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The History of N. M. Chernova's Scientific School of Soil Zoology at the Moscow Pedagogical State University

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Abstract: The article reviews the history and scientific contributions of the soil zoology school at Moscow Pedagogical State University, founded by Academician Mercury Sergeevich Gilyarov and led by Professor Nina Mikhailovna Chernova. A key theoretical contribution from this school was the development of succession theory, which describes changes in soil invertebrate communities during plant litter decomposition. The school's primary research focus has been on soil microarthropods, particularly springtails (Collembola) and mites—groups that are crucial for soil fertility and bioindication yet remain understudied. We trace the school's progress in the taxonomy, faunistic studies, and ecology of soil invertebrates, emphasizing its foundation in field studies and laboratory experiments. Though its development was further strengthened through

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national and international collaborations, many of N. M. Chernova's seminal ideas are not widely known outside Russia due to language barriers and limited access to publications. Her students continue to address this issue while advancing the study of soil zoology, ecology, and its history.

Keywords: history of soil zoology, Nina Mikhailovna Chernova, scientific school, Moscow Pedagogical State University, soil microarthropods, Collembola/springtails, succession theory, agricultural ecology

摘　要：本文回顾了由梅尔库里·谢尔盖耶维奇·吉利亚罗夫院士创立、尼娜·米哈伊洛芙娜·切尔诺娃教授领衔的莫斯科国立师范大学土壤动物学学派的发展史与学术贡献。该学派的一项重要理论成果是对演替理论的发展，用以阐释植物枯落物分解过程中土壤无脊椎动物群落的变化。该学派的主要研究对象是土壤微节肢动物，尤其是跳虫（弹尾目）和螨类——这些类群对土壤肥力维持与生物指示具有重要作用，但相关研究仍较为薄弱。本文梳理了该学派在土壤无脊椎动物分类学、动物区系研究及生态学领域的进展，强调其以野外调查与实验室实验为基础。尽管国内外合作进一步推动了该学派发展，但由于语言障碍及文献获取受限，切尔诺娃教授的许多开创性观点在俄罗斯以外未得到广泛认知。目前，她的学生们在推进土壤动物学、生态学及其发展史研究的同时，正积极致力于改变这一现状。

关键词：土壤动物学史，尼娜·米哈伊洛芙娜·切尔诺娃，学派，莫斯科国立师范大学，土壤微节肢动物，弹尾目/跳虫，演替理论，农业生态学

1 Introduction

Soil zoology is a relatively young science about rich but hidden animal life within the soil cover. A major impetus for the development of soil zoology came from the extensive, long-term research by Charles Darwin (1809–1882) on the soil-forming activity of earthworms (Darwin 1838; 1881, 326). The Russian translation of his final book on this topic was immediately printed and discussed (Darwin 1882, 2, 188; Kalinskiy 1882, 46). The translation was accompanied by commentary from the eminent Russian zoologist Mikhail Aleksandrovich Menzbir (1855–1935). Crucially, as a professor, he introduced Darwin's ideas to the institution where N. M. Chernova would later both study and work.

Agricultural specialists also actively promoted Darwin's ideas in Russia. The founder of modern soil science (pedology), Vasily Vasilievich Dokuchaev (1846–1903), was well acquainted with Darwin's ideas (Ivanov and Rusakova 2021). Starting in 1883, he identified the distinct nature and properties of soils, acknowledging how integral the role of animals was, "though not as fundamental as Darwin believed," who described soils as an "animal layer" (Dokuchaev 1883, 306).

Modern soil zoology emerged at the junction of zoology, ecology, and soil science with soil geography. In the USSR, its establishment is associated with Mercury Sergeevich Gilyarov (Ghilarov, Giliarov; Меркурий Сергеевич Гиляров 梅尔库

里·谢尔盖耶维奇·吉利亚罗夫; 1912–1985, member of the USSR Academy of Sciences, 1974). His works (Gilyarov 1949, 280; 1965, 278; 1970, 276) laid the foundations for the study of soil invertebrates in the USSR (Striganova 2008).

On January 29 and 31, 2025, the A. N. Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences hosted the Memorial Scientific Conference in Moscow dedicated to the ninetieth anniversary of the birth of Professor Nina Mikhailovna Chernova (1935–2010) (Figure 1). N. M. Chernova earned renown both for her immense contribution to ecological education and for establishing the prominent soil zoology school. This article recounts the history and traditions of this scientific school, a project initiated during a dedicated conference.



Figure 1: Participants in the discussion at the Memorial Conference of N. M. Chernova in Moscow (January 29, 2025).

The institute where the school was formed traces its origins to the Natural Sciences Division of the Physics and Mathematics Faculty at the Moscow State Higher Courses for Women, established in 1900. Between 1918 and 1930, these courses were reorganized into the Second Moscow State University. Later, it became known as the Faculty of Natural Sciences at the Moscow State Pedagogical Institute (MGPI). In 1990, the Institute was renamed the Moscow Pedagogical State University (MPGU), and in 2014, its Biology and Chemistry Faculty were transformed into the modern Institute of Biology and Chemistry MPGU.

The history of the soil zoology research area at MPGU began in 1949 (Figure 2) when the head of the Department of Zoology and Darwinism, Professor Sergei Pavlovich Naumov (1905–1987), an eminent mammalogist, invited M. S. Gilyarov to deliver a lecture course on invertebrate zoology (*Mercury Sergeevich Gilyarov* 1990;

History of the Department 2025). Professor Gilyarov organized annual expeditions to study soil fauna in various regions of the USSR, engaging talented students in the process. Among them was Nina Chernova, whose life became forever intertwined with the zoology and ecology of soil invertebrates. This article traces her ascent to becoming one of the leading figures in this scientific field in the USSR and Russia.



Figure 2: M. S. Gilyarov's main workplaces as branches of his school of soil invertebrates study.

