The training plan of the Juhász-Nagy Pál Doctoral School

2018

Training at the Doctoral School is uniform. Within the uniform training, the research topics are related to eight doctoral programs:

1. Applied Ecology Program, 2. Botany Program, 3. Evolution and Diversity Biology Program, 4. Fermentation Biotechnology and Bioengineering Program, 5. Functional and Restoration Ecology Program, 6. Hydrobiology Program, 7. Quantitative and Terrestrial Ecology Program, 8. Plant Biology and Biotechnology Program

Applied Ecology Program

Leader of the program: Dr. Tibor Magura, Doctor of the Hungarian Academy of Sciences

General objective of the program

The condition, protection, and sustainability of our natural, built, and social environment, which is necessary for a high quality of human life, and the enforcement of its rational use are increasingly important social and economic factors today, which is why the teaching and training of environmental science and applied disciplines is a particularly important task of higher education. The doctoral program focuses on the following key topics: 1. Applied ecology and environmental protection, 2. Applied ecology and nature conservation, 3. Ecotoxicology and ecophysiology, 4. Environmental analytics.

Applied ecology and environmental protection

Study of living coatings (periphyton) in shallow standing waters and watercourses

Organisms forming living coatings (periphyton) in shallow waters and aquatic habitats are ideal biomonitoring organisms for monitoring environmental conditions and water quality because, through their autotrophic and heterotrophic processes, they are in constant interaction with their environment and therefore provide useful information and reliably indicate upcoming changes.

Periphyton taken from natural or artificial substrates allows for the comparison of different areas due to its short colonization time and general occurrence. The composition of the living cover is influenced by environmental factors such as the origin, age, architecture, and nature of the substrate, or the trophic status of the environment, but also by anthropogenic effects (organic pollutants, plant nutrients, toxic substances, substrate removal, or simply changes in water level). Aquatic plants play a direct or indirect role of decisive importance in the life of waters, in the formation of habitats, and in material and energy flows. The water quality-shaping and water quality-regulating function of aquatic plants is greatly enhanced by the biofilm that forms on the underwater parts of the plants, the study of which we continue to consider our task.

Paleolimnological studies in shallow standing waters

Natural processes and anthropogenic impacts have led to significant changes in our water bodies. Through paleolimnological studies of shallow waters and sediments, we can retrospectively detect the impacts on water bodies and track their direct or indirect effects on habitat characteristics and biotic communities. Paleolimnological research can also identify changes that have occurred or are occurring in water bodies as a result of climate change, environmental pollution, and other anthropogenic impacts. For all these reasons, paleolimnological research plays a prominent role in the doctoral program.

Biological wastewater treatment using constructed wetlands

One of the key issues in environmental protection and water conservation is the purification of rainwater and wastewater from various sources and the improvement of the efficiency of purification technologies and processes. The essence of wastewater treatment is to remove pollutants from the wastewater and transform its quality to such an extent that the treated water does not cause pollution when it enters natural receiving waters. The treatment of municipal and industrial wastewater in Hungary is still not fully resolved in many respects, and the continuous development and monitoring of environmental protection activities, as well as their multifaceted professional evaluation, cannot be neglected. It is also necessary to rationalize and optimize industrial environmental protection technology. The literature also reports on a number of new, mainly natural, environmentally friendly, and energy-efficient treatment methods, the adoption and adaptation of which in Hungary we continue to consider our task in our research.

The theory and practice of bioremediation (phytoremediation)

In recent decades, it has been recognized that plants are capable of absorbing heavy metals and toxic organic compounds from water and soil. This recognition and the possibility of application are due to plants that are able to reproduce in contaminated or poisoned areas after a certain adaptation period and to measurably and demonstrably change the amount of heavy metals and organic pollutants. Studies conducted in recent years clearly demonstrate that soil and wastewater contamination is reduced by the life processes of plants. Using advanced bioremediation technology, plants can accumulate nearly 2% of their dry weight in pollutants. When the harvested biomass is burned, the ash contains approximately 40% metal, which is worth utilizing, but even when transported to a landfill, the mass to be deposited is 85-98% less than that of the excavated soil. The success of the process depends on careful analysis of the site, understanding the quality and quantity of the pollutants, and then selecting the appropriate plant. Phytoremediation is an energy-efficient, environmentally friendly, aesthetic, and, last but not least, inexpensive solution, so we will continue our research within the framework of our doctoral studies.

Applied ecology and nature conservation

Natural forest regeneration methods

Human activities, agriculture, forestry, urbanization, and radical changes in land use have transformed the natural environment globally and altered the spatial proportions and boundaries of its constituent elements (e.g., forests, fields, wetlands, settlements, etc.). Perhaps Hungary's forest cover has undergone the most significant transformation. Recognizing this, there is now a growing need to introduce and establish forest regeneration methods that mimic natural processes (e.g., small-scale gap regeneration mimicking windthrow) in forest management. In order to verify the success of forest regeneration methods that mimic natural processes, it is essential and extremely important to study and monitor the changes taking place in communities of living organisms and to compare them with the communities of the original habitats.

Ecotoxicology and ecophysiology

Ecotoxicology and ecophysiology in nature conservation

Previously, toxicity was determined by examining the appearance of general poisoning symptoms and various developmental characteristics. These parameters are inexpensive and easy to measure, and they characterize the changes that occur well. Their disadvantage is that the changes resulting from poisoning often appear after a long time, which is not acceptable in cases of pollution requiring immediate intervention, for example. This has increased the demand for faster, more sensitive methods. With the growth of scientific knowledge and technological advances, it has become possible to use newer, more suitable testing methods in ecotoxicological studies, such as biomarkers. Biomarkers are the physiological or biochemical responses of living organisms to environmental stress factors, which they use to compensate for or tolerate the effects. Most biomarker tests are substance-specific, but there are also many general indicators. These include monitoring changes in physiological activity (photosynthetic efficiency, respiration intensity, chlorophyll fluorescence, etc.), measuring the formation of stress proteins, the appearance of certain metabolites, the activity of oxidases, lipid peroxidation, or the amount of photosynthetic pigments.

Environmental analytics

Sampling and sample preparation procedures

Development and refinement of sampling and sample preparation strategies for the analytical examination of environmental, biological, and human biological samples. This includes the development and improvement of sampling and sample preparation methods for airborne pollutants, airborne and settled dust for instrumental analysis. Sampling and sample preparation of drinking water, surface water, groundwater and wastewater. Sampling, sample preparation and fractionation of soils, river and lake sediments. Analysis of airborne and settled dust and fog according to particle size distribution using cascade impactor sampling. Development and optimization of sample preparation methods for biological samples (plants, fungi, blood, urine, tissues, animal organs). Comparison of different sample preparation methods.

Development of elemental analysis and elemental speciation methods

Development of highly sensitive elemental analysis and elemental speciation methods for determining the concentration ratios and elemental form ratios of toxic and essential elements. Development of speciation analysis methods for mercury, arsenic, selenium, tin, and chromium forms from the above sample types.

Adaptation of environmental samples for large-scale instrumental analysis

Development of methods for the enrichment of trace elements and trace element forms by liquid-liquid extraction, liquid chromatography (HPLC) column, and solid-phase microextraction (SPME). Application and optimization of high-performance analytical methods (flame emission spectrometer, FES), flame atomic absorption spectrometer (FAAS), graphite furnace spectrometer (GFAAS), inductively coupled plasma atomic emission spectrometer (ICP-AES), inductively coupled plasma mass spectrometer (ICP-MS), capillary electrophoresis (CE)) for the analysis of environmental samples containing a wide variety of accompanying substances.

