9.09J/7.29J - Cellular Neurobiology, Spring 2005
Massachusetts Institute of Technology
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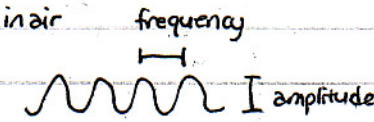
Lecture notes courtesy of Wyan-Ching Mimi Lee. Used with permission.

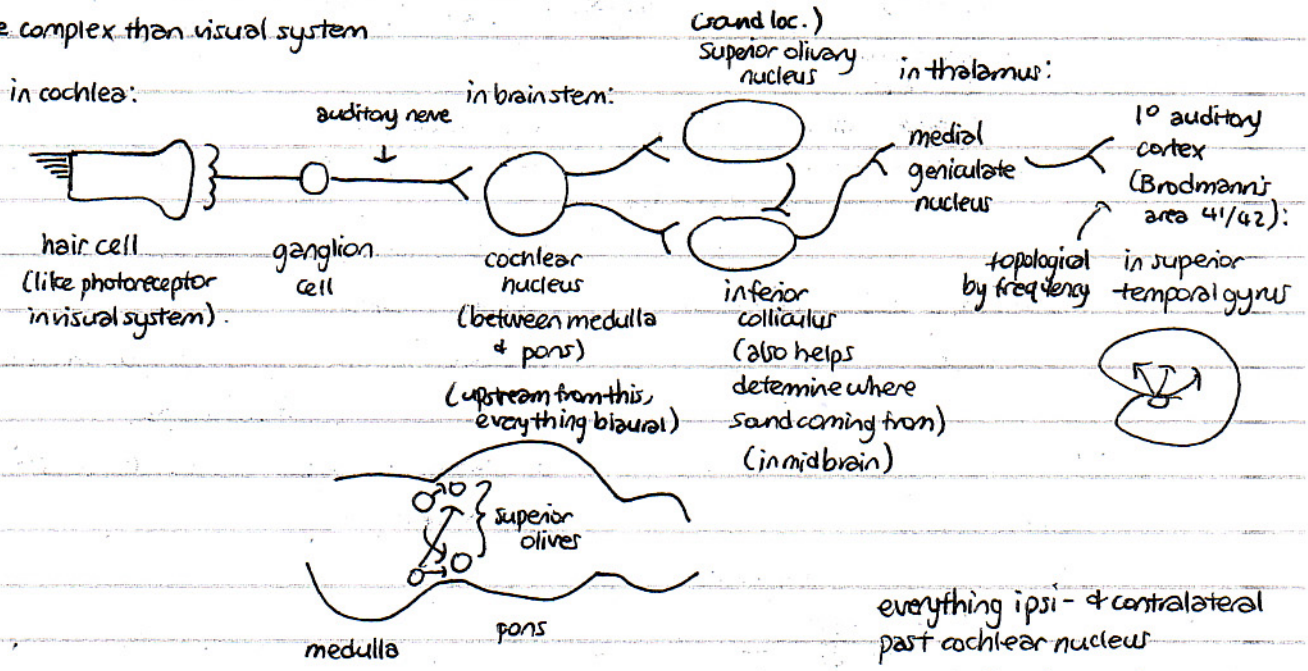
5/3/04

auditory system:

- very fast processing (visual system slower)
  - ↳ 2nd messengers etc.
- very sensitive: process 2 components of sound
  1. amplitude of sound wave (decibels)
     - human ear detects 0 → 120 dB, can detect 0.01 nm shift in air
  2. frequency of sound (Hz)
     - 20 - 20,000 Hz: speech ~ 1000 - 3000 Hz
     - 50 μsec detection (faster than synaptic transmission?) ← 1 ms



