Work of Soviet Biologists:

Theoretical Genetics

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PROBLEMS OF THEORETICAL GENETICS are of exceptional importance for the development of the science of life and in elaborating methods of controlling the evolution of agricultural plants and domestic animals.

The succession of all organic forms is determined by heredity. Every animal and plant develops from an original cell, and it is clear, therefore, that the system of heredity must form an important part of this cell, since the entire process of development rests upon it. The persistence of characters of both the species and the individual through many generations is based on the innermost peculiarities of the material cellular organization of the fertilized egg. Variations in this organization present the material for the evolution and selection of organisms.

The researches of Boveri, Wilson, and Morgan showed that heredity rests, in the first place, in the cell nucleus, consisting of separate segments called chromosomes, and is connected with the transmission of certain specific substances contained in them. Development and hereditary variation are caused by metabolism between the chromosomes and cytoplasms of the cell. This shows that the problem of molecular organization of chromosomes and metabolism between the chromosomes and the cytoplasms is the central one in theoretical genetics, as well as for the solution of the entire question relating to the organization of living matter and the origin of life.

Of special importance in analyzing problems of heredity is the historical method used to solve the questions of the evolution of hereditary forms in serious changes of organisms, the evolution of genetic systems during the processes of formation of species, and the evolution of species of plants and animals. The great range and depth of modern problems of theoretical genetics have given rise to many synthetic methods combining the materials and methods of genetics, cytology, physics, chemistry, mathematics, and the theory of evolution.

The elucidation of problems of evolutionary genetics played an important role in the history and development of Soviet genetics. This trend was originated and evolved in the works of Russian scientists. The pioneer of experimental research in the genetics of population was S. S. Chetverykov, who in 1926 published a work entitled *Certain factors of the evolutionary theory from the point of view of modern genetics*. In 1928–29 Chetverykov published a short, preliminary report on experimental analysis of the wild population of *Drosophila melanogaster* from Gelendjik. Beginning in 1930, the writer and his laboratory staff carried out a number of experiments connected with new questions of the genetics of populations with regard to both the mutation of genes and the evolutionary structure of chromosomes. At about the same time a number of important works by D. D. Romashev and his assistants appeared.

These researches served as a source for the development of the comprehensive Soviet school of evolutionary genetics, and works on this subject were published by S. M. Gershenson and his laboratory staff, R. L. Berg, N. N. Sokolov, G. G. Tinyakov, Y. M. Olenov, G. D. Muretov, and others.

After the appearance of the above-mentioned researches, the new tendency rapidly assumed the nature of one of the central trends in world genetics. In the United States, Dobzhansky, Sturtevant, and other scientists published important contributions to the genetics of populations and the general theory of the origin of species. The works of Gordon appeared in Great Britain, of Timofeyev-Ressovsky in Germany, etc.

The initial discovery, serving as the source for this entire trend, was the establishment of the fact that populations of wild species possess vast, historically accumulated reserves of hereditary variability, a considerable part of these reserves being hidden in the populations in a heterozygous state (Chetverykov, Dubinin). The new hereditary changes which appear in each generation and the system of historically accumulated variability became the center around which works on genetics and evolution of populations revolved. The honor of formulating the rule that a genetical analysis of the processes of the origin of species must be based on the theory of corpuscular heredity in populations belongs to S. S. Chetverykov (1926). This was an important principle in creating new teachings about the factors of evolution and methods of selection.

Just as chemistry and physics were founded on Dalton's theory (1802) of the atomic structure of matter and as genetics was founded on Mendel's law (1866), the theory of evolution received a new basis for the development of the teachings on the origin of species in the theory of the corpuscular system of hereditary variability in populations. This idea was also developed by Fisher in England in 1930, in his well-known book, *The genetical theory of natural selection.*

Experimental research into natural selection in nature encountered great difficulties. The first work on this subject was that of V. N. Sukachev, who in 1927 made a study of the competition between genotypically different forms of dandelions taken from various localities. Pisarev (1923) and Sapegin (1922) studied the struggle for existence in fields sown with different varieties of wheat. In 1941 Gershenson made an attempt to study natural selection in wild populations of *Drosophila.* Unexpected possibilities were suddenly disclosed in Dubinin's and Tinyakov's paper (1946) on the structural evolution of the nucleus in natural populations of *Drosophila funebris.*

