Physics of Musical Sound

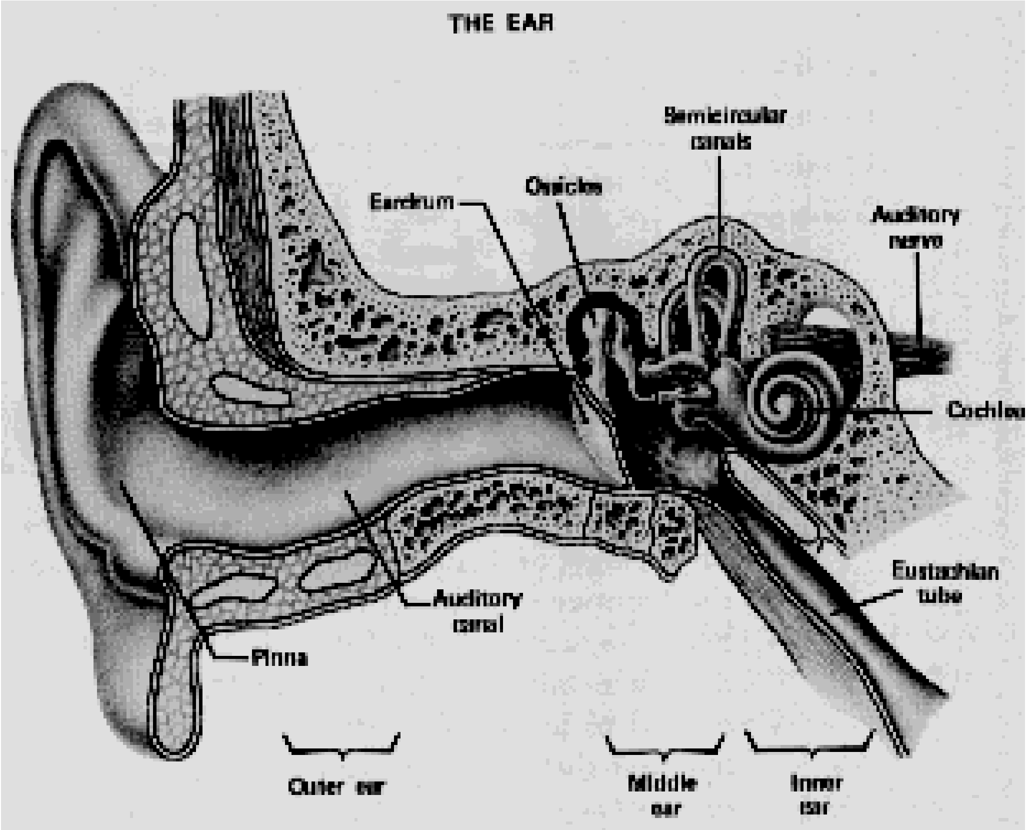
Class 7

Finish Chapter 5

Quiz today

Physiology of Hearing

- Sound collected by Pinna
- Enters through Ear Canal. Couples in low frequencies and has slight resonant enhancement for high frequencies.
    - 2-6kHz increased in pressure about 10 times (20dB).