Fermentation Biotechnology and Bioengineering Program

Leader of the program: Dr. Levente Karaffa, Doctor of the Hungarian Academy of Sciences

General objective of the program

The objective of the Fermentation Biotechnology and Bioengineering Program is to provide highly qualified professionals for research institutions, service providers, and companies engaged in industrial biotechnology research, development, innovation, and production in the region and the country. We welcome applications from students who aim to acquire up-to-date, fundamentally molecular knowledge in the fields of bioengineering mechanics and operations, as well as microbial physiology and biotechnology. The program focuses on three main areas: (1) regulation of carbon source degradation in fungi, (2) technical and biological background of organic acid (citric acid, itaconic acid) overproduction in fungi, (3) investigation and characterization of special RNA structures.

Thematic areas recommended and prioritized by the program

Regulation of fermentation carbon source degradation

The carbon source is necessary for the growth of cells cultured in the fermenter—half of the dry matter content of an aerobic microorganism consists of carbon skeleton—and is also necessary for the biosynthesis of the target product of the industrial fermentation process. Both functions can be performed by a single carbon source (e.g., production of organic acids), but the same carbon source may have partially or completely different effects on growth and production (e.g., formation of antibiotics). The effect of carbon sources on metabolite biosynthesis can also be varied: they can exert specific induction on a given gene or biosynthetic

pathway, act as epigenetic regulators, or modify global metabolic regulators that affect the entire genome. For all these reasons, it is impossible to design and control a fermentation technology without knowledge of the assimilation mechanisms of the carbon source(s) in the culture medium.

In the program, students can study the genetic regulation of the breakdown of the most important monomers (D-galactose, L-arabinose, D-xylose) that make up plant hemicellulose, as well as the molecular interactions between the breakdown pathways in the fungal species *Aspergillus niger* and *A. nidulans*. The practical significance of this research lies in the increasing industrial use of plant biomass as an abundant, renewable source of carbon and energy. Understanding its degradation and the intracellular metabolism of its constituent components is a prerequisite for the industrial fermentation of "second-generation" carbon sources.

Analysis of manganese(II)-dependent transcripts in *Aspergillus niger*, an overproducer of citric acid

Citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid) is the second most important mass product in industrial biotechnology in terms of quantity. Its global annual production (with an annual growth rate of 4-5%) reaches 2.2 million tons, representing a market of approximately $4 billion. It is primarily used in the food industry (syrups, soft drinks, baked goods), but it also has significant applications in the chemical and pharmaceutical industries. With the construction of a Chinese-funded citric acid factory with an annual capacity of 60,000 tons in the Szolnok Industrial Park, Hungary will become one of the EU's major producers.

Citric acid is produced using submerged fermentation technology with the use of *A. niger* filamentous fungi. High citric acid yields are only achieved with an extremely low (4 ppb) Mn (II) ion concentration in the culture medium. Nevertheless, the primary causes of Mn(II) deficiency in citric acid overproduction are still unknown.

In our research, we create cultivation conditions in which genetic elements (genes, transcription factors) that respond to changes in Mn(II) ion concentration emerge and can be studied. We analyze the transcriptome of the *A. niger* strain (ATCC 1015 = NRRL 3) with high citric acid production capacity and a sequenced and multiply annotated genome at three precisely adjusted Mn(II) ion concentrations. Using the data, we identify genes that are expressed at least twice as strongly or weakly as the control, depending on the Mn(II) concentration. The genes are identified by BLASTP (and, if necessary, phylogenetic) analysis, using the annotated proteins of the *A. niger* NRRL 3 strain. For those genes (or some of them) that meet the above criteria, we generate knockout or overexpression mutants using CRISPR/Cas9 gene editing technology. The mutant strains are subjected to phenotypic analysis, during which growth, carbon source utilization, cell morphology, citric acid production capacity, and Mn(II) ion uptake rate are studied.

Itaconic acid overproduction in *Aspergillus terreus*

Itaconic acid (2-methylenebutanedioic acid, methylene succinate) has been selected by the US Department of Energy as one of the 12 most important biotechnologically produced raw

materials for the chemical industry. Due to its methylene group linked to unsaturated dicarboxylic acid by a double bond, itaconic acid is easily polymerizable, which opens up possibilities for many important chemical applications (production of plastics, lubricant additives, resins, hydrophobic paints, etc.). Its global market is worth over US$200 million annually. It is produced by submerged aerobic fermentation using the metabolism of the filamentous fungus *Aspergillus terreus*. Despite continuous optimization, industrial-scale technology involves several increasingly costly steps. The two most important of these are the continuous provision of high dissolved oxygen levels during fermentation and the almost complete removal of manganese(II) ions, which reduce itaconic acid yield, from the culture medium.

The Experimental Fermentation Plant of the Department of Bioengineering at the Institute of Biology and Ecology of TTK offers the possibility of complete mapping and uniform study of industrial-scale itaconic acid fermentation. Based on our research results, we also formulate cost-reduction proposals for the two elements of fermentation technology mentioned above. The broader significance of our research lies in a better understanding of the overproduction of primary metabolites and a more detailed understanding of the general regulatory mechanisms of eukaryotic cells.

Functional and phylogenetic analysis of spliceosomal twin introns (stwintrons)

Spliceosomal introns are found in eukaryotic genes and require a complex system consisting of small RNA molecules and proteins for their excision. Recently, we found novel splice sequences in filamentous fungi, which we named spliceosomal twin introns (stwintrons). In stwintrons, the excision of the inner intron must precede the excision of the outer intron. Stwintrons are the first examples of the phenomenon in which introns of transcripts of certain nuclear genes are excised in successive steps. We would like to learn about the basic principles and mechanisms of excision and try to understand the functional aspects. Stwintrons may have arisen randomly during the mutation of existing introns, but our research may also shed light on whether they have specific functions in alternative splicing or, more generally, in the regulation of gene expression. Knowledge of their excision mechanisms, occurrence, and distribution may help us understand the formation and function of eukaryotic spliceosomal introns.

Botany Program

Leader of the program: Dr. Attila Molnár V., Doctor of the Hungarian Academy of Sciences

General objective of the program

To continue the long tradition of botanical education at the University of Debrecen and to develop it in line with the opportunities and challenges of our time. We aim to renew the mission of the workshop founded by Rezső Soó, known in Hungary as the "Debrecen School" and of

decisive importance in Hungarian botanical research, by taking advantage of technological developments and adapting to international expectations. This will provide talented and interested students with the opportunity to engage in classical botanical research using modern methodologies.

Thematic groups recommended and strongly supported by the program

Natural values of anthropogenic habitats

Nowadays, intensive human activity (primarily agricultural cultivation, deforestation, and habitat development) is causing a significant decline in the extent of areas covered by natural vegetation worldwide. This is particularly true in Europe, which has been densely populated for centuries and has been intensively cultivated for the longest time. In intensively cultivated landscapes, not only small, near-natural habitat patches are valued, but also habitats maintained and created by human activity. However, the important role these habitats play in biodiversity has only recently been recognized, and they can therefore be considered 'under-researched' to date. We have little knowledge of how and to what extent natural and social factors in their area determine the survival chances of members of natural communities, just as we know little about which characteristics of species determine how and to what extent they are able to survive in different types of anthropogenic habitats. Scientific research into these questions is not only important for conservation biology and nature protection, but also Research on this topic focuses on the following habitat types: plantations of native and non-native woody plants, roadsides, cemeteries, flooded fields, abandoned mines, and orchards.

