DEVELOPMENT OF BIOPHYSICS IN THE FORTY YEARS FOLLOWING THE GREAT OCTOBER SOCIALIST REVOLUTION*

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SOON after the establishment of Soviet rule, against the background of a general rapid development of science in Soviet Russia, new regions of knowledge began to be built up as a result of the contact of various disciplines, such as physical chemistry, biological chemistry and biological physics. The contact between physics and biology took place on two levels. On the one hand, research was carried out on the physical properties of and the physical processes in living systems, and on the other, the action of physical agents on these systems was studied.

Among the physical factors, the action of ionizing radiations on the organism was especially intensively studied because of its exceptional importance in medical practice. Because of the subsequent progress of atomic physics and the mastering of atomic energy this factor became of prime importance and led to the separation of an independent discipline which received the name "radiobiology" and which is very closely connected with biophysics.

During the first years of Soviet rule, foresight into the future trends of science and a clear understanding of the advantages of using physics in biology and medicine, not only led to the formation of new border disciplines on the basis of those already existing, but also stimulated the organized moulding of institutes of a completely new type. Here, in the first place, one should name the Institute of Biophysics of the Ministry of Public Health of the U.S.S.R., which arose on the basis of the pre-revolutionary Institute of Physics and which, according to the conception of its founder, Academician P. P. Lazarev, directed the efforts of the trained physicists collected there to the solution of the principal problems of biology.

Of great importance for the development of radiobiology, apart from its value in connexion with practical problems such as X-ray diagnosis, and X-ray therapy and radiotherapy, was the founding of another centre, the Institute of Röntgenology and Radiology in Leningrad, which was uninterruptedly directed by Prof. M. I. Nemenov for about 30 years.

The school of Academician Lazarev preserved its leading role in the field of biophysics up to the death of its founder at the beginning of World War II.

In justice we should consider Lazarev to be the creator of Soviet biophysics since he has not only done most work in the field of biophysics, but has has also formulated the general tasks of this young science and defined its subject and its special methodological procedures. His ionic theory of excitation, which plays an important role in understanding the biophysics of living processes, at a definite stage of development of science, was fundamental for the development of the whole trend in the field of research on the mechanisms of the phenomenon of excitation. At the same time it

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served as a starting point for the study of the problem of the biophysics of vision, which was especially widely developed in Lazarev's school.

Certain physiological investigations should be considered as directly bordering on biophysics, particularly those carried out by Academician L. A. Orbeli and his students on the functions of sense organs. In this connexion one should recall the work of one of the pioneers of Soviet electrophysiology, Prof. A. A. Samoilov, who studied electrophysiological processes of nerve excitation.

The work of a number of the most outstanding Soviet physicists, who began their activity in the Institute of Biophysics under the direction of Lazarev, was very important for 'the subsequent development of biophysics. The experiments of Academician S. I. Vavilov acquired world-wide fame; using the eye as a light-sensitive apparatus he showed, directly, that it is possible visually to observe the discrete nature of light. Investigations in the field of vision were further pursued; among these one should mention, in the first place, the work of S. V. Kravkov on the interaction of the sense organs and the work of N. T. Fedörov on the mechanism of colour vision.

S. N. Rzhėvkin and L. A. Andreev developed the bases of the biophysics of the auditory apparatus. The investigations of A. G. Gurvich, who discovered mitogenetic rays in 1923 and who showed that they were ultra-violet rays, evoked lively discussion in the world literature.

At the beginning of the twenties, G. A. Nadson and his co-workers, when studying the action of radiations on micro-organisms and plant cells, made a discovery of enormous importance: they established that it was possible to obtain hereditary changes by irradiating the parent organism. Two years later, Muller published the results of experiments which showed that, by X-ray irradiation, hereditary changes could be evoked in fruit flies, and he was awarded the Nobel prize for this work.

At the same time, in the Institute of Röntgenology and Radiology, investigations were started which formed the basis of the original Soviet trend in radiobiology. In the work of P. S. Kupalov, and also of Nemenov, it was shown (and subsequently developed) that the nervous system has a high functional sensitivity to radiation. This opposed the ideas of the majority of foreign investigators on its considerable resistance, ideas based only on comparative morphological analysis of various organs and tissues.

