

Audition: Solutions to Exercises

BIO-311 Neuroscience
2023

1) (i) Explain what a “tone” with a pure sound frequency

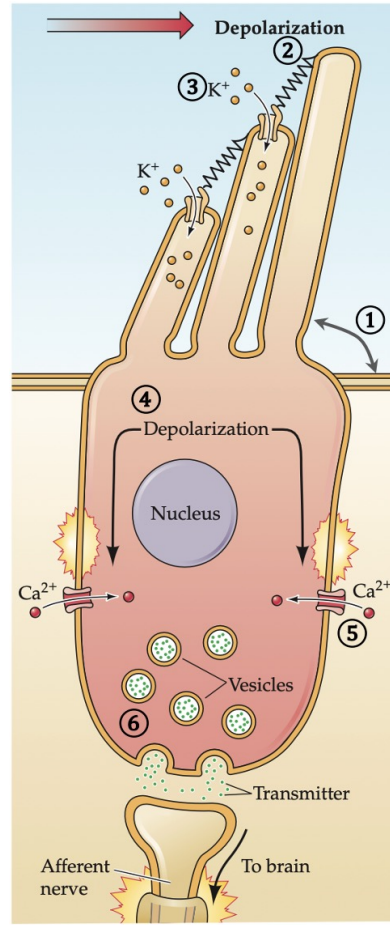
is. (ii) In which range of sound frequencies and sound intensities can the human ear perceive sounds?

(i) A pure tone is a periodic oscillation of air pressure with a single wavelength / frequency.

(i) Human ear perceives frequencies between 20 Hz (lowest pitch) to 20 kHz (highest pitch), and intensities from 0 dB (reference sound pressure level) to 120- 130 dB.

2) (i) Explain the primary sensory transduction process in hearing. (ii) In which cells does this take place?

(i)



03 – Mechanism From mechanical waves to electrical potentials

The ionic basis

Mechanical wave leads to shearing force

- ① Stereocilia bend
- ② Tip links stretch
- ③ Transduction channel opens
- ④ Depolarization of IHC
- ⑤ Ca^{2+} channel opening at the base of the IHC, local Ca^{2+} influx
- ⑥ Transmitter (glutamate) release at the base

(ii) Inner hair cell (IHC)

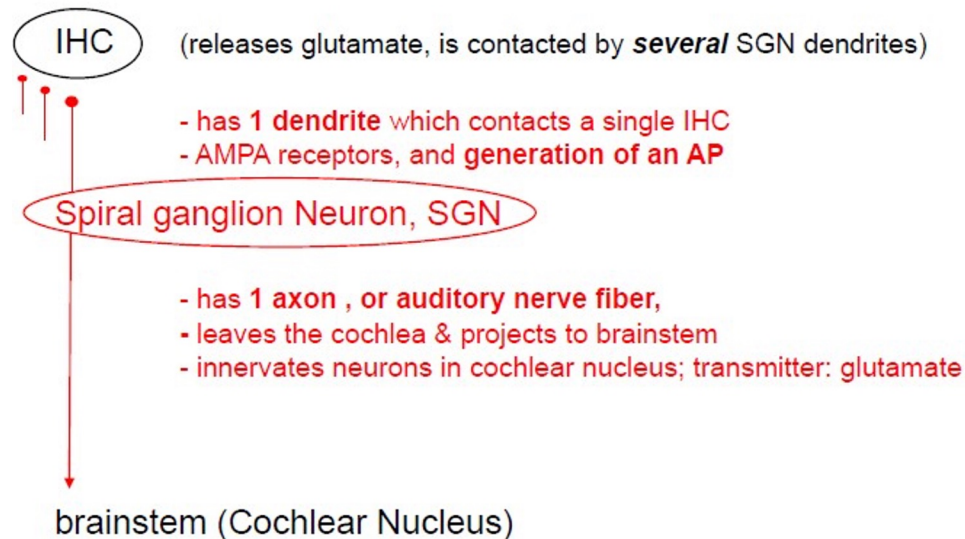
3) (i) Which neurons transmit the auditory signal from the cochlea to the brain?

(ii) Explain the anatomy of these neurons, which cells they contact, and which neuronal processes of these neurons (dendrite/axon), are involved where.

