Auditory system

Section 1: energy transduction

Recall: first goal of a sensory/perceptual system is to transduce environmental energy into neural energy (or energy that can be interpreted by perceptual system).

in hearing:

environmental energy = pressure/sound waves.

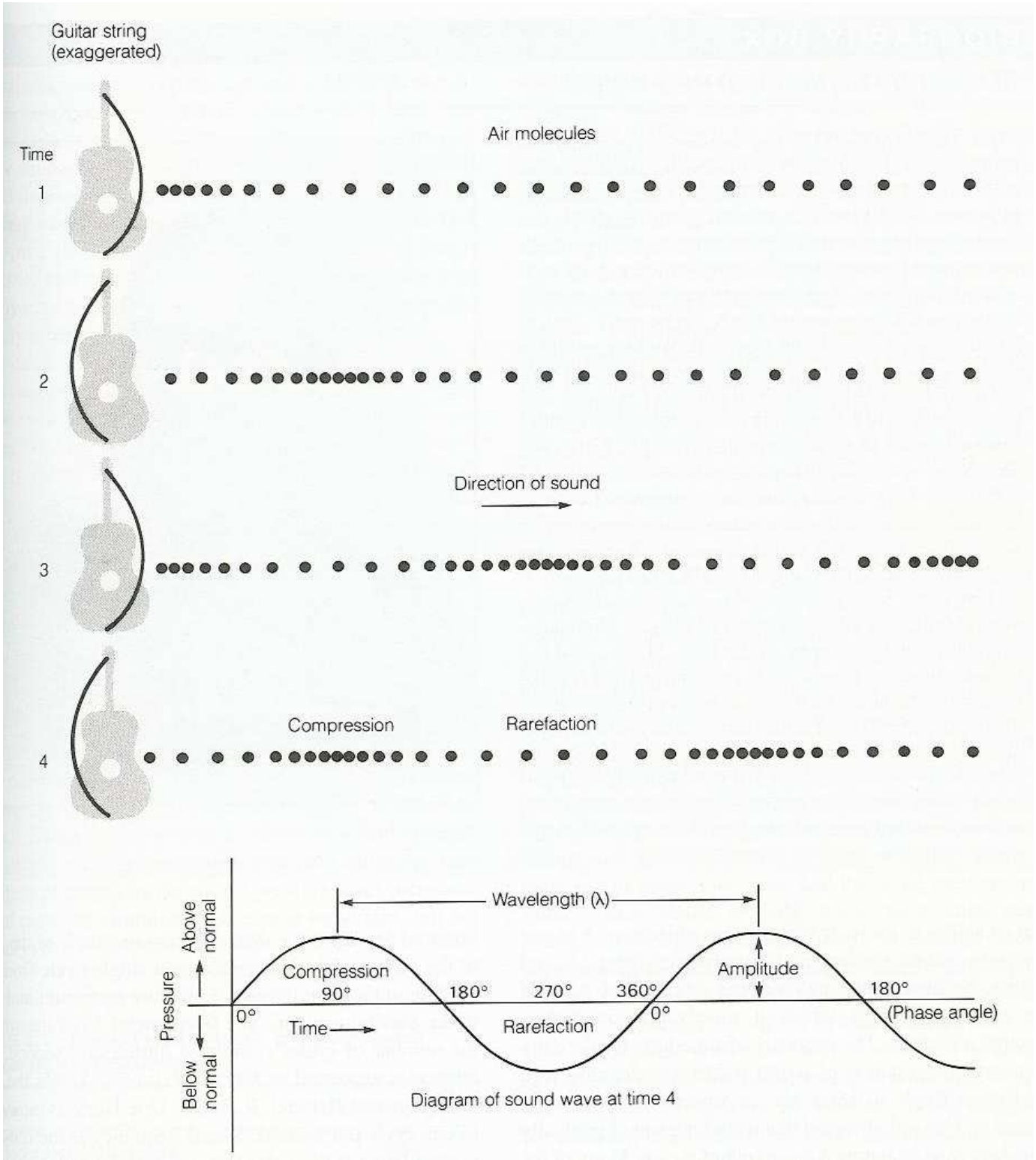
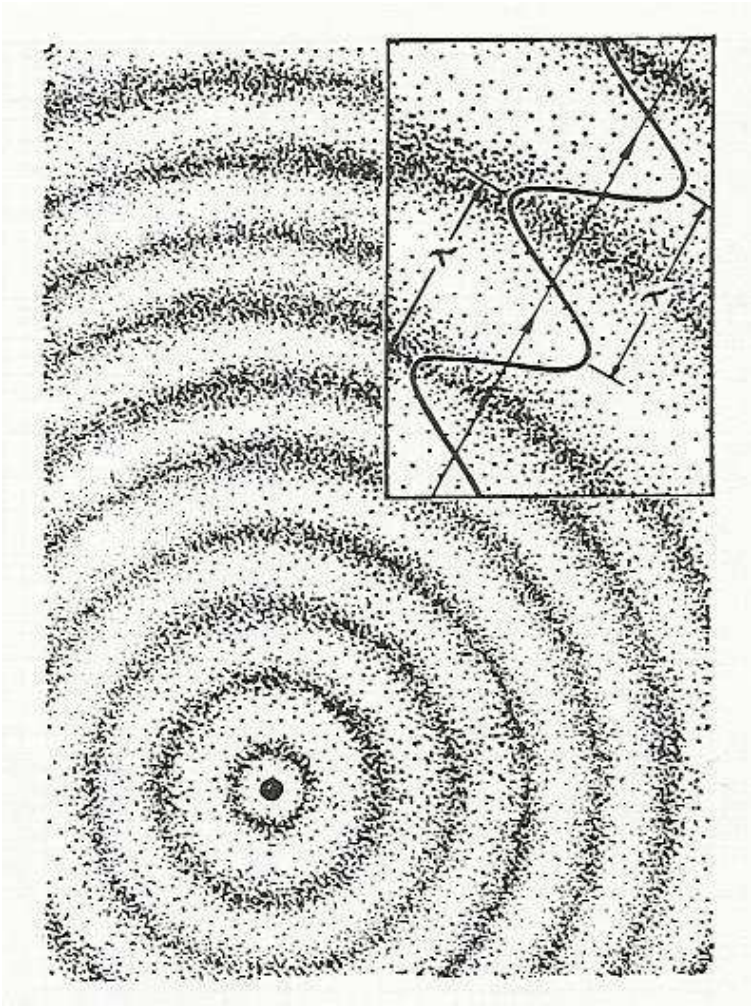
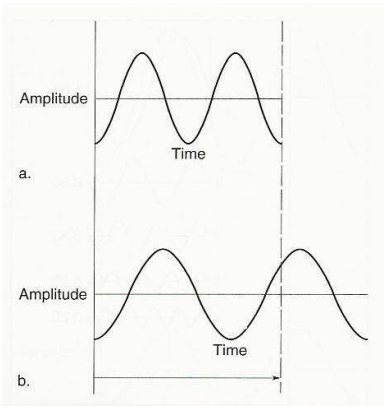