In these same years, side by side with Moscow and Leningrad, investigations in the field of radiobiology were started in many other towns of the Soviet Union. Here we should primarily mention the work of N. M. Voskresenskii in the Experimental Biology Laboratory of the Kiev X-ray Institute and the work of A. V. Rentev and I. P. Mishchenko in the Ukraine Röntgenology and Radiology Institute in Kharkov.

To 1936 pertains the organization, in the All-Union Institute of Experimental Medicine (V.I.E.M.), of a department of biophysics and photobiology (G. M. Frank) in which, on the one hand, the action of physical factors on the organism and, on the other, the physical and physico-chemical processes lying at the basis of vital phenomena were studied. The most important aspect of the researches was the development of a new approach to the specificity of the biological action of ultra-violet rays of different wavelengths. The disclosed features of this specificity were explained by analysis of the photochemical basis of the action of the ultra-violet rays. In the same

Institute, by the method of X-ray structure analysis, the first work on the ultrastructure of living tissues was carried out and the basis of the application of isotopic indicators was laid.

The investigation of those physico-chemical processes which are fundamental in vital phenomena attracted the attention of many investigators in those years. Problems of permeability, the role of surface phenomena in biological processes, colloid-osmotic phenomena, sorption processes in living systems, were worked on by D. N. Nasonov, V. Aleksandrov, P. A. Rebinder, B. V. Deryagin, D. L. Rubinshtein and others.

In the investigations of Rubinshtein and his co-workers the theory of the biological action of ions was developed and clear quantitative criteria were proposed of the phenomena of sensitization, synergism and antagonism of ions in salt mixtures. The theory of "one-sided" permeability of tissue membranes was put forward on the basis of the principle of stationary states in biological systems.

To this same time (1928–1939) should be referred a series of beautiful studies on the biomechanics of motion of marine animals carried out by V. V. Shuleikin and his co-workers and also the work of N. A. Bernshtein on human biomechanics.

In 1935 the Agrophysical Institute (A. F. Ioffe) was organized in the system of the V. I. Lenin All-Union Academy of Agricultural Sciences in order to make systematic use of the achievements of physics in agrobiology. This considerably helped the development of light-culture, the more rational use of fertilizers and the solution of other problems which faced agriculture.

Thus, in the pre-war period contacts between physics and biology were established, a tradition of biophysical and radiobiological experiment was founded, and a nucleus of research workers, using physics in one or other way for the solution of biological problems, was developed.

After the end of the war the advances in nuclear physics, which led to the discovery of the method of using atomic energy, the construction and use by the U.S.A. of an atomic weapon, the building in the U.S.S.R. of power stations using atomic fuel, the construction of powerful accelerators and the wide introduction of radioactive isotopes into scientific and technical investigations, confronted biophysics with a series of new problems and aided the increased development and separation as an independent discipline of one of the branches of biophysics—radiobiology.

Radiobiology became the theoretical basis for the development of methods of protection against radiation, for the prophylaxis and treatment of radiation sickness, and also for the practical utilization of atomic energy in medicine and agriculture.

The Radiation Laboratory, reorganized into the Institute of Biophysics of the Academy of Medical Sciences of the U.S.S.R., was founded in the Academy of Medical Sciences of the U.S.S.R. (G. M. Frank, subsequently A. V. Lebedinskii). A laboratory for isotopes and radiations was founded in the Division of Biological Sciences of the Academy of Sciences of the U.S.S.R. (A. M. Kuzin). A biophysical laboratory was organized in the K. A. Timiryazev Agricultural Academy (V. M. Klechkovskii). In the Ukrainian Academy of Sciences a biophysical laboratory (A. A. Goradetskii) began working at the Bogomolets Institute. Radiobiological work was expanded at the Central Scientific Research Röntgen-radiology Institute of the Ministry of Public Health of the U.S.S.R. (M. N. Pobedinskii).

At the A. N. Bakh Institute of Biochemistry of the Academy of Sciences of the U.S.S.R. a biophysical laboratory was created for the study of photosynthesis (A. N. Terenin). An electron microscopy laboratory (A. E. Kriss) has been started in the Division of Biological Sciences of the Academy of Sciences of the U.S.S.R.