Inversions, which represent the chief types of structural changes of the chromosomes, proved to be environmentally controlled. The rate of evolution of populations proved to be very rapid against the background of the changes introduced by man's interference. The species was divided into chromosomal-ecological urban and rural races. The processes of divergence of these races under the experimental influence of natural selection could be reproduced both in the laboratory and in nature. The sharp influence of war on the chromosomal structure of populations, as well as the climatic gradients in the distribution of various inversions in populations from the north to the south, and the transitional zones between populations of the central urban and the rural races, were ascertained. This work opened up new fields including analysis of the actual influence of natural selection, study of the roles played by migration and isolation, and use of natural selection for experimental purposes.

A different approach to the problems of evolution of plants was found by N. I. Vavilov, who in the course of 20 years carried out highly important genetical and ecological research, classification, and selection work on cultivated plants, covering all the chief world centers of origin of these plants. He has given us highly important conceptions of homologous variability, of hereditary immunity in wheat, and of other problems in genetics, selection, and evolution. The work on geographical distribution of wheat is now being continued by T. K. Lepin.

The phenomena of polyploidy, *i.e.* the multiple increase of the chromosomes in a nucleus, is of great importance in the evolution of plants in nature, in ascertaining the origin of cultivated plants, and in selection. New methods of controlling evolution and selection by experimentally caused polyploidy were evolved in Russia in 1902 by Gerasimov in the course of his remarkable experiments. By influencing the cells of *Spirogyra* (fresh-water algae), by means of narcotics and other factors, Gerasimov caused artificial doubling of the nucleus mass (autopolyploidy). He also discovered autopolyploidic races with doubled chromosome masses in nature.

The works of G. D. Karpechenko (1925–40) proved that doubling the number of chromosomes in sterile hybrids obtained from interspecific crosses leads to the appearance of fruitful forms. His classic example of the cabbage-radish hybrid established the basic principles of allopolyploidy (doubling the number of chromosomes in hybrids).

Following Blakeslee's and Avery's discovery (1937) that colchicine is a powerful medium for the artificial derivation of polyploids, numerous experiments were carried out in this field in the U.S.S.R. Of these, only the successful application of the polyploid method in selection work and in propagating new varieties of cultivated plants will be mentioned here.

Between 1941–46 V. V. Sakharov, S. L. Frolova, and V. V. Mansurova obtained an autotetraploid variety of buckwheat with 32 chromosomes instead of 16. This is a large, evenly developed plant with surprisingly large grains. The crop yield of tetraploid buckwheat is one and a half or twice that of the ordinary variety, the flowers have an increased nectar content, etc. This plant presents exceptionally favorable material for further selection of varieties with a great number of chromosomes.

M. S. Navashin obtained a tetraploid form of the kok-sagyz rubber plant through the action of colchicine. The new variety has roots 1.6 times larger than the old, resulting in an accordingly higher rubber yield, large seeds with increased strength of germination, larger rubber granules in the latex, an easier flow of sap from the roots because of the larger size of the latex vessels, a higher crop yield, and so on.

A. R. Zhebrak, utilizing colchicine, has carried out a great deal of work connected with the synthesis of new varieties and species of wheat (1938–46). Particularly interesting among these is the variety known as Timofeyev wheat, discovered by P. M. Zhukovsky in the Caucasian Mountains. This variety is hardy and has good resistance to the majority of plant diseases. Zhebrak crossed Timofeyev wheat with many ecological-geographical races of 28-chromosomal wheats of 5 different species from Abyssinia, Algiers, Morocco, Turkey, America, and other countries and as a result a new species of wheat with 5 subspecies and 32 varieties was propagated. By crossing this species with 42-chromosomal and 14-chromosomal species and after doubling the chromosomes in the sterile hybrids, Zhebrak obtained new 42- and 70-chromosomal species. Species of wheat with 56 and 70 chromosomes were hitherto unknown in nature. At the end of Zhebrak's book, *The synthesis of new species of wheat* (published in 1944), the author writes: "In view of the new data about artificial polyploidia we may state that modern experimental cytogenetics has achieved a great end—the synthesis of new species of cultivated plants."