Molecular taxonomy, phylogenetics, and phylogeography

In recent times, the classification of living organisms and research into their evolutionary history have undergone revolutionary changes. This can be attributed to the explosive development of two technologies: on the one hand, the increase in access to information stored in genetic material through molecular genetic methods, and on the other hand, the IT revolution that has made it possible to process and evaluate this information. The Botany Program offers the opportunity to study the evolutionary relationships, origins, and taxonomic connections of the living organisms of Hungary and the Carpathian Basin (with a special focus on the steppe biota).

Analysis of natural and induced plant cell death processes using plant cytology, histology, and enzymology

Classic morphological and histological studies are still important today, not only in taxonomic research, but also in plant ecology and ecotoxicology studies, supplemented by other research methods. Plant stress biology research today seeks to examine the responses of plants to biotic and abiotic stresses using as many approaches as possible, from cellular genetic, structural, and biochemical changes to the more obvious effects on plant growth and morphology. The Department of Botany has long been conducting research aimed at analyzing plant stress responses triggered by the specific metabolic products of cyanobacteria that cause periodic

mass production, or "algal blooms," in surface waters, with a particular focus on plant cell death processes. Several successful Ph.D. theses and publications report on the effects of two important groups of cyanotoxins, microcystins and cylindrospermopsins, on plant cells. Several successfully defended Ph.D. theses and publications report on the stress responses of two important groups of cyanotoxins, microcystins and cylindrospermopsins, in vascular plants; changes in the pattern and activity of stress enzymes (peroxidases, nucleases, proteases) and the resulting detectable tissue-level changes (lignification, suberization, increased autofluorescence due to the accumulation of phenolic compounds, inhibited tracheal differentiation, callus formation, loss of cell nucleus integrity, chromatin condensation, etc.). In the future, we plan to conduct further impact studies of this type on special metabolites derived from algae/sprouting plants, expanding the plant microtechnological processes used. Plant histological studies contribute to medicinal plant research, taxonomic revision of herbarium materials, and the exploration of anatomical characteristics that aid the successful spread and survival of invasive species.

Vegetation dynamics studies, lichen diversity and dynamics

Assessing the current state of vegetation is difficult because it is strongly influenced by responses to weather fluctuations and land management practices (e.g., mowing, grazing). Long-term vegetation dynamics studies, management experiments, and soil seed bank analysis can provide a more accurate picture of the role of these factors and the regenerative capacity of vegetation. This knowledge is extremely useful for the conservation of protected grasslands and is becoming increasingly important due to changes in land use. Only a few experts are capable of identifying and evaluating cryptogams, including lichens. This field of expertise is neglected despite the fact that the extent of dry grasslands is expected to increase, even though cryptogams account for a significant part of the diversity and biomass in these habitats. The response of lichens and mosses to management (e.g., grazing exclusion), their microclimatic preferences, biomass estimates, and characterization of their dynamics are expected to play an important role in the utilization and conservation of grassland vegetation in steppe areas. In addition to the discovery of a new species in Hungary (*Xanthoparmelia mougeotii*) and the confirmation of a species not found for 50 years (*Stereocaulon tomentosum*), a series of new occurrence data for several of our landscapes (Gerecse, Zemplén, Nyírség, Vértes) indicate the potential of this topic.

Plant ecophysiology

Plants, as organisms with a sedentary lifestyle, have developed various strategies to adapt to the conditions of their habitat. Research into the mechanisms that ensure maximum productivity and tolerance to environmental extremes, as well as the limits of adaptability, is becoming increasingly important as human-induced changes to nature intensify. Climate change, habitat transformation, the spread of adventitious species, and the release of xenobiotics and other toxic compounds into the environment pose problems from a nature conservation, environmental protection, and economic perspective, which can be addressed with the help of plant ecophysiology, a field at the intersection of plant physiology and ecology. In the ecophysiological research conducted at the Department of Botany, we use non-destructive in

vivo and in situ methods and laboratory analyses to study the environmental responses of plants and inter- and intraspecific differences. The Botany Program offers opportunities to participate in field and laboratory research exploring plant carbon allocation strategies and their tolerance and responses to stress factors.

Dispersal biology

Nowadays, due to human-induced landscape transformation and climate change, large-scale natural habitats are becoming increasingly scarce. Habitat fragmentation affects plants most severely due to their immobility (and consequently limited dispersal capacity). The gene flow between populations in fragmented habitats and the colonization of new habitats can only be ensured by the dispersal of their propagules. Plants have successfully adapted several methods for dispersing their propagules. One of the most effective is dispersal by animals, which takes two forms: 1) epizoochory (propagules travel attached to the outer coat of animals), 2) endozoochory (propagules are transported in the intestinal tract). Recent research has shown that the importance of endozoochory has been significantly underestimated in the past. The topic is particularly relevant given the serious implications of this process for the spread of invasive species, which have significant economic and social (public health) implications. The Botany Program offers the opportunity to participate in research on one of the most important and least studied aspects of this topic, endozoochory.

The role of herbaria in documenting long-term processes

Natural science collections traditionally play an irreplaceable role in learning about plants, preserving individual taxa types, and documenting occurrence data. However, the specimens preserved in these collections also carry a wealth of additional information that opens up further perspectives. The herbarium of the Department of Botany at the University of Debrecen (also Hungary's second largest collection of vascular plants), in cooperation with other domestic and foreign collections, offers opportunities, for example, to monitor biological invasions, detect changes in environmental factors (such as climatic factors and pollutant concentrations), explore the genetic and morphological variability of species decades or centuries ago, and explore biotic interactions (with herbivores, parasites, pathogens) with other organisms (herbivores, parasites, pathogens), and examining autecological aspects (e.g., the long-term viability of seeds).

Evolution and Diversity Biology Program

Leader of the program: Dr. Zoltán Barta, Doctor of the Hungarian Academy of Sciences

The general objective of the program

The world of living organisms is characterized by enormous diversity. This diversity manifests itself at every level of biological organization: genes exist in the form of different alleles, there is enormous variety in physiological mechanisms, perhaps the most important characteristic of individuals is that they differ from one another, and the enormous diversity at the level of species, communities, and biomes needs no introduction.

One important consequence of this variability is that it enables natural selection, which fundamentally determines the development of life, to function and adaptive traits to evolve. However, the interaction is twofold, as natural selection, together with other evolutionary mechanisms such as genetic drift, contributes significantly to the emergence and maintenance of this variability. Research into this variability and the evolutionary mechanisms that maintain it has become particularly important today, as one of the global challenges we currently face is the threat to the diversity of life, genetic resources, and the diversity of species and communities. This loss affects all levels of biological organization, from the macromolecules that carry genetic information, through the variability of individual characteristics, to the biosphere as a whole, since the principle of variability, natural selection and adaptation based on variation, and the laws of evolution apply to all biological systems, including the human species, which have emerged through evolution.

