Central Nervous System

Sheet 7

Subject | Physiology

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Correction | ...

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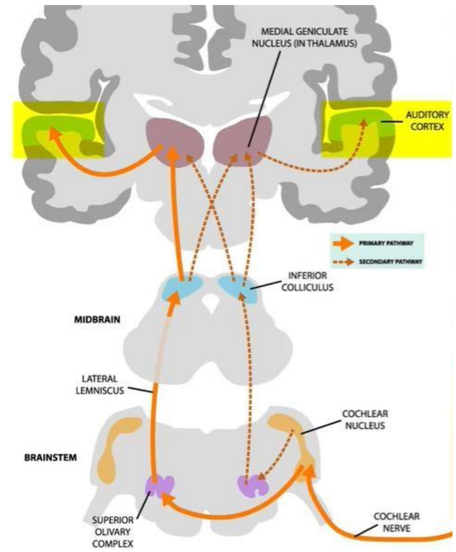
Cont. **The Visual System**

Auditory Pathway 'in general'

After transformation into signals, they need to reach the CNS:

1- **First-order neuron**:

Hair cells in the Organ of Corti are connected to **type I spiral ganglion** neurons (90% from **inner** hair cells, the rest are from the outer hair cells), whose axons form the **cochlear part** of the vestibulo-cochlear nerve.



The fibers of the 1st order neurons (cochlear nerve) enter the **brainstem** where they synapse with 2nd order neurons in the **cochlear nuclei**.

2- **Second-order neuron**:

The **majority** of the fibers **cross over** to the contralateral side, while the **rest** remain **ipsilateral**.
In both pathways, the neurons synapse in the '**superior olivary complex**' in the **brainstem**. Fibers then ascend as the '**lateral lemniscus**' to the '**inferior colliculus**' in the **midbrain** where few fibers cross over to the opposite side. Finally, 2nd order fibers reach the '**medial geniculate nucleus**' in the **thalamus** where they synapse with the 3rd order neurons cell bodies.

> **Note**: since fibers ascend **both** ipsilaterally and contralaterally, each cerebral hemisphere processes stimuli from **both** sides. This is advantageous for two reasons: damage in one hemisphere wouldn't cause complete loss of the sense of hearing. Also, getting input from both ears to both hemispheres allows for **more processing**.

3- **Third-order neuron**:

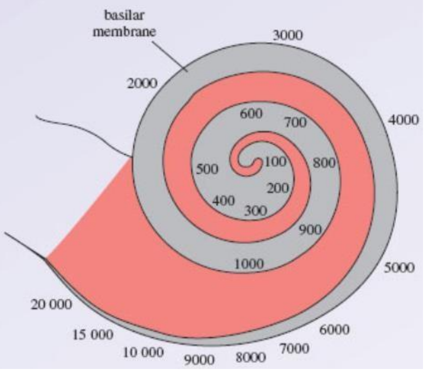
Finally, from the **medial geniculate nucleus** of the thalamus, the neurons continue into the **primary auditory cortex** (area 41 or 42) in the temporal lobe of the cortex.

> **Note 1:** to **preserves** the labelled line principle and the ability of detecting **different** frequencies, neurons transmitting different frequencies will synapse at **distinct** sites a in the **cochlear nucleus**, **thalamus**, and the **cortex** (Tonotopic organization); **higher** frequencies synapse **medially**, while the **lower** frequency will synapse **laterally**.
>
> **Note 2:** to be more precise, **1st order** ❼ cochlear nerve // **2nd order** ❼ fibers leaving cochlear nuclei // **3rd order** ❼ lateral lemniscus fibers // **4th order** ❼ fibers leaving the inf. colliculus // **5th** ❼ fibers leaving the medial geniculate bodies. It isn't that important; since orders can still change between the different auditory pathways as seen in the following lecture. Just know the

Sounds Characteristics

- The cochlea doesn't only detect the presence of sound waves, but also it can detect their **characteristics**: frequency, amplitude, and location:

1- **Frequency (type / pitch):** different sounds are determined by the **activated** part of the basilar membrane.



