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# A New Theory of Hearing Sub Molecular Theory of Hearing

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**SUMMARY**

The problems of Bekesy's traveling wave theory are discussed in relation to the natural frequencies of the basilar membrane, the resonance of the longitudinal wave in cochlear fluids with the transverse wave of the basilar membrane. Flows have been questionedcochlear fluids and mechanical amplification of tones quiet ones. A new signal path to the receptor and the mechanisms of receiving information by the receptor through molecular changes are described. The intracellular mechanism of sound signal amplification was elucidated.

**Keywords:** Vibrations of the Eardrum; Theory of Hearing; Inertia in the Ear; Mechanotransduction

## Controversies of Bekesy's Traveling Wave Theory

George von Bekesy's theory of traveling wave hearing, announced in 1928, became the basis for consideration of the incomprehensible facts regarding this theory [1]. The mechanisms adopted by the author of the theory almost 100 years ago do not explain all problems related to the reception, processing and transmission of auditory information in a manner consistent with current knowledge. Bekesy assumed that a sound wave passing from air to the fluids of the cochlea loses 99.9% of energy due to the difference in impedance of both environments. The energy loss is 30 dB. He assumed that the mechanisms of the middle ear provide signal amplification due to the lever mechanism and the difference between the surface of the eardrum and the surface of the stapes plate. The proportion of the length of the handle of the malleus and the long limb of the incus is 1.3:1 and this proportion reduces the amplitude of the sound wave conducted by the ossicles. Reducing the amplitude excludes amplification of the wave. The wave energy is proportional to the square of the wave deflection. The proportion of the area of the eardrum and the oval window is 55 mm2: 3.2 mm2 is 17: 1.

It was assumed that this gives a 17-fold amplification of the acoustic pressure of the sound wave acting on the cochlear fluids compared to the pressure exerted by this wave on the eardrum [2]. The sound pressure measured in Pascals is proportional to the wave amplitude measured in nanometers and is converted to wave amplitude. It is difficult to assume that the amplitude of the wave in the atrial fluid increases 17 times compared to the 90 dB wave measured at the input, when the amplitude of this wave is 500 nm. In stapedotomy surgery, a piston with a diameter of 4 mm has an active surface of 0.502656 $mm^2$ transmitting vibrations to the fluids of the atrial canal. This surface is approximately 100 times smaller than the surface of the eardrum. There is no 100-fold increase in sound pressure in the atrial fluid [3]. As the basis of Bekesy's theory, he assumed the hydrodynamics of cochlear fluids, the resonance of the longitudinal sound wave in the cochlear fluid with the transverse wave of the basilar membrane and the transmission information by a wave traveling on the basilar membrane onto the cochlear fluids tilting the hairs of the hair cells.

He incorrectly calculated the natural vibrations of the basilar membrane, giving a value of 16 Hz to 20 kHz in humans. Mammals can hear up to 100 kHz, with the same structure of the basement membrane. The basement membrane has no innervation, no tension regulation, and it vibrates in the cochlea's fluids with high damping abilities. It is burdened by the organ of Corti with fluid spaces and connective tissue on the lower surface of the basement membrane. It is not an independent entity; it cannot vibrate on its own without the load placed on the basilar membrane. The wave traveling on the basilar membrane moves slowly from the oval window towards the cones. The resonance of the longitudinal wave in the fluid of the atrial canal with the natural vibrations of the basilar membrane causes the wave amplitude to increase to the maximum wave deflection depending on the resonant frequency. Suddenly it disappears and changes the phase of the wave - which is incomprehensible for a wave to change its phase while running. During the greatest deflection of the transverse wave, energy is generated on the basilar membrane, setting the fluid in motion between the organ of Corti and the tegmental membrane.