Chernova, Nina Mikhailovna (Černova, Чернова Нина Михайловна; 尼娜·米哈伊洛芙娜·切尔诺娃; maiden name Barabanova) was born on May 16, 1935 in Volokolamsk city (100 km west of Moscow). She studied at the Faculty of Natural Sciences MGPI (1953–1957), and then started working at the Institute of Phytopathology of the Ministry of Agriculture of the USSR. She later returned and became a researcher at the MGPI's Problem Biological Laboratory (1960–1972). Under the supervision of M. S. Gilyarov, she completed her postgraduate studies and prepared a PhD dissertation: "Invertebrates in Composts and the Potential for Enriching Field Soils with Beneficial Animals through the Application of Compost Fertilizers" (1964). In 1972, N. M. Chernova moved to the MGPI's Department of Zoology and Darwinism, where she worked until her death on August 9, 2010. In 1975, she defended her doctor of science dissertation "Ecological Successions in the Decomposition of Dead Plant Material." She became a full professor, developed a new Ecology education program with lecture courses, and then published both university and the first Russian high school textbooks on modern ecology (Chernova and Bylova 1981, 255; Chernova, Galushin, and Konstantinov 1995, 240), which were reissued multiple times. In addition to her work at MPGU, she established and headed the Department of Bioecology at the International Independent University of Ecology and Political Science (1992–2003). Details of Professor Chernova's career were published in obituaries and memorial papers (Kuznetsova and Potapov 2010; Makarova and Babenko 2011; Uvarov 2011; Zhigarev, Kuznetsova, and Galushin 2012), as well as in MPGU reference book (Chernova 2012).

2 Scientific school and followers

N. M. Chernova's work marked a milestone in soil science and ecological education in Russia. However, as her works were primarily published in the Russian language, she remains largely unknown in other countries. This article focuses on the scientific aspects of Professor Chernova's work. Her contributions to the development of ecological education must be discussed in a separate publication.

A standardized definition of the scientific school is still lacking with historians of science and different national traditions using divergent understandings of the term (Kuznetsova 2022). This term was particularly widespread in the USSR and later in post-Soviet states as a general scholarly tradition. Science in the USSR remained a closed system, with stable, long-term research teams. This environment fostered the development of scientific schools as informal permitted associations for solving common research problems. Their methodologies became well-established and universally accepted, enabling the accumulation and comparison of data across the vast territory of the USSR. Furthermore, the scale of scientific research in the USSR was immense, allowing numerous schools to thrive, each with distinct research focuses and minimal competition.

In countries where research teams are mostly international and mobile, there is no concept of a permanent scientific school. In such a school, a continuity of scientific knowledge and traditions is maintained, their cultural roots are respected, and various societies and associations are formed to address diverse research problems. This type of school can be compared to a school of thought, an intellectual tradition, or a center of excellence (Popova 2023).

In its contemporary understanding, a scientific school is an informal group of researchers who work not so much under the direct supervision, but rather under the intellectual influence of their mentor. Therefore, the theoretical and philosophical concept of this "tacit knowledge," introduced by Michael Polanyi (1891–1976), who extensively studied scientific communities, became essential for analyzing the phenomenon of scientific schools (Kuznetsova 2022). He demonstrated that the traditions of a scientific school—its methods, techniques, skills, and subtleties of professional mastery—constitute the hidden, submerged part of the knowledge iceberg (Polanyi 1962, 493; 1966, 108). He reconsiders human knowledge using the idea that we can know more than we can tell. Our explicit, formal knowledge (what we can write or say) is like the tip of an iceberg, supported by a much larger foundation of tacit knowledge—the unspoken, intuitive, and often unteachable understanding that guides our actions. Scientists within a community absorb a shared set of tacit skills, intuitions, and passions. This "Republic of Science" self-corrects through mutual criticism, guided by a shared, tacit commitment to the truth, rather than by rigid rules or central

planning. "The visitor to the research school of a great master—whose intuitive apprehensions can filter through, even though imperfectly, to an inner circle of collaborators—may dimly discern the premises of prospective discoveries by the way the collaborators talk about their work" (Polanyi 1962, 175). This exact atmosphere prevailed within Chernova's scientific school.

M. Polanyi described this scientific community of researchers led by a master scientist like a craft guild. Its core purpose is to pass on the tacit art of science—the intuitive skills, judgments, and passions—that cannot be learned from textbooks alone. This occurs through a master-apprentice relationship, where apprentices learn by doing and absorbing the master's unspoken knowledge, sometimes just imitating the teacher. This school operates as a self-correcting community where truth is established through shared practice, mutual criticism, and a common commitment to scientific ideals, rather than by rigid rules. M. Polanyi showed that the engine of scientific progress is not a flawless method, but a community of fallible but passionate people, bound together by a shared tradition and a love of truth, which they pursue with both their explicit minds and their tacit capacities. A defining feature of the scientific school is its unique intellectual ethos, cultivated through the master-apprentice transmission of tacit knowledge.

The scientific school of Chernova serves as an exemplary case study of the formation of a model based on the extensive networks of her students, colleagues, and followers. In this model, culture and relationships among scientists themselves became both the means and the meaning for generating new knowledge. It is precisely this unarticulated excess of knowledge, cultivated within a scientific school, that acts as the engine for the productive development of science. It's a "living tradition": students learn by working alongside an established master. They don't just memorize explicit facts; they absorb the master's tacit skills and learn the art of scientific inquiry, practicing techniques and methods, and a system of norms and intuitions. The school is held together by a common framework of beliefs, interpretive assumptions, and intellectual commitment to a specific research tradition. It provides stability for scientific knowledge and, because tacit knowledge is most effectively passed on through direct, personal contact and hands-on interaction, is localized.

"Nina Mikhailovna, together with Professor I. Kh. Sharova, led the scientific school of Soil Zoology, which was founded by Academician M. S. Gilyarov" (Abdurakhmanov 2010). In contrast to Inessa Khristianovna Sharova (1931–2021) who focused on the soil mesofauna and therefore primarily had researchers studying ground beetles (Carabidae) ("In memoriam" 2021), Professor Chernova led the research of small soil arthropods (microarthropods), primarily springtails (Collembola) and various groups of soil mites. Both scientific directions complemented each other in soil zoology

research. It was essential for them not only to preserve scientific traditions but also to transmit knowledge and skills, disseminating them through graduate students (aspirants). It is a good example of how this university provides a system of fundamental knowledge, while scientific schools furnish experience, professional networks, and scientific values. A scientific school is a mechanism for the reproduction of science and the development of young scientists by initiating them into the school's traditions.

