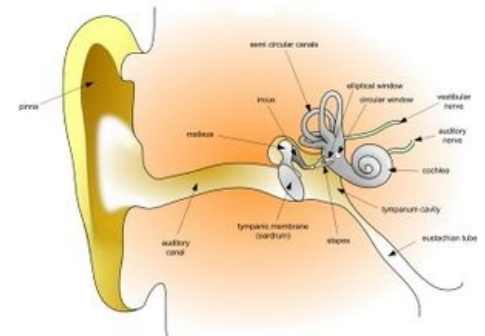


Hearing

Introduction

- Hearing is one of the five senses, based on the perception (processing and guidance) of acoustic (sound) stimuli. Its essence is the transformation of mechanical sound waves into electrical action potentials.
- Sound is a mechanical wave caused by some external factor, occurring in the form of a longitudinal wave based on the alternating thickening and thinning of molecules in the vicinity of the source of the stimulus (i.e. sound pressure fluctuations). To display a sound wave, we use its properties: amplitude and wavelength.
- Amplitude is the maximum deviation of sound pressure. It indicates the strength of the sound (in direct proportion): the higher the amplitude, the stronger the sound.
- A wavelength is a section of a wave that repeats itself periodically. It is inversely proportional to frequency. It indicates the pitch (inversely proportional). The higher the frequency, the higher the tone. (The longer the wavelength, the lower the pitch).



Anatomy of the human ear

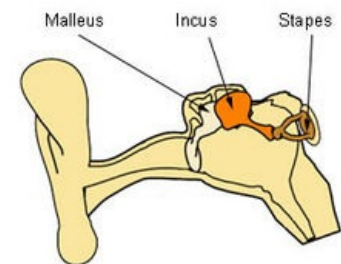
External ear

The sound wave is captured by the auricle and is conducted unchanged through the external auditory canal to the eardrum, which functions as a resonator.

Middle ear

Description

There are 3 auditory ossicles in the middle ear cavity, articulately connected to each other: the **malleus**, **incus** and **stapes**, as well as the muscles of the **tensor tympani** muscle (attachment to the malleus, innervation from the N.V.) and the **stapedius muscle** (attachment to the stirrup foot, innervation from N. VII.). The malleus is connected to the eardrum, articulated with the anvil, and the latter with the stirrup, the foot of which tilts and tilts the **fenestra ovalis** into the space of the inner ear, specifically the scala vestibuli of the cochlea. The inner ear exits the cochlear scala tympani back into the middle ear through a second window, the **fenestra rotunda**, which lies just below the fenestra ovalis.



Cranial Bones

Middle ear

Principle

The auditory ossicles act as a lever system that transmits the vibrations of the tympanic membrane to the movements of the stirrup foot against the fenestra ovalis. Since the transition from the middle ear to the inner ear changes the medium through which the wave passes, from gas (in the middle ear) to liquid (perilymph and endolymph in the cochlea of the inner ear), while the liquid medium offers a much greater resistance to the sound wave, **it is necessary to increase the pressure** by which the sound the wave invades the inner ear. This is done by mechanical air conditioning:

- **by the ratio of the area of the tympanic membrane (large area)** and fenestra ovalis (tiny area);
- **unevenness of the levers of the auditory ossicles** (the hammer is longer than the projection of the anvil).

As a result, the pressure of the sound wave increases (about 22×) and the amplitude decreases.

Tympanic reflex

This is an increase in the stiffness and resistance of the transmission system in the middle ear cavity (and thus a reduction in sound conduction) during the simultaneous contraction of the tensor tympani and stapedius muscles; it arises as a protective reflex based on loud sounds of low frequency, e.g. an explosion. It protects the auditory receptors from excessive stimulation by too strong sound waves.

Inner ear

Description

In the inner ear, as auditory relevant (there is also a vestibular apparatus , but we will not focus on this), there is a bony cochlea, copied from the inside by a membranous cochlea (a coiled membranous tube inside a coiled bony tube), filled with fluid.

