

HISTORY OF MEDICINE AND DEVELOPMENT

The scientific heritage of Professor Aron Gutman (Commemorating the 10th anniversary of Aron Gutman's death)

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Summary. Aron Gutman started his scientific research when he was a student of the Department of Physics and Mathematics, Vilnius University. At that time, he developed the theory of nonhomogenous vector relations between magnetic moments of electrons in an atom and applied it for explanation of energy spectrum of real atoms. Since 1960, he worked in Kaunas Medical Institute, and his main field of scientific interests was theoretical biophysics and electrophysiology of living tissues and cells. The earlier biophysical works of A. Gutman dealt with problems of the bioelectrical fields that underlie electroencephalogram, electrocorticogram, and electrocardiogram. The most important achievement was a theory of individual potential or postsynaptic field potential of synapses from individual axon (EEG quantum) and its role in shaping of electroencephalogram. In the later works (from 1971), he looked into properties and function of the individual nerve cells. He had created and developed the theory of nonlinear (bistable) dendrites and analyzed functional implications of such dendrites. In the last works, A. Gutman tried to relate the functioning of the nervous system at the cellular and system levels. He made efforts to find connection between the properties of individual neurones and principles (laws) of functioning of the nervous system. He had managed to relate dendritic bistability of neurones and Gelfand-Tsetlin principle of the functioning of the central nervous system (also known as the principle of minimal afferentiation). He explained some regularities in motor control by the dendritic bistability of motoneurones.

Short biography

Aron Gutman was a famous Lithuanian Jewish scientist, Professor of Biophysics, the principal researcher of the Laboratory of Neurophysiology at the Institute of Biomedical Research of Kaunas Medical University.

Aron Gutman was born in 1936 in Zhitomir, Ukraine. In 1945, Gutman's family moved to Lithuania, and it has been living there since. In 1958, Aron graduated from the Faculty of Physics of Vilnius University. In 1959, he started to work in the Laboratory of the Scientific Investigations of Kaunas Medical Institute. Aron Gutman carried out scientific research concerning biopotentials of the brain, and at the same time, he taught at the Department of Physics, Mathematics,

and Biophysics of Kaunas Medical Institute. In 1962, he defended his PhD thesis in the field of quantum physics entitled "Nonhomogenous vector relations in the atomic spectra." In 1965, he was appointed to the position of Head of the Department of Physics, Mathematics, and Biophysics and promoted to Associate Professor in 1969. In 1974, he defended his thesis of Habilitated Doctor in field of biophysics and electrophysiology entitled "Extra- and intra-cellular electrical fields of the dendrites of neocortex" and became Habilitated Doctor of Biophysics, the first one in Lithuania. In 1990, Aron Gutman was advanced to the professorship in biophysics.

Aron Gutman is an author and coauthor of more than 200 scientific publications, including two books



Professor Aron Gutman

and a series of chapters in biophysics textbooks. He is well known among the biophysicists and neuroscientists across the world. Professor Gutman's papers were published in prestigious international scientific journals, and his works have been frequently cited by scientists in Lithuania and abroad. Aron Gutman was an excellent teacher and mentor. He trained a number of neuroscientists who are successfully working in Lithuanian as well as European and American Universities. His knowledge and erudition were surprisingly deep, such that researchers from other fields outside of biophysics frequently asked for Aron's advice on various complicated scientific matters.

A. Gutman was a member of the Society for Neuroscience and the International Academy of Social and Natural Sciences. He was a referee of Human Frontier Science Program Organization. In 1999, he was granted a Lithuanian State Stipend for outstanding researchers. The Kapitsa medal was awarded to him for his achievements in physics.

In addition to his scientific activity, Aron Gutman actively participated in the social and political life of Lithuania. He was a member of the Lithuanian Movement for Independence, Sąjūdis, which was the main force in restoration of independence of Lithuania in 1991. He propagated a peaceful way of solving conflicts, and he publicly condemned violence of Soviet troops in Lithuania in January 1991. For many

years, Aron Gutman was an active member of the Lithuanian Jewish community. He was also working at the International Council for the Investigation of the Crimes by Occupational Regimes.

Scientific research

Below we present more detailed description of A. Gutman's scientific research pointing out the scientific problem, field of science, period, when A. Gutman was engaged in solving the corresponding problem, and principal publications related to the problem.

1. Inhomogeneous vector relations (atomic quantum mechanics), 1957–1963

Together with his supervisor Y. Levinson, A. Gutman had formulated a general theory of inhomogeneous vector relations for magnetic momenta of atomic electrons and applied it to the $l^m l'$ configuration. He discovered a new vector relation SL_0 and the corresponding energy spectra of real atoms. A. Gutman suggested using the principle of inhomogeneous vector relations to explain x-ray spectra. The theory was later applied at the Vilnius University by the group of Prof. J. Jucys. Principal publications are (1, 2).

