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CHRONICLE

The 50th Anniversary of the Department of Soil Biology, Faculty of Soil Science, Moscow State University

The Department of Soil Biology is in its prime. It is a unique department of such a specialization. The staff of the department amounts to 30 members. The academic staff of the department includes 10 candidates and 9 doctors of biology, 5 of which are professors. The department has 20 postgraduate students and annually gives courses to 10–12 students on soil and ecological microbiology. About half of the 460 graduates of the department received candidate and doctoral degrees, and some became recognized microbiologists.

Clearly, the 50 years of the department saw many fundamental changes in both teaching and research programs. However, the traditions of the department, namely, commitment to education, training, and research, remained the same.

The department was founded in 1953 by the outstanding microbiologist N.A. Krasil'nikov. The theoretical courses given at the department (the general course is *The Biology of Soils*) go along with practical courses on the morphology, systematics, physiology, biochemistry, and genetics of microorganisms and special courses on soil enzymes and particular groups of soil microorganisms: bacteria, actinomycetes, fungi, yeasts, and algae. Beginning from their third year, students of the department are involved in researches and do work on their theses, which are often published in scientific journals as research papers.

Together with his collaborators, Krasil'nikov concentrated on three major problems: (1) the biology of soil microorganisms, (2) the interaction of microorganisms with plants, and (3) the ecological role of physiologically active substances produced by soil microorganisms.

Since 1973, the department has been headed by Krasil'nikov's pupil Prof. D.G. Zvyagintsev, who kept on the pedagogical and research traditions of the department. In research activity, the emphasis is now given to ecological problems, whereas investigations on the industrial production of amino acids, gibberellins, animal feed additives, and antibiotics against plant diseases are terminated. Teaching and training programs are reviewed and modified according to modern trends in soil biology. The students are given a new course, *Ecology*, which is adapted to soil scientists. Soil biology is now considered part of general ecology. Research interest is focused on the study of microbe–soil invertebrate interactions, the effect of anthropogenic factors on soil microorganisms, the ecological–geographic aspects of distribution of microorganisms, the enzymatic activity of soil, soil respiration, nitrogen fixation, denitrification, methanogenesis, and the estimation of fungal and bacterial biomass in soil. Let us consider the main lines of research at the department.

Soil as a habitat of microorganisms. This line of research is developed by Prof. D.G. Zvyagintsev, Prof. V.S. Guzev, leading researchers Dr. P.A. Kozhevin and Prof. L.M. Polyanskaya, associate prof. I.V. Aseeva, senior researchers E.A. Vorob'eva and V.S. Soina, and researcher G.M. Khlebnikova. The successful work of this research group led to the formulation of the general principles of the structural and functional organization of the soil microbial complex (the idea of soil as a multitude of habitats, the pool of microorganisms, the pool of metabolites, the principle of soil unsaturation with microorganisms, the principle of doubling), the determination of the role of cell adhesion in the metabolism of soil microorganisms and the specificity of cell growth in thin films and capillar tubes, and the development of new approaches to the assessment of the mass of soil microorganisms and the activity of extracellular enzymes.

In 1970, Zvyagintsev defended his doctoral dissertation *The Adhesion of Microorganisms in Soils.* This dissertation was followed by a few monographs, *The Interaction of Microorganisms with Solid Surfaces* (1973), *Soil and Microorganisms* (1987), and *Microorganisms in Permafrost* (1995), and the book *Methods of Soil Microbiology and Biochemistry* (1991), which was edited by Zvyagintsev.

Guzev put forward the ideas that the microbial complex of soil is a functional triad of copiotrophs, oligotrophs, and hydrolytics and that different anthropogenic loads on the microbial complex of soil give rise to different soil zones (zones of homeostasis, stress, development of resistant microbial forms, and repression). In 1988, Guzev defended his doctoral dissertation *The Ecological Assessment of Anthropogenic Impact on the Microbial Complex of Soil.*

Soil mycology. The research group specializing in this field (leading researcher Dr. O.E. Marfenina, senior researcher T.G. Mirchink, associate prof. A.V. Kurakov, and junior researcher A.E. Ivanova) investigated the role of toxins produced by soil saprotrophic micromycetes in the inhibition of plant growth and the role of fungal melanins in the formation of humic acids and discovered how the species composition of soil microbiota changes under the action of anthropogenic factors. The most dramatic changes in soil fungal com-

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plexes take place in urban soils, in which anthropogenic impact leads to the accumulation of opportunistic, allergenic, and toxic soil fungi. The investigations of Marfenina in this field culminated in 1999 in her doctoral dissertation *Anthropogenically Induced Changes in Soil Micromycete Complexes.*

