THE AUDITORY SYSTEM (p.1)

1. The Sound Stimulus

a waveform of different pressures (usually air, could be water, etc.)
of less to more to less to more, etc. compressed air/water molecules
(lower to higher to lower to higher air/water pressure waves)

frequency of the waveforms = # compressions/second = **Hertz** = Hz
corresponds to **pitch** (greater frequency --- higher pitch)
human ear hears from **20 to 20K Hz** (no auditory damage)
elephant ear hears from 10 to 35K Hz
mice, cats & dogs hear from 20 to 40K Hz
bats hear up to 120K Hz
seals & porpoise hear up to 180K Hz
Note: by age 40 years average adult in USA now hears only up to 12K Hz; loses 160 Hz/year after that…

amplitude of the waveform = intensity = **decibels** = dB
corresponds to **loudness** (greater amplitude --- louder sound)
human ear hears from **10 to 140 dB**
note: exposure to 140 dB is severely painful; exposure to 120 dB for even a few minutes --- kills auditory sensory receptors/ nerve cells; exposure to sound above 100 dB will also cause hearing loss if prolonged (e.g. 40 minutes)
"dose-response curve"

"audiogram" = similar to a spectral sensitivity curve, but for sound
sensitivity to sound on Y-axis, wavelengths/frequency on X-axis

sound have hearing tested about once per year from 40 years on, sooner if have noticed hearing problems
hearing and vision should be tested in preschool children

2. **Structure of the Ear**

pinna, ear lobe
external ear canal
tympanic membrane (ear drum)
middle ear & middle ear bones (**malleus, incus, stapes**)
oval window, **round window**
cochlea: upper & lower chambers, Organ of Corti
basilar membrane, **tectorial membrane**
hair cells (12K **outer** h.c.s, 3.4K **inner** h.c.s)
h.c.s near oval window – sensitive to high frequency waves;
h.c.s near end of basilar membrane (apex) – sensitive to low frequency waves ("**place theory**" of hearing)
auditory neurons, axons form **C.N. VIII** ("acoustic" branch)
eustacean tube (between middle ear and throat)
inner ear & **semi-circular canals**
sense of direction/intensity of head movements
rotation, acceleration, deceleration, contributes to sense of balance
sensory neurons help also form C.N. VIII ("vestibular" branch)

3. **Auditory Pathway into the Brain**

hair cells (inner) --- 1st sensory neurons --- axons form C.N. VIII --- **cochlear nucleus** (in medulla) --- **olivary nucleus** (superior olive) --- **trapezpoid body** (to contralateral side of brainstem) --- **lateral lemniscus** --- **medial geniculate nucleus** (thalamus) --- **primary auditory cortex** (in lateral fissure, dorsal/superior temporal lobe)

primary auditory cortex, 3 areas of **tonotopic organization**
columns of cells, each column responds to a given range of tones from a given ear or binaural
analogous to the "simple" and "complex" visual cells
secondary auditory cortex, 7 areas of organization
neurons here probably respond best to complex, biologically significant sounds (e.g. mating calls, alarm calls, etc.)
analogous to the "hypercomplex" visual cells in inferotemporal cortex

4. **CNS Pathway for Sound Localization**

hair cells --- C.N. VIII --- cochlear nucleus --- olivary nucleus (**medial superior olive** and **lateral superior olive**) --- trapezoid body --- contralateral lateral lemniscus --- **superior and inferior colliculi**

superior colliculus receiving axons carrying sound location are organized in a **"map" of auditory space** (not tonotopically)

this same structure also has inputs from visual system, which is organized retinotopically – in a "map" of visual space

thus, superior colliculus seems to do localization and coordination of both sounds and sights in space around *S*

cues to sound localization are: **time of arrival** at each ear and **loudness** at each ear

medial superior olive passes on time of arrival information

lateral superior olive passes on loudness information

ear stimulated first is closer to sound

ear stimulated by louder sound is closer to sound

5. **Miscellaneous**

Waardenberg's Syndrome

"**nerve" deafness** vs. "**conduction" deafness**

rubella/syphilis during pregnancy; anoxia at birth, hypothyroid; repeated exposure to loud sounds

otosclerosis

presbyacusia (senile hearing loss, esp. for high pitches)

damage to auditory cortex --- can hear but cannot identify complex sound

damage to midbrain tectum (colliculi) --- can hear/identify, cannot locate

damage to C.N. VIII --- cannot hear

drug effects: asperin, antibiotics (may cause "**tinnitus**")