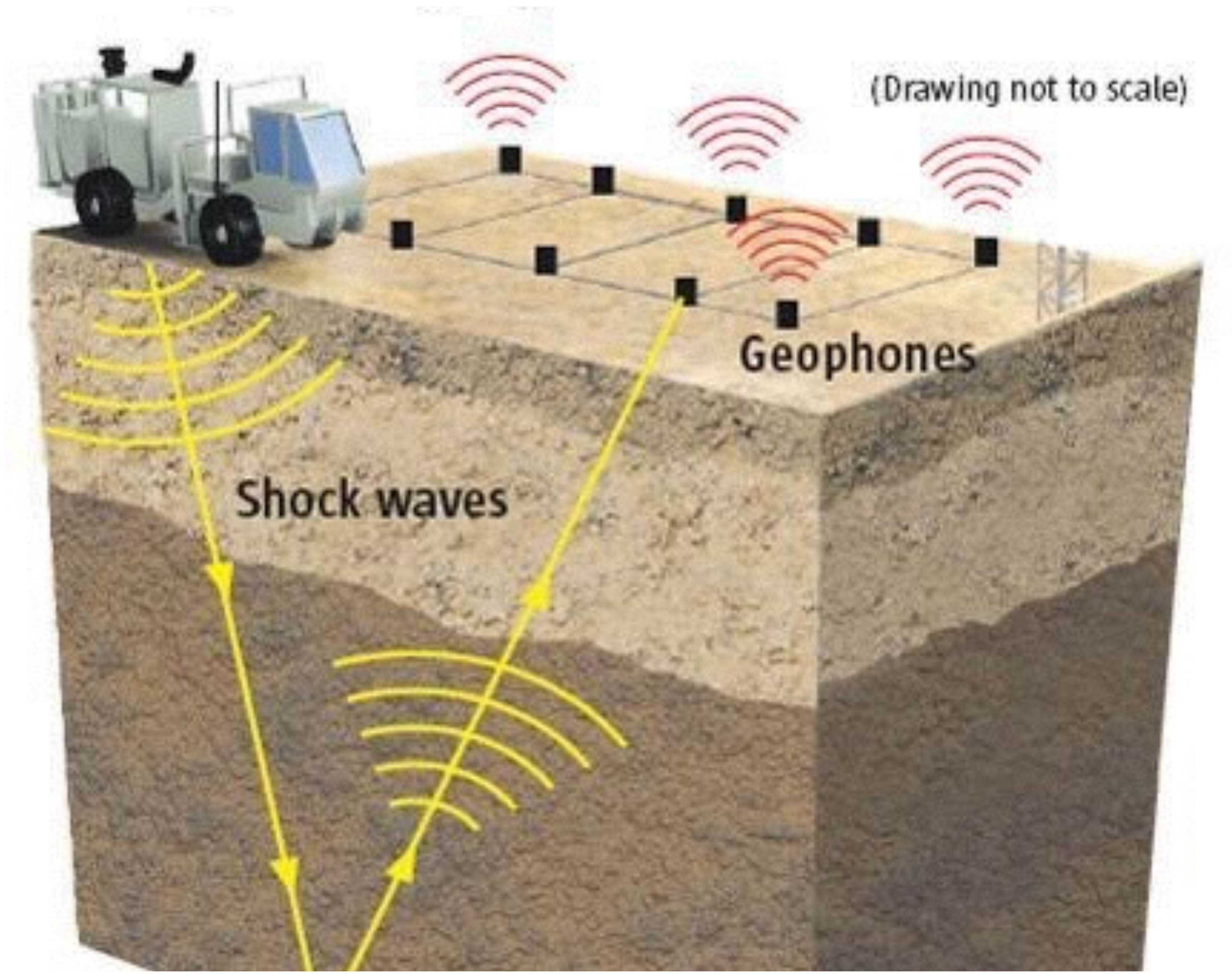


THE PERCEPTION

- Anyway to get back to that part that we CAN hear, it is anyway defined, on the base of average measurements, as being between 20 - 20k Hz in frequency and 0/~140 dB SPL in intensity.
- What is there beyond those values?
- Vibration of frequency < 20Hz = infrasound.
- Vibration of frequency > 20k Hz = ultrasound.
- Some animals are still able to transcode those vibrations into sonic phenomena (i.e. dogs), some use them to integrate vision at night (bats) in a phenomenon known as *echolocation,* analogous to marine sonars, or to seismic surveying.