- more complex than visual system



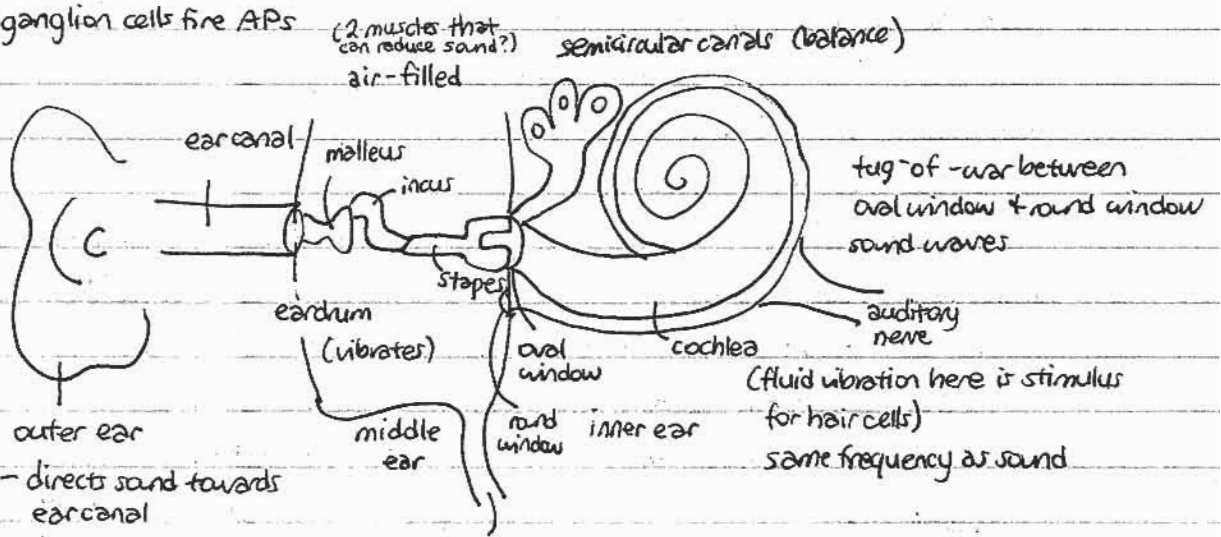
contralateral projections (each to other ~~auditory~~ olivary nucleus), allows to compare inputs from each ear

everything ipsi- & contralateral past cochlear nucleus
(to get hearing loss in one ear, must affect path before cochlear nucleus)
past this, must have bilateral lesions for hearing loss

↑ association area

Wernicke's area: important for language, unilateral lesion (esp. on left) can have devastating effects

- hair cells have graded potentials (like PRs & bipolar cells)
  - ganglion cells fire APs



tug-of-war between oval window & round window sound waves

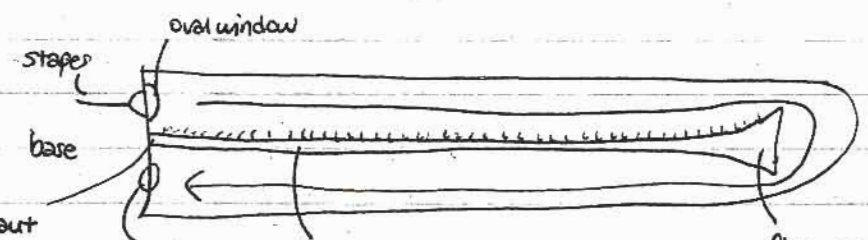
(fluid vibration here is stimulus for hair cells)
same frequency as sound

- directs sound towards ear canal
  (damage still lets you localize sound b/c one ear can do this somewhat)

if get ear infections, can get middle ear scar tissue
(common in children)
otosclerosis in old people, bone spurs in connective tissues
(can correct w/ prosthetic stapes)
or damage to cochlea, certain frequencies you hear over & over

eardrum is 35x bigger than oval window

unfold cochlea:



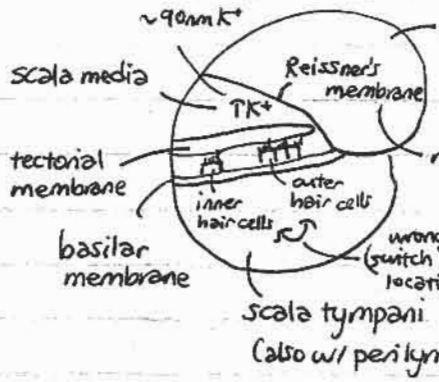
taut end
(vibrates well to high-frequency (20,000 Hz))
small hair bundles