The problem of extraspecies crossing of plants is also being dealt with by N. V. Tsitsin. Working in conjunction with V. E. Pisarev, Blakhsheyev, and others, Tsitsin succeeded in crossing wheat with *Elymus*. He is continuing analysis on the formation of varieties in hybrids of wheat and couch grass.

In 1928 N. K. Koltsov published his remarkable work on *The physical-chemical elements of morphology*, in which he outlined the concept of the molecular organization of chromosomes. This hypothesis formed the basis for one of the chief modern trends in genetics. According to Koltsov, the basis of a chromosome is the polypeptid chain, the separate radicals of which are genes. The most important part of this hypothesis touches upon the question of the reproduction of a chromosome. Koltsov proposed the theory of autocatalysis, according to which the chromosome does not split up, as was formerly supposed, but reproduces a double—a daughter—chromosome from the cytoplasmic substances, analogous to the growth of crystals. In his work, *The structure of chromosomes and their metabolism* (1938), Koltsov developed a number of highly important conceptions of the physical nature of the metabolism between the genes and the cytoplasm during the processes of reproduction of genes, and of the general nature of the metabolism between the chromosomes and the cytoplasm.

A. N. Belozersky proved the presence of complex proteins in the chromosomes of plants, which changes the hitherto prevalent opinion that only proteins of the type of protamines and histones participate in the structure of chromosomes. Belozersky's discovery coincided with the work of the Shtedmans in Great Britain on chromosomin. Belozersky (1945–46) developed an interesting theory on the evolution of nucleic acids, and the blockading effect of thymonucleic acid on the reactive groups of chromosome proteins and others.

Koltsov's hypothesis on the autocatalytic reproduction of genes is now the most widely accepted in world scientific circles. In 1945 Prokofieva attempted by cytogenetic methods to establish the difference between the mother chromosome and the daughter which had formed as the result of autocatalysis next to the former. Between 1941 and 1946 S. L. Frolova applied the methods of partial digestion of chromosomes by enzymes in order to ascertain the delicate structure of the former. In the U.S.S.R. Koltsov had laid the foundations of the teachings on the cytogenesis of the lower organisms; continuing this work, M. A. Peshkoff achieved considerable success when he showed the nuclear organization of chromatin in the bacterial cell. Along with the nuclear organization of chromatin in karyophan (discovered by him) and other bacteria, the nucleus proved to be peculiar also to other typical pathogenetic microbes. These data are extremely important for an understanding of the forms of evolution of the organization of hereditary systems and the nature of the bacterial cell itself. Robino and other scientists subsequently arrived at the same conclusions in England.

The modern teaching on the morphology of chromosomes also originated in Russia, where it was based on the classic works of S. G. Navashin (1910–30). A number of his works indicated important trends in modern cytogenetics. This line of research is represented by many outstanding contributions by S. G. Navashin's pupils—G. A. Levitsky, M. S. Navashin, L. N. Delonay, L. N. Sveshnikova, N. T. Kakhidze, and others. Y. Elengorn (1940–46) has submitted interesting papers on the nature of meiosis, and D. F. Petrov (1940–46), on the nature of autosynthesis. The delicate structure of chromosomes is being investigated by A. A. Prokofieva. Research into the general cytology of heredity is being conducted by I. I. Sokolov, L. P. Breslavets, L. S. Pashkovsky, E. N. Gerasimova, and others.

A large group of scientists, including N. P. Dubinin, B. N. Sidorov, N. N. Sokolov, V. V. Sakharov, G. G. Tinyakov, I. A. Rapoport, M. L. Belgovsky, and V. V. Khvostova, are engaged in research into the nature of the gene, structural mutations of chromosomes, the phenomena of the effect resulting from the position of the genes, artificially caused mutations, sudden variation, etc. This work is being conducted chiefly on *Drosophyllum*. Mention must also be made of the organization of special roentgen-genetic laboratories in Moscow (1946) by S. N. Ardashnikov, N. I. Shapiro, and M. A. Arsenyeva, and in Leningrad (1946) by Y. M. Olenov and Solodovnikov.

Problems of phenogenetics are also engaging the attention of a number of scientists. Artificially caused morphosis was first effected in Moscow by G. G. Frizen, while the method of temperature morphosis was elaborated by Goldschmidt in America at the same time (1939). The parallelism of hereditary and nonhereditary variability discovered here enables us to judge the means of gene action on development. New successes were achieved by I. A. Rapoport in 1941–46 when he developed the method of homomorphosis and showed that almost all mutative variations can be caused (copied) by the action of certain chemical substances. N. N. Medvedev is working out methods of transplanting imaginal buds.