The foundation of Professor Chernova's school remains rooted in the scientific traditions of soil biology study established by Academician Gilyarov. Her development of modern and original scientific programs, as well as the broad scope of her organized research and numerous followers, allows us to characterize this as an independent scientific direction of small soil invertebrates study established by Professor Chernova at the MPGU. During field expeditions, Professor Chernova would assess the scope and nature of the work on-site, establishing and adjusting the scientific program for the research team.

Thus, the core criteria of an established scientific school, which Professor Chernova's school formally meets, can be summarized as follows:

- The defining role of its leader in setting research objectives
- A shared focus on core scientific interests and the significance of the research
- A high level of scientific achievement and international recognition
- Continuity, development, and promising prospects, enabling the creation of a holistic scientific direction based on a system of concepts and original methods.

The work of the Chernova scientific school first gained international recognition via publications originating from the German Democratic Republic, beginning in 1967. A key platform for this recognition was *Pedobiologia*, a leading journal in the field published by a major European center for soil biology research. Regular participation in the International Colloquium on Apterygota, the International Colloquium on Soil Zoology, and the All-Union (then Russian) Conferences on Problems of Soil Zoology also played a major role. In the post-Soviet years, their most significant contributions emerged from international collaborative research on springtails. In this work, Chernova's school produced comprehensive, modern syntheses on the systematics, ecology, and distribution of springtails across Russia and neighboring countries.

Professor Chernova's academic influence extended beyond her role as the formal advisor of diploma theses and dissertations and encompassed numerous informal mentees. While these individuals had other official dissertation supervisors, she provided them with essential teaching, advice, and editorial guidance. The main research areas investigated in the PhD theses supervised by N. M. Chernova are outlined below (Table 1).

Table 1: Main research directions of the Professor Chernova's school of soil zoology

Year	Chernova's PhD student	Dissertation title
Adaptive morphology and systematics		
1974	Tarba, Zara Mekhtatovna	Morpho-Ecological Characteristics of Oribatid Mites (Oribatei) in Certain Forest Soils
1992	Potapov, Mikhail Borisovich	Genus Structure and Species-Specific Traits in Springtails of the Family Isotomidae
1992	Tanasevich, Andrey Viktorovich	Spiders of the Genus *Leptyphantes* Menge in the Northern Palaearctic
1994	Iordansky, Sergey Nikolaevich	Fine Structure of the Integument in Oribatid Mites at Different Ontogenetic Stages
Fauna and populations of Collembola		
1976	Tereshkova, Elena Vikentievna	Springtails of Northern Kazakhstan: Fauna and Spatial Distribution Patterns
1979	Kutyreva, Lidiya Trofimovna	Fauna and Populations of Forest Soils in Southern Primorye: A Case Study of Springtail Communities
1985	Kuznetsova, Natalia Alexandrovna	Fauna and Populations of Springtails in Coniferous Forests of the European Part of the USSR
1985	Banasco Almentero, Josefa	Springtails in the Microarthropod Complex of Arable Soils in Cuba
1987	Dobrolyubova, Tatyana Vasilievna	Structure and Dynamics of Springtail Populations in Mountain Forest Soils of the North-Western Caucasus
1994	Budaeva, Lyudmila Ivanovna	Life Cycles and Population Dynamics of Species of the Genus *Drepanura* (Collembola, Entomobryidae) in the Steppe Zone of Khakassia
1995	Kaprus, Igor Yaroslavovich	Population Structure of Springtails as an indicator of the Condition of Primary and Transformed Forests in the Ukrainian Carpathians.
2004	Shveenkova, Yulia Borisovna	Springtails of Ecotone Communities in the Forest-Steppe Zone
2010	Chimitova, Ayuna Bayaskhalanovna	Springtail Populations in Cryo-Arid Basins of the Vitim Plateau (Transbaikalia)
Succession processes study		
1989	Uvarov, Alexei Vyacheslavovich	Energy Assessment of the Role of Soil Mesofauna in Decomposition of Plant Remains
2001	Schwartz, Elena Semyonovna	Local Successions of Microarthropods in Forest Litter

continued

Year	Chernova's PhD student	Dissertation title
Succession processes study		
2004	Bokova, Anna Ivanovna	Successions of Springtail Communities in Forest Ecosystems
2009	Geras'kina, Anna Petrovna	Dynamics of Earthworm Complexes During Restorative Successions
Specific microarthropod communities		
1992	Makarova, Olga Lvovna	Coprophilic Complexes of Mesostigmata Mites (Parasitiformes) in Different Natural Zones
2005	Sharin, Vladislav Gennadievich	Springtails (Hexapoda: Collembola) in Urban Waste Dumps in the Moscow Region
2012	Vanyavina, Liliya Viktorovna	Ecology of Epigeic Springtails in Slightly Disturbed Biotopes of the Moscow Region
Agricultural ecosystems		
1983	Blinnikov, Valery Ivanovich	The Influence of Mineral Fertilizers on the Microarthropod Complex of Arable Soils in the Moscow Region
1984	Kapin, Georgy Yurievich	Comparative Assessment of the Effects of Organic and Mineral Fertilizers on Microarthropods in Arable Soddy-Podzolic Soils
1989	Kulikov, Nikolai Ivanovich	Structure and Dynamics of Arthropod Complexes in Agroecosystems of Cereal Crops in the South of the Non-Chernozem Zone
1998	Tyapkina, Angela Pavlovna	The Microarthropod Complex of Dark-Grey Forest Arable Soils in the South of the Non-Chernozem Zone Within a Crop Rotation System
2005	Kremenitsa, Alexander Mikhailovich	The Structure of the Springtail (Collembola) Complex in Chernozem Soils of the Lower Don Region
2006	Mironov, Sergey Yurievich	Springtail Populations in Typical Chernozem Soils Under Agricultural Use
Anthropogenic impacts		
1983	Yuryeva, Nina Dmitrievna	Microarthropods in Recreational Forests of the Moscow Region
1985	Antoshchenkov, Viktor Fedorovich	Changes in Soil Fauna Under the Influence of Grazing Regimes

continued

Year	Chernova's PhD student	Dissertation title
Recultivation of soil		
1981	Bulavintsev, Valery Ivanovich	Formation of Animal Communities in Areas Disturbed by Open-Pit Mining
1984	Babenko, Anatoly Borisovich	Formation of Soil-Dwelling Microarthropod Communities on Mining Spoil Heaps
1992	Zainulgabidinov, Erik Renatovich	Changes in the Springtail Complex Under the Influence of Technogenic Salinization and Soil Reclamation
Ecological toxicology		
1990	Ponomareva, Olga Nikolaevna	Changes in Life Cycles and Population Dynamics of Soil-Dwelling Springtails Under the Influence of Herbicides
1991	Balabina, Irina Pavlovna	Dynamics of Soil Springtail Populations Under Herbicide Contamination of the Environment
Functional ecology		
1984	Simonov, Yuri Vladimirovich	The Role of the Microarthropod Complex in the Transformation of Organic Matter in Forest Litter
Collembola behavior		
1988	Varshav, Elena Vladimirovna	Assessment of the Trophic Activity of Springtails Using Direct Observation Methods
2000	Avilkina, Anna Tikhonovna	Behavior and Population Relationships of Springtails
2003	Goloshchapova, Natalya Pavlovna	Behavior of Springtails of Different Life Forms