The described snail fluid flows and fluid vortices are created. These flows are supposed to bend or bend the hairs of hair cells, which are connected to each other by tip-links. A thin cadherin filament connects the top of one hair to an adjacent hair in the upper third of the hair [4]. Halfway down the length of the hairs there are similar connections called lateral links, the meaning of which is not described. The tip-links mechanism, according to theory, is responsible for the gating of mechano-dependent potassium ion channels. These channels regulate the flow of potassium ions from high potassium endolymph into the cell. The light of the potassium channel with a cross-section of 0.3 nm is regulated - according to theory - by deflecting the hair of the hair cell with a diameter of 100-200 nm and pulling on the molecular mechanism, the cadherin fibril, connecting the hair with the mechanism that gates the flow of ions. The channel is opened to varying degrees and for different periods of time depending on the information in the sound wave with a frequency of up to 100 kHz in mammals. The influx of positive ions into the cell initiates its depolarization. Within 1 ms, 6,000 potassium ions flow through the open channel after prior dehydration. In the 1980s, Bekesy's traveling wave theory was enriched with a mechanism for amplification of quiet tones. The discovery of the mobility of OHC under the influence of electric current contributed to the development of this theory. It was assumed that OHC contractions after depolarization reduce their length by approximately 4-5% and are the mechanism responsible for the amplification of quiet tones.

The contraction of the OHC, pulling the basilar membrane towards the tectal membrane, amplifies the sound by 40 dB. This amplification means the sound is amplified 10,000 times. It is difficult to explain why such an amplified sound still sounds quiet. Based on an electric current test of the contractility of hair cells, it was found that they can contract up to 50,000/s. OHC cells cannot contract so often because cell contraction depends on depolarization and the operation of ion channels and not on electrical irritation from an external source. Resonance is one of the foundations of Bekesy's traveling wave theory. The mechanism involves transmitting information encoded in the longitudinal sound wave in the inner ear fluids to a transverse wave running along the basilar membrane from the oval window towards the cones. A sound wave in a fluid is a forcing wave, and the forced wave is the natural frequencies of the basilar membrane - vibrations in a different plane. For resonance to occur, three conditions must be met:

1. The frequency of the forcing wave and the forced wave must match - this match may be incomplete,
2. The match of direction may also be similar,
3. The energy of the forcing wave must be greater than the damping of the forced wave.

This condition is necessary for resonance to occur. In our hearing, at low sound intensity, the third condition is not met, and threshold and above-threshold sounds are heard well. The first condition is also not met - the natural frequencies of human body tissues range from 5-100 Hz. The natural vibrations of the basilar membrane adopted by Bekesy as the basis for calculations are inconsistent with studies of natural vibrations of human tissues [5]. Animals can hear up to 100 kHz. Bat even up to 200 kHz. There is no way that their basement membranes have such natural frequencies. At a speed of sound in the cochlear fluid of 1450 m/s and a frequency of 1000 Hz, the distance from the maximum pressure of the wave transmitting energy to the minimum pressure of this wave is 72.5 cm. There is a significant disproportion with the lengths of the basement membranes, as the carrier of transverse waves, which are forced waves. There is no consistency in the direction of sound waves (2nd condition). These waves travel in planes at 90 degrees to each other0.

Pushing the swing from the side, at an angle of 900 to the swing plane, does not increase the amplitude of these swings. There is no evidence for complete transfer of information from the longitudinal wave to the transverse wave. The transmission of quantized energy encoding auditory information through the resonance of a longitudinal wave with a transverse wave is impossible in the ear. Studies of auditory reactions to short sound signals lasting tenths of a millisecond speak against the resonance theory [6,7]. In such a short time, the receptor receives information from one or only 2 periods of the sound wave. Resonance takes time, it is not possible to transmit 100% of the wave energy in one sound wave period. We receive the energy of the sound wave, which produces a signal - a receptor potential with an intensity of 10-12A. We recognize time differences in directional hearing in air with a time of 0.0006 s. In water, this difference is 0.0005 s. A difference of 0.1 ms means that there is no directional hearing in water. At such a low speed of the traveling wave, such time differences are impossible to recognize. The speed of the sound wave

in the cochlear fluid is 1450 - 1500 m/s. However, the speed of wave travel on the basilar membrane from the oval window to the crown is as follows: Bekesy 2.9- 50 m/s. According to American research, 5-100 m/s depending on the frequency and place on the basilar membrane [8]. At the top of the cochlea, the speed of the traveling wave decreases rapidly, while the speed of the sound wave in the fluid remains constant.