2. Description of δ -activity in the electrocorticogram (electrophysiology of the cortex), 1963–1969.

In the electrical activity of the cortex (electrocorticogram), one distinguishes a number of oscillations with a different frequency. Among these, low frequency (~ 1 Hz) oscillations are termed the δ -activity. A. Gutman together with K. Grinevičius and others proposed the adequate phenomenological description of the δ -activity. They proved that the δ -activity reflects an electrical bistability of the cortex. The bistability of the cortical pyramidal neurones that could be related to the electrical bistability of the cortex was observed experimentally (3, 4). The results of this work were used to explain the nature of high frequency (~ 100 Hz) oscillations in the electrocorticogram. They were useful in the analysis of the evoked potentials and changes in electrocorticogram under narcosis. Principal publications are (5–11).

3. Development of the theory of extracellular current field (biophysical bases of electrophysiology), 1967–1980.

A. Gutman supplemented the theory of extracellular current field by simple quantitative and semiquantitative estimation methods. He succeeded in deriving formulae, whose parameters were directly related to known morphological and electrophysiological quantities. This made it possible to an-

swer why the impulse activity of the cortex cells only weakly is reflected in the electrocorticogram; to explain theoretically the magnitude of the observed potentials of the electrocorticogram; to explain the pattern of the electric potential change deep in the cortex; to improve the theory of electrostimulation and to invalidate the ephaptic theory according to which the neurons were thought interact strongly via their extracellular current fields. Later he had used the results of this work to introduce the notion of a quantum of the encephalogram (EEG) and to analyze the electrotonic (ohmic) properties of the neurons. Principal publications are (12–20).

4. Description of anisotropic syncytial media of the myocardium (biophysical bases of heart electrophysiology), 1970–1988. Dr. F. Bukauskas, the biophysicist from Institute for Biomedical Research, Kaunas University of Medicine, and his coworkers investigated the spreading of the electric excitation in the heart muscle. To explain the properties of this spreading, a model of anisotropic syncytium that treats the myocardium as network of the muscle cells connected with each other by the anisotropic intercellular contacts was used. A. Gutman described such syncytial medium using an anisotropic equation of the intracellular field. This greatly simplified the theory and its matching to the experimental data. His students continued the work in this field at the Laboratory of Heart Electrophysiology, Institute for Biomedical Research, Kaunas University of Medicine. Principal publications are (21–25).

5. Quantum of electroencephalogram (biophysical bases of brain electrophysiology), 1969–1989. The introduction of a notion of quantum of encephalogram (an elementary impulse of the electrical brain activity) and foundation of the corresponding theory is one of A. Gutman's greatest scientific achievements. The theory of the quantum of the EEG enabled to interpret the EEG as an impulse process and to explain general features of the frequency spectrum of EEG. The theory had elucidated the nature of high frequency oscillations studied by Prof. A. Mickis and his students. A. Gutman had estimated the magnitude of EEG quantum by using the theory of the extracellular current field, which he described in his book "Biophysics of the extracellular brain currents" (13). He proved that the magnitude of the EEG quantum is large enough to detect it experimentally. The biophysicists of the Institute for Biomedical Research, Kaunas University of Medicine, registered the quantum in the frog tectum and in the somatosensory cortex of rabbits (26). They achieved

this independently from famous American neurophysiologists Mendel and Henneman, who discovered this impulse at the same time by accident (27). The registration of the quantum of EEG became one of the standard methods of investigation of synaptic transmission in the central nervous system (CNS). This method is still used in the Laboratory of Neurophysiology, the Institute for Biomedical Research, Kaunas University of Medicine, to study the properties of the synaptic transmission from frog retina to tectum (28–30). Principal publications are (31–34).

6. Theory of electric properties of the skull and scalp (biophysical bases of human encephalography), 1972–1989. The electric potentials of the surface of the head (electroencephalogram, EEG) are a reflection of the electric potentials of the cortex (electrocorticogram) disturbed by the scalp and the bones of the skull. Therefore, it is important to understand how the cover tissues of the brain transform the electrocorticogram into EEG. A. Gutman proposed a simplified solution to this problem by treating the brain cover tissues as thin double layers. This enabled him to use equations for a 2D spherical cable in order to describe the above transformation and to obtain analytical mathematical expressions with a clear physical meaning. Dr. A. Šimoliūnas (Vilnius Institute of Mathematics and Informatics) developed numerical algorithms based on this theory, which were applied to solve the reverse problem of electroencephalography – to restore the electrocorticogram from EEG. The theory was applied to examine possibilities of the electrostimulation of the brain as well as in search of the correlation between the position of the electrodes on the scalp and the physiological significance of the electric potentials registered. Dr. A. Šimoliūnas was further developing this theory for a number of years. Principal publications are (35–42).