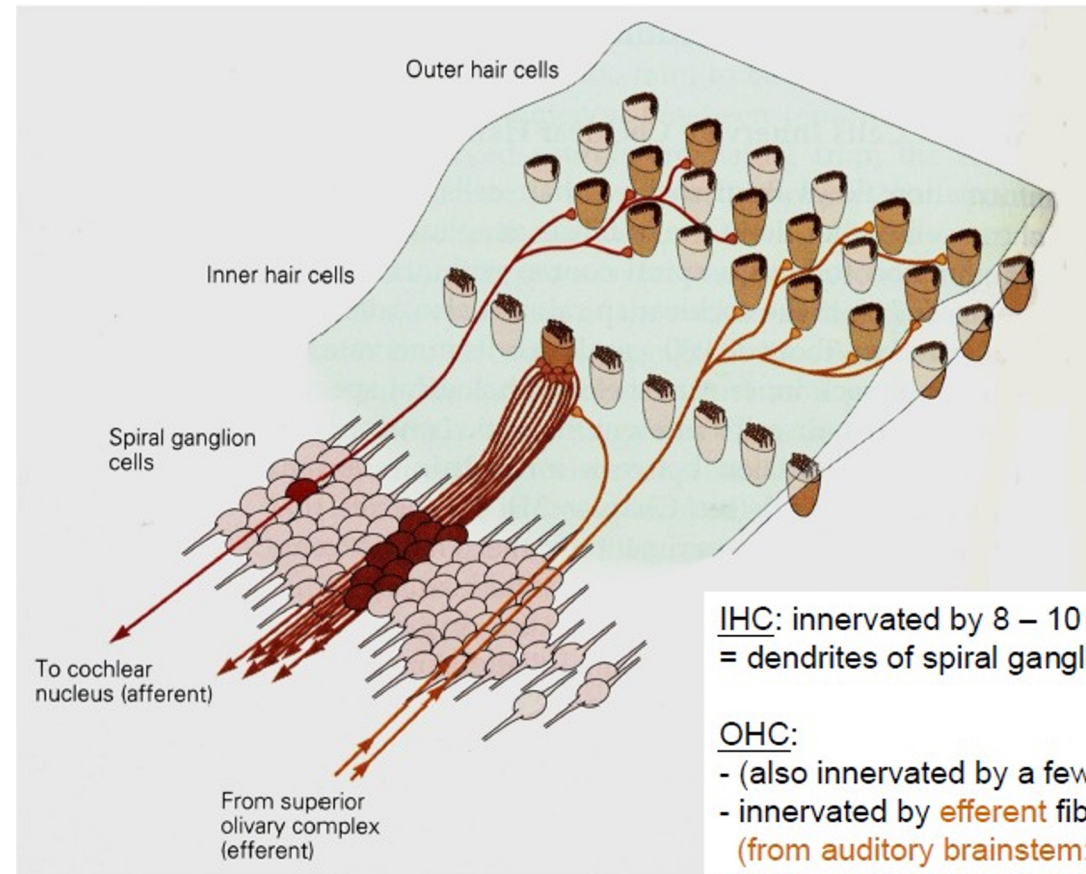
(i) Spiral ganglion neuron (SGN)

(ii) Each SGN has one dendrite which contacts a single inner hair cell, and has one axon (also called auditory nerve fiber), which innervates neurons in the cochlear nucleus

Summary of inner hair cell - spiral ganglion neuron connectivity:



Innervation of inner hair cells (and outer hair cells)



IHC: innervated by 8 – 10 **afferent** fibers
= dendrites of spiral ganglion cells

OHC:
- (also innervated by a few **afferent** fibers)
- innervated by **efferent** fibers
(from **auditory brainstem**:
superior olivary complex)