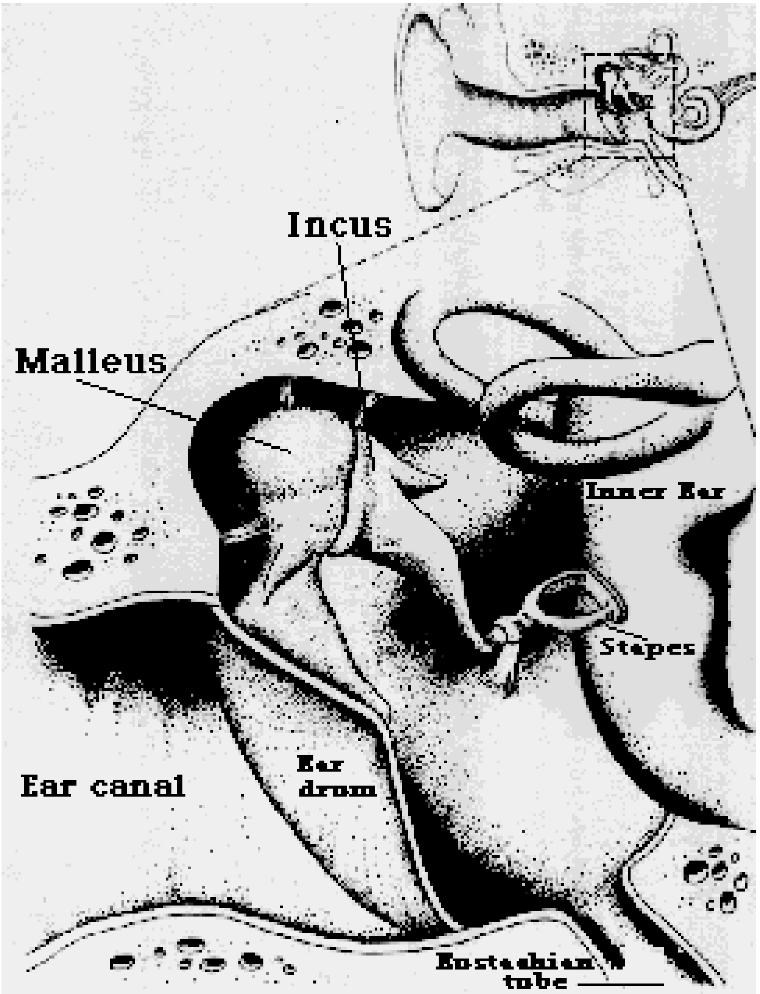
Physiology of Hearing

•Sound waves falling on Tympanum are converted to mechanical vibrations.

•Vibrations are transmitted through middle ear by Ossicles--Malleus, Incus, and Stapes.

•Ossicles act as lever system, reduce motion and increase force.

•Force is tripled and motion reduced by factor of 3.



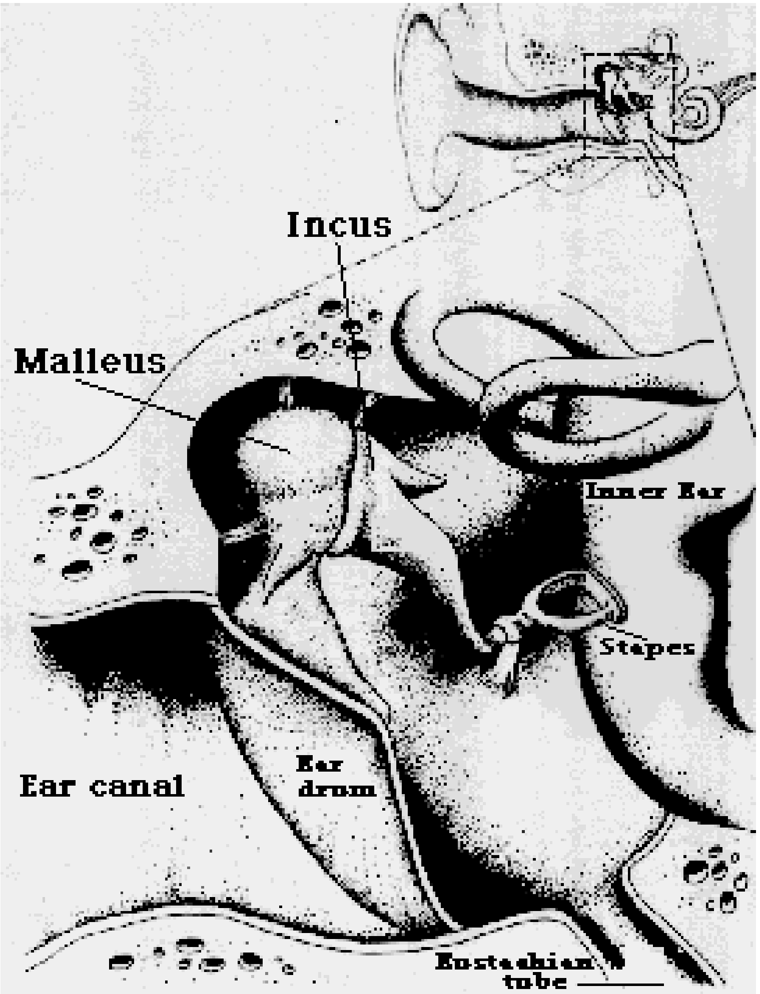
Physiology of Hearing

•Stapes presses on the Oval Window that leads to the Cochlea

•Oval Window is 15-30 times smaller than Ear Drum and this gives another 15-30 fold increase in the pressure.