Diagram of sound wave at time 4



frequency vs. amplitude



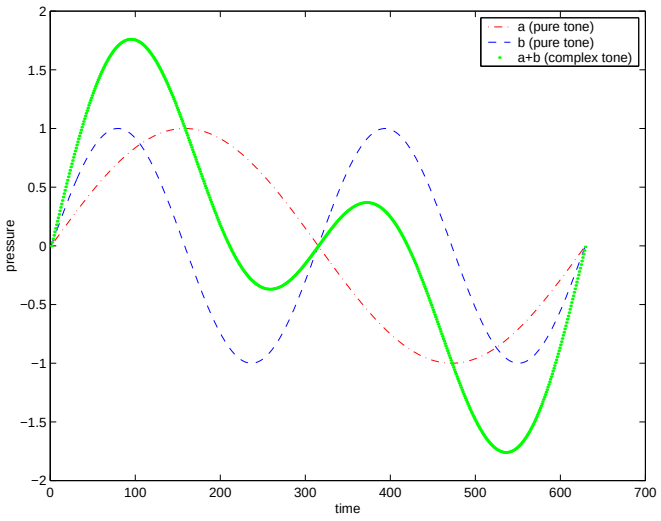
amplitude = loudness

frequency = pitch (measured in cycles per second, or Hz)

Humans hear tones with frequencies from 20-20,000 Hz

Highest sensitivity in 2000-5000 range. (Baby cry)

