# The Contemporary Relevance of Serhiy VYNOHRADSKY's Scientific Heritage

*Portrait of S. Vynohradsky of Yaroslav Matselyukh's work*

On February 24, 2023, we marked the 70th anniversary of the day when the heart of the world-famous microbiologist, one of the founders of general and soil microbiology and ecology, the discoverer of the phenomenon of chemosynthesis in a large variety of autotrophic microorganisms Serhiy Mykolaevych Vynohradsky, stopped beating.

Serhiy Mykolaevych was born on September 1, 1856, in Kyiv to the wealthy family of Mykola Vynohradsky, the director of a credit bank and descendant of the Cossack chieftain A. Vynohradsky, and Natalia Skoropadska from the famous Hetman Skoropadskyi's family.

Studying law and physics at the University of Kyiv or piano at the St. Petersburg Conservatory did not satisfy the aspirations of the inquisitive young man, and he was finally admitted to the second-year course of the faculty of natural sciences of the St. Petersburg University in 1877.

After graduating from the university, to deepen his knowledge of the state-of-the-art in natural sciences, Serhiy Mykolaevych entered the University of Strasburg, where he studied the metabolism of sulfur in the gliding sulfur bacteria Beggiatoa in the laboratory of the famous mycologist Anton de Barry. Here S. Vynohradsky makes his first great discovery — the oxidation by the bacteria of dissolved hydrogen sulfide first to elementary sulfur and then to sulfate, using sulfur as a single energy source, for the fixation of carbon dioxide. This phenomenon was called chemosynthesis or autotrophy in microorganisms and was discribed in a monograph published in Leipzig in 1888.

Serhiy Mykolaevych made his second discovery at the University of Zurich in the laboratory of Ernst Schultz, exploring the complex and not yet studied process of gaseous nitrogen fixation, which in the second stage was called nitrification. He first isolated pure bacterial cultures of the genera Nitrosomonas and Nitrosococcus, which oxidize ammonia ($NH_3$) to nitrite ($NO_2^-$ anion), and Nitrobacter, which oxidizes the latter to nitrate ($NO_3^-$ anion). Through this process, the bacteria use the released energy to fix carbon dioxide from the atmosphere. Thus, S. Vynohradsky first solved the problem of nitrification and the circulation of nitrogen in nature and gained renown as one of the greatest microbiologists in the world.

While working as director of the Institute of Experimental Medicine in St. Petersburg, Serhiy Mykolaevych investigated the fixation of gaseous nitrogen from the atmosphere by free-living microorganisms. He named the isolated anaerobic bacteria *Clostridium pasterianum* in honor of Pasteur.

The October revolution and the civil war in Russia were the reasons for the emigration of S. Vynohradsky to France. In 1922, he published a scientific article «Über Eisenbakterien» («On Iron Bacteria») in Zentralblatt fűr Mikrobiologie, which reported that iron bacteria oxidize bivalent-to-trivalent iron compounds and form iron ore deposits. That aroused great interest in the international scientific community.

The scientist spent the last period of his life in Bri-Kont-Rober near Paris, where he organized a new laboratory of agricultural microbiology at the Pasteur Institute in order to study soil microflora.

Summarizing S. Vynohradsky's scientific heritage in the study of soil microflora, we can assert that he established the decisive role of specialized autotrophic microorganisms in the carbon, nitrogen, iron, and sulfur cycle in nature, which acts as a whole. After Serhiy Vynohradsky's research, the range of such soil autotrophs was supplemented by microorganisms of hydrogen and methane cycles, sulfate-reducing, and other groups of microorganisms.

To discover chemosynthesis, Serhiy Mykolaevych applied new methods for isolating microorganisms from soil, which were fundamentally different from the then generally accepted methods. Instead of nutrient media with organic compounds proposed by R. Koch, he used selective media (following the method of enrichment culture) to isolate pure cultures of sulfur and iron bacteria and atmospheric nitrogen fixers, which became key methods in modern microbiology. In addition, the scientist proposed a test for *Azotobacter*, a device later named «Vynohradsky's column» (for closed circulation of substances), and a direct soil microscopy (silica gel plates containing soil samples). He considered the soil an incredibly complex environment and a graveyard of plant and animal organisms, i.e. the source of nutrient compounds for various microorganisms.

The scientist made an indisputable conclusion about the existence of a much larger number of microorganisms in the soil compared to those isolated on artificial environments, which was fully confirmed by modern research. In laboratory conditions today, it is possible to isolate and cultivate only about 1% of all soil microorganisms. Structural and functional genomics (metagenomics), which allows us to study metagenomes without isolating and cultivating certain types of microorganisms in the laboratory has significantly expanded our ability to explore microbial communities of soil and to make conclusions about their phylogenetic position.

Using cytochemical methods (fluorescent hybridization in situ) and specific probes (labeled oligonucleotides) up to 16S RNA, specific microorganisms can be detected directly in nature without cultivation in the laboratory.

Today, the international GenBank database records genome sequences of many species and genera of microorganisms, the function of more

than half ofgenes not being known makes but in the absence of knowledge of the functions of more than half the genes, it is difficult to build biological systematics and determine the evolution of microorganisms. In the sequenced genomes of microorganisms, there are clusters of genes of biosynthesis of unknown substances that are of great interest to science and industry. Today, scientists are developing methods to activate these silent genes to obtain substances useful for medicine, veterinary science, and agriculture. Genome editing technologies CRISPR/Cas 9 and the detection of biosynthetic clusters of genes using antiSMASH are successfully used to solve this problem.

Chemosynthesis compared to photosynthesis makes up about 1% of the fixation processes in nature, but its importance for the biological cycle and geochemical transformations is quite large. This process is important for the transformation of chemical elements in biogeochemical cycles and ensuring the flow of energy among different components of the biosphere. It participates in the formation of rocks, deposits of iron and manganese ores, corrosion of metals, and purification of wastewater. The formation of biologically active compounds from inorganic compounds in the process of chemosynthesis can be used to obtain products useful for humans. Chemosynthesis is an important resource for the development of innovative technologies and remains an essential means for preserving ecosystems and human life.

Serhiy Mykolaevych left a precious gift to his successors — his fundamental book «Soil Microbiology. Problems and methods. 50 years of research», which is very popular among microbiologists of the world.

Based on the evidence above, we can conclude that S.M. Vynohradsky is not only the founder of soil microbiology and ecology and the discoverer of chemosynthesis but also remains a modern scientist based on his worldview as a naturalist, and the modern relevance of his methodology and ideas.

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