The disproportion of wave speed, which is very variable in the course from the oval window to the cones, from 15 times to 300 times, precludes the accurate transmission of auditory information. Each small section of the sound wave contains new information. The problem, according to this theory, is the transmission of multitones with numerous overtones, phase shifts, quantities and accents to the transverse wave and the traveling wave. Bekesy assumed that the sound wave travels on both sides of the basilar membrane, creating a pressure difference on both sides of the membrane, which generates a traveling wave. The wave travels in the ear (contrary to Bekesy's assumptions) in the vestibular canal from the oval window to the capus and then through the capsular fissure and tympanic canal to the round window. From the basilar membrane, the wave is separated by Reissner's membrane, the fluid of the cochlear canal, the membranetectum and the organ of Corti with receptor cells. The sound wave, according to Bekesy's suggestion, would have to pass through the membrane separating the vestibular duct from the cochlear duct.

This membrane is very tight and strong - it separates two reservoirs of fluids with different electrolyte concentrations, preventing fluid osmosis. The next obstacles are the cochlear duct fluid with the possibility of wave dispersion, thetical membrane and the organ of Corti with hair cell receptors. The sound wave is supposed to travel according to: Bekesy through the receptor without transmitting information, because the task of the sound wave is to create a wave traveling on the basilar membrane, which cannot vibrate on its own. The entire delicate organ of Corti with its receptors must vibrate. Laser Doppler vibrometry studies have shown that for a wave of 90 dB corresponding to an input amplitude of 500 nm, at 2-3 kHz - the vibrations of the eardrum are on average 100 nm/Pa - which corresponds to 80 dB. As the frequency increases, the amplitude of the eardrum deflections decreases to 10 nm/P - which corresponds to 60 dB [9]. Up to a frequency of 2400 Hz, the hammer has the same vibration amplitude as the eardrum. If, according to vibrometric tests of the sound wave at the input of 90 dB, the hammer has a vibration amplitude of 100 nm, corresponding to 80 dB - it is difficult to agree with the thesis that the wave at the input, or the 80 dB wave on the eardrum, conducted through the ossicles, is increased by 33 dB, or about 44 times.

The proof that the thesis of such reinforcement is incorrect is provided by vibrometric tests of the wave amplitude on the stapes plate on the side of the inner ear and in the initial section of the fluids of the vestibular canal [10]:

The tests were performed for a wave of 90 dB (500 nm) at the input.

Frequency--------plate----------vestibule

1000-Hz---------5.09nm----------0.275nm

4000Hz----------1.37nm----------0.00886nm

8000Hz----------0.0905nm---------0.00153nm

Such a large decrease in wave energy transmitted to the cochlear fluids may be caused by the structure of the oval window - bone and connective tissue, dimensions - length 2.24 mm, width 1.4 mm, ring width 0.1 - 0.04 mm, ring thickness 0, 2mm. It is influenced by the length of the annular ligament, which is a linear-elastic material with a deflection of approximately 100 nm, with a stiffness of approximately 1200 N/m and a calculated modulus of elasticity of approximately 1.1 MPa. The stirrup plate acts like a piston at low frequencies. At medium frequencies, it performs rocking movements around the transverse axis of the stirrup. At high frequencies, rocking movements take place along the longitudinal axis of the stapes plate. During rocking movements, part of the plate generates forward wave motion, while at the same time the remaining part of the stapes plate generates backward motion. The rocking (rocking) movement is provided by the spherical incus-stapedius joint. Sound waves traveling in opposite directions in the same plane are subject to destructive interference. There is friction between particles vibrating the environment.