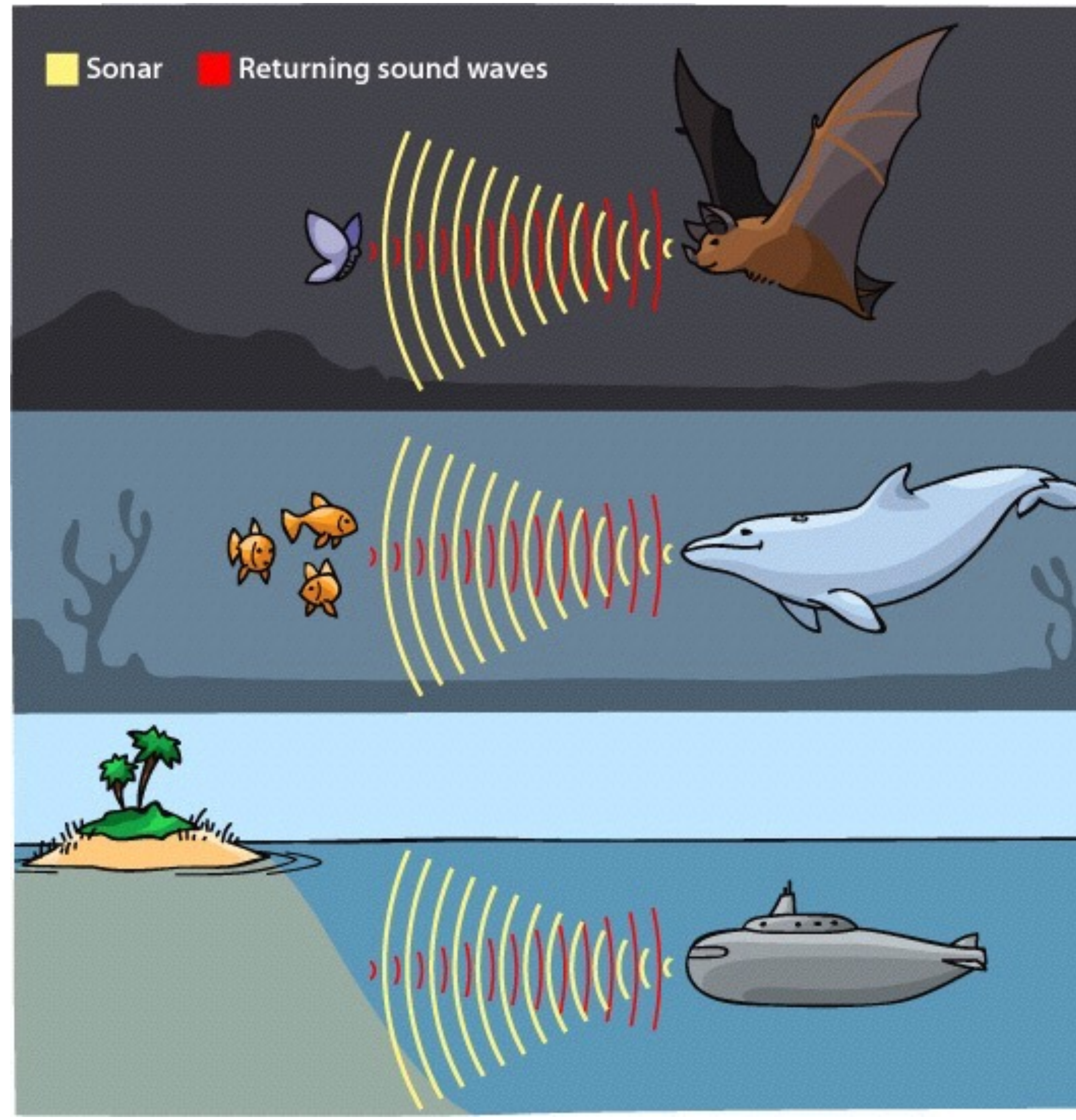
SEISMIC SURVEYING

- In the drilling industry, bursts of sounds are used, via an analysis of the way it bounces back through materials, to determine the composition of the ground.



