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ComparisonofTwoTheoriesofHearing

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1.TheoreticalStudy

Acomparisonoftwotheoriesofhearing:

TheoryNo.1–theoldtheorybyBekesy,publishedin1928.

Theory No. 2 – a new, modern theory, Submolecular Theory of Hearing –.

Authoroftheotheory:JanMyjkowski.

Theory No. 1 – does not take into account the value of inertia in the ear and does not calculate it properly.

Theory 2 –recognizesitandcalculatesthevalueofinertiain the ear byusing theformula: $(2\pi x \text{ frequency})^2$ x amplitudexmassg/ mm/s^2. For a threshold tone of 1,000 Hz and 0 dB, the inertia of the middle ear is 0.009859 $g/mm/s^2$. For a tone of 10,000 Hz and 100 dB, the inertia of the middle ear is 98596 $g/mm/s^2$. For each frequency, the value of inertia is different and proportional to the squareofthefrequency.Tothesevaluesmustbeaddedtheinertia of the inner ear. A sound wave travelling to the receptor through the bony housing of the cochlea has no mass and no inertia.

Theory No. 1 – does not recognize the existing fading of energy on its way to the receptor; instead, it recognizes the mechanical amplification of quiet tones of 40 – 50 dB through an OHC contraction, and we still perceive those tones as quiet.

Theory No. 2 – a tone below the auditory threshold cannot be amplified byan OHC contraction. An amplification occurs in the auditorycell atthemolecular level, but onlyin thecaseofsignals received by the receptor, and too small to reach the center.

Theory No. 1 – the basilemma is responsible for the frequency resolution.

Theory No. 2 – a receptor in the form of auditory cells with a specific abilitytoreceive sound waves ofa given frequencyisresponsible for the frequencyresolution. A piece of evidence is the immobilizationofthebasilemmawhich doesnotaffect therecognition. of both a tone and a timbre.

TheoryNo.1–isbasedonthecalculationofthebasilemma'snatural oscillations, calculated according to Bekesy's methodology.

Theory No. 2 – those calculations are incorrect, the basilemma vibrates along with the entire organ of Corti, the fluid spaces and the connective tissue on the lower surface of the basilemma, all being embedded in a fluid that has some suppressive properties. Bekesywouldcalculatepropervibrationsintheair fora verythin and narrow strip of connective tissue.

Theory No. 1 – resonance is the basis for the transmission of sound wave vibrations to the basilemma.

Theory No. 2 – resonance is a process of energy transfer over time, with frequencycompatibility or high similarity between the forcingandforcedwaves.Therateofreceptorpotentialformation lies within tenthsofa millisecond – which isin conflict with resonance. Asoundwave is alongitudinal wave, whereasa wave on the basilemma isa transverse wave. The speed of the wave in the fluid is 1,450 m/s and the speed of the wave on the basilemma – from 1.9 m/s to a few dozen or so m/s.

Theory No. 1 – the tip–links mechanism is responsible for the gating of mechanosensitive channels.

Theory No. 2 – the mechanical energy of the sound wave is responsible for gating the mechanosensitive potassium channels of the auditory hair cells. This takes place on the atom, particle and

molecular level. Further evidence is a low energy – since on the pathwayof fluids of both the cochlea and basilemmano tip–links mechanismisfeasiblebecauseitdisappears.Itreachesthereceptor bya differentroute, viz.through the bonehousing of the cochlea.

TheoryNo.1–cadherinfibers,tensionedupduetothebendingof the auditory cell hairs, will tighten the cell membrane of thehair, and this is sufficient to gate the ion channel located next to the cadherin attachment to the cell membrane.

Theory No. 2 – it is impossible that such a simple mechanism couldberesponsiblefor thetransmissionofcomplexinformation. It is impossible to open and close a channel with a lumen of 0.3 nanometersto1nm.The fiber tip springsdescribed above arenot connected to the channel gating mechanism. Molecular motors – myosins– aresupposed toberesponsiblefor closingan ion channel.Thesearetooslowtohandlechannelsoperatingatfrequencies of up to 200 kHz. It is difficult to accept the encoding of multitones that have numerous harmonics by means of pulling on the cell membrane itself, without contact with the mechanosensitive channel itself.

Theory No. 1 – does not explain all the molecular processes that makeuptheconversion ofreceptor potentialtoactionpotentialin the auditory nerve.

Theory No. 2 – describes subsequent processes within the auditorycellrelatedtoproteins, enzymes, calcium, intracellularinformation transmitters, transmitter production, its transport and secretion,synapseoperation,intracellularamplification,summation, presynapticandpostsynapticinhibition,theimportanceofafferent and efferent innervation, etc. A detailed description can be found in the paper entitled: "Przetwarzanie i przekazywanie informacji słuchowych"(Auditoryinformationprocessingandtransmission). – Otolaryngologia Polska Nr 2,2004, pp.377–383.