The formation of a traveling wave on the basilar membrane is doubtful or impossible. The transmission of accurate, quantized packets of auditory information is impossible. One of the foundations of Bekesy's theory is the hydrodynamics of snail fluids. The wave traveling on the basilar membrane grows from the oval window towards the crown, to a point maximum amplitude, suddenly disappears and changes phase. Along the entire length of the traveling wave, it stimulates the cochlear fluid to flow towards the tectal membrane. The movement of the fluid tilts or bends the hairs of the hair cells. The maximum wave on the basilar membrane also produces vortices in the cochlear fluid. These are not laminar flows. Vortices occur in turbulent flow. The fluid flows and fluid vortices of the cochlea cannot encode in addition to amplitude and frequency, overtones, phase shifts and quantity Times. Fluid movements tilt or bend the hairs of hair cells - when the top of the hair is connected to the tectal membrane. If the audible threshold tone is 0.008 nm at the input and the amplitude of this wave decreases by at least 100 times on its way through the fluids and basement membrane, then the hair cell diameter of hair cells of 100-200 nm is 1 - 2 million times greater than the wave amplitude.

The tilting of the hairs must encode the transmitted, quantized energy of the sound wave. The possibility of transmitting information by tightening cadherin fibrils and pulling the gating mechanism of mechano-dependent potassium ion channels also requires explanation. The problem is the gradual change in energy transmitted by the

sound wave. It cannot be a continuous change. Auditory information is encoded in the gradation of transmitted wave energy. This mechanism is difficult to explain in other mammals. The traveling wave theory relates frequency and intensity resolution to the action of the basilar membrane. A human recognizes an average of 3,000 pure tones, which, with a basement membrane length of 32 mm, gives 0.01 mm of basement membrane per tone. It is difficult to imagine that such sections of the basilar membrane would differentiate frequencies with an accuracy of 1 Hz. All mammals have the same hearing mechanism. A young mouse can hear a frequency range from 1-100 kHz, which is 5 times larger than in a human, with a basilar membrane that is about 10 times shorter. There is 0.0002 mm of basement membrane per 1 ton. Perfect mouse hearing resolution is impossible with this method. In addition, a mouse hears sounds with an amplitude much smaller than a human hears. In Bekesy's traveling wave theory, supplemented in the 1980s, a big problem is the amplification of quiet tones, especially those included in multitones.

Loud sounds are picked up and the information is transmitted to the center. However, quiet sounds requiring amplification are separated and directed to the time-consuming route of mechanical amplification. The contraction of the OHC generated by a quiet sound is supposed to pull up the basilar membrane in a specific place by the frequency of the amplified wave, increasing its deflection by inducing a greater flow of fluid, which this time tilts only - for some reason - only the Italian IHC. The received information is to be sent to the center with a significant delay compared to loud tones of the same multitone. When you pull up the basilar membrane to amplify a quiet tone, the basilar membrane transmits a completely different wave, different information, via a traveling wave. It may be a wave of high intensity and a different frequency. There is a conflict of interest - which wave is to be transmitted further.

Fluid flows cannot simultaneously conduct waves of different amplitudes and different frequencies. They cannot interrupt the transmission of information recorded on the sound wave to amplify the previously received wave. This is a very bad solution. Nature could not accept this. This is an invention of the authors of this concept of mechanical amplification of quiet sounds. An important problem concerns the depolarization of the hair cell–how long after another depolarization and contraction of the hair cell can occur. The depolarization of a sodium channel, which is very important in cell depolarization, lasts about 1 ms. The problem is that the time for a complete cycle of depolarization and polarization of a hair cell is approximately 3-4 ms. Mainly affects high frequencies. During repolarization, sodium channels are insensitive to depolarizing stimuli. They are in a state of inactivation. This is a state of refraction. Re-occurrence of depolarization is possible after the sodium channel transitions to a state susceptible to excitation. The time in which the hair cell fully regains the ability to generate the next depolarization is approximately 1-2 ms [11].