STILL ABOUT THE BATS…

- By the way, getting back to in terms of loudness, bats can emit calls as quiet as 50 dB and as loud as 120 dB, which is louder than a smoke detector 10 centimeters from your ear.
- That would be damaging to human hearing, but since it is ultrasound we cannot hear it.
- But, ultrasound are waves of energy that are not able to move the eardrum, but will rather convert into heat and be potentially harmful.

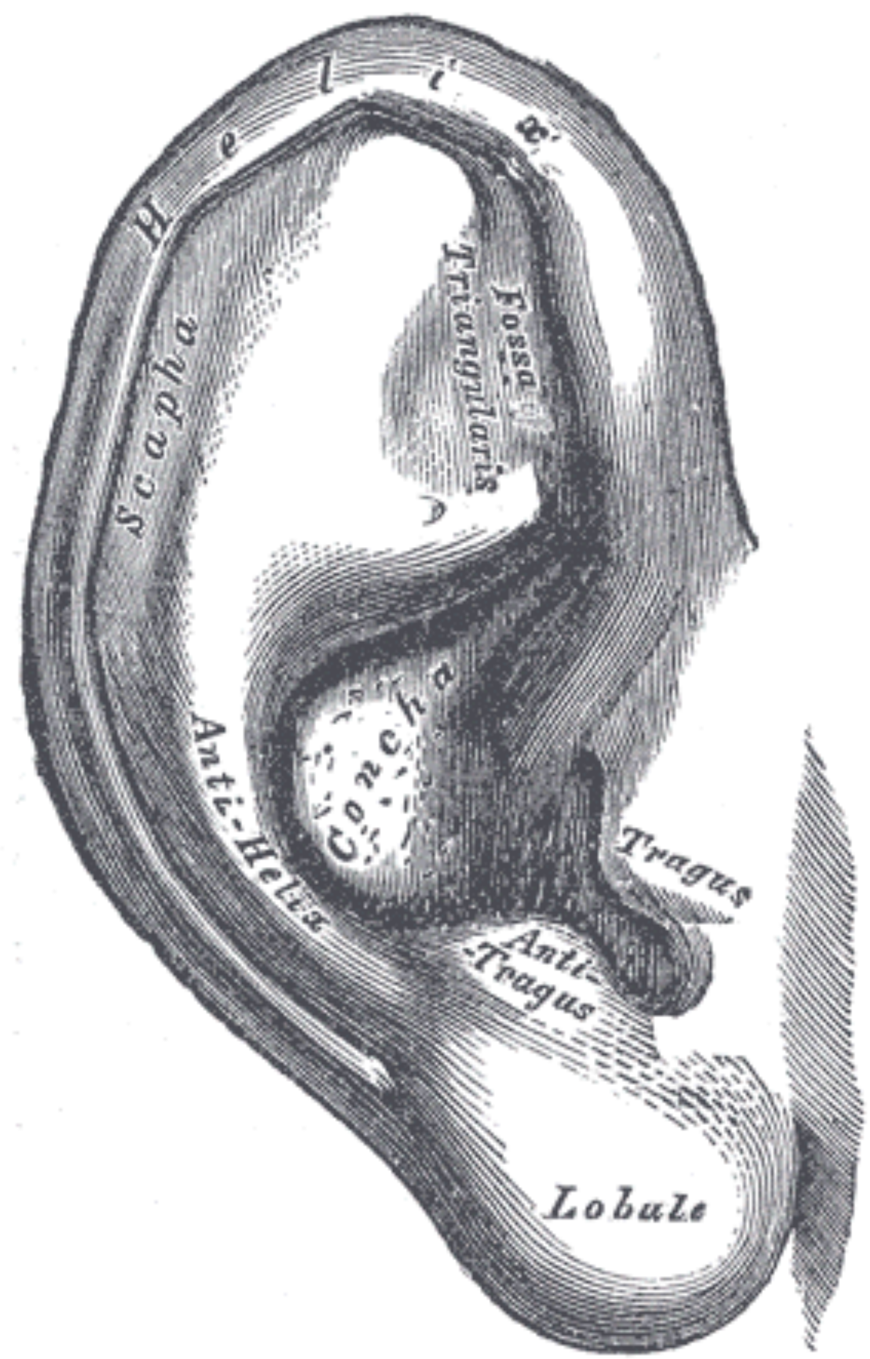


THE HUMAN EAR

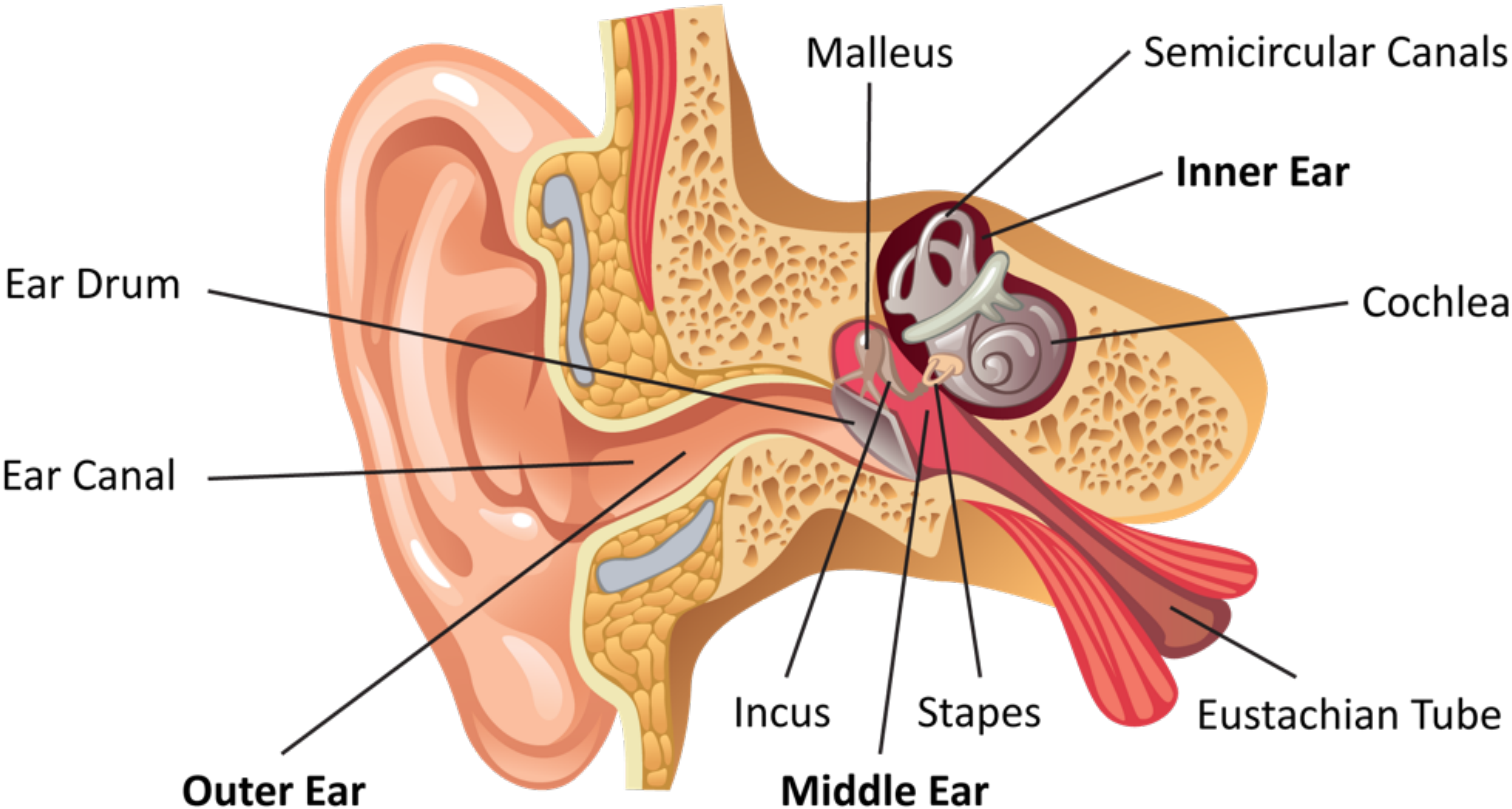
- The human ear is centered on the voice frequency range: approximately between 80 Hz to about 6 kHz.
- It is the physical shape of the ear, and particularly of the canal and eardrum to allow to easily “catch” frequency in that range, in order to maximise voice intelligibility.
- It is a product of evolution.

