Computer Music

An Interactive Approach

Aristotle University of Thessaloniki
Department of Informatics 2015

ανοικτάμαθήματα
opencourses

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

An Introduction to Computer Music

From Sound Waves and the Hearing Mechanism to Musical Instruments

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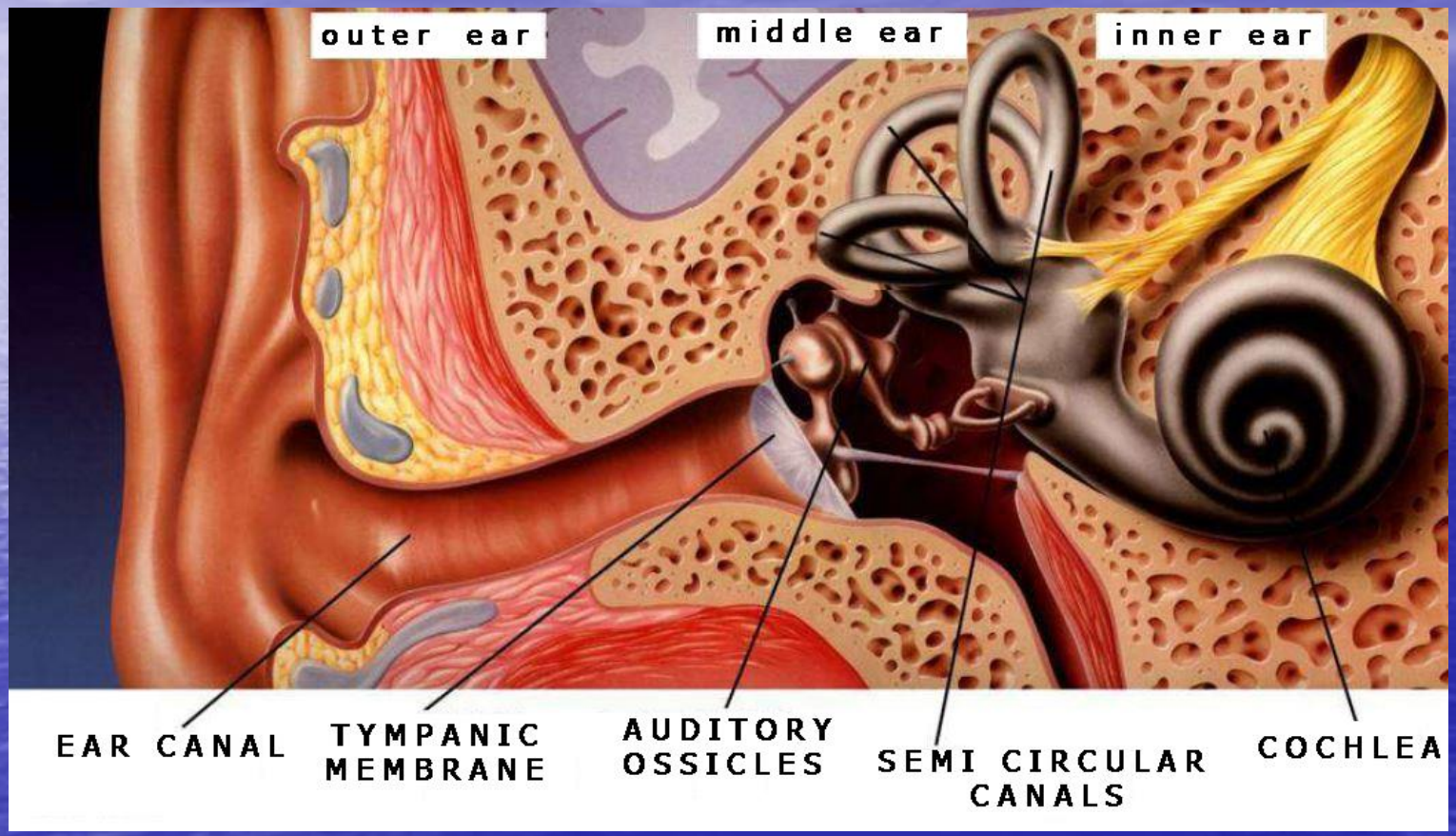
Part B: The Ear, the Listening Apparatus and Psychoacoustics

- **Ear:** a transducer that converts the pressure of sound waves to electrical pulses. Therefore, Mechanical Energy is transformed to its Electrical equivalent.

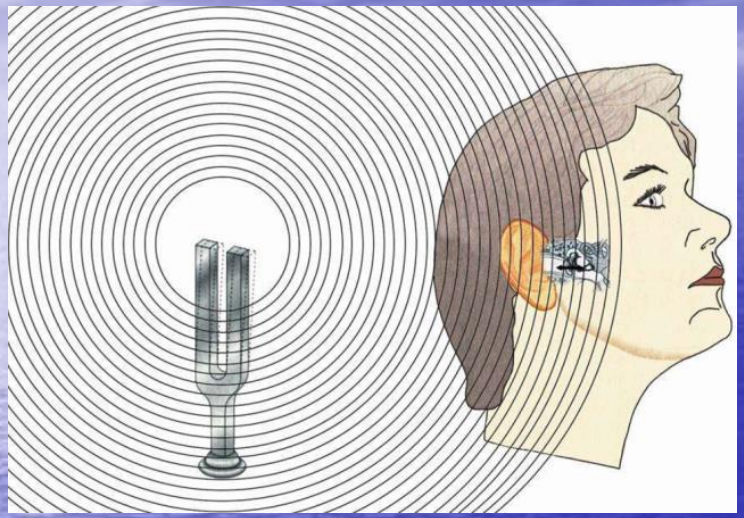
- The ear comprises of three main parts:
  a. the **External Ear** or **Outer Ear**
  b. the **Middle Ear**
  c. the **Internal Ear**