Professor Chernova also served as a primary scientific advisor for Doctor of Science dissertations, among them significant scientific theoretical and practical works: Natalia Alexandrovna Kuznetsova (2002) "Organization of Soil-Dwelling Springtail Communities," and Igor Alexandrovich Zhigarev (2006) "Organization and Stability of Recreational Communities: A Case Study of Small Mammals." N. M. Chernova conducted ongoing advisory work, designed scientific research, supervised dozens of student theses, and acted as an unofficial consultant and advisor for other dissertations.

In the 1980s, N. M. Chernova inspired her students to establish the Center for the Study of Collembola Taxonomy and Ecology. This initiative was supported by a library of reprints on springtails donated by M. S. Gilyarov and by taxonomy papers received

from Elena Fyodorovna Martynova (1925–2003), a leading specialist on springtails from St. Petersburg (Tikhonova 2025). Under N. M. Chernova's editorship were published modern identification guides for springtails of the USSR (Key to Collembola of the USSR Fauna 1988) and the fauna of Russia and adjacent countries (Collembola of Russia 1994). The research of N. M. Chernova and her school members was supported by numerous grants from the national Russian Foundation for Basic Research. The extensive training of Mikhail Borisovich Potapov (born 1963) at MPGU as a specialist in Collembola taxonomy, combined with his unique artistic talent, ensured the high quality of species identification in the faunistic and ecological research conducted by his students and followers. This work led to the description of over twenty genera and many new species. The results of this work were actively published, and the center garnered international recognition.

3 The succession theory

N. M. Chernova's most significant contributions to the theory of successions were made during the 1960s to 1980s. These include two books (Chernova 1966, 154; 1977) and numerous papers (Černova 1970; Chernova, Byzova, and Chernova 1971; Chernova 1987; etc.). These works marked an important point in the development of soil invertebrate ecology in the USSR. They were published during a period when the topic of successions was central in global ecology, and debates about their mechanisms—particularly in plant communities—reached their peak. Simultaneously, the development of a functional-energy approach to ecosystem studies, especially within the framework of the International Biological Program (IBP: 1964–1974), led to the elaboration of precise quantitative methods for measuring the energy relations in organisms and accumulation of extensive data on the state and dynamics of communities. Furthermore, this period marked the heyday of M. S. Gilyarov's school of soil zoology, a novel discipline that integrated the achievements of genetic soil science, evolutionary concepts of animal adaptations to soil environment, and the role of animals in soil formation and fertility maintenance. Chernova was one of Gilyarov's most talented students who expanded his ideas into new directions of soil zoological science.

Addressing the problem of successions, Professor Chernova, with her deep intuition, chose heterotrophic succession during the decomposition of organic residues in the soil as her study model. This area was largely unexplored at the time, with the exception of a few microbiological studies. The fundamental feature of her approach was the application of quantitative, functional-energetic methodology to studying the most complex natural system—the soil. The community of soil invertebrates, particularly the microarthropod complex, became her highly informative yet convenient object of study.

Microarthropods are characterized by taxonomic and ecological diversity, a variety of adaptations to the soil environment, complex internal relationships, relatively short life cycles, high population densities, and the ability to respond quickly to environmental changes. Additionally, microarthropods can be sampled easily with reasonably high precision, enabling quantitative estimates of their successional shifts in various natural and anthropogenic decomposing substrates, such as forest litter, composts, crop residues in arable soil, and so forth.

Through numerous experiments and observations, N. M. Chernova identified the following general patterns of invertebrate successions in decomposing substrates:

Convergence of Community Development: Regardless of the initial properties of an organic substrate and its community composition, successions lead to the dominance of animal species typical of soil horizons. This trend was consistently observed across different decomposing plant materials (Figure 3).

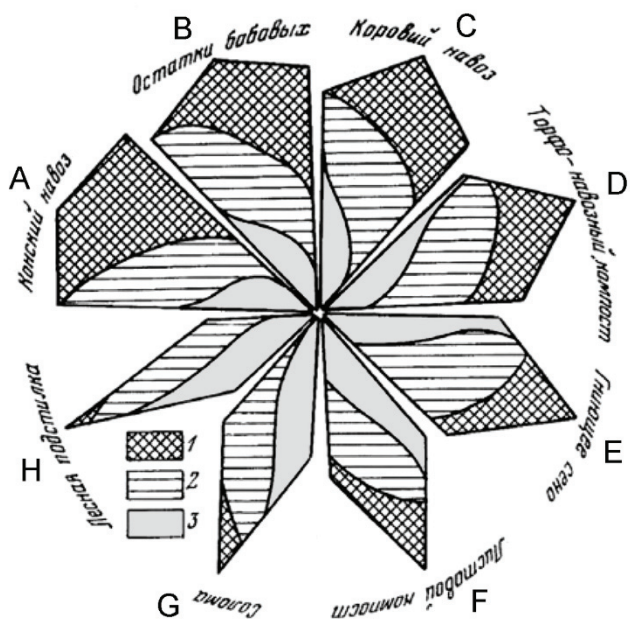


Figure 3: N. M. Chernova's general scheme of changes in the abundance of microarthropods (size and configuration of the petals) and in the proportion of their ecological groups in successional series during the decomposition of various organic materials: A – horse manure, B – legume residues, C – cow manure, D – turf-manure compost, E – decaying hay, F – leaf compost, G – straw, H – forest litter. 1 – phoretic species, 2 – litter-compost species, 3 – soil species (Chernova 1977).