The general objective of the doctoral program in Evolutionary and Diversity Biology is to conduct extensive scientific research into the evolution of life and the diversity that arises from this process, and to train professionals and doctoral students capable of conducting such research at a high level. The program focuses on the following main areas:

1. The physiology of adaptive traits: evolutionary physiological studies;

2. The trade-off between lifespan and reproduction: evolutionary studies of life history;

3. Variability of individual traits: behavioral ecology studies;

4. Systematization and spatiotemporal dynamics of biological diversity;

5. Genetic basis of diversity: population and conservation genetics studies.

Evolutionary physiology

Numerous studies have examined the evolution of adaptive traits through natural selection, and as a result, these processes are relatively well understood. However, much less is known about how these traits appear, what mechanisms are involved, and how they "work." We also have very little knowledge about how physiological mechanisms, such as hormonal regulation, evolve. Research within the subprogram aims to answer the following questions:

1. Recent advances in molecular biology have revealed that an evolutionarily conserved hormonal signaling pathway, the insulin signaling pathway, may play an important role in the evolution of the trade-off between lifespan and reproduction and survival. However, very little is known about the role of these mechanisms in free-living animals, and almost nothing is known about their function in birds. The aim of this research is to study the role of the insulin signaling pathway in wild birds.

2. Migratory bird populations have undergone significant declines in recent decades. In contrast, our knowledge of how migratory species can adapt to their rapidly changing environment is still limited. To predict this, we need much more accurate and detailed knowledge of the genetic and developmental mechanisms responsible for the development of migratory behavior. Our research focuses on an important and previously unexplored mechanism, the role of maternal influence and maternal stress in the development of migratory behavior. As a result of our research, we will be closer to answering important questions such as how migratory behavior appears and disappears from a population as a result of disturbance and environmental change. Finally, another important outcome of such studies may be to inform conservationists and legislators about the sensitivity of an important behavior such as migration to environmental stress.

Life history evolution

The expected lifespan of living organisms varies greatly and is related to reproductive strategies. A significant part of this variation is genetically programmed and subject to physiological regulation. Understanding these regulatory mechanisms is one of the fundamental problems of evolutionary biology, and exploring them may help us understand human aging. The subprogram involves studies combining ecological, physiological, and genetic methods:

1. The aim of the project on the physiological regulation of life history traits is to explore the evolutionary trade-off between survival and reproduction, as well as the physiological regulatory mechanisms underlying aging, using a freshwater jellyfish model system. At the Department of Evolutionary Zoology and Human Biology at the University of Debrecen, we have developed a methodology for studying natural populations of freshwater hydras and described the details of the aging process. This work has resulted in several publications in recent years, which lay the foundation for the achievement of the objectives set out in the proposal.

2. Aging and cancer are among biology's greatest unsolved mysteries. Why do individuals differ in their rate of aging, and how is it that some individuals have a much higher risk of developing tumors than others? Based on previous studies, we have reason to believe that these two phenomena are related: a higher rate of aging may provide protection against tumor development. This means that if we want to understand cancer, we must also study aging (and vice versa). Our goal is to study the relationship between these two phenomena using an old-new biological model system, the freshwater hydra. Hydras are animals with an extremely simple body structure, yet they are susceptible to aging and cancer. In our research, we will examine the relationship between the rate of aging and the risk of tumor development in natural hydra populations. We hope that this work will help us better understand the relationship between the two phenomena, which may contribute to the development of new therapeutic methods.

Behavioral ecology

Based on behavioral ecology and evolutionary biology research conducted over the past few decades, a relatively coherent picture of the evolution of social behavior has emerged. However,

one of the main shortcomings of this vast body of knowledge is that it has generally focused on the evolution of a single trait, such as the degree of parental care. In other words, the study of the co-evolution of traits, i.e., their joint change, has largely been neglected. There are a number of problems where the study of the joint change of several traits may provide a solution to the emergence of social behavior, even between species. Research conducted within the framework of the subprogram focuses on the following topics:

1. Previous studies have shown that when caring parents can specialize in different tasks, a coevolutionary spiral kicks in, quickly resulting in specialized, cooperative parents. Unlike breeding parents, where there is always a mother and a father, the composition of teams is not necessarily fixed, and there is no a priori guarantee that individuals specialized in different tasks will come together. For this reason, it is unclear whether the task specialization mechanism can also function in teams. There may be team-forming mechanisms that can guarantee that suitable individuals find each other, e.g., based on partner selection.

2. The functioning of animal groups is greatly influenced by the social network between group members. The structure of these networks can significantly determine the spread of information and infections within the group, as well as the evolutionary processes taking place within the group. The social structure of a group can be characterized by several networks, e.g., dominance hierarchy, food-sharing network, leader-follower relationship network, or simply a network based on co-occurrence. It is unclear how these structures relate to each other. It is conceivable that the different networks are independent of each other, but it is also conceivable that there is a deep-seated common structure and that the networks we observe are only different projections of it. In the latter case, some connection between the characteristics of the observed networks can be expected.

3. One of the fundamental forms of inter-species relationships is symbiosis. In ecology, this relationship is traditionally defined as one that is beneficial to both parties. However, based on research in recent years, it seems that the concept of cooperation between species is more appropriate for these relationships, as mutual exploitation is common between the parties, which can result in a co-evolutionary "arms race" between the host and the symbiont. Freshwater hydras and their symbiotic algae are important model organisms for studying these mutualistic relationships.

4. We also investigate the mechanisms behind the development of gender roles. The big-headed beetle (*Lethrus apterus*) is an extremely interesting member of the Hungarian fauna, belonging to the rare group of beetles where both parents participate in raising their offspring. Our studies to date have shown that the parents specialize in different tasks, with the female bringing food while the male guards the nest dug into the ground. We analyze the gene expression of females and males during the breeding season to identify candidate genes underlying behavioral differences. Then, based on the sequence of these genes, we draw conclusions about the rate of their evolutionary change and thus the history of the development of specialization.

Biodiversity

A thorough understanding of biological diversity is becoming increasingly important from a practical point of view, as evidenced by the recent appearance of alien species in Hungary. On the one hand, the subprogram aims to contribute to a better understanding of biodiversity and

to the dynamic management and geospatial analysis of existing and expanding knowledge. Another goal is to study interactions between species. The subprogram focuses on the following questions:

1. Laboulbeniales fungi are ectoparasites with a special lifestyle that affect various arthropods. Our knowledge of the effects of these fungi on their hosts is incomplete. Among them, we found the fungus *Rickia wasmannii* and its ant host *Myrmica scabrinodis* to be the most suitable model organisms for this research question. Our main goal is therefore to study the relationship between these two species. In our research, we will examine the effect of the *R. wasmannii* fungus on the food selection, daily activity, microhabitat selection, and collective intelligence of *M. scabrinodis* colonies.

2. Building an open source, community-based scientific and educational database framework for biological, biodiversity, and nature conservation data. Establishing the theoretical basis for the database framework, developing software components, and creating an international consortium for distributed operation. Strengthening the use of open access data and tools.