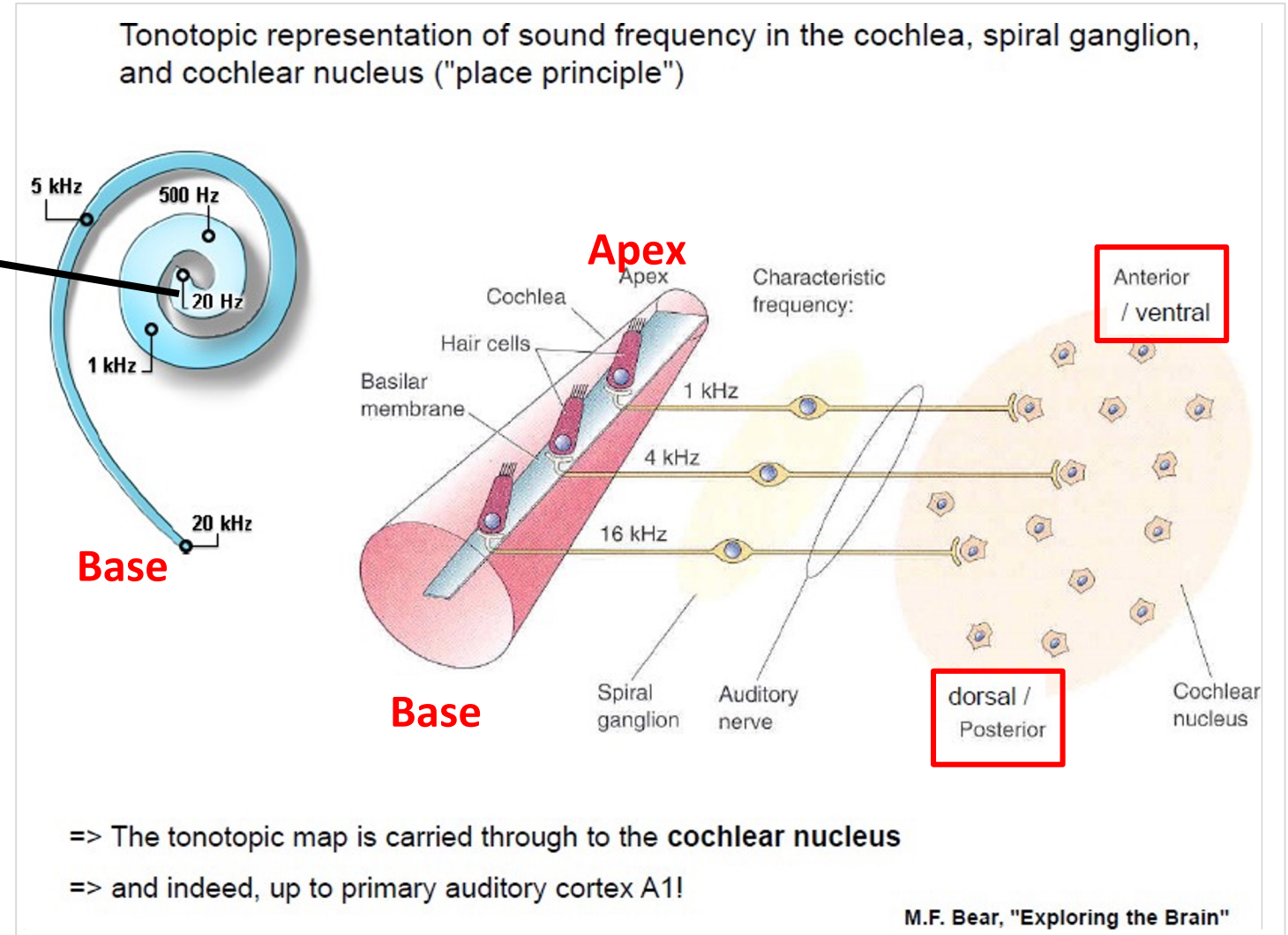
4) How is sound frequency decoded by the cochlea?

Describe how different sound frequencies are coded by i) an array of inner hair cells ii) by an array of spiral ganglion neurons ("SGN", which make "auditory nerve fibers"), iii) by an array of neurons in the cochlear nucleus.

i) in the array of inner hair cells (IHC), those IHCs sitting at the base of the cochlea will be activated by high-frequency sounds, and those at the apex by low frequency sounds (due to the mechanical properties of the cochlear partition)

ii) Thus, SGNs innervating IHC at the base will carry high-frequency sound information, and vice-versa.

iii) Because SGNs innervate specific areas in the cochlear nucleus along a tonotopic gradient, the sound frequency information is also coded by the localization of neurons in the cochlear nucleus

