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Short Communication

The Main Directions and Tasks of Ecological Microbiology

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Microorganisms are present everywhere. For example, one gram of soil contains billions of them. An adult human body contains 10 times as many microbial cells as mammalian cells, consisting of approximately 1.25 kg of microbial biomas. They are combined into systematic groups, have various properties and interact in different ways [1].

Ecological microbiology is a science that studies the diversity of microorganisms in terrestrial biomes, and also develops approaches for the study and subsequent use of the activity of these microorganisms, their beneficial and detrimental impacts on human health and welfare.

Microorganisms, by their omnipresence, impact the entire biosphere. Microbial life plays a primary role in regulating biogeochemical systems in virtually all of our planet's environments, including some of the most extreme, from frozen environments and acidic lakes, to hydrothermal vents at the bottom of deepest oceans [2-4].

The term “microbial ecology” (“ecological microbiology”) was first used only in the 1960s although ecologically directed research of microorganisms began to be carried out long before that. Although the of microbial inhabitants of humans resides within clinical microbiology, it was the discovery of environmental pathogenic microorganisms that invaded the human body that resulted in the beginning of environmental microbiology. These roots were enabled by the work of Louis Pasteur and Robert Koch, who developed the Germ Theory of Disease in the 1870s, following which, the presence of waterborne human pathogens then became the initial focus of environmental microbiology. In developed countries, applied environmental studies related to drinking water and wastewater treatment dramatically reduced bacterial waterborne disease [1,5,6].

S.N. Vinogradsky (1856–1953) and M.V. Beyerink (1851–1931), who developed the principles of obtaining elective (accumulative) cultures, are rightfully considered to be the founders of ecological microbiology. S.N. Vinogradsky was the first to use the gradients of light, sulfide and oxygen to study the natural populations of sulfide-oxidizing photoautotrophic bacteria, sulfate-reducing and chemoautotrophic sulfide- and sulfur-oxidizing bacteria, simultaneously present in one habitat and carrying out interdependent processes and developing the “Winogradsky column” in the process [7].

Modern microbial ecology was launched by Robert Hungate and coworkers, who investigated the rumen (also known as a paunch) ecosystem. The study of the rumen required Hungate to develop techniques for culturing anaerobic microbes, and he also pioneered a quantitative approach to the study of microbes and their ecological activities that differentiated the relative contributions of species and catabolic pathways [4].

Some researchers [8] believe that "environmental microbiology" is related to, but also different from, “microbial ecology”, which focuses on the interactions of microorganisms within an environment such as air, water or soil. The primary difference between the two disciplines is that environmental microbiology is an applied field in which we attempt to improve the environment and benefit society. Environmental microbiology is also related to many other disciplines.

The main position of ecological microbiology is the concept of the dominance of microbes in the creation of the Earth's biosphere and the subsequent maintenance of its ecological balance. This concept is based on the concept of microbes as the source of the only living inhabitants of the Earth, on the ubiquitous distribution of microbes in the biosphere, the predominance of microbial biomass over the total biomass of plants and animals, the ability of microbes to participate in the processes of circulation of substances, maintain radiation balance. Such an important role of microbes is provided by their numerous populations, high rates of reproduction, the ability to move for a long time to a state of rest, diversity in physiological needs, small size and weight, determining the possibility of their migration with air and water [8].

Natural habitats of microorganisms: soil, water, air, organisms of plants, animals and people. In each of them there are distinguished: permanent (resident, indigenous, autochthonous) microflora and random (transient, allochtonous) microflora. Soils with plants and animals form complex and diverse biogeocenoses, the composition, density, functional activity of which depends on the type and structure of the soil, the composition of mineral and organic substances, physicochemical state, temperature, humidity, etc. Microorganisms are combined into systematic groups have various properties and interact in different ways [5,6].

The maximum number of microorganisms in chernozem soil and red earth at a depth of 10-20 cm, at a depth of more than 1-2 m - are found in small quantities, starting from 5-6 m the soil is sterile. Pathogenic microorganisms enter the soil with secretions, urine, manure, sputum, saliva, with the corpses of people and animals, when discharging household fecal and waste waters of various enterprises.

In the 60s of the twentieth century appeared a new field of study for environmental microbiology known as "bioremediation." Many chemicals discharged into the environment without regard to the consequences have been shown to result in adverse human health impacts. However, since hydrocarbons, chlorinated solvents and most pesticides are organic in nature, they can potentially be degraded by heterotrophic microorganisms including bacteria and fungi. The field of bioremediation within environmental microbiology involves enhancing and optimizing microbial degradation of organic pollutants, resulting in environmental cleanup and reduced adverse human health effects. The efficacy of bioremediation was demonstrated in 1989, when the Exxon Valdez oil tanker spilled approximately 11 million gallons of crude oil into Prince William Sound. Optimization of bioremediation was a major factor in cleaning up and restoring Prince William Sound. Bioremediation has also been shown to be critically important in cleaning up 2010 Gulf of Mexico oil spill. Also in the 20th century, soil microbiology, a component of environmental microbiology, became important as a means to enhance agricultural production. Studies on the rhizosphere (the soil surrounding plant roots), and specific studies on root-microbial interactions involving nitrogen fixing rhizobia, and mycorrhizal fungi that enhanced phosphorus uptake, were all utilized to improve plant growth. Other studies of plant growth-promoting bacteria that reduced the incidence of plant pathogens were also effective in aiding the "Green Revolution," which resulted in stunning increases in crop yields in many parts of the world. Overall, these fundamental study areas have helped shape the current discipline of environmental microbiology, and all affect our everyday life [8].