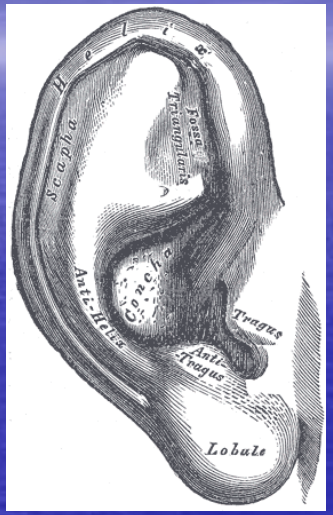
The Human Ear



a. The **outer ear**

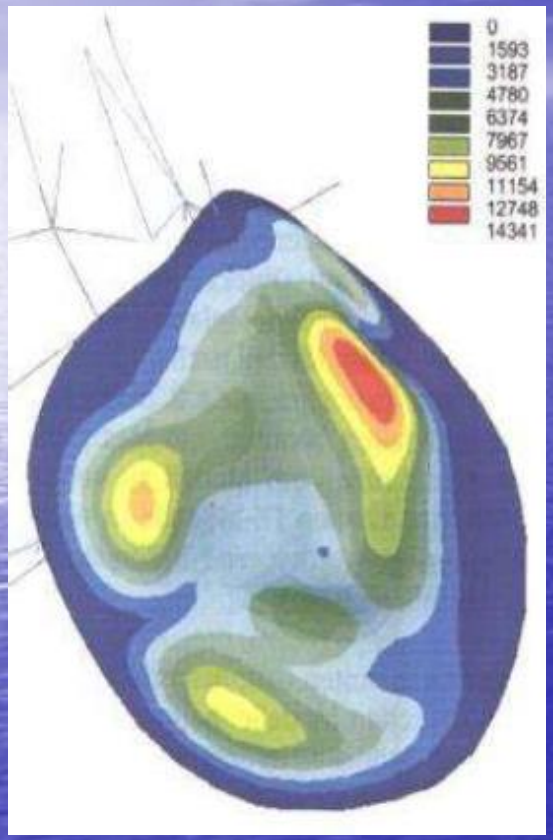
- Its main characteristic is the **auricle** (pinna) which assembles the acoustic energy

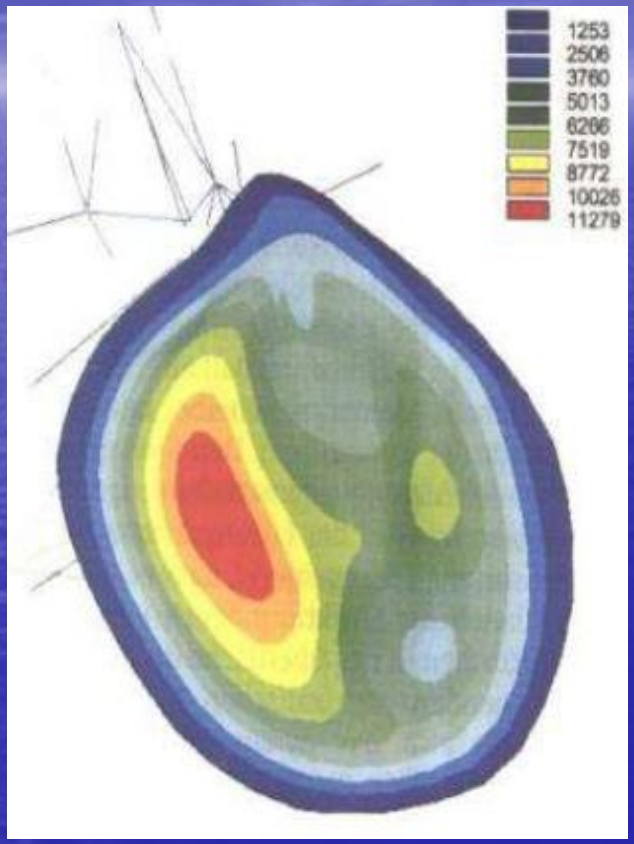


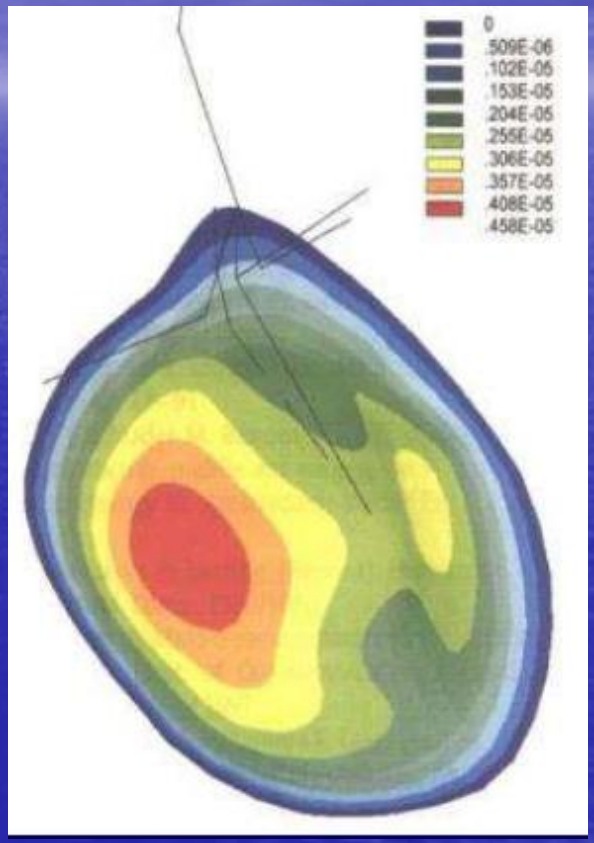


- The canal that leads from the auricle to the inside of our head is named **external auditory meatus**. Its dimensions, 25 mm in length and 7mm in diameter, are crucial for the range of sounds we hear.
- At the end of the canal we find the **tympanic membrane**, the eardrum, which is cone shaped, and not flat, separating the outer ear from the middle ear.