Theory No. 1 –assumes a displacement ofcochlear fluid masses in linewith thesoundwavein arangeofamplitudes,accordingto the amplitude of the transverse basilemma wave, for the inclina- tion of theauditorycell hairs and the functioning of thetip–links.

Theory No. 2 – a displacementof a sound wave insolids and ina fluidisnotrelated tothemass displacement oftheenvironment. There is only a displacement of the environmental particles according to the amplitude of the wave in both directions, with no changeinpositionwithrespecttotheaxisofexcursion.Apressure wave moves forward,has nomass andis not subject to thelaw of inertia.

Theory No. 1hasit,an OHC, provided withafferent innervation, doesnotuseit,andsignalstothecenteraretransmittedexclusively through the IHC.

TheoryNo.2–theafferentinnervationoftheOHCperformswell. Otherwise, it has no right at all to exist.

Theory No. 1 – multi–tones of different loudness are separated, quiettonesareamplifiedandloudtonesaretransmitteddirectlyto thecenter.Thereisnodescription ofthetransmission oftheinformation ofthequiettones,aswellasafter whattimeandwithwhat subsequent waves does the transmission occur.

TheoryNo.2–believesthatasignalcannotbesplitandtheinformation of quiet sounds cannot be transmitted in delay with other information.

Theory No. 1 – cannot explain the lack of high frequency transmission in stapedotomy operations.

TheoryNo.2–anoperationshutsdownthetransmissionofwave energy to the bone housing of the cochlea for a direct and rapid signal transmission to the receptor. A sound wave, for having no mass,isnotsubjecttoinertia.Itcanbetransmittedupto20kHzin humansandupto200kHzinbats.Upto100kHzinmice.Swayingmovementsofthestapesplayaroleinthetransmission ofhigh frequencies. Those movements are excluded in stapedotomy.

TheoryNo.1–doesnotexplaindirectionalhearing.Theproblem isthetimingofthereceptor potentialandthedisappearanceofenergyonthewaytothereceptor throughthecochlear fluidsandthe basilemma, as well as an amplification of quiet tones.

Theory 2 – the basis for directional hearing is the interaural distanceinbinauralhearing.Thissizeofearspacinginhumans,other mammals and birds results in different distances between the ear andthesoundsource, deflected from a linestraight ahead. Anangleofhearingwillbeformed.Thedifferencein thedistancetothe respectiveearproducesadifferenceinthereceptorexcitationtime, the difference in the path also causes a reduction in the energyof the incoming sound wave. In humans, the time difference of the waves reaching the respective ear is 0.0006 seconds! There is a very small difference in intensity.

TheoryNo. 1–cannot explainthepreservation ofexistingpartial hearingin thecaseofcochlear implant surgerywhen thebasilem- ma is immobilized.

Theory No.2 – the sound wave runs through the bony housingofthecochlea, regardless of theimmobilization of thebasilemma – which is corroborated byhearing. This provides ossicular hear- ing and 'boneless ossicular'hearing, i.e. the conduction of sound waves through the soft tissues from the eardrum cavity to the re- ceptor.

TheoryNo. 1–thereisathresholdofexcitabilityandmechanical amplification of a signal by pulling the basilemma by OHC contractions.

Theory2–lowintensityandhighfrequencyamplitudesareheard byus,butnotviathecochlearandbasilemmafluidpathway.They arebelowthehearingthreshold,donotcauseOHCdepolarization, and therefore cannot be mechanically amplified.

Theory No. 1 – uses an incorrect name 'auditorycell cilia'. Also incorrect is the name 'stereocilia', viz. rigid cilia.

Theory2–therearenocilia on theauditorycells.Therearesome protrusions oftheauditorycells formed intosmallhairs.The cilia arefoundin therespiratorytracts,havea completelydifferentcell structurefrom theauditorycell hairs,andhaveanabilitytomove.

TheoryNo.1–Doesnotdifferentiatebetweenquietandloudtone response times, does not analyses the hearing of mammals and birds that have the same hearing system.

TheoryNo.2–isbasedonstudiesonthetimeofthesignalpathto thereceptorandonthestudyofhearingthresholds.Inhumans,the receptorpotentialarisesaftertenthsofamillisecond.Accordingto calculations**consistentwiththetravelingwavetheory,**forquiet tonesthistimeisabout 3milliseconds.Ahuman hearsathreshold tone havingintheexternalauditory canalawaveamplitudeof 0.01nm=10picometres.

TheoryNo. 1– doesnot explainthehearingofshorttoneswhose duration time is as long as tenths of a millisecond and which are perceived by the receptor.

Theory No. 2 – the signal pathway through the cochlear fluids requiressomeresonanceaction.Resonancewithintenthsofamillisecond is not possible, and yet, the signal reaches the receptor. Therefore, there is another signal pathway to the receptor.

