International Journal on Biomedical Research and Technology

Remarks to the Theory of Hearing - A Traveling Wave Part Three

Short Communication

Volume 1 Issue 1- 2023

Abstract

In the paper attention was paid to the difficulties in translating the phenomena which accompany hearing, while applying the theory of hearing the so-called 'Bekesy's travelling wave. All mammals have an identical ear structure with a cochlea and three ossicles in the middle ear. Birds are provided with a cochlea but only with one middle ear ossicle, referred to as 'the columella'. Analyzed was the difference in the middle ear structure of birds and mammals, as well as the effect of this difference upon the hearing. The conclusions allow setting a thesis there is another signal path to the receptor, different from the one described by the traveling wave theory. This is a signal path running through the osseous cochlear housing directly to the receptor.

Keywords: Acoustic cells; Amplification; Receptor; Stapedotomy; Transforming and Transmitting auditory information

Abbreviations: Hz: Hertz; kHz:1000Hz= kilo Hz; Pa: Pascal, pm: picometre=10-12 m; OHC: Outer Cell Hair, nm: nanometer= 10-9m; ms – millisecond= 10-3second; BM: Basilemma = Basilar Membrane; μm: mikrometr.

Hearing Mechanisms

In the middle ears of mammals, the ratio length of the manubrium mallei to the length of the lenticular process of the incus is 1.3:1, which leads to a reduction of the deflection of the stapedial lamina vs. deflections of the eardrum equal to 1.3:1[1]. If, as in the case of hearing of the threshold tone in young people, we have a 0 dB wave, then, the amplitude of this wave in the external auditory meatus is 8 pm. Hence, the deflection amplitude of external the stapedial base is 6.1pm. Such an amplitude value is insufficient to reach the receptor through cochlear fluids and the basilemma [2]. It must be borne in mind that the energy of that wave on the way to the receptor is reduced hundreds of times [3]. Such a wave, around 10 times smaller than the average size of atoms constituting the basilemma structure, is unable to generate a traveling wave on the basilemma, or flows of cochlear fluids which are supposed to bend the auditory cell hairs. Proven is the disappearance of the sound wave energy in the cochlear fluids from the oval window to the round window [3]. Then, there is also the issue of inertia in the middle and external ear, especially in the case of high tones.

While analyzing the signal path through cochlear fluids, into consideration should be taken the sense of hearing of mammals which can hear sounds of intensities (-) minus 10dB SPL (cats). Upon entering the system, the amplitude of this wave is 2-3pm. If that sound wave is yet more reduced in the middle ear, it will be approx. 20times smaller than the hydrogen diameter. That wave, disappearing in cochlear fluids, is unlikely to bend auditory cell hairs which are approx. 100,000 times thicker that the audible threshold sound wave - in humans [4].

A barn owl (Tyto alba) can hear from 100Hz do 20kHz. Something particular for this species, hunting chiefly by night, is its hearing sounds 20 dB SPL below zero dB, when the amplitude of the sound wave entering the system is 0.001nm = 1 pm. Such a wave, more than 50 times smaller than the hydrogen atom diameter, disappearing in cochlear fluids is unlikely to generate a pressure difference on both the BM sides, and therefore, is unable to generate a traveling wave on the basilemma, motions of labyrinth fluid and the bending of acoustic cell hairs [5]. At such a low wave energy, the basilemma will not work. The traveling wave theory combines resonance and frequency resolution with the basilemma. This mechanism is improbable for such a small amplitude of a sound wave. At such a low amplitude of a sound wave, a barn owl has not only a perfect frequency resolution, but also an excellent skill of directional hearing - based upon the difference in time in which a sound reaches each ear and the difference in the wave energy in both the ears. Those differences are on a nano level and cannot be conveyed the long way around through cochlear fluids, viz. a slow wave on the basilemma, more than 10times slower than the speed of a sound wave in cochlear fluids. Sound waves together with numerous harmonics cannot be encoded by the basilemma, actually immovable, and through cochlear fluids. Nevertheless, precise information is received, and this attribute ensures the species to survive on Earth. Such attributes of the hearing organ can imply or constitute a proof of other signal path from the middle ear to the receptor. Also, the speed of auditory reaction suggests that this path must be short and fast. Conveyed are sounds of very high frequency, which is improbable according to the traveling wave due to the inertia of the elements vibrating on the signal's way towards the receptor. Since a sound wave has no mass, it is not subject to the inertia law. A bone can convey a sound at a speed of up to 4,000 m/s. Also soft tissues convey sounds, but at lower speeds. Such an efficient reception of information in the receptor can be ensured only by the signal path from the middle ear through the osseous cochlear housing directly to the receptor [6].