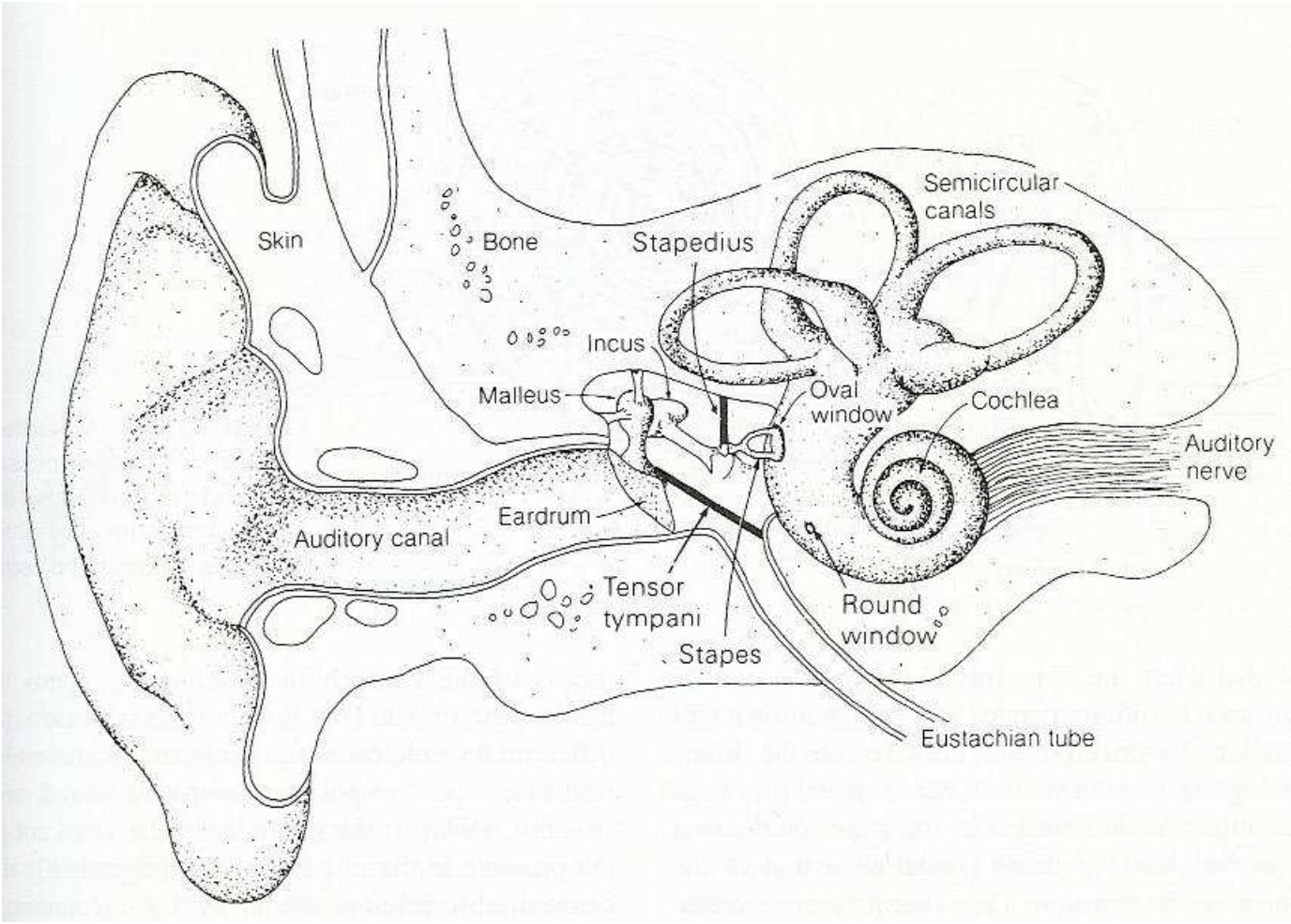
Most tones aren't pure tones, like above; they're complex tones:



Humans are fairly good about decomposing complex tones into pure components - fourier analysis!

Section 2: Anatomy

Ear divided into 3 parts; outer, middle, inner.



outer ear

pinna part you see; amplifies sounds around 400 hz; plays a role in sound localization

auditory canal cylindrical tube; conducts vibrations to eardrum; acts like a horn - amplifies sound (esp. around 3000 hz)