- Color-coded vibration amplitude of the tympanic membrane as a function of frequency

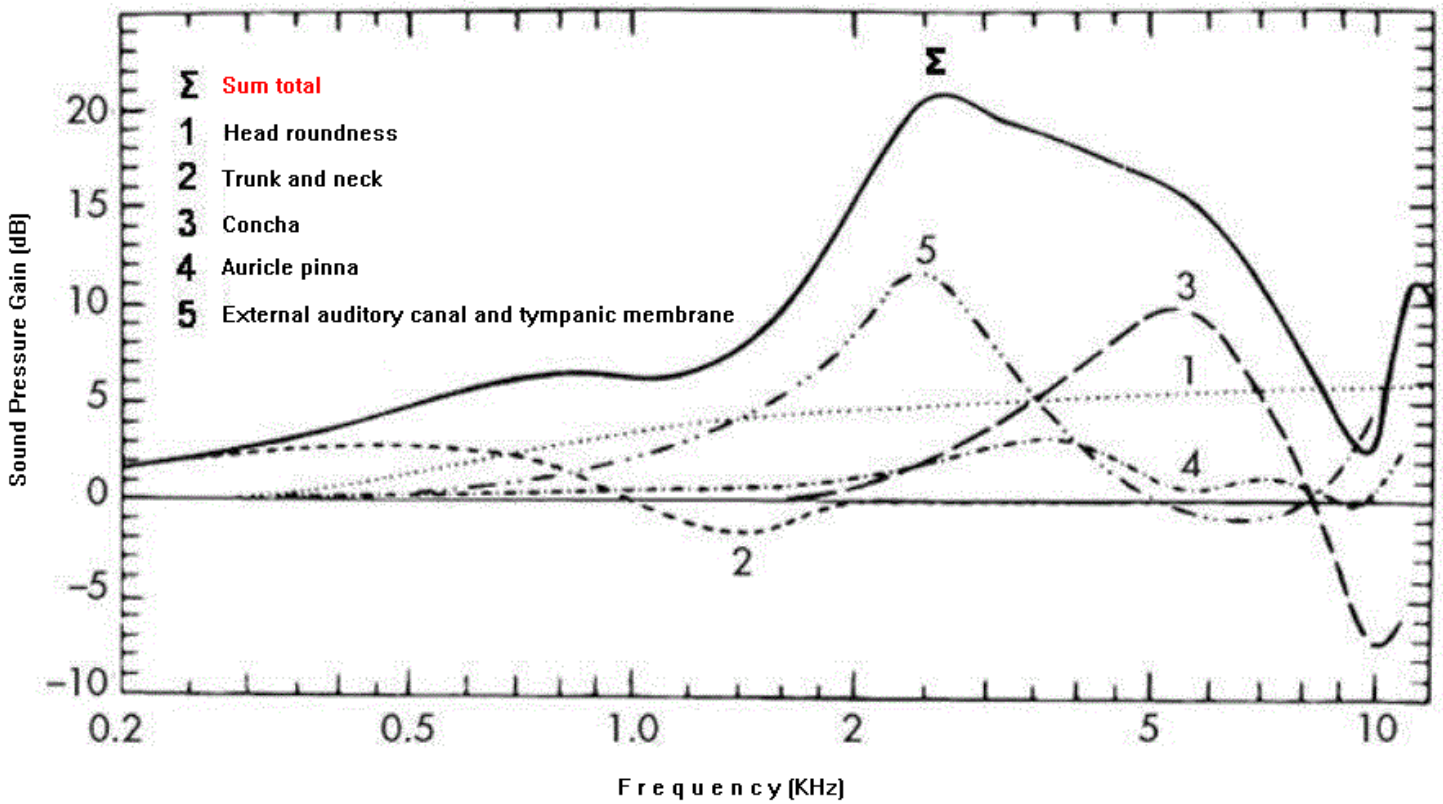






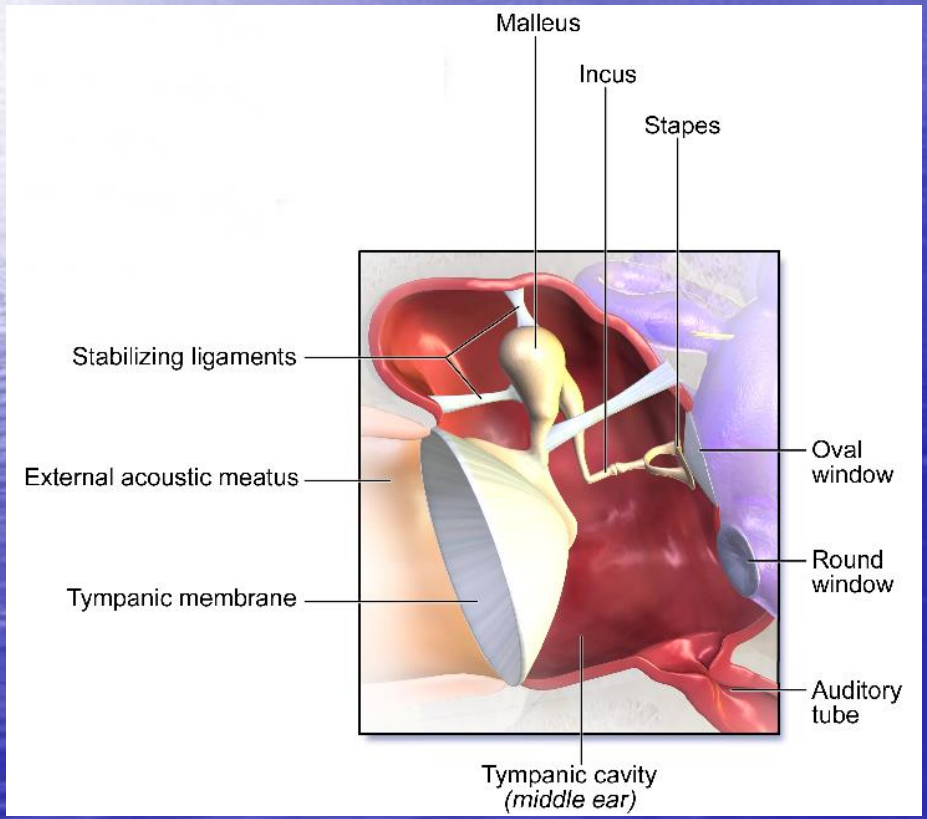
… from low to high frequencies
(black: minimum, red: maximum vibration)

- Parts of the body and the ear and their contribution to the hearing transfer function