A proof can be also osseous hearing when the stapedial base is immobilized, in which case cannot be generated any wave traveling from the oval window to the cupula. Since the flexibility of the round window is 20 times higher than that of a healthy, mobile oval window, there can be generated a wave traveling backwards from the round window to the cupula. The more because the oval window in otosclerosis is immobile. Resonance on the BM is unlike to occur in the absence of a traveling wave. Nor is the frequency resolution dependent upon the basilemma.

As far as humans are concerned, mentioned must be also stapedial rocking (swinging) movements in the reception of high frequency sounds. High sounds are not received through cochlear fluids, which is corroborated by results of stapedotomy [7]. Instead, they are received physiologically - in some mammals their frequency can reach even up to 100kHz. The path through cochlear fluids and basilemma is improbable for some reasons, viz. inertia, reaction time - generation of receptor potential, information encoding in fluids, frequent energy transformations on the way to the receptor, reception of tones shorter than decimal parts of a millisecond, difficulties in amplifying silent multi-tones with numerous harmonics. If a signal is very precise and reaches quickly the receptor, it makes use of another path. Rocking (swinging) movements of the stapes may play some role among mammals in transmitting the wave sound energy to the osseous cochlear housing. They depend upon the eardrum's reaction to frequencies and intensities of a sound wave. Birds have only one middle ear ossicle, called columella, which connects the eardrum with the stapedial base, and like mammals they can hear high sounds of very low amplitude.

The eardrum is responsible for a pre-analysis of frequency which has a differentiated thickness and tension at various places. Low tones, with frequencies of up to a few thousands Hz may be conveyed through cochlear fluids and the basilemma to the receptor as they have low inertia depending, among other things, upon the frequency. Instead, sounds with frequencies of up to 200 kHz, are transmitted to the receptor on another path - fast and short, where there is no inertia in the path elements participating in the information transfer. An important proof that it is possible to hear without the participation of the basilemma and cochlear fluids is excellent hearing of insects. The greater wax moth (Galleria mellonella) generates and receives sounds whose frequencies are up to 300 kHz. The receptor receives and processes the energy encoded in a sound wave without participation of cochlear fluids and the basilemma, since it is bereft of both of them. Such a direct ability of receiving high frequency information contained in a sound wave is also found among all invertebrates [6].

Conclusion

A new theory of hearing, referred to as "Submolecular theory of hearing", allows elucidating all processes - components of the deception, processing and transmission of auditory information. It underlines the importance of molecular transformations in the auditory cell itself, responsible for the creation of transmitters and post-synaptic potential, and what is important, for an intracellular amplification of a signal, no longer of a sound wave [6,8,9]. A new theory, announced 20 years ago, offers an opportunity of improving one's hearing also of high frequency after stapedotomy [6]. The prerequisite for such an improvement is following the Nature in the transfer of information from the middle ear to the receptor on a new path [7].

References

1. Guinan JJ Jr, Salt A, Cheatham MA (2012) Haer Progress Cochlear Physiology after Bekesy. Res 293(1-2): 12-20.
2. Myjkowski J (2004) Przetwarzanie i przekazywanie informacji słuchowych. Transforming and transmitting auditory information. Otolaryngol Pol 58(2): 377-383.
3. Kwacz M, Wysocki J, Mrówka M (2011) Pomiary drgań błony okienka okrągłego metodą wibrometrii Dopplerowskiej [Measurements of vibrations of the circular window membrane by Doppler vibrometry. PAK 57(5): 471- 478.
4. Marnell D, Jabeen T, Nam JH (2018) Hydrostatic measurement and finite element simulation off the complicance of the organ Corti complex. J Acoust Soc Am 143(2): 735.
5. Fettiplace R (2017) Hair cell transduction, tuning and synaptic transmission in the mamalians cochlea - Compr. Physiol 7 (4): 1197-1227.
6. Myjkowski Jan (2021) Submolecular Hearing Theory. The New American J Med V 2(2): 1-3.
7. Faranesh N, Magamseh E, Zaaroura S, Zeidan R, Shupak A (2017) Hearing and Otoacoustic Emissions Outcome of Stapedotomy: Does the Prosthesis Diameter Matter? Department of Otolaryngology, Head and Neck Surgery, French Hospital, Nazareth, Israel. OBJECTIVE: To compare the hearing and otoacoustic emissions (OAE) outcome of stapedotomy employing 0.4 and 0.6 mm diameter prostheses. The Journal International Advanced Otology 13(2): 162-170.
8. Fettiplace R (2017) Hair cell transduction, tuning and synaptic transmission in the mamalians cochlea - Compr. Physiol 7 (4): 1197-1227.
9. Zaid A, Adewale M, Mc Lean L, Ramblow P (2018) The plasma membrane calcium pump - The old and the new. Neurosci Lett 663: 12-17.

Author Details

*Jan Myjkowski**

Specialist Otolaryngologist, Poland

*Corresponding author

Jan Myjkowski, Specialist Otolaryngologist, Pensioner, Poland

Article History

Received: April 22, 2023 Published: April 28, 2023