In 1952, on the basis of the Laboratory for Isotopes and Radiations of the Division of Biological Sciences of the Academy of Sciences of the U.S.S.R., the Biophysics Laboratory of the I. P. Pavlov Institute of Physiology of the Academy of Sciences of the U.S.S.R. and S. V. Kravkov's Laboratory for Vision and the Laboratory for Speech and Hearing, there was created the Institute of Biophysics of the Academy of Sciences of the U.S.S.R. (A. M. Kuzin). In order to train numbers of biophysicists, a chair of biophysics (B. N. Tarusov) was founded at the Moscow State University in 1953.

Biophysical investigations are carried out in the State Optical Institute (E. M. Brumberg, G. N. Rautyan), in the physics department of the Military Medicine Academy (N. T. Fedorov), in the department of animal physiology of Moscow State University (Kh. S. Koshtoyants), in the Biophysical Laboratory of the Ural branch of the Academy of Sciences of the U.S.S.R. (N. V. Timofeev-Resovskii), in the physics department of the V. I. Lenin Moscow State Pedagogical Institute (N. N. Malov), in the P. F. Lesgaft Natural Science Institute (M. A. Khenokh), in the I. P. Pavlov Institute of Physiology of the Academy of Sciences of the U.S.S.R. (G. V. Gershuni), in the Gorky State University (V. A. Opritov) and in many other scientific and educational establishments.

For the development of radiobiological research, radiobiological laboratories have been created in the Academy of Sciences of the U.S.S.R.: in the Institute of Microbiology (M. N. Meisel'), in the A. N. Bakh Institute of Biochemistry (A. G. Pasynskii), in the Institute of Genetics (A. N. Nuzhdin), in the A. N. Severtsov Institute of Animal Morphology (E. Ya. Graevskii), in the I. P. Pavlov Institute of Physiology (I. A. Chetvernikov), in the Institute of Higher Nervous Activity (I. A. Plantkovskii), Also, radiobiological work is carried out in the universities, institutes of the academies of sciences of the union republics and in a large number of medical science establishments.

The founding, two years ago, of a special organ of the Academy of Sciences of the U.S.S.R.—the journal "Biofizika"—has undoubtedly been of great importance for the development of biophysics and radiobiology and for the consolidation of investigations in these fields.

Corresponding to the general advances of Soviet biological science, which has attained pre-eminence in the development of the idea of "nervism", considerable advances in the biophysical field have recently been made on problems of excitability, irritability and functions of the sense organs.

In the numerous papers of D. A. Nasonov and his co-workers a new trend of research in the field of cell physiology has crystallized. It has been established by various methods that the basis of the reaction of living protoplasm to external agents is a special change in the physico-chemical state of the protein complexes—a reversible denaturation. This has enabled Nasonov to reach a conclusion about the physico-chemical basis of the reaction of a cell to stimulating and injuring effects.

For the first time, by the work of Frank and his co-workers, the changes were detected which arise on excitation of nerve conductors and which are propagated along the nerve fibre at the speed of conduction of the excitation. This, side by side with the electrophysiological method, disclosed the possibility of analysing excitation phenomena by studying optical and visco-elastic properties and has definitely changed our concepts of their nature. To the same field of research belongs the application of structural analysis to "dynamic molecular morphology", using X-ray diffraction and electron microscopy studies of tissues whose structures have been "arrested" in various functional states. The results obtained have enabled general opinions to be expressed about the role of the mobility of biological structures.

Out of the work carried on in the department of medical physics of the S. M. Kirov Military Medicine Academy (N. T. Fedorov), it is necessary to name first of all a long series of investigations in the field of colour contrast. In these investigations the dependence of the magnitude of the simultaneous colour contrast on the magnitude of the inducing field and on its brightness and saturation, was quantitatively studied. It was shown, both for simultaneous and successive colour contrast, that contrasting colours regularly differ from complementary, coinciding with them only at four "special" points of the spectrum and at two points in the purple region. By studying the effect of passing direct current through the eye-ball on simultaneous colour contrast, they succeeded in showing the "perielectrotonic" character of these phenomena.