7. Dendritic bistability (theoretical neuro-electrophysiology), from 1969. Dendrites are neuronal processes that branch in a tree-like manner. They can be a few mm long and a few μm thick. For more than 100 years, when the first pictures of silver-stained neurons had been obtained, the neurophysiologists have been interested in general function of dendrites. For a long time it was believed that dendrites are simple linear summators, and their main function is to add up synaptic signals arriving from other neurons. In 1971, having analyzed experimental data on neurons electrical properties, A. Gutman proposed the hypothesis of bistable (or N-) dendrites, which postulated nonlinear electrical properties of the dendritic membrane (43). Based

on the hypothesis of bistable dendrites, A. Gutman predicted electrophysiological phenomena that were later observed experimentally (44–47). Results of experimental investigations on electrical properties of motoneurons confirmed that at least the dendrites of the motoneurons are bistable (48–52). The information processing can take place in the bistable dendrites. For example, the elementary logical operations can be performed in a single dendritic branchlet (53–57). Such neurons can implement the general Gelfand-Tsetlin's minimal afferentiation principle of functioning of the CNS (58). Based on the theory of bistable dendrites, A. Gutman explained the principles behind the functioning of the motor nervous system (unpublished results). A. Gutman and coworkers theoretically analyzed the propagation of the synaptic signals along the bistable dendrites (59, 60). They suggested the new interpretation of the slow negative potential of the cortex surface that is based on stable depolarization of the apical dendrites of the pyramidal neurons rather than on depolarization of glia cells caused by increased extracellular concentration of potassium ions. The theory of dendrite bistability is further developed by A. Gutman's students (61, 62). New experiments are proposed, and the theory is applied to propose novel hypotheses on motor control (63).

8. Electrotonic reconstruction of neurones (biophysical bases of neuroelectrophysiology), from 1980. In order to understand the function of neurons, it is

important to know how fast potential deviations evoked by synaptic inputs fall off with distance from the source along the dendrite. Passive propagation of the potential in the dendrites is termed electrotonic one. Neurophysiologists have been engaged in the problem of the electrotonic reconstruction of neurons for a long time (64–66). Yet, no reliable way to solve it exists (67, 68). Presently, the most widely used method of electrotonic reconstruction of neurons is computer simulation of the cell response to a short current impulse. A. number of various model parameters have to be fitted to the experimental data. A. Gutman and his coworker and former PhD student G. Svirskis suggested a new method of the electrotonic reconstruction of neurones that exploits the response of a neuron to an extracellular current field (DC current field) (69). This method allowed reducing the number of fitted parameters (70) and to detect heterogeneity of membrane properties (69). The method was applied to the turtle spinal motoneurons and interneurons, and their electrotonic reconstructions were obtained. A. Gutman and collaborators had investigated how the irregularity and inhomogeneity in cross-section of dendrites influence their electrotonic properties (71). They proposed and developed an adiabatic method for solving the cable equation, which could help to estimate the electrotonic parameters of neurones and dendritic cables (72). A. Gutman's students continue to work in this field (73).

Profesorius Arono Gutmano mokslinis palikimas (Arono Gutmano 10-osioms mirties metinėms paminėti)

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Raktažodžiai: nervų sistema, elektroencefalograma, elektrokardiograma, neuronas, dendritai.

Santrauka Savo mokslinę veiklą Aronas Gutmanas pradėjo dar būdamas Vilniaus universiteto Fizikos-matematikos fakulteto studentu. Tuo metu jis plėtojo nehomogeninių vektorinių ryšių tarp atomo elektronų magnetinių momentų teoriją ir taikė ją realių atomų energetinių spektrų paaiškinimui. Nuo 1960 m. jis dirbo Kauno medicinos institute. Pagrindinė jo mokslinių interesų sritis buvo teorinė biofizika ir gyvųjų audinių bei ląstelių elektrofiziologija. Ankstyvieji Arono Gutmano biofizikos darbai skirti bioelektrinių laukų (elektroencefalogramos, elektrokortikogramos ir elektrokardiogramos) kilmės problemoms. Svarbiausias pasiekimas buvo individualaus aksono sinapsių aktyvumo sukeltą posinapsinio potencialo (EEG kvanto) teorija, aiškinanti elektroencefalogramos struktūrą. Vėliau (nuo 1971 m.) jis gilinosi į atskiros nervų ląstelės funkciją bei savybes. Jis sukūrė bei plėtojo netiesinių (bistabilių) dendritų teoriją ir analizavo tokių dendritų funkcines savybes.

Paskutiniuose savo darbuose Aronas Gutmanas mėgino susieti nervų sistemos funkcionavimą ląsteliniame ir sisteminiame lygmenyse. Jis stengėsi išaiškinti ryšį tarp individualaus neurono savybių ir nervų sistemos funkcionavimo dėsnių. Siedamas neuronų dendritų bistabilumą su Gelfand-Tsetlin'o centrinės nervų sistemos veikimo principu (kitai vadinamu minimalios aferentacijos principu), Aronas Gutmanas paaiškino kai kuriuos judesių kontrolės mechanizmo savitumus motoneuronų dendritų bistabilumu.

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