Qualitative estimations showed that fungi are largely responsible for the immobilization of nitrogen in soils. Nitrifying fungi are widely spread in soils. The intensity of heterotrophic nitrification in natural ecosystems is higher than in agrocenoses. The contribution of soil fungi to the oxidative pathway of the nitrogen cycle decreases in the order from the undisturbed soils of taiga forests to the biocenoses of deciduous forests, steppes, and agricultural soils. Kurakov identified soil micromycetes producing nitrogen oxide and estimated the emission of this gas from soils. The results of these investigations are summarized in his doctoral dissertation *The Involvement of Soil Fungi in the Nitrogen Cycle.*

The Laboratory of Yeasts (Prof. I.Yu. Chernov, associate prof. I.P. Bab'eva, senior researcher I.S. Reshetova, and junior researchers G.A. Lisichkina and I.N. Maksimova). For many years the laboratory was headed by Bab'eva and, since 2000, it has been headed by her pupil Prof. Chernov. The researchers of this laboratory succeeded in obtaining a great deal of information on the distribution of yeasts in all natural zones of the former Soviet Union, including the Caucasus, Pamirs, Tien Shan, Kamchatka, Sakhalin, and Kuril Islands. This information formed the basis for the development of the ecological–geographic principles of yeast distribution. These principles were then used for the quantitative synecological analysis of microbial communities in biocenoses, which made it possible to reveal the relationship between the structure of soil microbial communities and the longitudinal–zonal environmental factors. The electronic database created by Chernov stores all available information on the geographic distribution of soil yeasts, including the abundance and taxonomic composition of yeast in different habitats. In 2000, Chernov defended his doctoral dissertation *The Synecology and Geography of Soil Yeasts.*

Of great scientific significance is the collection of soil yeasts, whose creation was initiated by Bab'eva. This collection allowed more than 20 new yeast genera and species to be described.

The Laboratory of Bacteriology. This laboratory was founded by Corresponding Member of the USSR Academy of Sciences N.A. Krasil'nikov and Prof. N.N. Sushkina. The staff members of this laboratory are leading researcher T.G. Dobrovol'skaya, associated prof. L.V. Lysak, senior researchers I.N. Skvortsova and A.V. Golovchenko, and researcher M. Kh. Orazova. These researchers succeeded in elucidating the vertical organization of phytocenoses and the conveyor degradation of plant residues by microorganisms. A comparative analysis of bacterial communities in different horizons of particular biogeocenoses made it possible to differentiate and describe different types of soil bacterial communities. The investigations carried out in nature reserves made it possible to assess the natural diversity of bacterial communities in unaffected ecosystems. Skvortsova and Lysak studied the structure of bacterial complexes in anthropogenically impacted soils (urban soils, oil-contaminated soils, and saline soils and showed that anthropogenic factors induce changes in the structure of soil bacterial complexes, so that some species become dominant. This allowed the indicator genera and species to be proposed (for instance, the indicator microorganisms of soil urbanization), many of which turned out to be pathogenic or toxic. The major results of these studies are summarized in the monograph *The Structure of Soil Bacterial Complexes* (2002) written by Dobrovol'skaya.

Soil mycelial bacteria (actinomycetes). N.A. Krasil'nikov, head of the department from 1953 through 1973, was a recognized specialist on the biology of actinomycetes. This line of research is being extended by Prof. G.M. Zenova, Corresponding Member of the Russian Academy of Sciences L.V. Kalakutskii, Dr. N.S. Agre, researcher A.A. Likhacheva, and junior researcher Yu.V. Zakalyukina. They devised some new methodological approaches to the ecology of soil actinomycetes (as geographical, vertical–gradual, microlocal, and successional) and revealed some hitherto unknown regularities in the ecology of these soil bacteria. The employment of new methods of isolation of rare actinomycete genera made it possible to show that particular soil ecosystems may be dominated not only by streptomycetes (as is widely accepted) but also by other actinomycete genera. The actinomycete complexes of particular bioclimatic zones were found to be considerably different in structure. The vertical distribution of actinomycetes in biogeocenoses was characterized by continuity in the distribution of streptomycetes and discreteness in the distribution of other genera. The most significant experimental results are summarized in the monographs *Ecology of Actinomycetes* (Zvyagintsev, Zenova, 2001) and *Diversity of Actinomycetes in Terrestrial Ecosystems* (Zenova, Zvyagintsev, 2002).