Stages of succession: Succession involves regular changes in the composition of

animal life forms, with distinct stages characterized by the predominance of (1) pioneer, (2) litter/compost, and (3) soil life forms (Figure 3). The presence of particular species appears random, as a set of ecologically vicarious species (species that occupy similar ecological niches, but in different habitats) is always present. **Pioneer communities**: These vary significantly in composition and abundance depending on the nature of the decomposing organic material. In rapidly decomposing substrates (e.g., nitrogen-rich manure or legume residues), species diversity is low, while community density increases sharply due to specialized (primarily phoretic) species and then declines just as rapidly. In contrast, substrates with low initial decay rates (e.g., freshly fallen leaf litter) exhibit higher species diversity but slower density increases due to a gradual immigration of non-phoretic fauna from the surrounding environment. **Intermediate stage**: The second stage of succession shows substantial similarity in community composition across different substrates, with a dominance of *hemiedaphic* and litter species (the compost fauna stage). Typically, communities at intermediate succession stages exhibit the highest taxonomic diversity of soil invertebrates. **Soil stage**: The final stage, analogous to the climax stage in successions of biocenoses, is characterized by a highly mineralized substrate in a relatively stable state. The community is dominated by *euedaphic* (deep soil) species, and density fluctuations are primarily determined by seasonal factors.

The rates of succession transformations are determined by the quality of the decomposing substrate, the nature of invertebrate community development, and environmental conditions. Wave-like dynamics in animal groups are explained by the emergence of successive generations and the influence of weather and seasons.

Adaptations and biotic relationships: Adaptations of soil invertebrates to colonizing organic substrates of different origin and physicochemical properties explain their association with various stages of destructive succession. Biotic relationships within the community are recognized as crucial for understanding the mechanisms of succession shifts. Professor Chernova made the first attempts at a comprehensive analysis of temporal changes in the condition of decaying substrates and the dynamics of key groups within the soil communities, including bacteria, microfungi, and micro-, meso-, and macrofauna.

Metabolic activity and energy relationships in the soil community: For the first time, successional dynamics of energy relationships within the soil community during the decomposition process were assessed. This was based on metabolic activity estimates of numerous species of soil invertebrates, and evaluation of energy content in various organic materials and energy flow through the soil system in the course of decay.

In general, N. M. Chernova understood succession as a regular process of soil community development driven both by the environment and interactions among its living components. However, the primary mechanisms of succession transformations

are the interrelationships within the community, while the physical environment only influences the course of succession to a certain extent. These interactions determine directed changes in the community internal structure, including fluctuations in species diversity, the complexity of food webs, increased spatial heterogeneity, and a development of interspecific and mutualistic relationships. Energetically, the main vector of successional shifts is the growth of soil system stability, achieved through the gradual equalization of system productivity and energy expenditure.

Chernova's scheme, designed in the shape of a flower (Figure 3), proved to be so successful and interesting that it was included in the influential German book by Wolfram Dunger (1929–2019), *Tiere im Boden*—Animals in the Soil (Dunger 1983, Figure 136, p. 214).

4 Agricultural ecology

One of the areas of soil-zoological research pursued by N. M. Chernova and studied by her students was the structure and dynamics of soil microarthropod communities in agricultural ecosystems. This research direction was built upon earlier studies on zoological methods of the soil diagnostics (Gilyarov 1965). A close relationship was observed between these small arthropods and the soil environment. This relationship is interdependent: soil characteristics determine the viability of specific species, while soil animals, in turn, participate in the decomposition of organic matter, influencing soil properties. This interdependence suggested that microarthropods could be used as indicators of the impact of various agricultural practices on soils. High microarthropod numbers and species diversity were proposed as indicators of favorable soil processes, while low levels of these parameters were seen as indicators of negative impacts.

For the successful application of this method, it was essential to establish the normal range of variation in community metrics within agroecosystems. These studies revealed that, in agricultural fields, the species richness of springtails was higher than that of soil mites (Kapin 1982; Blinnikov 1982; Mironov 2006). Most microarthropods were found in the upper soil layer, despite deep ploughing of the field (Tyapkina 1998). The spatial distribution of springtails varied from uniform to sharply mosaic (Chernova 1982b). The upper soil layers were characterized by aggregation of springtails, while their horizontal distribution became random deeper in the soil (Mironov 2006). Interestingly, two types of springtail aggregations were identified in the fields: small-scale aggregations, linked to the biological characteristics of species, and large-scale aggregations, reflecting variations in soil properties and thus having indicator value (Chernova 1982a).

The influence of cultivated crops was also studied. In the non-Chernozem zone of

Russia, the lowest microarthropod abundance was observed in the uncultivated fallow fields, while the highest abundance was recorded in the fields with barley and fall wheat (Tyapkina 1998). Species diversity, however, remained almost unchanged. In contrast, in chernozem soils, the lowest levels were observed under grain crops, while the highest diversity levels were found in the fields with a pea-oat intercrop (Kremenitsa 2005).

Seasonal dynamics of microarthropods in agroecosystems depend on the crop cultivated. The highest soil animal abundance occurs during the heading, ripening, and post-harvest stages of crops such as wheat and oat (Blinnikov 1982; Kapin 1984; Kremenitsa, Kazadaev, and Bulysheva 2003). The most significant factors influencing soil fauna in agroecosystems were found to be temperature, moisture, and winter snow cover thickness (Mironov 2006).

Data on the diversity, abundance, and distribution of microarthropods in the fields allowed the evaluation of the impact of various agricultural practices on soil fauna as an integral indicator of agricultural sustainability. These practices included soil tillage methods, the application of mineral and organic fertilizers, and the usage of pesticides and insecticides. It was found that the abundance of springtails and oribatid mites was higher in the fields with surface tillage compared to those with deep ploughing (Tyapkina 1998). Springtails were more sensitive to the degree of mechanical soil disturbance than mites. Traditional deep ploughing negatively affected both species composition and abundance of springtail communities (Blinnikov 1982; Tyapkina 1998).