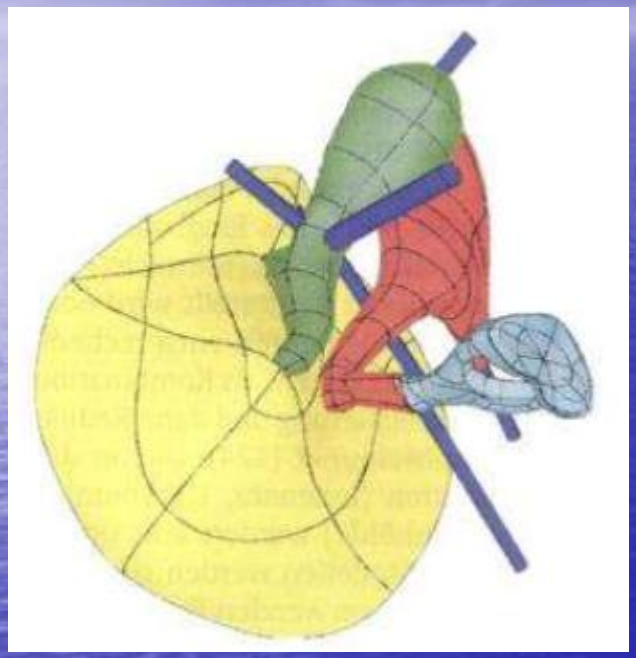
b. **The Middle Ear**

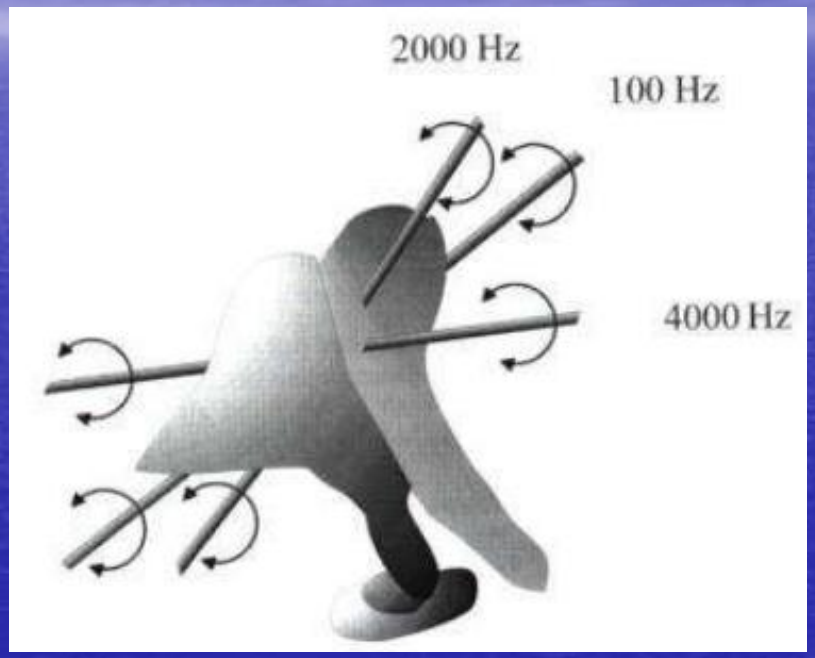
- It is a small cavity inside the bones of our head, within the tubotympanic cavity, following the eardrum.



Three small bones, the **malleus** (hammer), **incus** (anvil) and **stapes** (stirrup) transmit the acoustic energy gathered at the outer side of the eardrum to the inner ear fluids. Two membrane like intratympanic muscles, the **stapedius** and **tensor tympani** protect the inner ear from excessive sound levels.
At the lower part is located the **eustachian tube**, a 35mm tube, aiming to counterbalance the pressure of air coming from the outer ear on the eardrum with that of nasal air passages.

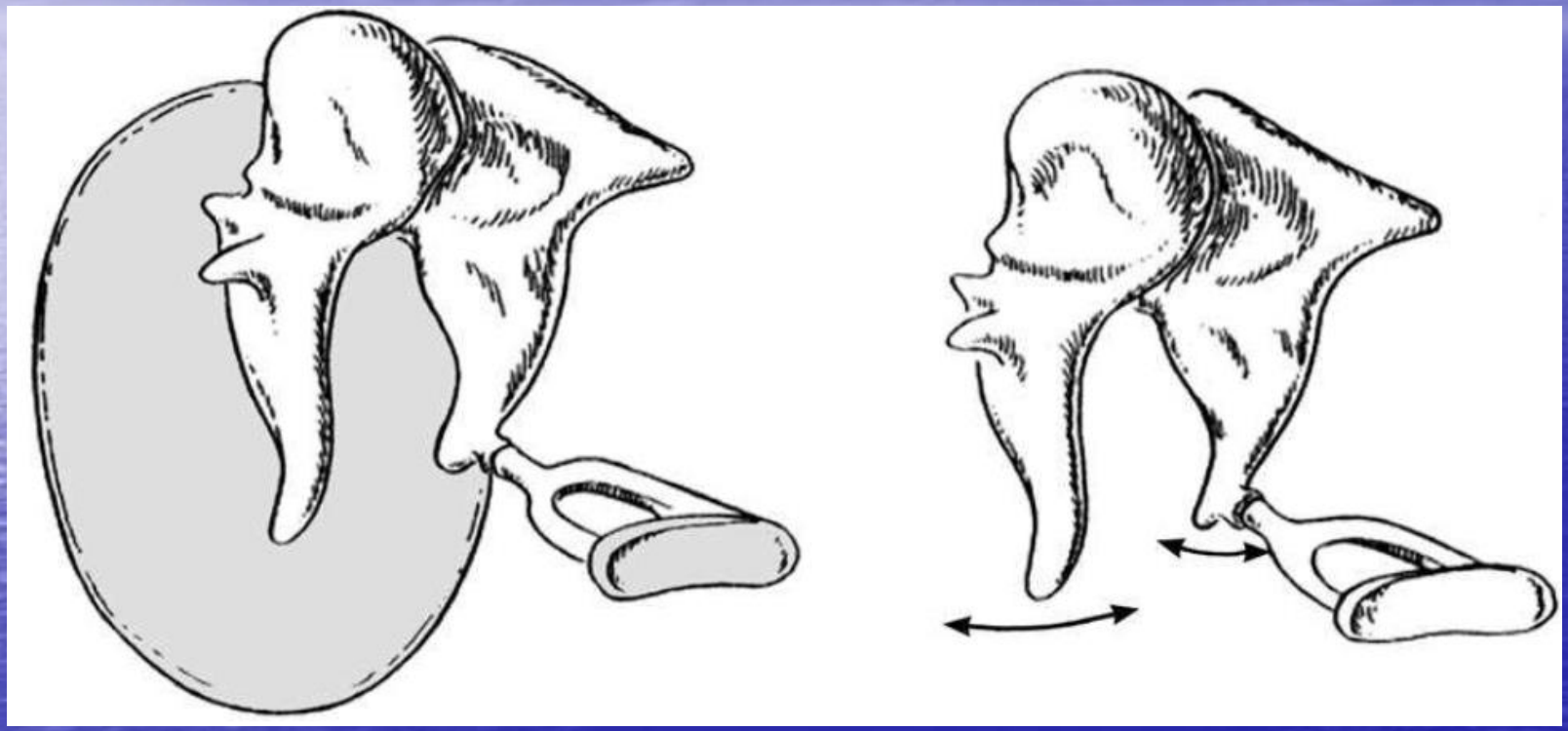
- The instruments of middle ear are vital for Impedance Matching …