•Pressure changes on oval window are about 100-800 times sound pressure changes!

•Eustachian tube balances average pressure with outside. Normal pressure variations due to weather and height variation are thousands of times variations due to sound.



Physiology of Hearing

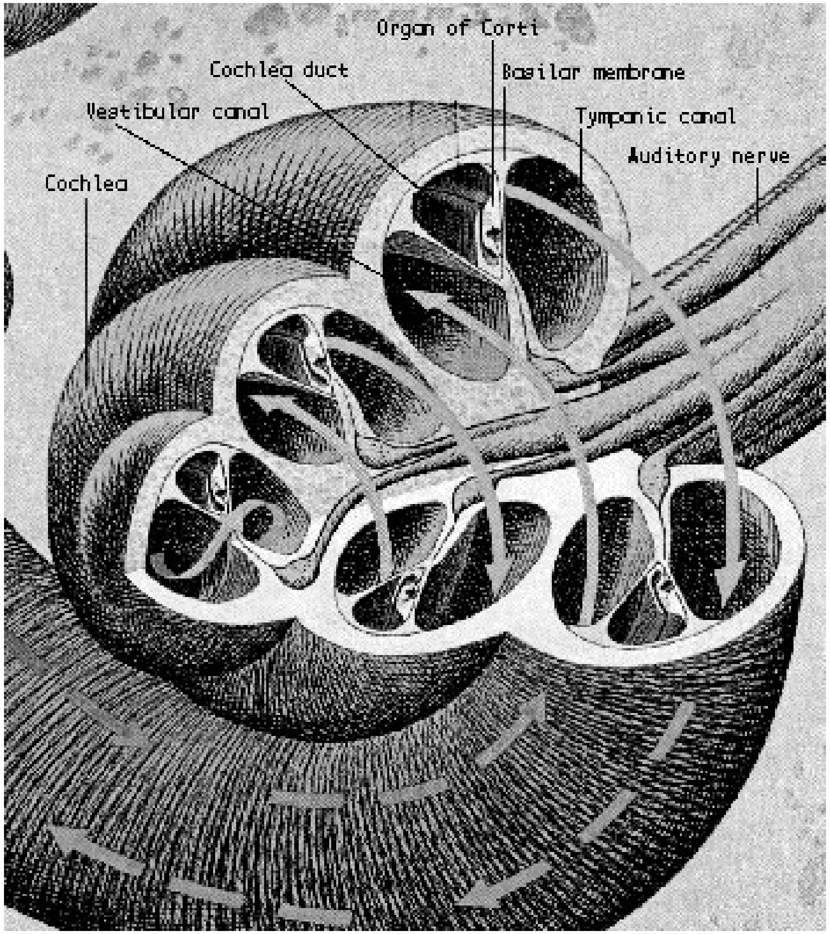
•Actual organ of hearing is Cochlea.

•3.5cm spiral tube filled with fluid.