eardrum (tympanic membrane) pressure waves are converted into mechanical motion

middle ear

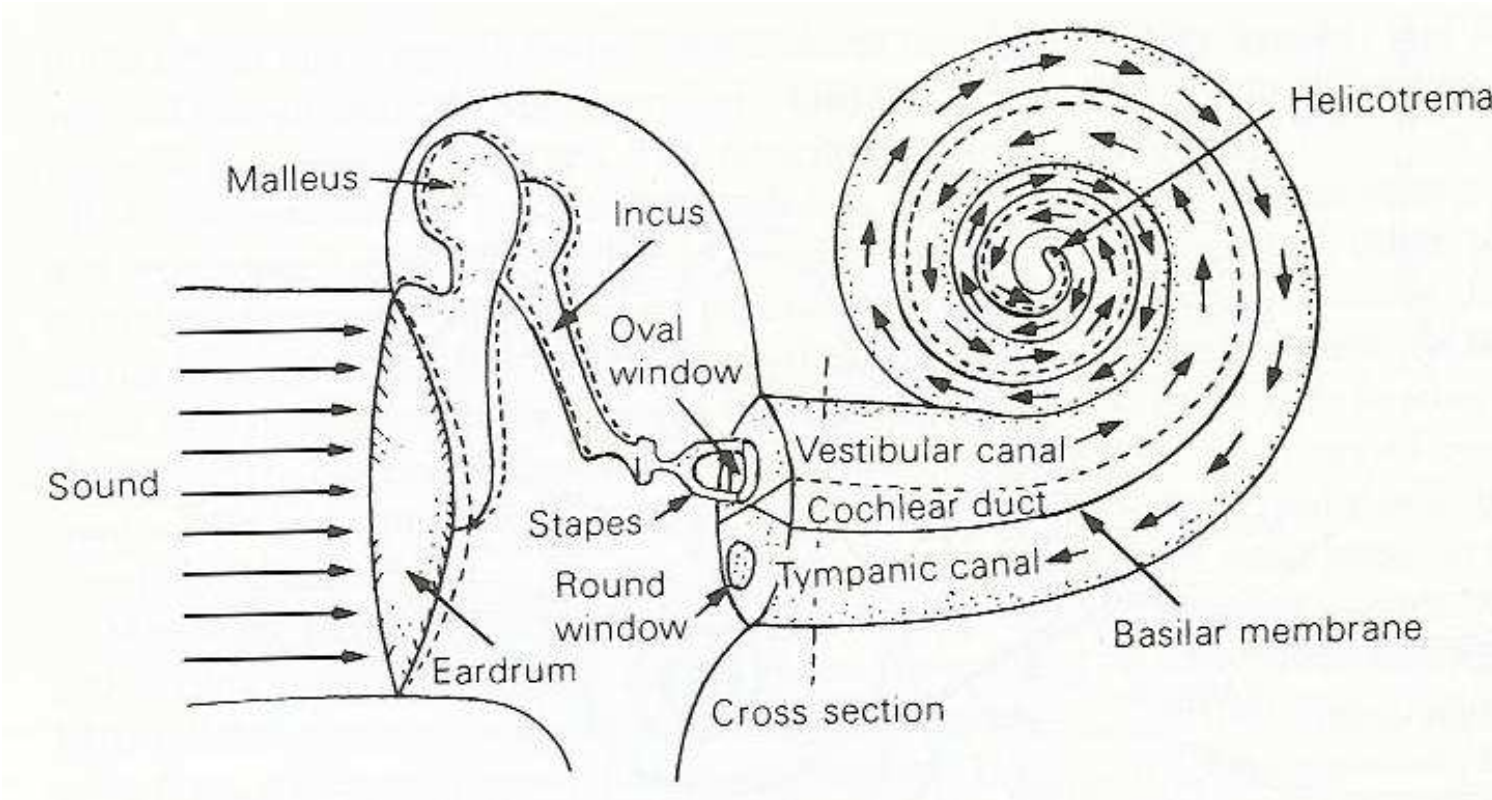
ossicles : malleus (hammer), incus (anvil), stapes (stirrup). conduct vibrations from eardrum to oval window; more amplification;

muscles attached to the ossicles can retract reflexively if loud, low frequency sounds are heard, reducing amplitudes at levels that might cause hearing damage.

eustachian tube : ossicles are surrounded by air; important to keep pressure in middle ear the same as pressure outside; otherwise eardrum would stiffen and become less responsive.

E. tubes go to throat, open every time we swallow, equalizing pressure. a cold can block tubes, resulting in hearing loss (usually temporary). Infection can be transmitted through E. tubes, esp. in children, causing fluid buildup - eardrum can bulge or even burst.

Bones of the middle ear are necessary because of the problem of *impedance mismatch*. Sound doesn't conduct well between air & water - most sound will be reflected back.



Middle ear problems - conduction deafness:

ear drum punctured

ear infection - fluid or solid build up in auditory canal.