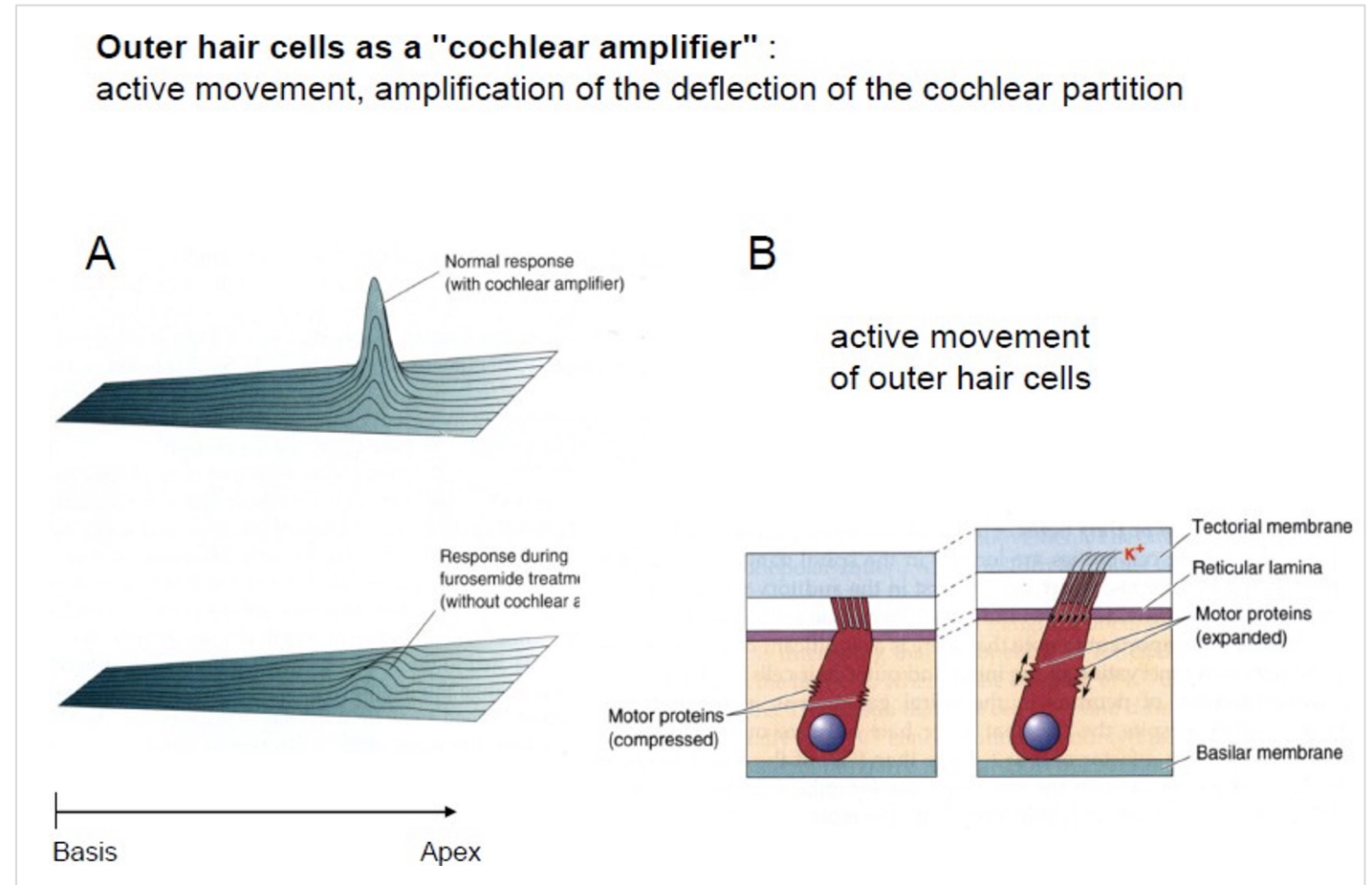


5) i) What is the function of the outer hair cells? ii) What can you say about the innervation of the outer hair cells (afferent vs efferent)?

i) outer hair cells (OHCs) amplify the movement of the tectorial membrane, and therefore the sound energy perceived by inner hair cells