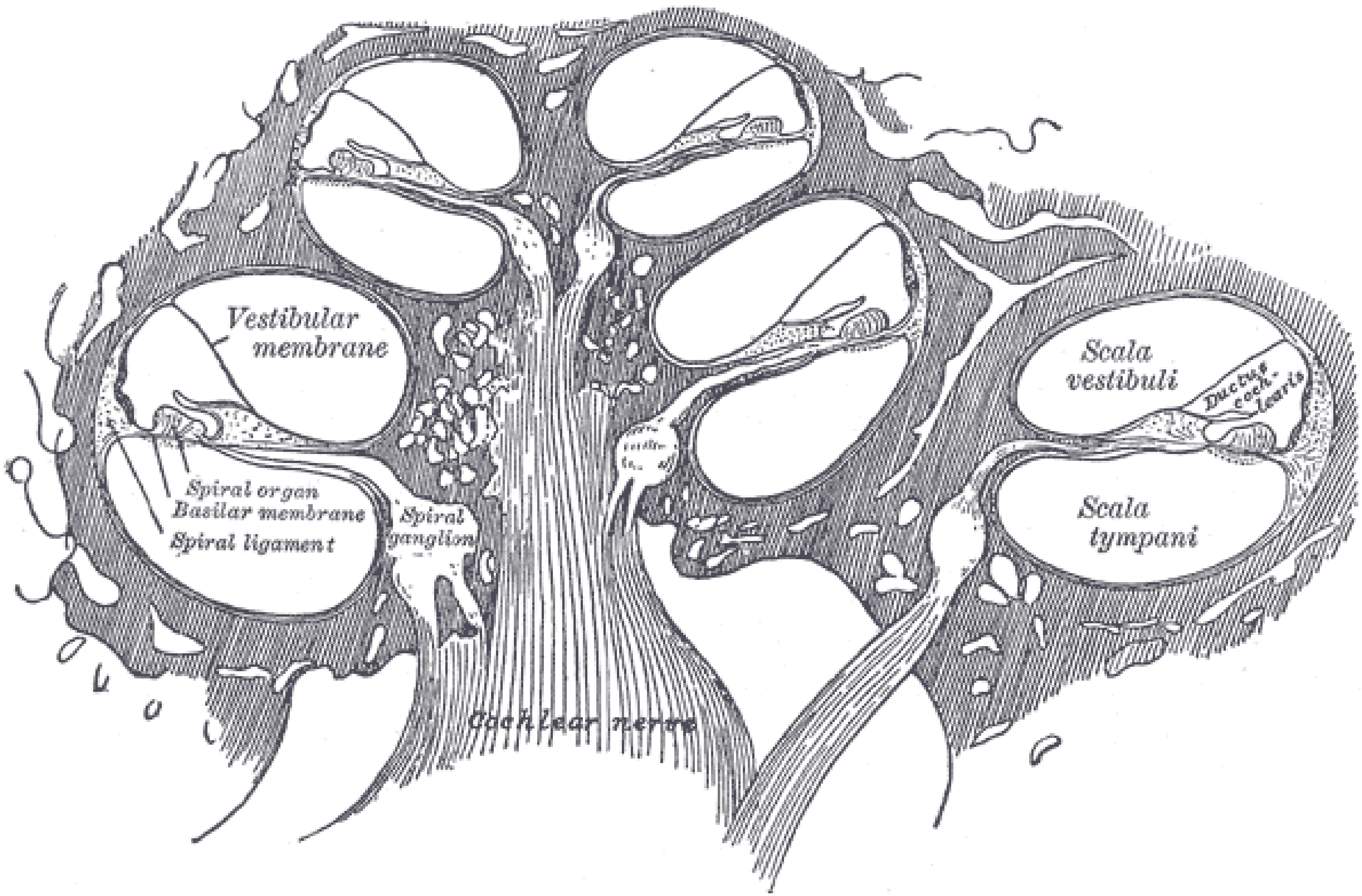
•Tube is separated down middle by Basilar Membrane into two chambers, Scala Vestibuli and Scala Timpani.

•Oval window connects Scala Vestibuli to middle ear. As it moves it pushes and pulls on the fluid in the ear.