… and Pressure Equalization, as the vibration is forwarded towards the aural nerve

. The contractions of middle ear muscles manage to transfer with amplification the vibration to the inner ear!

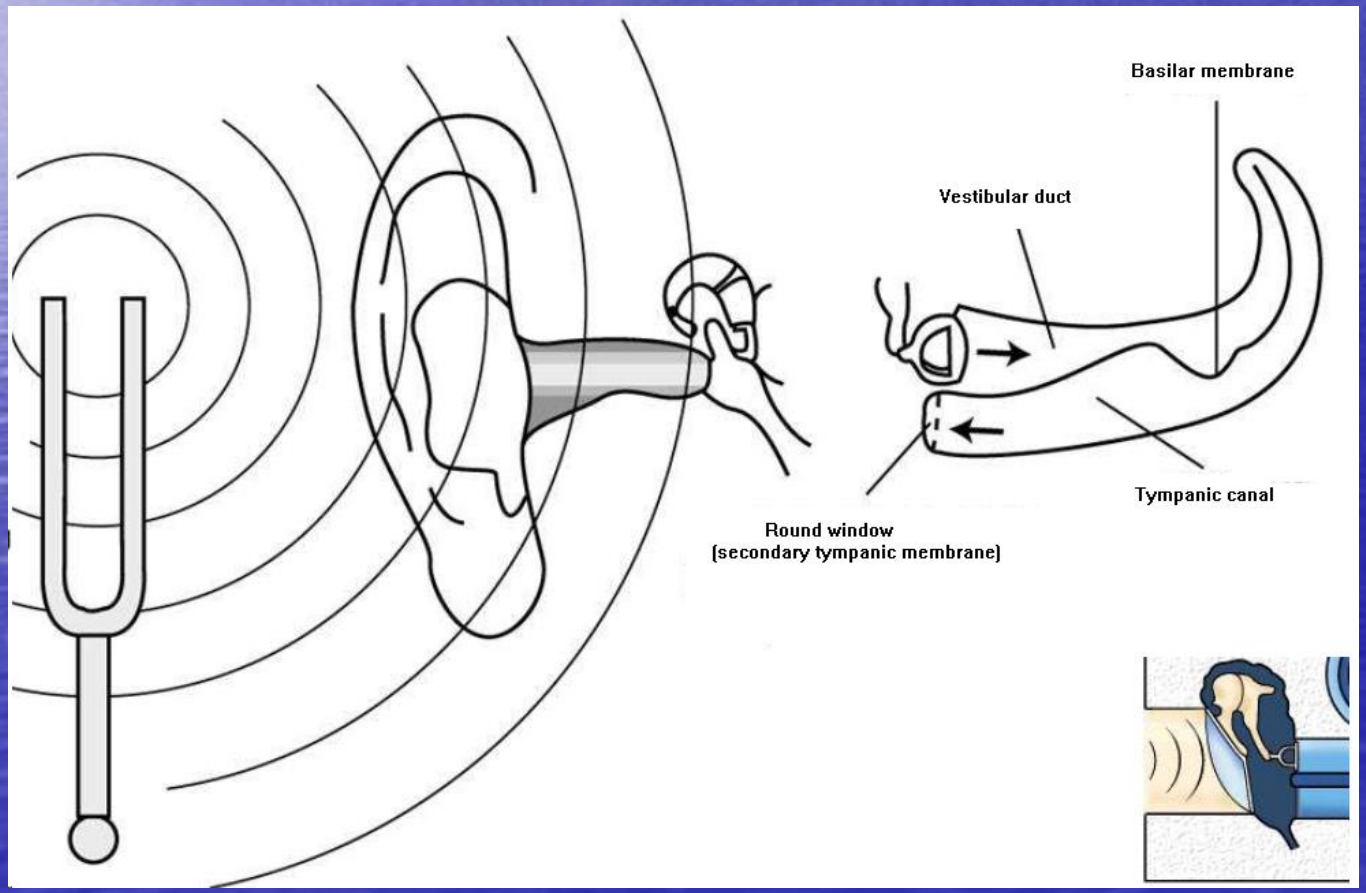


Without these fast moving ossicles, there would be no adequate way to lever aural action to the next stage.