Therefore, simultaneous depolarization of the entire hair cell at high frequencies is impossible. Depolarization determines the operation of the hair cell, the production and exocytosis of the transmitter to the synapse. It generates a postsynaptic excitatory potential that is transmitted to the spiral ganglion nerve cells, where an action potential is created and is conducted via the auditory nerve to the center. Depolarization affects regulated and constitutive activities in the cell. A sound wave is only a movement of energy, not mass, it is a longitudinal wave traveling in a straight line [12]. The worm is a tapered tube twisted in a spiral. The sound wave encounters the wall of the conduit and some of the energy is reflected according to the law: the angle of reflection is equal to the angle of incidence. Reflections take place from the concave surface, which causes the concentration of reflected waves falling on the organ of Corti and the basilar membrane. Short waves are reflected earlier than long waves. Successive reflections add up, which can cause the energy on the basilar membrane to be summed and may lead to the formation of a wave collected at the basilar membrane. The walls of the screw are uneven, and the reflected energy is dissipated. Snail fluids contain numerous "impurities" on which the waves dispersion (proteins-70-100 mg%, sodium-135-150 mEq/l, potassium-7-8 mEq/l, chlorine-135 mEq/l, phosphorus-0 ,32-0.99mg%, magnesium-0.82 mEq/l, CO2-10 mEq/l, and oxygen and nitrogen).

These components have different refractive indices. The flow of the wave through the narrowing duct of the vestibule stairs and the obstacle in the form of a concave gap causes the phenomena of reflective attenuation and absorption attenuation. However, flows of waves reflected in different directions, often in opposite directions, reflected many times, cause interference attenuation. The basement membrane also has damping abilities. This explains the loss of energy on its way through the snail's fluids. If it is assumed that the wave traveling to the round window is not the full path to the receptor, then it can be assumed that the energy loss is 500 times - this is the wave path to the round window, which is the path of the traveling, evanescent wave. The energy loss is much greater on the way to the cap due to the narrowing of the channel and the high resistance of the narrowing of the cap gap. According to the traveling wave theory, we hear a sound wave that decreases in the cochlear fluids from an amplitude of 8 pm by about 500 times. Such a wave has an amplitude of about 0.016 pm, which is 625 times smaller than the diameter of a hydrogen atom.

The wave is supposed to cause a traveling wave on the basilar membrane. We hear it! This is confirmed by thorough laser vibrometric tests. The barn owl hears input tones with an amplitude of 1 pm. This wave in fluids decays. In the case of cochlear implant surgery, electrodes inserted into the eardrum cause mobility impairment or immobilization of the basement membrane, which does not change the existing hearing. According to Bekesy's theory, this cannot be explained. In the case of stapedotomy surgery, there is no reception and transmission of high frequencies to the receptor. This phenomenon is inconsistent with the traveling wave theory [13,14]. The diameter of

the cochlear ducts from the oval window to the capus decreases approximately three times. The wall separating the cochlear duct from the tympanic duct at the base is 1.7 mm - 2.0 mm high. For the calculation of the natural vibrations of the basilar membrane, Bekesy assumed that the basilar membrane separating these ducts at the base of the cochlea is 0.25 mm and widens to 0.75 mm in the vicinity of the cones.

The width of the basement membrane of 0.25 mm cannot separate the fluid spaces of channels with dimensions of 1.7 - 2.0 mm, channels with different fluid concentrations. The separation of channels must be tight. The length of the basement membrane in small mammals and birds ranges from 1 mm to several mm. The received frequencies reach up to 100 kHz. The basement membrane does not have such resonance capabilities. If a pigeon perceives sounds from 5 Hz upwards, the length of this wave in the cochlear fluid is 290 m. Half of this wave with the maximum deflection falls on 145 m of the wave (the maximum deflection of the wave is the maximum energy transfer). Resonance is impossible with a basement membrane length of 2-5 mm. The vibration of a string depends on the tension in the string. The basement membrane has no afferent and efferent innervation and is unable to regulate tension. It is a flaccid connective tissue. Studies of human tissues have shown that their natural frequencies range from 5 to 100 Hz. A hummingbird can hear 50 Hz waves with a wavelength of 29 m in the inner ear fluids when the length of the basilar membrane is 1 mm. Resonance is not possible when one wave period is 29,000 times longer than the length of the basilar membrane.