The application of elevated doses of mineral fertilizers in field experiments elicited variable responses of both springtails and mites, contingent upon the specific chemical dosages administered (Blinnikov 1983; Kapin 1982; Mironov 2006). Pesticide application typically led to a restructuring of microarthropod communities. In general, the application of chemical substances resulted in population increases in certain species, while adversely impacting the populations of others. For example, among springtails, species such as *Hypogastrura assimilis*, *Xenylla grisea*, and *Pseudosinella alba* were particularly sensitive to soil contamination by pesticides. Following herbicide application, a sharp predominance of species from the genera *Onychiurus* (likely *Protaphorura*), *Mesaphorura*, *Isotoma*, *Folsomia*, and *Lepidocyrtus* was observed (Ponomareva 1992).

Laboratory experiments on cultures of different springtail species (Figure 4) demonstrated that field application rates of pesticides, despite the tenfold higher dosages, did not cause mortality in adult individuals. However, even low doses of herbicides significantly inhibited springtail reproduction, reducing female fertility and egg viability, and causing larval mortality (Ponomareva 1989; Balabina 1992; Chernova, Balabina, and Ponomareva 1995).



Figure 4: Springtail culture (from Varshav and Davydova 2013). The dark spots on individuals of *Onychiurus stachianus* (modern gen. *Orthonychiurus*) represent temporary markings created using the original method. E. V. Varshav introduced this technique in 1987 for marking live springtails with a heated needle (Varshav 1988). This enabled the observation of individual behavior of springtails and the tracking of their trophic rhythms.

In summary, the studies conducted under N. M. Chernova's supervision established a scientific view on microarthropods as an important component of agroecosystems, contributing to the maintenance of natural soil fertility. These studies demonstrated the potential of using these small soil arthropods as indicators of environmentally sustainable agricultural practices. For the history of science, the assessment of soil biota in agricultural fields initiated fifty years ago is of great importance. These data serve as an invaluable historical reference, useful for evaluating the current state of soil health in agroecosystems of the Non-Chernozem and Chernozem zones of Russia.

5 Microarthropod behavior

In the late 1980s, under the leadership of Professor Chernova, a unique ethological approach to soil organism ecology emerged, focusing on the behavior of springtails. Prior to this, global research had only partially examined specific behavioral aspects of springtails, such as the reproductive performance of Sminthuridae, spatial distribution, and the trophic activities of certain soil-dwelling species (e.g., Christiansen 1970; Joosse 1971; Tosi 1979; Leonard and Bradbury 1984; Hopkin 1997). However, systematic

ethological knowledge on this invertebrate group was fragmented. N. M. Chernova's school initiated comprehensive investigations of the intricate behavioral mechanisms underlying the life activities of these microarthropods.

A scientifically validated methodology was developed for maintaining springtails in long-term laboratory cultures. This approach emphasized optimal humidity conditions and dietary organization, enabling continuous observation. This facilitated the study of behavioral specifics across phylogenetic lines and life forms, revealing species-specific traits in their trophic activities. Using a combination of morphological analysis and live individual marking, researchers described, for the first time, food-search strategies, trophic rhythms, and dietary preferences for several species. Additionally, they evaluated the role of springtails in soil dehelminthization processes (Varshav 1988).

During the 1990s and 2000s, N. M. Chernova with her PhD students developed general frameworks for classifying springtail behavioral forms. Studies explored the diversity and complexity of individual behavioral responses of various species, including locomotion, exploratory activities, feeding behavior, defensive actions, grooming, and resting states. Ethological traits such as aggression and territoriality were described in detail. For the first time, a functional classification of behavioral forms was created for Collembola. Links between species' phylogenetic status and specific motor activities—such as the molting process and grooming behavior—were identified (Avilkina 2000; Goloshchapova 2003; Chernova and Avilkina 2003; Savenkova 2009).

In its early decades, Chernova's ethological research program adopted an inductive approach to studying springtails. Their work was characterized by meticulous, observation-based analyses that led to broad conclusions. Today, the school remains a leading centre for springtail behavior research, further developing existing study directions and seeking innovative methods to address modern challenges.

6 Taxonomy of springtails

N. M. Chernova demanded a deep understanding of the complex systematics of springtails from her students and required them to possess a proficient ability to identify taxa, which was essential for both ecological and faunistic studies. However, she never formally supervised research focused on the taxonomy details of springtails. It so happened that many of her students subsequently mastered the identification of springtails to such an extent that they became professional taxonomists, taking up the baton from E. F. Martynova and other soviet collembologists who primarily worked in the 1960s and 1970s.

At one of the initial meetings for novice collembologists in the late 1980s, Professor Chernova encouraged each scientist to specialize in a specific group of springtails for

taxonomic research. This directive served as the initial impetus for taxonomic specialization within the school, which led to the publication of a series of modern identification keys of Collembola (two volumes were published in 1988 and 1994), for which N. M. Chernova was the editor and the author of introductory chapters. The release of subsequent volumes was hindered by an insufficient knowledge of the fauna. New species began to be actively described, alongside with taxonomic revisions of specific groups across the entirety of Russia, and well beyond. One of her students contributed to the creation of the large volume "Synopses on Palaearctic Collembola" (Potapov 2001, 603). Since 1985, a total of 418 new species of springtails have been described. The springtail families receiving the most attention include Hypogastruridae, Onychiuridae, Neanuridae, and Isotomidae. Of the total number of species, 312 have been described from Russian territory, 21 from other former Soviet republics, and 85 from other countries. In the field of Collembola taxonomy, the most actively engaged professionals include A. B. Babenko, N. A. Kuznetsova, M. B. Potapov, and Yu. B. Shveenkova. All were students of N. M. Chernova, having completed their dissertations under her supervision.

A taxonomic specialization has developed among them: Anatoly Babenko is an international-level expert on the subfamilies Hypogastrurinae and Pseudachorutinae, as well as the family Onychiuridae; Mikhail Potapov focuses on Isotomidae; and Yulia Shveenkova works on Onychiuridae. The groups Entomobryomorpha and Symphypleona remain relatively unexplored, prompting the involvement of collembologists outside Russia in their study. Collaborations with specialists from various countries were actively established. A. B. Babenko works closely with Arne Fjellberg (Norway) and Dariusz Skarżyński (Poland); N.A. Kuznetsova collaborates with Adrian Smolis (Poland); while M. B. Potapov has established partnerships with several specialists from South Africa ("Collembola of South Africa" 2025) and from China (Potapov 2025: see co-authors from Shanghai Natural History Museum, Center for Excellence in Molecular Plant Sciences, Chinese Academy of Sciences, South China Normal University, Guangzhou, and other organizations).