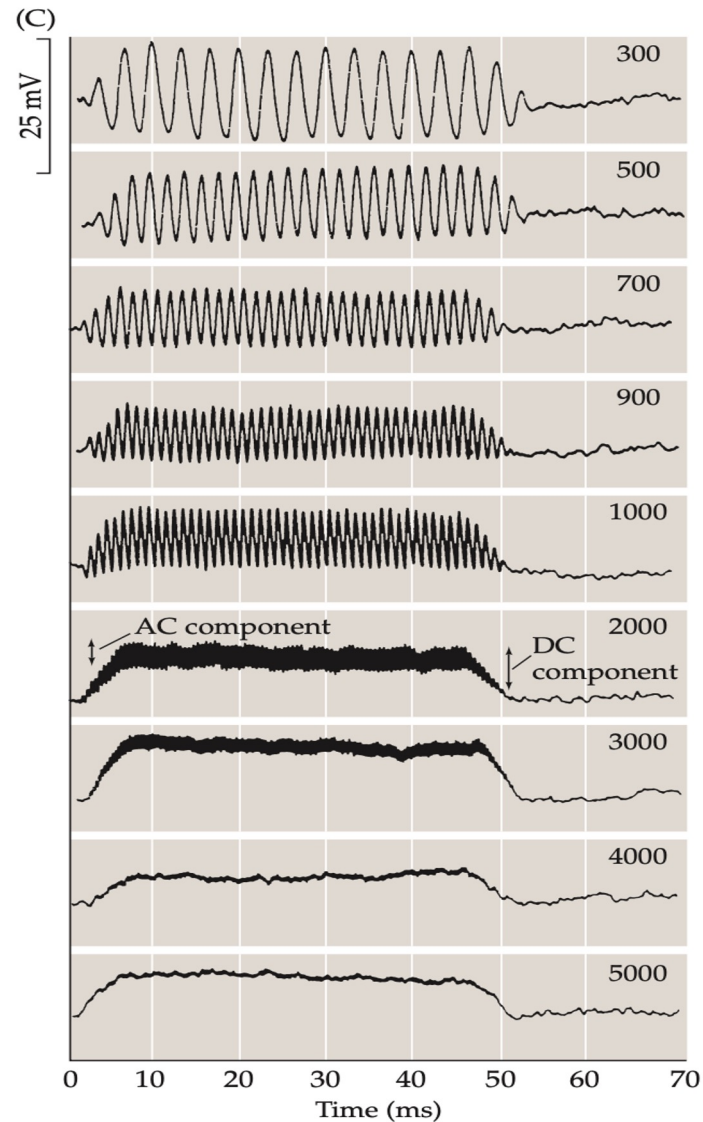
ii) outer hair cells receive only few afferent fibers ($\neq$ IHCs), i.e., mostly does not send info to brain

OHCs mainly receive efferent fibers from the brain. This "efferent system" hyperpolarizes the OHCs, and thereby down-regulates the amplifier function of OHCs



6) (i) Explain what is meant by the term of “phase locking”. Is phase locking a frequency-dependent phenomenon?

(i) Phase locking refers to the ability of an auditory neuron to synchronize its membrane potential (V_m) signaling to the frequency of sound. This occurs up to 1- 2kHz, so we can say that phase locking is frequency-dependent as it occurs until around 2kHz.