In the laboratory of vision of the Institute of Biophysics of the Academy of Sciences of the U.S.S.R. (D. N. Nyuberg) new, and very important, facts have been obtained on the probability of the existence in every cone of the human eye of all three receptors of colour vision. Hence, the question arose of the possibility of transmission of three different types of signal along one and the same fibre. This possibility was confirmed by direct experiment in a study of the electrical signals on a single fibre of the optic nerve of the frog. The great novelty of these facts opens up a new trend in the study of the material basis of visual perception.

A new field of application of physics to biology—the investigation of photosynthesis (A. N. Terenin, A. A. Krasnovskii)—is being developed in the A. N. Bakh Institute of Biochemistry. The principles established by Academician A. N. Terenin in his long-continued investigations devoted to fluorescence have proved fruitful for the discussion of the conversion of energy absorbed by green leaves, the mechanism of photochemical reactions and the participation of energy migration in the process.

The investigations carried out by L. A. Blyumenfel'd on the spectra of the electron paramagnetic resonance of proteins are very important for understanding the physical and physico-chemical processes taking place in the living substrate. The anomalously narrow absorption band detected by him is characteristic of protein systems in a state of catalytic activity and disappears in inactivated enzymes. This phenomenon can be interpreted as evidence for the existence in protein systems of free-electron conductivity. Hence, comparisons with the available facts suggest that energy migration is some general property of living structures and protein systems in an elevated state of chemical activity.

Important results on the uniqueness of the structure of the living, physico-chemical state of a heterogeneous substrate and on the localization of enzyme systems in the structures have been obtained by the method of the action of ultrasonics on biological objects (I. E. El'piner).

Facts have emerged which indicate that properties, recalling the features of semiconducting systems and including processes of energy migration, are in some measure also characteristic for the substrate of the elements of nervous tissue, in particular the visual receptors. This brings together the different trends of biophysics, of which we spoke earlier, creating a completely new and original system of concepts.

It is very characteristic of the modern stage of biophysics that wider use is constantly made of various modern physical methods, opening up new perspectives in the study of the properties of and the processes in the living system.

Of especially great importance is the development and utilization of methods of investigating submicroscopic structures, particularly by electron microscopy of ultrathin sections and also by X-ray structure analysis of biological material and organic substances. Great success has been achieved in the field of ultra-violet microscopy, which has furthered the development of ways of founding a sort of "topographical biochemistry", and also in other methods of physical investigation of chemical structure or chemical processes. One could mention a whole series of such methods, starting from molecular spectroscopy and ending with the method of paramagnetic electron resonance:

The use of isotopic indicators occupies a special place in these methodological procedures; at first they were applied in specialized laboratories and then gradually introduced into biological establishments of the most varied types. Both the quoted and other methodological procedures have essentially re-armed modern biology, enabling it to penetrate more deeply into the intimate processes of the material foundations of vital phenomena.

Leaving aside applied and purely medical problems of radiobiology, it should be noted that the pathological physiology and pathological morphology of radiation sickness has been studied on a great deal of experimental material in recent years, and theories of the pathogenesis of radiation sickness have been developed (L. A. Orbeli, P. D. Gorizontov, A. N. Kraevskii, G. M. Frank and others).

When studying radiation effects on higher animals much attention has been paid to the action of ionizing radiation on the nervous system (L. A. Orbeli, M. N. Livanov, F. P. Maiorov, P. I. Lomonosov, N. M. Livshits, P. F. Minaev and others). The facts on the high radio-sensitivity of the nervous system have been experimentally confirmed and broadened and valuable material has been obtained on the regularities of the radiation effects on the nervous system due to various types of agent. In this connexion it should be especially noted that, by means of delicate electrophysiological research methods (M. N. Livanov), the characteristics of the reactions of the various links of the central nervous system to the effects of ionizing radiations have been demonstrated. Investigations on the reactions of the vascular system are of great importance for the understanding of the mechanism of radiation sickness (G. M. Frank, A. V. Lebedinskii). The effect of ionizing radiations on the development of immunity and on the resistance of an organism to infections has been studied (V. L. Troitskii).