The hummingbird hears well and recognizes frequencies. Bekesy's traveling wave theory lacks a description of processes at the molecular and submolecular level. There is no description of the regulation of mechanisms in the hair cell at the constitutive and regulated level. No explanation of the operation of receptive fields, temporal and spatial summation, presynaptic and collateral inhibition, and the importance of calcium in information transmission. The intracellular signal amplification that exists in all sense organs was not taken into account. The sum of the problems of the age-old theory of hearing prompts a solid analysis and revision of the theory, which leads to the presentation of a new, modern vision of hearing, proposed for 20 years under the name. Submolecular Theory of Hearing.

## Submolecular Theory of Hearing

Sound waves fall on the auricles, which in humans are not shaped in such a way as to concentrate the waves into the ear canal. Their varied shape means that wave reflections cause scattering rather than concentration of waves. The angle of reflection of the wave is equal to the angle of incidence. Part of the incident energy is absorbed by the ear tissues, and part is conducted further after passing through the tissues. Absorbed energy is important for hearing because it is conducted to the bone and then to the receptor. Sound waves enter the ear canal directly, and additionally scattered waves reflect from the irregularities of the auricle. Part of the sound wave energy absorbed by the auricle is in addition to the energy conducted through the ear canal. It plays an important role in recognizing the direction from which a sound wave is coming. Sound transmitted through the ear canal stimulates the eardrum to cause vibrations transmitted through the ossicles of the middle ear to the stirrup plate.

The vibrations of the ossicles are transmitted to the bony casing of the cochlea and are transmitted via the bone to the receptor. Soft tissues conduct sound waves. The proof is the hearing of the baby in the mother's womb in the second half of pregnancy, when the baby's middle ear is not yet functioning. We hear a tuning fork placed on the knee or ankle on the leg, the wave energy does not act through the ear canal. Bats, having the best hearing among mammals, have very large, asymmetric ears. One is directed forward, the other backward. They receive signals very quickly from all directions. There is no concentration of energy flow into the ear canal. Some bats produce and receive from 20 to 250 signals/s. There is no possibility of time-consuming resonance or slow traveling waves acting on the basilar membrane. The signal goes directly to the receptor and to the analysis of central centers. The vibrations of the stapes plate are transmitted through the tendinous ring to the bony casing of the cochlea. Waves transmitted from the auricle and ossicles of the middle ear overlap - interference or superposition of waves occurs.

These waves go straight to the receptor, without unnecessary energy exchanges on the way to the receptor and without energy loss. Stapes plate movements are pistoning at low frequencies and rocking at higher frequencies pthey transfer wave energy to the cochlear fluids. The wave energy constantly flowing into the ear cannot be accumulated in the ear and cannot disappear. The unusable sound wave energy is gradually converted into another form of energy. During rocking movements of the stapes plates, the transmission of auditory information to fluids is difficult. While one half of the plate generates forward motion of the fluid in a wave, the other half of the plate generates backward motion. This wave motion of the fluid in the atrial canal, equal in energy and opposite in direction, cannot cause a pressure difference on both sides of the basilar membrane or a traveling wave on the basilar membrane. The signal is sent via bone at a speed of 3-4 thousand km/h. m/s reaches the receptor without loss of wave energy.

Molecularly, the information encoded in the sound wave is transferred to the mechanism that gates mechano-dependent potassium channels. A sound wave is the movement of energy without transporting the mass of the environment. These are vibrations of particles propagating in an elastic medium. Each particle oscillates around its equilibrium position, transferring energy to its neighboring particle. Energy is transferred at a rate that depends on the elasticity of the environment. A sound wave has a period of vibration and an amplitude of swing. It is assumed that a sound wave has no mass and is not subject to the law of inertia. This view requires verification. The mea-

sure of inertia is the mass of the vibrating element maintaining speed and acceleration. Particles vibrating in a sound wave have speed and positive and negative acceleration. They consist of at least 2 atoms of an elastic environment. The average mass of atoms of vibrating molecules = 10-24 to 10-23 g. The mass of even many atoms of vibrating molecules, multiplied by acceleration and amplitude, is not of much importance in itself. With a large increase in amplitude and especially frequency, it may be important - it is an added value. A sound wave should be treated as a stream of energy portions in the form of multiples of the energy quanta carried by atoms and molecules. Free atom and atomin a molecule it has a total energy composed of the kinetic energy of electrons and the proton-electron potential energy. The electron circulates in its own orbit and has a specific constant energy.