The genetic basis of diversity

The diversity of living organisms is based on the genetic composition of species. This diversity is fundamentally inherent in genetic material, DNA, but it also manifests itself at the level of gene products and proteins, as well as in physiological and morphological characteristics resulting from the different functions of enzymes. Species appear in population systems within their range. Thus, the diversity manifested within populations, between individuals, is complemented by differences in the genetic composition of populations. Therefore, we can speak of a pattern of genetic variability, which is influenced by various microevolutionary changes. Thus, the analysis of the structure of genetic variability sheds light on the nature and intensity of the evolutionary effects on populations. We study variability at the molecular level and at the level of morphological characteristics. Our study subjects are insects, primarily Orthoptera and Lepidoptera species. The main question of the studies is:

Microbial symbionts can have a significant evolutionary and ecological impact on their eukaryotic hosts. Since such interactions are completely unexplored in butterfly species in the Carpathian Basin, we are studying the occurrence of intracellular *Wolbachia*, its possible effects, and its main transmission routes in various skippers and fritillaries. This will give us insight into the speciation processes of host species and provide useful information for the development of conservation measures aimed at protecting protected species.

Functional and Restoration Ecology Program

Leader of the program: Dr. Péter Török, Doctor of the Hungarian Academy of Sciences

General objective of the program

The functional and restoration ecology program undertakes the discipline-independent, integrated development of knowledge related to the functioning and restoration of biotic communities acquired during gradual training. The program places particular emphasis on the study of the functioning and restoration of terrestrial and aquatic communities and provides assistance in participating in this research. The program is based on the work of researchers from the Department of Ecology and, in close collaboration with them, researchers from the Departments of Botany, Hidrobiology, and MTA Centre for Ecological research. The basic approach of the program is to understand the functioning of natural communities and to examine the possibilities for their restoration, which provides an excellent opportunity for close cooperation with state environmental and nature conservation institutions (the Upper Tisza Region, Tiszántúl and Middle Tisza Region Environmental and Nature Conservation Inspectorates, and the Hortobágy National Park Directorate).

The relationship between functional and restoration ecology

In order to maintain human quality of life, it is essential to establish and maintain a strategically planned network of natural and semi-natural areas capable of providing a wide range of ecosystem services, as well as other environmental features. Maintaining and restoring the diversity of natural habitats is key to establishing this network. Landscape-scale habitat restoration is an effective tool for developing the structure and efficient functioning of habitat networks. In the case of habitat restoration, cost-effective implementation and maintenance, as well as the replacement of costly technical solutions, are very important. The main objective of the program is to provide appropriate and adaptive responses to the challenges posed by landscape use and climate change by integrating the results of theoretical functional ecology, conservation biology, and restoration ecology research conducted by students participating in the program with the results of practical habitat reconstruction and management.

Thematic groups recommended and prioritized by the program

The role of functional characteristics in the functioning of natural ecosystems

A functional-based examination and understanding of community organization and association rules is key to understanding the ecological processes taking place in communities. In addition to classic taxon-based approaches, studies based on the diversity of functional characteristics related to ecological functions and community functioning are gaining ground. These studies have come to the forefront of ecological research in recent decades. The main reason for this is that, although studies based on taxonomic composition characterize certain aspects of community dynamics well, function-based analyses shed more direct light on the ecological processes that shape communities than analyses based purely on species composition. The most important living objects of study are terrestrial and aquatic plant communities, phytobenthos, and phytoplankton taxa, which exhibit significant functional diversity.

Restoring the biodiversity of grassland communities

Over the past century, most of the remaining grasslands have degraded and their natural species composition has become impoverished. The need to halt or slow down these unfavorable processes has brought habitat restoration research and interventions to the forefront of scientific interest. Grassland restoration can rely exclusively on technical methods or, at least in part, on spontaneous grassland formation processes. There is a growing demand for grassland restoration interventions to be cost-effective and for very expensive technical methods to be replaced. These goals can be achieved by incorporating the latest results and methods of theoretical plant ecology research into the planning and implementation of practical grassland restoration projects. This means that testing theories and results proven by studying ecosystem functioning and dispersal processes under natural conditions (1) can increase the chances of success of restoration programs and (2) ensure the selection and application of the most cost-effective methods. Research into these issues is therefore of paramount importance.

Nature conservation management and monitoring

Species-rich, untouched or traditionally managed natural areas across Europe and elsewhere in the world have been significantly degraded, mostly as a result of changes in land use (more intensive land use or abandonment). In order to preserve the species composition of these areas, maintain landscape-level diversity, and plan nature conservation management, it is essential to examine the factors responsible for maintaining biodiversity and to test planned conservation strategies and management interventions under real-world conditions. The program gives priority to research directions that examine the role of local interventions and landscape-scale effects in the conservation and restoration of communities by studying one or a few selected groups of organisms.

Hydrobiology Program

Leader of the program: Dr. György Dévai, Doctor of Biology

General objective of the program

Within the framework of the doctoral program, we are expanding basic and applied research related to the organisms and communities inhabiting the aquatic and semi-aquatic habitats of the Pannonian ecoregion. In the training and education of students participating in the program, we place particular emphasis on the study of species and communities at the population and community levels, exploring their occurrence patterns, identifying the factors that influence and/or determine them, and interpreting the processes that regulate their structural and functional composition.

The program is based at the Department of Hydrobiology, including the Department of Applied Hydrobiology in Szolnok, but due to the national scope of the program, we carry out our educational and training tasks in close cooperation with partner departments (Department of Ecology and Department of Botany) and numerous external research centers (primarily the

MTA Ecological Research Center). Department of Botany) and numerous external research institutions (primarily the MTA Ecology Research Center; ELTE Department of Microbiology; Department of Biology, University of Oradea) and practical institutions carrying out high-quality professional work (such as BioAqua Pro Kft., Hortobágy National Park Directorate, Middle Tisza Region, and Upper Tisza Region Water Management Directorate).

A shift in perspective in hydrosphere research and its impact on the program

It has become abundantly clear throughout the world that water is the most limited natural resource available to humankind (on the "blue planet," only about 3% of the total water envelope is actually usable!). It is no coincidence that authoritative professional and political circles believe that by 2050, water will be "liquid gold," and that by then, the most critical factor in the emergence of international conflicts will not be oil, but the "possession" of water reserves (it is therefore understandable that the German slogan "Das Wasser ist der Spiegel unserer Zukunft" is gaining increasing resonance and followers).

The domestic situation is alarmingly bad due to the country's basin-like nature and unfavorable climate conditions (more than 90% of our surface water resources come from "upstream" countries, in increasingly smaller quantities, and even now, the quality is not good and is deteriorating). Furthermore, recent events suggest that climate change in our region will primarily concern water and the rational management of water resources. At the same time, our drinking water reserves are very significant even by European standards, and maintaining them in good condition is one of the key issues for the future (which is why water resource management is increasingly being treated as a strategic sector of paramount importance in Hungary). Our responsibility for the future is further increased by the fact that our water areas are of great importance in terms of landscape and biological diversity, ecosystem functions, and land use. Many of them can be considered unique, having preserved many features of the ancient landscape and its former wildlife, and the habitat and biotic diversity here is still exceptionally valuable even by international standards. At the same time, serious environmental disasters (extreme floods, significant and widespread pollution, major inland flooding) have occurred in recent years, threatening this type of value preservation.