TheoryNo.1–cannot explaintheencodingofinformationtransmitted bythetransversewave ofthebasilemma, bycochlear fluid flows,bybendingtheauditorycellhairs,bythecadherinjunctions of auditorycell hairs, bythe springs of the lower cadherin termi- nals, bythe stretched cell membrane of a shorter hair. Multitones of varying intensity, with numerous harmonic tones, will pose a problem.

Theory No. 2 – promotes a signal pathway through the cochlear bonyhousing,whichmeansthatsuchencodingissuperfluous.The energy of the sound wave reaches the receptor directly, quickly without any change, with no superfluous coding transformations

Theory No. 1 – fails to analyses and to account for multiple exchanges of energyfor encoding information on the wayto thereceptor.

Theory No. 2 – postulates that theamount of energyconversions on thewaytothereceptor, assuminga pathwaythrough thecoch- lear fluids and the basilemma, is far too high and can influence a distortionofinformation.Alongitudinalwaveinfluidsisconvert- ed into a transverse, slow wave on the basilemma. A transverse wavein fluidsdoesnot work,soitisconvertedintoalongitudinal wave. This wave is supposed to move the hairs of the auditory cells accordingto the wave's amplitude and frequency. Thehairs bend in a fluid thathas attenuating properties and transmit theinformation to the cadherin fibers.At thelower end of thehairs are arranged some springs–actingaslinks; in operation arealsomolecular motors–myosins,whosetaskistoclosetheK+mechanosensitive channels. This pathway will be subject to inertia.

Theory No 1 – mechanosensitive channels are calcium channels andsuchmayalsobepotassiumchannels,or bothatthesametime.

Theory2–assumesthatthemechanosensitivechannelsintheear are potassium channels. The rationale is that there are very high levels of potassium in the endolymph produced by a large inputofATP energy by the potassium pumps in the vascular striatum.

Theory No. 1 – describes a single mechanosensitive ion channel on theauditorycell capillaries, andinaddition onlyintheinferior rows of capillaries.

Theory 2 – thisthesisisfalse. Thecell membraneof theauditory cell capillaries constitutes an extension of the cell membrane of thewholecell.Thismembranehasonitseverysquaremicrometer alargenumberofsodiumionchannels,tension–relatedpotassium ion channels, calcium–dependent and ligand–dependent calcium channelsof3typeswithdifferentconductanceanddifferentsensitivitytodepolarisation.Thereare alsochloridechannelsandwater pores.

TheoryNo. 1–thetip–linksmechanismisessentialfor thetransmission of sound wave energy to the receptor.

TheoryNo.2–Mammalshavetheabilitytoperceivesoundwave energy over a wide range, and some mammals use echolocation, others make use of electromagnetic fields and also electric fields generated by other organisms. The energy and encoded information are conveyed by a sound wave directly to the specific receptor. Here, the potential energy of a sound wave is converted into the chemical potential of the atomic bonds of the sound–sensitive molecules. Thereare changes in the vibrations of atoms andmolecules, changes in atomic bond lengths, changes in oscillations, changesinvalenceangles,changesinelectronspheres.Thiscauses conformational changesin themolecules, changesintheir dimensionsandcreatesan opportunitytoperform work, viz. controlling theopennessofmechanosensitivepotassiumionchannels–thatis, dependent on the information contained in the sound wave. This process is referred to as ion channel gating.

TheoryNo.1–basingupontestswith electriccurrent,OHCcells haveanabilitytocontractupto70000/s.Thisprovidesfor OHCs an opportunity of amplifying quiet sounds.

TheoryNo.2–investigationsintocontractionsofanauditorycell byusingelectriccurrentisincorrectandunreliable.Depolarization and contractions of the OHC depend on ion channels, and these have their own cycle of action, viz.: excitation, opening, closing and a period of refraction with no sensitivity to stimulation, to a changeinpotential.Thisprocesstakesplaceoveraperiodoftime that cannot be reduced almost to zero.

Theory No. 1 – the energyof a sound wave in bone conductivity istransferredtothecochlearfluidandthesubsequentsignalpathis the sameas in air conduction with the origin of the wave running on the basilemma.

Theory 2 – believes that such a ratiocination is **incorrect**: The round window has 20 times more elasticitythan the oval window and, in the event of a break in the middle ear ossicular chain, a waveon thebasilemmamaypossiblybegeneratedfromtheround window – viz. 'reverse' on the basilemma. If both windows are blocked,ossicularhearingispreservedintheabsenceofanywave on the basilemma.

Theory No. 1 – does not explain the mechanism of resonance of thelongitudinalsoundwave withthetransversewave on thebasilemma. Neither does it explain whya simple, while beingpushed on the side at right angles will not increase the amplitude of the swing excursion.

TheoryNo.2–hasnosuch problems!