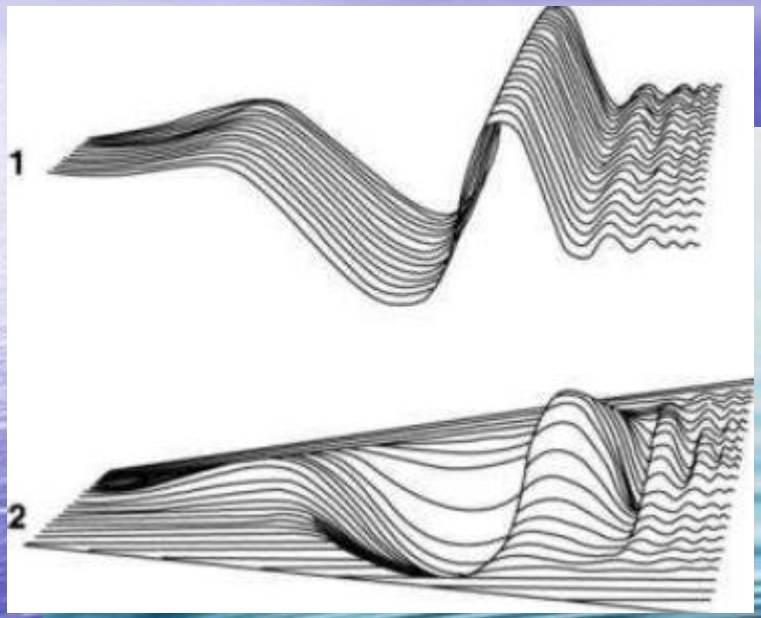
c. The Inner Ear

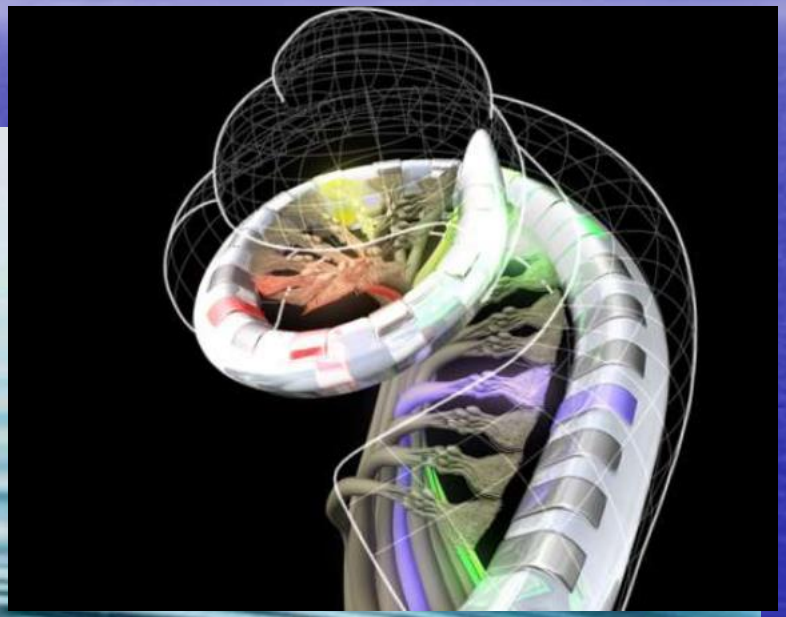
- It is a cavity within the temporal bone of our scull.
- The cochlea, literally snail shell, is a spiral tube with 2 ½ circumvolutions
- We can find there various sensors that inform the brain about the position of the head and the state of equilibrium for our body!

- The incoming vibration is inserted to the vestibular duct by the by stirrup, which mechanically transmits sound energy towards the acoustic nerve.

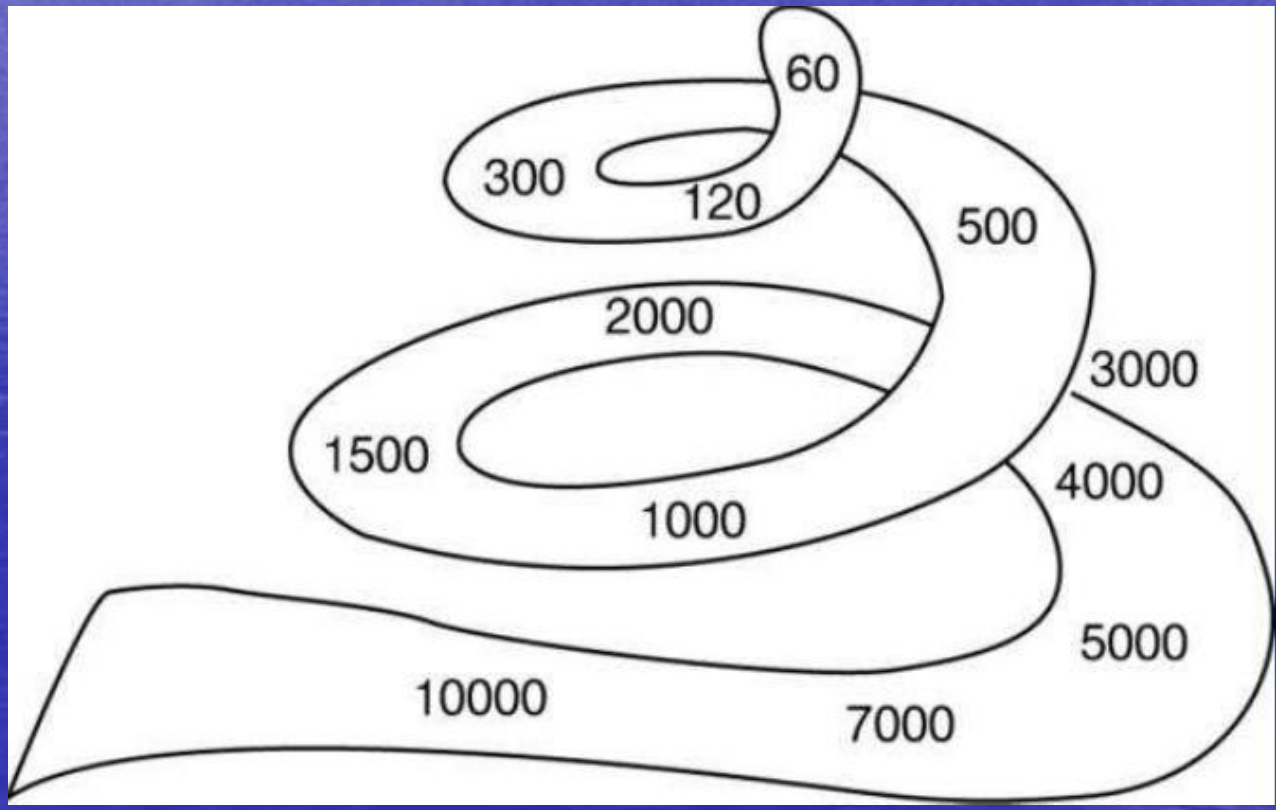


- The vibrations travel in various patterns through the cochlear fluid (perilymph and endolymph) and trigger the receptors (hair cells) of the organ of Corti.
- From there, the vibrations are transmitted to auditory nerve fibers r nerve s cerebral cortex, where they are interpreted.