The cochlea (cochlea) is formed by two and a half turns of a coiled tube, longitudinally divided into three parts: **scala vestibuli** , **ductus cochlearis** and **scala tympani**. The scala vestibuli begins behind the fenestra ovalis and, at the apex of the cochlea, passes continuously into the scala tympani, which opens into the fenestra rotundum. The inner chamber is formed by the ductus cochlearis, which ends blindly at the apex of the cochlea. The ductus cochlearis is separated from the scala vestibuli by **Reissner's** and from the scala tympani by the **basilar membrane** . In the ductus cochlearis, the cells of the organ of Corti sit on the basilar membrane , as well as outer (lateral) and inner (medial) hair cells , among others, acoustic stimulus sensors. The outer cells are embedded in the tectorial membrane, covering the organ of Corti from above. The inner hair cells are not firmly attached to the tectorial membrane.

Principle

A sound wave coming from the fenestra ovalis ripples the fluid in the scala vestibuli. Since the scala vestibuli is covered (in front of the ductus cochlearis) by a flexible Reissner's membrane, it also undulates this and subsequently the basilar membrane. In this way, the wave continues through the snail - we call it a **progressive wave**. Due to the properties of the basilar membrane, the speed of propagation decreases with the distance from the fenestra ovalis, but the amplitude of the wave, on the contrary, increases until it reaches a maximum at a certain point and then rapidly decreases. The place where a sound wave reaches the maximum deflection of the membranes (maximum amplitude) depends on the frequency of that sound wave. The higher the frequency, the earlier (i.e. the closer to the fenestra ovalis) it reaches its maximum. Such a place of reaching the maximum amplitude is characteristic for individual frequencies; the principle in which each frequency is assigned a specific place of maximum amplitude is called the **principle of tonotopy** . It means that afferent nerve fibers carry sound information of a single frequency from a certain specific place to the brain. **Frequency analyzer** of sound waves is the basilar membrane, which determines at which point the wave reaches its maximum.

Hair cells

At the point where the maximum amplitude is reached, the basilar membrane also bulges to the maximum. By arching, it moves the tectorial membrane towards itself and changes the direction of the stereocilia of the outer hair cells (VB), which are immersed in the tectorial membrane. This depolarizes the outer VB: it opens cation channels and there is an influx of potassium, sodium and calcium cations. At the same time, the outer VB shortens. This is followed by bending of the cilia in the opposite direction, the cell becomes hyperpolarized and lengthens to its original length. In this way, **the outer VB** acts as a **cochlear** sound amplifier (increases the amplitude) - the amplified wave passes to the inner VB. They have the task of converting processed mechanical waves with the help of chemical processes into electrical energy - action potential. This transformation, which the **internal VB** performed is called **transduction**. The principle of depolarization is the same here: the stereocilia of the inner VB, stimulated by the fluid, change direction, open ion channels, and thereby depolarize. As a result, they release transmitters, thereby creating a nerve impulse at the ends of adjacent afferent fibers, which is conducted to higher levels (to the brain). The outer VB are surrounded by efferent endings and their function is to modulate (amplify) the sound wave. The internal VBs are surrounded by afferent endings of bipolar neurons from the spiral ganglion and their function is to transduce mechanical energy into electrical energy.

Summary

1. oscillation of the basilar membrane;
2. displacement of the tectorial membrane relative to the basilar membrane;
3. change in the direction of the stereocilia of the outer VB;
4. opening of ion channels and shortening of outer VB = depolarization of outer VB;
5. sound amplification by external VBs;
6. irritation of the stereocilia of the internal VB by the movement of ductus cochlearis fluid;
7. change of direction of stereocilia of internal VBs;
8. opening of ion channels and release of transmitter = depolarization of internal VB;
9. generation of an electrical impulse at the synapse with the afferent fiber.

Links

Related articles

- Vestibulocochlear nerve
- Development of olfactory system
- Classification of hearing disorders
- Hearing threshold and auditory field

External links

- Sluch (Czech wikipedia)
- Hearing (sense) (English wikipedia)

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