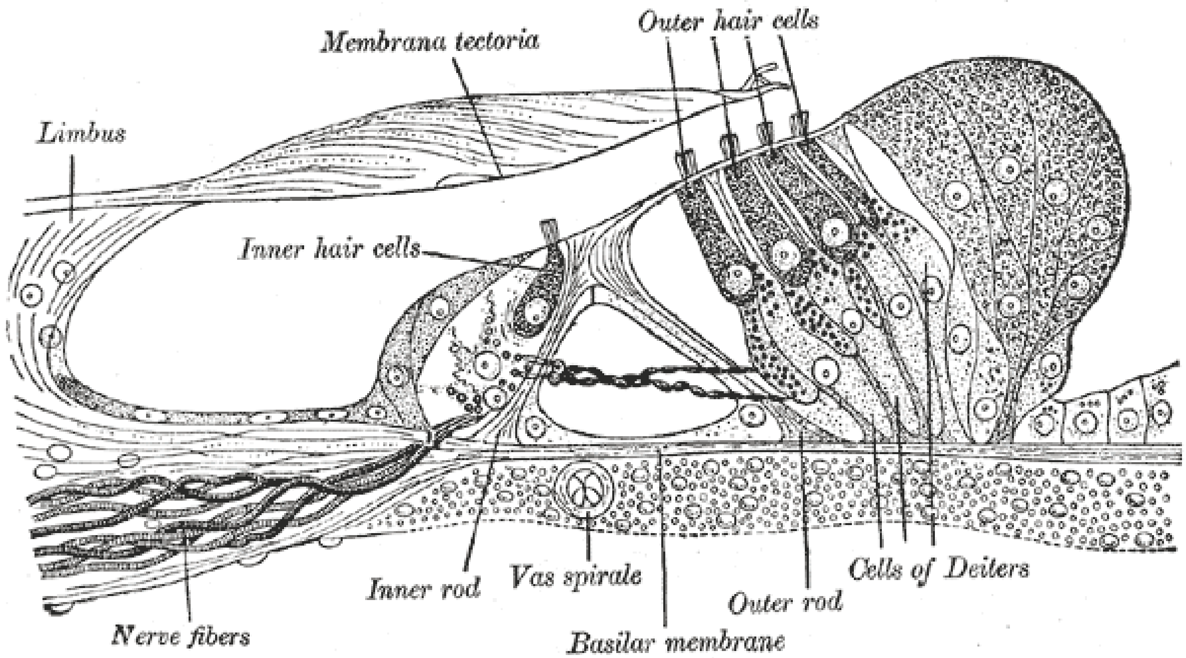
•At far end of Cochlea is a small hole in the Basilar Membrane, the Helicotrema. Fluid flows through this and up the Scala Timpani to the Round Window which bulges and bows as the pressure alters .



Physiology of Hearing



Organ of Corti



- As fluid flows the pressure changes affect tiny Hair Cells on the Organ of Corti which lies on the Basilar Membrane.
- Hair cells move and stimulate parts of the Auditory Nerve which takes signals to a special part of the brain called the Auditory Cortex.
- Part of Basilar Membrane nearest Oval Window is narrowest, lightest, and stiffest. Hair cells here respond best to high frequencies.
- As go along membrane get lower and lower frequencies.

Limits of Hearing

- Most sensitive around 5kHz due to resonance in ear canal. Ideally can hear 10^{-12}W/m^{2} but realistic minimum 10-100 times that.
- Much less sensitive at low and high frequencies.
- Lower limit on hearing pure sinewaves in 20-40Hz range (very bottom of piano).
- Upper limit around 20kHz. Most students can hear 18kHz, by middle age upper limit falls until at retirement age is about 5-10kHz (off top of piano).

Testing Limits of Hearing

- Different intensities of sound produce different responses in the auditory nerve--more amplitude more response.
- Again, we can measure the smallest difference in sound intensity that we can detect. This is the Just Noticeable Difference for intensity.
- Typical JND for intensity is about 0.5-1dB at 1kHz and 40dB. Gets a little larger at lower frequencies and intensities.
- Min. detectable increase in intensity is ~15-30%.

Testing Limits of Hearing

- Different positions on the basilar membrane respond to different frequencies.
- Our ability to distinguish frequencies is determined by how close two points on membrane can be and appear as two distinct signals.
- Compare ability to distinguish with touch. On finger tips can distinguish <<1mm but on back may only distinguish several cm!
- Call smallest difference in frequency we can hear a Just Noticeable Difference.

Critical bands