In other words, **each** point along the **basilar membrane** vibrates at a **specific** frequency, thus, **different frequency** sounds vibrate **different positions** on the basilar membrane. The brain then determines the frequency of a certain sound by **detecting** the pathway of the neuronal signals it received from the specific hair cells that were activated on the basilar membrane.

⇨ **Example**: Assume that we have a sound frequency of about 1000 Hz that activates the (X) portion on the basilar membrane. This means that whenever we hear that sound, only the (X) portion will vibrate and then sends neuronal signals to the CNS.

Note: the basilar membrane is **narrow** at the **base** and near the **oval** and **round gates**., whereas its **apex** is **wide** and **free**. This characteristic, along with the unique shape of the cochlea, **determine** which part of the basilar membrane will respond to a **certain frequency**.

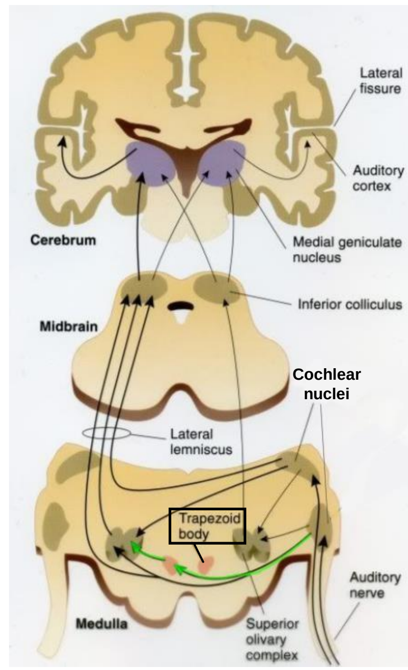
Recall that the standard hearing range for humans is 20 to 20,000 Hz. Therefore, if there is a sound with a frequency of 25,000 Hz, vibrations will be transmitted to the tympanic membrane, the 3 ossicles, and the perilymph fluid. However, they will **terminate** there since there **isn't** any part of the basilar membrane that **designed** for this frequency; thus, it **won't vibrate** and send signals to the CNS.

Note: different shapes of cochlea lead to different ranges of frequencies. For example, animals' cochlea differs in shape from humans so they can hear a different range of frequencies.

2- **Amplitude (intensity):** the higher the intensity, the stronger the vibrations are. In the case of transmitting a **high-intensity** sound wave, the basilar membrane moves more causing more **bending of cilia** on the hair cells so more ion channels will **open** and the generated potential will be **higher** and more **frequent**.

3- **Location**: when the sound, for example, originates from the right side, it reaches the right ear within a **short span of time** and with a **stronger intensity** compared to the left ear. Thus, localization depends on two characteristics: time and intensity.

Localization and reflexes:



- Localization of the sound is important for the conscious cortex as well as for **unconscious subcortical reflexes**. For example, when someone calls you suddenly; you will respond quickly by turning your head towards the direction the sound came from.
- Auditory information undergoes processing that leads to the **alteration** of the intensity and time of the sound and **loss** of exact auditory information upon **reaching** the **cortex**. Thus, it's important to **determine** the **side** of sound **early** in the pathway to **preserve** the sounds' characteristics.
- In the **cochlear nucleus**, second-order neurons will send fibers to the **superior olivary complexes** on **both** sides – right and left. In other words, the **right** superior olive nucleus receives information from **both** the right and left cochlea and vice versa.

> **Note**: auditory fibers can cross from one side to the other through the **trapezoid** body; which connects auditory fibers **from** the ventral **cochlear nucleus** from one side to the **superior olive nucleus** in the **opposite side**.

⇨ By **comparing** information from both sides, superior olive nuclei determine the location of the sound.

Good Luck