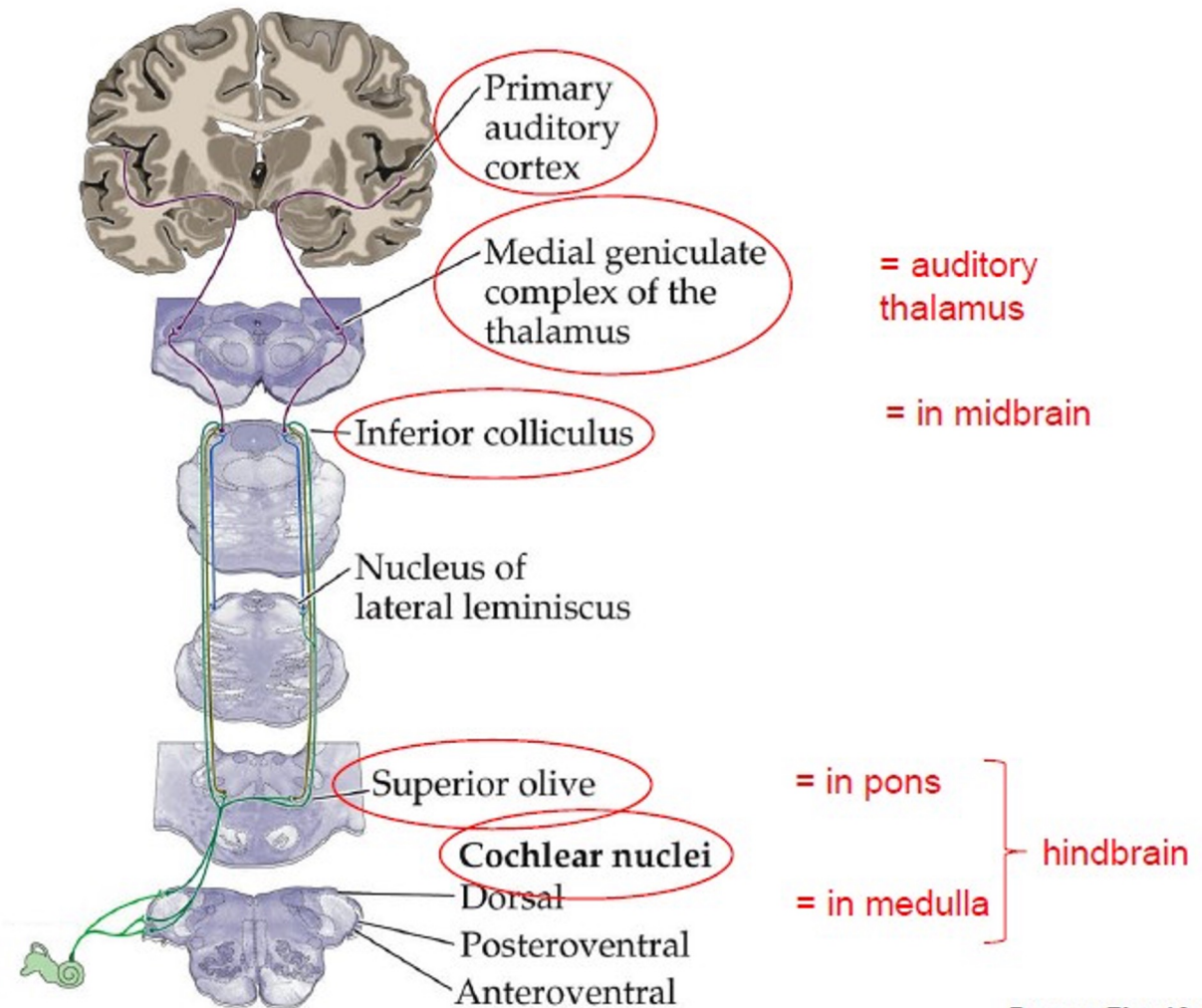


7) Name three auditory nuclei that are positioned in-between the cochlear nucleus and the primary auditory cortex (A1), and their "ascending" order.

in ascending order:

- Superior Olive
(in the pons/medulla)
- Inferior colliculus
(in the midbrain)
- Auditory portion of
the thalamus

The major auditory nuclei and ascending auditory pathways



8) Explain how the localization of a sound is calculated by auditory brain nuclei.