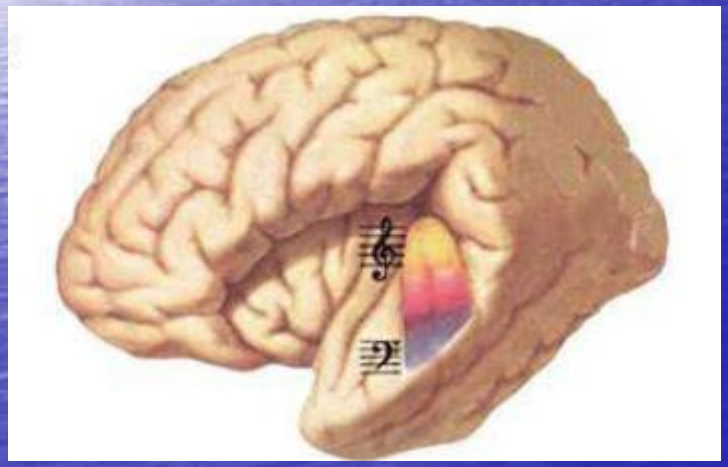


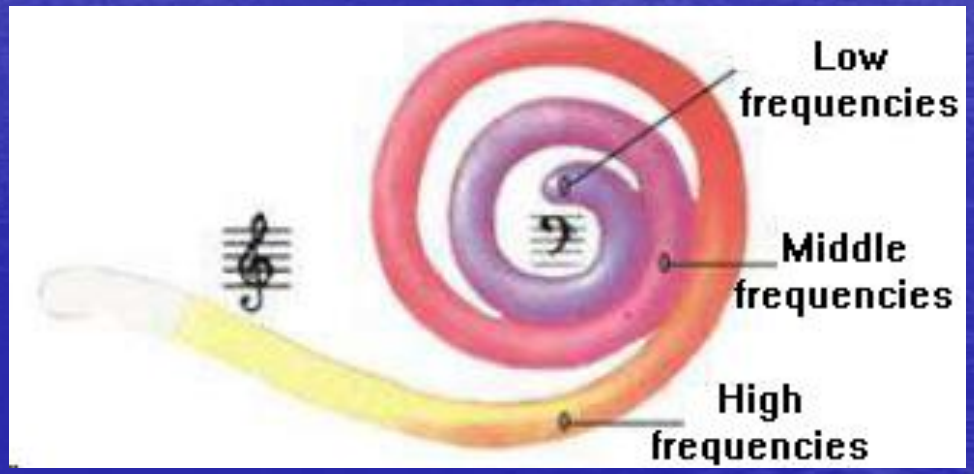


- The manner in which the basilar membrane vibrates in response to sound is the key to understanding cochlear function. Measurements of the vibration of different parts of the basilar membrane, as well as the discharge rates of individual auditory nerve fibers, show that both these features are highly tuned; that is, they respond most intensely to a sound of a specific frequency.

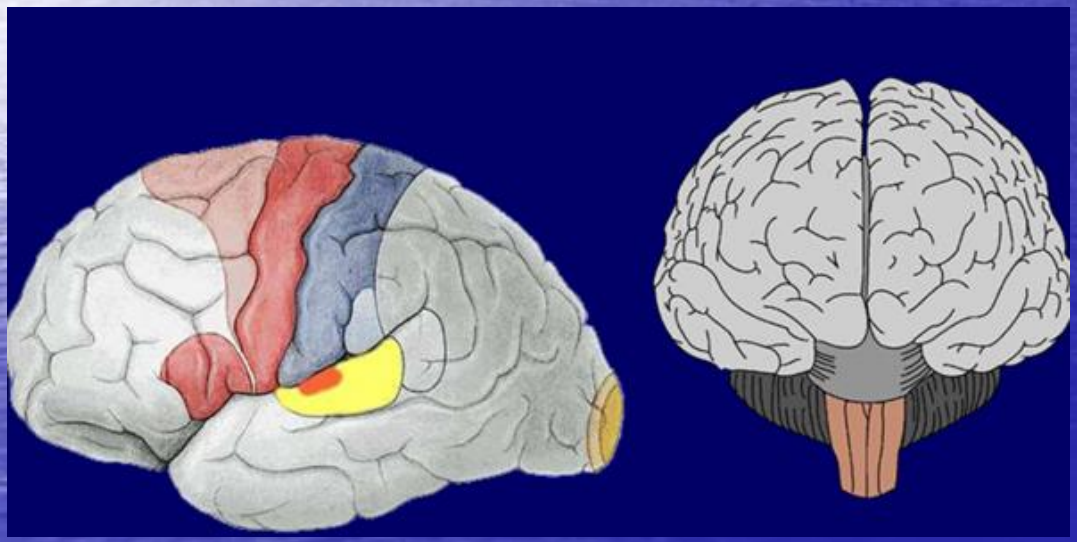


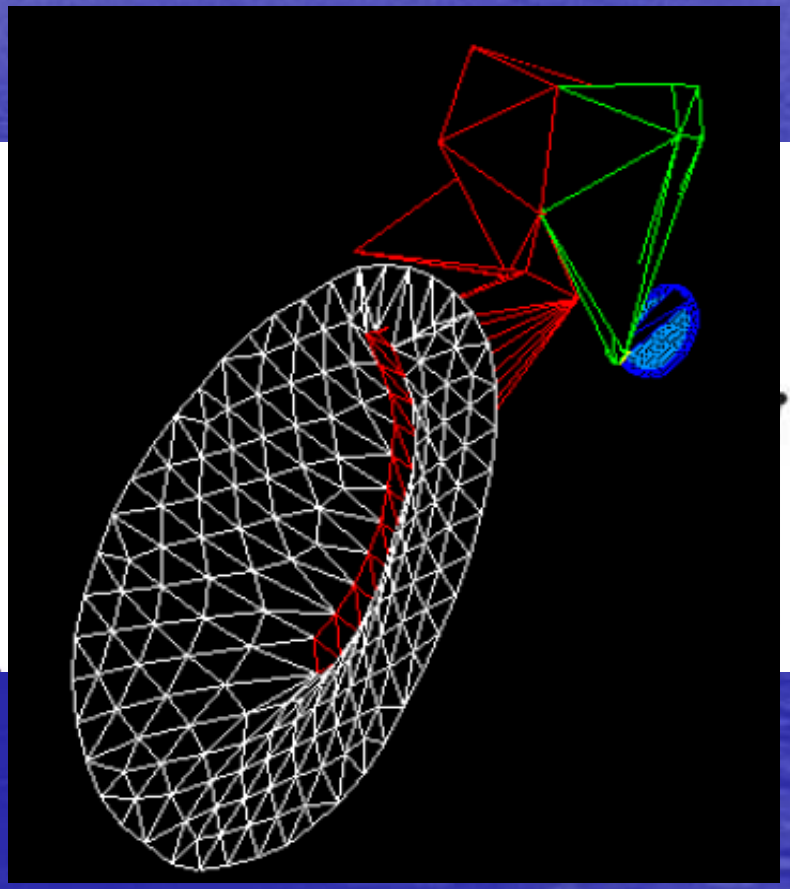
- So, objectively monitored magnitudes of physical phenomena, like intensity and frequency for sound waves, are perceived by our brain as loudness and pitch.