The current situation in the field of biological and ecological knowledge is disappointingly poor (in contrast to, for example, the fields of hydrology and chemistry). Our knowledge of the wildlife of Hungarian water bodies is very patchy and random, and we still know very little about the structural and functional characteristics of aquatic ecological systems. The development of hydrobiological education and research is made particularly relevant by the European Union's Water Framework Directive (Directive 2000/60EC), which sets the preservation and achievement of "good ecological status" as one of the most important goals of water policy. This objective cannot be achieved without taking wildlife into serious consideration, and the scientific elaboration of the path leading to this goal – taking into account the special conditions and wildlife of the Pannonian ecoregion – must be a priority task for Hungarian experts. The successful implementation of all this requires highly skilled experts who are familiar with aquatic wildlife and know how to use their knowledge effectively, and this is what we aim to prepare our students for in the Hydrobiology Doctoral Program.

Thematic groups recommended and prioritized by the program

Modern hydrobiological research has four main areas of focus: (1) studying the taxonomic classification and chorological, phenological, ethological, and ecological characteristics of organisms inhabiting aquatic and wetland habitats; (2) exploring the role of biotic communities (populations and coenoses) in the structural and functional processes of aquatic ecological systems; (3) Clarifying the theoretical basis of biological water quality assessment as reflected in the occurrence of organisms and ecological water quality assessment linking the characteristics of wildlife and the surrounding area, and developing practical implementation options for these; (4) research into the biotechnological applications of algae (bioremediation, accumulation of high-value metabolites).

Within the first topic group, we offer doctoral students the opportunity to join three research directions, which differ partly in terms of taxonomy and partly in terms of methodology. During the training, we will take great care to ensure that doctoral students are not only taught according to the traditional (mainly morphological) taxonomic approach, but also familiarized with modern methods (e.g., karyological, enzymological, molecular genetic studies, numerical and quantitative taxonomic procedures) and to introduce new trends (e.g., phylogeography, ecoethology, conservation biology) in the analysis of occurrence patterns.

(a) Taxonomic, material flow and ecological study of bacteria and unicellular organisms occurring in various surface waters of the Pannonian ecoregion, focusing on the following groups of organisms: Eubacteria, Cyanobacteria, Archaea (Chlorophyta, Rhodophyta, Glaucophyta), Cabozoa (Euglenozoa), Alveolata (Dinoflagellata), Chromista (Heterokontophyta, Haptophyta, Cryptophyta). The aim of the research is to establish taxonomic and ecological knowledge suitable for characterizing the hydroecological status of the main watercourses and standing waters of the Pannonian ecoregion in relation to bacteria and unicellular organisms, so that the doctoral students participating in the training have the applied knowledge necessary to ensure the international publication of their results through successful research projects. We intend to give a prominent role to modern molecular biology and electron microscopy techniques, as well as to the functional hydrobiological approach.

(b) Research into aquatic microscopic and macroscopic invertebrate fauna, with particular emphasis on plankton, metaphytofauna and benthos (pedon + biotecton) inhabiting animal groups that are important in terms of water quality and/or material turnover (e.g. Nematoda; Rotatoria; Mollusca; Annelida; Isopoda; Amphipoda; Cladocera; Ostracoda; Copepoda; Ephemeroptera; Odonata; Plecoptera; Heteroptera: Nepomorpha, Gerromorpha; Coleoptera: Haliplidae, Dytiscidae, Hydrophilidae; Trichoptera; Diptera: Chironomidae), as well as due to their special occurrence conditions and lifestyle (e.g. Porifera; Hydrozoa; Acari: Hydrachnidae; Anaspidacea; Mysida; Decapoda; Brachypoda; Notostraca; Conchostraca; Coleoptera: Gyrinidae; Lepidoptera: Nymphulidae; Diptera: Syrphidae, Bryozoa), due to their special habitat requirements (e.g. Turbellaria; Tardigrada; Collembola; Heteroptera: Gerromorpha; Diptera: Tipulidae), due to their importance for animal or human health (e.g. Cestoda; Monogenea; Trematoda; Arguloida; Diptera: Culicidae, Ceratopogonidae, Simuliidae, Tabanidae).

(c) Among vertebrates associated with aquatic and wetland habitats, we place particular emphasis on the study of fish fauna, which, in addition to traditional faunistic research, includes the analysis of population dynamics, interactions between native, exotic, and invasive fauna

elements, using molecular biological tools in addition to the tools commonly used in aquatic ecology. The relationship between conservation value and economic value, as well as scientific issues related to conservation, fishing, and fishing practices, may also play a role. Among other significant vertebrates in aquatic and wetland habitats, amphibians (Amphibia) and reptiles (Reptilia) are fully protected, while birds (Aves) and certain representatives of mammals (Mammalia) are also of scientific interest, partly because of their conservation value and partly because of their competitive and predatory relationships with other organisms in aquatic and wetland habitats.

Within the second group of topics, in the case of structural topics, we primarily aim to provide doctoral students with a comprehensive overview of the composition of the fauna and flora inhabiting different types of water bodies, learn about the specific life forms associated with habitats, acquire a modern understanding of population dynamics and coenology, and, with this knowledge, be able to process the communities of organisms they have chosen to a high standard. In the case of functional topics, we wish to place emphasis on the multifaceted presentation of interactions between populations and deepening knowledge of material cycles (mass and energy flows) so that doctoral students can assess the place of their own biotic communities in aquatic ecological systems from this perspective and correctly evaluate their role and significance in them.

Within the third thematic group, the primary objective is to clarify the theoretical basis for biological water classification, ecological water classification, and water classification in accordance with the EU WFD, as well as to develop practical implementation options, with particular regard to the management of aquatic and wetland habitats (preservation, conservation, rehabilitation, reconstruction, creation) . During the planning and implementation of interventions, the main focus is on the enforcement of ecological considerations, as well as impact assessment and monitoring. This also includes the scientific processing of hydrobiological data related to hydroecological status assessments and environmental impact assessments.

Within the fourth thematic group, research into the role of algae in bioremediation (the biological removal of pollutants) is one of the main areas of focus. The effect of trace elements and small-molecule organic pollutants on the growth of algae species has long been a focus of interest. Their study is very important from both a natural and environmental perspective, especially because they are among the most frequently detected pollutants in our domestic surface waters. In light of international findings, algae are playing an increasingly important role in the biological remediation of various polluted waters. Another line of research within the topic group is the investigation of the agricultural, industrial, and commercial uses of algae biomass and its metabolic products. This field of research is extremely broad and has been growing in recent years. The advantages of microalgae over arable crops are that they photosynthesize more efficiently per unit area and are capable of producing larger quantities of biomass more quickly. Many microalgae are capable of accumulating high-value metabolites (lipids, carbohydrates, proteins, and pigments).

The aim of the program is to examine the factors that induce the accumulation of substances valuable to agriculture, the food industry, healthcare, and the cosmetics industry, and to develop a method that can be assembled cost-effectively, based on simplified nutrient solutions, and

effectively enable the production of large quantities of biomass and the induction of the accumulation of valuable metabolites in it.

Quantitative and Terrestrial Ecology Doctoral Program

Leader of the program: Dr. Béla Tóthmérész, Doctor of Biological Sciences

General objective of the program

The doctoral program involves modern ecological research, with an emphasis on quantitative analysis, testability, and operability. The program is based at the Department of Ecology at the University of Debrecen and the MTA-DE Biodiversity Research Group, in close cooperation with partner departments and numerous domestic and foreign research centers and universities. The research is also supported by international LTER (long-term ecological research) projects. The spectrum of research topics is extremely broad, ranging from quantitative ecological analysis of biodiversity monitoring activities with practical applications to community ecological modeling and statistical ecology.