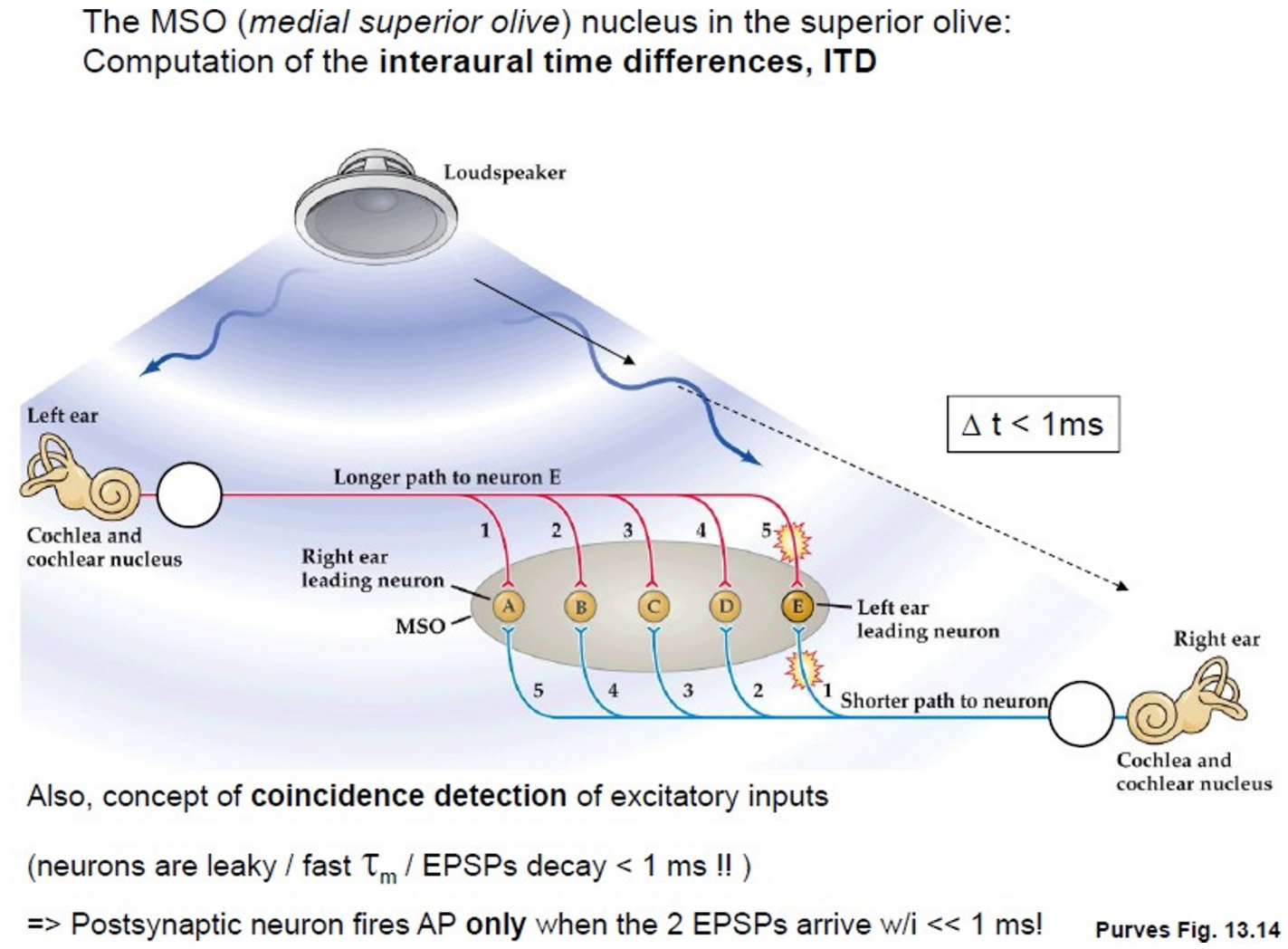
- i) which two main "cues" are used for this computation?
- ii) Name the auditory nuclei concerned with each cue.

Roughly describe the mechanisms used by each circuit to compute sound localization.

- i) interaural timing difference (ITD) and interaural intensity difference (IID): respectively, time difference and intensity difference as perceived by the two spatially-spaced ears
- ii) See next slides

ii)

- ITD detection: in medial superior olive (MSO). mechanisms: coincidence detection of two EPSCs, that arrive with very small time differences from the left- and right ear.



still ii)

- IID detection: lateral superior olive (LSO)

mechanism:

Sounds ipsilateral ear generates **strong ipsilateral higher center excitation** and **strong contralateral inhibition**.