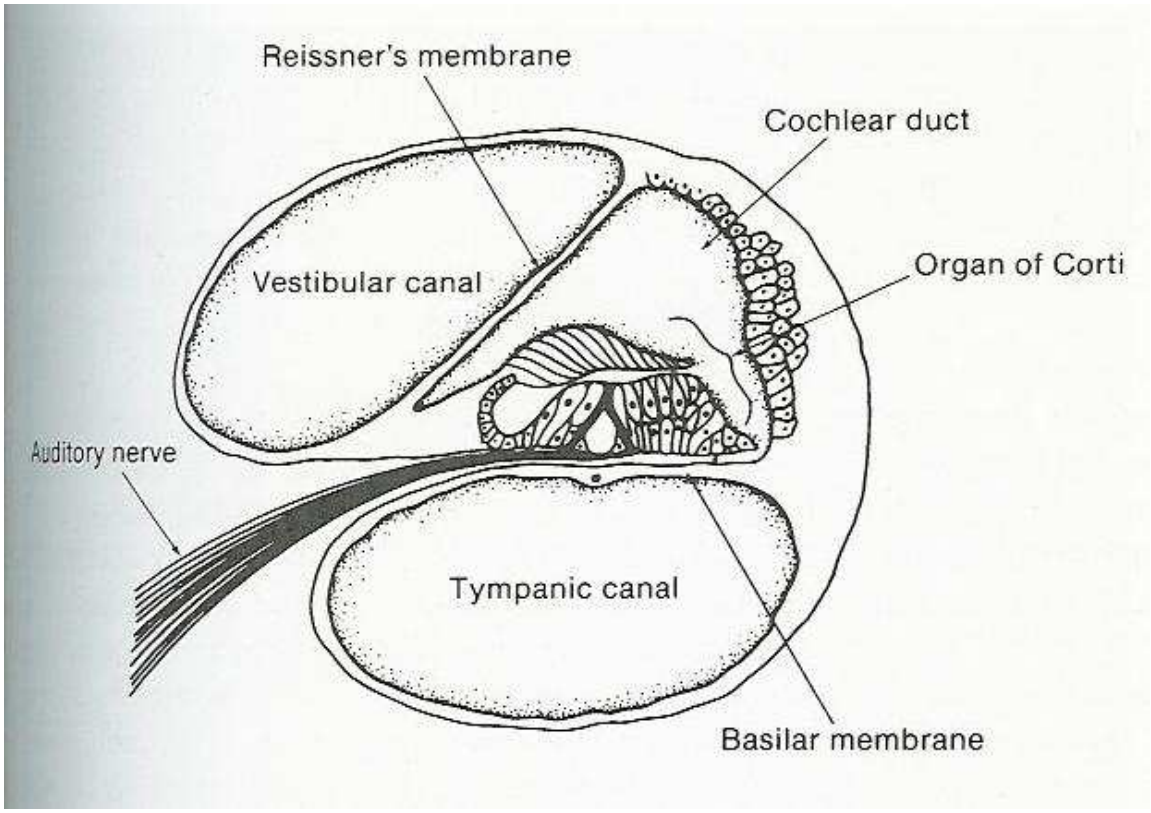
otosclerosis - stiffens stapes so won't function.

inner ear

semicircular canals : Already discussed - used for determining orientation, not hearing

oval window 1/15th area of eardrum; helps increase pressure & deal with impedance mismatch problem.

cochlea : snail-shell-like structure; contains auditory receptors that transduce sound into neural signals.

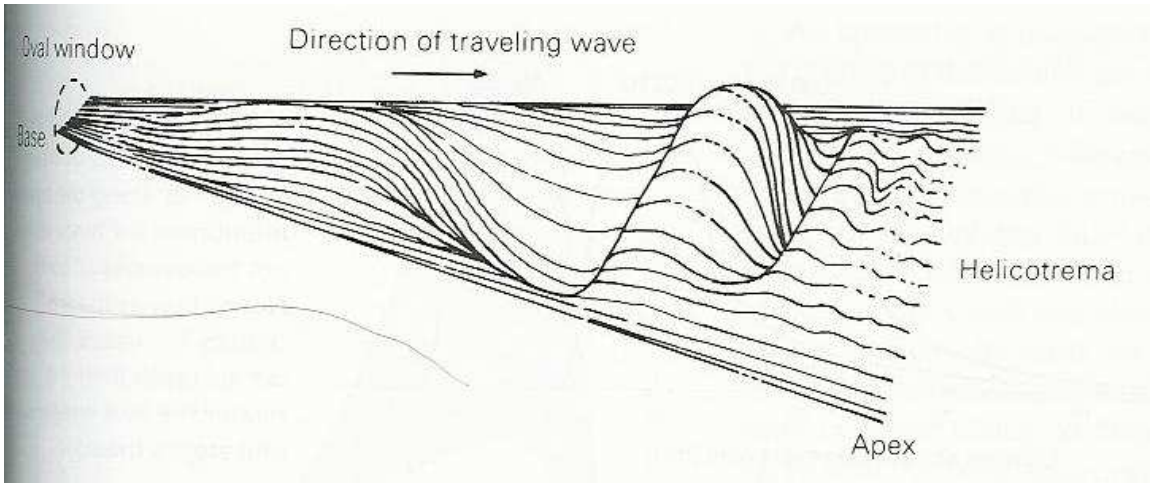


vestibular canal : next to oval window; liquid is set in motion here; vibrates reissner's membrane.

tympanic canal : connected to vestibular canal via *helicotrema* (basically a small hole). Vibrates basilar membrane.