Changing the orbit to a further or closer one is accompanied by the sending or absorption of a certain portion of energy - energy quanta. Total energy of the hydrogen atom = 1/n2 x A (A= 2.17 x 10-18 J). n – is the orbit number. Each atom has a different total energy, and each orbital has a different energy. The ground state of hydrogen in 1 orbit = 2.17 x 10-16 J. H electrons in a higher orbit are the excited state, higher energy. Absorbing a quantum of energy results in the electron jumping to a higher orbit and a higher energy level. The atom becomes an exciting atom. The added energy must be exactly equal to the energy difference between electron orbits, between energy states. However, the return of the electron to a lower level causes the electron to radiate in the form of electromagnetic radiation, exactly equal in energy between the energy levels changed by the electron. It is possible to jump back and forth several levels and requires a lot of energy.

The atom stays in the excited state for a short time, on average 10-8 s, then it gets rid of excess energy and moves to a lower level with lower energy. It may jump straight to energy level 1, but it is usually a gradual transition. When moving to a lower level, the atom emits a quantum of energy - it is the emission of a wave with a precisely defined wavelength. When atoms in constant motion collide, kinetic energy is transferred to the other atom. The second atom absorbs energy and moves to a higher energy level - this is the excited level. Changes in electronic states take place in 10 attoseconds-18s. During this time, the electron cloud changes. Particles with single bonds are susceptible to conformational changes. There is a constant rotation of groups of atoms around the bond. Such particles change their shape. Any shape change requires external energy. The rotation is not permanent, giving away energy causes the body to return to the state with the lowest energy. Too large molecules or double or triple bonds may create steric hindrances, making the formation of conformers difficult. (Nobel 1969). Oscillations change, bond lengths, bond angles change, and electron clouds change. Conformational changes of receptor molecules (sound-sensitive molecules) sensitive to an adequate stimulus, i.e. sound wave energy, are responsible for the mechanism gating of mechano-dependent potassium ion channels.

The bandwidth and frequency of the potassium channel are precisely determined by the energy of the sound wave. Another important change in sub molecular theory is to amplify the received signal, which is too weak to reach the center. This takes place in the hair cell in a molecular way. In all senses there is a perfect mechanism of intracellular amplification, regulated, molecular. Intracellular amplification is a whole complex of factors such as: phosphorylation and dephosphorylation of ion channels responsible for the conductivity of cell membranes, ATP concentration, cAMP level, cGMP, cell pH, osmotic pressure, the presence of ligands, and the operation of Ca++ATPase pumps. These pumps, associated with the cell membrane, play a large role in maintaining variable calcium levels in the cell. Intracellular strengthening is also related to the work of proteins binding to calcium, where calmodulin plays an important role, influencing the production and breakdown of cAMP and cGMP. It activates protein kinases and phosphatases and regulates the functioning of the calcium pump. It affects the contraction of muscle and non-muscle cells by activating the cAMP-independent myosin light chain kinase. Calmodulin affects exocytosis. Saturation of the 4 domains of calmodulin increases its effect up to 10,000 times.

The process of enzyme production or the rate of their degradation is regulated. Calcium is the second transmitter of information in the cell, acting faster than the iother second transmitters: cAMP, cGMP, DAG, IP3, which are produced in connection with the increase in calcium levels or activated by protein G. The stage of production of second messengers is one of several intracellular strengthening mechanisms. One enzyme molecule can produce several hundred-second messengers. For the proper functioning of the hair cell, a balance must be maintained between the influx of calcium into the cell through ion channels in accordance with the electrochemical potential and the rapid release of calcium outside the cell through ion channels, ion pumps and ion exchangers. The work of hair cells and synapses, as well as the importance of calcium and prestin, are discussed in another publication.

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