THE HUMAN EAR

- The pinna acts like a parabolic antenna, concentrating sound waves in the ear canal
- Inside the ear the sound is transduced several times:
- Different mechanical transducers (membrane, bone, fluid) like in a bucket brigade.
- Finally, inside the cochlea it is transduced into a chemical “analogy” to be delivered in the brain.

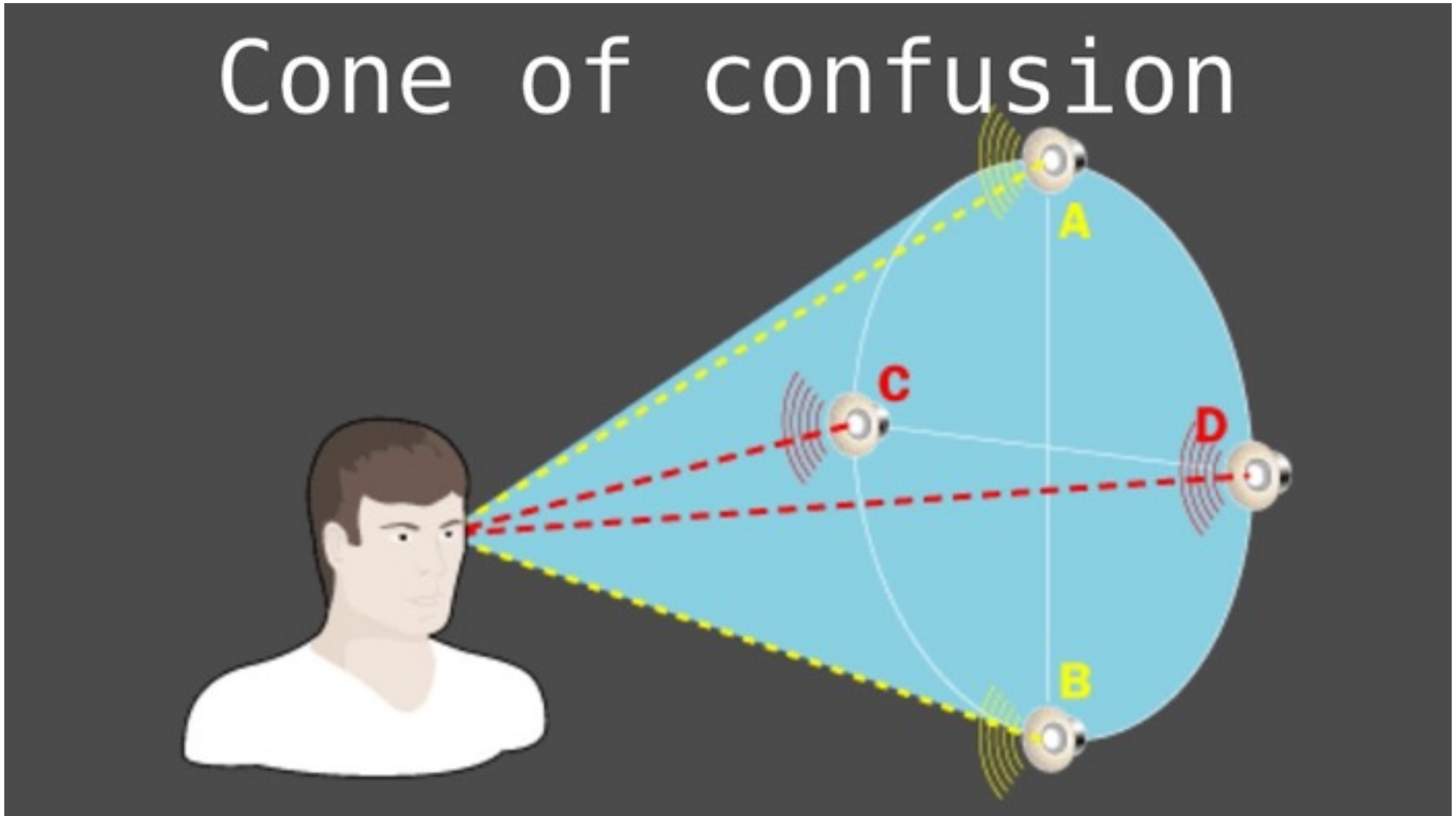



THE HUMAN HEAR



WHAT DO WE USE THE EAR FOR?

- Most mammals are adept at resolving the location of a sound source interaural time difference and interaural level differences. However, no such time or level differences exist for sounds originating along the circumference of circular conical slices, where the cone's axis lies along the line between the two ears.



SOUND LOCALISATION STRATEGIES

- Interaural time differences: the distance between ears is about 15 cm, causing ~0.4 millisecond delay for sounds coming from one side. If a sound arrives at the left ear a little before the right ear we perceive the sound as coming from the left.

- Interaural phase differences: If the phase of the peaks in the sound wave arriving at the left ear is slightly ahead of the phase of the peaks arriving at the right ear our ear-brain system interprets the sound as coming from the left. Works for frequencies below 1500Hz.

- Interaural level differences: The ear is also able to distinguish little intensity differences between ears, providing a clue about direction. If the left ear perceives a louder sound we experience the sound as coming from the left. Works for high frequencies.

BINAURAL DUMMY-HEAD MICROPHONE

HRTF - HEAD-RELATED TRANSFER FUNCTION

- Filtering effect of our bodies on sounds while traveling to the ears:
- Can be modelled mathematically to reproduce the same effect via headphones.

Composed of:

1) Filtering by the outer ear flap (pinna) affects the propagation of different (especially high) frequencies. The precise nature is determined by the ear shape, thus is unique to each individual.

2) The upper torso reflects frequencies (especially mid- range) to produce very short time-delayed echoes. The length of this time delay varies with the elevation of the sound source.

...AND THE ENVIRONMENT?

- Although we are not as good as bats are, we are also able to understand through sound how the environment around us is made.
- By recognising certain characteristics in the way the space “colours” (i.e. filters) the sound around us, or how long reverberation (the sum of all the reflections due to obstacles around us) is mixed with it. In particular:
- Absorption by air: greater for humid or polluted environments
- Reflection: solid surfaces will reflect more than soft furnishings which will absorb energy from the sound waves.
- Diffusion: Scattering the sound rather than reflecting it.
- Is interpreted as: Is it an open space? Are we close to a wall? Are there obstacles?
- In other words, we never hear a sound as-it-is, (whatever this could mean), but always a mixture of the effect on the air a physical event determines + the way the environment modify the air flow + the way our ear work + last but not least, our cultural predisposition.

ABOUT THE ENVIRONMENT...

https://www.youtube.com/watch?v=mY-f68J5PPo

RESOURCES

- http://newt.phys.unsw.edu.au/jw/basics.html
- https://soundphysics.ius.edu
- http://web.arch.usyd.edu.au/~wmar0109/DESC9090/old/BechZach_doc/Organized_Sound/Malham.pdf