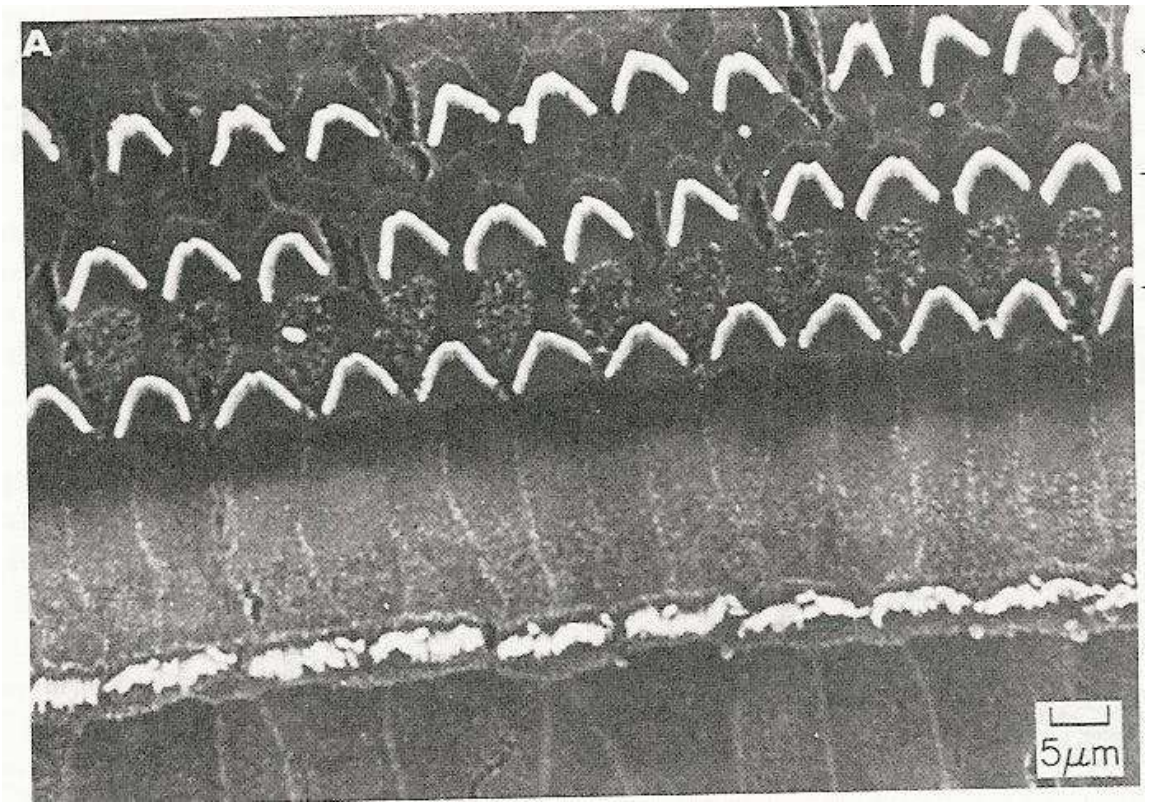
cochlear duct : separate canal, contains organ of corti.

basilar membrane : When pressure is applied to vestibular & tympanic canals, basilar membrane becomes distorted - creating a *travelling wave*

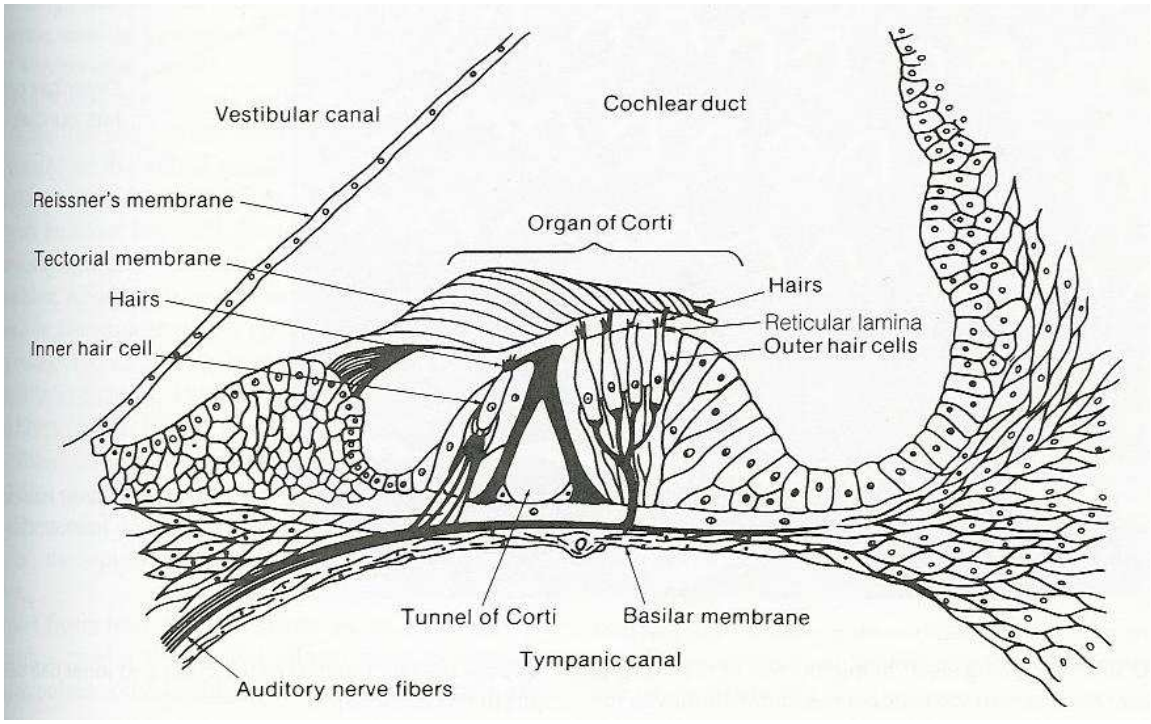


organ of corti : contains hair cell receptors that rest between basilar membrane & tectorial membrane.