One of the central problems of modern radiobiology which is agitating mankind is the effect of irradiation on posterity. Valuable research on this problem has been carried out by N. I. Shapiro and N. I. Nuzhdin. In order to construct a theory of the biological effect of irradiation it is especially important to study the effect of radiation on elementary living processes. From this point of view investigations on the effect of radiations on the cell, carried out by the application of new methods of luminescence microscopy (M. N. Meisel'), are very interesting, as are also delicate investigations on the first-stage and primary processes of the radiation reaction of an organism (B. N. Tarusov, A. G. Pasynskii, A. M. Kuzin, M. A. Khenokh, Ya. L. Shekhtman, L. Kh. Eidus and others).

The problems of the primary processes have been developed in many directions. The presence of chain reactions in the lipid phase of organs and tissues and the appearance of peculiar, toxic, high-polymer substances, have been detected and investigated in detail (B. N. Tarusov). A method of sorption of radioactive amino acids (A. G. Pasynskii) has been used to observe initial denaturation processes in irradiated protein solutions. A study of the change in the infra-red and ultra-violet spectra of irradiated proteins showed the prevalence of aggregation processes due to the effect of radiation. The possibility of sensitizing nucleic acids to the action of ionizing radiation, the parallelism between radio-sensitivity of a tissue and the degree of depolymerization of DNA after exposure, and the role of a change in the native condition of high-polymer substances in the radiation reaction of an organism, have all been shown (A. M. Kuzin). A change in the isoelectric point of nuclear and mitochrondrial proteins has been demonstrated (A. L. Shabadash). The role of "complex-formation" in the protective effect of substances of high molecular weight has been shown (L. Kh. Eidus). Early changes in the biocolloids in cells and tissues were shown by the method of luminescence microscopy (M. N. Meisel', V. A. Sondak), which finds wide application.

Electrophysiological investigations of the effect of radiation on the nervous system have shown that there is practically no latent period for this reaction and that functional changes of the nervous system are observed in the very first seconds after the beginning of exposure (M. N. Livanov, N. A. Aladzhalova, Yu. G. Grigor'ev). The development and application of a method of *in vivo* tissue polarography (A. D. Snezhko) has disclosed the disturbance of tissue oxidation processes which sets in, primarily, in the part of the tissue which is directly exposed to the effect.

All this makes penetration possible into the so-called "open" period of the radiation reaction of animals, deciphering processes which are developing at this stage.

The study of the radiobiology of plant organisms has been of great importance for practice and theory: the general laws of the effect of radiation on growth and development of plants have been worked out (V. M. Klyachkovskii), the fundamentals of the effect of radiation on the metabolism of plants have been studied (N. M. Sisakyan), the activating effect (under known conditions) of radiation on higher plants has been detected (L. P. Breslavets, N. V. Timofeev-Resovskii, Zhezhel'). Here we should also refer to a whole series of cyto-biochemical studies on the action of radiation on micro-organisms, radio-sensitive structures in the microbe cell, and disturbances of energetic processes have been demonstrated (M. N. Meisel').

The wide development of radiobiology in the U.S.S.R. has enabled the leading radiobiological laboratories to generalize the results obtained and to demonstrate the development of original Soviet trends at the session of the Academy of Sciences of the U.S.S.R. on the peaceful uses of atomic energy (1955), at the International

Conference on the Peaceful Uses of Atomic Energy in Geneva (1955). At the Scientific–Technical Conference on the Application of Isotopes and Radiations in the National Economy and Science (1957) it was possible both to sum up and theoretically generalize current investigations (A. V. Lebedinskii, M. N. Meisel', A. M. Kuzin, G. M. Frank, P. F. Gorizontov).

The basic task of biophysics is the close co-operation of physicists and chemists with biologists so as to uncover the hidden secrets of life. In the 40 years since the Great October Revolution great and fruitful work has been done along these lines. However, all the growing demands which are made on biophysics by medicine, agriculture and such vigorously expanding branches of our national economy as atomic industry, compel all workers in this field to be still more exacting in their work and to strive to give everything that we have a right to expect from this promising young discipline.

Translated by J. Dainty