- However, the process of hearing which is integrated at its final stages in the lobes of the brain, involves electrorheologic fields, chemical fields, piezoelectric fields, to name a few …





Dynamics of the sound source

- Science wants to provide a quantitative explanation for what we hear. We easily detect two thresholds:

  A. the lower limit or threshold of hearing, which represents the intensity of a sound barely audible;

  B. the upper limit or limit of pain which represents energy flow causing pain. Prolonged exposure to such sounds leads to the destruction of the hearing apparatus

- These limits may differ more or less from one subject to another.

Objective and Subjective elements of sound

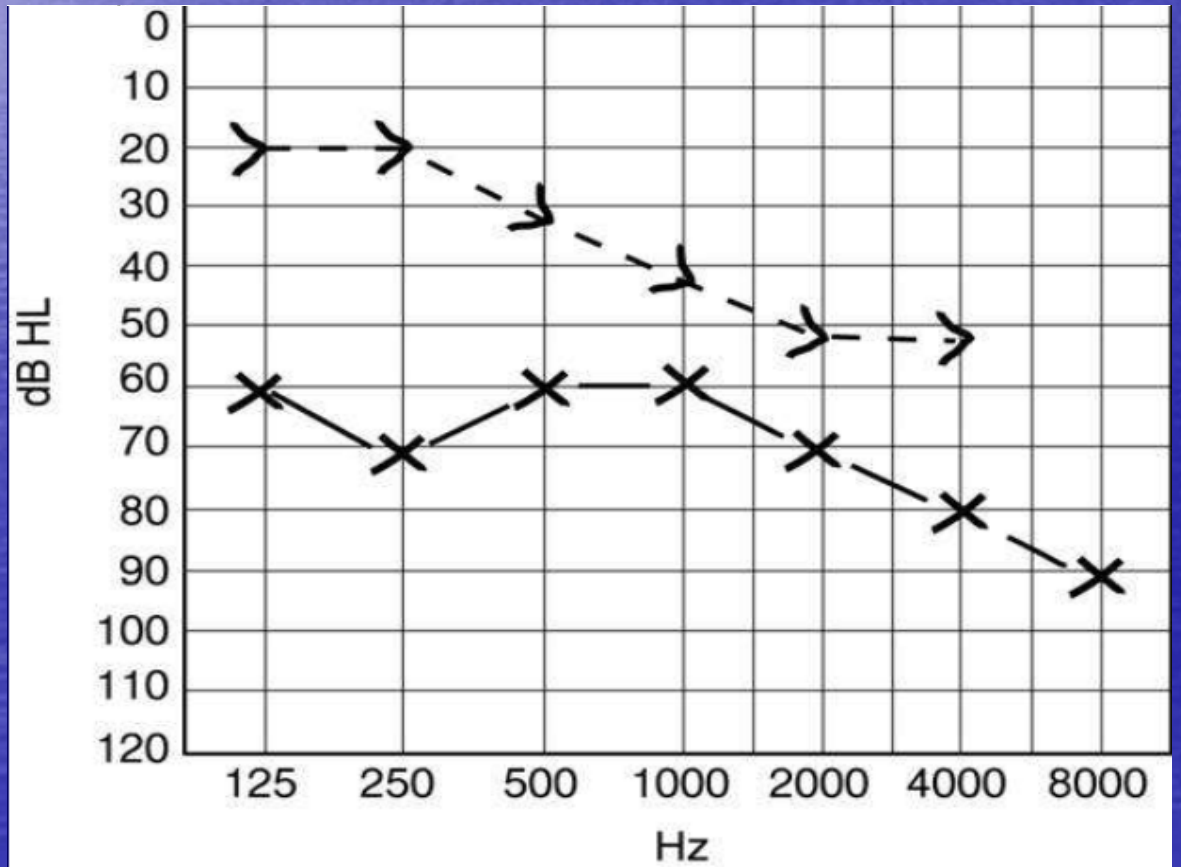
- **Intensity of a sound wave**: it is the sound energy transmitted per unit of time in a specified direction through a unit area normal to this direction at that point.
- Therefore, intensity is measured in Watt/m^2. Experiments have shown that for a tone of a 1000 Hz the average threshold intensity lies at about 10^{-12} Watt/m^2 whereas the limit of pain is near 1 Watt/m^2 ! This represents a ratio of intensities of one trillionth to one, a really impressive dynamic range.
- As a result, a more handy unit has been devised to denote how humans perceive the "volume control" of sounds: the **decibel**.
- The number of decibels for a sound of intensity I_1 is given by the following formula

number of decibels (dB) = $10 \log_{10}(I_1/I_o)$

which would yield for $I_1 = 1$ Watt/m^2 and $I_1 = 10^{-12}$ Watt/m^2 a mere 120 dB!

Objective and Subjective elements of sound

- The number of decibels we get for a hearing tone in a specific frequency gives the **intensity level (IL)**
- Experiments have been performed to establish the curves of equal loudness that denote how our hearing responds to acoustic signals
- The IL of sounds, a physical magnitude, produce psychological loudness levels, a subjective magnitude determining how humans perceive in various frequencies how loud a sound is!



Reference Note

Licensing Note

End of unit

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