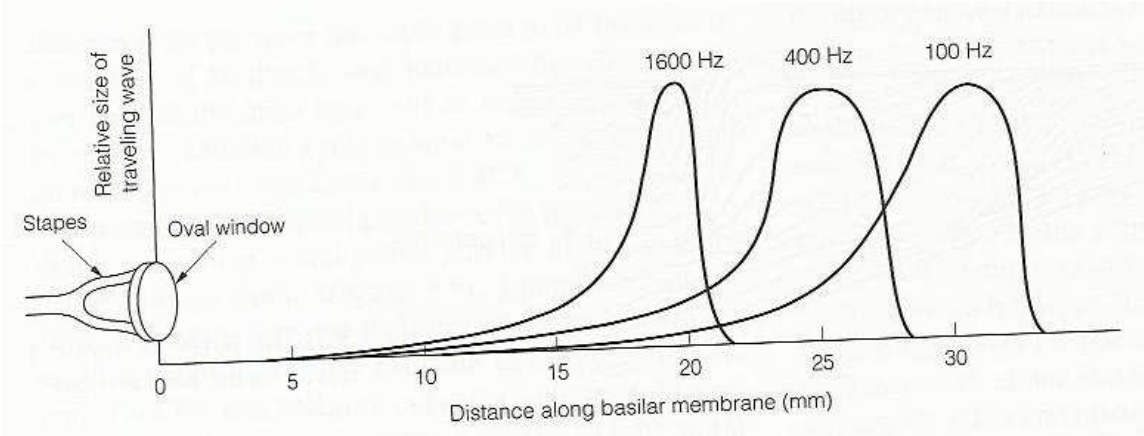
hair cells : receptors that cause cell to fire when tips are bent.



When basilar membrane is displaced, hair cells are bent by tectorial membrane; when a hair cell is stimulated, its neuron fires.



Basilar membrane vibrates differently depending on tone of sound stimulating it.



Different hair cells are stimulated for different tones!

inner ear problems - nerve deafness

hair cells damaged or broken - can cause tinnitus, ringing in the ears.

cochlear implants - can essentially replace a cochlea for people who have damage for any number of reasons. The implant breaks sounds into component frequencies & then stimulates auditory nerve, much as cochlea would.

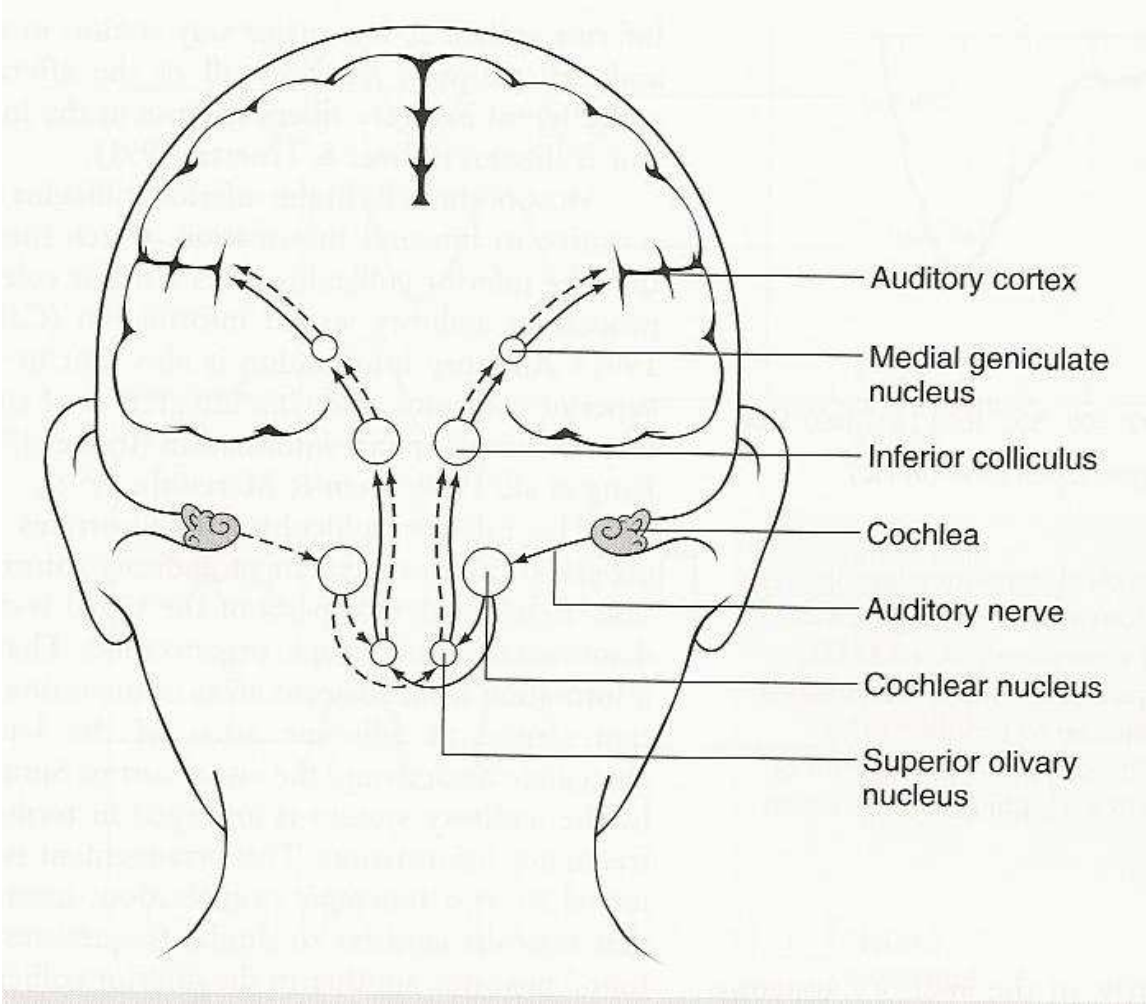
Bone conduction: alternate way of transmitting sound to inner ear.