Development of methods for quantitative analysis of scale dependence

Scale dependence is of particular importance in understanding ecological processes. Despite this, measurement methods are relatively poor, although there has been a strong trend in recent years towards publications on this topic in leading international journals. In the field of developing scale-dependent quantitative methods, we intend to examine and test in detail methods for measuring mosaicism and beta diversity. Based on a critique of these methods, we are developing a new method for characterizing beta diversity. We will test the methodological results achieved in the previous year in connection with beta-diversity analysis based on data from several field studies. A key issue to be examined is the topic of finite size effects and scale-dependent comparative functions. We plan to develop comparative functions that take into account the pattern constraints of vegetation.

Biodiversity conservation, traditional and organic farming

Regular extensive human intervention is key to preserving the existence and diversity of many grasslands. Throughout Europe, these include pasturelands and hay meadows, which were once characteristic of many landscapes but have been increasingly abandoned with the decline of traditional farming. Mountain hay meadows are particularly valuable and deserve special attention from a nature conservation perspective. Many of the plant species found there are highly protected, protected, or worthy of protection. Their survival is threatened by the cessation of mowing, the resulting accumulation of grass litter, and the risk of afforestation. From a nature conservation and restoration ecology perspective, it is important to determine whether the areas can be restored to their former state despite intensive use. Similarly, the

preservation and maintenance of the current natural state and species economy are essential issues.

General neutral biodiversity and island biogeography (UNTB), null and neutral models

The emergence of null models was a milestone in modern ecology. This essentially marked the birth of model-oriented, operational ecology in the 1970s. It was shocking that predictions based on the mainly verbal models of ecology at the time could not be distinguished from null models based on field data. In other words, they could neither be verified nor falsified. The solutions brought about a fundamental development and restructuring of ecology. At the turn of the millennium, general neutral biodiversity and island biogeography models (UNTB) appeared. According to these models, the very high biodiversity (mainly observed in the tropics) can be explained solely by the effect of randomness. The further development of dynamic neutral models and their adaptation to various field data will bring further significant advances in all areas of ecology.

Habitat and biotic filters

In alkaline grasslands, we have already demonstrated that the species composition of vegetation and seed banks is determined by a combination of abiotic filters (soil water and salt content and microtopography) and biotic interactions. From both a practical restoration and theoretical point of view, it is important to understand the role of the above variables in grassland regeneration in saline habitats. We are investigating this phenomenon in the reconstructed grasslands of the former bombing range in Hortobágy National Park. After the removal of ammunition, the bomb craters were filled in on the 4,000-hectare site, creating large areas of vegetation-free soil surfaces in many locations, which provide a unique opportunity for research. The relationship between biotic filters and dark diversity is a central issue in contemporary ecology, which we are also testing using our previous botanical and zoological data.

Classical and molecular ecological methods in urbanization research

The global increase in anthropogenic activity is causing significant changes in the natural environment. The decline in species and functional diversity of living organisms is damaging the functioning of urban ecosystems and affecting the quality of life of city dwellers. To compensate for the effects of urbanization, we need to understand the functional responses of organisms to disturbance. In our research, we analyze the effects of urbanization, habitat fragmentation, edge effects, and environmental filters on soil-dwelling arthropod communities by studying several taxa (millipedes, spiders, ground beetles, and earwigs). In our metagenomic study, we use next-generation sequencing methods to examine how the composition of the pathobiome (pathogenic microbial communities) spread by ticks changes along an urbanization gradient. The study may yield important results from both a human health and urban planning perspective.

Paleolimnological research

Paleolimnological studies are at the forefront of ecological research, providing a better understanding of the history of ecological processes in addition to those related to climate change. Zooplankton organisms are ideal for this type of research. They occupy a key position in the aquatic food chain, and their species composition and size distribution are excellent indicators of the strength of top-down or bottom-up regulation. They are good indicators of changes in habitats and trophic relationships. The size, shape, and microhabitat diversity of our waters provide a number of differentiated habitats for zooplankton communities. The rich and varied habitat structure keeps diversity high. Changes in waters and habitats result in changes in diversity, and the replacement and transformation of species provide a more complete picture of complex ecological conditions.

Invasion biology research

The spread of invasive species is a major threat to global biodiversity. Our invasion biology research focuses on linear landscape elements, as these structures play a dual role in nature conservation: they can help maintain functional connections between metapopulations of species linked to natural habitats, but they also contribute to the spread of invasive species. In our landscape-scale, high-replication studies, we examine the role of linear structures and associated human activities in the spread of invasive plant species. We test which plant characteristics (spread types, clonality, seed bank type) make species the most successful invaders. We investigate the pathways of invasive plant species spread, with a focus on the role of humans in propagule dispersal. Furthermore, we examine the effects of invasive species on the species composition, structure, and functional diversity of natural ecosystems. Our results contribute to the development of effective defense strategies against invasive species.

The role of seed banks in maintaining biodiversity and community organization

Seed banks play a key role in the dynamics of plant communities and in the processes of vegetation regeneration and degradation. Our goal is to study the processes observed in the vegetation and seed bank dynamics of natural grasslands and to utilize them in the regeneration of grasslands. The aim of reconstruction interventions is to create a long-term resilient system that is close to the natural target state and provides a suitable habitat for plant and animal species. A key question is how close we can get to the desired target state and how we can support regeneration processes. The study of the vegetation and seed bank dynamics of regenerating grasslands provides an important reference point for this. In our research, we examine the role of seed banks and soil parameters in the species composition of regenerating grassland vegetation in landscape-scale habitat restoration projects that are significant even at the European level, within the framework of an international collaboration involving three countries.

Landscape ecology, isolation, and fragmentation

In Europe's human-modified landscapes, grassland habitats often survive only as small islands, which are of outstanding conservation importance. Exploring the mechanisms of local and landscape variables that influence the organization of plant and animal communities in isolated

habitats contributes significantly to our understanding of the ecological processes of habitat islands and provides a scientific basis for the development of conservation and restoration plans for their preservation. We place particular emphasis on examining the effects of biotic and abiotic habitat variables and the landscape environment on the species richness and abundance of common generalist and habitat-specialist species living on habitat islands. In assessing the effects of the variables studied on wildlife, we examine the functional diversity of communities in addition to species-level analyses. Given that in intensively used landscapes, local and landscape variables primarily exert their effects on the composition of flora and fauna through the persistence and dispersal characteristics of individual species, we place great emphasis on examining these characteristics.

Plant Biology and Plant Biotechnology Program

Leader of the program: Dr. Gábor Vasas, Doctor of the Hungarian Academy of Sciences

General objective of the program

To continue and develop plant biology and biotechnology research at the University of Debrecen. To cultivate research topics and groups related to modern plant biology that have emerged in recent decades. To provide talented and interested students with the opportunity to engage in plant biology and plant biotechnology research using modern infrastructure and methodology.

Thematic groups recommended and prioritized by the program

Plant cell and developmental biology

Within this topic, we primarily investigate the regulatory role of type 1 and 2A protein phosphatases (PP1 and PP2A) and the relationship between protein phosphatase and oxidative stress in plant cells. Our model organisms are primarily *Arabidopsis thaliana* and *Vicia faba*, which are the main model systems in plant cell and developmental biology and molecular biology.