Microbial succession and microbial biomass in soils (leading researcher Prof. L.M. Polyanskaya). The study of microbial succession in the microcosms occurring in soil samples yielded valuable data on the temporal dynamics of microbial cenoses, including changes in the abundance of different functional and taxonomic groups of soil microorganisms. In 1996, Polyanskaya defended her doctoral dissertation *Microbial Succession in Soil.* Her recent research interest is in the study of microbial succession in soil by the direct luminescence microscopic count of fungal mycelium and spores. She showed that the fungal biomass dominates the microbial complexes of almost all types of soil at all successional stages. The total microbial biomass (primarily fungal) in soil may reach tens of tons per hect-

are. Fungi (mostly alive) occur in all soil horizons. Fungal complexes in soil are more vulnerable to the action of anthropogenic factors than are bacterial complexes.

Microbe–invertebrate interactions in soil (leading researcher B.A. Byzov). The microbial communities inhabiting the intestinal tract of diplopods and earthworms are divided into wall-bound and free communities, the former being symbiotic. The intestinal microsymbionts serve as food for host invertebrates, are involved in digestion, and provide for the defense of the intestine against foreign microorganisms. There is evidence that the digestive juice of invertebrates kills ingested microorganisms through the action of nonprotein substances and then digests them with the aid of hydrolytic enzymes. Such a digestive mechanism explains why invertebrates feed on specific microorganisms alone. The finding that conjugative plasmids can be transferred from genetically modified introduced bacteria to the intestinal microorganisms of soil invertebrates indicates that soil invertebrates are involved in genetic exchange, in particular, in the horizontal transfer of genes between soil microorganisms (including genetically modified bacteria). The effect of soil invertebrates on the soil microbial complex becomes noticeable at such a low population density as 10 nematodes per g soil. Nematodes may serve as a source of nutrition for carnivorous soil fungi. Byzov proposed a classification of invertebrate–microbe interactions according to the trophic and metabolic principles. The results of these studies are summarized in his doctoral dissertation *The Zoomicrobial Complexes of Soils*.

The population ecology of soil microorganisms (leading researcher Dr. P.A. Kozhevin). This is a new trend in soil microbiology, which is concerned with such problems of general ecology as population density, the dynamics of reproduction, death, and migration of individuals, regulatory mechanisms, and ecological strategy. The results of these studies were summarized by Kozhevin in the monograph *Microbial Populations in Nature* (1989) and the doctoral dissertation *The Population Ecology of Soil Microorganisms* (2000).

Investigations showed that introduced microbial populations (as nodule bacteria, azospirilla, and streptomycetes) can long survive in soils and the plant rhizosphere through compensating for the death of cells by their reproduction. The adaptation and stabilization of introduced microbial populations in natural habitats poses the problem of risks associated with the introduction of genetically modified microorganisms into soil. The dynamics of the introduced microbial populations (including bacterial fertilizers) in soil largely depends on the state of indigenous soil microflora at the time of introduction. To be efficient, bacterial fertilizers should be applied with due consideration for the stage of microbial succession in soil, inoculation dose, and the population characteristics of introduced microorganisms.

Microbial transformation of nitrogen in soil (Prof. M.M. Umarov, Prof. A.L. Stepanov, senior lecturer N.V. Kostina, junior researchers N.A. Manucharova and M.V. Golichenkov). The investigation of the primary pathways of the nitrogen cycles (nitrogen fixation, denitrification, and heterotrophic nitrification) were started in 1973 under the guidance of Umarov. The researchers proposed to distinguish the actual (field) and potential activity of these processes. The potential activity of a process is measured under the optimal values of soil moisture and temperature in the absence of substrate limitation. Consequently, the potential activity shows the highest possible level of the process in a given soil. The conception of potential activity has proved to be methodologically advantageous, as it allows relatively rapid and simple laboratory measurements to be done instead of intricate field measurements. Now this approach is widely used for the rapid diagnosis of soil contamination with heavy metals and pesticides and for the biotesting of soils. In 1983, Umarov defended his doctoral dissertation *Associative nitrogen fixation: characteristics, productivity, importance in the nitrogen balance of soils*, in which he had formulated the concept of associative nitrogen fixation as a self-regulated ecological process.

The most significant results of the investigation of the processes of nitrogen oxide formation and consumption were summarized by Stepanov in his doctoral dissertation *The Microbial Transformation of Nitrogen Oxide in Soils*. In this dissertation, Stepanov made an inference that the increasing flow of nitrogen oxide from soil into the atmosphere is a consequence of the anthropogenically disturbed equilibrium between the processes of nitrogen oxide formation and consumption.

D.G. Zvyagintsev,
Head of the Department of Soil Biology,
Moscow State University