The main tasks of ecological microbiology are: the study of patterns of the impact of various environmental factors on a person's normal microflora; development of methods for indicating microbial pollution of the environment, including under conditions of concomitant chemical, biological, radioactive contamination; determining the distribution of microbial producers of biologically active substances (and their metabolic products - toxins) into the environment and assessing their role in human pathology; studying the processes of self-purification of the environment; improvement of methods of dealing with nosocomial infections [8].

Currently, the following areas of research in the field of ecological microbiology can be distinguished: outecology, demecology, synecology, ecophysiology, ecobiotechnology. Outecology a section of ecology that studies the influence of external abiotic factors (physical and chemical) on microorganisms. Determining the properties of a collection of individuals of the same species (population) is the subject of demecology, It is known that a population has properties that cannot be determined for an individual individual of this species, for example, the number of individuals in the aggregate, the rate of change in their abundance, the average size of the individual in the aggregate, etc. Since the population is the main object of de-ecology, it is also called population ecology [9,10].

- Synecology: Is a section of ecology that studies the interaction of a given microorganism with other organisms surrounding it, that is, with biotic factors. Thus, the object of the study of synecology are communities of organisms, and the subject is the diversity of interspecific relationships within this community. The relationship between microorganisms can be symbiotic (mutualism, commensalism, parasitism, amensalism), metabiotic, satellitism, synergistic, antibiosis, predatoriness [8,9].

- Symbiosis: Microbes, especially bacteria, often engage in symbiotic relationships (either positive or negative) with other microorganisms or larger organisms. Although physically small, symbiotic relationships amongst microbes are significant in eukaryotic processes and their evolution. The types of symbiotic relationship that microbes participate in include mutualism, commensalism, parasitism, and amensalism, and these relationships affect the ecosystem in many ways [9-11]. Symbiosis (positive) - two or more species create mutually beneficial conditions for the development of each other.
- Metabiosis: Only one partner benefits. The most interesting is the synthrophic type of cooperation, when the interaction of various microorganisms can occur such a process that is not able to carry out any of these microorganisms separately. Thus, bacteria of the genus Arthrobacter, in association with certain Streptomyces species, can completely degrade the organophosphate insecticide diazonin, using it as a source of carbon and energy. At the same time, none of these organisms separately grows on this substrate.
- Satellitism is a type of metabiosis, in which the development of one microorganism is stimulated by another through the release of growth factors.
- Synergism: Members of the association stimulate the development of each other through the release of waste products.
- Antibiosis: Relationships between microorganisms can be competitive in nature (competitive relations): antagonism, predation and parasitism
- Amensalism (also commonly known as antagonism) is an active competition between species, which results in a delay or complete suppression of the development of microorganisms of one species by another or mutual oppression.
- Predatoriness: One group of microorganisms uses another for food.
- Parasitism: One species (parasite) uses another species (host) as a source of food and habitat, while the host is harmed.
- The relationship of microorganisms with microorganisms in a broad sense is defined as a symbiosis and may be in the nature of mutualism, parasitism and commensalism.
- Mutualism: Mutually beneficial symbiosis, for example, symbiosis of marine animals (fish, mollusks) with luminous bacteria (Photobacterium, Vibrio), producing chitinase – an enzyme necessary for hydrolysis of plankton shells, the main food of most relatively large marine animals.
- Parasitism: One of the partners in symbiosis, in this case, the macroorganism, is experiencing the harmful effects of another partner - a microorganism that is pathogenic. Parasitism is quite widespread among microorganisms. The influence of parasites on the state of the microorganism occurs not only due to trophic interactions (using the host organism as a habitat and food source), but also due to pathogenic effects caused by toxic and immunologically alien parasite metabolites.
- Commensalism: Microorganisms feed at the expense of the host microorganism, without causing damage to it. This type of interaction can be observed, for example, in the rhizosphere of a plant. In the process of plant growth and development in soil, so-called root deposits are formed, consisting of root exudates (low molecular weight substances - sugars, hormones, vitamins, amino acids, etc., released by the plant roots into the soil), high-polymer mucus of polysaccharide and protein nature, dead cells of the root . Many microorganisms use root deposits as a food source, therefore, a higher density of microorganisms, a rhizosphere effect, is observed around the roots of plants [9-11].
- An important section of ecological microbiology is ecophysiology: The study of microorganisms in connection with the ecological niche they occupy - a set of conditions that ensure the existence of the species. The concept of "ecological niche" includes not only the physical space inhabited by a particular organism, but also the conditions, trophic position, its functional role in the community. In microbiology, the ecological (fundamental) niche most closely corresponds to the physiological group of organisms, that is, the group of organisms with certain functional properties (for example, nitrogen-fixing agents, sulfate-reducing agents, methanogens, etc.). Ecological niches can be narrow and wide. However, two organisms with the same needs, if there is a competitive interaction between them, cannot occupy the same ecological niche, therefore, the realized ecological niche is always narrower than the potential one [8].

The development of approaches to the use of microorganisms for solving environmental problems is one of the directions of ecobiotechnology [8]. Microorganisms are especially actively used to clean natural and industrial environments from pollutants of various nature: oil, petroleum products, pesticides, industrial wastes, etc.

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