These taxonomists continue to engage in ecological research, upon a foundation laid by N. M. Chernova. This may explain why springtail taxonomy in Russia is closely linked to the ecology and geography of species. Russian collembology literature contains a comprehensive examination of species' habitat preferences, their indicator properties, and the ecological characteristics of closely related taxa.

The fauna of European Russia is the most extensively studied, having been actively investigated by N. A. Kuznetsova (northern region), A. M. Kremenitsa, and Yu. B. Shveenkova (southern region). Springtail research is continued by Professor Chernova's students T. V. Dobrolyubova in the Caucasus and L. T. Kutyreva in Russian East Asia. The species composition of the Arctic has been studied by A. B. Babenko.

Springtails in Siberia have been studied by Sofia Kuzminichna Stebayeva, and A. B. Chimitova is conducting studies in Transbaikalia. In recent years, the regions of the Russian Far East have been investigated with particular intensity, revealing a fauna that remains largely unexamined and highly diverse.

The overall trend in the description of new species is illustrated in Figure 5. A distinct period prior to 1980 saw work by E. F. Martynova, S. K. Stebayeva, and V. G. Chelnokov. Following 1980, the work has mostly been conducted by Professor Chernova's postgraduate students.

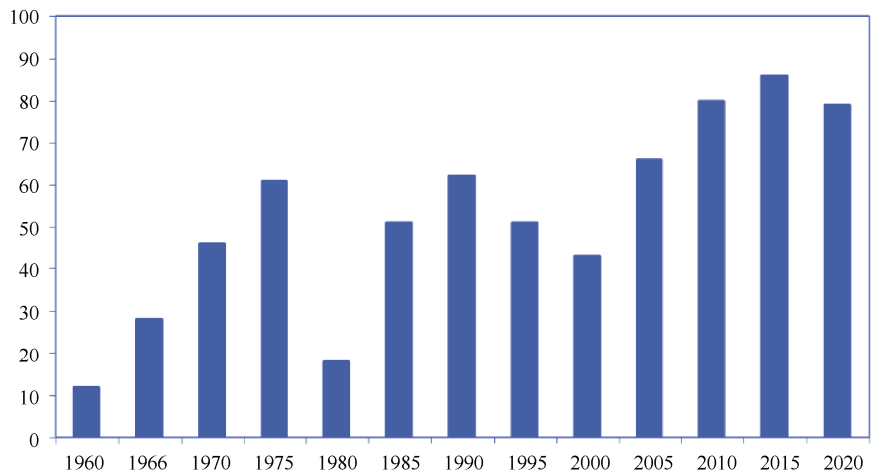


Figure 5: The number of new species described by Russian collembologists over five-year periods. The primary contributors were E. F. Martynova, A. R. Grinbergs, and S. K. Stebyaeva (1960–1980), and from 1985, the majority of the work was carried out by taxonomists of Professor Chernova's school.

7 Bibliometrics

For the history of science, the accumulation of citations of N. M. Chernova's works in contemporary scientific literature is of considerable interest. Additionally, we aimed to compare these findings with data pertaining to other early contributors and foundational figures in the field of Russian soil zoology in order to propose potential explanations for the observed trends. To this end, we utilized the Statistical Reports data provided by the largest electronic library of scientific publications in Russia—eLIBRARY.RU (established in 1999). It is worth noting that only about 10% of all publications by Russian-speaking scholars are indexed in international scientific citation databases such as Web of Science or Scopus (eLIBRARY.RU 2025). N. M. Chernova authored 130 publications, excluding reprints and translations ("Chernova Bibliography" 2025), 75 of which are recent works available in the eLIBRARY database. Considering the relative youth of this library, it may be inferred that the left portion of

the diagram presented in Figure 6 is of limited relevance, as it does not account for any citations referring to the beginning of her scientific career. However, the rightmost portion appears to be quite representative and demonstrates a clear decline in citation frequency in recent years.

This decline, according to data from eLIBRARY.RU, is characteristic of other foundational figures in soil zoology (Figure 7), notably for M. S. Gilyarov, Yuri

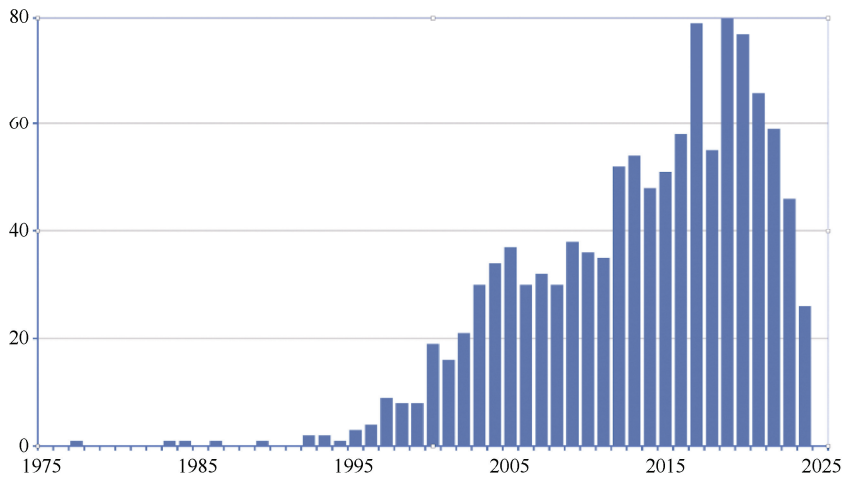


Figure 6: Number of works per year citing the publications of N. M. Chernova, based on the data from eLIBRARY.RU.