sounds produce vibration in skull that stimulates inner ear directly (bypassing middle ear) - usually only low frequencies.

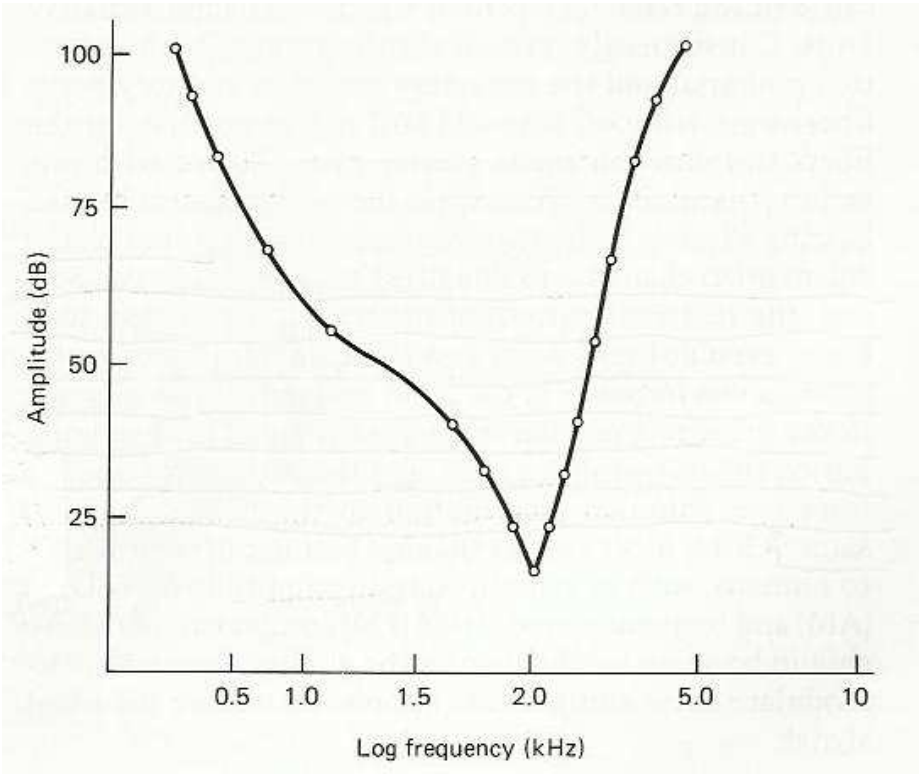
ex: chewing on food; dentists drill

explains why your voice sounds different on tape.

into the brain!



auditory nerve : like optic nerve, carries info from ear to cortex. Different auditory neurons are sensitive to different frequency tones - frequency tuning curves:



cochlear nucleus first stop; transmits half info to same side of brain, and half to opposite side. (allows *binaural processing*)

inferior & superior colliculus : Superior colliculus involved in integration of vision & audition. I.C. has *tonotopic organization*, meaning neurons sensitive to similar tones are found near each other.

auditory cortex : Still tonotopic, some cells require more complex stimuli (than mere pure tones) to become active; clicks, bursts of noise, etc. - similar to edge detectors in visual cortex.