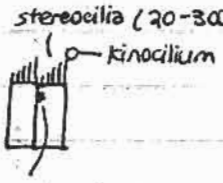
basilar membrane w/ hair cells
(moves up & down)
important in freq. detection:
acts as frequency decoder

floppy end
(vibrates well to low-frequency stimuli (20-200 Hz))
large hair bundles

Specific frequency will give vibration at specific area
- hair cells have <u>place code</u>

cochlear cross-section:

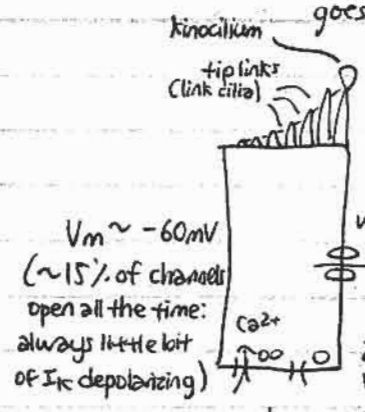




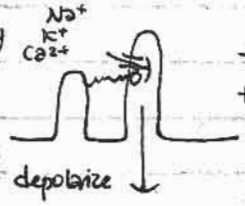
outer hair cells work in vibrating, help to vibrate basilar membrane

connections between hair cells so only cilia bathed in high K+ (rest of hair cell in normal fluid)
(adherens junctions)

- as basilar membrane goes up, //// goes down, ////



cycle resting potential just like sound wave

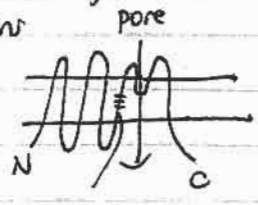


tip link connects to accessory protein that connects to channel

(activity)
no sign change:
acti fire at slow constant rate;
more w/ sound,
less when sound off

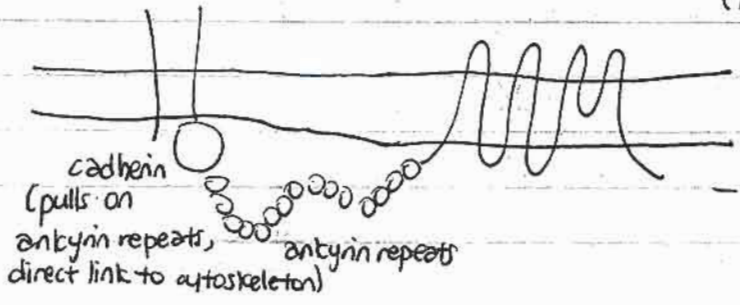
unusual b/c charge carried by only one ion (K+)
- this helps make it fast:
- direct gating of ion channel (ms time scale)
- K+ can come in & leave

ion channel that mediates mechanotransduction yet to be cloned in humans
- trp channel / (K+ channel)



S4 voltage sensor (not in trp)

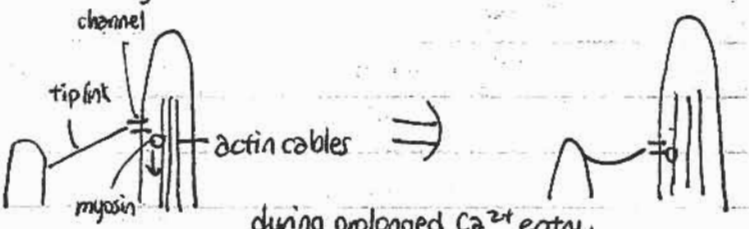
trp channels - 6 TM
- no S4
- very unusual N- termini (long, w/ ankyrin repeats)
↳ motif that binds cytoskeleton (eg actin)



- nonselective cation channel

- when hair bundle shifted, little bit of Ca^{2+} goes in channel (along w/ K^+)
  - adaptation to constant sound