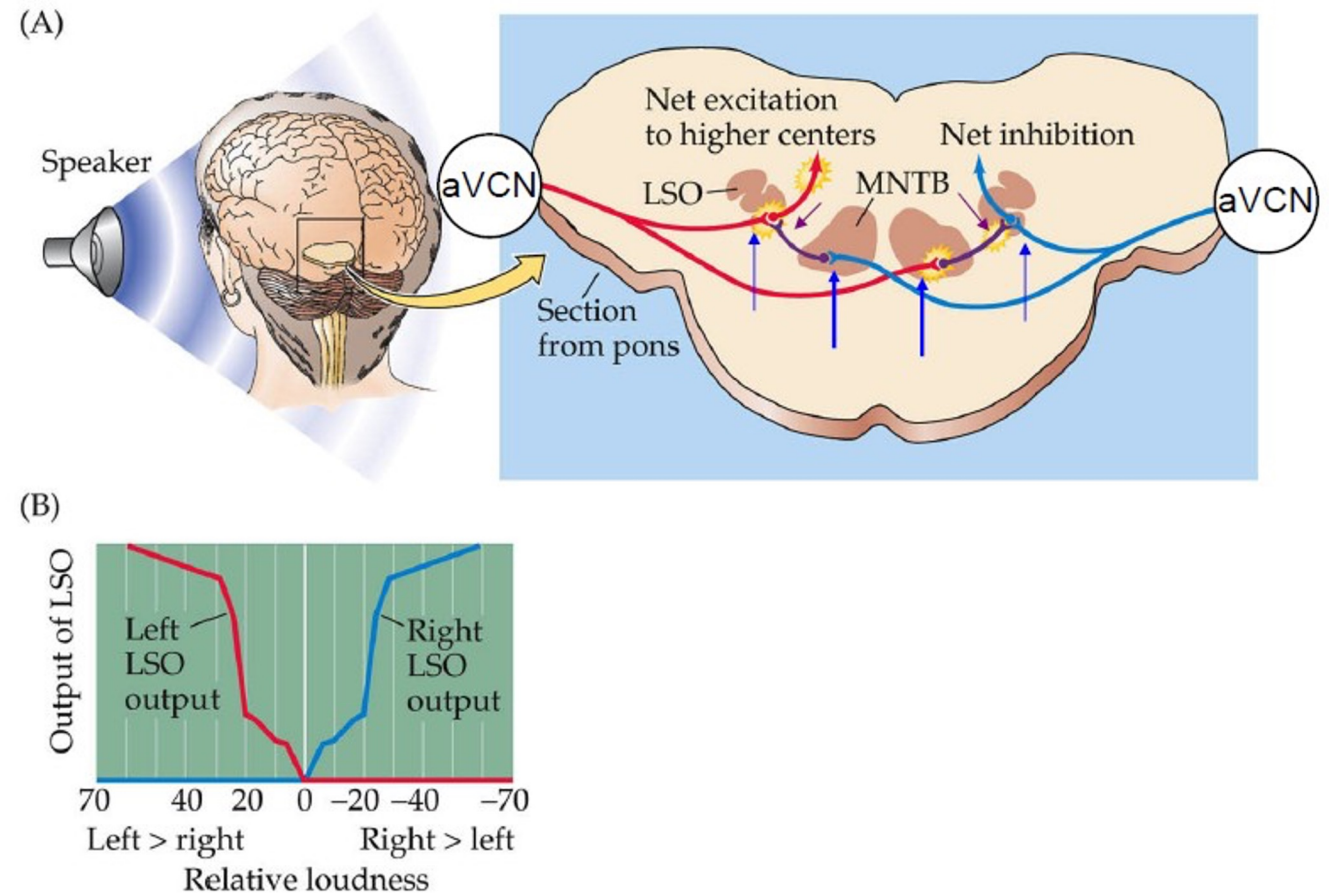
Contralateral ear to sound arrival has **weaker higher center excitation** and **weak contralateral inhibition**.

Thus:

the LSO on the **SAME** brain side to which sound arrives stronger, will be activated, the LSO on the **OPPOSITE** side will be inhibited

2) Interaural intensity difference (IID):

The LSO and MNTB nuclei in the superior olive represent IID



9)) Speculate how otosclerosis, a condition affecting the ossicles, particularly the stapes, may lead to conductive hearing loss. Discuss the changes in the auditory pathway and the implications for sound transmission

Pathophysiology of Otosclerosis:

Otosclerosis primarily affects the stapes, leading to its abnormal bone remodeling and fixation. Normally, bone remodeling is a balanced process of bone deposition and resorption. In otosclerosis, there is an imbalance where excessive new bone formation occurs, particularly around the oval window. This extra bone growth can cause the stapes to become fixed or less mobile, hampering its ability to transmit sound vibrations efficiently.

Impact on Sound Transmission:

The fixation of the stapes results in inefficient transmission of sound vibrations to the inner ear. Since the stapes cannot move properly, the energy from the sound waves is not adequately transferred to the cochlea. This leads to a reduction in the intensity of the sound signals reaching the cochlear hair cells. Consequently, the electrical signals generated by these hair cells and transmitted to the brain are weaker, resulting in diminished hearing ability.

Implications for the Auditory Pathway:

1. **Reduced Amplitude of Sound Waves:** The primary implication is the reduced amplitude of sound waves reaching the cochlea, leading to quieter perceived sounds.
2. **Frequency Range Affected:** Typically, lower frequencies are more affected in otosclerosis, which can change the patient's perception of sound quality.
3. **No Impact on Cochlear Function:** It's important to note that otosclerosis does not directly affect the cochlea or the auditory nerve. Therefore, the sensory and neural components of hearing are intact.
4. **Potential for Tinnitus:** Some patients may also experience tinnitus (ringing in the ears) due to the altered vibration patterns.
5. **Speech Discrimination:** Unlike sensorineural hearing loss, speech discrimination is usually preserved in otosclerosis, as the clarity of sound is not affected as much as the volume.