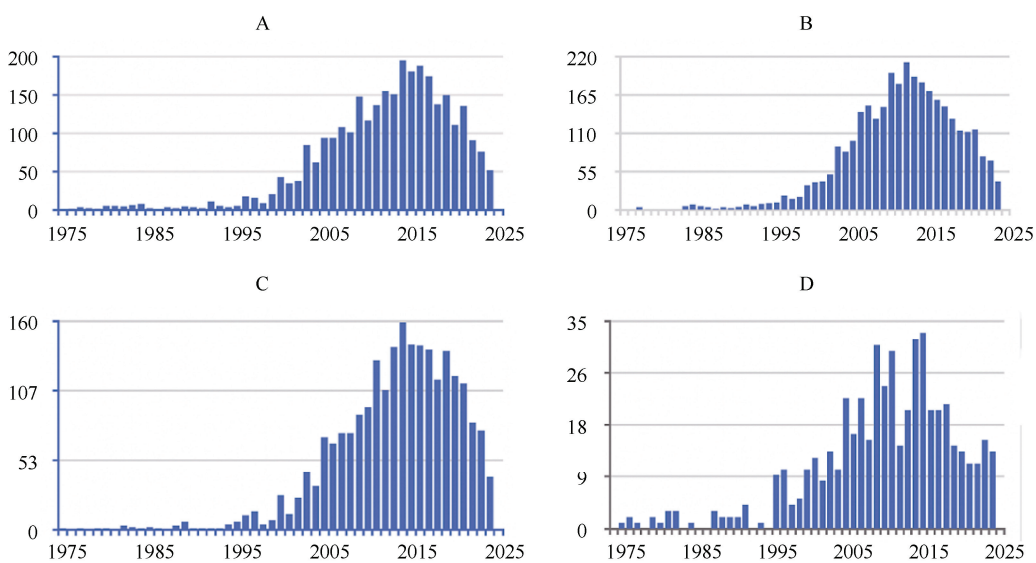


Figure 7: Distribution by years of the number of works citing publications of domestic founders of soil zoology (according to eLIBRARY. RU). **A** – M. S. Gilyarov; **B** – Y. I. Chernov; **C** – B. R. Striganova; **D** – I. V. Stebayev.

Ivanovich Chernov (1934–2012), Bella Rafailovna Striganova (1932–2017), and Igor Vasilyevich Stebayev (1924–2009). Of course, fluctuations in these types of indicators can occur among living and actively working researchers. However, such ubiquitous declines in recent years among the founders of our scientific disciplines are not generally observed. Clearly, this represents an objective reality, both felt and supported by factual evidence (a quote refers to the classic definition of matter: Lenin 1909, 440). The most apparent explanations for this reality are as follows:

- The works of these soil zoologists have simply moved into textbooks, and their results have become so familiar to modern researchers that they do not require specific citation.
- The discipline itself has undergone significant changes, with contemporary approaches and topics being largely disconnected from the work of their mentors. This reason sounds less optimistic, especially for the older generations, but is plausible.
- Many papers by the classics of soil zoology were published in personal or collective monographs, as well as in regional and thematic collections. Their electronic versions are not readily accessible. Modern scientists prefer online references; accessing a library to obtain an original paper requires an additional effort.

Other similar explanations could be proposed, but these three seem most probable to us. Furthermore, the first two reflect a certain trend that may be agreeable or worthy of debate, yet is largely beyond our control. On the other hand, enhancing the recognition and citation of the works of the founders of soil invertebrate zoology, based on the third explanation provided, is entirely within our power.

8 Other scientific activities

Professor Chernova played an active role in organizing and conducting meetings of the Entomological Society of the USSR (1966–1969), other conferences, scientific colloquiums, and schools on soil invertebrates, which were held regularly and brought together scientists from various regions. She served on organizing committees and edited numerous scientific books and thematic collections of research papers and conference proceedings, including the following key issues titled:

1982 – Anthropogenic Impact on Soil Fauna
1982 – Formation of Animal and Microbial Communities in Agroecosystems
1984 – Fauna and Ecology of Invertebrate Animals
1984 – Fauna and Ecology of Springtails (Collembola)
1985 – Ecological Principles of Land Reclamation
1986 – Biocenosis of Wheat Fields

1986 – Ecology of Life Forms of Soil and Terrestrial Arthropods

1988 – Ecology of Microarthropods in Forest Soils

She also contributed to conference proceedings (Problems of Soil Zoology), identification keys, and other publications. N. M. Chernova's scientific articles were compiled in two large volumes and presented for the first time at her seventy-fifth anniversary celebration in May 2010 (Figure 8).



Figure 8: Professor N. M. Chernova (in the middle) at the ceremonial session of the Department of Zoology and Ecology, (Institute of Biology and Chemistry, MPGU), commemorating her seventy-fifth anniversary (Moscow, 2010).

The history of N. M. Chernova's pedagogical activities, the educational programs she developed, as well as her textbooks and lecture courses on biology and ecology, deserve an additional article. We underscore Professor Chernova's pivotal role in advancing the study of soil zoology, particularly of microarthropods, as a distinct scientific discipline. Her enduring legacy is reflected in the achievements of her students, her influential publications, and the ongoing research inspired by her pioneering work. N. M. Chernova's soil zoological school's finest traditions will continue to thrive at new technological, educational, and international levels. Her versatile work and contributions will undoubtedly find their rightful place in the history of science and ecological education.

9 Conclusion

The methodologies for studying soil microarthropods, developed by N. M. Chernova, her students, and followers, have enabled extensive, long-term research across various

regions. These methods have facilitated the accumulation of reference and baseline material, the successful analysis and comparison of results, and the assessment of the degree of anthropogenic impact on soils and their inhabitants.

Through N. M. Chernova's roles on the Environmental Education Council of the Ministry of Education of the Russian Federation and as Chair of the Instructional and Methodological Commission for Biology, she significantly influenced the quality of textbooks, teaching standards, and the enhancement of scientific rigor and systematicity in life science education throughout Russia.

Currently, the scientific school founded by professor N. M. Chernova is advancing the following research agendas:

- Systematics of microarthropods, mostly springtails (having described over 500 Collembola taxa new to science)
- The problem of cryptic species (visually identical but genetically distinct Collembola species)
- Population genetics of widely distributed species
- Spatial structure of springtail diversity
- Niche structure of communities (using the stable isotope method)
- Soil health bioindication and testing of eco-friendly technologies in agriculture
- Fauna of understudied regions, primarily the Caucasus, the Urals, Central Asia, and the Russian Far East.

International collaboration with institutes and museums in countries such as China, Japan, Germany, France, Kazakhstan, South Africa, and others to be developed.

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We would also like to thank the journal reviewers whose comments highlighted that the history of the formation and evolution of scientific schools plays a pivotal role in comprehending the mechanisms of scientific progress, preserving traditions, and fostering conditions for new scientific achievements. The head of a scientific school is key to its success, ensuring the connection between generations of scientists and stimulating the creativity of both young researchers and the scientific community as a whole.

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