  - change in way channel is gated



during prolonged Ca^{2+} entry, channel binds myosin, drags down actin cable, channels start to close:

now tip link doesn't activate channel anymore

air waves

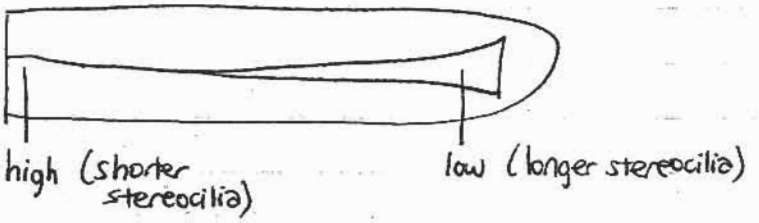
~~stimus~~ stimulus locking:
hair cell Vm oscillates w/ movement of stereocilia
(→ 3 KHz)
in upper ranges, doesn't keep up but talks to many ganglion cells

each hair cell talks to many (10-20) ganglion cells
- need dense body (particular to hair cells): like conveyor belt to release NT very rapidly

frequency of firing matches stimulus oscillation

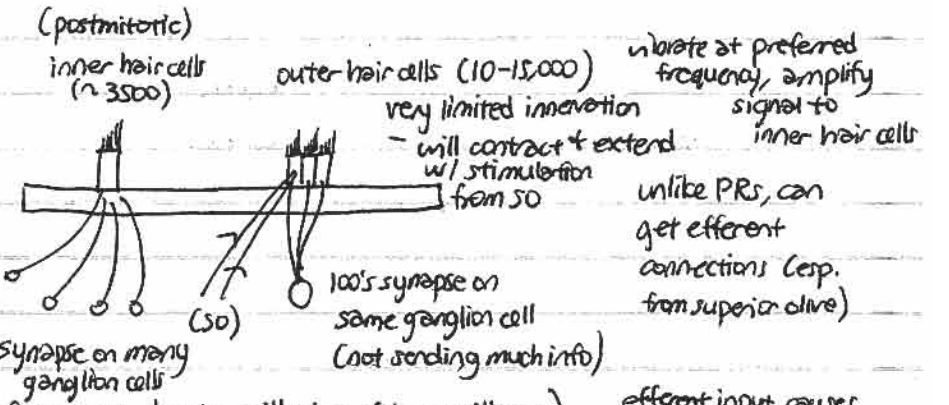
place code: depending on where hair cells are, encode particular frequencies

Stereocilia length also help tune to specific frequencies



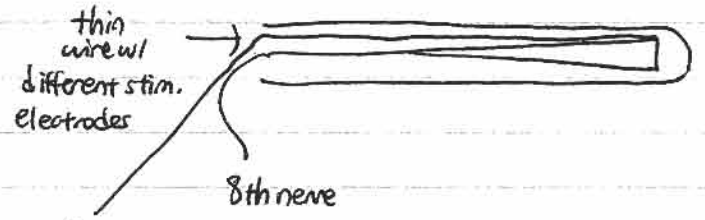
specific frequency response:

1. basilar membrane
2. stereocilia length
3. slo K^+ channels
4. outer hair cells

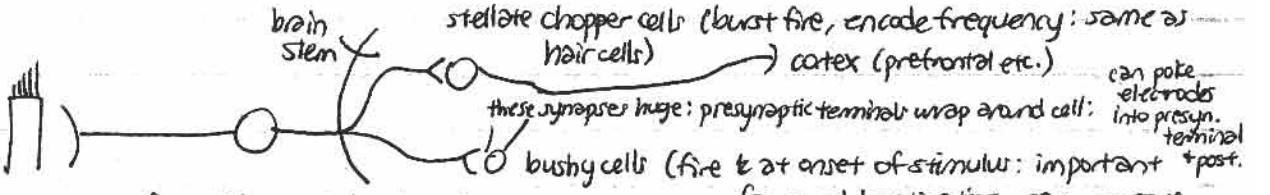


- hair cells can lock into particular frequency, best oscillation (V_m oscillates) — efferent input causes to vibrate?
  - stereocilia resonate
  - feedback between Ca^{2+} & efflux of K^+ (slo channels, voltage-gated)
    - many splice variants (placed along membrane) ie - also used in frequency tuning

- aminoglycoside antibiotics (eg kanamycin, streptomycin) block mechanosensitive channels, can kill hair cells over time
- loud noises can shear stereocilia: worst if same frequencies over + over
  - correct w/ hearing aids at base of eardrum (tune to defective frequencies)
  - can also use cochlear implants: if ganglion cells still alive



packet, motor, amplifier (frequency decoder) (doesn't work if have 8th nerve damage)
- takes place of basilar membrane frequency decoder, excite correct electrodes, stimulate correct axons



audio

no APIs

visual

no APIs