B. L. Astaurov is studying the cytogenetics of androgenesis and gynogenesis and the problem of relation between the nucleus and the cytoplasm in heredity. V. N. Natali and L. Y. Blyakher have studied methods of determining the sex of viviparous fishes. The former's latest work (1946) deals with differentiation of sex in teleost fishes. The author has shown a special type of medullocortical antagonism in the differentiation of the sex glands and draws a number of conclusions on the forms of evolution of sex differentiation in fishes as compared with amphibians.

S. S. Chetverikov, V. P. Efroimson, and B. L. Astaurov are engaged in researches into the genetics and phenogenetics of the complicated phenomenon of voltinism in mulberry and oak silkworms.

Problems of the phenogenetics of behavior and instinct are being studied on dogs by L. V. Krushinsky, on birds by A. N. Promptov, and on *Drosophyllum* by R. A. Mazing. The majority of this work is being conducted in the Institute of Genetics of Nervous Activity, founded by I. N. Pavlov.

A new synthesis of genetics and evolutionary teachings is presented in various published papers by I. I. Shmalhausen. Highly interesting, also, are the experiments on correlation and selection, carried out in the laboratory of I. I. Shmalhausen and M. M. Kamshilov. The question of the evolutionary importance of nonhereditary variability is being studied in great detail by I. I. Shmalhausen, V. S. Kirpichnikov, I. I. Lukin, G. F. Gause, and others. All these researches are building up a genetic foundation for Morgan's idea that adaptive modification paves the way to evolution. Shmalhausen's general teachings on the ways of the evolutionary process throw a new light on the conception of the importance of reactive correlative systems, the most important peculiarity of which is the ability for modificatory adaptations.

As has been shown in this short review, Soviet biologists are devoting much attention to the problems of genetics, which are among the most important confronting modern science. We are confident that we shall achieve further great progress in genetics in the near future.

Ultrashort Application Time of Penetrating Electrons:

A Tool for Sterilization and Preservation of Food in the Raw State[1]

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DURING THE LAST SEVERAL YEARS, in an attempt to determine the selective effects of ultrashort time exposures as compared with prolonged radiation periods, we have exposed a number of drugs and other chemical compounds, foodstuffs, and cultures of microorganisms to the action of penetrating, negatively charged particles (electrons), which were released during a time period of about 1/1,000,000 of a second. The electronic intensity applied during such short radiation impulses amounted to about 30,000–50,000 amperes.

It is a well-known fact that all chemical reactions need a certain starting time, and it remained to be seen if various desired biological effects could be exercised ahead of undesired chemical side reactions (*5*).

There exists today no convenient method of preserving foodstuffs in their fresh, raw state, and our experiments were in part directed to this need. Another aspect of the work involved the use of this radiation method in the field of bacteriology and medicine to determine whether we had at our disposal a more differentiated tool than was heretofore available in the treatment of microorganisms—as, for example, attenuation.

Actually, the experiments indicate that ultrashort exposure times are a vital factor in differentiation and in suppressing undesired side reactions.

Theoretically, it would appear relatively easy to avoid undesirable side reactions, such as oxidation, by removing the air as far as possible and by irradiating either in a partial vacuum or by replacing the oxygen with inert gas; but it must be kept in mind that this can be achieved only to a limited degree, since foodstuffs per se contain so much water that the vacuum reduction cannot proceed below the evaporation point, if dehydration and subsequent changes in texture are to be avoided. Even under inert gases, the water remaining in the target would still interact with the electrons and lead to harmful changes in flavor and appearance.

To determine the over-all extent of side reactions, such as the formation of oxidation products during exposure to high-speed electrons of ultrashort duration, distilled and tap water were irradiated, and it was found that with dosages comparable to those causing complete sterilization, the hydrogen peroxide formation amounted to less than .005 per cent. These experiments were conducted at room temperature. Subsequently, we repeated the experiments with the same dosages but with progressive reduction of the temperature to $-100°$ C., and found a continuous decrease of hydrogen peroxide formation, the final percentage being only about 1/10 that formed at room temperature. Thus, a second method became

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