Our areas of focus:

1. The role of PP1 and PP2A in the regulation of plant mitosis, primarily the study of chromatin and microtubule organization. The role of histone phosphorylation and microtubule-associated proteins, their regulation through protein dephosphorylation.

2. Is there a correlation between defense against oxidative stress and the activity of protein phosphatases? What signal transduction processes play a role in this?

The infrastructure necessary for the implementation of the above topics is in place, ensuring the application of the appropriate techniques. The methodological approach primarily involves histochemical/immunohistochemical and biochemical/molecular biological techniques (e.g.,

protein electrophoresis, enzyme activity testing on native gels, Western blot, long-term transcription/protein expression profile testing). Since histochemical/immunohistochemical procedures can only be performed on fixed cells, which do not always provide an accurate picture of the actual events taking place in living cells, we also plan to conduct long-term living cell studies in model plants expressing GFP fusion proteins. In this system, we can monitor a number of subcellular processes.

Production of plant tissue cultures and their biotechnological application

The Department of Botany at the University of Debrecen has had a rich collection of plant tissue cultures for many years, which includes cultures of protected species that are potential producers of secondary metabolites. Among these, our current interest is primarily focused on the Crocus genus (*Crocus sativus* – true saffron, as well as protected species from the Carpathian Basin) and some representatives of the Amaryllidaceae family (*Galanthus*, Leucojum, Sternbergia). Our preliminary results show good antioxidant capacity in tissue cultures made from individuals of the above taxa, as well as effects influencing the cell cycle in the case of saffron species. As our results are also promising in terms of practical application (production of raw materials for medicines), we would like to continue this research as part of a PhD program.

Research into the relationship between plant microbiome and metabolome

Non-pathogenic microorganisms living inside plants, known as endophytes, are bacteria, fungi, and other microorganisms that are extremely diverse in terms of taxonomy but can be divided into several groups based on their function. Within this topic, the interaction of endophytic filamentous fungi with plants, primarily with their secondary metabolites, will be investigated. Plant secondary metabolites are not only useful to the plant as insect repellents, antimicrobials, or bioactive compounds that promote competitiveness in other ways. These same compounds are what make many plants medicinal herbs, functional foods, or industrial raw materials: the mixture of secondary metabolites biosynthesized by plants is also responsible for effects that influence the biology of other species. We are testing the basic hypothesis (that there is a difference between endophytes and non-endophytes in terms of adaptation to plants, metabolome, or other levels) using various models. This involves, on the one hand, in vitro approaches, such as studying the effects of plant compounds on the growth and metabolism of endophytic fungi, etc., and, on the other hand, investigating whether endophytic fungi are capable of modifying, biotransforming, and utilizing plant (primarily secondary) metabolites as a carbon source. In vivo studies involve studying the colonization patterns of endophytes or changes in the plant's metabolome, proteome, or transcriptome as a result of colonization. In the latter case, differences between endophytes originating from soil, rhizosphere, or other plants may also be of interest, and the phenomena will be studied using data mining methods. Where relevant, we will carry out large-scale cultivation of a selected endophyte and isolate and chemically characterize its bioactive compounds that affect the plant. It is also important to mention the approach where, in the case of individuals originating from the field, we use data mining methods to try to correlate the microbiome pattern with chemical variability – that is, we seek to answer the question of how the presence of certain endophyte species groups

influences the plant metabolome. In the latter case, culture-independent microbiome analysis methods are also used.

We have several years of experience in this field, model plant clones, and fungal strains of known origin that we have isolated and partially characterized (but largely identified). In addition to general microbiological equipment, we also have all the tools necessary for general chromatographic sample preparation.

Metabolite production in microalgae – variability and function

More than 90% of plant-based preparations and metabolites used in industry today are derived from higher-order vascular plants, but due to unrelated circumstances, increasing attention is being paid to the use of various lower-order photosynthetic algae organisms for this purpose. Over the past 50 years, with the development of structural identification methods and the advancement of algal mass production and artificial algal cultivation (breeding) technologies, numerous carbohydrate, peptide, terpenoid, alkaloid, and phenoloid-type components with various biological activities have been described from algae. We examine the diverse metabolite production by characterizing some of the molecules with special effects in certain algae species. We focus on the active ingredient patterns, production, and functional characteristics of microalgae that can be used directly (*Spirulina* sp., *Chlorella* sp., *Haematococcus* sp., *Dunaliella* sp.). The appearance and spread of algal blooms is well known in both freshwater and marine habitats. In addition to the spectacular discoloration of the water, the mass occurrence of algae has many unpleasant consequences, including economic and public health problems, but at the same time, the properties and characteristics of toxins are of interest in many areas. Algae can produce large quantities of various toxic metabolites, which can exacerbate known problems associated with them, such as deterioration of drinking water quality and fish mortality. In recent decades, several scientific studies have focused on the effects and properties of algal toxins. Our research focuses on the biosynthesis, patterns, functions, and potential applications of these potent metabolites.

Main and minor subjects of the comprehensive examination

Main subjects
Animal anatomy
Animal physiology
Animal ecology
Biodiversity
Biogeography and phylogeography
Bioinformatics
Biochemistry
Biological engineering
Biotechnology
Bioproduct technology
Genetics of eukaryotic microorganisms
Evolutionary biology
Genetics
Genomics
Fungal genetics
Medicinal plant biology
Human biology
Conservation biology
Environmental analysis
Environmental protection
Limnobiology
Microbial physiology
Microbiology
Molecular biology
Plant ecology and vegetation mapping
Plant physiology
Plant ecology
Plant systematics and molecular taxonomy
Plant anatomy and plant cell biology
Ecotoxicology
Population genetics
Potamobiology
Cell biology
Behavioral ecology
Water quality assessment
Zootaxonomy, systematics, and phylogenetics

Minor subjects
Agroecology
Animal geography and faunistics
Animal-plant interaction

Mechanism of action of antifungal agents
Material flow (element cycles and energy flow)
Molecular basis of muscle function
Biodiversity and its measurement
Biodiversity and ecosystem services
Bioindication
Bioconversion
Purification and analysis of biological molecules
Structure of biomolecules
Biomonitoring
Bioremediation
Wine biotechnology
DNA chip technology and data management
Biology and genetics of yeast fungi
Habitat typology
Entomological taxonomy and systematics
Enzymology
Life cycle evolution
Evolutionary physiology
Fermentation process control
Phylogenetics
GMO organisms and their application in biotechnology
Evolution and phylogeny of fungi
Fish and fisheries biology
Network ecology
Molecular biology of fission yeasts
Hydrobotany
Hydromicrobiology
Hydrozoology
Industrial microorganism strain improvement
Conservation genetics
Modern elemental analysis methods
Environmental impact assessments
Seed bank
Metabolite metabolism
Microbial enzyme production and practical application
Pattern analysis
Molecular evolution
Instrumental analysis
Plant geography and floristics
Physiology of archaea
Pathogenic fungi
Population dynamics
Prokaryotic genetics

Restoration ecology
Insect ecology
Cell cycle
Multivariate ecological methods
Stress biology
Metabolism of secondary metabolites
Sociobiology
Tissue culture
Conservation and reconstruction of natural habitats
Hydrological and physical properties of natural waters
Chemical composition of natural waters
Nature conservation management and monitoring
Transcription
Vegetation mapping
Water pollution and wastewater treatment